Introductory Astronomy Problems

David J. Jeffery

Department of Physics & Astronomy, Nevada Center for Astrophysics

University of Nevada, Las Vegas

Nevada, Las Vegas

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Introduction

Introductory Astronomy Problems (IAP) is a source book for introductory astronomy courses for non-science majors. The book is available in electronic form to instructors by request to the author. It is free courseware and can be freely used and distributed, but not used for commercial purposes.

The problems are grouped by topics in chapters: see Contents below. For each chapter there are two classes of problems: in order of appearance in a chapter they are: (1) multiple-choice problems and (2) full-answer problems. At present there may be few or no full-answer problems Almost all the problems have complete suggested answers. The answers may be the greatest benefit of IAP. The questions and answers can be posted on the web in pdf format.

The problems have been suggested by many sources, but have all been written by me. Given that the ideas for problems are the common coin of the realm, I prefer to call my versions of the problems redactions.

At the end of the book is an appendix consisting of a set of answer tables for multiple choice questions.

IAP currently suffices only for the Solar System part of introductory astronomy. Some of the early chapters contain problems suitable for a stars and galaxies course too.

Everything is written in plain TEX in my own idiosyncratic style. The questions are all have codes and keywords for easy selection electronically or by hand. A fortran program for selecting the problems and outputting them in quiz, assignment, and test formats is also available. Note the quiz, etc. creation procedure is a bit clonky, but it works. User instructors could easily construct their own programs for problem selection.

I would like to thank the Department of Physics of the University of Nevada, Las Vegas for its support for this work. Thanks also to the students who helped flight-test the problems.

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Chapters

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References

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Chapt. 0 A Philosophical and Historical Introduction to Astronomy

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Multiple-Choice Problems

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001 qmult 00005 1 4 1 easy deducto-memory: reading-homework-self-testing done

1. Did you complete reading-homework-self-testing for the Introductory Astronomy Lecture (IAL) by the weekly due date?

   a) Yes! b) No. c) No! d) No, sir! e) OMG no!

---

001 qmult 00007 1 4 1 easy deducto-memory: reading-homework-self-testing done 2

2. Did you complete reading-homework-self-testing for the Introductory Astronomy Lecture (IAL) by the weekly due date?

   a) YYYessss! b) Jawohl! c) Da! d) Sí, sí. e) OMG no!

---

000 qmult 00010 1 4 5 easy deducto-memory: introductory astronomy lectures

3. "Let's play *Jeopardy*! For $100, the answer is: It is the course textbook, the student's notes, the instructor's lecturing tool, and the intructor's notes."

   What is ____________, Alex?

   a) Ptolemy's *Almagest* (c. 150 CE)
   b) Copernicus's *De Revolutionibus Orbium Coelestium* (1543)
   c) Kepler's *Astronomia Nova* (1609)
   d) Newton's *Principia* (1687)
   e) *Introductory Astronomy Lectures* (2003)

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000 qmult 00020 1 1 3 easy memory: reading-homework-self-testing reports precise

4. Reports of reading-homework-self-testings (RHSTs) shoud be:

   a) vague. b) illegible. c) precisely as specified. d) ambiguous. e) mystifying.

---

000 qmult 00022 1 1 5 easy memory: all caught up on RHSTs is unacceptable

5. For a reading-homework-self-testing report, "All caught up." is ____________ acceptable.

   a) always b) once c) once and once only d) depending-on-the-instructor-mood e) never

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000 qfull 00024 1 3 0 easy math: report readings done | obsolete with weekly due dates

Extra keywords: Note this a qfull question, and so will not be counted in the count of qmult questions.

6. The intro astronomy class AST 103/104 has assigned reading-homework-self-testings for Introductory Astronomy Lectures (IAL) with reading -1 being the course website/syllabus. Circle below—and **NOT** on your scantron—all of the IAL lecture numbers of the lectures you have read completely to date:

   -1 0 1 2 3 4 5 6 7 8 l9 20 21 22 23 25 26 28 29 30 .

   NAME: ____

This question does **NOT** count on this test, but the reported readings do count for your grade. If you can't remember all the ones you have read at this moment, then report all your readings to me ASAP on an activity slip or by email. Remember, at the end of the semester, it is the student's responsibility to get a confirmation of reported readings from the instructor **OR** by consulting the online grades posted under anonymous aliases.

---

000 qmult 00026 1 1 1 easy memory: the RHSTs for Ast103: Planetary systems

7. The 20 reading-homework-self-testings (RHSTs) for Ast103: Planetary Systems are

   a) -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 21.
   b) -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 20, 21, 22, 23, 25, 26, 28, 29, 30.
   c) -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.
   d) 11, 12, 13, 14, 15, 16, 18, 21.
   e) 21, 22, 23, 25, 26, 28, 29, 30.

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000 qmult 00028 1 1 2 easy memory: the RHSTs for Ast104: Star and Galaxies/Cosmology

8. The 20 reading-homework-self-testings (RHSTs) for Ast104: Star and Galaxies/Cosmology are

   a) -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 21.
   b) -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 20, 21, 22, 23, 25, 26, 28, 29, 30.
   c) -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.
   d) 11, 12, 13, 14, 15, 16, 18, 21.
   e) 21, 22, 23, 25, 26, 28, 29, 30.

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000 qmult 00030 1 1 3 easy memory: group activities | in-person instruction only

9. For in-person instruction where we have group activities, how many people should be in a group for group activities? Typically:

   a) zero. b) 1. c) 2 or 3. d) at least 30. e) a committee of the whole.

---

000 qmult 00032 1 1 2 easy memory: group activity slip name | in-person instruction only

10. For in-person instruction where we have group activities, your name should appear printed legibly on a group activity slip:

   a) never. b) once. c) twice. d) as often as needed.
   e) with letters randomly permuted.

---

000 qmult 00040 1 4 4 easy deducto-memory: interview mark | in-person instruction only

11. "Let's play *Jeopardy*! For \$100, the answer is: For in-person instruction where we have interviews, it is due by the last day of classes of the semester and is worth 1 % of the final grade."

   What is ____________, Alex?

   a) graduation b) the final exam c) a skill test and question
   d) the interview with the instructor e) a group activity report

---

000 qmult 00042 1 1 2 easy memory: interview substitute | in-person instruction only

12. For in-person instruction where we have interviews, the interview can be substituted for by some special activity, e.g., a visit to an observatory or

   a) class attendance. b) attendance at public astronomy lecture.
   c) attendance at poetry reading. d) going out to see *Gravity* (2013 film).
   e) going out to see *The Wolverine* (2013 film).

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000 qmult 00080 1 4 5 easy deducto-memory: final exam comprehensive

13. "Let's play *Jeopardy*! For \$100, the answer is: Comprehensive."

   What is ____________, Alex?

a) *Introductory Astronomy Lectures* b) Exam 1 c) Exam 2
d) the mathematics included in this course e) the Final Exam

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000 qmult 00090 1 4 5 easy deducto-memory: grade categories | in-person instruction only

14. "Let's play *Jeopardy*! For $100, the answer is: For in-person instruction, reading-homework-self-testings (RHSTs) 10 %, group activities 9 %, interview 1 %, 2 in-class tests 40 %, comprehensive final exam 40 %."

What are grading categories and weighting for ____________ with in-person instruction, Alex?

a) organic chemistry b) film history c) graphic design d) calculus III
e) intro astronomy

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000 qmult 00092 1 4 5 easy deducto-memory: grade categories | remote instruction only

15. "Let's play *Jeopardy*! For $100, the answer is: For remote instruction, reading-homework-self-testings (RHSTs) 10 %, 2 in-class tests 40 %, comprehensive final exam 50 %."

What are grading categories and weighting for ____________ with in-person instruction, Alex?

a) organic chemistry b) film history c) graphic design d) calculus III
e) intro astronomy

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000 qmult 00094 1 1 3 easy memory: grade record explanation

16. The grade records posted by anonymous aliases for Ast103/104 are undestandable without explanation since they are:

a) invisible. b) just bottom-up. c) just top-down. d) left-to-right
e) right-to-left.

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000 qmult 00096 1 1 1 easy memory: site to explain grade record | obsolete with mark5.f

17. A website that explains how to interpret your grade record for this course:

a) does exist. b) does not exist. c) maybe exists. d) will exist in the future.
e) used to exist.

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000 qmult 00100 1 1 2 easy memory: philosophical/historical/poetical intro

18. It is somewhat traditional or at least not unusual to begin a book or course on ____________ with a philosophical/historical/poetical statement.

a) agronomy b) astronomy c) metallurgy d) proctology e) tautology

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000 qmult 00130 1 4 3 easy deducto-memory: Carl Sagan

19. "Let's play *Jeopardy*! For $100, the answer is: An American astronomer of the 2nd half of the 20th century, famous for planetology and science popularization—arguably the most well known scientist of his time."

Who is ____________, Alex?

a) Albert Einstein (1879–1955) b) George Gamow (1904–1968)
c) Carl Sagan (1934–1996) d) Richard Feynman (1918–1988) e) Brian Greene (1963–)

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000 qmult 00131 1 4 4 easy deducto-memory: Carl Sagan

20. "Let's play *Jeopardy*! For $100, the answer is: An American astronomer of the 2nd half of the 20th century, famous for planetology and science popularization—arguably the most well known scientist of his time."

Who is ____________, Alex?

a) Albert Einstein (1879–1955) b) George Gamow (1904–1968)
c) Carl Sagan (1934–1996) d) Richard Feynman (1918–1988) e) Brian Greene (1963–)

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000 qmult 00200 1 4 5 easy deducto-memory: science partially defined

21. "Let's play *Jeopardy*! For $100, the answer is: An activity that involves a study of objective reality and the scientific method."

    What is ____________, Alex?

    a) accounting b) poetry c) home repair d) homework e) science

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000 qmult 00210 1 1 2 easy memory: scientific method described

Extra keywords: physci KB-24-1 but much altered

22. The scientific method can be schematically described as a/an:

    a) hypothesis of theorizing and experiment/observation.
    b) cycle of theorizing and experiment/observation. c) reductive process.
    b) integrative process. e) cycle of experiment and observation.

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000 qmult 00220 1 3 3 easy math: Occam's razor

23. In scientific theorizing, a rule that has come to be accepted is *"Pluralitas non est ponenda sine necessitate,"* i.e., "Plurality is not to be posited without necessity" which was stated by Medieval scholastic philosopher John Duns Scotus (c.1266–1308). The rule is called Occam's razor after another Medieval scholastic philosopher William of Occam (c.1287–1347), who said something similar. In fact the general idea was expressed by none other than Aristotle (384–322 BCE): "We may assume the superiority *ceteris paribus* (other things being equal) of the demonstration which derives from fewer postulates or hypotheses." The essential idea in modern jargon is don't introduce into theories hypotheses that:

    a) are needed. b) both needed and not needed. c) are not needed.
    d) that neither needed nor not needed. e) not purely philosophical.

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000 qmult 00230 1 4 1 easy deducto-memory: Pascal on Falsifiability

24. "Let's play *Jeopardy*! For $100, the answer is: This **17TH CENTURY FRENCH** scientist gave an early (and probably the first) statement of the falsifiabilty doctrine—which has been much debated, but at least with qualifications has been accepted by many. His statement is as follows:

    To prove a hypothesis, it is not sufficient to show that all known phenomena can be derived from it. On the other hand, if the hypothesis leads to a single wrong prediction, it is false.

    —yours truly's own free translation.

    As it stands, this statement is open to some qualifications and objections—but that's another story."

    Who is ____________, Alex?

    a) Blaise Pascal (1623–1662) b) Isaac Newton (1643–1727)
    c) Charles Darwin (1809–1882) d) Louis Pasteur (1822–1895)
    e) Carl Sagan (1934–1996)

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000 qmult 00240 1 1 3 easy memory: science progressive

25. Most people would agree that science is:

    a) digressive. b) regressive. c) progressive. d) impressive. e) depressive.

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000 qmult 00242 1 4 5 easy deducto-memory: art defined sort of

Extra keywords: physci

26. "Let's play *Jeopardy*! For $100, the answer is: To give an inadequate, but arguably useful, definition: A human pursuit which has no absolute standard (although personal or local

standards are common and probably essential) that, among other things, tries to extend human understanding and to give pleasure, sometimes of a very qualified sort."

What is ____________, Alex?

a) a science b) nonsense c) geology d) of no conceivable use e) an art

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000 qmult 00310 1 4 2 easy deducto-memory: system defined

27. "Let's play *Jeopardy*! For $100, the answer is: In science jargon, that part of reality you have identified for study."

What is the ____________, Alex?

a) quadrant b) system c) environment d) surroundings e) segment

---

000 qmult 00350 1 1 3 easy memory: hierarchy of systems: special test

28. Planets (e.g., the Earth) and galaxies (e.g., the Milky Way) can be seen as levels in a ____________ of physical systems.

a) Jansenite b) Ptolemosaic c) hierarchy d) equation e) inequality

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000 qmult 00400 1 4 3 easy deducto-memory: physics defined partially

Extra keywords: physci

29. Physics can be briefly defined as the science of:

a) human relations. b) sports and leisure. c) matter and motion.
d) matter and rest. e) light.

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000 qmult 00410 1 4 2 easy deducto-memory: fundamental physics

30. "Let's play *Jeopardy*! For $100, the answer is: It is the branch of physics that is the search for very general laws and very general results (which are derived from those general laws). The general laws and results are always (or almost always) expressible as mathematical formulae."

What is ____________, Alex?

a) applied physics b) fundamental physics c) astronomy
d) low-temperature physics e) geophysics

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000 qmult 00412 1 4 4 easy deducto-memory: fundamental in physics

Extra keywords: physci

31. "Let's play *Jeopardy*! For $100, the answer is: 'Just so' in physics."

What is ____________, Alex?

a) a story by Rudyard Kipling b) essential c) eternal d) fundamental
e) infernal

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000 qmult 00420 1 4 2 easy deducto-memory: applied physics astronomy

Extra keywords: physci

32. Astronomy includes both ____________ and fundamental physics.

a) psychology. b) applied physics. c) other than physics.
d) fundamental physics. e) indifferent physics.

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000 qmult 00520 1 4 2 easy deducto-memory: emergent theory

33. "Let's play *Jeopardy*! For $100, the answer is: In the opinion of the intstuctor, it is any important theory that applies to reality in some form. Such theories are in some sense and to some degree independent of other theories including the true fundamental theory of physics. They emerge from reality and are like Platonic ideals. Another view is that it is a theory that applies to a complex system but not to that system's components. It emerges from the complexity. The two views arn't all that far apart if you define complexity broadly enough."

What is a/an ____________ theory, Alex?

a) convergent b) emergent c) divergent d) specious e) faux

---

000 qmult 00560 2 4 2 moderate deducto memory: genetic algorithm

34. Evolution by survival of the fittest is used in computer calculations to find optimum solutions to problems where the solutions are treated as breeding entities. The best known of such techniques is called the:

a) genetic methodology. b) genetic algorithm method. c) Darwin algorithm method.
d) no-name method. e) evolution method.

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000 qmult 00570 2 4 1 moderate deducto-memory: 2nd law a pan-universal theory

35. In the multiverse paradigm, it is posited that the 2nd law of thermodynamics must ____________ absolutely everythere in the multiverse—in all the pocket universes and all the regions between them—even though the multiverse outside our pocket universe may have different physics in most respects from our pocket universe.

a) hold b) not hold c) be impossible d) be infernal e) be notorious

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000 qmult 00599 1 4 3 easy deducto-memory: true approximate theory

Extra keywords: Abandoned forever. I just no longer like "true approximate theory" concept

36. Newtonian physics can be described as:

a) modern day fundamental physics. b) an exactly true theory.
c) a true approximate theory. d) a false approximate theory.
e) both false and true.

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000 qmult 00600 1 4 3 easy deducto-memory: Bayesian analysis

37. "Let's play *Jeopardy*! For $100, the answer is: It a technique in statistics for dealing of the probability of truth of theories to your knowledge. It could be called the scientific method quantified."

What is ____________, Alex?

a) Bayes' theorem b) Occam's theorem c) Bayesian analysis d) Occam's razor
e) Bayes' axiom

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000 qmult 00610 1 1 1 easy memory: Bayes' theorem

38. ____________ is profound, but simple:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} ,$$

where $P(A|B)$ is the probability of A given B, $P(B|A)$ is the probability of B given A, $P(A)$ is the probabilty of A, and $P(B)$ is the probability of B. Note all the probabilities could be given some undisplayed event or events (e.g., events C, D, etc.) which in a Bayesian analysis are within your knowledge.

a) Bayes' theorem b) Occam's theorem c) Bayesian analysis d) Occam's razor
e) Bayes' axiom

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000 qmult 00700 1 1 2 easy memory: aphorism for anthropic principle

39. The aphorism "Things have to be the way they are or we wouldn't be here to observe them." loosely summarizes:

a) the cosmological principle. b) the anthropic principle. c) Bayesian analysis.
d) the fundamental principle. e) falsifiability.

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000 qmult 00730 1 1 3 easy memory: anthropic principle, triple alpha process

40. Fred Hoyle (1915–2001) in 1952 hypothesized that a nuclear reaction process with special properties, now called the triple-alpha process, had to exist to create abundant carbon in the observable universe since abundant carbon does exist and our understanding cosmology even in 1952 did not imply there necessarily had to be abundant carbon. Soon after Hoyle's prediction, the triple-alpha process was discovered. Now Hoyle was not using ____________ in a formal sense as a discovery tool since our existince in a direct sense does not imply the triple-alpha process. But his hypothesis was based on a generalization: the existence of A implies B even though we have never before observed B.

a) the cosmological principle. b) Bayesian analysis. c) the anthropic principle.
d) the fundamental principle. e) falsifiability.

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000 qmult 00810 1 1 4 easy memory: branches of physics

41. From one perspective, the important branches or realms physics that are exact in certain limits (as far as we know) can be regarded as approximations to the ultimate fundamental physics which is often called theory of everything (TOE) or TOE-plus to include thermodynamics. Another perspective is to call these branches true:

a) cosmological theories. b) Bayesian theories. c) branches.
d) emergent theories. e) anthropic theories.

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000 qmult 00820 1 1 4 easy memory: astronomy applied and fundamental physics

42. Astronomy can be considered both applied physics (since it uses all branches of physics) and fundamental physics since it includes:

a) psychology. b) biology. c) cosmetology. d) cosmology.
e) nuclear physics.

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000 qmult 00920 1 1 2 easy memory: physical science defined
Extra keywords: physci

43. A physical science can be defined as:

a) an art form. b) a science that depends strongly on physics. c) a science that does not depend on physics at all. d) a science that is identical with fundamental physics. e) a pointless pursuit.

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000 qmult 00922 1 4 3 easy deducto-memory: example physical sciences
Extra keywords: physci

44. The following are usually considered physical sciences:

a) proctology, theosophy, and Deuteronomy. b) proctology, immunology, and biology.
c) chemistry, geology, and meteorology. d) proctology, geology, and biology.
e) chemistry, geology, and biology.

---

000 qmult 01000 1 1 3 easy memory: astronomy defined

45. In the broadest sense, ____________ is the study of all extraterrestrial phenomena and also terrestrial phenomena that fall into the same categories as extraterrestrial phenomena.

a) agronomy b) antimony c) astronomy d) antiquity e) antigone

---

000 qmult 01050 1 1 1 easy memory: astronomy oldest empirical science

46. Although one can quibble, most would agree that astronomy is the best candidate for being:

a) the oldest empirical science. b) the newest empirical science.
c) of little interest. d) the same as astrology. e) the queen of the sciences.

Chapt. 1 Scientific Notation, Units, Math, Angles, Plots, and Orbits

Multiple-Choice Problems

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001 qmult 00100 1 4 5 easy deducto-memory: math needed for astronomy

47. "Let's play *Jeopardy*! For \$100, the answer is: It is a math intensive field of science."

    What is ____________, Alex?

    a) painting b) sculpture c) literature d) music e) astronomy

---

001 qmult 00200 1 1 3 easy memory: scientific notation defined 1

48. In ____________, a number is written in the form

$$a \times 10^b ,$$

where a is the coefficient (or in more elaborate jargon the significand or mantissa) and b is the exponent. In normalized ____________, $a \in [1, 10)$ (i.e., $1 \leq a < 10$).

    a) logarithmic notation b) ordinary decimal notation c) scientific notation
    d) natural logarithmic notation e) power-10 notation

---

001 qmult 00202 1 4 2 easy deducto-memory: scientific notation defined 2
Extra keywords: physci

49. "Let's play *Jeopardy*! For \$100, the answer is: It is a notation in which one expresses a number by a prefix number (usually in the range 1 to 10, but not including 10) multiplied explicitly by 10 to the appropriate power."

    What is ____________, Alex?

    a) British notation b) scientific notation c) metric notation d) tensy notation
    e) Irish notation

---

001 qmult 00210 1 3 3 easy math: hundred million billion in sci. not.
Extra keywords: physci

50. Write a hundred million billion miles in scientific notation.

    a) 10^2 mi. b) 10^6 mi. c) 10^{17} mi. d) 10^9 mi. e) 10^{-9} mi.

---

001 qmult 00220 1 3 1 easy math: show in scientific notation

51. Express 4011 and 0.052 in the most conventional scientific notation form.

    a) 4.011×10^3 and 5.2×10^{-2}. b) 40.11×10^3 and $52. \times 10^{-2}$.
    c) 40.11×10^2 and $52. \times 10^{-3}$. d) 4.011×10^{-2} and 5.2×10^3. e) 4011 and 0.052.

---

001 qmult 00230 1 3 2 easy math: scientific notation understood

52. The quantity 2.9979×10^{10} cm/s is the same as:

    a) 29979000 cm/s. b) 29979000000 cm/s. c) 2.9979×10^{10} km/s.
    d) the speed of sound. e) 2.9979 cm/s.

---

001 qmult 00240 1 1 1 easy memory: not scientific notation

53. Which quantity is **NOT** expressed in scientific notation?

a) 3.1416. b) 3.1416×10^0. c) $\pi \times 10^7$ s. d) 3.1416×10^7s.
e) 2.99792458×10^8 m/s.

---

001 qmult 00250 1 3 4 easy math: sci. not. and sig. fig.

54. Add and multiply 3.01×10^2 and 1.1×10^{-1} rounding off to significant figures. The answers to the two questions are, respectively:

a) 3.0111×10^2 and 3.311×10^1. b) 3.01×10^2 and 3.311×10^1.
c) 3.0111×10^2 and 3.3×10^1. d) 3.01×10^2 and 3.3×10^1.
e) 3.0×10^2 and $3. \times 10^1$.

---

001 qmult 00300 1 4 5 easy deducto-memory: units needed
Extra keywords: physci

55. "Let's play *Jeopardy*! For $100, the answer is: In any measurements of quantities, they are conventionally agreed upon standard things."

What are ____________, Alex?

a) unities b) dualities c) duplicities d) quantons e) units

---

001 qmult 00310 1 4 3 easy deducto-memory: SI and MKS

56. "Let's play *Jeopardy*! For $100, the answer is: The international standard units for science and probably the most common subset of these units."

What are the ________ units and ________ units, Alex?

a) US customary; Btu b) SI or metric; HMS c) SI or metric; MKS
d) US customary; MKS e) ancient Babylonian; HMS

---

001 qmult 00320 1 1 4 easy memory: non-metric US

57. The only major country (if you don't count Liberia and Myanmar as major) that does **NOT** use metric units for standard units is:

a) Ireland. b) Belize. c) the United Kingdom. d) the United States.
e) France.

---

001 qmult 00330 1 4 3 easy deducto-memory: MKS

58. MKS stands for:

a) meters, kilometers, centimeters. b) meters, kilometers, seconds.
c) meters, kilograms, seconds. d) millimeters, kilometers, seconds.
e) millimeters, kilograms, seconds.

---

001 qmult 00340 1 1 5 easy memory: metric kilo and centi
Extra keywords: physci

59. In the metric system, the prefixes kilo and centi indicate, respectively, multiplication by:

a) π and e. b) 0.01 and 1000. c) 1000 and 100. d) 60 and 0.01.
e) 1000 and 0.01.

---

001 qmult 00342 1 4 2 easy deducto-memory: SI prefix symbols M- and m-

60. The metric or SI unit prefix symbols M- and m- stand for:

a) mega (factor of 10^6) and milli (factor of 10^{-6}). b) mega (factor of 10^6) and milli (factor of 10^{-3}). c) kilo (factor of 10^6) and milli (factor of 10^{-3}). d) kilo (factor of 10^6) and milli (factor of 10^{-6}). e) merger (factor of 10^9) and melba (factor of 10^{-6}).

---

001 qmult 00350 1 1 2 easy memory: natural units

61. Standard units like the metric units—and metric units are the only recognized standard ones—are essential for elaborate calculations and the comparison of amounts of vastly different size. But for special systems, it is often convenient to use units adapted for those systems at least in thinking about the systems and sometimes in simple calculations. Following the supreme authority, Wikipedia, these units can be called:

a) unnatural units. b) natural units. c) base units. d) low, despised units. e) good units.

---

001 qmult 00360 1 1 1 easy memory: astronomical unit

62. The mean distance from the Earth to the Sun in astronomical units (AU) is:

a) 1 AU. b) 40 AU. c) 1.496×10^{13} cm. d) 1.5 AU. e) 8 arcminutes.

---

001 qmult 00362 1 4 3 easy deducto-memory: Pluto-Sun distance

63. Ex-planet Pluto's mean distance from the Sun is about:

a) 0.387 AU. b) 1.0 AU. c) 39.54 AU. d) 67.781 AU. e) 700 AU.

---

001 qmult 00364 1 4 1 easy deducto-memory: Mercury-Sun distance

64. Mercury's mean distance from the Sun is about:

a) 0.387 AU. b) 0.95 AU. c) 1.0 AU. d) 67.781 AU. e) 700 AU.

---

001 qmult 00366 1 1 3 easy memory: Earth equatorial radius natural unit

65. The Earth equatorial radius $R_{\text{eq},\odot} = 6378.1370\,\text{km}$ is a good natural unit for distances to Solar System objects significantly less 1 AU from the Earth. It is used most commonly for:

a) Earth-Mars mean dist. 60.2687 $R_{\text{eq},\odot}$. b) Earth-Moon mean dist. 30.2687 $R_{\text{eq},\odot}$. c) Earth-Moon mean dist. 60.2687 $R_{\text{eq},\odot}$. d) Earth-Venus mean dist. 30.2687 $R_{\text{eq},\odot}$. e) Earth-Cruithne mean dist. 30.2687 $R_{\text{eq},\odot}$

---

001 qmult 00370 1 4 4 easy deducto-memory: light-year definition

66. A light-year is:

a) the opposite of a leap year. b) less filling. c) the cause of eclipses. d) the distance light travels in one year. e) the time it takes the Earth to return to the same point relative to the observable universe (i.e., the fixed stars in the traditional expression).

---

001 qmult 00372 1 4 4 easy deducto-memory: light-year a natural unit

67. "Let's play *Jeopardy*! For $100, the answer is: It is a good natural unit for interstellar distances since nearest neighbor stars (not in multiple-star systems) are typically of order this unit apart. Additionally, for non-cosmologically remote astronomical objects, the value of the distance in this unit usually approximately equals the value of the lookback time in a natural unit of time for astronomical and many other purposes."

What is ____________, Alex?

a) parsec b) meter c) kilometer d) light-year e) year

---

001 qmult 00374 1 1 2 easy memory: lookback time calculation 1

68. The lookback time to an object 10 light-years away is:

a) 3 years. b) 10 years. c) 30 years. d) 100 years. e) 300 years.

---

001 qmult 00376 1 1 5 easy memory: lookback time calculation 2

69. The lookback time to an object 300 light-years away is:

a) 3 years. b) 10 years. c) 30 years. d) 100 years. e) 300 years.

---

001 qmult 00380 1 1 4 easy memory: parsec the pimary natural unit

70. Astronomers use ____________ as the primary natural unit for interstellar distances. The secondary one is ____________. They probably should use the secondary one since it has a good modern rationale. But history has stuck us with the primary one.

a) parsec; kilometer b) light-year; kilometer c) light-year; parsec
d) parsec; light-year e) megaparsec; kilometer

---

001 qmult 00382 1 4 2 easy deducto-memory: parsec defined
71. "Let's play *Jeopardy*! For \$100, the answer is: Its definition is the distance to an object that subtends 1 arcsecond ($1''$) for a baseline of 1 astronomical unit (1 AU)."

What is the ____________, Alex?

a) light-year b) parsec c) astronomical unit d) kilometer e) light-minute

---

001 qmult 00384 1 1 1 easy memory: parsec distance in light-years
72. A parsec (pc) is:

a) about 3 light-years. b) the same as a light-year. c) about the same as a light-year. d) the distance light travels in a year. e) about 2 light-years.

---

001 qmult 00386 1 1 1 easy memory: parsec usage
73. A parsec (pc) is a unit typically used for:

a) nearest-neighbor interstellar distances. b) nearest-neighbor intergalactic distances.
c) terrestrial distances. d) foot races. e) horse races.

---

001 qmult 00387 1 1 3 easy memory: kiloparsec usage
74. A kiloparsec (Kpc) is a unit typically used for:

a) terrestrial distances. b) interstellar distances.
c) **INTRAGALACTIC** distances. d) **INTERGALACTIC** distances.
e) horse races.

---

001 qmult 00388 1 1 2 easy memory: megaparsec usage
75. A megaparsec (Mpc) is a unit typically used for:

a) interstellar distances. b) intergalactic distances. c) terrestrial distances.
d) foot races. e) horse races.

---

001 qmult 00390 1 4 3 easy deducto-memory: solar units defined
76. "Let's play *Jeopardy*! For \$100, the answer is: Because the Sun is our star and because it is not particularly large or small as stars go, we use it as the basis for these natural units."

What are ____________, Alex?

a) terrestrial units b) Venusian units c) solar units d) Mars units
e) Jupiter units

---

001 qmult 00392 1 1 2 easy memory: primordial solar nebula composition
77. The solar mass and solar luminosity are the most commonly used solar units. We also use the ________________ composition as the reference composition in astronomy since to 1st order it is the cosmic composition, except that metallicity can vary by orders of mangitude.

a) red giant phase solar b) primordial solar nebula c) Jupiter d) terrestrial
e) lunar

---

001 qmult 00396 1 4 1 easy deducto-memory: relevant physical scales
78. Name three astronomically relevant physical scales.

a) The Earth-Moon distance, the Earth-Sun distance, and the radius of the Galactic disk.

b) The Earth-Moon distance, the Earth-Sun distance, and the length of a snail's trail.
c) The Earth-Moon distance, the Earth-Paris distance, and the length of a snail's trail.
d) The Earth-Moon distance, the Earth-Sun distance, and the Las Vegas-Reno distance.
e) The Earth-Moon distance and the Earth-Sun distance.

---

001 qmult 00397 1 4 4 easy deducto-memory: irrelevant physical scale

79. Name a physical scale that is **NOT** relevant to astronomy.

a) The Earth-Moon distance. b) The Earth-Sun distance.
c) The radius of the Galactic disk. d) The Las Vegas-Reno distance.
e) The radius of the Galactic halo. The Galactic halo is a spherical mass distribution surrounding the Galactic disk. It has relatively little luminous matter, but apparently a lot of dark matter.

---

001 qmult 00398 1 4 5 easy deducto-memory: Fermi micro-century lecture 1
Extra keywords: mathematical physics

80. "Let's play *Jeopardy*! For $100, the answer is: Nearly the time period of a standard 50-minute lecture period as noted by Italian-American physicist Enrico Fermi (1901–1954)."

What is ____________, Alex?

a) an eternity b) a deci-century (i.e., a tenth of a century) c) 360 seconds d) a centi-century (i.e., a hundredth of a century) e) a micro-century (i.e., a millionth of a century)

---

001 qmult 00399 2 5 4 moderate thinking: Fermi micro-century lecture 2
Extra keywords: Requires deduction, but a calculation works too.

81. "Let's play *Jeopardy*! For $100, the answer is: The approximate length of a standard university lecture as pointed out by Nobel-prize-winning physicist Enrico Fermi."

What ____________, Alex?

a) is a century b) seems like a century c) is a centi-century
d) is a micro-century e) is a milli-century

---

001 qmult 00400 1 1 3 easy memory: 3 common temperature scales

82. The only three temperature scales in common use are the Fahrenheit scale, the Celsius scale, and the:

a) Rankine scale. b) centigrade scale. c) Kelvin scale. d) Calvin scale.
e) Calvin-Hobbes scale.

---

001 qmult 00410 1 1 5 easy memory: Fahrenheit scale

83. Nowadays the Fahrenheit scale is adequate for:

a) nothing. b) physics calculations. c) engineering calculations outside of the U.S.
d) understanding biota. e) conventional uses in the U.S.

---

001 qmult 00420 1 1 3 easy memory: Celsius scale

84. Biota require liquid water and the ____________ scale has zero as freezing and 100 as boiling at 1 atmosphere pressure (except that values under super precisely defined conditions are actually slightly different). So the ____________ scale is a good natural temperature scale for biota since it is easy to think about the temperature state of biota when using ____________ scale.

a) Fahrenheit b) Rankine c) Celsius d) Kelvin e) Rankine-Hugoniot

---

001 qmult 00430 1 1 5 easy memory: Kelvin scale zero

85. The Kelvin scale degree (symbolized K, but with symbol $^\circ$ omitted by convention) is the same size as the Celsius scale degree (symbolized C). The Kelvin scale is a good natural scale for physics and astronomy since absolute zero is defined to be:

a) 100 K.   b) 300 K.   c) −40 K.   d) 273.15 K.   e) 0 K.

---

001 qmult 00440 1 1 1 easy memory: absolute zero defined

86. Absolute zero is when all microscopic kinetic energy has been removed that can be removed. This is the coldest that matter can be. However, quantum mechanics (the best verified of all physics theories) dictates that there is an irremovable minimum microscopic kinetic energy which is called the:

a) zero-point energy.   b) negative-point energy.   c) positive-point energy
d) triple-point energy.   e) infinite energy.

---

001 qmult 00442 1 4 1 easy deducto-memory: absolute zero reached

87. "Let's play *Jeopardy*! For $100, the answer is: It is a matter of point of view that this temperature state can actually be reached. A small enough sample can be put in the state, but some say if it is small enough to be put in the state, then it is too small to be considered to have a temperature since temperature is an average property of matter. In any case, where the state is is exactly known from limiting processes.

What is ____________, Alex?

a) absolute zero   b) the freezing point of water   c) the boiling point of water
d) the triple point of water   e) absolute hot

---

001 qmult 00444 1 1 1 easy memory: negative Kelvin scale temperatures

88. Remarkably there are negative temperature states even for the Kelvin scale. They are **NOT** colder than absolute zero since the microscopic particles have more than the zero-point energy. The situation is that temperature among other things is a parameter controlling how particles are distributed among microscopic energy levels in statistical mechanics. Some ____________ distributions require negative temperatures. Negative temperature states can be constructed in the laboratory, but probably exist only fleetingly in nature.

a) unusual   b) normal   c) everyday   d) freezing   e) boiling

---

001 qmult 00450 1 1 3 easy memory: temperature scale conversions

89. The conversion formulae worth knowing for the common temperature scales are:

$$T_{\rm K} = T_{\rm C} + 273.15 \;, \quad T_{\rm C} = T_{\rm K} - 273.15 \;, \quad T_{\rm F} = 1.8 T_{\rm C} + 32 \;, \quad T_{\rm C} = (5/9)(T_{\rm F} - 32) \;,$$

where K, C, and F stand for, respectively:

a) Fahrenheit, Celsius, and Kelvin.   b) Celsius, Kelvin, and Fahrenheit.
c) Kelvin, Celsius, and Fahrenheit.   d) Celsius, Fahrenheit, and Kelvin.
e) Kilroy, Calvin, and Fassbinder

---

001 qmult 00500 1 1 5 easy memory: two simple math formulae

90. Two simple math formulae that everyone should know are for the amount A accumulated at constant rate R in time t and the inverse formula for the time t to accumulate amount A at constant rate R. The formulae are, respectively:

a) $t = A/R$ and $A = Rt$.   b) $t = AR$ and $A = R/t$.   c) $A = R/t$ and $t = AR$.
d) $A = Rt^2$ and $t = A/R^2$.   e) $A = Rt$ and $t = A/R$.

---

001 qmult 00510 1 3 4 easy math: light-minute

91. About how many kilometers are there in a light-minute? Recall the speed of light $c = 2.99792458 \times 10^{10}$ cm/s.

a) 2.9979×10^{10} km.   b) 3×10^{10} km.   c) 1.8×10^{12} km.   d) 1.8×10^{7} km.
e) 3×10^{7} km.

---

001 qmult 00512 1 3 3 easy math: length of day in seconds

92. "Let's play *Jeopardy*! For \$100, the answer is: 86400."

What is the length of ________ in seconds, Alex?

a) a minute b) an hour c) a day d) a year e) four score and seven years

---

001 qmult 00514 1 3 3 easy math: length of year in seconds

93. The length of a Julian year of 365.25 days in seconds is:

a) 60 s. b) 86400 s. c) about $\pi \times 10^7$ s. d) about 10^5 s. e) about 2.2×10^6 s.

---

001 qmult 00520 1 3 2 easy math: Earth speed on equator

94. The Earth rotates once per day and its equatorial radius is 6378.1370 km. What is the speed of a point on the equator relative to the observable universe (i.e., the fixed stars as one says traditionally)? The rotational period of the Earth relative to the observable universe is the sidereal day, not the day which is relative to the Sun. The mean sidereal day is 86164.0905 s.

a) 1 km/s. b) 0.465 km/s. c) 3×10^5 km/s. d) 1 km. e) 0.465 km.

---

001 qmult 00522 1 1 2 easy memory: sidereal period

Extra keywords: CK-61-4

95. The ____________ period is the time it takes a Solar System body (e.g., a planet) to return to the same point relative to the observable universe (i.e., the fixed stars in the traditional expression).

a) lunar b) sidereal c) synodic d) **TROPICAL** e) **TOPICAL**

---

001 qmult 00524 1 5 5 easy thinking: Earth speed at the poles

Extra keywords: Save this one for finals?

96. The Earth rotates once a day and its equatorial radius is 6378.1370 km. What is the speed of a point at the **POLES** relative to a reference frame orbiting with the Earth, but **NOT** rotating with respect to the observable universe?

a) 1 km/s. b) 0.46 km/s. c) 3×10^5 km/s. d) 1 km. e) Zero velocity.

---

001 qmult 00530 2 5 4 moderate thinking: falling speed in 3 seconds

97. The acceleration due to gravity of a free-falling object near the surface of the Earth is $g = 9.8\,\text{m/s}^2$. If an object falls from rest and one can neglect air resistance, what is its speed after 3 seconds?

a) $9.8\,\text{m/s}^2$. b) 9.8 m/s. c) 0.1 m/s. d) about 30 m/s. e) 98 m/s.

---

001 qmult 00540 1 3 2 easy math: light travel time to Moon

98. The mean distance from the Moon to the Earth is 3.844×10^{10} cm and the speed of light is 2.998×10^{10} cm/s. How long does it take light to travel from the Moon to the Earth?

a) 8 minutes. b) 1.28 seconds. c) No time at all. d) 30 seconds.
e) 30 arcminutes.

---

001 qmult 00542 2 3 4 moderate math: light travel time to Pluto

Extra keywords: a trick question

99. Pluto is about 40 astronomical units from the Sun. One astronomical unit is about 1.5×10^{13} cm. The speed of light is 3.00×10^{10} cm/s. The light travel time from the Sun to Pluto is:

a) 2×10^3 s or about half an hour. b) 2×10^3 s or about 5.5 hours.
c) 3.6×10^3 s or one hour. d) 2×10^4 s or about 5.5 hours.
e) 2×10^4 s or about 8 hours.

---

001 qmult 00544 1 3 2 easy math: light travel time to Proxima Cen

100. The star Proxima Centauri is 4.2 light-years from the Earth. How many years does it take for light to travel from Proxima to Earth?

a) 4.2 light-years. b) 4.2 years. c) 4.2 seconds. d) 8 minutes.
e) Millions of years.

---

001 qmult 00600 1 4 5 easy deducto-memory: subtend definition

101. "Let's play *Jeopardy*! For $100, the answer is: It is the transitive verb used in geometry to mean an angle delimits a line or curve or, vice versa, to mean a line or curve delimits an angle."

What is to ____________, Alex?

a) sublend b) submend c) subrend d) subspend e) subtend

---

001 qmult 00610 1 1 4 easy memory: degree, arcminute, arcsecond

102. How many degrees in a circle, arcminutes in a degree, and arcseconds in an arcminute?

a) 100, 10, 10. b) 360, 10, 10. c) 360, 100, 100. d) 360, 60, 60.
e) 360, 24, 60.

---

001 qmult 00622 2 4 2 moderate deducto-memory: fist angle

103. A fist at arm's length for the average person spans about how many degrees?

a) About 1°. b) About 10°. c) About 18°. d) 180°. e) 360°.

---

001 qmult 00624 2 5 4 easy memory: satellite angular separation in fists

104. A Earth-orbiting artificial satellite is passing by Polaris. At closest approach it is about a fist at arm's length away in angular separation. What is the closest approach in angle and in spatial separation?

a) About 10° in angle and about 10 light years in space.
b) About 100° in angle and about 100 light years in space.
c) About 360° in angle and you **CANNOT** tell the spatial separation with the information given.
d) About 10° in angle and the spatial separation is virtually the same as the Earth-Polaris spatial separation since the Earth-satellite spatial separation is negligible for most purposes compared to the Earth-Polaris spatial separation.
e) About 10° in angle and also about 10° in spatial separation.

---

001 qmult 00626 2 4 4 moderate deducto-memory: star angular separation

105. Two stars are about 1 fist width apart on the sky. (The fist is at arm's length.) What is the angular separation of the two stars? How far apart are they in space?

a) The angular separation is about 100° and the stars are separated by about 100 light-years.
b) The angular separation is about 360° and the stars are separated by about 360 light-years.
c) The angular separation is about 10° and the stars are separated by about 10 light-years.
d) The angular separation is about 10°. The spatial separation **CANNOT** be determined from the given information.
e) The angular separation is about 1 arcsecond. The spatial separation **CANNOT** be determined from the given information.

---

001 qmult 00652 1 1 2 easy memory: angular velocity of the Moon

106. The Moon's orbital period (i.e, the sidereal month) is 27.321661547 days (J2000). What is the Moon's orbital angular velocity relative to the observable universe (i.e., the fixed stars in the traditional expression)?

a) 12.19°/day. b) 13.18°/day. c) 12.50°/day. d) 15.19°/day.
e) 27.32°/day.

---

001 qmult 00710 1 4 1 easy deducto-memory: linear function

107. A straight line on a linear plot represents a/an ____________ function.

a) linear b) inverse-square c) quadratic d) logarithmic e) perpendicular

---

001 qmult 00722 1 4 2 easy deducto-memory: inverse-square function

108. A curve on a linear plot that decreases as 1 over the square of the horizontal axis coordinate represents a/an ____________ function.

a) linear b) inverse-square c) quadratic d) logarithmic e) perpendicular

---

001 qmult 00730 2 5 4 moderate thinking: infinity at x=0

109. If a function goes to infinity at $x = 0$ (i.e., the origin of the horizontal axis), it

a) is a linear function. b) may be a linear function.
c) must be an inverse-square function. d) may be an inverse-square function.
e) cannot be an inverse-square function.

---

001 qmult 00752 1 1 2 easy memory: base-10 log plot unit

110. On a base-10 log plot (i.e., logarithmic plot), an axis unit is:

a) one. b) a power of ten. c) one or two. d) one, two, or three.
e) a power of one.

---

001 qmult 00754 2 1 1 moderate memory: base-10 log plot unit 2

111. On a base-10 logarithmic scale, the unit is a power of:

a) 10. b) e. c) 2.512. d) 3. e) 2.

---

001 qmult 00754 1 4 5 easy deducto-memory: log plot jeopardy

112. "Let's play *Jeopardy*! For $100, the answer is: On this kind of plot, the axis unit represents some power of ten."

What is a ____________ plot, Alex?

a) linear b) non-linear c) story d) nefarious e) standard logarithmic or log

---

001 qmult 00800 1 1 3 easy memory: inertial frame defined to a degree

113. An inertial frame is a reference frame with respect to which all laws of physics are referenced (at least in any ordinary sense), except general relativity which tells us what an exact inertial frame is. An elementary inertial frame (as told to us by general relativity) is is a/an ____________ that is **NOT** rotating with respect to the observable universe (i.e., the bulk mass-energy of the observable universe).

a) accelerating frame b) rotating frame c) free-fall frame d) non-rotating
e) oscillating frame

---

001 qmult 00809 1 1 5 easy memory: inertial frames explicated

114. In our modern understanding, all physical theories are referenced to ________________, except general relativity which tells us how ________________ are defined. There may, in fact, be some other theories **NOT** referenced to ________________, but it is probably arguable. General relativity tells us ________________ are free-fall frames.

To be concrete, the center of mass of a system (i.e., an astro-body or collection of astro-bodies) is in free-fall if the system only interacts with environment via the external gravitational field: i.e., the gravitation field from gravity sources outside the system (i.e., the enviroment). One has to further specify that the macroscopic motions of of interest in system are all in the classical limit (i.e., no relativistic velocities, no close black hole interactions). If they are not in the classical limit, then relativistic physics itself must be used to analyze the system. The center of mass defines a free-fall frame or a ________________. It is usually convenient make the center of mass the origin of coordinate system of the frame. All motions in system can be analyzed with respect to the origin and the only external force that needs to be considered is the tidal force (i.e., the difference in external gravitational field between points in the system). Motions outside the system **CANNOT** be analyzed in the system's ________________, but they must be known if they change the external gravitational field significantly. A special case of interest is a system so small that the tidal force is negligible and the self-gravity of the system is negligible: e.g., a spacecraft.

An important point to make is that a/an ________________ does **NOT** rotate with respect to the bulk mass-energy of the observable universe (i.e., with respect to the observable universe to be brief), except maybe in strong graviational fields like near black holes. This means all ________________ (except maybe in strong graviational fields) do **NOT** rotate with respect to each other. But note that pressure-supported asto-bodies in a system are almost always in rotation relative to the observable universe.

There are whole hierachies of ________________. For example, one can analyze the whole Solar System in its center-of-mass ________________ (i.e., approximately the Sun's center-of-mass ________________). However, subsystems can be treated in their own ________________ which is a convenient simplification if the subsystem is of detailed interest. In the Solar System, one can treat the Earth-Moon system as in its center-of-mass ________________ or the Earth alone as in its center-of-mass ________________. In fact, we usually treat the surface of the Earth at any location as an ________________. How can we do this since the locations are **NOT** in free fall? Well, the Earth's center of mass is in free fall and the locations are only slightly accelerated with respect to that center of mass. So for most purposes (but **NOT** all purposes), the locations can be treated as ________________ to good approximation. Very sensitive tests like Foucault's pendulum show that they are **NOT** exactly ________________.

a) non-inertial frame/s. b) isochronous frame/s. c) Lissajous frame/s.
d) centrifugal frame/s. e) inertial frame/s.

---

001 qmult 00900 1 4 5 easy deducto-memory: orbit defined

115. "Let's play *Jeopardy*! For $100, the answer is: Most generally, it is the trajectory of a body acted on only by gravity aside from perturbations by other forces."

What is a/an ____________, Alex?

a) escape trajectory b) closed orbit c) circular orbit d) hyperbolic orbit
e) orbit

---

001 qmult 19110 1 1 1 easy memory: Newton's cannonball

116. Newton's cannonball is a thought experiment showing what being in orbit is. It shows how initial velocity determines whether an orbit will be:

a) parabolic crashing, circular, elliptical, or unbound escaping.
b) parabolic escaping, great circular, ecliptical, or unbound crashing.
c) circular crashing, small circular, ecliptical, or unbound escaping.
d) Ptolemaic, Keplerian, Newtoninian, ecliptical, eclipsing.
e) parabolic crashing, circular, elliptical, or eclipsing.

---

001 qmult 00930 1 4 4 easy deducto-memory: eccentricity of circle

117. "Let's play *Jeopardy*! For $100, the answer is: Zero."

What is ____________, Alex?

a) less than b) the eccentricity of the Earth's orbit
c) the eccentricity of Pluto's orbit d) the eccentricity of a circular orbit
e) a legendary outlaw hero of old California

---

001 qmult 00940 3 1 4 tough memory: comet orbit eccentricities

118. Most comets that are gravitationally bound to the Sun have very elliptical orbits. This means that most bound comet orbits have eccentricities that are:

a) exactly zero. b) almost zero. c) exactly 1.
d) >> 0 in some sense, but less than 1. e) bigger than 1.

---

001 qmult 00944 1 4 1 easy memory: eccentricity and distance variation

119. The eccentricity of a body in orbit about the Sun is 0.20. How does its distance from the Sun vary?

a) At **APHELION** the body is **20 %** farther from the Sun than the standard mean distance. At **PERIHELION** it is **20 %** closer to the Sun than the standard mean distance.
b) At **APHELION** the body is **10 %** farther from the Sun than the standard mean distance. At **PERIHELION** it is **20 %** closer to the Sun than the standard mean distance.
c) At **APHELION** the body is **20 %** farther from the Sun than the standard mean distance. At **PERIHELION** it is **10 %** closer to the Sun than the standard mean distance.
d) The distance does not vary. The orbit is circular.
e) The orbit is extremely elliptical. At **APHELION** the planet is well beyond the orbit of **PLUTO**. At **PERIHELION** the planet is well within the orbit of **VULCAN**. Vulcan is an asteroid (sometimes called a planet in the past) that is within the orbit of Mercury. The body is clearly a comet.

---

001 qmult 00950 2 1 5 moderate memory: two-body elliptical orbits

120. There are two gravitationally-bound bodies isolated in space. Describe their motion.

a) The **LARGER** mass body orbits the **SMALLER** mass body in a circle.
b) The **SMALLER** mass body orbits the **LARGER** mass body in a circle.
c) The two bodies orbit their joint center of mass in ovals.
d) The two bodies orbit their joint center of mass in circles always.
e) The two bodies orbit their joint center of mass in ellipses.

---

001 qmult 00960 1 1 4 easy memory: planets move about the Sun

121. To very good approximation, the planets move in:

a) elliptical orbits with the Sun at the geometric center of ellipse. (The geometric center of an ellipse is where the major and minor axes cross: i.e., where the symmetry axes of the ellipse cross.)
b) planar orbits with the Sun at plane center.
c) circular orbits with the Sun at circle center.
d) elliptical orbits with the Sun at one focus of the ellipse.
e) spherical orbits with the Sun at sphere center.

---

001 qmult 00970 1 1 3 easy memory: planet elliptical orbits

122. The orbits of the planets are best described as:

a) highly elongated ellipses. b) perfect circles.
c) ellipses, most of them very nearly circular. d) triangles. e) 36-sided polygons.

---

001 qmult 00980 2 1 2 moderate memory: speed on orbit

123. A planet is orbiting the Sun in an **ELLIPTICAL** orbit.

a) It moves fastest at **APHELION** and slowest at **PERIHELION**.
b) It moves fastest at **PERIHELION** and slowest at **APHELION**.
c) It moves fastest at **HELLION** and slowest at **ANTIHELLION**.
d) It moves at a constant speed.
e) It doesn't move at all.

---

001 qmult 19810 1 1 4 easy memory: multi-body system solutions

124. In general, mult-body systems of mutually gravitating bodies have their motions solved by ____________ and/or pure ____________.

a) Bayesian theory; computer calculation
b) Bayesian theory; general relativity
c) perturbation theory; general relativity
d) perturbation theory; computer calculation
e) quantum mechanics; perturbation theory

---

001 qmult 01200 1 4 4 easy deducto-memory: Pluto and Neptune

125. Which is the outermost planet in our Solar System from the Sun? Why is the outermost planet not always the same planet? **HINT:** You may have to look some information up.

a) Pluto is always the outermost planet of the Solar System.
b) Uranus is always the outermost planet of the Solar System.
c) The outermost planet is either **PLUTO** or **URANUS**. Most of the time Pluto is the outermost planet, but because of its very elliptical orbit Pluto is sometimes within the orbit of Uranus and then Uranus is the outermost planet. In the period 1979 February 7 to 1999 February 11 Uranus was the outermost planet.
d) The outermost planet is either **PLUTO** or **NEPTUNE**. Most of the time Pluto is the outermost planet, but because of its very elliptical orbit Pluto is sometimes within the orbit of Neptune and then Neptune is the outermost planet. In the period 1979 February 7 to 1999 February 11 Neptune was the outermost planet.
e) The outermost planet is either **MERCURY** or **NEPTUNE**. Most of the time Mercury is the outermost planet, but because of its very elliptical orbit Mercury is sometimes within the orbit of Neptune and then Neptune is the outermost planet. In the period 1979 February 7 to 1999 February 11 Neptune was the outermost planet.

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001 qmult 01250 3 4 3 tough deducto-memory: point-spread function

126. Why is it difficult to see planets orbiting other stars? **NOTE:** A point spread function is the spread-out light image of a star: from Earth stars are effectively point sources of light. The point spread function becomes fainter overall as one moves away from its center. It is caused by the wave nature of light which spreads out all images into diffraction patterns and the turbulence of the atmosphere which causes images to fluctuate about.

a) The planets are often eclipsed by the star itself.
b) The planets emit no light. (By "emit" it is meant either reflect or intrinsically generate.)
c) The planets are very **FAINT** in comparison to the point spread function of the host star. Thus, even a planet at a fairly **LARGE** angular separation from the host star (because the host star is very close to Earth or the planet is very far from the host star) is difficult to detect against the point spread function background.
d) The planets are very **BRIGHT** in comparison to the point spread function of the host star. Thus, even a planet at a fairly **LARGE** angular separation from the host star (because the host star is very close to Earth or the planet is very far from the host star) is difficult to detect against the point spread function background.
e) The planets are very **FAINT** in comparison to the point spread function of the host star. Thus, even a planet at a fairly **SMALL** angular separation from the host star (because the host star is very close to Earth or the planet is very far from the host star) is difficult to detect against the point spread function background.

---

001 qmult 01510 2 5 2 moderate thinking: center of mass calculation

Extra keywords: If they've never seen this question before, they must think.

127. Say you have a set of masses m_1, m_2, etc. at positions x_1, x_2, etc. Their center of mass position $x_{\rm cm}$ along the x-axis is given in general by

$$x_{\rm cm} = \frac{m_1 x_1 + m_2 x_2 + \ldots}{m_1 + m_2 + \ldots} \ ,$$

where "..." just means "and so on." This formula follows from the definition of center of mass as the mass-weighted average position of a body. Now I give you a special case of $m_1 = 9\,\text{kg}$ at $x_1 = 0\,\text{m}$ and $m_2 = 1\,\text{kg}$ at $x_2 = 10\,\text{m}$. What is the center of mass position of the masses in the special case?

a) 0 m. b) 1 m. c) 5 m. d) 9 m. e) 10 m.

---

001 qmult 02000 1 1 3 easy memory: synodic period
Extra keywords: CK-61-4

128. The __________ period is the time it takes a Solar System astrononical body (e.g., a planet) to return to the same point relative to the Sun as seen from the Earth.

a) lunar b) sidereal c) synodic d) tropical e) topical

---

001 qmult 02100 1 3 5 easy math: synodic=Earth year
Extra keywords: CK-61-11

129. The general formula for the synodic period of a planet is

$$P_{\text{syn}} = \frac{P_{\text{pl}} P_{\text{Ea}}}{P_{\text{Ea}} - P_{\text{pl}}} = \frac{P_{\text{pl}}}{1 - P_{\text{pl}}/P_{\text{Ea}}} \ ,$$

where P_{syn} is the synodic period, P_{pl} is the planet sidereal period, and P_{Ea} is the Earth sidereal period. Note for compact generality, we have written the formula so that negative periods imply clockwise revolution as viewing down from the north ecliptic pole and not negative time. For $P_{\text{syn}} = P_{\text{Ea}}$, one requires $P_{\text{pl}} = x P_{\text{Ea}}$ where x is:

a) 3/2, b) 2, c) 1/3, d) 3, e) 1/2.

Chapt. 2 The Sky

Multiple-Choice Problems

002 qmult 00100 1 1 4 easy memory: old astronomy

130. Much of astronomy lore about what is seen on the sky is at least vaguely well known and dates back:

a) days. b) months. c) decades. d) millennia. e) millions of years.

002 qmult 00210 2 1 3 moderate memory: parallax definition

131. Parallax is:

a) the westward motion of a planet.
b) the change in angular position of an object due to the subjective nature of observations.
c) the change in angular position of an object due to the change in position of the observer.
d) an optical illusion, but one that can be used to determine magnitude.
e) the change in angular position of an object due to the change in position of the observer. Parallax is **NEVER** detected for astro-bodies in modern astronomy.

002 qmult 00212 2 4 2 moderate deducto-memory: parallax of astro-bodies

132. "Let's play *Jeopardy*! For $100, the answer is: This condition of astro-bodies means that they show no parallax to unaided-eye observations for any movements about the Earth's surface."

What is their ____________, Alex?

a) closeness relative to the size of the Earth b) remoteness relative to the size of the Earth c) spherical nature d) reflectivity e) sensitivity

002 qmult 00220 1 1 1 easy memory: celestial sphere defined

133. The celestial sphere is:

a) an imaginary remote sphere (centered on the **EARTH**) on which all the celestial bodies are located.
b) a solid sphere (centered on the Earth) on which all the celestial bodies are located.
c) an imaginary remote sphere (centered on the **SUN**) on which all the celestial bodies are located.
d) the path of the Sun on the sky.
e) cause of eclipses.

002 qmult 00222 2 5 2 moderate thinking: celestial sphere described

134. Briefly describe the celestial sphere.

a) It is an imaginary sphere **CENTERED** on **EARTH**. All the heavenly bodies are located on it. It is **SMALL ENOUGH** that the relative positions of the stars and planets **DEPEND ON** one's location on Earth. This agrees with actual appearance of the sky. The axis of the celestial sphere is an extension of Earth's axis: the northern end of the axis is the north celestial pole and the southern end, the south celestial pole. The celestial equator is just a projection on the sky from the Earth's center of the Earth's equator. The celestial sphere rotates west once per day. The stars are carried with this motion, but are fixed to high approximation in relative orientation: they are called the fixed stars. The Solar System bodies move on the celestial sphere relative to the fixed stars. The celestial sphere is a **USEFUL** description of the appearance of sky.

b) It is an imaginary sphere **CENTERED** on **EARTH**. All the heavenly bodies are located on it. It is **SO LARGE** that the size of the Earth is **INSIGNIFICANT** in comparison: this implies that every point on Earth is effectively exactly at the center of the celestial sphere. The axis of the celestial sphere is an extension of Earth's axis: the northern end of the axis is the north celestial pole and the southern end, the south celestial pole. The celestial equator is just a projection on the sky from the Earth's center of the Earth's equator. The celestial sphere rotates west once per day. The stars are carried with this motion, but are fixed to high approximation in relative orientation: they are called the fixed stars. The Solar System bodies move on the celestial sphere relative to the fixed stars. The celestial sphere is a **USEFUL** description of the appearance of sky.

c) It is an imaginary sphere **CENTERED** on **EARTH**. All the heavenly bodies are located on it. It is **SO LARGE** that the size of the Earth is **INSIGNIFICANT** in comparison: this implies that every point on Earth is effectively exactly at the center of the celestial sphere. The axis of the celestial sphere is an extension of Earth's axis: the northern end of the axis is the north celestial pole and the southern end, the south celestial pole. The celestial equator is just a projection on the sky from the Earth's center of the Earth's equator. The celestial sphere rotates west once per day. The stars are carried with this motion, but are fixed to high approximation in relative orientation: they are called the fixed stars. The Solar System bodies move on the celestial sphere relative to the fixed stars. Because the celestial sphere has no physical reality it is perfectly **USELESS**. It is just a relic of historical astronomy.

d) It is just a projection on the sky from the Earth's center of the Earth's equator.

e) It is just the extension of the Earth's axis into space.

---

002 qmult 00224 1 1 2 easy memory: celestial sphere rational

135. Thinking of the celestial sphere as an actual giant sphere centered on the Earth with stars pasted on it makes some sense if like some of the ancient Greek cosmologists, you believe the Earth is at the center of the cosmos and is:

a) ovoid. b) round. c) square. d) sediment at the bottom of the cosmic vortex.
e) the top of a pillar.

---

002 qmult 00226 1 4 5 easy deducto-memory: Aristotelian cosmology

136. "Let's play *Jeopardy*! For \$100, the answer is: The cosmology handed down from Greco-Roman Antiquity (c.800 BCE–c.500 CE) to Medieval Islamic, Medieval European, and early modern European cultures as a sort of philosophical dogma. It offered a qualitative explanation of the motion of the celestial bodies. The stars were pasted on a giant remote celestial sphere. The other bodies rotated by varying rates on inward nested invisible celestial spheres with unaligned axes connecting them and compounding their rotations. The behavior of spheres very roughly accounted for the complex motions of the other bodies, in particular, apparent retrograde motion. The motions were driven by gods in the ancient conception and angels in the Medieval and Early modern European conception. The ancient cosmology was completely superceded by the work of Copernicus (1473–1543), Galileo (1564–1642), Kepler (1571–1630), Newton (1643–1727), and others."

What is ____________, Alex?

a) Babylonian cosmology b) Thalean cosmology c) Parmidean cosmology
d) Democritean cosmology e) Aristotelian cosmology

---

002 qmult 00230 1 4 3 easy deducto-memory: celestial poles

137. "Let's play *Jeopardy*! For \$100, the answer is: They are the extensions of the Earth's axis out to the celestial sphere."

What are ____________, Alex?

a) zenith and nadir b) horizon and nadir c) the north and south celestial poles (NCP and SCP) d) the celestial equator and the eliptic e) the ecliptic pole and the celestial axis

---

002 qmult 00232 1 1 1 easy memory: celestial equator defined

138. What is the celestial equator?

a) The projection of the Earth's equator (as viewed from the Earth's center) onto the celestial sphere. b) The Zodiac by another name. c) An ancient Chinese astronomical device. d) A circumpolar constellation. e) The belt of Orion.

---

002 qmult 00240 2 1 2 moderate memory: zenith and nadir

139. What is zenith? What is nadir?

a) The point directly to the east; the point directly below.
b) The point directly above; the point directly below.
c) A kind of television; a kind of refrigerator.
d) The point directly above; the point directly west.
e) The name of the spring equinox point; the name of the fall equinox point.

---

002 qmult 00250 2 4 3 moderate deducto-memory: Polaris position

Extra keywords: a look-up question

140. How far in angle is Polaris (called alpha Ursa Minoris or α Ursa Minoris or some abbreviation thereof in tables) from the North Celestial Pole (NCP) in J2000 equatorial coordinates? **Note:** J2000 equatorial coordinates are just the preferred modern reference equatorial coordinates for the celestial sphere: they are the equatorial coordinate values for the reference year, year 2000. All the student needs to know is that declination is like latitude and the angle from the NCP is 90° minus declination. And by the way, arcminutes are indicated by prime symbols (e.g., $10'$ is 10 arcminutes) and arcseconds by double prime symbols (e.g., $10''$ is 10 arcseconds). **Hints:** See Wikipedia: Polaris.

a) 90°. b) 10°. c) 44 arcminutes, 9 arcseconds. d) 30 arcminutes, 45 arcseconds. e) 1°, 30 arcminutes, 45 arcseconds.

---

002 qmult 00251 1 1 2 easy memory: Polaris located

141. Polaris is easily located using the pointer stars of:

a) the Very Tiny Dippler b) the Big Dipper. c) the Little Dipper. d) the Big Tipper. e) Cassiopea.

---

002 qmult 00253 1 1 4 easy memory: Polaris at zenith

142. Polaris is at zenith. You are:

a) on the equator. b) in New York City. c) in Las Vegas. d) near the north pole. e) below the horizon.

---

002 qmult 00254 1 1 1 easy memory: Polaris on horizon

143. Polaris is on the horizon. You are:

a) near the equator. b) in New York City. c) in Las Vegas. d) near the north pole. e) over the rainbow.

---

002 qmult 00256 3 4 3 tough deducto-memory: Polaris in Vegas

144. The altitude of Polaris is 36°. (Recall altitude in astronomy is angle measured straight up from the horizon.) You are:

a) on the equator. b) at the latitude of Fairbanks, Alaska. c) at the latitude of Las Vegas, Nevada. d) near the north pole. e) below the horizon.

---

002 qmult 00258 3 4 2 tough deducto-memory: Polaris on 49th parallel

145. The altitude of Polaris is 49°. (Recall altitude in astronomy is angle measured straight up from the horizon.) You are:

a) on the equator. b) perhaps on the border of Canada. c) at the latitude of Las Vegas. d) near the north pole. e) in the southern hemisphere.

---

002 qmult 00280 2 4 2 moderate deducto-memory: circumpolar stars

146. Circumpolar stars are those stars that:

a) are located at the north celestial pole (NCP). b) never go below the horizon or never rise above it. c) are in the Zodiac constellations. d) circle the zenith. e) are below the horizon as seen from all latitudes.

---

002 qmult 00282 1 4 4 easy deducto-memory: point-like stars

147. Why do all stars, except the Sun, look like twinkling points of light as seen from the Earth? They are:

a) points of light, literal points of light, without extent or shape. b) the cause eclipses. c) too remote to be seen. d) too remote to resolve their shapes. e) too remote to detect their color.

---

002 qmult 00300 1 1 3 easy memory: three astronomical location systems

148. Three astonomical location methods are by using modern constellations, horizontal coordinates, and:

a) Cartesian coordinates. b) polar coordinates. c) equatorial coordinates. d) vertical coordinates. e) miscellaneous coordinates.

---

002 qmult 00310 1 1 2 easy memory: horizontal coordinates

149. In horizontal coordinates, the center is ____________. The coordinates are altitude and ____________. Special features are zenith, nadir, and the ________.

a) the Earth's center; compass angle; longitude b) where you are; azimuth; meridian
c) the Earth's center; compass angle; latitude
d) the Earth's center; azimuth; longitude e) where you were; azimuff; meringue

---

002 qmult 00320 2 4 3 moderate deducto-memory: transit the meridian

150. What does "to transit the meridian" mean? It means that an object:

a) passes through the zenith.
b) crosses the meridian of **GREENWICH** due to the rotation of the Earth.
c) crosses the meridian (i.e., the **LOCAL MERIDIAN**) due to the rotation of the Earth.
d) is in conjunction with the Sun.
e) is in opposition (to the Sun).

---

002 qmult 00350 1 1 4 easy memory: equatorial coordinates

151. The most standard set of astronomical coordinates are

a) longitude and latitude. b) polar coordinates. c) cartesian coordinates. d) equatorial coordinates. e) galactic coordinates.

---

002 qmult 00352 1 1 2 easy memory: equatorial coordinates center

152. Corrections need to be made for the parallax of close astro-bodies, but usually speaking the center for the equatorial coordinates is:

a) the North Pole. b) any place on Earth. c) the Earth's center. d) the equator. e) any place on Mars.

---

002 qmult 00360 2 4 3 moderate deducto-memory: declination defined
153. What is declination (dec or δ)?

a) The point directly below.
b) The point directly above.
c) The angular position of an object measured north or south from the celestial equator.
d) The angular position of an object measured east or west from the celestial equator.
e) The azimuthal angular position of an object measured east from the vernal (or spring) equinox.

---

002 qmult 00370 2 4 5 moderate deducto-memory: right ascension
154. What is right ascension (RA)?

a) The point directly below.
b) The point directly above.
c) The angular position of an object measured north or south from the celestial equator.
d) The angular position of an object measured east or west from the celestial equator.
e) The azimuthal angular position of an object measured east from the vernal (or spring) equinox.

---

002 qmult 00410 1 1 4 easy memory: ecliptic defined
155. The ecliptic is:

a) the great circle path of Pluto on the celestial sphere.
b) a sphere (centered on the Earth) on which all the celestial bodies are located.
c) an imaginary sphere (centered on the Sun) on which all the celestial bodies are located.
d) the great circle path of the Sun on the celestial sphere.
e) the cause of eclipses.

---

002 qmult 00412 1 1 5 easy memory: solar year
156. Every _____________, the Sun completes a eastward circuit of the ecliptic.

a) Draconic year (346.620075883 days on average as of J2000)
b) Egyptian year (365 days) c) lunar year (354.37 days on average)
d) Julian year (365.25 days)
e) solar (or tropical) year (365.24218967 days on average as of J2000)

---

002 qmult 00414 1 1 5 easy memory: ecliptic plane and ecliptic pole
157. The _____________ is the plane of the ecliptic (the path of the Sun on the celestial sphere) and the _____________ is the perpendicular to this plane.

a) elliptic variation; elliptic mean b) variation; mean c) elliptic plane; elliptic pole
d) ecliptic plane; elliptic pole e) ecliptic plane; ecliptic pole

---

002 qmult 00420 1 4 5 easy deducto-memory: Sun motion on celestial sphere
158. Every day the Sun moves west on the sky with the celestial sphere. Relative to the fixed stars on the celestial sphere it is:

a) not moving. b) moving mainly west. c) moving mainly north. d) oblique.
e) moving mainly east.

---

002 qmult 00432 1 4 4 easy deducto-memory: summer solstice
159. When the Sun is at the (northern hemisphere) summer solstice, it is:

a) at the most southern point (i.e., most southern declination) of the ecliptic from the celestial equator.
b) on the celestial equator.
c) in the Big Dipper asterism.

d) at the most northern point (i.e., most northern declination) of the ecliptic from the celestial equator.
e) at zenith.

---

002 qmult 00434 2 1 1 moderate memory: Sunrise direction

160. Does the Sun rise north or south of east in the summer in northern latitudes?

a) North. b) South. c) Neither. It rises due east always. d) Yes. e) No.

---

002 qmult 00436 1 4 1 easy deducto-memory: summer tilt

161. In the summer of the northern hemisphere:

a) the northern hemisphere day side is tilted toward the Sun.
b) the northern hemisphere day side is tilted away from the Sun.
c) the southern hemisphere day side is tilted toward the Sun
d) the Earth is nearest the Sun.
e) the Earth is at 0.7 astronomical units from the Sun.

---

002 qmult 00438 3 4 2 tough deducto-memory: gnomon shadow

162. Say you are in the northern hemisphere and have a gnomon (a stick set in flat ground and set perpendicular to the ground). It is the winter solstice and noon. It is sunny and clear.

a) The shadow of the gnomon points due **SOUTH**.
b) The gnomon has its shortest shadow for that day, but it has its **LONGEST** noon shadow of the year.
c) The gnomon shadow points due **EAST** and it is the longest it can be for that day.
d) The gnomon has no shadow.
e) The gnomon has its shortest shadow for that day and it has its **SHORTEST** noon shadow of the year.

---

002 qmult 00440 2 4 5 moderate deducto-memory: equinox defined

163. An equinox is:

a) the path of the Earth on the sky.
b) a sphere (centered on the Earth) on which all the celestial bodies are located.
c) an imaginary sphere (centered on the Sun) on which all the celestial bodies are located.
d) the path of the Sun on the sky.
e) a point where the ecliptic crosses the celestial equator.

---

002 qmult 00510 1 1 1 easy memory: eastward motion on celestial sphere

164. As viewed from the Earth, the Sun, the moon, all the planets, and most of the asteroids move ____________ on the celestial sphere (and relative to the fixed stars) all or most of the time. Their paths are close to the ecliptic, except that the Sun path is the ecliptic by definition.

a) eastward b) westward c) northward d) southward
e) outward with the expansion of the universe

---

002 qmult 00520 1 1 4 easy memory: conjunction and opposition defined

165. When two astro-bodies are aligned on the sky, they are ____________ and when they are 180° apart on the sky, they are in ____________.

a) conjunction; antiparallel b) construction; opposition c) conduction; opposition
d) conjunction; opposition e) parallel; antiparallel

---

002 qmult 00530 1 1 1 easy memory: retrograde motion

166. Retrograde motion (or in modern astro-jargon apparent retrograde motion) is when a planet moves ____________ on the celestial sphere.

a) westward b) eastward c) northward d) southward
e) outward with the expansion of the universe

---

002 qmult 00546 1 1 3 easy memory: long-period comets

167. Long-period comets have orbital periods ranging from 200 years to millions of years and sometimes to infinity (i.e., they escape the Solar System). Their orbits ____________ and viewed in projection can be clockwise or counterclockwise for any viewing direction.

   a) are very roughly aligned with the ecliptic plane
   b) are nearly aligned with the ecliptic plane c) have random orientations
   d) are circular e) are always open

---

002 qmult 00580 1 1 2 easy memory: number Solar System planets
Extra keywords: physci

168. The number of officially recognized Solar System planets is:

   a) 9. b) 8. c) 6. d) 2. e) 1.

---

002 qmult 00582 1 1 5 easy memory: name 3 planets
Extra keywords: physci

169. Name three planets.

   a) The Moon, Pluto, Mars. b) The Moon, Jupiter, Saturn.
   c) Ganymede, Uranus, Neptune. d) Ganymede, Toronto, Orion.
   e) Mercury, Uranus, Earth.

---

002 qmult 00584 1 1 3 easy memory: planets shine by reflected light
Extra keywords: physci KB-604

170. The Solar System planets shine in visible light because they:

   a) reflect moonlight. b) reflect earthlight. c) reflect sunlight. d) emit light powered by their internal heat. e) have a little nuclear burning.

---

002 qmult 00586 1 1 5 easy memory: 8-year Venus cycle

171. Sometime circa 1650 BCE, the ancient Babylonian astronomers discovered the Venus cycle. Their record of this is called (by moderns) the *Venus Tablet of Ammisaduqa*: King Ammisaduqa was Hammurabi's grandson. The Venus cycle is just a result of the synodic period of Venus being about 583.92 days and the Earth's orbital period being about 365.25 days (a Julian year). The synodic period is the time for the planet to return to the same position in the sky relative to the Sun. Five synodic periods is 2919.60 days and 8 Julian years is 2922.00 days. These times are nearly equal. So 8 years from any day, Venus will be back where it was on that day relative to the Sun (because 8 years is 5 synodic periods) and relative to the fixed stars (because the Sun comes back to the same position relative to the fixed stars every year). It is now easy to predict Venus' position approximately to the past or future from 8 years of observations. A lot of ancient astronomical prediction skill comes down to using approximate cycles like the Venus cycle. It's not rocket science.

   If Venus is nearly in same place relative to the Sun every 8 years, where is it relative to the fixed stars at the same intervals?

   a) Far off the ecliptic. b) 30° farther east on the ecliptic every Venus cycle period.
   c) 30° farther west on the ecliptic every Venus cycle period. d) It's unpredictable.
   e) Nearly the same place.

---

002 qmult 00592 3 4 2 tough deducto-memory: superman and Mars

172. You are Superhuman. Thus you have super vision, and can see any object against any background and right through anything else (including the Sun) with your X-ray vision. You are on Earth and see Mars rising over the horizon of Earth and with your super vision see that Mars is completely full: i.e., a full illuminated disk. Note that even with super vision, the dark and illuminated sides of Mars are distinct to you. What time of day is it on Earth?

a) Noon and not any other time. b) Sunset or one other time. c) Sunset and not any other time. d) Sunrise and not any other time. e) Happy hour.

---

002 qmult 00600 1 1 2 easy memory: constellation traditionally defined

173. A constellation by the traditional definition is:

a) a conventional grouping of **PLANETS** on the celestial sphere. b) a conventional grouping of **STARS** on the celestial sphere. c) a group of gravitationally bound **STARS**. d) the Moon at sunset. e) stars seen at sunset.

---

002 qmult 00602 1 1 2 easy memory: naked eye stars

174. The constellations are made up of naked eye stars. The number of naked eye stars visible under typical good observing conditions is estimated to be:

a) about 100. b) about 5600. c) exactly 5600. d) in the millions. e) infinite.

---

002 qmult 00610 1 1 4 easy memory: constellation relationship
Extra keywords: physci KB-24-5

175. The stars in a constellation are:

a) in orbit about the Earth. b) all about the same age. c) at about the same distance from the Earth. d) usually unrelated, except that they are close in angular position as seen from the Earth. e) members of the Solar System.

---

002 qmult 00620 2 1 2 moderate memory: asterism defined

176. What is an asterism?

a) A group of gravitationally bound stars moving about their common center of mass in orbits that are very roughly elliptical. Because of the many-body nature of the system, the orbits cannot be true ellipses. There are too many perturbing gravitational effects and usually no true absolutely dominant massive star located near the center of mass.
b) An angular grouping of stars not officially identified as a constellation: e.g., the Big Dipper which officially is only a part of Ursa Major (the Big Bear). Usually asterism is used only for named angular groupings. In older usage asterism could be used as a synonym for constellation, but that usage is disfavored by astronomers.
c) A telescopic lens problem that makes stars look elongated.
d) A barbarian Gaul.
e) The dog belonging to Nick and Nora Charles.

---

002 qmult 00640 2 4 4 moderate deducto-memory: circumpolar constellation defined

177. A circumpolar constellation:

a) sometimes rises and sets. b) is a group of gravitationally bound stars. c) is located at zenith. d) never rises or sets. e) is a group of stars seen at sunset.

---

002 qmult 00650 1 1 4 easy memory: 6 easy constellations

178. Six relatively easily found constellations in the sky seen from the Northern Hemisphere are Ursa Major (containing the Big Dipper), Ursa Minor (containing the Little Dipper and Polaris), Cassiopia (the big W in the northern sky), Orion (lord of the winter sky), Canis Major (containing Sirius, the Dog Star), and:

a) Mensa. b) Antinous. c) Tucana. d) Taurus. e) Norma.

---

002 qmult 00670 1 4 5 easy deducto-memory: cultural constellation sets

179. All historical cultures eventually arrived independently at the same set of constellations.

a) Yes. b) For short periods of time. c) Every other Thursday. d) No. They all started with the same set of constellations, but as time passed they varied them to arrive at very different sets. e) No.

---

002 qmult 00680 1 4 5 easy deducto-memory: 48 classical constellations

180. "Let's play *Jeopardy*! For $100, the answer is: He defined the 48 classical constellations (i.e., the 48 constellations passed on by the ancient Greco-Roman civilization)."

Who is ____________, Alex?

a) Aristotle (384–322 BCE) b) Berossos, priest of Bel Marduk (3rd century BCE) c) King Ptolemy I (c.367–c.283 BCE) d) Cleopatra (69–30 BCE) e) Ptolemy (c.100–c.170 CE)

---

002 qmult 00682 1 1 3 easy memory: zodiac constellations

181. The 12 zodiac constellations:

a) are all within a band of 90° right ascension. b) are very near 90° declination. c) straddle the ecliptic. d) are very near −90° declination. e) do **NOT** straddle the ecliptic.

---

002 qmult 00710 1 4 3 easy deducto-memory: IAU constellation defined

182. "Let's play *Jeopardy*! For $100, the answer is: Any traditionally recognized group of stars on the sky or one of the 88 International Astronomical Union (IAU) recognized groups of stars and its defined region on the celestial sphere."

What is ____________, Alex?

a) a star cluster b) a star party c) a constellation d) an astigmatism e) Asterix

---

002 qmult 00730 1 4 3 easy deducot-memory: three IAU constellations

183. Three IAU (International Astronomical Union) official constellations are:

a) the Big Dipper, the Little Dipper, and the Tiny Dipper. b) the Big Dipper, Orion, and Callisto. c) Ursa Major (the Big Bear), Orion, and Cassiopeia. d) Ursa Major (the Big Bear), Orion, and Buffy. e) Ulysses, Euripides, and Federigo.

---

002 qmult 00750 1 4 5 easy deducto-memory: X is in constellation Y

184. A modern astronomer, speaking in conventional jargon, who wished to indicate that an astro-body X was located in the patch of sky belonging IAU defined constellation Taurus would say:

a) X is on Taurus. b) X is within Taurus. c) X is superimposed on Taurus. d) X is digested by Taurus. e) X is in Taurus.

---

002 qmult 01010 1 1 1 easy memory: daytime defined

185. Daytime is:

a) the time between sunrise and sunset. b) the time between sunset and sunrise. c) any time of the day or night. d) high noon. e) an optical illusion.

---

002 qmult 01110 2 4 1 moderate deducto-memory: Vegas latitude

186. Las Vegas is at about:

a) 36° north latitude. b) 36° north longitude. c) 36° south latitude. d) 72° north latitude. e) 49° north latitude.

---

002 qmult 01120 2 4 1 moderate deducto-memory: Topeka latitude

187. Topeka is at about:

a) 39° north latitude. b) 39° north longitude. c) 39° south latitude. d) 72° north latitude. e) 49° north latitude.

---

002 qmult 01220 1 1 5 easy memory: Venus, goddess of love
Extra keywords: physci
188. In mythology and popular culture Venus has been identified with the:

a) god of transits. b) devil of retrograde motion. c) imp of recession. d) monk of remonstrance. e) goddess of love.

---

002 qmult 01222 2 4 4 moderate deducto-memory: full phases of Venus
Extra keywords: physci KB-605
189. The planet with a full set of phases (like the Moon) is

a) Jupiter. b) Saturn. c) Mars. d) Venus. e) Werewolf.

---

002 qmult 01224 3 4 5 tough deducto-memory: Venus transiting Sun
190. Venus is in inferior conjunction. But it is not transiting the Sun (i.e., crossing the face of the Sun). Why not?

a) It is behind the Sun relative to Earth.
b) It is in retrograde motion.
c) It never transits the Sun.
d) The tilt of the orbit of Venus from the ecliptic means that Venus is usually **WEST** of the Sun during inferior conjunction. This must be the case in the present example.
e) The tilt of the orbit of Venus from the ecliptic means that Venus is usually **ABOVE OR BELOW** the Sun at conjunctions (using the ecliptic plane to establish up and down). Venus must be above or below in the present example.

---

002 qmult 01250 1 1 3 easy memory: largest planet Jupiter
Extra keywords: physci KB-604-11
191. The largest planet by mass and radius in the Solar System is:

a) Earth. b) Mars. c) Jupiter. d) Mercury. e) Pluto.

---

002 qmult 01260 1 1 2 easy memory: Saturn, the ringed world
Extra keywords: physci
192. The Solar System planet with the overwhelmingly most obvious rings is:

a) Mercury. b) Saturn. c) Pluto. d) Sedna. e) Werewolf.

---

002 qmult 04500 2 4 3 moderate deducto-memory: precession of the equinoxes
193. The precession of the Earth's axis (or of the equinoxes) is:

a) the recession of the Earth.
b) the precession of the Earth's axis about the ecliptic pole. The angle between the axis and the ecliptic pole is about 36°.
c) the precession of the Earth's axis about the ecliptic pole. The angle between the axis and the ecliptic pole is about 23.5°.
d) the precession of the Earth's axis about the ecliptic pole. The angle between the axis and the ecliptic pole is about 23.5°. The **period of precession** is 10 years.
e) the precession of the Earth's axis about the Sun.

---

002 qmult 04510 1 4 3 easy deducto-memory: precession of the equinoxes
194. The precession of the Earth's axis (or of the equinoxes) is:

a) rather like the march of the toreadors. b) at the north celestial pole. c) the precession of the Earth's axis about the ecliptic pole. d) the precession of the Earth's axis about the Sun. e) is a myth.

---

002 qmult 04520 1 4 4 easy deducto-memory: precession of the equinoxes

195. The precession of the Earth's axis (or of the equinoxes):

a) causes the Sun to rotate. b) brings Mars into daily opposition. c) is an illusion. d) is the precession of the Earth's axis about the ecliptic pole. e) is the precession of the Sun's axis about the ecliptic pole.

---

002 qmult 04530 1 1 1 easy memory: cause of precession

196. The precession of the equinoxes is caused by:

a) the gravitational forces of the Sun and Moon on the axially tilted, oblate rotating Earth. b) the Earth's axis precessing about the ecliptic pole. c) the slosh of the tides. d) air friction. e) the Earth's revolution about the Sun.

---

002 qmult 05400 1 4 2 easy deducto-memory: star names

197. The names of three astronomical stars are:

a) Aldebaran, Sirius, and Las Vegas. b) Aldebaran, Sirius, and Vega. c) Aldebaran, Sirius, and Hepburn. d) Aldebaran, Tracy, and Hepburn. e) Spencer, Tracy, and Hepburn.

---

002 qmult 05500 2 4 4 moderate deducto-memory: Arabic star names

198. Many of the names of the bright stars such as Adhara (the Maidens), Aldebaran ("Follower" of the Pleiades), and Algol (the Ghoul) are derived from:

a) Greek. b) Latin. c) Persian. d) Arabic. e) Old English.

---

002 qmult 05600 1 4 3 easy deducto-memory: star names Greek letters

199. "Let's play *Jeopardy*! For $100, the answer is: The designations of the three putatively brightest stars in a constellation according to the scheme of Johann Bayer's *Uranometria* (Augsburg, 1603)."

What are ____________, Alex?

a) 1st magnitude, 2nd magnitude, and 3rd magnitude b) A, B, and C c) α, β, and γ d) Alpher, Behte, and Gamow e) Larry, Curly, and Moe

---

002 qmult 05700 2 1 3 moderate memory: Greek letter star names

200. The Greek letters in order are

$$\alpha\beta\gamma\delta\epsilon\zeta\eta\theta\iota\kappa\lambda\mu\nu\xi o\pi\rho\sigma\tau\upsilon\phi\chi\psi\omega\ .$$

In the scheme of Johann Bayer's *Uranometria* (Augsburg, 1603), the putatively 8th brightest star in a constellation is named:

a) α. b) γ. c) θ. d) o. e) ω.

---

002 qmult 05800 2 4 2 moderate deducto-memory: star name coordinates

201. A modern way of naming stars is just to name them by their celestial coordinates. This mean a star's name is just the star's:

a) longitude and latitude. b) right ascension and declination. c) inclination and attitude. d) rigth ascension and derivation. e) longitude and shortitude.

Chapt. 3 The Moon: Orbit, Phases, Eclipses

Multiple-Choice Problems

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003 qmult 00100 1 4 2 easy deducto-memory: satellite Moon

202. "Let's play *Jeopardy*! For $100, the answer is: It is the Earth's only known natural satellite."

What is ____________, Alex?

a) the Sun b) the Moon c) Cruithne d) the International Space Station (ISS)
e) Krypton

---

003 qmult 00250 2 5 5 moderate thinking: intercalary month

203. The mean lunar month is 29.53059 days. How many days are there in a year of 12 mean lunar months and approximately how many years on a lunisolar calendar before you need to insert a 13th lunar month in a year (an intercalary month) in order to keep the lunisolar calendar roughly consistent with the solar year (i.e., keep the months in the seasons they are supposed to be in)?

a) 29.53059 days and every twelfth of a year.
b) 365.25 days and every 3 solar years.
c) 354.367 days and every **4 SOLAR YEARS**. Note you won't get perfect consistency with an every-4-solar-year insertion since your luni-solar calendar will be short about **33 DAYS** after 4 solar years and a mean lunar month is only 29.53059 days
d) 354.367 days and every **3 SOLAR YEARS**.
e) 354.367 days and every **3 SOLAR YEARS**. Note you won't get perfect consistency with an every-3-solar-year insertion since your luni-solar calendar will be short about **33 DAYS** after 3 solar years and a mean lunar month is only 29.53059 days.

---

003 qmult 00320 2 4 5 moderate deducto-memory: Moon distance

204. The mean distance from the Earth to the Moon is:

a) 66 Earth radii. b) 40 Earth radii. c) 1 astronomical unit. d) negligible.
e) 60 Earth radii.

---

003 qmult 00322 1 4 5 easy deducto-memory: Earth focus of ellipse

205. The Earth is at:

a) the geometrical center of the Moon's **ELLIPTICAL** orbit.
b) the geometrical center of the Moon's **ECLIPTICAL** orbit.
c) both foci (i.e., focuses) of the Moon's elliptical orbit.
d) the perigee of the Moon's orbit.
e) one of the foci (i.e., focuses) of the Moon's elliptical orbit.

---

003 qmult 00324 2 4 1 moderate deducto-memory: Moon inclination to ecliptic

206. The plane of the Moon's orbit is:

a) at an inclination of about 5° from the **ECLIPTIC PLANE**.
b) at an inclination of about 5° from the **ECLIPTIC POLE**.
c) at an inclination of about 50° from the ecliptic plane.

d) in the ecliptic plane.
e) parallel to, but far above, the ecliptic pole.

---

003 qmult 00330 1 4 2 easy deducto-memory: lunar sidereal month

207. "Let's play *Jeopardy*! For \$100, the answer is: A lunar time period that is 27.321661 days long."

What is the ____________, Alex?

a) lunar month b) lunar sidereal month c) lunar anomalistic month d) lunar draconitic month e) lunar pathetic month

---

003 qmult 00332 1 3 1 easy math: lunar angular speed synodic

208. The mean lunar month is 29.53059 days. The **ANGULAR VELOCITY** of the Moon relative to the Sun (**NOT** relative to the fixed stars) is

a) 12.19° per day. b) 13.18° per day. c) 29.531° per day. d) 360° per day. e) 12.19°.

---

003 qmult 00334 1 3 2 easy math: lunar angular speed sidereal

209. The mean lunar sidereal period is 27.322 days. The **ANGULAR VELOCITY** of the Moon relative to the fixed stars is:

a) 12.19° per day. b) 13.18° per day. c) 27.32° per day. d) 360° per day. e) 13.18°.

---

003 qmult 00340 2 4 4 moderate memory: nodes of Moon's orbit

210. The nodes of the Moon's orbit are:

a) the foci (i.e., focuses) of the orbit. b) the perigee and apogee of the Moon's orbit. c) at the solstice positions. d) where the Moon's orbit crosses the ecliptic plane. e) always aligned with the Earth-Sun line.

---

003 qmult 00380 2 5 3 moderate thinking: low-Earth-orbit satellite rising west

211. The sidereal period of a low-Earth-orbit satellite is about 90 minutes. Say we have such a satellite and it is orbiting the Earth in basically an eastward direction relative to the fixed stars. What is its angular speed relative to the **FIXED STARS**? Where does it rise and set?

a) Its angular speed is $\sim 4°$ per minute. It **RISES EAST AND SETS WEST** like all other astronomical bodies due to the daily rotation of the Earth.
b) Its angular speed is $\sim 360°$ per minute. It **RISES EAST AND SETS WEST** like all other astronomical bodies due to the daily rotation of the Earth.
c) Its angular speed is $\sim 4°$ per minute. It **RISES WEST AND SETS EAST**.
d) Its angular speed is $\sim 360°$ per minute. It **RISES WEST AND SETS EAST**. This retrograde motion is simply because the satellite revolves faster to the east than the Earth rotates east.
e) Its angular speed is $\sim 0.25°$ per minute. It **RISES EAST AND SETS WEST** like all other astronomical bodies due to the daily rotation of the Earth.

---

003 qmult 00382 2 4 4 moderate deducto-memory: lunar synodic sidereal

212. Why is the lunar month (i.e., the synodic period of the Moon) longer than the lunar orbital period relative to the fixed stars (i.e., the lunar sidereal period)? **Hint:** draw a diagram of the top (i.e., high-northern-celestial-sphere) view of the Earth-Moon-Sun system.

a) The gravitational attraction of the Sun causes the Moon to slow down when it is nearest the Sun. The stars are too remote to have such a gravitational effect.
b) The difference has no known explanation. It was just established by the unknown initial conditions of the Solar System.
c) Both the Earth and the Moon revolve **COUNTERCLOCKWISE** when viewed from the **NORTH ECLIPTIC POLE**: the Earth about the Sun and the Moon about the

Earth. Say we think of new moon, when the Moon is in the line between Sun and Earth (i.e., is in conjunction with the Sun). One sidereal period later the Moon has done a complete orbit with respect to the fixed stars. But the Sun relative to the Earth has moved further in the **CLOCKWISE DIRECTION** due, of course, to the Earth's **COUNTERCLOCKWISE MOTION**. Thus the Moon has to travel a bit farther than 360° relative to the fixed stars in order to come back into alignment with the Sun-Earth line and complete a lunar month. Traveling this extra bit takes more time, of course, and thus the lunar month is longer than the Moon's sidereal period.

d) Both the Earth and the Moon revolve **COUNTERCLOCKWISE** when viewed from the **NORTH ECLIPTIC POLE**: the Earth about the Sun and the Moon about the Earth. Say we think of new moon, when the Moon is in the line between Sun and Earth (i.e., is in conjunction with the Sun). One sidereal period later the Moon has done a complete orbit with respect to the fixed stars. But the Sun relative to the Earth has moved further in the **COUNTERCLOCKWISE DIRECTION** due, of course, to the Earth's **COUNTERCLOCKWISE MOTION**. Thus the Moon has to travel a bit farther than 360° relative to the fixed stars in order to come back into alignment with the Sun-Earth line and complete a lunar month. Traveling this extra bit takes more time, of course, and thus the lunar month is longer than the Moon's sidereal period.

e) Both the Earth and the Moon revolve **CLOCKWISE** when viewed from the **NORTH ECLIPTIC POLE**: the Earth about the Sun and the Moon about the Earth. Say we think of new moon, when the Moon is in the line between Sun and Earth (i.e., is in conjunction with the Sun). One sidereal period later the Moon has done a complete orbit with respect to the fixed stars. But the Sun relative to the Earth has moved further in the **COUNTERCLOCKWISE DIRECTION** due, of course, to the Earth's **COUNTERCLOCKWISE MOTION**. Thus the Moon has to travel a bit farther than 360° relative to the fixed stars in order to come back into alignment with the Sun-Earth line and complete a lunar month. Traveling this extra bit takes more time, of course, and thus the lunar month is longer than the Moon's sidereal period.

---

003 qmult 00400 1 4 5 easy deducto-memory: lunar phase defined

213. "Let's play *Jeopardy*! For $100, the answer is: It is the appearance of the sunlit portion of the Moon as seen by an observer usually located on the Earth."

What is ____________, Alex?

a) the terminator b) lunar month c) the leaping rabbit d) a mare
e) lunar phase

---

003 qmult 00410 1 1 3 easy memory: the lunar phases in sequence

214. The standard lunar phases in time sequence are: new moon, waxing crescent, ____________, waxing gibbous, full, waning gibbous, 3rd quarter, ____________.

a) quarter lit; waning crescent b) quarter full; morning crescent
c) 1st quarter; waning crescent d) half lit; morning crescent
e) quartic; Mornington Crescent

---

003 qmult 00424 1 1 2 easy memory: named full moons

215. Full moons occuring at particular times of the year often have traditional names associated with them that varying with culture. A folkloric (or maybe pseudo folkloric) name for a full moon in or near January is:

a) June Moon b) Wolf Moon c) Juney Moon d) Green Cheese Moon
e) Waning Moon

---

003 qmult 00440 2 5 3 moderate thinking question: Moon phase 1999jan20

216. Describe the Moon's phase on 1999 January 20. **HINT:** You could look up the answer (except in a test mise en scène, of course), but do you really have to?

a) Waning crescent in the western sky at sunset.
b) A new moon in opposition.
c) Waxing crescent in the western sky at sunset.
d) A full moon in the western sky at sunset.
e) Waning gibbous moon in the eastern sky at sunrise.

---

003 qmult 00450 1 4 2 easy deducto-memory: Moon phase sunset

217. At sunset, you see the Moon in the western sky. It is:

a) a waning crescent. b) a waxing crescent. c) a full moon. d) a gibbous moon. e) partially eclipsed.

---

003 qmult 00452 1 4 5 easy deducto-memory: Moon phase sunrise

218. At sunrise, you see the Moon in the eastern sky. It is:

a) partially eclipsed. b) a waxing crescent. c) a full moon. d) a gibbous moon. e) a waning crescent.

---

003 qmult 00454 2 4 2 moderate deducto-memory: half moon phase

219. The Moon is 90° from the Sun on the sky and it is sunset. The Moon is a/an:

a) waning gibbous moon. b) waxing half moon. c) waxing crescent moon. d) new moon. e) old moon.

---

003 qmult 00456 2 4 5 moderate deducto-memory: full Moon opposition

220. The Sun is setting; the Moon is 180° away from the Sun on the sky. The Moon is:

a) setting too. b) half-full. c) a crescent. d) being eclipsed. e) rising and it is full.

---

003 qmult 00458 1 4 4 easy deducto-memory: Moon phase full

221. The Moon is rising, the Sun is setting. The Moon is:

a) a crescent. b) a waning crescent. c) about to be eclipsed. d) full. e) blue.

---

003 qmult 00460 1 4 2 easy deducto-memory: Moon phase horned

222. The Moon is a crescent—the horned Moon. Which way, in a rough sense, do the horns point relative to the Sun?

a) Toward the Sun. b) Away from the Sun. c) They can have any orientation depending on the time of year. d) They can have any orientation depending on the time of day. e) Perpendicular to the line from the Moon to the Sun.

---

003 qmult 00654 1 1 3 easy memory: tidal locking slowing the Earth

223. Currently the tidal locking effect of the Moon on the Earth is increasing the length of the Earth's solar day by 1.70×10^{-3} seconds per century. This rate is probably not constant due to many perturbations. However, assuming it is constant, how long until the solar day is 1 second longer than at present? ________ centuries.

a) 160 b) 454 c) 588 d) 674 e) 1012

---

003 qmult 00820 1 4 2 easy deducto-memory: lunar eclipse

224. A lunar eclipse can occur only when the Moon is:

a) a crescent. b) full. c) half full. d) gibbous. e) waning gibbous.

---

003 qmult 00824 1 4 3 easy deducto-memory: annular eclipse

225. "Let's play *Jeopardy*! For $100, the answer is: In this kind of solar eclipse a ring of photosphere of the Sun is seen around the dark moon."

What is a/an ___________, Alex?

a) total solar eclipse b) partial solar eclipse c) annular solar eclipse d) ring eclipse e) diamond ring eclipse

---

003 qmult 00830 2 1 1 moderate memory: Earth umbra

226. From the umbra of the Earth, the:

a) Sun's photosphere cannot be seen. b) Moon cannot be seen. c) stars cannot be seen. d) planets cannot be seen. e) Sun is partially visible. It appears as a bright crescent.

---

003 qmult 00832 2 4 5 moderate deducto-memory: Earth penumbra

227. From the penumbra of the Earth, the:

a) Sun cannot be seen at all. b) Moon cannot be seen at all. c) stars cannot be seen. d) planets cannot be seen. e) Sun is partially visible.

---

003 qmult 00840 2 5 1 moderate thinking: lunar eclipse seasons

228. For lunar eclipses (any of partial, total, annular, or penumbral) to occur, the Moon's orbital nodes do **NOT** have to be exactly on the Earth-Sun line: i.e., the line drawn through the centers of Earth and Sun. This is because the light-emitting body, the eclipsing body, and the eclipsed body all have finite sizes. The eclipse season is the period during which nodes are sufficiently close to an exact nodal alignment that an eclipse is possible. The eclipse season for the Moon (for partial and total eclipses, and **NOT** including penumbral eclipses) is about 24 days: 12 days before exact nodal alignment and 12 days after. Why is there **NOT** a partial or total lunar eclipse during every lunar eclipse season?

a) Lunar eclipses can only happen very near exact **FULL MOON**. If the Moon is just past an eclipsable **FULLISH MOON** when a lunar eclipse season begins, it will only get back to an eclipsable **FULLISH MOON** only somewhat less than **29.5 DAYS** later and so miss the eclipse season. Consequently, there doesn't have to be either of a total or partial lunar eclipse in every lunar eclipse season albeit usually there **IS**.

b) Lunar eclipses can only happen very near exact **NEW MOON**. If the Moon is just past an eclipsable **NEWISH MOON** when a lunar eclipse season begins, it will only get back to an eclipsable **NEWISH MOON** only somewhat less than **29.5 DAYS** later and so miss the eclipse season. Consequently, there doesn't have to be either of a total or partial lunar eclipse in every lunar eclipse season, and, in fact, there usually **IS NOT**.

c) Lunar eclipses can only happen very near exact **NEW MOON**. If the Moon is just past an eclipsable **NEWISH MOON** when a lunar eclipse season begins, it will only get back to an eclipsable **NEWISH MOON** only somewhat less than **22 DAYS** later and so miss the eclipse season. Consequently, there doesn't have to be either of a total or partial lunar eclipse in every lunar eclipse season albeit usually there **IS**.

d) Lunar eclipses can only happen very exact **FULL MOON**. If the Moon is just past an eclipsable **FULLISH MOON** when a lunar eclipse season begins, it will only get back to an eclipsable **FULLISH MOON** only somewhat less than **29.5 DAYS** later and so miss the eclipse season. Consequently, there doesn't have to be a either of a total or partial lunar eclipse in every lunar eclipse season, and, in fact, there usually **IS NOT**.

e) The Bos Domesticus effect in which the Sun sort of dodges the Earth happens frequently near nodal alignment. This often prevents lunar eclipses.

---

003 qmult 00850 1 4 4 easy deducto-memory: lunar eclipse seen

229. Given clear skies everywhere, from what part of the Earth is a lunar eclipse visible?

a) From almost the entire day side. b) From a small region near the equator. c) From half of the night side. d) From almost the entire night side. e) It is not visible at all.

---

003 qmult 00860 2 5 1 moderate thinking: eclipsed Moon darkest

230. The Moon in a total lunar eclipse tends to be darkest when the Moon:

a) goes through the center of the Earth's umbra.
b) goes through the edge of the Earth's umbra.
c) doesn't go through the Earth's umbra at all.
d) doesn't go through the Earth's penumbra at all.
e) eclipses the Sun at the same time.

---

003 qmult 00862 2 4 3 moderate deducto-memory: lunar eclipse coppery

231. When totally eclipsed, the Moon often appears reddish or coppery. Why?

a) Reddish is the Moon's natural color. When the glaring white light of the Sun is removed, we see this natural color.
b) Some sun light is **REFLECTED** from the Earth's atmosphere and re-directed toward the Moon. Light reflected by the atmosphere tends to be reddish. Thus the atmosphere reflected light gives the Moon its reddish color. The direct white light from the Sun completely (or almost completely) washes out any reddish color when the Moon is not totally eclipsed.
c) Some sun light is **REFRACTED** from the Earth's atmosphere and toward the Moon. (Refraction bends light beams toward the normal to the media interface when the medium the light is entering has a higher index of refraction. In the case of the Earth's atmosphere, refraction tends to bend the light beams around the Earth.) The atmosphere preferentially scatters blue light (hence the blue of the day-time sky) and transfers red light (hence the red color of the Sun at sunrise and sunset when more of the blue has been scattered out of the line of sight). Thus, the refracted light is reddish. This reddish light is reflected by the Moon, and hence we see the Moon as reddish. The direct white light from the Sun completely (or almost completely) washes out any reddish color when the Moon is not totally eclipsed.
d) The reddish color is an optical illusion caused by the human eye's tendency to see as red that which is not green.
e) The Moon is actually red hot: i.e., it is emitting red light due to high surface temperature. The eclipsed face of the Moon is after all the day side of the Moon, and we all know about day-time temperatures on the Moon. The direct white light from the Sun completely (or almost completely) washes out any reddish color when the Moon is not totally eclipsed.

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003 qmult 00870 2 4 2 moderate deducto memory: lunar eclipse on Moon

232. In a partial eclipse of the Sun (as defined by **EARTHLINGS**), an Earthling in a partially eclipsed part of the Earth sees the photosphere of the Sun with a bite out of it. In a partial eclipse of the Moon (as defined by **EARTHLINGS**), how does the Sun appear to a Moon-dweller (i.e., a Lunarian, Selenite, or even Subvolvan) on the Earth-facing side of the Moon?

a) A disk with a bite out of it in **ALL** cases.
b) A disk with a bite out of it **OR** it could be totally eclipsed. It depends on the location of the Selenite on the Moon.
c) The Sun is totally eclipsed **ALWAYS**.
d) It will look exactly like the Earth.
e) It would be nighttime on the Moon and the Selenite wouldn't see the Sun in any case.

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003 qmult 00880 1 4 3 easy deducto-memory: Aristotle, Earth's shadow

233. Why did Aristotle (384–322 BCE) conclude that lunar eclipses prove or at least strongly suggest that the Earth was a sphere?

a) Based on the duration of total lunar eclipses Aristotle was able to deduce the diameter of the Earth.

b) From the reddish color of some total lunar eclipses, Aristotle deduced that the a circular limb of the Earth's atmosphere was refracting light onto the Moon. Since the limb was circular, it was reasonable that the whole atmosphere and Earth was spherical.

c) If you have parallel light beams (which is nearly the case for beams from the Sun at the Earth because of the Sun's remoteness), then the shadow they cause from sphere has a circular cross section for all orientations of source and sphere. The sphere shadow will tend to look circular on most objects on which it falls. Now the shadow (i.e., the umbra) of the Earth on the Moon is circular or nearly circular in all cases: i.e., for all times of day when the partial lunar eclipse is seen and all locations of the Sun on the celestial sphere. Ergo, it seems that the Earth must be spherical, unless there is some strange other way to arrange a circular or nearly circular umbra on Moon's face.

d) Only perfect bodies can cause eclipses. Spherical bodies are perfect. Ergo only spherical bodies can cause eclipses.

e) We don't know. The argument was given in a lost work: *De Caelo* (*On the Heavens*).

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003 qmult 00940 2 5 2 moderate thinking: solar eclipse seasons

234. For eclipses (any of partial, total, annular, or penumbral) to occur, the nodes do not have to be exactly on the Earth-Sun line: i.e., the line drawn through the centers of Earth and Sun. This is because the light-emitting body, the eclipsing body, and the eclipsed body all have finite size. The eclipse season is the period during which nodes are sufficiently close to an exact nodal alignment that an eclipse is possible. The eclipse season for the Sun (total, annular, and partial) is about 34 days: 17 days before exact alignment and 17 days after. Will there be solar eclipse of some kind in every solar eclipse season?

a) Solar eclipses can only happen at nearly exact **FULL MOON**. If the Moon is just past an eclipsing **FULLISH MOON** when a solar eclipse season begins, the Sun misses an eclipse just at the start of the season. The Moon will get back to new moon in a lunar month of about 29.5 days. This is less than the eclipse season, and thus a solar eclipse will occur. Clearly if the Moon enters the solar eclipse season at any other phase, a solar eclipse **MUST HAPPEN** as well.

b) Solar eclipses can only happen at nearly exact **NEW MOON**. If the Moon is just past an eclipsing **NEWISH MOON** when a solar eclipse season begins, the Sun misses an eclipse just at the start of the season. The Moon will get back to new moon in a lunar month of about 29.5 days. This is less than the eclipse season, and thus a solar eclipse will occur. Clearly if the Moon enters the solar eclipse season at any other phase, a solar eclipse **MUST HAPPEN** as well.

c) Solar eclipses can only happen at nearly exact **NEW MOON**. If the Moon is just past an eclipsing **NEWISH MOON** when a solar eclipse season begins, the Sun misses an eclipse just at the start of the season. The Moon will get back to new moon in a lunar month of about 29.5 days. This is less than the eclipse season, and thus a solar eclipse will occur. Clearly if the Moon enters the solar eclipse season at any other phase, a solar eclipse will **NOT** occur.

d) Solar eclipses can only happen at nearly exact **FULL MOON**. If the Moon is just past eclipsing **FULLISH MOON** when a solar eclipse season begins, the Sun misses an eclipse just at the start of the season. The Moon will get back to new moon in a lunar month of about 29.5 days. This is less than the eclipse season, and thus a solar eclipse will occur. Clearly if the Moon enters the solar eclipse season at any other phase, a solar eclipse will **NOT** occur.

e) The Bos Domesticus effect in which the Sun sort of dodges the Moon happens frequently near nodal alignment. This often prevents solar eclipses.

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003 qmult 00970 3 4 3 tough deducto-memory: Sun corona defined 1

235. The solar corona:

a) is a thin surface layer of the Sun seen as a thin pink ring surrounding the totally eclipsed Sun. The corona often has eruptions of gas called solar prominences.
b) is the outermost part of the atmosphere of the Sun. It is a very hot, rarefied gas. Although very hot (of order 10^6 K), the corona is very **BRIGHT** because of it's low density. In **TOTAL SOLAR ECLIPSES** it becomes visible to the unaided human eye. It has a milky white color and appears rather wispy. Magnetic field lines extending out from the Sun tend to concentrate corona gas into filaments.
c) is the outermost part of the atmosphere of the Sun. It is a very hot, rarefied gas. Although very hot (of order 10^6 K), the corona is very **FAINT** because of it's low density. In **TOTAL SOLAR ECLIPSES** it becomes visible to the unaided human eye. It has a milky white color and appears rather wispy. Magnetic field lines extending out from the Sun tend to concentrate corona gas into filaments.
d) is the outermost part of the atmosphere of the Sun. It is a very hot, rarefied gas. Although very hot (of order 10^6 K), the corona is very **FAINT** because of it's low density. In **TOTAL AND ANNULAR SOLAR ECLIPSES** it becomes visible to the unaided human eye. It has a milky white color and appears rather wispy. Magnetic field lines extending out from the Sun tend to concentrate corona gas into filaments.
e) was a **CROWN** awarded to the preeminent astronomer of ancient Greece. Poets have their laurel wreath; astronomers have their crown. Demosthenes (384?–322 BCE), defying tyranny, argued in his oration *On the Crown* that it should not be given to Alexander (356–323 BCE) for discovering that the Sun at sunrise in India is not a hundred times larger than in Greece. Later Ptolemy (c.100–c.170 CE) was awarded the crown.

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003 qmult 00972 1 4 4 easy deducto-memory: visible corona

236. Why is the corona visible to the unaided eye only during a total solar eclipse?

a) It is behind the photosphere of the Sun ordinarily, and thus cannot be seen ordinarily.
b) The Moon's shadow usually hides it.
c) Only during total eclipses is it compacted by magnetic fields.
d) It is too faint to be seen when any significant part of the photosphere of the Sun is visible.
e) Only a total solar eclipse is long enough to let it stand out.

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003 qmult 00980 2 4 2 moderate deducto-memory: Saros cycle

237. The Saros cycle is an approximate cycle of:

a) **ALL** eclipse phenomena with a period of 6585 days which equals **EXACTLY** 18 Julian years plus 9 days.
b) **ALL** eclipse phenomena with a period of 6585.3213 days which equals about 18 Julian years plus 11 days.
c) **SOLAR** eclipse phenomena with a period of 6585.3213 days which equals about 18 Julian years plus 11 days.
d) **SOLAR** eclipse phenomena with a period of 6585 days which equals **EXACTLY** 18 Julian years plus 9 days.
e) **SOLAR** eclipse phenomena with a period of 6585 days which equals **EXACTLY** 18 Julian years plus 9 days that was discovered by Thales (c. 624–c. 546 BCE).

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003 qmult 00982 3 5 2 hard thinking: Saros Cornwall

238. The Solar System is not truly periodic and stable. Over billions of years the orbits and rotation rates even of the major planets and moons evolve significantly. The motions of smaller bodies can evolve even more quickly in some cases. Nevertheless, the motions of the major bodies over long periods of time are periodic to a very high degree of accuracy. Therefore it is not surprising that the **RELATIVE POSITIONS OF THE SUN-EARTH-MOON SYSTEM** form a sequence in time that approximately repeats itself: i.e., the relative positions occur in a cycle. This cycle when used to describe the occurrence of eclipses is called the **SAROS CYCLE**. The

use of the ancient Sumerian word saros for this cycle was a historical inaccuracy on the part of Edmund Halley (1656–1742) (Neugebauer, O. 1969, *The Exact Sciences in Antiquity,* p. 142).

The Saros cycle is 6585.3213 days long (Wikipedia: Saros). This is 18 Julian years (of 365.25 days each exactly) plus 10.8213 days. In calendar years, the period is trickier to report because of leap years. It is 18 calendar years plus 10.3213 days for the 5 leap year case and 18 calendar years plus 11.3213 days for the 4 leap year case. (The two cases exist because 18 years can include 4 or 5 leap years depending on when the 18 year period begins.) If the 18 year period includes a century year not whole number divisible by 4, then the 18 year period can include 3 or 4 leap years. In the 3 leap year case, the Saros cycle period is 18 years and 12.3213 days.

If a particular eclipse (i.e., total solar, annular solar, partial solar, total lunar, partial lunar, penumbral lunar) occurs on a given day, 6585.321 days later the same eclipse will occur again with Earth, however, rotated $\sim 120°$ further east from where it was due the approximate third of day beyond an even number of days in the Saros cycle period. For a particular total solar eclipse in the Saros cycle to occur in approximately the same location one has to wait ____ Saros cycle periods.

There was a total solar eclipse crossing Cornwall, England and Europe on 1999 August 11. This "Cornwall" eclipse recur on very approximately the same eclipse path in ____________.

a) 4; 2071 September b) 3; 2053 September c) 3; 2053 August
d) 5; 2089 October e) 5; 2089 June

Chapt. 4 The History of Astronomy to Galileo

Multiple-Choice Problems

004 qmult 00010 1 1 1 easy memory: astronomy oldest science

239. Astronomy is often cited as the:

a) oldest exact, empirical science. b) youngest exact, empirical science. c) oldest inexact, empirical science. d) youngest, inexact, colonial science. e) oldest form of folklore.

004 qmult 00020 1 1 5 easy deducto-memory: neolithic astronomy

240. Moon-shaped cut marks on bones in groupings of order 30 from paleolithic times (as long ago as 36,000 BCE) suggest that people then were doing astronomy by:

a) whiling away the time. b) counting sheep. c) whittling. d) counting fingers and toes. e) counting days of the lunar month.

004 qmult 00090 1 4 4 easy deducto-memory: alignment astronomy

241. "Let's play *Jeopardy*! For \$100, the answer is: Stonehenge and many other prehistoric monuments suggest that the makers were doing this."

What is/are ____________, Alex?

a) predicting eclipses b) orbital physics c) casting horoscopes d) simple alignment astronomy e) worshipping celestial gods.

004 qmult 00100 1 4 2 easy deducto-memory: Stonehenge midsummer sunrise

242. Stonehenge demonstrates that some prehistoric people:

a) could predict eclipses.
b) knew the northernmost rising location of the Sun.
c) knew nothing of astronomy.
d) knew more than the ancient Greeks about the universe.
e) suffered from back pain.

004 qmult 00200 1 4 2 easy deducto-memory: Stonehenge use

243. It is very probable that the Stonehengers used Stonehenge and other stone and wood circles:

a) for scientific astronomical research.
b) for religious and ritual purposes certainly including those depending on astronomical knowledge.
c) for religious and ritual purposes. The astronomical alignments were **NOT** intentional. Their discovery is an example of the "ingenuity of posterity".
d) for corralling cattle.
e) as habitations. Large thatch roofs rested on the stone and wood uprights.

004 qmult 00300 1 1 5 easy memory: sexagesimal angular units

244. Sexagesimal angular units were introduced in astronomy insofar as we know by:

a) the Mayans. b) the Pueblo Indians. c) Isaac Newton (1642/3–1727).
d) Renaissance astronomers. e) the ancient Babylonians.

004 qmult 00400 3 2 2 tough math: sexagesimal subtraction

245. The ancient Babylonians were using a sexagesimal (number) system as early as circa 1800 BCE. We do not know why, but it may well have been to save labor in division. The many whole number factors of 60 (1 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60 for a total of 12 factors) simplifies many division problems. The sexagesimal system seems to have been used consistently only for mathematical and astronomical purposes. For everyday use, the Babylonians often or maybe mainly used other systems including the ubiquitous decimal system: counting on fingers is as old as the hills so to say. In the last centuries BCE the sexagesimal system was taken over into astronomy. Using a large base number with a lot of factors has advantages. But one needs a lot of symbols for all the numerals unless one uses some subsidiary base which is what the Babylonians did: 10. In any case 10 as a base has nothing very special to recommend it, except for the old (very old) finger exercise.

As a non-finger exercise, subtract $61^\circ 43' 14''$ from $120^\circ 41' 03''$. Recall that $'$ stands for arcminutes and $''$ for arcseconds. **HINT:** If sexagesimal subtraction seems too tricky, you can try sexagesimal addition to recover $120^\circ 41' 03''$.

a) $182^\circ 24' 17''$. b) $58^\circ 57' 49''$. c) $58^\circ 31' 14''$. d) $59^\circ 51' 49''$. e) $58^\circ 51' 14''$.

004 qmult 00500 2 4 4 easy deducto-memory: 3 early Greeks

246. The earliest 6th century BCE names in ancient Greek science include:

a) Thales, Copernicus, and Aristotle. b) Thales, Caesar, and Aristotle. c) Eratosthenes, Thales, and Kepler. d) Thales, Anaximander, and Pythagoras. e) Aristotle, Eratosthenes, and Ptolemy.

004 qmult 00600 1 4 1 easy deducto-memory: Parmenides round Earth

247. The spherical Earth theory may have been first proposed by Parmenides of Elea. Parmenides was:

a) Greek, but he lived in southern Italy. b) Babylonian, but he lived in Antioch. c) Roman, but he lived in Alexandria. d) Celtic, but he lived in Athens. e) Roman, but he lived in southern Italy.

004 qmult 00610 3 4 5 tough deducto-memory: round Earth reasons

248. The ancient Greek Presocratic philosophers:

a) may have hypothesized a spherical Earth in order to explain the daily rotation of the celestial sphere. But it is equally likely that they thought that a spherical Earth was proven by the axioms of geometry.
b) may have hypothesized a spherical Earth in order to explain the daily rotation of the celestial sphere. Thales of Miletus then used the spherical Earth theory to predict a solar eclipse.
c) may have hypothesized a spherical Earth because they thought the Earth needed to be spherical in order to be in balance at the center of the cosmos. Aristotle (384–322) later summarized empirical arguments for the spherical Earth. These included the varying celestial locations of the stars and planets relative to the horizon as one moved north-south and the fact that the Earth's shadow on the Moon in a lunar eclipse was always round. However, **ARISTOTLE** went on to affirm that Greece must be on top of the spherical Earth because the ground in Greece was nearly level.
d) may have hypothesized a spherical Earth because they thought the Earth needed to be spherical in order to be in balance at the center of the cosmos. Aristotle (384–322) later summarized empirical arguments for the spherical Earth. These included the varying celestial locations of the stars and planets relative to the horizon as one moved north-south and the fact that the Earth's shadow on the Moon in a lunar eclipse was always round. However, **PTOLEMY** went on to affirm that Greece must be on top of the spherical Earth because the ground in Greece was nearly level.

e) may have hypothesized a spherical Earth because they thought the Earth needed to be spherical in order to be in balance at the center of the cosmos. **ARISTOTLE (384–322)** later summarized empirical arguments for the spherical Earth. These included the varying celestial locations of the stars and planets relative to the horizon as one moved north-south and the fact that the Earth's shadow on the Moon in a lunar eclipse was always round.

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004 qmult 00620 2 4 4 easy deducto-memory: Eratosthenes

249. A determination of the radius of the Earth was:

a) made by **ERATOSTHENES** in the **15TH CENTURY CE**. This measurement proved the Earth was spherical and was the inspiration for Columbus's voyage.
b) made by **ARISTOTLE** in the **15TH CENTURY CE**. This measurement proved the Earth was spherical and was the inspiration for Columbus's voyage.
c) made by **ERATOSTHENES** in the **3rd CENTURY BCE**. This measurement was based on the assumption that the Earth was **SPHERICAL** and the Sun was very distant from the Earth. If the Earth was not spherical, the measurement would have required the **SAME** interpretation.
d) made by **ERATOSTHENES** in the **3rd CENTURY BCE**. This measurement was based on the assumption that the Earth was **SPHERICAL** and the Sun was very distant from the Earth. If the Earth was not spherical, the measurement would have required a **DIFFERENT** interpretation.
e) made by **ERATOSTHENES** in the **3rd CENTURY BCE**. This measurement was based on the assumption that the Earth was an **OVAL SHAPE**. When the result came out spherical, Eratosthenes was surprised.

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004 qmult 00700 2 4 3 moderate deducto-memory: Greek distances

250. A major obstacle that ancient Greek astronomers had in trying to determine the nature of the Solar System was:

a) the eastward motion of the planets.
b) the inability to measure any distances beyond Pluto.
c) the inability to measure any distances beyond the Moon.
d) the lack of all theoretical biases.
e) the lack of geometrical skills.

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004 qmult 00800 1 4 3 easy deducto-memory: time sequence Greek astronomers

251. Which of the following sequences is correctly ordered in time?

a) Aristotle, Ptolemy, Kepler, Copernicus, Thales.
b) Aristotle, Ptolemy, Galileo, Copernicus, Thales.
c) Thales, Aristotle, Ptolemy, Copernicus, Galileo.
d) Ptolemy, Aristotle, Thales, Copernicus, Galileo.
e) Kepler, Aristotle, Thales, Copernicus, Galileo.

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004 qmult 00910 3 5 5 tough thinking: days of the week

252. The ancient Babylonians of the 5th century BCE probably invented horoscopic astronomy (No-41), but its main structure as passed down to the present probably evolved in the Greco-Roman world from the 2nd century BCE onward (Ne-170–171).

This Greco-Roman astrology has left some unusual imprints on modern conventions. For example, each hour of the 24-hour day—which itself came from the ancient Egyptians of the 2nd millennium BCE by no very logical process (Ne-86)—has a ruler (Ne169). The rulers are the seven moving stars which are ordered in decreasing order by their sidereal periods: Saturn, Jupiter, Mars, Sun, Venus, Mercury, and Moon. The Greco-Roman astronomers (including Ptolemy) believed this was the order of decreasing distance from the Earth: actually it is the order of decreasing distance from the Sun if Earth replaces Sun in the list and you eliminate the Moon.

The rulers of each hour are assigned using the ordered sequence of moving stars. The assignment of rulers starts with the 1st hour of Saturday being Saturn. The next hour is assigned Jupiter as its ruler and so on. When one completes assigning the sequence of 7 stars, then one starts the sequence over again.

Each day of the week has a ruler too: its ruler is the ruler of that day's first hour. A little calculation—or knowing that Jupiter's day got assigned to Thor in English—shows that the day rulers starting from Saturday's ruler Saturn are:

a) Saturn, Sun, Moon, Mars, Saturn, Sun, and Moon.
b) Saturn, Saturn, Saturn, Saturn, Saturn, Saturn, and Saturn.
c) Saturn, Sun, Saturn, Mars, Saturn, Mercury, and Saturn.
d) Saturn, Sun, Moon, Mars, Jupiter, Mercury, and Venus.
e) Saturn, Sun, Moon, Mars, Mercury, Jupiter, and Venus.

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004 qmult 01000 3 5 3 tough thinking: Aristotelian cosmology

253. Aristotelian cosmology:

a) consisted of perfect eternal cubes rotating about the Earth.
b) put the Earth at the center of the cosmos. The planets and fixed stars were located on sets of solid spheres that rotated about the Earth. The celestial phenomena were eternal exactly repeating motions. Beyond the sphere of the fixed stars was a **CHAOS** of primordial material in which were embedded other finite cosmoses.
c) put the Earth at the center of the cosmos. The planets and fixed stars were located on sets of solid spheres that rotated about the Earth. The celestial phenomena were eternal exactly repeating motions. Beyond the sphere of the fixed stars was **NOTHING**, not even empty space. The universe was finite.
d) was **DISCARDED** by everyone in the medieval Islamic period. It put the Earth at the center of the cosmos. The planets and fixed stars were located on sets of solid spheres that rotated about the Earth. The celestial phenomena were eternal exactly repeating motions. Beyond the sphere of the fixed stars was **NOTHING**, not even empty space. The universe was finite.
e) was never seriously considered again after Ptolemy's time.

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004 qmult 01300 1 1 4 easy memory: stellar parallax defined 1
Extra keywords: the other definition is in ch-38

254. Stellar parallax is:

a) the westward motion of the planets.
b) the daily westward motion of the fixed stars.
c) an optical illusion.
d) the change in angular position of a star relative to background stars due to the Earth's yearly motion around the Sun.
e) the change in magnitude of a star due to the Earth's year motion around the Sun.

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004 qmult 01310 2 5 2 moderate thinking memory: stellar parallax historical

255. Take a pencil (or pen or finger). Hold it upright at arm's length in front of some distant object of smallish angular size such as a wall clock. Center the pencil on the object. Then keeping your hand steady (rock steady) shift your head until the object is just out of eclipse. Neither the pencil nor the object has moved in space, but they have shifted in relative angular position because of the movement of the observer. This change in angular position of objects due the shift in the spatial position of the observer is called **PARALLAX**. (Note the term **PARALLAX** is used both for the phenomena of shift in general [e.g., "we know this from parallax"] and for particular angular shifts [e.g., "the parallax" caused by this motion is $10°$].) Try the experiment again but this time with the pencil right in front of your eye: move your head as much as before. Is the angular shift between the pencil and object larger than before? Yes/No? Well, maybe

after you've tried it carefully a few times it will be clear that parallax effects are bigger for closer objects since the same head movement (the same observational baseline) gives a larger angular shift or parallax. If the Earth were moving in space, would the stars show parallaxes relative to each other?

a) Yes, unless they were so distant that we couldn't detect parallax or unless they were all flying in formation with the Earth. The latter exception was so obviously **REASONABLE** that the ancient Greeks decided the Earth must be moving around the Sun.
b) Yes, unless they were so distant that we couldn't detect parallax or unless they were all flying in formation with the Earth. The latter exception was so obviously **CONTRIVED** that it doesn't seem to have been discussed in history as a means of accounting for the lack of stellar parallax in moving-Earth theories. Stellar parallax was, in fact, first observed in **1838**.
c) Yes, unless they were so distant that we couldn't detect parallax or unless they were all flying in formation with the Earth. The latter exception was so obviously **CONTRIVED** that it doesn't seem to have been discussed in history as a means of accounting for the lack of stellar parallax in moving-Earth theories. Stellar parallax was, in fact, first observed in **2008**.
d) No, never, no matter how close or far they were. Stars unlike any other object just cannot show parallax.
e) Parallax is the change in angular position of an object due to the change in spatial position of the observer.

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004 qmult 02010 1 4 5 easy deducto-memory: Aristotelian cosmology dogma

256. "Let's play *Jeopardy*! For $100, the answer is: A cosmology became something of a philosophical dogma in Greco-Roman Antiquity, the Medieval Islamic and European societies, and in Europe up until the 17th century."

What is ____________, Alex?

a) Democritean cosmology b) Newtonian cosmology c) Big Bang cosmology
d) inflation cosmology e) Aristotelian cosmology

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004 qmult 02100 1 1 1 easy memory: Copernicus's model

257. In modern times (which here we mean to be after circa 1450), who first proposed the heliocentric theory of the solar system?

a) Nicolaus Copernicus (1473–1543). b) Thomas Digges (c. 1546–1595).
c) Tycho Brahe (1546–1601). d) Galileo Galilei (1564–1642).
e) Isaac Newton (1643–1727).

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004 qmult 02102 1 1 3 easy memory: Copernicus's model 2

258. In modern times (which here we mean to be after circa 1450), who first proposed the heliocentric theory of the solar system?

a) Socrates (469?–399 BCE). b) Aristarchos of Samos (310?–230? BCE).
c) Nicolaus Copernicus (1473–1543). d) Galileo Galilei (1564–1642).
e) Isaac Newton (1643–1727).

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004 qmult 02110 2 5 3 moderate thinking: Aristotelian/Ptolemaic
Extra keywords: Needs work: Ptolemy had a size scale and ordering

259. The Aristotelian and Ptolemaic cosmologies were:

a) mutually **COMPLETELY CONSISTENT**. Together they gave a reasonable explanation of celestial phenomena. In the Medieval Islamic and European cultures, they were regarded as totally satisfactory. The heliocentric model of Copernicus was introduce only due to Copernicus' personal eccentricity. He merely made a lucky guess.

b) **ABANDONED** almost as soon as they were proposed. In the Medieval Islamic and European cultures, no theoretical interpretation was put on celestial phenomena at all. The prediction of celestial events was done entirely using Babylonian cycles.
c) were largely accepted during in the Medieval Islamic and European cultures despite their **PARTIAL INCONSISTENCY** and their lack of any definite size scale or ordering for the planets. Occasional attempts to improve these cosmologies came to little. The Copernican theory was a **RADICAL ALTERNATIVE**.
d) were largely accepted during in the Medieval Islamic and European cultures despite their **PARTIAL INCONSISTENCY** and their lack of any definite size scale or ordering for the planets. Occasional attempts to improve these cosmologies came to little. The Copernican theory was **NOT A RADICAL ALTERNATIVE**. It was completely consistent with Aristotelean physics and even kept epicycles.
e) were largely accepted during in the Medieval Islamic and European cultures despite their **PARTIAL INCONSISTENCY** and their lack of any definite size scale or ordering for the planets. Occasional attempts to improve these cosmologies **ALWAYS SUCCEEDED** in making their quantitative predictions much more accurate. The Copernican theory was only the lucky last of these attempts. Sheer bias kept the Aristotelean and Ptolemaic cosmologies dominant until then.

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004 qmult 02020 1 4 4 easy deducto-memory: Copernicus reason for heliocentrism

260. A key reason (perhaps the most important reason) that led Copernicus to propose the heliocentric Solar System was to:

a) get rid of uniform circular motion.
b) appease the Sun god.
c) answer Galileo's insult.
d) get a prediction of the relative positions of the planets.
e) prove that the universe was infinite.

---

004 qmult 02030 2 1 2 moderate memory: apparrent retrograde motion

261. Apparent retrograde motion is:

a) the **WESTWARD** motion of a **STAR** on the sky.
b) the **WESTWARD** motion of a **PLANET** on the sky.
c) the **EASTWARD** motion of a **PLANET** on the sky.
d) the **EASTWARD** motion of a **STAR** on the sky.
e) the result of an inter-planetary collision.

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004 qmult 02040 2 4 2 moderate deducto-memory: Earth retrograde motion

262. If you lived on Mars, the Earth would be:

a) an inner planet that was sometimes in opposition.
b) an inner planet that sometimes retrogrades.
c) an outer planet that was sometimes in opposition.
d) invisible.
e) indivisible.

---

004 qmult 02150 1 4 4 easy deducto-memory: elliptical orbit discoverer

263. "Let's play *Jeopardy*! For $100, the answer is: He/she discovered that the planets orbited the Sun in elliptical orbits."

Who is ____________, Alex?

a) Apollonios of Perga (circa 3rd century BCE) b) Nicolaus Copernicus (1473–1543)
c) Galileo Galilei (1564–1642) d) Johannes Kepler (1571–1630)
e) Caroline Herschel (1750–1848)

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004 qmult 02200 2 5 3 moderate thinking: Kepler's 3 laws

264. Kepler's three laws of planetary motion:

a) **PROVED** the Copernican theory. But this was not immediately realized because it was difficult to master the mathematical techniques and data needed to verify the three laws.
b) were partially empirical discoveries made by analyzing Tycho's data. The laws were inconsistent with the Tychonic model, and hence **PROVED** the Copernican model.
c) were partially empirical discoveries made by analyzing Tycho's data. The laws were consistent geometrically with both the Tychonic and Copernican theories. Thus they were **INSUFFICIENT** by themselves to prove the Copernican theory. Nevertheless, since the Earth fit so well as a planet obeying the three laws and was so exceptional as the center of the Solar System (given the three laws), an unbiased person might well have said that the three laws strongly favored the Copernican theory.
d) were partially empirical discoveries made by analyzing Tycho's data. The laws were consistent geometrically with both the Tychonic and Copernican theories. Thus they were **SUFFICIENT** by themselves to prove the Copernican theory.
e) were partially empirical discoveries made by analyzing Tycho's data. The laws were consistent geometrically with both the Tychonic and Copernican theories. Thus they were **SUFFICIENT** by themselves to prove the Copernican theory. Realizing this Kepler **SUPPRESSED** them for term of his life.

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004 qmult 02202 1 1 3 easy memory: Kepler's 3rd law

Extra keywords: physci KB-24-12

265. According to Kepler's 3rd law, the orbital period of a planet (i.e., the planet's year) depends on planet:

a) mass. b) diameter. c) distance from Sun. d) color. e) axis tilt.

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004 qmult 02204 2 3 4 mod. math: Kepler's 3rd law calculation 1

Extra keywords: physci KB-25-13

266. Kepler's 3rd law for the Solar System planets can be conveniently written

$$P_{\rm year} = A_{\rm AU}^{3/2} \qquad \text{or, less conveniently,} \qquad P_{\rm year}^2 = A_{\rm AU}^3 \ ,$$

where $P_{\rm year}$ is the orbital period in Earth years and $A_{\rm AU}$ is the mean Sun-planet distance in astronomical units (AU) (i.e., in mean Sun-Earth distances). If an asteroid is 9 AU from the Sun, what is its orbital period in years?

a) 9. b) 3. c) 729. d) 27. e) 1.

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004 qmult 02210 3 3 5 hard math: Kepler's 3rd law calculation 2

267. If a planet has a mean distance from the Sun of 9 astronomical units, what is its orbital period in years?

a) 28 years. b) 3 years. c) 9 years. d) 81 years. e) 27 years.

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004 qmult 02220 3 4 3 hard math: comet period: Kepler's 3rd law calculation 3

Extra keywords: Should give calc 1 as lead-in on tests

268. If a comet has a mean distance from the Sun of 144 astronomical units, what is its orbital period in years? **HINT:** Recall Kepler's 3rd law: $p_{yr}^2 = r_{\rm AU}^3$.

a) 144 years. b) 12 years. c) 1728 years. d) 20,000 years. e) 247.7 years.

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004 qmult 02420 1 4 3 easy deducto-memory: Galileo, fll phases of Venus

269. Galileo's discovered that Venus showed a full set of phases like the Moon. But it was already known since Antiquity that Venus is never opposite the Sun on the sky and in fact is never further than 46° from the Sun. Thus, Galileo's discovery proved:

a) Venus orbited the Earth.
b) Venus orbited the Moon.
c) Venus orbited the Sun.
d) Venus executed an orbit about an empty point in space that always lies between the Earth and Sun on the Sun-Earth line.
e) Venus is falling into the Sun perpetually.

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004 qmult 02430 2 4 3 moderate deducto-memory: Galileo's discoveries

270. Galileo did **NOT** discover:

a) the four largest moons of Jupiter. b) the full phases of Venus. c) the moons of Mars. d) sunspots. e) the mountainous surface of the Moon.

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004 qmult 02440 2 5 4 moderate thinking: Galileo, moons of Jupiter

271. Galileo's discovery of the moons of Jupiter:

a) had no bearing on the debate over the Copernican theory.
b) meant that the Earth was the center of Jupiter's orbit.
c) explained the full phases of Venus.
d) meant that the Earth was not the physical center of all motion in the Solar System, and that Earth could have a moon and still be a **PLANET**.
e) meant that the Earth was not the physical center of all motion in the Solar System, and that Earth could have a moon and still be on an **EPICYCLE**.

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004 qmult 02450 2 4 2 moderate deducto-memory: Galileo, Saturn's rings

272. From his observations of Saturn in 1610, Galileo's discovered:

a) that Saturn had an obvious ring.
b) that Saturn had odd protuberances, but he couldn't make out what they were. Christiaan Huygens later in the **17TH CENTURY** concluded that Saturn had a ring.
c) that Saturn had odd protuberances, but he couldn't make out what they were. Christiaan Huygens later in the **20TH CENTURY** concluded that Saturn had a ring.
d) that Saturn had 3 obvious rings that he labled A, B, and C.
e) that Saturn's rings, which are visible to the naked eye were green.

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004 qmult 02500 1 5 3 easy thinking: Galileo and Copernicanism

273. Galileo's telescopic discoveries:

a) **PROVED** Copernicanism absolutely. Resistance to this proof was simply irrational.
b) proved that the ancients had been wrong about the cosmos and that they had not had all the evidence. But Kepler's laws had already **PROVEN** Copernicanism to all the mathematically-minded including Galileo. Not everyone had accepted these proofs, of course. Soon—but not soon enough for Galileo—they would.
c) proved that the ancients had been wrong about the cosmos and that they had not had all the evidence. Now Tycho's demonstrations that the heavens were mutable and the crystalline spheres had no existence in a strong sense had already proved some of the ancient beliefs wrong. And Kepler's first two laws, published 1609 just a year before the telescopic discoveries were published in 1610, were so much better descriptions—that is they were more accurate, more unique, and simpler (with a certain interpretation of "simpler" of course)—that they made the ancient descriptions seem implausible. But Tycho's work and Kepler's work (at least prior to the publication of the *Rudolphine Tables* [1627]) was **NOT EASILY VERIFIABLE** by anyone else. The telescopic discoveries could be verified fairly easily (some very easily) by anyone and no expertise with mathematical astronomy was needed. Thus, the telescopic discoveries tore the mask from the cosmos (well a bit anyway) and opened minds to new ideas, even Copernicanism.
d) proved that the ancients had been wrong about the cosmos and that they had not had all the evidence. Now Tycho's demonstrations that the heavens were mutable and the

crystalline spheres had no existence in a strong sense had already proved some of the ancient beliefs wrong. And Kepler's first two laws, published 1609 just a year before the telescopic discoveries were published in 1610, were so much better descriptions—that is they were more accurate, more unique, and simpler (with a certain interpretation of "simpler" of course)—that they made the ancient descriptions seem implausible. But Tycho's work and Kepler's work had been mostly ignored because they were **BOTH COPERNICANS** when Copernicanism was still considered to be **COMPLETELY DISCREDITING**. The telescopic discoveries, on the other hand had been made by a Copernican whose Copernicanism was still secret (a closet Copernican), and therefore were generally taken as being well founded. Thus, the telescopic discoveries tore the mask from the cosmos (well a bit anyway) and opened minds to new ideas, even Copernicanism.

e) were completely irrelevant to the debate over Copernicanism. The fact that they were made at about the same time that Copernicanism became a hot topic is a historical coincidence.

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004 qmult 02510 1 1 4 easy memory: heliocentrism proof in 1610

274. Could heliocentrism be proven to be physically correct in circa 1610? By physically correct we mean showing that the planets geometrically orbited the Sun **AND** that this structure (i.e., the structure of the Solar System) was derivable from physical law: i.e., that the planets "physically" orbited the Sun.

a) Yes. Galileo's telescopic discoveries were proof.
b) Yes. Kepler's 3 laws of planetary motion were proof.
c) Yes. Galileo and Kepler's work combined constituted proof.
d) No. Only Newton's physics published 1687 constituted proof.
e) No. Only Einstein's general relativity published 1915 constituted proof.

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004 qmult 03000 1 4 3 easy deducto-memory: unified terrestrial/celestial 1

275. Newtonian physics unified:

a) thermodynamics and special relativity. b) terrestrial and substantial physics. c) terrestrial and celestial physics. d) terrestrial and Aristotelian physics. e) thermodynamics and substantial physics.

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004 qmult 03010 1 4 4 easy deducto-memory: unified terrestrial/celestial 2

276. "Let's play *Jeopardy*! For $100, the answer is: This person's work made astronomy in a sense and to a degree an experimental science in that he/she showed that the same physics applies on Earth and in the heavens."

Who is ____________, Alex?

a) Marguerite de Navarre (1492–1549) b) Giordano Bruno (1548–1600) c) Galileo Galilei (1564–1642) d) Isaac Newton (1643–1727) e) Johann Sebastian Bach (1685–1750)

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004 qmult 03012 1 4 2 easy deducto-memory: unified terrestrial/celestial 3

277. "Let's play *Jeopardy*! For $100, the answer is: This person's work made astronomy in a sense and to a degree an experimental science in that he/she showed that the same physics applies on Earth and in the heavens."

Who is ____________, Alex?

a) Galileo Galilei (1564–1642) b) Isaac Newton (1643–1727) c) Johann Sebastian Bach (1685–1750) d) Ben Franklin (1706–1790) e) Caroline Herschel (1750–1848)

Chapt. 5 Newtonian Physics, Gravity, Orbits, Energy, Tides

Multiple-Choice Problems

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005 qmult 00100 1 5 5 easy thinking: victory of Newtonian heliocentrism

278. The contest in the 16th and 17th centuries in Europe between the geocentric and heliocentric world models was won by the heliocentric world model. The victory was a modified one. Heliocentricism no longer meant, as it did for Copernicus and Kepler, the Sun at the center of the universe, but only the Sun at the center of the planetary system of the Sun. The universe was generally taken to be much larger, perhaps infinite, and the stars recognized as perhaps other suns. The basis of the victory was that planetary and terrestrial motions were derived mathematically and with high accuracy from a small set of very abstract axioms (i.e., postulated physical laws) and initial conditions. The derived planetary motions conformed to the heliocentric view in that the Sun caused the planets to move as they did whereas the planets barely affected the motion of the Sun. From a geometrical point of view the Sun could be described as moving around the Earth or the Earth, around the Sun. This had long been recognized: e.g., probably by Ptolemy (circa 100–175 CE). The contested issue had not been geometrical description, but physical causation. The geocentric world model had been basically the Aristotelian one either in pure form (e.g., Aristotle's own system which was not even altogether qualitatively accurate) or in the Ptolemaic or Ptolemaic-like forms (which were or could be made quantitatively accurate). The Aristotelian world model had been based on Aristotelian physics. By modern standards Aristotelian physics is very unsatisfactory: it is almost entirely qualitative and is not always even qualitatively accurate and it is rather ad hoc (i.e., new principles need to be invented to explain new phenomena). One strength of Aristotelian physics was that in many instances it agreed with the common sense, concrete sense of the world: e.g., "the Earth's at rest or we'd feel it moving"; "a hammer falls faster than a feather." That Aristotelian physics and cosmology had been brought into concordance with Medieval theology was another strength in a time in which it was thought by many that the world should and did manifest the divine in an easily accessible manner. The theological concordance seemed to offer a guarantee of absolute truth, whereas the axiomatic, mathematical physics, only a provisional truth. The victory of the new physics and the new heliocentric system of the world showed that quantitative accuracy and mathematical elegance had come to be valued above naive common sense and naive concrete sense and that the religious objections could in fact be overcome. The victory was effectively completed by:

   a) Aristotle (384–322 BCE). b) Nicolaus Copernicus (1473–1543).
   c) Galileo Galilei (1564–1642). d) Johannes Kepler (1571–1630).
   e) Isaac Newton (1642/3–1727).

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005 qmult 00110 1 4 3 easy deducto-memory: planetary motions and Newton
Extra keywords: CK-61-7

279. "Let's play *Jeopardy*! For $100, the answer is: This person was the first to understand the planetary motions using a physical theory that very adequately accounted for terrestrial motions."

   a) Ptolemy (c.100–c.170 CE). b) Nicolaus Copernicus (1473–1543).
   c) Isaac Newton (1642/3–1727). d) Richard Feynman (1918–1988).

e) Stephen Hawking (1942–2018).

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005 qmult 00200 1 1 5 easy memory: hammer and feather on Moon

280. Drop a feather and hammer at the same time on the Earth (given realistic conditions) and then on the Moon (also given realistic conditions).

a) They **BOTH** hit the ground at the same time on both worlds.
b) The **HAMMER** lands first by a large margin on both worlds.
c) The **FEATHER** lands first on both worlds.
d) The **FEATHER** lands second on Earth and first by a large margin on the Moon.
e) The **FEATHER** lands second on Earth and at about the same time as the **HAMMER** on the Moon.

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005 qmult 00300 1 1 4 easy memory: speed and velocity

281. What is the difference between speed and velocity?

a) Velocity is the rate of change of speed.
b) There is no difference.
c) The difference is merely theoretical, not practical.
d) Both measure the rate of change of position with time: velocity specifies direction as well as magnitude of the rate of change; speed specifies only magnitude.
e) Both measure the rate of change of position with time: velocity specifies acceleration as well as magnitude of the rate of change of position; speed specifies only magnitude of rate of change of position.

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005 qmult 00310 1 1 4 easy memory: mass defined
Extra keywords: CK-61-8

282. The dynamic variable ________ is the resistance of a body to acceleration. The fact that gravitational force depends on ________ was one of those curious coincidences that led Einstein to formulate general relativity.

a) acceleration b) force c) angular momentum d) mass e) emass

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005 qmult 00400 1 1 3 easy memory: Newton's 1st law 1

283. Newton's first law states:

a) a body continues at rest or in **ACCELERATED** motion in a straight line in an inertial frame unless acted on by a net force.
b) a body continues at rest or in **DECELERATED** motion in a straight line in an inertial frame unless acted on by a net force.
c) a body continues at rest or in **UNIFORM** (constant speed) motion in a straight line in an inertial frame unless acted on by a net force.
d) a body is **ALWAYS** at rest in an inertial frame unless acted on by a net force.
e) a body is always at rest in an inertial frame unless acted on by **GRAVITY**.

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005 qmult 00402 1 4 5 easy deducto-memory: Newton's 1st law 2

284. "Let's play *Jeopardy*! For $100, the answer is: According to this law a body is unaccelerated unless acted on by a net force."

What is ____________, Alex.

a) the universal law of gravity b) Newton's 3rd law c) Kepler's 3rd law d) the cosmological principle e) Newton's 1st law

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005 qmult 00410 1 4 5 easy deducto memory: Newton's 2nd law

285. Newton's second law proposes that:

a) a body continues at rest or in **ACCELERATED** motion in a straight line in an inertial frame unless acted on by a net force.

b) for every force, there is an **equal** and **opposite** force.
c) a body continues at rest or in **UNIFORM** (constant speed) motion in a straight line in an inertial frame unless acted on by a net force.
d) a body is **ALWAYS** at rest in an inertial frame unless acted on by a net force.
e) an acceleration of a body is caused by a net force and the resistance of the body to acceleration is determined by a quantity called mass. In equation form the law is precisely

$$\vec{F}_{\text{net}} = m\vec{a} ,$$

where $\vec{F}_{\text{net}}$ is the net force, m is the body's mass, and $\vec{a}$ is the acceleration. Force and acceleration are both vectors (i.e., they have both magnitude and direction); mass is a scalar (i.e., it has only a magnitude).

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005 qmult 00500 1 1 5 easy memory: Newton's 3rd law
286. Newton's 3rd law states:

a) for every force, there is an **EQUAL** and **PERPENDICULAR** force.
b) for every force, there is an **SMALLER** and **PERPENDICULAR** force.
c) for every force, there is an **EQUAL** and **OPPOSITE** force. The two forces act on the same body always, and so their are no accelerations at all.
d) for every force, there is a **LARGER** and **OPPOSITE** force.
e) for every force, there is an **EQUAL** and **OPPOSITE** force.

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005 qmult 00510 1 5 3 easy thinking: Newton's 3rd law and accelerations
287. Newton's third law states that for every force there is an equal and opposite force. But since two equal and opposite forces add vectorially to give zero, there should never be a net force and thus by Newton's second law there should never be any accelerations at all. What is the fallacy in this argument?

a) The fallacy is bringing Newton's second law into the argument. The second and third law refer to entirely different kinds of motions, and so can never be used at the same time.
b) There is none. The argument is completely valid. Accelerations are an illusion. So is motion for that matter. Parmenides of Elea (circa 5th century BCE) was right: nothing changes; all change is but seeming.
c) The equal and opposite forces **DO NOT** have to be on the same body. Newton's second law refers to the net force on a single body. Thus, the net force on a body experiencing one of the pair of forces **NEED NOT** be zero. Thus accelerations **ARE** possible.
d) The equal and opposite forces **DO** have to be on the same body. Newton's second law refers to the net force on a single body. Thus, the net force on a body **NEEDS TO** be zero. Thus accelerations **ARE NOT** possible.
e) The full statement of the third law makes an **EXCEPTION** for forces that cause accelerations: there **DO NOT** have to be equal and opposite forces for acceleration-causing forces. Thus accelerations **ARE** possible.

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005 qmult 00550 1 5 3 easy thinking: inertial frames defined
288. Inertial frames are:

a) rotating frames.
b) accelerating frames.
c) frames with respect to which all physical laws are referenced (at least in the usual sense), except general relativity which tells us that exact inertial frames are free-fall frames. To be concrete, the center of mass of a system of astro-bodies (which may consist of just one astro-body) that only interacts with the rest of the universe through gravity defines an exact inertial frame (i.e., a free-fall frame) and this frame **DOES NOT** rotate with respect to the observable universe. Any part of the system **NOT** accelerating with respect to the center of mass also defines an exact inertial frame relative the center-of-mass inertial frame.

Parts of system accelerating sufficiently slowly relative to the center-of-mass inertial frame are approximate inertial frames for some effects. To give an example, the Earth center of mass defines an inertial frame. Any location on the surface of the Earth is accelerated with respect to the Earth center-of-mass inertial frame because of the Earth's rotation, and so **IS NOT** an exact inertial frame relative to the Earth center-of-mass inertial frame, but is an approximate inertial frame for many effects.

d) frames with respect to which all physical laws are referenced (at least in the usual sense), except general relativity which tells us that exact inertial frames are free-fall frames. To be concrete, the center of mass of a system of astro-bodies (which may consist of just one astro-body) that only interacts with the rest of the universe through gravity defines an exact inertial frame (i.e., a free-fall frame) and this frame DOES rotate with respect to the observable universe.

e) frames with respect to which all physical laws are referenced (at least in the usual sense), except general relativity which tells us that exact inertial frames are free-fall frames. To be concrete, the center of mass of a system of astro-bodies (which may consist of just one astro-body) that only interacts with the rest of the universe through gravity defines an exact inertial frame (i.e., a free-fall frame) and this frame does **NOT** rotate with respect to the observable universe. Any part of the system **NOT** accelerating with respect to the center of mass also defines an exact inertial frame relative the center-of-mass inertial frame. Parts of system accelerating sufficiently slowly relative to the center-of-mass inertial frame are approximate inertial frames for some effects. To give an example, the Earth center of mass defines an inertial frame. Any location on the surface of the Earth is accelerated with respect to the Earth center-of-mass inertial frame because of the Earth's rotation, and so **IS** an exact inertial frame relative to the Earth center-of-mass inertial frame.

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005 qmult 00570 3 1 3 tough thinking: rotating frame

289. A rotating frame (i.e., rotating with respect to an inertial frame) with **NO** inertial forces invoked is:

a) **NOT** an inertial frame. Nevertheless, there **CAN BE NO** accelerations in such a frame without a net force.
b) an inertial frame.
c) **NOT** an inertial frame. There **CAN BE** accelerations in such a frame without a net force.
d) **BOTH** an exact inertial frame and an exact non-inertial frame at the same time.
e) a practical impossibility.

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005 qmult 00580 2 5 3 moderate thinking: Newton's laws not obvious

290. Newton's laws of motion are:

a) obvious. This is why Aristotle knew them more than 23 centuries ago. He just rejected them for moral reasons.
b) not obvious. Nevertheless, Aristotle knew of the them more than 23 centuries ago. He just rejected them for hygienic reasons.
c) not obvious. To get to them, one probably first has to imagine what happens in the absence of all resistive media.
d) 6 in number.
e) not obvious. To get to them, one probably first has to imagine what happens in the center of the Earth.

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005 qmult 00600 1 1 4 easy memory: force definition

291. A force is:

a) what sustains a constant velocity.
b) what sustains a uniform motion.
c) the same as acceleration.

d) a physical relation between bodies or between a body and a the field of some force that causes a body to accelerate (if not balanced by other forces).
e) a physical relation between bodies that causes them to orbit each other.

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005 qmult 00800 2 5 1 moderate thinking: time discussed: defective
Extra keywords: This needs reworking.

292. Time, time, what is time? Newton's laws, which invoke uniform motion and acceleration, imply that there is a standard time: Newton called it absolute time. But he knew it was a postulate. How do we actually get a hold of time in a purely Newtonian world at least? (It's a bit trickier in a relativistic world.)

a) We use prescribed force laws to construct devices that are supposed to be in uniform motion or that have constant periods according to Newton's laws. These devices are called **clocks**. It turns out that they are all synchronizable. So the units of time they mark (e.g., the pendulum periods of a small-amplitude pendulum or the orbital periods of a planet) are considered to count **absolute time**. Thus, Newton's laws plus known force laws give us a unique time that we identify with the time in Newton's laws. Are there unsynchronizable clocks? **Yes,** consider counting time by the crowing of the cock, the length of daylight, human generations, the human pulse, a beating heart. The **astronomical clocks** that humans had come to rely on since earliest times are, of course, Newtonian clocks. And water clocks (good ones anyway) and mechanical clocks are also Newtonian clocks. Thus, there was no "shock of the new" in time keeping at the advent of Newton's laws.
b) We use prescribed force laws to construct devices that are supposed to be in uniform motion or that have constant periods according to Newton's laws. These devices are called **clocks**. It turns out that they are all synchronizable. So the units of time they mark (e.g., the pendulum periods of a small-amplitude pendulum or the orbital periods of a planet) are considered to count **absolute time**. Thus, Newton's laws plus known force laws give us a unique time that we identify with the time in Newton's laws. Are there unsynchronizable clocks? **No.** Thus, there was no "shock of the new" in time keeping at the advent of Newton's laws.
c) We use prescribed force laws to construct devices that are supposed to be in uniform motion or that have constant periods according to Newton's laws. These devices are called **clocks**. It turns out that they are only **approximately synchronizable.** The length of a solar day counted by ticks of a mechanical clock varies in length by about 20 %. Thus, we use mechanical clocks as standards and admit that there is something badly wrong with Newton's laws even for everyday purposes.
d) We use prescribed force laws to construct devices that are supposed to be in uniform motion or that have constant periods according to Newton's laws. These devices are called **tick-tocks**. It turns out that they are all synchronizable. So the units of time they mark (e.g., the pendulum periods of a small-amplitude pendulum or the orbital periods of a planet) are considered to count **absolute space**. Thus, Newton's laws plus known force laws give us a unique time that we identify with the time in Newton's laws. Are there unsynchronizable tick-tocks? **Yes,** consider counting time by the crowing of the cock, the length of daylight, human generations, the human pulse, a beating heart. The **astronomical tick-tocks** that humans had come to rely on since earliest times are, of course, Newtonian tick-tocks. And water tick-tocks (good ones anyway) and mechanical tick-tocks are also Newtonian tick-tocks. Thus, there was no "shock of the new" in time keeping at the advent of Newton's laws.
e) We use prescribed force laws to construct devices that are supposed to be in uniform motion or that have constant periods according to Newton's laws. These devices are called **clocks**. It turns out that they are all synchronizable. So the units of time they mark (e.g., the pendulum periods of a small-amplitude pendulum or the orbital periods of a planet) are considered to count **absolute time**. Thus, Newton's laws plus known force laws give us a unique time that we identify with the time in Newton's laws. Are there

unsynchronizable clocks? **Yes,** consider counting time by the crowing of the cock, human generations, the human pulse, a beating heart. Since humans had always relied primarily on these **biological clocks,** there was a "shock of the new" in time keeping at the advent of Newton's laws. Are mechanical clocks real time we asked. Do we really have to wait on bells and whistles and wear watches, become nothing but cogs in a machine?

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005 qmult 00900 2 5 5 moderate thinking: gravitation law

293. Newton's force law for gravitation for the magnitude of the force is

$$F = \frac{GM_1M_2}{r^2} \ .$$

a) The force is **ALWAYS ATTRACTIVE** and is felt only by the mass designated M_2. The distance between the centers of the two masses is $2r$. This force law strictly holds for **CUBICAL BODIES**.
b) The force is **USUALLY ATTRACTIVE** and is felt by both masses M_1 and M_2. The distance between the centers of the two masses is r. Because r^2 appears in the denominator, the force law is an **INVERSE-CUBE LAW**. This force law strictly holds only for **POINT MASSES**: a **TOTALLY DIFFERENT FORCE LAW** applies to **SPHERICALLY SYMMETRIC BODIES**.
c) The force is **ALWAYS ATTRACTIVE** and is felt by both masses M_1 and M_2. The distance between the centers of the two masses is r. Because r^2 appears in the denominator, the force law is an **INVERSE-SQUARE LAW**. This force law strictly holds only for **POINT MASSES**: a **TOTALLY DIFFERENT FORCE LAW** applies to **SPHERICALLY SYMMETRIC BODIES**.
d) The force is **ALWAYS ATTRACTIVE** and is felt by both masses M_1 and M_2. The distance between the centers of the two masses is r. Because r^2 appears in the denominator, the force law is an **INVERSE-SQUARE LAW**. This force law applies to all **POINT MASSES** and also to **SPHERICALLY SYMMETRIC BODIES**. For nonspherically symmetric bodies, the force of gravitation **VANISHES**.
e) The force is **ALWAYS ATTRACTIVE** and is felt by both masses M_1 and M_2. The distance between the centers of the two masses is r. Because r^2 appears in the denominator, the force law is an **INVERSE-SQUARE LAW**. This force law applies to all **POINT MASSES** and also to **SPHERICALLY SYMMETRIC BODIES** outside of those bodies. For two **NONSPHERICALLY SYMMETRIC BODIES**, the force of gravitation can be calculated by finding the force between each pair of small parts (one of the pair from each of the two bodies) using the point-mass force law in its vector formulation. The forces between all the pairs can be added up vectorially to get the net force between the bodies.

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005 qmult 00910 2 5 2 moderate thinking: gravity force law approximations

294. Newton's force law for gravitation for the magnitude of the force is

$$F = \frac{GM_1M_2}{r^2} \ ,$$

where $G = 6.67430 \times 10^{-11}$ is the gravitational constant in mks units, M_1 is the mass of one point mass, M_2 is the mass of a second point mass, and r is the distance between the two point masses. The law is usually presented as holding between point masses even though point masses are idealization that probably do not exist. Black holes may be true point masses, but they must be treated by general relativity or perhaps quantum gravity: they are outside of the realm of Newtonian physics and gravity.

Nevertheless, the law allows one to calculate the gravitational force between non-point masses by dividing them up into small bits each of which can be treated as a point mass. The net gravitational force on a single bit in the 1st body due to all the others in the 2nd body can then be found by vector addition of the individual bit gravitational forces. One then add up vectorially the gravitational forces on all the bits in the first body. This final sum is the net gravitational force of the 2nd body on the 1st body. The net gravitational force of the 1st body on the 2nd body is just equal and opposite by Newton's 3rd law. There is an approximation in that the bits are not point masses, but the smaller they are the more like point masses they become and the more accurate the result. The net gravitational force can thus be calculated as accurately as one likes and when calculated sufficiently accurately the net gravitational force always agrees with observations as long as one does not go to the strong gravity realm where general relativity is needed.

Fortunately, the gravity force law has several important special cases. It holds approximately between all bodies and becomes more accurate the further they are apart: it approaches being exact as the body separation becomes very large compared to the sizes of the bodies. Also a spherically symmetric body acts just like an ideal point mass with all the body mass concentrated at the center provided one is outside the body. Newton himself proved this result first: it was a vast relief to him and everyone else.

From the last paragraph of this disquisition, one can conclude that the gravity force law holds between a planet and small bodies on or above its surfaces:

a) only very crudely.
b) to high accuracy.
c) not at all.
d) only when the planet has a very high temperature.
e) only when the planet is green.

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005 qmult 01000 1 5 1 easy thinking: inverse-square law of gravity 1

295. The force of gravity between two bodies is proportional to the inverse square of the distance between the centers of the two bodies either exactly or approximately depending on nature of the bodies. At 10 Earth radii, the Earth's gravity force is ________ times its gravity force on its surface.

a) 1/100 b) 1/20 c) 20 d) 1/10 e) zero

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005 qmult 01010 1 5 4 easy thinking: inverse-square law of gravity 2

296. The force of gravity between two bodies is proportional to the inverse square of the distance between the centers of the two bodies either exactly or approximately depending on nature of the bodies. At 100 Earth radii, the Earth's gravity force is ________ times its gravity force on its surface.

a) 1/100 b) 1/200 c) 200 d) 1/10000 e) zero

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005 qmult 01100 1 5 1 easy thinking: gravity dominates large scales

297. Newton's force law for gravitation for the magnitude of the force is

$$F = \frac{GM_1M_2}{r^2} ,$$

where $G = 6.67430 \times 10^{-11}$ is the gravitational constant in mks units, M_1 is the mass of one point mass, M_2 is the mass of a second point mass, and r is the distance between the two point masses. The force is always attractive and always acts along the line joining the two point mass. The force can be viewed as either the force on 1 due to 2 or on 2 due to 1: this is consistent with the third law. Although strictly speaking the law has only been defined for point masses, the law can be applied approximately for non-point masses. Moreover, it is exactly correct for spherically symmetric masses, except inside of the masses. **CALCULATE** the force between two 1 kilogram point masses separated by a distance of one meter. **CALCULATE** the force between a kilogram mass at the surface of the Earth and the Earth ($M_\oplus = 5.9742 \times 10^{24}$ kg; $R_\oplus = 6.378136 \times 10^6$ m). The electromagnetic force holds small bodies like humans together: gravity clearly cannot do this. The electromagnetic force is obviously much stronger in some sense than the gravitational force. Why then does the gravitational force, not the electromagnetic force dominate the intermediate and large scale structure of the universe?

a) 6.674×10^{-11} newtons and 9.8 newtons. The electromagnetic force is generated by positive and negative charges. Positive and negative charges tend to cancel each other's effect when they are **CLOSE TOGETHER** and they are **HIGHLY ATTRACTIVE** to each other. On a microscopic scale, quantum mechanical effects keep the charges from exactly overlapping and canceling each other. Thus very strong microscopic derived forces can exist: e.g., chemical and ionic bonding forces. These forces hold everyday materials together. But over large distances it is very **HARD** to develop a large net charge and thus the electromagnetic forces tend to cancel over large distances. Gravity has only one "charge," mass, and the gravitational force is always attractive. No cancellation is possible. Thus with large masses, the gravitational force can become large and have effects over large distances.

b) 6.674×10^{-11} newtons and 9.8 newtons. The electromagnetic force is generated by positive and negative charges. Positive and negative charges tend to cancel each other's effect when they are **CLOSE TOGETHER** and they are **HIGHLY REPULSIVE** to each other. On a microscopic scale, quantum mechanical effects keep the charges from exactly overlapping and canceling each other. Thus very strong microscopic derived forces can exist: e.g., chemical and ionic bonding forces. These forces hold everyday materials together. But over large distances it is very **HARD** to develop a large net charge and thus the electromagnetic forces tend to cancel over large distances. Gravity has only one "charge," mass, and the gravitational force is always attractive. No cancellation is possible. Thus with large masses, the gravitational force can become large and have effects over large distances.

c) 6.674×10^{-11} newtons and 9.8×10^{-11} newtons. The electromagnetic force is generated by positive and negative charges. Positive and negative charges tend to cancel each other's effect when they are **CLOSE TOGETHER** and they are **HIGHLY REPULSIVE** to each other. On a microscopic scale, quantum mechanical effects keep the charges from exactly overlapping and canceling each other. Thus very strong microscopic derived forces can exist: e.g., chemical and ionic bonding forces. These forces hold everyday materials together. But over large distances it is very **EASY** to develop a large net charge and thus the electromagnetic forces tend to cancel over large distances. Gravity has only one "charge," mass, and the gravitational force is always attractive. No cancellation is possible. Thus with large masses, the gravitational force can become large and have effects over large distances.

d) 6.674×10^{-11} newtons and 9.8 newtons. The electromagnetic force is generated by positive and negative charges. Positive and negative charges tend to cancel each other's effect when they are **CLOSE TOGETHER** and they are **HIGHLY ATTRACTIVE** to each other. On a microscopic scale, quantum mechanical effects keep the charges from exactly overlapping and canceling each other. Thus very strong microscopic derived forces can exist: e.g., chemical and ionic bonding forces. These forces hold everyday materials together. But over large distances it is very **EASY** to develop a large net charge and thus the electromagnetic forces tend to cancel over large distances. Gravity has only one "charge," mass, and the gravitational force is always attractive. No cancellation is possible. Thus with large masses, the gravitational force can become large and have effects over large distances.

e) 6.674×10^{-11} newtons and 9.8 newtons.

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005 qmult 01102 1 5 4 easy thinking: Galileo and balls

298. In the early 1590s when he was a professor (untenured) at the University of Pisa, Galileo probably performed a public demonstration of dropping balls from the Leaning Tower of Pisa. The idea was to show that Aristotle was wrong in saying that balls of different masses fell in markedly different times. But the balls never fell in quite the same time. This was because:

a) of the gravitational perturbation of Jupiter.
b) according to Newton's laws the acceleration of a ball under gravity is proportional to its mass.
c) according to Newton's laws the acceleration of a ball under gravity is inversely proportional to its mass.
d) they had differing air resistance and probably Galileo's inability to release them at exactly the same time.
e) they had the same air resistance and the fact that Galileo was standing tilted because of the tower's tilt.

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005 qmult 01110 1 5 3 easy thinking: free fall, terminal velocity
299. The acceleration due to gravity near the surface of the Earth is:

$$a = \frac{GM_\oplus}{R_\oplus^2} = 9.8\,\mathrm{m/s^2}$$

to 2-digit accuracy. Say you are a skydiver and—in a momentary lapse—have forgotten your parachute (golden or otherwise). Imagine there is no air resistance. What will be your speed after 10 s? In kilometers per hour? (The conversion factor is 3.6 (km/hr)/(m/s).) In reality, what mitigates your predicament?

a) About 100 m/s or 360 km/hr. Air resistance opposes the your downward motion and in fact increases with your downward velocity. Thus, eventually, you stop accelerating and reach a terminal velocity. For skydivers this is ~ 200 km/hr. You won't accelerate to the ground. So in reality your **SURVIVAL** is guaranteed.
b) About 10 m/s or 36 km/hr. Air resistance opposes the your downward motion and in fact increases with your downward velocity. Thus, eventually, you stop accelerating and reach a terminal velocity. For skydivers this is ~ 200 km/hr. You won't accelerate to the ground. So in reality your **SURVIVAL** is guaranteed.
c) About 100 m/s or 360 km/hr. Air resistance opposes the your downward motion and in fact increases with your downward velocity. Thus, eventually, you stop accelerating and reach a terminal velocity. For skydivers this is ~ 200 km/hr. You won't accelerate to the ground. Nevertheless, the landing will be **VERY HARD**. But some people have survived such falls.
d) About 10 m/s or 36 km/hr. Air resistance opposes the your downward motion and in fact increases with your downward velocity. Thus, eventually, you stop accelerating and reach a terminal velocity. For skydivers this is ~ 200 km/hr. You won't accelerate to the ground. Nevertheless, the landing will be **VERY HARD**. But some people have survived such falls.
e) About 9.8 m/s or 36 km/hr. Air resistance opposes the your downward motion and in fact increases with your downward velocity. Thus, eventually, you stop accelerating and reach a terminal velocity. For skydivers this is ~ 200 km/hr. You won't accelerate to the ground. Nevertheless, the landing will be **VERY HARD**. But some people have survived such falls.

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005 qmult 01200 1 4 4 easy deducto-memory: centripetal acceleration
300. In uniform circular motion the acceleration always:

a) is formally infinite. Of course, there is really no acceleration, but the mathematical calculation always comes out infinite.
b) is zero.

c) points **IN THE DIRECTION OF MOTION** and has magnitude v^2/r, where v is the speed and r is the circle radius. The acceleration is called the **TANGENTIAL ACCELERATION**.
d) points **TOWARD** the center and has magnitude v^2/r, where v is the speed and r is the circle radius. The acceleration is called the **CENTRIPETAL ACCELERATION**.
e) points **AWAY FROM** the center and has magnitude v^2/r, where v is the speed and r is the circle radius. The acceleration is called the **CENTRIFUGAL ACCELERATION**.

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005 qmult 01210 1 4 2 easy deducto-memory: circular orbital velocity

301. The velocity of a smallish body in a circular orbit about a large spherically symmetric mass is given by

$$v = \sqrt{\frac{GM}{r}} \ ,$$

where M is the mass of the central object and r is the radius of the orbit. This expression is derived using:

a) Newton's 1st law, the force law of gravity, and the kinematic result for centripetal acceleration (i.e., the magnitude of the acceleration is v^2/r).
b) Newton's 2nd law, the force law of gravity, and the kinematic result for centripetal acceleration (i.e., the magnitude of the acceleration is v^2/r).
c) Newton's 3rd law, the force law of gravity, and the kinematic result for centripetal acceleration (i.e., the magnitude of the acceleration is v^2/r).
d) Newton's 3rd law, Coulomb's law, and the kinematic result for centripetal acceleration (i.e., the magnitude of the acceleration is v^2/r).
e) from nothing at all. It is a fundamental law. It is a "just so" of nature.

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005 qmult 01220 1 3 4 easy math: escape velocity from Earth

302. The escape velocity for a small body from a large spherically symmetric body is

$$v = \sqrt{\frac{2GM}{r}} \ ,$$

where M is the mass of the large body, r is the radius from which the launch occurs (which could be on or anywhere above the body), and $G = 6.67430 \times 10^{-11}$ is the gravitational constant in mks units. The launch can be any direction at all as long as only gravity acts on the small body: you cannot let the small body hit the planet.

Calculate the escape velocity from the Earth given $M = 5.9722 \times 10^{24}$ kg and $r = 6.3781370 \times 10^6$ m (which is the Earth's equatorial radius). Give the answer in km/s.

a) 7.91 km/s. b) 0.791 km/s. c) 1.0×10^{-3} km/s. d) 11.2 km/s. e) 11200 km/s.

---

005 qmult 01270 1 4 4 easy deducto-memory: orbital free fall and so weightless

303. Astronauts in orbit about the Earth are weightless because:

a) gravity vanishes in space.
b) gravity becomes repellent in space.
c) they are in free fall. They are perpetually falling away from the Earth.
d) they are in free fall. They are perpetually falling toward the Earth, but keep missing it.
e) they are in free fall. But they reach terminal speed due to air resistance and this hides any effects of acceleration.

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005 qmult 01280 1 4 3 easy deducto-memory: space debris

304. Space debris is:

a) space heating, b) the same thing as ultraviolet radiation, c) space junk, d) the remains of a Romulan attack, e) has the last "s" pronounced.

005 qmult 01350 3 5 2 hard thinking: changing orbits

305. Up until Saturday 1998 October 24, all interplanetary probes had been accelerated when in flight by chemical-burning rocket propulsion. (Note: On said Saturday of 1998 October, NASA launched Deep Space 1, an ion propulsion probe: the non-linear effects of science fiction keep turning up.) These kind of probes (i.e., chemical-burning rocket propulsion probes) periodically get accelerated by brief rocket firings.

a) The paths of these probes cannot be described by orbits at all: before, during or after firings.
b) Between firings the probes travel along **PARTICULAR ORBITS**. The firings change the orbits. A **SUFFICIENTLY STRONG FIRING** would cause a probe to reach **ESCAPE SPEED** for the Solar System. After such a firing the probe goes into an **OPEN ORBIT**.
c) Between firings the probes travel along **PARTICULAR ORBITS**. The firings change the orbits. An **EXTREMELY WEAK FIRING** causes a probe to reach **ESCAPE SPEED** for the Solar System. After such a firing the probe **FALLS INTO THE SUN**.
d) Between firings the probes travel along **PARTICULAR ORBITS**. The firings change the orbits. A **SUFFICIENTLY STRONG FIRING** would cause a probe to reach **ESCAPE SPEED** for the Solar System. After such a firing the probe **FALLS INTO THE SUN**.
e) Between firings the probes travel along **PARTICULAR ORBITS**. The firings change the orbits. A **SUFFICIENTLY STRONG FIRING** would cause a probe to reach **ESCAPE SPEED** for the Solar System. After such a firing the probe goes into an **ELLIPTICAL ORBIT**.

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005 qmult 01380 1 4 3 easy deducto-memory: energy definition

306. "Let's play *Jeopardy*! For $100, the answer is: Everyone admits that there is no adequate one-sentence definition of fundamental quantity X of physics and the natural world in general. Nevertheless, it is useful to have even an inadequate one-sentence definition as a starting point for further specification. Yours truly, at this moment in time, suggests the following: X is the conserved capability of change. Conserved means X cannot be created or destroyed though it can be transformed among different forms and transferred through space. (Actually, simple conservation holds in almost all ordinary contexts, but general relativity dictates that a more general conservation principle is needed in general.) The "capability of change" means, among other things, the amount of X added to or subtracted from a system dictates, without other specified information, the amount of change in an unspecified sense that must occur in that system—except that the change in X itself is specified. X and its spectrum of forms are characteristics of the state of a system, but they are far from being the only ones—but they are the most general characteristics since all states have X and at least some forms of X, but not necessarily all other characteristics. X and its spectrum of forms (except the rest mass form) are always calculated by formulae from more direct observables: e.g., velocity, position, electric field. Outside of the realm of physics, a vague semi-quantitative version of X under various names has probably been used throughout much of human existence to mean capability of change, transformation, or doing something in many different realms.

What is ____________, Alex?

a) force b) horse c) energy d) gravity e) electromagnetism

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005 qmult 01400 1 1 5 easy memory: kinetic energy definition

307. Kinetic energy is the energy of:

a) acceleration. b) the electromagnetic field. c) electromagnetic radiation.
d) rest mass. e) motion.

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005 qmult 01402 1 3 2 easy math: kinetic energy and velocity

308. The formula for kinetic energy is

$$KE = \frac{1}{2}mv^2 ,$$

where m is mass and v is velocity. If velocity is doubled, kinetic energy changes by a multiplicative factor of:

a) 2. b) 4. c) 1/2. d) 1/4. e) 1 (i.e., it is unchanged).

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005 qmult 01410 1 1 2 easy memory: energy conversions

309. Energy:

a) comes in many forms which are all interconvertible **WITHOUT ANY RESTRICTIONS**.
b) comes in many forms which are all interconvertible. However, **WHETHER OR NOT** a conversion occurs or not depends initial conditions and on a complex set of rules: these rules come from force laws, conservation laws, quantum mechanics, **AND** thermodynamics.
c) comes in many forms which are all interconvertible. However, **WHETHER OR NOT** a conversion occurs or not depends initial conditions and on a complex set of rules: these rules come from force laws, conservation laws, and quantum mechanics, but **NOT** thermodynamics.
d) comes in the form of kinetic and heat energy only.
e) comes in the form of rest mass energy only.

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005 qmult 01412 1 1 2 easy memory: Einstein equation E=mc**2 identified

310. Einstein's most famous equation is:

a) $E = c^2$. b) $E = mc^2$. c) $E = mc^3$. d) $E = m$. e) $E = m/c^2$.

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005 qmult 01420 1 5 5 easy thinking: Einstein equation E=mc**2

311. The Einstein equation

$$E = mc^2 ,$$

where E is an amount of energy, m is mass, and c is the vacuum speed of light, can be read correctly in two ways. First, it can be read as saying all forms of energy have mass (i.e., resistance to acceleration and gravitational "charge") equal to E/c^2, where E is the amount of the energy. Second, it can be read as saying:

a) the vacuum speed of light is a form of energy.
b) the square of the vacuum speed of light is a form of energy.
c) the equal sign is a form of energy.
d) that rest mass (the resistance to acceleration of matter in a frame in which it is at rest) is a form of energy with the amount of energy being equal to the rest mass times c^2. We usually refer to rest mass simply as "mass" without qualification when there is no danger of confusion. Because rest mass is a form of energy it can be converted into any other form. Usually in terrestrial conditions one **CAN** completely convert the rest mass of a macroscopic body to another form of energy easily.
e) that rest mass (the resistance to acceleration of matter in a frame in which it is at rest) is a form of energy with the amount of energy being equal to the rest mass times c^2. We usually refer to rest mass simply as "mass" without qualification when there is no danger of confusion. Because rest mass is a form of energy it can be converted into any other form, but usually in terrestrial conditions one **CANNOT** completely convert the rest mass of a macroscopic body to another form of energy easily.

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005 qmult 01450 1 5 1 easy thinking: 2nd law of thermodynamics

312. An everyday example of the 2nd law of thermodynamics is that:

a) heat flows from **HOT TO COLD BODIES** (at least at the macroscopic level) provided there is no refrigeration process or absolute thermal isolation in effect.
b) heat cannot flow at all.
c) heat flows from **COLD TO HOT BODIES** (at least at the macroscopic level) provided there is no refrigeration process or absolute thermal isolation in effect.
d) heat and coolness are both fluids.
e) heat is a fluid and coolness is relative absence of that fluid.

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005 qmult 01460 1 4 4 easy deducto-memory: entropy
Extra keywords: physci

313. Entropy is:

a) the same as temperature.
b) the same as heat.
c) a measure of magnetic field energy.
d) a **PHYSICALLY** well-defined kind of disorder.
e) a **SPIRITUALLY** well-defined kind of disorder.

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005 qmult 01470 2 5 1 moderate thinking: non-rigorous 2nd law of thermodynamics

314. One way of stating the 2nd law of thermodynamics is that:

a) entropy (a physically well-defined kind of **DISORDER**) always increases or stays the same for a closed system. For an open system, it can decrease. When entropy is constant in a closed system, then that system is in **THERMODYNAMIC EQUILIBRIUM**.
b) entropy (a physically well-defined measure of **TEMPERATURE**) always increases or stays the same for a closed system. For an open system, it can decrease. When entropy is constant in a closed system, then that system is in **THERMODYNAMIC EQUILIBRIUM**.
c) entropy (a physically well-defined kind of **DISORDER**) always increases or stays the same for a closed system. For an open system, it can decrease. When entropy is constant in a closed system, then that system is **NOT IN THERMODYNAMIC EQUILIBRIUM**.
d) entropy (a physically well-defined measure of **TEMPERATURE**) always increases or stays the same for a closed system. For an open system, it can decrease. When entropy is constant in a closed system, then that system is **NOT IN THERMODYNAMIC EQUILIBRIUM**.
e) heat flows from **COLD TO HOT BODIES SPONTANEOUSLY** (at least at the macroscopic level) when they are in thermal contact (i.e., they are not thermally insulated from each other).

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005 qmult 01500 1 4 3 easy deducto-memory: Fundy Tides

315. The world's largest tidal range is:

a) of order 0.5 m in the deep oceans. b) 1 m in the Bay of Fundy. c) 12 m or more in the Bay of Fundy. d) 0.1 m or less in the Bay of Fundy. e) 12 m or more in Lake Erie.

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005 qmult 01510 1 4 1 easy deducto-memory: lake tides

316. Compared to ocean coastal tides, small lake coastal tides are usually:

a) unnoticeably small. b) large. c) about the same. d) slightly smaller, but quite noticeable. e) much larger.

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005 qmult 01600 1 4 3 easy deducto-memory: tides discussed

317. The tides (the terrestrial tides that is) are

a) the periodic rise and fall of the waters of the **LAKES AND STREAMS** with a primary period of about **12 HOURS, 25 MINUTES**. The tides are caused by the tidal currents which in turn are caused by the tidal forces of **PRIMARILY THE MOON** and **SECONDARILY THE SUN**.

b) the periodic rise and fall of the waters of the **OCEANS AND THEIR INLETS** and all waters bodies to some degree (sometimes minute) with a primary period of about **2 HOURS, 25 MINUTES**. The tides are caused by the tidal currents which in turn are caused by the tidal forces of **PRIMARILY THE SUN** and **SECONDARILY THE MOON**.

c) the periodic rise and fall of the waters of the **OCEANS AND THEIR INLETS** and all waters bodies to some degree (sometimes minute) with a primary period of about **12 HOURS, 25 MINUTES**. The tides are caused by the tidal currents which in turn are caused by the tidal forces of **PRIMARILY THE MOON** and **SECONDARILY THE SUN**.

d) the periodic rise and fall of the waters of the **OCEANS AND THEIR INLETS** and all waters bodies to some degree (sometimes minute) with a primary period of about **2 HOURS, 25 MINUTES**. The tides are caused by the tidal currents which in turn are caused by the tidal forces of **PRIMARILY THE MOON** and **SECONDARILY THE SUN**.

e) the periodic rise and fall of the waters of the **OCEANS AND THEIR INLETS** and all waters bodies to some degree (sometimes minute) with a primary period of about **29.531 DAYS**. The tides are caused by the tidal currents which in turn are caused by the tidal forces of **PRIMARILY THE SUN** and **SECONDARILY THE MOON**.

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005 qmult 01700 3 5 4 tough thinking: tides and tidal locking: defective

Extra keywords: The answers still have to be fixed for this defective question.

318. Imagine that there were no continents and the Earth's solid surface was a frictionless, smooth, perfectly spherical surface covered by a world ocean. Also imagine that solar tidal effects can be ignore and that only lunar tidal effects occur. In this case, the tidal bulges of the Earth's ocean's would be locked tightly on the Earth-Moon line, and to first order there would be no internal currents: i.e., the world ocean would be in internal equilibrium and tidally locked to the Moon. On the other hand, the whole solid Earth would slip eastward under the world ocean very rapidly executing the Earth's daily motion. For simplicity imagine that the Moon orbits in the equatorial plane of the Earth. (It doesn't, of course, which is another complication for real tides.)

What is the relative speed (i.e., the high-sea tidal current) between solid Earth and world ocean at the equator in kilometers per hour? Remember the Moon and therefore the tidal bulges move eastward with a mean period relative to the fixed stars of 27.3 days and the Earth moves eastward relative to the fixed stars with a period of 86164.0906 s.

Hint: Calculate the equatorial velocity of the solid Earth and the tidal bulges relative to the fixed stars and subtract. Recall the length of the equator is $2\pi R_\oplus^{\rm Eq}$, where $R_\oplus^{\rm Eq} = 6378.136\,{\rm km}$.

Now in the real case, ships at sea do not get hurled against the continents at speeds like one just calculated. Why not?

a) $1000\,{\rm km\,hr^{-1}}$.

b) $1613\,{\rm km\,hr^{-1}}$.

c) $1613\,{\rm km\,hr^{-1}}$. Actually, the oceans tend to get dragged along with the solid Earth by viscous (fluid frictional) forces that act between the Earth surface and water and between layers of water. This slows down the high-sea tidal currents to of order a few kilometers per hour. The continents have no effect on the tidal current.

d) $1613\,{\rm km\,hr^{-1}}$. Actually, the oceans tend to get dragged with the solid Earth by viscous (fluid frictional) forces that act between the Earth surface and water and between layers of water, and by continent and shallow ocean barriers to free flow. This slows down the high-sea tidal currents to of order a few kilometers per hour.

e) $813\,{\rm km\,hr^{-1}}$. Actually, the oceans tend to get dragged along with the solid Earth by viscous (fluid frictional) forces that act between the Earth surface and water and between layers of water. This slows down the high-sea tidal currents to of order a few kilometers per hour. The continents have **NO** effect on the tidal current.

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005 qmult 01800 2 5 1 moderate thinking: leap seconds

319. Currently, the Moon's tidal effect on the Earth (principally through the frictional force of the tides on the Earth's seabeds) is increasing the Earth's solar day by about 0.0014 seconds per century averaged over many centuries. The standard 24 hour day we use with precisely defined seconds (set by atomic clocks) was in fact close to being exactly a solar day **circa year 1820**. Currently, (i.e., circa year 2000) the solar day is about 86400.002 s. In order to keep the atomic-clock-generated time we actually use synchronized with solar time, leap seconds have to be added periodically to the atomic-clock-generated time. About how often would this be at the present time? **HINTS:** You could try checking out some course links, although the calculation is trivial actually. You could also just ask yourself a simpler question—if my watch runs a second fast per day, how many days will it be before it is one minute ahead of standard time?—and see if that helps.

   a) About every 500 days. b) About every 365 days. c) About every 50,000 years.
   d) About every month. e) About every day.

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005 qmult 01900 3 5 2 tough thinking: leap seconds in 2100 CE

320. Currently, the Moon's tidal effect on the Earth (principally through the frictional force of the tides on the Earth's seabeds) is increasing the Earth's solar day by about 0.0014 seconds per century averaged over many centuries. The standard 24 hour day we use with precisely defined seconds (set by atomic clocks) was in fact close to being a solar day **circa year 1820**. In order to keep the atomic-clock-generated time we actually use synchronized with solar time, leap seconds have to be added periodically to the atomic-clock-generated time. About how often would this have to be done **circa year 2100**? **HINTS:** The calculation is trivial actually. You could also just ask yourself a simpler question—if my watch runs a second fast per day, how many days will it be before it is one minute ahead of standard time?—and see if that helps.

   a) About every 500 days. b) About every 250 days. c) About every 50,000 years.
   d) About every month. e) About every day.

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005 qmult 02000 1 3 4 easy math: increasing Earth-Moon distance

321. The mean Earth-Moon distance is 3.844×10^{10} cm. Currently tidal interaction is increasing this distance by 3 cm/yr as we know from bouncing laser beams off reflectors on the Moon left by the Apollo missions. Assuming that the rate of increase is constant (which is actually unlikely), how long until the mean Earth-Moon distance is twice its current value?

   a) 3.844×10^{10} s. b) 3.844×10^{10} yr. c) 1.281×10^{10} s. d) 1.281×10^{10} yr.
   e) 400 yr.

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005 qmult 02100 1 4 1 easy deducto-memory: synchronous tidal locking

322. Synchronously tidally locked to an orbital companion usually means:

   a) that a body has an average rotation period that to a high accuracy **EQUALS** its average revolution period about that orbital companion and that this situation was brought about by the **COMPANION'S** tidal force.
   b) that a body has an average rotation period that to a high accuracy **EQUALS TWICE** its average revolution period about that orbital companion and that this situation was brought about by the **COMPANION'S** tidal force.
   c) that a body has an average rotation period that to a high accuracy **EQUALS TWICE** its average revolution period about that orbital companion and that this situation was brought about by the **BODY'S OWN** tidal force.

d) that a body has an average rotation period that to a high accuracy **EQUALS** its average revolution period about that orbital companion and that this situation was brought about by the **BODY'S OWN** tidal force.
e) that no tidal force is present.

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005 qmult 02200 3 5 5 easy deducto-memory: tidal locking: defective
Extra keywords: This question may be too cumbersome.

323. Tidally locked means:

a) that the gates on dykes are closed.
b) that a body has a rotation period that is the same to high accuracy (and on average) as its period of revolution about an orbital companion. Tidal locking is just an accident of the initial conditions of the body-companion formation. Tidal locking can never be predicted practically speaking.
c) that a body has a rotation period that is the same to high accuracy (and on average) as its period of revolution about an orbital companion. Tidal locking occurs in a rather complex manner. In an unlocked situation, the tidal bulges are dragged a bit ahead if the rotation rate exceeds the revolution rate (**case 1**) or lag a bit behind in the opposite case (**case 2**). The tidal force of alignment is a bit stronger on the bulges (tidal force increases with distance from the center of the body) and therefore tends decelerate the body in **case 1**, **but can do nothing for the body** in **case 2**. The lost rotational energy of the body in **case 1** can go into the orbital motion. In addition, there is a continual tidal deformation of the body due to the tidal force continually trying to create tidal bulges along the body-companion line and the body continually rotating these bulges off of that line. The continual deformation causes rotational energy to be lost to heat in the body: i.e., resistive forces (i.e., frictional or viscous forces) in the body dissipate the bulk energy of layers sliding over layers. This continual deformation and dissipation continues until tidal locking is reached (i.e., a state of tidal equilibrium) where the continual deformation and dissipation is quelled. Obviously dissipation of rotational energy into heat speeds the progress toward tidal locking in **case 1**. In **case 2**, where no tidal locking is possible, the dissipation is perpetual. In **case 1** whatever a body's original rotation rate tidal forces will **always** effect tidal locking sooner or later.
d) that a body has a rotation period that is the same to high accuracy (and on average) as its period of revolution about an orbital companion. Tidal locking occurs in a rather complex manner. In an unlocked situation, the tidal bulges are dragged a bit ahead if the rotation rate exceeds the revolution rate (**case 1**) or lag a bit behind in the opposite case (**case 2**). The tidal force of alignment is a bit stronger on the bulges (tidal force increases with distance from the center of the body) and therefore tends decelerate (**case 1**) or accelerate (**case 2**) the body. The lost or gained rotational energy of the body can go into or come at the expense of the orbital motion. In addition, there is a continual tidal deformation of the body due to the tidal force continually trying to create tidal bulges along the body-companion line and the body continually rotating these bulges off of that line. The continual deformation causes rotational energy to be lost to heat in the body: i.e., resistive forces (i.e., frictional or viscous forces) in the body dissipate the bulk energy of layers sliding over layers. This continual deformation and dissipation continues until tidal locking is reached (i.e., a state of tidal equilibrium) where the continual deformation and dissipation is quelled. Obviously dissipation of rotational energy into heat speeds the progress toward tidal locking in **case 1** and slows it in **case 2**. Whatever a body's original rotation rate (slower or faster than the rotational rate), tidal forces will **always** effect tidal locking sooner or later.
e) that a body has a rotation period that is the same to high accuracy (and on average) as its period of revolution about that orbital companion. Tidal locking occurs in a rather complex manner. In an unlocked situation, the tidal bulges are dragged a bit ahead if the rotation rate exceeds the revolution rate (**case 1**) or lag a bit behind in the opposite case

(**case 2**). The tidal force of alignment is a bit stronger on the bulges (tidal force increases with distance from the center of the body) and therefore tends decelerate (**case 1**) or accelerate (**case 2**) the body. The lost or gained rotational energy of the body can go into or come at the expense of the orbital motion. In addition, there is a continual tidal deformation of the body due to the tidal force continually trying to create tidal bulges along the body-companion line and the body continually rotating these bulges off of that line. The continual deformation causes rotational energy to be lost to heat in the body: i.e., resistive forces (i.e., frictional or viscous forces) in the body dissipate the bulk energy of layers sliding over layers. This continual deformation and dissipation continues until tidal locking is reached (i.e., a state of tidal equilibrium) where the continual deformation and dissipation is quelled. Obviously dissipation of rotational energy into heat speeds the progress toward tidal locking in **case 1** and slows it in **case 2**. Whatever a body's original rotation rate (slower or faster than the rotational rate), tidal forces try to effect tidal locking. Of course, tidal locking **may never occur** if the tidal forces are too weak to effect it in the lifetime of the system or if some other weird orbital effect supervenes.

Chapt. 6 Light and Telescopes

Multiple-Choice Problems

006 qmult 00100 1 4 3 easy deducto-memory: What light does for nature

324. "Let's play *Jeopardy*! For \$100, the answer is: It is fastest way nature has to convey information and energy relative to local inertial frames."

What is ____________, Alex?

a) sound b) conduction c) electromagnetic radiation d) seismic waves
e) convection

---

006 qmult 00110 1 1 3 easy memory: light is a wave phenomenon

325. Light is a ____________ that requires ____________.

a) not wave phenomenon; no medium b) wave phenomenon; a medium
c) wave phenomenon; no medium d) not wave phenomenon; a medium
e) particle; a medium

---

006 qmult 00120 1 1 4 easy memory: standing waves on a string

326. Standing waves on a string of length L with fixed ends must consist of an integral number of half wavelengths n (i.e., antinodes n): thus $L = n(\lambda/2)$. In musical terms, n is the harmonic number. What is the wavelength formula and, given the general frequency formula $f\lambda = v_{\rm phase}$, what is the frequency formula?

a) $\lambda = 2L/n$; $f = n[v_{\rm phase}(2L)]$. b) $\lambda = 2Ln$; $f = n[v_{\rm phase}/(2L)]$.
c) $\lambda = 2Ln$; $f = n[v_{\rm phase}(2L)]$. d) $\lambda = 2L/n$; $f = n[v_{\rm phase}/(2L)]$.
e) $\lambda = 2Ln^2$; $f = n[v_{\rm phase}/(2L)]$.

---

006 qmult 00150 1 1 2 easy memory: wave-particle duality

327. Quantum mechanics dictates that all microscopic particles have both a particle and a wave nature. This rule is called the ____________.

a) wave-particle unity b) wave-particle duality c) wave-particle triality
d) wave-particle multiplicity e) wave-particle basis

---

006 qmult 00160 1 1 2 easy memory: wave function nature

328. The nature of the wave function (with conventional symbol Ψ) in quantum mechanics has been debated ever since quantum mechanics was discovered circa 1925–1926. One view is that it is just ____________ like the probability for getting any face of a dice cube. The other view is that it is a real physical thing from which one can calculate the density of existence of a particle at any point in space. The particle existing in a superposition of positions. The latter view seems to be the majority view and your instructor adopts it. Of course, maybe the wave function is somewhere in between. Which view is right is a fundamentally important question. However, for all practical purposes (so far), it does not seem to matter which is right. Quantum mechanics is never wrong—there are mistakes in calculations and in experiments, but **NO** anomaly has ever resisted attack. Quantum mechanics is the best verified of all physical theories and your cell phone would **NOT** work if quantum mechanics did **NOT** work the way we think it does.

a) physical b) informational c) loaded d) unreal e) both real and unreal

---

006 qmult 00200 1 4 3 easy deducto-memory: emr powers the biosphere

329. Electromagnetic radiation from the Sun is important, for among many other things, providing almost all of the energy for ____________.

What is ____________, Alex?

a) volcanoes b) night c) the biosphere d) plate tectonics e) earthquakes

---

006 qmult 00310 1 4 4 easy deducto-memory: speed of light

330. "Let's play *Jeopardy*! For $100, the answer is: In modern physics, it is the highest physical speed: i.e., the highest speed at which information can propagate."

What is the speed of ____________, Alex?

a) sound b) thought c) rumor d) light in vacuum
e) rumor in an information vacuum

---

006 qmult 00312 1 4 1 easy deducto-memory: fireworks sound and flash

331. At fireworks displays, the explosions produce a light flash and sounds.

a) The flash is seen before the sound is heard.
b) The sound is heard before the flash is seen.
c) Sound and flash come simultaneously.
d) The sound is seen before the flash is heard.
e) Neither effect is noticed by the spectators.

---

006 qmult 00330 2 1 2 easy memory: electromagnetic radiation and ether

332. Electromagnetic radiation (EMR) is a:

a) **WAVE PHENOMENON**. The EM waves, however, are **NOT EXCITATIONS OF A MEDIUM** as in most other familiar wave phenomena: e.g., sound waves are excitations of air; water waves of water. The EM waves are just self-propagating electromagnetic fields: any description of them as oscillations in a medium has turned out to be physically superfluous: i.e., adds nothing to physical understanding. Of course, EM waves can propagate through media such as air, water, glass, etc. The speed of light **IN VACUUM** is $2.99792458 \times 10^{10}$ cm/s $\approx 3 \times 10^{10}$ cm/s. In matter, the speed of light is always **HIGHER**.
b) **WAVE PHENOMENON**. The EM waves, however, are **NOT EXCITATIONS OF A MEDIUM** as in most other familiar wave phenomena: e.g., sound waves are excitations of air; water waves of water. The EM waves are just self-propagating electromagnetic fields: any description of them as oscillations in a medium has turned out to be physically superfluous: i.e., adds nothing to physical understanding. Of course, EM waves can propagate through media such as air, water, glass, etc. The speed of light **IN VACUUM** is $2.99792458 \times 10^{10}$ cm/s $\approx 3 \times 10^{10}$ cm/s. In matter, the speed of light is always **LOWER**.
c) **WAVE PHENOMENON**. The EM waves are excitations of the **ETHER**. The ether permeates all space and has no other effects than as the medium of the EM propagation. Of course, EM waves at the same time as propagating in the ether can also propagate through media such as air, water, glass, etc. The speed of light **IN VACUUM** is $2.99792458 \times 10^{10}$ cm/s $\approx 3 \times 10^{10}$ cm/s. In matter, the speed of light is always **LOWER**.
d) **WAVE PHENOMENON**. The EM waves are excitations of the **ETHER**. The ether permeates all space and has no other effects than as the medium of the EM propagation. Of course, EM waves at the same time as propagating in the ether can also propagate through media such as air, water, glass, etc. The speed of light **IN VACUUM** is $2.99792458 \times 10^{10}$ cm/s $\approx 3 \times 10^{10}$ cm/s. In matter, the speed of light is always **HIGHER**.
e) **PARTICLE PHENOMENON** only.

---

006 qmult 00750 1 3 1 easy math: wavelength calculation

333. AM radio typically broadcasts at about $1\,\mathrm{MHz} = 10^6$ cycles per second. What is the **APPROXIMATE** wavelength of this radiation? (Just use the vacuum speed of light $c = 2.99792458 \times 10^{10}\,\mathrm{cm/s}$ for the calculation: it is good enough for the present purpose.)

a) $3 \times 10^4\,\mathrm{cm} = 300\,\mathrm{m}$. b) $1 \times 10^4\,\mathrm{cm} = 100\,\mathrm{m}$. c) $3 \times 10^{-4}\,\mathrm{cm}$. d) $3 \times 10^4\,\mathrm{m}$. e) $3 \times 10^2\,\mathrm{cm} = 3\,\mathrm{m}$.

---

006 qmult 00900 2 1 3 moderate memory: EMR spectrum

334. The electromagnetic spectrum is:

a) the distribution of electromagnetic radiation with respect to temperature.
b) the spectrum of radiation emitted by a non-reflecting (i.e., blackbody) object at a uniform temperature.
c) the entire wavelength range of electromagnetic radiation: i.e., the electromagnetic radiation range from zero to infinite wavelength, not counting the limit end points themselves.
d) the magnetic field of the Sun.
e) independent of wavelength.

---

006 qmult 00910 2 1 4 moderate memory: EMR does not include protons

335. The electromagnetic spectrum includes all forms of electromagnetic radiation. Which of the following is **NOT** a form of electromagnetic radiation?

a) gamma-rays b) visible light c) radio waves d) protons e) ultraviolet light

---

006 qmult 00950 1 1 5 easy memory: visible light

Extra keywords: CK-90-1

336. ________________ is a form of electromagnetic radiation.

a) Sound b) Wien c) Doppler d) The atom e) Visible light

---

006 qmult 00960 1 1 5 easy memory: visible light spectrum, visible band

337. Visible light is conventionally divided into:

a) violet, blue, green, yellow, orange, radio.
b) X-ray, violet, blue green, yellow, orange, tangerine, red.
c) Gamma-ray, X-ray, ultraviolet, visible, infrared, microwave, radio.
d) mauve, navy, forest lawn, goldenrod, tamarind, cerise.
e) violet, blue, green, yellow, orange, red.

---

006 qmult 00962 2 1 3 moderate memory: visible light range

Extra keywords: CK-91-key-3

338. The wavelength range of visible light is about:

a) 1–20 cm. b) 0.1–10 nm. c) 400–700 nm. d) 700–1000 nm. e) 0.700–1000 μm.

---

006 qmult 00970 1 1 4 easy memory: opaque bands

Extra keywords: CK-92-14

339. Astronomers must observe the gamma-ray, X-ray, and most of the ultraviolet bands from space since the Earth's atmosphere is quite ________________ in those bands.

a) transparent b) window-like c) hot d) opaque e) cold

---

006 qmult 00972 1 4 5 easy deducto-memory: light windows on Moon

340. The Moon has almost **NO** atmosphere. In what wavelength bands could an astronomer observe space from the Moon?

a) In the ultraviolet and X-ray only. b) In no bands at all. c) In nearly no bands at all. d) In practically all bands, but only when the Moon is gibbous. e) In practically all bands.

---

006 qmult 00990 1 4 4 yasy deducto-memory: human eye wavelength range

341. The Earth's atmosphere has various windows in which it is relatively transparent to electromagnetic radiation. The visible window extends from the very near ultraviolet to the near infrared. The intensity maximum of the solar spectrum actually falls in this window. Now the human eye is sensitive to electromagnetic radiation in the wavelength band $\sim$ 400–700 nm which falls in the visible window and which spans the maximum intensity region of the solar spectrum. Why might the human-eye sensitivity wavelength region be located where it is?

   a) Well, the visible window is round and so is the eye.
   b) The eye may have evolved to be sensitive to the form of radiation that was **LEAST ABUNDANT** on the Earth's surface. In this way radio emission for communication would be unnecessary, except during geomagnetic storms. Finally, the conclusion has to be that X-rays are not ordinarily visible.
   c) The eye may have evolved to be sensitive to a form of radiation that was **ABUNDANT** on the Earth's surface thereby making a **BAD USE** of the electromagnetic radiation resource.
   d) The eye may have evolved to be sensitive to a form of radiation that was **ABUNDANT** on the Earth's surface thereby making a **GOOD USE** of the electromagnetic radiation resource.
   e) The eye may have evolved to be sensitive to a form of radiation that was **ABUNDANT** on the Earth's surface thereby making use of **RADIO WAVES**.

---

006 qmult 00992 2 4 2 moderate deducto-memory: nocturnal animals

342. Why do nocturnal animals usually have large pupils in their eyes?

   a) For better vision in **DAY** conditions (when light levels are high) they have evolved large pupils (which are the apertures of the eyes). Light gathering power is proportional to the **SQUARE OF APERTURE DIAMETER**.
   b) For better vision in **NIGHT** conditions (when light levels are low), they have evolved large pupils (which are the apertures of the eyes). Light gathering power is proportional to the **SQUARE OF APERTURE DIAMETER**.
   c) For better vision in **NIGHT** conditions (when light levels are low), they have evolved large pupils (which are the apertures of the eyes). Light gathering power is proportional to the **APERTURE DIAMETER**.
   d) For better vision in **NIGHT** conditions (when light levels are low), they have evolved large pupils (which are the apertures of the eyes). Light gathering power is proportional to the **4TH POWER OF APERTURE DIAMETER**.
   e) For better vision in **NIGHT** conditions (when light levels are low), they have evolved large pupils (which are the apertures of the eyes). The large pupils allow them to see in the **RADIO**. All animals can actually see in the radio, but diffraction effects with small apertures make radio images too blurry to notice ordinarily.

---

006 qmult 01040 1 1 4 easy memory: spectrometer defined

343. Spectrometers (AKA spectroscopes):

   a) use prisms or photographic plates to dispers) light into spectra.
   b) are devices for measuring magnetic fields.
   c) are the same as spectra.
   d) use prisms or diffraction gratings to disperse light into spectra.
   e) are the same as phonographs.

---

006 qmult 01100 1 1 5 easy memory: particle of light is called a photon

Extra keywords: CK-91-photon

344. The quantum or particle of light is called a/an:

a) proton. b) electron. c) quarkon. d) lighton. e) photon.

---

006 qmult 01102 2 4 3 moderate deducto-memory: waves and photons

345. Electromagnetic radiation (EMR) is:

a) a wave phenomenon. The propagation speed is that of **SOUND**.
b) a wave phenomenon. However, EMR also acts as if it came in packets called **PROTONS** (i.e., pRotons).
c) a wave phenomenon. However, EMR also acts as if it came in packets called **PHOTONS** (i.e., pHotons).
d) a wave phenomenon. However, EMR also acts as if it came in packets called **ELECTRONS** (i.e., eLectrons).
e) a particle phenomenon.

---

006 qmult 01104 1 3 1 easy math: photon energy calculation

346. The particle of light is the photon. The energy of an individual photon is inversely proportional to the wavelength of the light. The formula for photon energy is

$$E = \frac{hc}{\lambda} ,$$

where h is a universal constant called Planck's constant, c is the vacuum speed of light, and λ is wavelength. If the wavelength of light is changed by a multiplicative factor of 3, the energy of its photons is changed by a multiplicative factor of:

a) 1/3. b) 3. c) 9. d) 1/9. e) 1 (i.e., it is unchanged).

---

006 qmult 01150 2 1 5 moderate memory: most dangerous gamma rays
Extra keywords: CK-90-2

347. What is the form of electromagnetic radiation that is usually most dangerous for life?

a) ultraviolet light. b) protons. c) radio waves. d) visible light.
e) gamma-rays.

---

006 qmult 02000 1 1 4 easy memory: two basic kinds of telescopes

348. The two basic kinds of telescopes are:

a) reflectors and diffractors. b) refractors and diffractors. c) spoilers and toilers.
d) reflectors and refractors. e) speculators and diffractors.

---

006 qmult 02100 1 1 4 easy memory: objective of a reflector

349. The objective of a reflector is a:

a) lens. b) spectrograph. c) CCD. d) mirror. e) photographic plate.

---

006 qmult 02200 2 5 1 moderate thinking: light gathering power

350. What is the ratio of the light gathering power of a 10-meter diameter telescope to that of a 1-meter diameter telescope?

a) 100. b) 10. c) 0.02. d) 20. e) 100 meters.

---

006 qmult 02300 2 4 3 moderate deducto-memory: building an observatory

351. Having made your fortune in the late, great Las Vegas boom of the tail end of the 20th century, you decide that you must benefit humanity. Pyramids being passé, you decide to build a new, state-of-the-art telescope for the exclusive use of UNLV (after remembering all the great times you had there). Which seems to be the most plausible plan?

a) The telescope should be put on the Strip in order to be maximally accessible to the astronomy faculty and tourists on public openings. The objective needs to be a very large reflector in order to be competitive with other modern telescopes. Resolution of 0.5° is adequate. The whole project can be done for less than the cost of the Bellagio.
b) The telescope should be put near Seattle. More than 200 nights of cloud cover and rain is no problem. The objective needs to be a very large reflector in order to be competitive with other modern telescopes. Without modern advanced optics resolution is limited by atmospheric conditions anyway. Therefore the optical quality need not guarantee more than 0.5° of resolution.
c) The telescope should be near the top of Mauna Kea in Hawaii at about altitude 4200 meters. The objective needs to be a very large reflector in order to be competitive with other modern telescopes. The original Keck telescope was built for 70 million dollars (officially speaking) and that is well within your price range even allowing for some small inflation that got passed Alan Greenspan. The air's a bit thin, but with some acclimation time astronomers can work there. The Mauna Kea volcano hasn't erupted in 4,500 years, and so the likelihood of a major insurance claim isn't too high. (If there is an eruption, no doubt a great IMAX film could be produced.) The extremely dry, still conditions on Mauna Kea guarantee that atmospheric resolution is as good as it gets. Infrared astronomy is also relatively good because of the high and dry conditions: water vapor being a major absorber of infrared radiation. The cost of sending UNLV astronomers to Mauna Kea for two-week observing runs can probably covered by some UNLV or Nevada matching funds. Of course, some observing time will have to be allocated to **CHILEAN ASTRONOMERS** since they own the mountain.
d) The telescope should be near the top of Mauna Kea in Hawaii at about altitude 4200 meters. The objective needs to be a very large reflector in order to be competitive with other modern telescopes. The original Keck telescope was built for 70 million dollars (officially speaking) and that is well within your price range even allowing for some small inflation that got passed Alan Greenspan. The air's a bit thin, but with some acclimation time astronomers can work there. The Mauna Kea volcano hasn't erupted in 4,500 years, and so the likelihood of a major insurance claim isn't too high. (If there is an eruption, no doubt a great IMAX film could be produced.) The extremely dry, still conditions on Mauna Kea guarantee that atmospheric resolution is as good as it gets. Infrared astronomy is also relatively good because of the high and dry conditions: water vapor being a major absorber of infrared radiation. The cost of sending UNLV astronomers to Mauna Kea for two-week observing runs can probably covered by some UNLV or Nevada matching funds. Of course, some observing time will have to be allocated to **UNIVERSITY OF HAWAII ASTRONOMERS** since Hawaii owns the mountain.
e) The telescope should be near the top of Mauna Kea in Hawaii at about altitude 4200 meters. Ultraviolet astronomy is possible there because it is above the ozone layer which reaches above altitude 40 km. Furthermore, land in Hawaii is dirt cheap. Hawaiians are eager to sell out before the New Guinea brown tree snake invades.

---

006 qmult 02400 2 1 2 moderate memory: eyepiece of a telescope

352. The eyepiece of a telescope:

a) is only really needed for visual astronomy, but it does add light gathering power and improve the resolution.
b) is only really needed for visual astronomy and provides magnification.
c) adds light gathering power.
d) is purely decorative.
e) improves resolution.

---

006 qmult 02600 2 4 4 moderate deducto-memory: CCDs

353. CCDs are

a) just photographic plates.
b) charge-coupled devices. They are digital electronic sound detecting devices that take an image and record the intensity. A CCD is divided into up to millions of sound detecting pixies.
c) charge-coupled devices. They are crude spectrographs that havn't been used since the 1950's. They were, however, essential for many important older astronomical discoveries.
d) charge-coupled devices. They are digital electronic light detecting devices that take an image and record the intensity. A CCD is divided into up to millions of light detecting pixels.
e) charge-coupled devices. They had a brief moment of glory in the 1980's, but have since been replaced by photonic devices that don't rely on electrons at all.

Chapt. 7 Spectra

Multiple-Choice Problems

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007 qmult 00150 1 4 1 easy deducto-memory: heat energy defined

354. Internal energy or heat energy is:

   a) statistically distributed forms of the other kinds of energy: most notably microscopic kinetic energy, microscopic potential energy, and electromagnetic radiation.
   b) temperature.
   c) the opposite of cold.
   d) the microscopic cause of friction.
   e) an invisible fluid that causes temperature.

---

007 qmult 00160 1 1 3 easy memory: heat energy to macroscopic motion

355. The heat energy of a fluid in heat engine (e.g., steam engines and internal combustion engines) is usually transformed into macroscopic energy (e.g., macroscopic kinetic, potential, and electrical energies) by means of the ____________ in a piston.

   a) Force b) elastic force c) pressure force d) given force e) relief force

---

007 qmult 00200 2 4 2 moderate deducto-memory: hot bodies radiate

356. Any body (including a cloud of dilute gas) at a nonzero temperature or range of temperatures will radiate (in addition to any reflected light):

   a) a pure line spectrum. b) electromagnetic radiation. c) only X-rays.
   d) a perfect blackbody spectrum. e) nothing at all.

---

007 qmult 00210 1 1 3 easy memory: blackbody spectrum and temperature 1

357. A solid, liquid, or dense gas at a uniform temperature (in addition to any reflected light) will:

   a) radiate a line spectrum.
   b) radiate a greybody spectrum.
   c) radiate a blackbody spectrum which is a fundamentally important spectrum whose shape depends only on the absolute (i.e., Kelvin scale) temperature of the radiating body.
   d) have a uniform color that depends only on the shape of the radiating body.
   e) radiate nothing.

---

007 qmult 00212 2 1 5 moderate memory: blackbody spectrum and temperature 2

358. A solid, liquid, or dense gas at a uniform temperature (in addition to any reflected light) will:

   a) radiate a line spectrum.
   b) radiate a greybody spectrum.
   c) radiate nothing.
   d) radiate a blackbody spectrum which is a fundamentally important spectrum whose shape depends on **NO PROPERTIES** of the radiating body.
   e) radiate a blackbody spectrum which is a fundamentally important spectrum whose shape depends **ONLY** on the absolute (i.e., Kelvin scale) temperature of the radiating body.

---

007 qmult 00350 1 3 1 easy math: using Wien's law for a star

359. Wien's law for blackbody spectra is

$$\lambda_{\mu\mathrm{m}}^{\max} = \frac{(2897.771955\ldots)\,\mu\mathrm{m\,K}}{T} \ .$$

Say one has a stellar spectrum with a maximum wavelength at $0.5\,\mu$m (i.e., 0.5 microns). What is the star's approximate photospheric temperature?

a) 6000 K. b) 600 K. c) 20000 K. d) 31416 K. e) 6000 nm.

---

007 qmult 00352 1 3 3 easy math: using Wien's law for a human

360. Wien's law for blackbody spectra is

$$\lambda_{\mu\mathrm{m}}^{\max} = \frac{(2897.771955\ldots)\,\mu\mathrm{m\,K}}{T} \ .$$

The average, healthy, resting human has a body temperature of about 310 K. Assuming the human radiates like a black body, what is the approximate wavelength of the peak of the black-body emission? About ________ microns which is ________ light.

a) 0.1; red b) 0.1; ultraviolet c) 10; infrared d) 10; red e) 3; red

---

007 qmult 00450 1 3 5 easy math: using Stefan-Boltzmann law
Extra keywords: CK-98,111-3

361. The total power per unit area (i.e., flux) radiated by a blackbody radiator is given by the Stefan-Boltzmann law

$$F = \sigma T^4 \ ,$$

where $\sigma = (5.670374419\ldots)\times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$ is the Stefan-Boltzmann constant in MKS units and T is absolute temperature in Kelvins. If temperature is changed by a multiplicative factor of 3, then flux F is changed by a multiplicative factor of:

a) 1/3. b) 3. c) 9. d) 27. e) 81.

---

007 qmult 00460 2 5 3 moderate thinking: Earth's blackbody temperature

362. A true blackbody absorbs all the electromagnetic radiation that hits it (i.e., it does not reflect any electromagnetic radiation) and has a uniform temperature. Let us treat the Earth as blackbody, except that it reflects that fraction of light that it actually does reflect. The light gathering surface area of the Earth is

$$\pi R_\oplus^2 \ ,$$

where $\pi = 3.14159265\ldots$ is pi, a pure number, and $R_\oplus$ is the Earth radius. The total light energy gathered per unit time by the Earth is thus

$$f(1-a)\pi R_\oplus^2 \ , \tag{1}$$

where $f = 1367.6$ watts per square meter is the mean solar constant and $(1-a) = 0.694$ is a factor accounting for the reflection of electromagnetic radiation from the Earth (Wikipedia: Earth: Bond albedo).

As a blackbody (except for the reflection correction), the Earth radiates a total energy per unit time of

$$A\sigma T^4 \ , \tag{2}$$

where

$$A = 4\pi R_\oplus^2$$

is the surface area of the Earth and σT^4 is the Stefan-Boltzmann law (i.e., the energy radiated per unit area per unit time by a blackbody). The constant $\sigma = 5.670373\times 10^{-8}$ in mks units.

Since the Earth is neither a net energy gainer or loser (at least not to an extent important for this problem), expression (1) must equal expression (2) to maintain a constant thermal energy content on Earth. Equating the expressions, we obtain:

$$f(1-a) = 4\sigma T^4$$

or

$$T = \left[\frac{f(1-a)}{4\sigma}\right]^{1/4} = 254\,\mathrm{K}\ .$$

This temperature is called the blackbody or effective temperature of the Earth.

a) At 254 K, the Earth would be way hotter than the boiling point of water. The reason the Earth isn't this hot is because the Earth is not actually a blackbody.
b) At 254 K, the Earth would be colder than the freezing point of water. The reason the Earth isn't this cold is because of the greenhouse **COOLING** effect.
c) At 254 K, the Earth would be colder than the freezing point of water. The reason the Earth isn't this cold is because of the greenhouse **HEATING** effect.
d) At 254 K, the Earth is at a comfortable temperature for life. Our simple analysis shows why life is possible on Earth. The same analysis for Venus and Mars would show why life as we know it would be unlikely there. Both Venus and Mars would be too cold. (Venus would be too cold despite being located closer to the Sun because of its high reflectivity.)
e) At 254 K, Mars is at a comfortable temperature for life. Nevertheless, life there seems unlikely.

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007 qmult 00510 1 1 3 easy memory: ion defined
Extra keywords: CK-110-ion

363. An ion is a:

a) synonym for an atom. b) neutral atom. c) charged atom. d) molecule.
e) proton.

---

007 qmult 00550 1 1 3 easy memory: spectral line spectrum
Extra keywords: CK-100,110

364. The line spectrum of an atom, ion, or molecule is:

a) the radiation emitted when the temperature of the atom, etc., goes over 10,000 K.
b) the radiation emitted when the temperature of the atom, etc., goes over 1000 K.
c) an almost unique identifier of the atom, ion, or molecule.
d) the radiation emitted when the temperature of the atom, etc., goes over 25,000 K.
e) never observed from astronomical bodies outside of Solar System.

---

007 qmult 00570 2 4 4 moderate deducto-memory: H-alpha line wavelength

365. The Hα line (AKA the H-alpha line), usually the strongest **VISIBLE** line of hydrogen, has a wavelength of 656 nm It is a/an ____________ line.

a) X-ray b) ultraviolet c) radio d) red e) red and blue

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007 qmult 00610 1 4 2 easy deducto-memory: photosphere defined 1
Extra keywords: CK-249,266, Sun-question

366. The layer of a star (e.g., the Sun) from which most of the emitted electromagnetic radiation comes is called the:

a) chromosphere. b) photosphere. c) hemisphere. d) hydrogen burning core.
e) corona.

---

007 qmult 00612 1 4 2 easy deducto-memory: photosphere defined 2

Extra keywords: Sun-question

367. "Let's play *Jeopardy*! For $100, the answer is: The layer of a star (e.g., the Sun) from which most of the escaping electromagnetic radiation comes."

What is the ____________, Alex?

a) nuclear-burning core b) photosphere c) chromosphere d) corona e) stellar wind

---

007 qmult 00650 3 1 2 tough memory: Sun's absorption line spectrum

368. The Sun emits a spectrum that is approximately a blackbody spectrum. It isn't exactly a blackbody spectrum because, among other reasons:

a) the photospheric emission forms over a range of temperatures and there is an **EMISSION LINE SPECTRUM** superimposed on the photospheric emission.
b) the photospheric emission forms over a range of temperatures and there is an **ABSORPTION LINE SPECTRUM** superimposed on the photospheric emission.
c) the photospheric emission forms at a single temperature.
d) the coronal emission is almost equal to the photospheric emission.
e) convective layer of the Sun is so huge: about 2/7 solar radii deep.

---

007 qmult 00728 1 1 5 easy memory: Doppler effect invariant quantity

369. There is a profound difference between the Doppler effect for waves in a medium (assumed at rest in an inertial frame) in the classical limit and the Doppler effect for electromagnetic radiation in a vacuum (as observed in a local inertial frame). One difference is the invariant as the observer moves. For the first case, the invariant is the wavelength of the wave and in the second case, it is the

a) frequency of the wave. b) motion of the source. c) direction of the wave. d) motion of the receiver. e) speed of light.

---

007 qmult 00730 1 1 1 easy memory: Doppler effect defined for light

370. The Doppler effect for light causes:

a) the wavelength of a wave phenomenon to change (or shift) when its **SOURCE AND RECEIVER** are moving with respect to each other along the source-receiver line.
b) the wavelength of a wave phenomenon to change (or shift) when its **SOURCE** (but **NEVER** its **RECEIVER**) is moving along the source-receiver line.
c) the wavelength of a wave phenomenon to change (or shift) when its **RECEIVER** (but **NEVER** its **SOURCE**) is moving along the source-receiver line.
d) the Sun to appear redder at sunset and sunrise than at midday.
e) the Sun to appear redder at midday than at sunset and sunrise.

---

007 qmult 00740 1 1 2 easy memory: redshift of receding source

371. A source of light is moving away from you, and thus the light is:

a) blueshifted. b) redshifted. c) greenshifted. d) yellowshifted. e) turquoiseshifted.

---

007 qmult 00750 2 4 1 moderate deducto-memory: Doppler shift

372. One light source is moving directly away from you; another light source is moving exactly perpendicular to your line of sight to it for the length of time of the observation: i.e., its moving on a **CIRCLE** centered on you.

a) The first source is Doppler shifted to the **RED** (i.e., to longer wavelength). The second source is **NOT** significantly Doppler shifted unless its velocity is not small compared to the vacuum speed of light.

b) The first source is Doppler shifted to the **BLUE** (i.e., to shorter wavelength). The second source is **NOT** significantly Doppler shifted unless its velocity is not small compared to the vacuum speed of light.
c) **NEITHER** source is Doppler shifted. There can only be a Doppler shift if the velocity is specified in the problem.
d) **BOTH** sources are Doppler shifted to the **RED** by about the same amounts.
e) **NEITHER** source is Doppler shifted. There can only be a Doppler shift when the source is approaching the receiver.

---

007 qmult 00760 3 5 5 tough thinking: Doppler effect and line spectra

373. The lines of atomic line spectra are not infinitely narrow in wavelength. There is a natural intrinsic width which is broadened by thermal and collisional effects. But let's ignore those effects for this question. How would an atomic line from a rapidly rotating star appear different from the same atomic line as measured in the laboratory?

a) The star line would be divided into three lines: a fast line, a slow line, and an intermediate line.
b) The star line would **NARROWER** due to the Doppler effect.
c) The star line would be expanded into a blackbody spectrum by the rotation.
d) The star line would be **BROADER** due to the Doppler effect. The part of the star moving toward the observer would broaden the line in the **LONG WAVELENGTH (REDWARD) DIRECTION**. The part of the star moving away from the observer would broaden the line in the **SHORT WAVELENGTH (BLUEWARD) DIRECTION**.
e) The star line would be **BROADER** due to the Doppler effect. The part of the star moving toward the observer would broaden the line in the **SHORT WAVELENGTH (BLUEWARD) DIRECTION**. The part of the star moving away from the observer would broaden the line in the **LONG WAVELENGTH (REDWARD) DIRECTION**.

Chapt. 8 The Sun

Multiple-Choice Problems

008 qmult 00100 1 5 5 easy thinking: Sun riddle
374. The Riddler strikes again:

> I am right red or unbearable gold,
> to my straight gaze, eyes flinch and fold,
> east bows at my paraded *levé,*
> I define—am—the essence of day,
> at noon, Inuit north and far Bedouin,
> but mutually me—I blister skin,
> shadows fear me—stay out of my path,
> and in the desert, all stands in my wrath.
>
> But—to the lazy rhythm of 3 pm time—
> I Earthward glide the ecliptic line,
> dying decently west, a ghost of late might,
> then before I'm quite gone, I cast my twilight.

a) Mars, Mars, it's got to be Mars.
b) The Moon—no wait—Venus.
c) Hamlet.
d) Sadi Carnot.
e) The Sun.

---

008 qmult 00200 1 4 3 easy deducto-memory: Sun diameter
375. The diameter of the Sun is about:

a) 1 Earth diameter. b) 30 Earth diameters. c) 109 Earth diameters. d) 1 astronomical unit. e) 1 light-year.

---

008 qmult 00220 1 4 4 easy deducto-memory: solar luminosity
Extra keywords: CK-262,266
376. The solar luminosity is $L_\odot$ is:

a) $100\,\mathrm{W}$. b) $1.496 \times 10^{11}\,\mathrm{m}$. c) $3.846 \times 10^{-26}\,\mathrm{W}$. d) $3.846 \times 10^{26}\,\mathrm{W}$. e) $6.9599 \times 10^{8}\,\mathrm{m}$.

---

008 qmult 00230 1 1 5 easy memory: Sun photosphere temperature
377. The temperature of the solar photosphere is about:

a) 300 K. b) 600 K. c) 273 K. d) 40000 K. e) 6000 K.

---

008 qmult 00240 2 4 2 moderate deducto-memory: Sun central temperature
378. The temperature at the **CENTER** of the Sun is about:

a) $16 \times 10^{6}\,\mathrm{K}$ as known from direct measurement. b) $16 \times 10^{6}\,\mathrm{K}$ as known from modeling. c) 273 K. d) 6000 K as known from modeling. e) 6000 K as known from direct measurement.

---

008 qmult 00250 1 4 4 easy deducto-memory: solar constant defined

379. "Let's play *Jeopardy*! For $100, the answer is: It is the electromagnetic radiation energy per unit time per unit area from the Sun at 1 astronomical unit from the Sun."

What is the solar ____________, Alex?

a) wind b) variable c) eclipse d) constant e) Sun

---

008 qmult 00252 1 1 5 easy memory: solar constant value

380. The solar constant (i.e., the electromagnetic radiation energy per unit time per unit area from the Sun at 1 astronomical unit from the Sun) is:

a) $136.76\,\mathrm{W/m^2}$. b) $1000.00\,\mathrm{W/m^2}$. c) 0. d) $-1367.6\,\mathrm{W/m^2}$. e) $1367.6\,\mathrm{W/m^2}$.

---

008 qmult 00256 2 5 5 moderate thinking: solar constant and light bulbs

381. The solar constant (i.e., the electromagnetic radiation energy per unit time per unit area from the Sun at 1 astronomical unit from the Sun) is about 1367.6 watts per square meter. If you were at 1 astronomical unit from the Sun in space and had a square kilometer of solar panels (of 100 % efficiency), how many 100 watt light bulbs could you run on solar power?

a) 100 watts. b) 1000. c) 1367.6. d) 1.3676×10^{11}. e) 1.3676×10^{7}.

---

008 qmult 00300 1 4 5 easy deducto-memory: interior of Sun specified

Extra keywords: CK-263,267-4

382. "Let's play *Jeopardy*! For $100, the answer is: This astrophysical body has three main interior layers: 1) a core (in which thermonuclear reactions occur) that extents out to about 25 % of the body's radius; 2) a radiative transfer zone which extends **OUT** to about 71 % of the body's radius; 3) a convective zone that extends **FROM** about 71 % of the body's radius to the body's surface."

What is ____________, Alex.

a) the Moon b) Venus c) the Milky Way d) the Earth e) the Sun

---

008 qmult 00310 1 4 3 easy deducto-memory: radiative transfer in Sun

383. Out to about 71 % of the Sun's radius, the dominant energy transfer mechanism is:

a) electron conduction. b) neutrino transfer. c) radiative transfer (i.e., transfer by electromagnetic radiation). d) convection. e) an explosive shock wave.

---

008 qmult 00410 1 1 5 easy memory: solar photosphere explained

Extra keywords: this question is specialized for the Sun

384. Why can't we see deeper into the Sun than the photosphere?

a) Line spectra overlap too severely at deeper layers.
b) The question is absurd. We see right through the photosphere to the bottom of the convection layer.
c) The question is absurd. Solar flares prevent any observation deeper than the chromosphere.
d) Radiation from deeper layers escapes too easily.
e) Radiation from deeper layers is absorbed before it can escape the Sun.

---

008 qmult 00450 2 1 3 moderate memory: solar granule

385. A granule is:

a) a kind of cereal.
b) a grain of dust.

c) the top of a rising current of **HOT** gas in the Sun. Granules are seen in the solar photosphere. They last about 10 minutes and then lose their identity with their surroundings. The risen gas **COOLS** and then sinks.
d) the top of a rising current of **COLD** gas in the Sun. Granules are seen in the solar photosphere. They last about 10 minutes and then lose their identity with their surroundings. The risen gas **HEATS** up and then sinks.
e) a solar flare by another name.

---

008 qmult 00510 1 4 4 easy deducto-memory: five Sun outer layers 1

386. The five outermost layers of the Sun (defining layers of the Sun generously) can be labeled:

a) convection zone, photon, chromosome, coronation street, and solar sail.
b) convection zone, photosphere, chromosphere, corona, and solar sail.
c) convection zone, photosphere, chromosphere, corona, and helio zone.
d) convection zone, photosphere, chromosphere, corona, and solar wind.
e) construction zone, photosphere, chromosphere, corona, and glabron.

---

008 qmult 00512 1 4 1 easy deducto-memory: five Sun outer layers 2

387. The five outermost layers of the Sun (defining layers of the Sun generously) can be labeled:

a) convection layer, photosphere, chromosphere, corona, and solar wind.
b) convection layer, photosphere, chromosphere, and corona.
c) convection layer, photosphere, chromosphere, corona, and paloma.
d) convection layer, ionosphere, chromosphere, corona, and solar wind.
e) convection layer, photosphere, chromosphere, corona, and the Asteroid Belt.

---

008 qmult 00514 1 4 1 easy deducto-memory: two of five Sun outer layers 3

388. Two of the five outermost layers of the Sun (defining layers of the Sun generously) are:

a) photosphere and chromosphere. b) carnation and corona. c) corona and paloma. d) rio and sands. e) chromosphere and Asteroid Belt.

---

008 qmult 00710 1 1 3 easy memory: corona visible to naked eye

389. The corona of the Sun is only visible to the naked eye:

a) at sunset. b) when the Moon is a crescent in the western sky. c) during total solar eclipses. d) during partial solar eclipses. e) when the Sun is below the horizon.

---

008 qmult 00750 2 3 3 moderate math: corona extent and Mercury

390. The solar corona has no sharp boundary, but it has been traced out to about 30 solar radii. The Sun's equatorial radius is 6.96342×10^{8} m and the astronomical unit in meters is $1.49597870700 \times 10^{11}$ m. How far has the corona been traced out in astronomical units and does this trace of the corona reach to the orbit of Mercury which has a mean radius of 0.38709893 AU?

a) 0.387 AU and yes. b) 0.14 AU and yes. c) 0.14 AU and no.
d) 0.387 AU and no. e) 1 AU and yes/no.

---

008 qmult 00800 1 4 4 easy deducto-memory: solar wind defined

391. The solar wind is:

a) the air that blows off the northern hemisphere oceans during geomagnetic storms.
b) the plasma gas that cools the Sun's photosphere.
c) an optical illusion in the corona that causes the corona to look like fluffy orange clouds.
d) the plasma gas that streams from the Sun out into **INTERSTELLAR SPACE**.
e) the plasma gas that streams from the Sun out into **INTERGALACTIC SPACE**.

---

008 qmult 00810 1 4 3 easy deducto-memory: solar wind speed

392. The solar wind is a stream of particles that moves approximately along radial paths outward from the Sun: inward is the negative direction and positive is the outward direction. The solar wind near the Earth is typically moving at a radial velocity of about:

a) -200 km/s. b) -200 m/s. c) 400 to 500 km/s. d) -400 to 500 cm/s.
e) 400 to 500 km.

---

008 qmult 00820 2 3 5 moderate math: solar wind mass loss
393. The Sun via the solar wind loses mass at a rate of about 2×10^9 kg/s. Convert this rate into solar masses per year to the same number of significant figures as given. **NOTE:** The mass of the Sun is $M_\odot = 1.98855 \times 10^{30}$ kg and the length of a year in seconds to 0.5 % accuracy is $\pi \times 10^7$ s.

a) 2×10^{30} kg/yr. b) $2 \times 10^{-30}\,M_\odot$/yr. c) $2 \times 10^9\,M_\odot$/yr. d) $3 \times 10^{14}\,M_\odot$/yr.
e) $3 \times 10^{-14}\,M_\odot$/yr.

---

008 qmult 00830 2 3 3 moderate math: solar wind mass loss to Sun gone
394. The Sun loses mass by the solar wind at a rate of $\sim 2 \times 10^9\,\mathrm{kg\,s^{-1}} \sim 3 \times 10^{-14}\,M_\odot$/yr. (Note that $M_\odot$ is the standard symbol for a solar mass: i.e., the mass of the Sun.) If this rate remained constant (which is highly unlikely), how long until the Sun is all gone? (Note a gigayear (Gyr) is a billion years.)

a) $\sim 10^{10}$ yr = 10 Gyr. b) $\sim 10^9$ s. c) $\sim 3 \times 10^{13}$ yr = 3×10^4 Gyr.
d) $\sim 5 \times 10^9$ yr = 5 Gyr. e) $\sim 3 \times 10^{13}$ s.

---

008 qmult 00900 2 4 4 moderate deducto-memory: charge in magnetic fields
395. Magnetic fields:

a) are caused by **ELECTRIC CURRENTS** (and time varying electric fields) and tend to cause charged particles to **PERAMBULATE**.
b) are caused by **ELECTRIC CURRENTS** (and time varying electric fields) and tend to cause charged particles to **ACCELERATE** to the speed of light.
c) are caused by **HEAT** and tend to cause charged particles to **ACCELERATE** to the speed of light.
d) are caused by **ELECTRIC CURRENTS** (and time varying electric fields) and tend to cause charged particles to move in **HELIXES**.
e) are caused by **HEAT** and tend to cause charged particles to move in **HELIXES**.

---

008 qmult 00910 2 1 4 moderate memory: cause of aurora
Extra keywords: Really needs fixing up to be correct
396. The aurora are caused by:

a) **MAGNETIC FIELDS** hitting the **EARTH'S** atmosphere.
b) **MAGNETIC FIELDS** hitting the **SUN'S** atmosphere.
c) charged particles from the **SOLAR WIND** that have been funneled by the Earth's magnetic field onto the Earth's upper atmosphere above the **EQUATOR**. The charged particles excite the atmospheric atoms and molecules and these emit the **AURORAL LIGHT**.
d) charged particles from the **SOLAR WIND** that have been funneled by Earth's magnetic field onto the Earth's upper atmosphere above **HIGH LATITUDE REGIONS USUALLY**. In a complicated way, the solar wind induces electrical currents in the atmosphere. The charged particles in the currents excite the atmospheric atoms and molecules and these emit the **AURORAL LIGHT**.
e) charged particles from the **SOLAR WIND** that have been funneled by Earth's magnetic field onto the Earth's upper atmosphere above **HIGH LATITUDE REGIONS USUALLY**. The charged particles excite the atmospheric atoms and molecules and these emit the **AURORAL SONIC BOOMS**.

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008 qmult 00920 1 4 1 easy deducto-memory: solar wind and Earth

397. The Earth's magnetic field:

a) gives **CONSIDERABLE** protection from the high-energy charged particles in the solar wind.
b) gives **NO** protection from the high-energy charged particles in the solar wind.
c) gives **CONSIDERABLE** protection from the high-energy charged particles in the solar wind. It also **STOPS** all high-energy electromagnetic radiation from reaching the Earth's surface.
d) gives **NO** protection from the high-energy charged particles in the solar wind. But it does **STOP** all high-energy electromagnetic radiation from reaching the Earth's surface.
e) is in the green band of the electromagnetic spectrum.

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008 qmult 01000 2 4 1 moderate deducto-memory: solar magnetic field

398. The magnetic field of the Sun is caused by

a) electrical currents inside the Sun. b) blackbody radiation. c) the Doppler effect. d) charged particles undergoing a Doppler shift. e) the aurora.

---

008 qmult 01100 1 1 1 easy memory: sunspots defined

399. Sunspots are:

a) dark spots on the Sun's surface. b) bright spots on the Sun's surface. c) never observable. d) larger than the Sun. e) only a theory.

---

008 qmult 01110 2 1 1 moderate memory: sunspot cycle

400. The mean length of the full sunspot cycle is:

a) 22 years. b) 220 years. c) 24 hours. d) 2000 years. e) 8 minutes.

---

008 qmult 01120 2 1 2 moderate memory: sunspot maxima, sunspot semi-cycle

401. The mean time from one sunspot maximum (i.e., time of the maximum number of sunspots) to the next is:

a) 22 years. b) 11 years. c) 24 hours. d) 2000 years. e) 8 minutes.

---

008 qmult 01130 2 4 5 moderate deducto-memory: sunspot cause mag-fields

402. Why do solar astrophysicists think the sunspots are caused magnetic field effects?

a) Because one of the pair of sunspots has a strong magnetic field. The other doesn't, but that **MAY NOT** be a problem with the theory.
b) Because one of the pair of sunspots has a strong magnetic field. The other doesn't and that **IS** a problem with the theory.
c) Because sunspots emit **BLACKBODY RADIATION** which is caused by magnetic fields. Moreover, all sunspots have **RELATIVELY STRONG MAGNETIC FIELDS**. The fact that sunspots come in pairs strongly suggests that magnetic field lines emerge from one member of a pair and enter the other member.
d) Because sunspots emit a **LINE SPECTRUM** which is caused by magnetic fields. Moreover, all sunspots have **RELATIVELY STRONG MAGNETIC FIELDS**. The fact that sunspots come in pairs strongly suggests that magnetic field lines emerge from one member of a pair and enter the other member.
e) All sunspots have **RELATIVELY STRONG MAGNETIC FIELDS**. The fact that sunspots come in pairs strongly suggests that magnetic field lines emerge from one member of a pair and enter the other member.

---

008 qmult 01200 1 4 4 easy deducto-memory: solar prominences defined

403. "Let's play *Jeopardy*! For $100, the answer is: These solar activities are arcs of hot gas with temperatures of order 10000 K that rise from the Sun. They can rise in hours and last weeks or months in which case they are quiescent. Or they can arise eruptively in a few hours and eject matter into space in which case they are eruptive."

What are ____________, Alex.

a) sunspots b) coronas c) granules d) prominences e) salients

---

008 qmult 02000 1 4 1 easy deducto-memory: solar flares defined

404. "Let's play *Jeopardy*! For $100, the answer is: These solar activities are giant explosions from the Sun with energies up to of order 10^{25} J (i.e., 2.5×10^9 megatons of TNT) with temperatures up to 5×10^6 K. They are believed to be caused by magnetic reconnection in which magnetic field energy is rapidly converted to thermal, electromagnetic radiation, and kinetic energy."

What are ____________, Alex.

a) solar flares b) granules c) granolas d) grains e) gravitons

---

008 qmult 02100 1 4 5 easy deducto-mem.: solar coronal mass ejections defined

405. "Let's play *Jeopardy*! For $100, the answer is: They are giant bubbles of hot gas ejected from the Sun within the time span of a few hours. If they impact the Earth's magnetosphere, they can cause magnetic storms and strong auroras."

What are ____________, Alex?

a) helium atoms b) hydrogen atoms c) granules d) sunspots e) coronal mass ejections

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008 qmult 02110 1 5 5 easy thinking: killer coronal mass ejections

406. In a best-selling novel of a few years ago (unless my source is just making this up), astronauts on the Moon were killed by high-energy protons from a coronal mass ejection (CME) that reached the Moon 8 minutes after the CME was ejected. What was wrong with this plot device?

a) High-energy protons never hurt anyone.
b) CMEs always happen near the solar poles and all the particles they eject get directed off in the solar polar direction: they never head toward Earth (or the Moon).
c) If one divides 8 minutes by the speed of light, one gets 36 hours. Clearly the astronauts could not have been affected until 36 hours after the CME.
d) If one divides 1 astronomical unit by the the speed of light, one gets 36 hours. Clearly the astronauts could not have been affected until 36 hours after the CME.
e) Particles with finite mass cannot move at the speed of light. 8 minutes is roughly the travel time for light from the Sun. (If you don't believe me, divide 1.496×10^{13} cm by 3.00×10^{10} cm/s and see what you get.) The protons couldn't have gotten to the Moon in 8 minutes or at least not in the exact light travel time. They could do it in a time very close to the exact light travel time if they were super-energetic: such super-energetic solar protons have not been observed. I don't think the author could have been Larry Niven.

Chapt. 9 Solar System Formation

Multiple-Choice Problems

010 qmult 00090 1 4 3 easy memory: evidence of Solar System formation

407. We will probably never be able to understand how our Solar System formed in exact detail, but can understand in more general terms how it formed by relying on various kinds of evidence: e.g.,

a) star formation regions that we observe, extrasolar planetary systems (of which **399** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **DINOSAUR FOSSILS**.
b) star formation regions that we observe, extrasolar planetary systems (of which **3992** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **BIOLOGY**.
c) star formation regions that we observe, extrasolar planetary systems (of which **3992** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **MODELING**.
d) star formation regions that we observe, extrasolar planetary systems (of which **3** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **MODELING**.
e) star formation regions that we observe, extrasolar planetary systems (of which **399** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **WISHFUL THINKING**.

010 qmult 00095 1 4 1 easy deducto-memory: Anthropic principle

408. "Let's play *Jeopardy*! For $100, the answer is: This principle (i.e., which is really a guiding hypothesis) explains coincidences in physics and in the universe that are favorable to life by stating that without these coincidences we would not be here to observe the universe. The opposite point of view is that such coincidences were dictated by the strict physical necessity of some underlying theory of everything. Of course, if the second view is correct, one wonders why the theory of everything in itself happens to be compatible with life (i.e., be biophilic)."

What is the ____________ Principle, Alex?

a) Anthropic b) Copernican c) Cosmological d) Biophilic e) Peter

010 qmult 00097 2 4 5 moderate deducto-memory: Kant's nebular hypothesis

409. "Let's play *Jeopardy*! For $100, the answer is: He/She was the first proposer of the nebular hypothesis for the origin of the Solar System in the context of Newtonian physics."

Who is ____________, Alex?

a) composer Johann Sebastian Bach (1685–1750) b) adventurer and writer Giovanni Jacopo Casanova (1725–1798) c) astronomer Caroline Herschel (1750–1848) d) English general and statesman John Churchill, Duke of Marlborough (1650–1722) e) philosopher Immanuel Kant (1724–1804)

010 qmult 00100 1 1 1 easy memory: radioactive dating

410. Radioactive dating:

a) uses radioactive decay to determine age.
b) uses radioactive decay to determine mass.
c) is useless in practice.
d) uses radioactive decay to determine the half-life of a radioactive isotope.
e) sounds more exciting than it is.

---

010 qmult 00110 2 5 3 moderate thinking: radioactive dating, half-life
411. Radioactive dating of a rock gives the:

a) age of the radioactive isotopes in the rock.
b) time since the rock was last exposed to sunlight.
c) time since the rock was formed provided the pre-formation daughter element abundance **CAN** be distinguished from the post-formation daughter element abundance.
d) time since the rock was formed even when the pre-formation daughter element abundance **CANNOT** be distinguished from the post-formation daughter element abundance.
e) time since the rock was last exposed to radioactivity.

---

010 qmult 00200 1 4 1 easy deducto-memory: half-life
412. A half-life is:

a) the time it takes for **HALF** a sample of a radioactive isotope to decay to a daughter isotope.
b) the time it takes for **a QUARTER** of a sample of a radioactive isotope to decay to a daughter nuclide.
c) the time between star and planet formation.
d) the age of the Sun.
e) the nuclear fuel burning life-time of the Sun.

---

010 qmult 00210 1 1 4 easy memory: half-life probability
413. Say you have a radioactive nucleus with half-life $t_{1/2}$. You've observed it for n half-lives. What is the probability that it will decay in the next half-life? **HINT:** Think about tossing coins.

a) 1. b) 0. c) $1 - 1/2^{n+1}$. d) 1/2. e) $1 - 1/2^n$.

---

010 qmult 00212 1 1 3 easy memory: radioactive sample after n half-lives
414. Say you had a pure sample of radioactive material at time zero. After n half-lives the average fraction of the sample that is still the radioactive material is:

a) 1/2. b) 2. c) $1/2^n$. d) $1/2^{n-1}$. e) $1/2^{n+1}$.

---

010 qmult 00214 1 1 5 easy memory: radioactive decay paradox
415. A sample of radioactive material decreases by 1/2 in one half-life in the sense that half of the radioactive nuclei decay to daughter radioactive nuclei in that time. But nuclei are discrete. Now most initial samples of radioactive nuclei will not consist of an exact power of 2. Thus, in general the predicted number of nuclei after any number of half-lives will not be a whole number, but will be some decimal number with a nonzero decimal fraction. Most dramatically at some point predicted number of nuclei will be less than 1. But nuclei are discrete. There is paradox: the number of nuclei are descrete, but the half-life decay rule predicts non-whole numbers of nuclei. The resolution of the paradox is:

a) the half-life rule is just crude approximation.
b) the half-life rule is an excellent approximation for **LARGE** samples that can be treated as consisting of continuous number of nuclei, but fails for fails for **SMALL** numbers of nuclei.
c) the half-life rule is an excellent approximation for **SMALL** samples that can be treated as consisting of continuous number of nuclei, but fails for fails for **LARGE** numbers of nuclei.
d) that there is no resolution. The whole idea of half-life is a crock.

e) the half-life rule makes an average prediction. For example, if you started with a set of many samples of radioactive nuclei, the average number of nuclei for a sample in the set after n half-lives would be predicted by the half-life decay rule. Average numbers of discrete items don't have to be discrete: e.g., the average American family proverbially has 2.3 children—but there is no 0.3 of child out there.

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010 qmult 00220 1 1 1 easy memory: carbon-14 calculation

416. Radioactive carbon-14 decays with a half-life of 5700(30) years. Living creatures acquire carbon-14 from the air: plants get the carbon from the air and animals from eating plants. The fraction of their carbon which is carbon-14 is that of the air at the time that they are living. But after death, no new carbon-14 is acquired and the carbon-14 decays away. By knowing the ratio of the carbon-14 fraction of dead organic material to the fraction of that material when living, you can:

a) calculate the age of the organic material. b) tell nothing. c) know what organism the material came from. d) tell the cause of death. e) konw waht ogsinram teh mtraiael cmae form.

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010 qmult 00300 1 3 1 easy math: radioactive dating/decay K-40

417. You have a sample of rock in which the ratio of ^{40}K (radioactive potassium) to ^{40}Ca (stable calcium) is 1 to 1. The half-life of ^{40}K is about 1.3 billion years. Assuming the rock was calcium-free at formation, what is the approximate time since the rock was formed?

a) 1.3 billion years. b) 2.6 billion years. c) Only a few years at most. d) 13 billion years. e) 4.6 billion years.

---

010 qmult 00400 1 3 1 easy math: radioactive dating, half-life U-238

418. A sample is initially pure radioactive $^{238}_{92}$U (isotope uranium-238). After four half-lives how much $^{238}_{92}$U is left?

a) 1/16. b) 1/2. c) 1/4. d) 1/10. e) None.

---

010 qmult 00500 1 5 3 easy thinking: radioactive dating, half-life

419. A sample was initially pure radioactive $^{238}_{92}$U (isotope uranium-238). The half-life of $^{238}_{92}$U is 4.5 billion years. Currently, only 1/128 of the sample is ^{238}U. How old is the sample?

a) 4.5 **BILLION** years old.
b) 4.5 **MILLION** years old.
c) 31.5 billion years old. This is older than the currently estimated age of the universe $\sim$ 10–20 billion years old. Clearly there is an inconsistency.
d) 35 billion years old. This is older than the currently estimated age of the universe $\sim$ 10–20 billion years old. Clearly there is an inconsistency.
e) 15 billion years old. This age puts a lower limit on the age of the universe (i.e., the time since the Big Bang).

---

010 qmult 00610 1 4 2 easy deducto-memory: decay energy conversion, Christmas

420. In dense environments, decay energy from radioactive decay is usually converted into:

a) macroscopic kinetic energy. b) heat energy. c) macroscopic gravitational potential energy. d) macroscopic magnetic field energy. e) reindeer energy.

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010 qmult 00800 1 1 1 easy memory: nebular hypothesis

421. The planets probably formed out of:

a) a disk of gas and dust that surrounded the early Sun or proto-Sun.
b) material pulled out of the Sun by a star that passed closely in the remote past.
c) pure hydrogen gas.
d) pure helium gas.
e) carbon dioxide gas.

---

010 qmult 00810 1 1 4 easy memory: planets form out of a protoplanetary disk

422. The planets orbit approximately in a single plane probably because:

  a) the early solar nebular magnetic field forced them to form in a plane.
  b) pure luck.
  c) pure bad luck.
  d) they formed out of the protoplanetary disk of material that formed about the proto-Sun.
  e) a passing star pulled them into a plane long after formation.

---

010 qmult 00900 2 5 2 moderate thinking: Sun's volatiles

423. Volatiles could not condense much in the inner Solar System, and thus did not get incorporated in massive amounts into the inner planets. But the Sun is mainly hydrogen and helium which are certainly volatiles. Why in the Sun and not in the inner planets?

  a) Because of the Sun's magnetic field.
  b) The proto-Sun grew massive enough to hold its volatiles by **GRAVITATION** despite the high temperature it reached.
  c) The proto-Sun grew massive enough to hold its volatiles by the **PRESSURE FORCE** despite the high temperature it reached.
  d) The hydrogen and helium that went into the Sun was sticky.
  e) The difference has no plausible explanation.

---

010 qmult 01000 2 3 1 moderate math: solar wind flushing

424. The solar wind probably flushed much of the primordial gas and dust out of the Solar System during its formation. Say that the solar wind has a speed of 400 km/s. Pluto is about 40 astronomical units from the Sun and the astronomical unit is about 1.5×10^{13} cm. How long does it take the wind to travel from the Sun to Pluto? About:

  a) 1.5×10^{7} s or half a year. b) 1.5×10^{7} s or 10 years. c) 1.5×10^{13} s. d) 1×10^{5} s or a day. e) 1×10^{5} s or 10 day.

---

010 qmult 01100 1 4 2 easy deducto-memory: planetesimals

425. Planetesimals are:

  a) objects of kilometer size or greater that are always lost from the Solar System during planet formation.
  b) objects of kilometer size or greater that can mutually accrete (largely because of gravitational attraction) to form protoplanets.
  c) centimeter size grains that mutually accrete (largely because of gravitational attraction) to form protoplanets.
  d) very tiny planets.
  e) always made of ices.

---

010 qmult 01200 2 1 4 moderate memory: planetary formation sequence with streaming instability

426. The planetary formation sequence as currently understood is:

  a) streaming instability (plus collective-self-gravitation accretion) changing gas to grains, condensation of grains to planetesimals, gravitational accretion of planetesimals to protoplanets.
  b) streaming instability (plus collective-self-gravitation accretion) changing gas to planetesimals, further streaming instability (plus collective-self-gravitation accretion) changing planetesimals to protoplanets.
  c) condensation of gas to grains, streaming instability (plus collective-self-gravitation accretion) changing grains to planetesimals, further streaming (plus instability/collective-self-gravitation accretion) changing planetesimals to protoplanets.

d) condensation of gas to grains, streaming instability (collective-self-gravitation accretion) changing grains to planetesimals, gravitational accretion of planetesimals to protoplanets.
e) gravitational coalescence of gas to grains, streaming instability (collective-self-gravitation) changing grains to planetesimals, gravitational accretion of planetesimals to protoplanets.

---

010 qmult 01300 2 4 5 moderate deduction: two planetesimals bind
427. Two planetesimals are most likely to totally bind together if:

a) they are moving toward each other at high relative speed for a head-on collision.
b) they are moving directly away from each other.
c) they are at very different distances from the star or protostar.
d) they are invisible.
e) they approach each other with low relative velocity.

---

010 qmult 01310 2 4 1 moderate deduction: two planetesimals fragment
428. Two planetesimals are most likely to fragment and **NOT** to bind together if:

a) they are moving toward each other at high relative speed for a head-on collision.
b) they are moving directly away from each other.
c) they are at very different distances from the star or protostar.
d) they are invisible.
e) they approach each other with low relative velocity.

---

010 qmult 01500 2 5 1 moderate thinking: where'd helium come from
429. What is the origin of the helium in the Sun's atmosphere, in the Sun's core, and in Jupiter?

a) The helium in the Sun's atmosphere and Jupiter is **PRIMORDIAL**: i.e., it was the helium present when the Solar System formed: most of this primordial helium formed in the Big Bang (or so the theory goes) and some in earlier generations of stars. The helium in Sun's core is partially primordial and partially from the **NUCLEAR BURNING** of the hydrogen that goes on in the Sun's core.
b) All this helium is **PRIMORDIAL**: i.e., it was the helium present when the Solar System formed: most of this primordial helium formed in the Big Bang (or so the theory goes) and some in earlier generations of stars.
c) All the helium in the Solar System was formed in the **SUN'S CORE** by the nuclear burning of helium. Convection transported this helium to the surface of the Sun and the solar wind transported some of it into the outer solar system where of it got accreted onto the proto-Jupiter.
d) All the helium in the Solar System was formed by nuclear burning of hydrogen that occurred **WHERE THE HELIUM IS NOW FOUND**. Thus, there was nuclear burning on the surface of the Sun and and in Jupiter in the early days of the Solar System. Of course, nowadays the nuclear burning of hydrogen occurs only in the Sun's core.
e) The chemical breakup of **PRIMORDIAL WATER** (i.e., water that existed before the Solar System formed) left the helium in all of these sites.

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010 qmult 01600 2 5 3 moderate thinking: ices and rocky material condense
430. In Solar System planetary formation:

a) the ices condensed mostly near the Sun; the rocky and metallic material in the outer Solar System.
b) the ices condensed everywhere; the rocky and metallic material in the inner Solar System only.
c) the ices condensed mainly in the outer Solar System. The rocky and metallic material condensed everywhere roughly speaking.
d) the ices condensed only near what became Jupiter. The rocky and metallic material condensed only in the neighborhood of what became the Earth.

e) the ices condensed only near what became Saturn. The rocky and metallic material condensed only in the neighborhood of what became the Earth.

---

010 qmult 01650 1 4 1 easy deducto-memory: gas giant formation

431. "Let's play *Jeopardy*! For $100, the answer is: These Solar System bodies are thought to form according to one of two possible theories. Theory 1: they start as rocky/icy protoplanets that are massive enough to gravitationally attract and hold abundant hydrogen and helium gas. Theory 2: they start as gravitationally collapsed dense cores of hydrogen and helium just as stars do and grow by further gravitational accretion of abundant hydrogen and helium."

What are ____________, Alex?

a) gas giant planets b) rocky or terrestrial planets c) minor planets or an asteroids d) Kuiper Belt objects or a trans-Neptunian objects e) mirror matter planets

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010 qmult 01700 2 5 2 moderate thinking question: Earth's water

Extra keywords: Maybe needs reworking to bring it up to date.

432. In the 1999 March 18 issue of the general science journal *Nature*, Blake et al. propose that comets were **not** important sources of the Earth's water in contrast to then-favored theory.

a) Their study of **microwave spectra** of Comet Hale-Bopp (which rounded the Sun in 1997) showed that its primordial water was richer in **deuterium oxide** than Earth's oceans. Deuterium is an isotope of hydrogen: ordinary hydrogen has only a proton as its nucleus; deuterium has a bound proton-neutron pair for its nucleus. **Since all comets** must be just like Hale-Bopp in composition, it is clear that comets could not have been a major contributor to Earth's oceans.

b) Their study of **microwave spectra** of Comet Hale-Bopp (which rounded the Sun in 1997) showed that its primordial water was richer in **deuterium oxide** than Earth's oceans. Deuterium is an isotope of hydrogen: ordinary hydrogen has only a proton as its nucleus; deuterium has a bound proton-neutron pair for its nucleus. **If most of the comets** that impacted Earth early on were like Hale-Bopp in composition, then comets could not have been a major contributor to Earth's oceans.

c) Their study of **microwave spectra** of Comet Hale-Bopp (which rounded the Sun in 1997) showed that its primordial water was richer in **tritium oxide** than Earth's oceans. Tritium is an isotope of hydrogen: ordinary hydrogen has only a proton as its nucleus; tritium has a proton and two neutrons bound to form its nucleus. Tritium is a radioactive isotope with a half-life of about 12 years: there can be no steady amount of tritium without continuous nuclear reactions to produce it. **Since all comets** must be just like Hale-Bopp in composition, it is clear that comets could not have been a major contributor to Earth's oceans.

d) Their study of **microwave spectra** of Comet Hale-Bopp (which rounded the Sun in 1997) showed that its primordial water was richer in **tritium oxide** than Earth's oceans. Tritium is an isotope of hydrogen: ordinary hydrogen has only a proton as its nucleus; tritium has a proton and two neutrons bound to form its nucleus. Tritium is a radioactive isotope with a half-life of about 12 years: there can be no steady amount of tritium without continuous nuclear reactions to produce it. **If most of the comets** that impacted Earth early on were like Hale-Bopp in composition, then comets could not have been a major contributor to Earth's oceans.

e) Their study of **gamma-ray spectra** of Comet Hale-Bopp (which rounded the Sun in 1997) showed that its primordial water was richer in **deuterium oxide** than Earth's oceans. Deuterium is an isotope of hydrogen: ordinary hydrogen has only a proton as its nucleus; deuterium has a bound proton-neutron pair for its nucleus. **Since all comets** must be just like Hale-Bopp in composition, it is clear that comets could not have been a major contributor to Earth's oceans.

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010 qmult 01800 1 1 3 easy memory: asteroids

433. Asteroids are:

a) very probably leftover **ICY** planetesimals (or planetesimal fragments) from the formation of the Solar System. Some have undergone internal-heat geological evolution.
b) very probably leftover **GASEOUS** planetesimals (or planetesimal fragments) from the formation of the Solar System.
c) very probably leftover **ROCKY** planetesimals (or planetesimal fragments) from the formation of the Solar System. Some have undergone internal-heat geological evolution. They may have some ice too.
d) **ICY** planetesimals that formed **OUTSIDE** of the Solar System. Some have undergone internal-heat geological evolution.
e) **ROCKY** planetesimals that formed **OUTSIDE** of the Solar System. Some have undergone internal-heat geological evolution.

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010 qmult 01810 1 4 1 easy deducto-memory: comet origins
434. Comets are:

a) very probably leftover **ICY/CARBONACEOUS** planetesimals (or planetesimal fragments) from the formation of the Solar System.
b) very probably leftover **ROCKY** planetesimals (or planetesimal fragments) from the formation of the Solar System.
c) very probably leftover **GASEOUS** planetesimals (or planetesimal fragments) from the formation of the Solar System.
d) **ICY/CARBONACEOUS** planetesimals that formed outside of the Solar System.
e) **ROCKY** planetesimals that formed outside of the Solar System.

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010 qmult 01900 1 1 3 moderate deduction: heating by collapse and collision
435. Both gravitational collapse and collisions tend to cause:

a) cooling. The heat from the bodies gets transformed into bulk kinetic energy and gravitational potential energy.
b) plate tectonics.
c) heating. The gravitational potential energy and bulk kinetic energy of the bodies gets randomized into microscopic kinetic energy.
d) plate tectonics. The gravitational potential energy and bulk kinetic energy of the bodies sets up convective flows which brings magma to the surface of the protostars. The magma pushes about the crustal plates.
e) magnetic fields which then cause the bodies to explode apart.

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010 qmult 01950 2 4 5 moderate deducto-memory: Seeds 4 stages of evolution
436. In one kind of analysis, the evolution of rocky/icy bodies in the solar system has been divided in to four stages. Not all rocky/icy bodies will go through all stages. These stages in probable time order are:

a) nuclear differentiation, heavy bombardment, flooding by liquid nitrogen and/or liquid helium, and plate tectonics.
b) nuclear differentiation, light bombardment, flooding by liquid nitrogen and/or water, and plate tectonics.
c) nuclear differentiation, light bombardment, flooding by lava and/or water, and plate tectonics.
d) chemical differentiation, light bombardment, flooding by lava and/or water, and plate tectonics.
e) chemical differentiation, heavy bombardment, flooding by lava and/or water, and continuing geologic evolution.

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010 qmult 02000 1 1 3 easy memory: chemical differentiation
437. In planet formation, the chemical differentiation stage is the stage:

a) of heavy cratering.
b) of heavy cratering and lava flows.
c) where the molten materials of the early planets separated under the action of **GRAVITY**. The **DENSER** materials sank to the deeper regions; the **LESS DENSE** materials rose to the upper regions.
d) where the molten materials of the early planets separated under the action of **MAGNETIC FIELDS**. The **DENSER** material sank to the deeper regions; the **LESS DENSE** materials rose to the upper regions.
e) where the molten materials of the early planets separated under the action of the **SOLAR WIND**. The **LESS DENSE** material sank to the deeper regions; the **DENSER** materials rose to the upper regions.

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010 qmult 02100 2 4 3 moderate deducto-memory: heavy bombardment

438. Mainly by studying the variations in lunar crater density per unit area and the variations in ages of rocks from the lunar highlands and maria, Solar System astrophysicists have concluded that there was a period of heavy bombardment by various Solar System bodies. This heavy bombardment:

a) was about 65 million years ago. b) was about 100 to 65 million years ago. c) covered about the first billion years of the Solar System after formation. d) was about 15 to 10 billion years ago. e) was coincident with the last ice age.

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010 qmult 02200 2 5 2 moderate thinking: cratering

439. Why is almost every Solar System body with a **SOLID** surface scarred by craters?

a) In the **10 BILLION YEARS** since the Solar System formed there has been a continuous increasing bombardment on solar system bodies by other Solar System bodies that was heaviest at early times in the heavy bombardment phase of the Solar System. Those bodies without solid surfaces can show impact effects only briefly. Those bodies with ongoing active geological activity (based on internal heat/erosion) erase traces of all but the most recent craters. But most solid-surface bodies do not have much active internal-heat/erosion-based geology. On these bodies cratering is principally erased only by newer cratering which does not of course erase the scarring.
b) In the **4.6 BILLION YEARS** since the Solar System formed there has been a continuous bombardment on solar system bodies by other Solar System bodies that was heaviest at early times in the heavy bombardment phase of the Solar System. Those bodies without solid surfaces can show impact effects only briefly. Those bodies with ongoing active geological activity (based on internal heat/erosion) erase traces of all but the most recent craters. But most solid-surface bodies do not have much active internal-heat/erosion-based geology. On these bodies cratering is principally erased only by newer cratering which does not of course erase the scarring.
c) The heaviest bombardment of Solar System bodies by other Solar System bodies has occurred in the last **100 MILLION YEARS**. This bombardment has cratered almost all the solid surfaces. It has also probably been responsible for the dinosaur extinction circa 65 million years ago. The likely deep impact of kilometer-scale asteroid 1997 XF_{11} on Earth in 2028 is just part of this bombardment phase.
d) Most solid bodies in the Solar System have suffered heavy continuous volcanism: the asteroids most of all. The craters are mostly volcanic, not impact, in origin.
e) The Earth isn't scarred by craters.

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010 qmult 02500 2 4 1 moderate deducto-memory: primordial-radiogenic heat geology

440. The rocky bodies in the Solar System from the largest asteroids upward in mass probably all experienced to some degree geological activity caused by:

a) internal heat from formation (i.e., primordial heat) and past and in some cases current radiogenic heating.

b) liquid water erosion.
c) hydrogen enbrittlement.
d) internal heat from the red giant phase of the Sun.
e) ice ages.

Chapt. 10 The Earth

Multiple-Choice Problems

011 qmult 00080 1 4 1 easy deducto-memory: gravity and sphere

441. "Let's play *Jeopardy*! For $100, the answer is: This geometrical shape is normal for massive astronomical bodies where gravity and the pressure force dominate the structure."

What is a/an ________, Alex?

a) sphere b) ellipse c) corona d) cone e) snow cone

011 qmult 00082 1 4 4 easy deducto-memory: Earth oblate sphere

442. The Earth is a slightly oblate sphere: i.e., it bulges a bit at the equator. The **DIFFERENCE** between the equatorial and polar radii (i.e., $R_{\text{equator}} - R_{\text{pole}}$) is approximately:

a) 6378 km. b) 1 astronomical unit. c) 60 Earth radii. d) 21 km. e) 1000 km.

011 qmult 00084 1 1 4 easy memory: Earth radius

443. The Earth's equatorial radius is:

a) 1500.2 km. b) 6378.1 m. c) 500 km. d) 6378.1 km. e) 131000.6 km.

011 qmult 00100 1 1 5 easy memory: Earth hot near formation

444. In order for chemical differentiation to occur near the time of its formation, the Earth then was:

a) cold. b) stone cold. c) lukewarm. d) much closer to the Sun. e) hot.

011 qmult 00200 1 1 5 easy memory: molten Earth

445. In order for chemical differentiation to occur near the time of its formation, the Earth then was:

a) cold. b) stone cold. c) lukewarm. d) much closer to the Sun for some time at least. e) mostly molten for some time at least.

011 qmult 00300 1 1 1 easy memory: internal structure of Earth

446. Three main ingredients in understanding the internal structure of the Earth are:

a) seismology, the primordial solar nebula composition, and modeling.
b) seismology, the primordial solar nebula composition, and biology.
c) seismology, biology, and cryptology.
d) seismology, biology, and cosmetology.
e) the primordial solar nebula composition, extinct marine invertebrates, and undesirable activities.

011 qmult 00310 1 4 1 easy deducto-memory: central region of Earth

447. The central region of the Earth is believed to be

a) hot and composed mainly of solid iron. b) cold and composed mainly of solid iron. c) hot and composed of gold. d) cold and composed of uranium. e) hot and composed of uranium.

011 qmult 00400 1 1 3 easy memory: water coverage of Earth

448. Of the Earth's surface, liquid water covers about:

a) 10 %. b) 30 %. c) 71 %. d) 95 %. e) 99 %.

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011 qmult 00450 2 4 2 moderate deducto-memory: crust composition
449. The composition of the Earth's crust is dominated by:

a) oxygen (O) and uranium (U) in about a 1 to 1 ratio by mass.
b) oxygen (O) and silicon (Si) in about a 2 to 1 ratio by mass.
c) oxygen (O) and iron (Fe) in about a 1 to 1 ratio by mass.
d) oxygen (O) and hydrogen (H) in about an 8 to 1 ratio by mass.
e) argon (Ar) and kryptonite (Ke) in about a 3 to 2 ratio by mass.

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011 qmult 00500 2 4 2 moderate deducto-memory: Earth's crust
450. The Earth's crust is:

a) divided into continental and oceanic components. The former is about 20–70 km thick and latter, about 6000 km thick.
b) divided into continental and oceanic components. The former is about 20–70 km thick and latter, about 6–10 km thick.
c) divided into continental, oceanic, and Hibernian components. The first is about 20–70 km thick. The second is about 6–10 km thick. The third has negative thickness.
d) divided into continental, oceanic, and Nevadan components. The first is about 20–70 km thick. The second is about 6–10 km thick. The third has negative thickness.
e) about 6000 km thick.

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011 qmult 00510 2 4 3 moderate deducto-memory: lithosphere defined
451. The upper rigid layer of the Earth's mantle is called the ____________ and it is of order ____________ kilometers deep.

a) lithenosphere; 6000 b) lithosphere; 6000 c) lithosphere; 100
d) asthenosphere; 100 e) lithenosphere; 100

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011 qmult 00512 2 4 2 moderate deducto-memory: Earth's surface warmth
452. The surface of the Earth is mainly kept warm by:

a) geothermal heat from the interior.
b) electromagnetic radiation from the Sun.
c) radioactive decay heat from radioactive isotopes on the surface.
d) natural natural gas fires in near-surface caves.
e) artificial natural gas fires in near-surface caves.

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011 qmult 00520 1 4 2 easy deducto-memory: crustal plates
453. The Earth's surface is divided into crustal plates. The plates:

a) have been fixed and unchanging since the Earth formed.
b) are pushed around and renewed by geological activity.
c) are heavily scarred by impact craters.
d) float directly on a sea of molten iron and nickel.
e) are pushed around and renewed by geological activity. The temperature of their upper surfaces is over 1000 K due to heat flow from the interior.

---

011 qmult 00522 1 4 5 easy deducto-memory: tectonic plate boundaries
454. "Let's play *Jeopardy*! For $100, the answer is: The divergent, convergent, and transform boundaries occur between these geological features."

What are ____________, Alex?

a) oceans b) earthquakes c) glaciers d) alluvial plains e) tectonic plates

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011 qmult 00600 1 4 4 easy deducto-memory: plate tectonics driver
455. Plate tectonics is driven by:

a) magnetic fields. b) the solar wind. c) comet impacts. d) convective heat flow in the mantle. e) convective heat flow in the atmosphere.

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011 qmult 00610 1 4 3 easy deducto-memory: Earth resurfacing
456. If the Solar System formed about 4.6 billion years ago, why are Earth rocks mostly younger than one billion years old?

a) Impacts by young asteroids have resurfaced the Earth.
b) The solar wind has rejuvenated Earth rock.
c) Internal-heat-driven geological activity and erosion have continually renewed most of Earth's surface rocks.
d) Internal-heat-driven geological activity and erosion have renewed once only most of Earth's surface rocks.
e) The Earth formed only within the last billion years.

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011 qmult 00700 1 4 4 easy deducto-memory: crust add and subtract
457. The Earth's crust is added to by ____________ and is removed by ____________?

a) impact craters; convergent boundaries (i.e., subduction zones often in oceanic trenches)
b) impact craters; volcanoes
c) impact craters; impact crater also
d) divergent boundaries (i.e., rifts, often oceanic rifts surrounded by oceanic ridges); convergent boundaries (i.e., subduction zones often in oceanic trenches)
e) divergent boundaries (i.e., rifts, often oceanic rifts surrounded by oceanic ridges); volcanoes

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011 qmult 00710 1 4 1 easy deducto-memory: tectonic plate boundaries
458. Most tectonic plate boundaries are under the ocean, but a few cross land: e.g.,

a) across Iceland (the Mid-Atlantic Ridge) and southern California from the Gulf of California to about San Francisco (the San Andreas Fault).
b) across Iceland (the Mid-Pacific Ridge) and southern California from the Gulf of California to about San Francisco (the San Fernando Fault).
c) across Nevada (the Las Vegas Wash) and northern California from San Francisco to the Klamath River Valley (the Sonoma Fault).
d) across Nevada (the Las Vegas Wash Basin) and northern California from San Francisco to the Klamath River Valley (the Sonoma Default).
e) across Nevada (the Mifault) and northern California from San Francisco to the Klamath River Valley (the Yurfault).

---

011 qmult 00900 1 4 2 easy deducto-memory: volcano defined defined
459. A volcano is:

a) a vent in the Earth's surface from which liquid water is expelled at irregular or regular intervals.
b) a vent in the Earth's surface from which lava, ash, and steam are expelled often at irregular intervals.
c) a crustal plate that is pushed around and renewed by geological activity. The temperature of its upper surface is over 1000 K due to heat flow from the interior.
d) a mountain in a folded mountain range.
e) an inhabitant of Vulcan.

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011 qmult 01110 1 4 2 easy deducto-memory: Pangaea
460. In the Permian period about 250 million years ago, the Earth is believed to have had one large super-continent called:

a) Panama. b) Pangaea. c) Pangloss. d) Pan-Am. e) Panic.

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011 qmult 01200 2 4 2 moderate deducto-memory: Earth atmosphere gases

461. The three most abundant gases by mass in the present-day Earth atmosphere (excepting water vapor which varies in abundance) are:

   a) molecular nitrogen (N_2), molecular oxygen (O_2), and carbon dioxide (CO_2).
   b) molecular nitrogen (N_2), molecular oxygen (O_2), and argon (Ar) which is a monatomic noble gas.
   c) molecular nitrogen (N_2), molecular oxygen (O_2), and ozone (O_3).
   d) molecular oxygen (O_2), carbon dioxide (CO_2), and molecular hydrogen (H_2).
   e) molecular oxygen (O_2), carbon dioxide (CO_2), and helium (H) which is a monatomic noble gas.

---

011 qmult 01202 1 1 5 easy memory: nitrogen 2 gas

462. Molecular nitrogen gas (N_2) is:

   a) poisonous. b) very reactive with all organic material. c) green in color. d) green in color and rather non-reactive. e) rather non-reactive.

---

011 qmult 01210 1 4 5 easy deducto-memory: trace gas carbon dioxide

463. "Let's play *Jeopardy*! For \$100, the answer is: This gas is a trace gas in the present-day Earth atmosphere, but its importance for the biosphere both in photosynthesis and as a greenhouse gas is immense."

   What is ____________, Alex?

   a) molecular oxygen (O_2) b) helium (H) c) ozone (O_3) d) argon (Ar) e) carbon dioxide (CO_2)

---

011 qmult 01500 1 1 3 easy memory: O_2 for breathing

464. For respiration we need:

   a) oxygen in any compound whatever. b) carbon monoxide (CO). c) molecular oxygen (O_2). d) krypton gas. e) neon gas.

---

011 qmult 01600 1 4 3 easy deducto-memory: ozone for UV shielding

465. The Earth's ozone (O_3) layer:

   a) is made of carbon dioxide. b) shields the Earth from solar **INFRARED** radiation. c) shields the Earth from solar **ULTRAVIOLET** radiation. d) prevented any biological activity on the early Earth. e) is made of factory soot.

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011 qmult 01700 1 5 1 easy thinking: albedo and heating

466. Albedo is the fraction of light reflected (as opposed to absorbed) by an astrophysical body. In general, of course, albedo depends on wavelength. Assume that the albedo of planet is 1 for all wavelengths: i.e., it reflects all light from its upper atmosphere.

   a) The surface temperature will depend on the heat content of the interior of the planet and the heat transport properties of the planet and its atmosphere.
   b) The surface temperature of planet will absolute zero in all cases.
   c) The surface temperature of the planet will be 273.15 K (which is the freezing point of water at one Earth atmosphere pressure).
   d) The surface temperature of the planet will be 77 K (which is the boiling point of molecular nitrogen at one Earth atmosphere pressure).
   e) The surface temperature will be negative on the absolute scale.

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011 qmult 01800 1 5 1 easy thinking: greenhouse effect defined

467. The greenhouse effect for the Earth is explained as follows:

a) The solar radiation peaks in the **VISIBLE** and the Earth's atmosphere is about 50 % transparent in the **VISIBLE**. Thus, a lot of solar radiation reaches the Earth's surface where it is mostly absorbed: this heats the surface. The surface radiates **INFRARED (IR) RADIATION** to which the atmosphere is fairly opaque and a large fraction of the **IR ENERGY** plus energy directly absorbed in the atmosphere from the Sun is radiated back to the Earth. Now an overall balance between energy absorbed and radiated from the Earth's surface must be achieved in order to keep the Earth in a steady state. In order to radiate enough to balance both the energy flow directly from the Sun and the energy flow from the atmosphere, the Earth surface temperature is **HIGHER** than it would be in the absence of the high **IR ABSORPTION** of the atmosphere and, in fact, a bit **HIGHER** than it would be with no atmosphere at all. The **INCREASE** of the mean Earth temperature caused by the comparatively high **IR ABSORPTION** of the atmosphere is the greenhouse effect.
b) The solar radiation peaks in the **INFRARED (IR)** and the Earth's atmosphere is about 50 % transparent in the **IR**. Thus, a lot of solar radiation reaches the Earth's surface where it is mostly absorbed: this heats the surface. The surface radiates **RADIO RADIATION** to which the atmosphere is fairly opaque and a large fraction of the **RADIO ENERGY** plus energy directly absorbed in the atmosphere from the Sun is radiated back to the Earth. Now an overall balance between energy absorbed and radiated from the Earth's surface must be achieved in order to keep the Earth in a steady state. In order to radiate enough to balance both the energy flow directly from the Sun and the energy flow from the atmosphere, the Earth surface temperature is **LOWER** than it would be in the absence of the high **RADIO ABSORPTION** of the atmosphere and, in fact, a bit **LOWER** than it would be with no atmosphere at all. The **DECREASE** of the mean Earth temperature caused by the comparatively high **RADIO ABSORPTION** of the atmosphere is the greenhouse effect.
c) The construction of a large number of greenhouses since the early 19th century has increased the amount of carbon dioxide in the atmosphere and in theory this is slowly choking all plant life on Earth. This choking problem is the greenhouse effect.
d) The construction of a large number of greenhouses since the early 19th century resulted from the English craze for **TROPICAL FLOWERS,** particularly orchids. The greenhouse fad is colloquially called the greenhouse effect.
e) Greenhouses release excessive amounts of molecular oxygen into the atmosphere. Molecular oxygen is a highly reactive compound. In excessive concentrations, it is very dangerous to living tissue. The release of molecular oxygen by greenhouses is the greenhouse effect.

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011 qmult 01900 1 4 2 easy deducto-memory: greenhouse effect on planets

468. The greenhouse effect is:

a) always disastrous for life.
b) one of the factors that determine the surface temperature of a planet.
c) always good for plants.
d) one of the factors that supposedly determine the surface temperature of a planet. The scientific consensus is that it **NEVER** happens at all.
e) one of the factors that determine the surface temperature of Sun.

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011 qmult 02000 1 4 4 easy deducto-memory: heat flow direction

469. Given a temperature difference and insulation between two bodies, the rate of heat flow between these two bodies increases with ____________ temperature difference and ____________ insulation.

a) decreasing; with increasing b) increasing; with increasing
c) decreasing; with decreasing d) increasing; with decreasing
e) increasing; is unaffected by

---

011 qmult 02100 2 4 4 moderate deducto-memory: greenhouse and heat balance

470. The heat flow into the Earth from the Sun is more or less constant averaged over the course of day.

   a) Greenhouses gases, mainly $\mathbf{H_2O}$ and $\mathbf{CO_2}$, keep a fraction of this heat flow from flowing back into space. Thus there is a continual increase in atmospheric heat and temperature.
   b) Greenhouses gases, mainly $\mathbf{H_2O}$ and $\mathbf{H_2}$, keep a fraction of this heat flow from flowing back into space. Thus there is a continual increase in atmospheric heat and temperature.
   c) Greenhouses gases, mainly $\mathbf{H_2O}$ and $\mathbf{H_2}$, provide extra insulation for the Earth's atmosphere. In order to balance the heat flow in with a heat flow out, the mean equilibrium temperature of the Earth's surface must be higher than in the absence of the greenhouse gases.
   d) Greenhouses gases, mainly $\mathbf{H_2O}$ and $\mathbf{CO_2}$, provide extra insulation for the Earth's atmosphere. In order to balance the heat flow in with a heat flow out, the mean equilibrium temperature of the Earth's surface must be higher than in the absence of the greenhouse gases.
   e) Greenhouses gases, mainly $\mathbf{H_2O}$ and $\mathbf{CO_2}$, provide extra insulation for the Earth's atmosphere. In order to balance the heat flow in with a heat flow out, the mean equilibrium temperature of the Earth's surface must be higher than in the absence of the greenhouse gases. The greenhouses gases are **RESPONSIBLE** for the Earth's mean temperature being about 80°C rather than −18°C.

---

011 qmult 02200 1 3 1 easy math: increasing CO_2

471. From about 1960 to 2000, the Earth's atmosphere CO_2 content increased from about 315 ppm (parts per million) to about 370 ppm. Assuming the rate of increase is constant, in about what year will the content be 800 ppm?

   Of course, constant increase is unlikely. There are several trends, some of them certainly varying, acting to increase and decrease CO_2 content. Wally Broecker (1931–2019) of Lamont-Doherty Earth Observatory and winner of the 12th Nevada Medal in 1998 or 1999 suggested the possibility—only possibility mind—that a catastrophic change in global climate could occur over a few decades if the content crosses the 700–800 ppm threshold.

   a) 2300. b) 2200. c) 2100. d) 2050. e) 2020!!!

---

011 qmult 02300 1 1 2 easy memory: rising ocean levels

472. Why would one expect an increase in carbon dioxide in the Earth's atmosphere to cause a rise in sea level?

   a) A carbon dioxide increase would tend to **DECREASE** the Earth's greenhouse effect leading to an increase in overall world temperatures. An increase in temperatures would tend to melt some of the polar ice caps, and so raise the sea level.
   b) A carbon dioxide increase would tend to **INCREASE** the Earth's greenhouse effect leading to an increase in overall world temperatures. An increase in temperatures would tend to melt some of the polar ice caps, and so raise the sea level. Also increased ocean water temperature, will cause the ocean water to expand.
   c) Carbon dioxide **INTERACTS** readily with atmospheric molecular hydrogen to form water vapor. Thus new water vapor would be created by increased carbon dioxide. This water vapor would mostly condense out and add to the oceans.
   d) Carbon dioxide **DOES NOT INTERACT** with atmospheric molecular hydrogen to form water vapor. Thus new water vapor would be created by increased carbon dioxide. This water vapor would mostly condense out and add to the oceans.
   e) A carbon dioxide increase would tend to **INCREASE** the Earth's greenhouse effect leading to an increase in overall world temperatures. An increase in temperatures would **NECESSARILY** cause more rain, and so raise the sea level.

---

011 qmult 02400 1 4 4 easy deducto-memory: rising Earth temperature

473. Carbon dioxide and water vapor are the main causes of the Earth's greenhouse effect. Without the greenhouse effect the Earth would be colder than it is. Human burning of fossil fuels is increasing the carbon dioxide gas content of the Earth's atmosphere.

a) Thus the temperature every place on Earth will go **UP**.
b) Thus the temperature every place on Earth will go **DOWN**.
c) The simplest conclusion is that the mean temperature of the Earth should increase and this could have many bad consequences. But there may be complex feedback mechanisms and other human generated effects that prevent any change or even cause a reduction in mean temperature. Moreover, completely natural trends in the global climate are also present. They may completely overwhelm any anthropogenic effects. However, sophisticated climate modeling confirms the simplest conclusion. So many people are **UNCONCERNED**.
d) The simplest conclusion is that the mean temperature of the Earth should increase and this could have many bad consequences. But there may be complex feedback mechanisms and other human generated effects that prevent any change or even cause a reduction in mean temperature. Moreover, completely natural trends in the global climate are also present. They may completely overwhelm any anthropogenic effects. However, sophisticated climate modeling confirms the simplest conclusion. So many people are **CONCERNED**.
e) Thus the mean temperature of the Earth will go down and then up.

---

011 qmult 03000 2 4 3 moderate deducto-memory: Earth's permanent atmosphere

474. In the most current understanding, what is the source of the Earth's original permanent atmosphere and its water? The source is:

a) gravitational accumulation of gases directly from the solar nebula.
b) the giant impact that caused the Moon's formation.
c) outgassing from rock caused by internal-heat-driven geological activity and possibly comet impacts.
d) biological activity.
e) the solar wind and comets.

---

011 qmult 03200 1 4 1 easy deducto-memory: Earth's oxygen

475. The molecular oxygen (O_2) in the Earth's atmosphere is probably mainly due to:

a) photosynthesis. b) catalysis. c) analysis. d) direct outgassing from rock.
e) cometary impacts.

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011 qmult 03500 2 5 3 moderate thinking: escaping molecules

476. Gas atoms or molecules in the rarefied upper region of a planet's atmosphere can escape to infinity (i.e., become unbound from a planet) since there they are unlikely to collide with other particles on their way out. Assume that the upper atmosphere is shielded from the solar wind by a magnetic field. For a given gas molecule of molecular mass m, the two main factors that determine how fast the gas molecules escape from the upper atmosphere are:

a) planet surface gravity and temperature.
b) upper atmosphere carbon dioxide content and temperature.
c) upper atmosphere gravity and temperature.
d) upper atmosphere biological activity and gravity.
e) planet surface biological activity and temperature.

Chapt. 11 The Moon and Mercury

Multiple-Choice Problems

012 qmult 00100 1 1 1 moderate memory: lunar tidal locking

477. The lunar month is:

a) the same length as the lunar day due to tidal locking (i.e., tidal coupling or tidal force effects).
b) the same length as the lunar day due to radioactivity.
c) the same length as the lunar day due to the solar wind (i.e., solar wind interactions with the Moon's magnetic field).
d) the same length as the lunar day due to light reflected from Earth.
e) twice the length of the lunar day.

012 qmult 00120 2 5 2 moderate thinking: Moon's daytime

478. The mean lunar month (i.e., the period from new moon to new moon) is 29.53059 days. The Moon is synchronously tidally locked to the Earth. How long is the **DAYLIGHT PERIOD** of the Moon's day at any point on the Moon? **HINT:** A diagram might help.

a) 29.53059 days. b) about 14.8 days. c) about 29 days. d) 12 hours. e) about 365.25 days.

012 qmult 00122 1 1 3 easy memory: average length of lunar day

479. The average length of a lunar day (i.e., day on the Moon) is about:

a) 25 hours. b) 27.3 days. c) 29.5 days. d) 33.3 days. e) 40.7 days.

012 qmult 00130 2 5 5 moderate thinking: Earth seen from Moon

480. You are standing on the near side of the Moon. How does the Earth's position in the sky change relative to your local horizon?

a) The Earth moves across sky from eastern to western horizon for a 12 hour period on average and then is below the horizon for another 12 hour period on average. The Earth does show phases that depend on the time of the lunar month.
b) The Earth circles the zenith position every 24 hours.
c) The Earth circles the zenith position every 29.53059 days on average.
d) The Earth zigzags randomly all across the sky.
e) The Earth stays more or less fixed in the sky relative to the local horizon because of the synchronous tidal locking of the Moon to the Earth. The Earth jiggles about a little because of some wobbling of the Moon. The Earth does show phases that depend on the time of the lunar month.

012 qmult 00200 1 1 1 easy memory: tidal force

481. The "tidal force" on a body can be defined as the difference in gravitational on the body along the line from the body to the source of the gravitational force. The tidal "force" tends to:

a) stretch the body along the line to the gravitational source. b) cause the body to collapse. c) stretch the body perpendicular to the line to the gravitational source. d) cause the body to rotate. e) cause the body to splash-down.

---

012 qmult 00210 2 4 2 moderate deducto-memory: two-Moon-Earth facts

482. Two immediately striking facts about the Moon in comparison to the Earth are (1) the Moon's radius is about ________ times the Earth's radius and (2) the Moon's mean density is about ________ times the Earth mean density.

    a) 1/4; 2 b) 1/4; 3/5 c) 1/2; 2 d) 2; 2 e) 1/10; 1/20

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012 qmult 00220 2 1 3 moderate memory: mean lunar density 1

483. The mean lunar density relative to the mean Earth density is:

    a) high. b) negligible. c) low. d) identical. e) practically the same.

---

012 qmult 00222 1 1 3 easy memory: mean lunar density 2

484. The mean lunar density is:

    a) $0.00120\,g/cm^3$. b)$1.00\,g/cm^3$. c) $3.3464\,g/cm^3$. d) $110\,g/cm^3$. e) $210\,g/cm^3$.

---

012 qmult 00225 2 5 3 moderate thinking: Moon's gravity

485. The Moon's mass is about 1/80 of the Earth's mass. But the Moon's surface gravity is about 1/6 of the Earth's surface gravity. Why isn't the Moon's surface gravity about 1/80 of the Earth's surface gravity?

    a) The gravitational force of the Earth increases the downward gravitational force on the Moon.
    b) The gravitational force law has mass **TIMES** radius squared. The Moon has a small mass relative to Earth, but also a small radius relative to Earth. The two differences cancel somewhat, and so the Moon's surface gravity is not as small as just considering the Moon mass only suggests.
    c) The gravitational force law has mass **DIVIDED** by radius squared. The Moon has a small mass relative to Earth, but also a small radius relative to Earth. The two differences cancel somewhat, and so the Moon's surface gravity is not as small as just considering the Moon mass only suggests.
    d) Magnetic fields on the Moon increase the effect of gravity.
    e) The astronauts were too full of turkey.

---

012 qmult 00230 1 1 3 easy memory: far side of the Moon

486. The far side of the Moon is:

    a) seen from Earth once per month. b) seen from Earth only at new moon. c) never seen from Earth. d) seen from Earth only during solar eclipses. e) constantly visible from Earth.

---

012 qmult 00240 1 4 1 easy deducto-memory: lunar sky

487. The sky on the Moon is always:

    a) black. b) blue. c) red. d) red and white. e) red, white, and blue.

---

012 qmult 00260 1 1 1 easy memory: Moon has no atmosphere

488. The Moon has:

    a) almost no atmosphere.
    b) a thick, dry, carbon dioxide atmosphere.
    c) a water vapor atmosphere which is thick enough to to cause clouds that are sometimes seen from Earth.
    d) a thin, but nearly breathable, oxygen-nitrogen atmosphere.
    e) a thick atmosphere of nearly transparent molecular hydrogen gas.

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012 qmult 00300 1 1 4 easy memory: lunar geology different from Earth

489. The geology of the Moon is quite different than that of the Earth. There is **NO** evidence that there is or ever was ____________ and ____________.

a) water and wind erosion; volcanism b) impact erosion; plate tectonics
c) impact erosion; volcanism d) water and wind erosion; plate tectonics
e) glaciation; volcanism

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012 qmult 00310 1 4 2 easy deducto-memory: lunar highlands
490. "Let's play *Jeopardy*! For $100, the answer is: They constitute the original lunar crust that formed during the chemical differential phase of the Moon's formation. They are made of relatively light colored anorthosite rock. Since formation they have been heavily modified by impact erosion by impactors of all sizes. Most of the erosion happened early on in the first billion years of the Moon's history."

What are the lunar ____________, Alex?

a) maria b) highlands c) lowlands d) seas e) craters

---

012 qmult 00320 1 1 2 easy memory: the lunar maria
491. Mare is Latin for "sea": the last "e" is not silent, but the pronunciation seems various—mar-ray may be closest—and who knows how the Romans really pronounced it. The plural form maria is more commonly used, often as if it were a singular. A lunar mare is:

a) a region of the light colored lunar highlands.
b) a dark lava plain on the Moon that is **LIGHTLY** cratered compared to the lighter colored lunar highlands.
c) a dark lava plain on the Moon that is **HEAVILY** cratered compared to the lighter colored lunar highlands.
d) a seabed of a dried up lunar sea.
e) the mother of a colt.

---

012 qmult 00322 1 1 2 easy memory: formation of lunar maria
492. The lunar maria formed when large flows of ____________ from the Moon's interior flooded the giant basins which were in turn often formed by giant impactors. The giant impactors may have initiated the flows, but this is still debated. The ____________ solidified to from basalt rock. Most of the maria formed between 3 and 3.5 billion years ago, but some are older and some younger. Because the maria formed after the heavy bombardment, they have suffered far less impact erosion than the rest of the lunar surface. The maria cover only about 16 % of the luncar surface. Most of the mare coverage is on the near side which gives Earth-based observers the impression that the mare coverage is more extensive than it is.

a) water b) lava c) plastic rock d) molten iron e) mud

---

012 qmult 00340 1 4 5 easy deducto-memory: crater Tycho
493. "Let's play *Jeopardy*! For $100, the answer is: It is the generally considered to be the most obvious rayed crater on the Moon when looking at an image of the Moon's near side. Actually, most people think it is the most obvious crater period."

What is ____________, Alex?

a) Meteor Crater b) Phobos c) Andromeda d) Barnes e) Tycho

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012 qmult 00370 2 1 5 moderate memory: the lunar mountains
494. The lunar mountains seem to be:

a) fold- and fault-mountains, impact crater rims or parts thereof, and hotspot volcanoes.
b) fold- and fault-mountains and hotspot volcanoes.
c) fold- and fault-mountains.
d) impact crater rims or parts thereof and many hotspot volcanoes.

e) mainly impact crater rims and parts thereof. There are also central crater peaks and some lunar domes (a kind of shield volcano).

---

012 qmult 00500 1 1 4 easy memory: moonquake definition

495. A moonquake is:

a) a wobble of the Moon in its orbit. b) a lunar mare. c) a fluctuation in the Moon's reflected brightness caused by a strong gust of the solar wind. d) the Moon's equivalent of an earthquake. e) a contradiction in terms.

---

012 qmult 00600 2 1 4 easy memory: moonquake cause

496. Most significant moonquakes (in the present epoch) are thought to be caused primarily by:

a) plate tectonic activity. b) volcanism. c) impacts and volcanism. d) impacts and solar tidal force effects. e) the solar wind.

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012 qmult 00700 1 1 5 easy memory: Moon giant impactor

497. The current favored theory for the formation of the Moon is the:

a) co-accretion theory. b) tidal coupling theory. c) capture theory. d) fission theory. e) giant impactor theory.

---

012 qmult 00800 3 1 3 hard memory: giant impactor formation of Moon

498. The giant impactor theory of the Moon's formation explains:

a) the heavy cratering of the Moon, the lunar maria, and the inclination of the Earth's axis.
b) the relatively low uncompressed mean density of the Moon compared to that of the Earth and the existence of the lunar maria.
c) the relatively low uncompressed mean density of the Moon compared to that of the Earth and the similar composition of the Earth and lunar crusts and mantles.
d) the relatively low uncompressed mean density of the Moon compared to that of the Earth and the length of the lunar month.
e) the heavy cratering of the Moon, the lunar maria, and the chemical differentiation of the lunar material.

---

012 qmult 00900 1 5 5 easy thinking: lunar crater age

499. How can one tell if a large lunar crater is comparatively old or young?

a) An old crater has dry water channels flowing from the rim both outward to the surroundings and inward toward the crater center. Young craters formed after all the lunar water was gone and so have no dry water channels.
b) The older the crater, the more ice has accumulated in the crater center. The ice comes from water vapor that is released by comet impacts. The ice condenses in the cold crater centers. There have probably been hundreds of comet impacts since geological activity stopped on the Moon. The ice is **EASILY SEEN** from the Earth because of its high reflectivity.
c) The older the crater, the more ice has accumulated in the crater center. The ice comes from water vapor that is released by comet impacts. The ice condenses in the cold crater centers. There have probably been hundreds of comet impacts since geological activity stopped on the Moon. The ice is covered by regolith and is **NOT EASILY SEEN** from the Earth. The ice was detected in the 1990's by radar techniques and by studying the speed of neutron emission from the lunar surface. (Energetic solar wind particles cause the lunar surface to emit neutrons.)
d) The older the crater, the greener it looks.
e) The older the crater, the more heavily it itself tends to be cratered.

---

012 qmult 01200 2 1 4 moderate memory: regolith

500. Lunar regolith is lunar rock ground down to fragments and dust by:

a) volcanic action.

b) strong winds present on the early Moon.
c) the solar wind.
d) space weathering (mainly micrometeoritic impacts and fragmentation by the diurnal temperature cycling).
e) the cosmic microwave background (CMB).

---

012 qmult 01210 2 4 5 moderate deducto-memory: lunar sedimentary rock
501. The percentage of lunar surface rock that is **SEDIMENTARY** is:

a) 90 %. b) about 60 %. c) 20 %. d) about 10 % as far as we know. e) zero as far as we know.

---

012 qmult 01300 2 4 3 moderate deducto-memory: breccias on the Moon
502. A large fraction of lunar rocks are breccias. These are:

a) sedimentary rocks.
b) sedimentary rocks laid down in early lunar oceans.
c) rocks made of earlier rocks cemented together by heat and pressure.
d) rocks made of earlier rocks cemented together by ice.
e) rocks made of earlier rocks cemented together by cold and damp.

---

012 qmult 01310 2 4 1 moderate deducto-memory: roundness and cratering
503. Until about the middle of the 20th century most geologists thought the lunar craters were mostly volcanic. This was so because it was thought that impact craters:

a) could not be mostly so round as almost all lunar craters appeared to be.
b) had to be mostly so round as almost all lunar craters appeared to be.
c) could not be on top of mountains as almost all lunar craters appeared to be.
d) had to be on top of mountains as almost all lunar craters appeared to be.
e) had to be squarish unlike lunar craters.

---

012 qmult 01400 2 4 4 moderate deducto-memory: first humans on the Moon
504. Astronauts **FIRST** landed on the Moon in:

a) 1962. b) 1984. c) 1958. d) 1969. e) 1948.

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012 qmult 01500 2 4 4 moderate deducto-memory: last humans on the Moon
505. Astronauts **LAST** went to the Moon in:

a) 1992. b) 1984. c) 1958. d) 1972. e) 1948.

---

012 qmult 01600 2 4 4 moderate deducto-memory: crewed lunar landing period
506. The time period of the crewed lunar landings was:

a) 1962–1972. b) 1984–1992. c) 1958–1962. d) 1969–1972. e) 1948–1958.

---

012 qmult 01900 1 4 4 easy deducto-memory: fate of the Moon
507. In future gigayears, the Moon:

a) will have an eventful history with volcanism and outgassing. It will develop a dense CO_2 atmosphere and become like Venus is today.
b) will split into tiny fragments and become a ring around the Earth. The ring will be rocky, and so less bright than Saturn's icy ring.
c) will crash into the Earth. This will probably end life on Earth.
d) will continue to suffer slow space weather and occasionally large impacts. The Moon's appearance will probably change only slowly and it might look roughly much the same as it does now when the Sun in its red giant phase or its asymptotic giant branch (AGB) phase envelops and vaporizes the Moon along with the Earth.
e) will turn into green cheese finally and become Santa's new home after the north polar cap melts.

---

012 qmult 10100 1 1 3 easy memory: Mercury closest to the Sun

508. Mercury is:

a) the largest rocky (or terrestrial) planet. b) the least cratered rocky (or terrestrial) planet. c) the closest planet to the Sun. d) always the brightest planet visible from the Earth. e) the red planet.

---

012 qmult 10200 1 4 3 easy deducto-memory: Mercury's distance from Sun

509. The mean distance of Mercury from the Sun is:

a) 1.52 astronomical units. b) 1 astronomical unit. c) 0.39 astronomical units. d) 39.5 astronomical units. e) 0.97 astronomical units.

---

012 qmult 10210 1 4 2 easy deducto-memory: Mercury's size

510. Among the rocky (or terrestrial) planets, Mercury is:

a) largest. b) smallest. c) most massive. d) farthest from the Sun. e) reddest.

---

012 qmult 10220 1 4 3 easy deducto-memory: Mariner 10 to Mercury
Extra keywords: Messenger has come

511. The only spacecraft through year 2004 to obtain close-up images of Mercury is:

a) Apollo 11. b) Apollo 13. c) Mariner 10. d) Venus. e) Mars.

---

012 qmult 10230 1 4 5 easy deducto-memory: Mariner 10 to Mercury

512. "Let's play *Jeopardy*! For $100, the answer is: It is the only probe to have obtained close-up images of Mercury through year 2004."

What is ____________, Alex?

a) Apollo 11 b) the Jupiter 2 c) the Enterprise d) Santa 6 e) Mariner 10

---

012 qmult 10240 1 4 1 easy deducto-memory: mercury's 3:2 spin resonance

513. "Let's play *Jeopardy*! For $100, the answer is: This Solar System body has 3:2 spin-orbit resonance (i.e., rotates 3 times relative to the fixed stars for every two orbits) due to complicated gravitational effects."

What is ____________, Alex?

a) Mercury b) the Moon c) Io d) Charon e) Lead

---

012 qmult 10250 2 5 2 moderate thinking: Mercurian day

514. The ratio of Mercury's rotation period (period for one axis rotation) to its revolution period (period for one orbit around the Sun) is 2/3. Both these periods are relative to the fixed stars and both are counterclockwise when view from the north ecliptic pole. How long is the Mercurian (i.e., noon to noon period) in units of its revolution period? **HINT:** An orbital diagram with artificial mountain on Mercury might help.

a) 1 revolution period. b) 2 revolution periods. c) 3 revolution periods. d) 1/2 revolution periods. e) 1/3 revolution periods.

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012 qmult 10260 3 5 3 hard thinking: planet day in general

515. Have you ever wondered how you calculate the length of a planet's day given its revolution (or orbital) period and axial rotation period (i.e., axial rotation period relative to the fixed stars)? "Yes!" This your lucky day.

The easiest way to understand and set up the problem is take the origin on the planet and then the Sun revolves around the planet. Imagine line from the origin to the Sun and another line from the origin through a mountain on the planet. Take counterclockwise as the positive direction in the diagram you should have drawn by now. First, align the lines and then let time advance. When the lines come back into alignment, one planet day has passed. **HINT:** Draw a diagram.

Mathematically, one can relate the planet and Sun rotation rates and the time of one day for cases where the axial tilt from the perpendicular to the orbital plane is not extreme by

$$360^\circ = (\omega_{\rm pl} - \omega_\odot)t \ ,$$

where $\omega_{\rm pl}$ is the planet angular rotation rate, $\omega_\odot$ is the Sun angular rotation rate, and

$$t = \begin{cases} \text{planet day} & \text{if } \omega_{\rm pl} - \omega_\odot \geq 0; \\ -\text{planet day} & \text{if } \omega_{\rm pl} - \omega_\odot < 0. \end{cases}$$

The peculiar definition of t allows a compact general expression. Now

$$\omega_{\rm pl} = \frac{360^\circ}{P_{\rm pl}} \qquad \text{and} \qquad \omega_\odot = \frac{360^\circ}{P_\odot} \ ,$$

where the P's are not periods, but periods multiplied by +1 for counterclockwise rotation and −1 for clockwise: this peculiar definition of the P's also allows a compact general expression.

Find the general formula for t in terms of $P_{\rm pl}$ and $P_\odot$. What happens if $|P_{\rm pl}| << |P_\odot|$? What happens if $P_{\rm pl} = P_\odot$?

a) The general formula is

$$t = \frac{P_\odot - P_{\rm pl}}{P_\odot P_{\rm pl}} \ .$$

If $P_{\rm pl} << P_\odot$, then $t \approx 1/P_{\rm pl}$ and the day is the inverse of the rotational period. If $P_{\rm pl} = P_\odot$, the day is zero time in length.

b) The general formula is

$$t = P_{\rm pl} - P_\odot \ .$$

If $P_{\rm pl} << P_\odot$, then the day is negative and time flows backward. If $P_{\rm pl} = P_\odot$, the day is zero time in length.

c) The general formula is

$$t = \frac{P_\odot P_{\rm pl}}{P_\odot - P_{\rm pl}} \ .$$

If $P_{\rm pl} << P_\odot$, then $t \approx P_{\rm pl}$ and the day is almost the same length as the rotation period. If $P_{\rm pl} = P_\odot$, the day is infinitely long and the planet is synchronously tidally locked to the Sun.

d) The general formula is $t = P_{\rm pl}$ since the day always the same length as the planet rotation period. If $P_{\rm pl} << P_\odot$ or $P_{\rm pl} = P_\odot$, then still one has $t = P_{\rm pl}$.

e) The general formula is $t = P_\odot$ since the day always the same length as the Sun rotation period. If $P_{\rm pl} << P_\odot$ or $P_{\rm pl} = P_\odot$, then still one has $t = P_\odot$.

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012 qmult 10300 2 4 3 moderate deducto-memory: Mercury's iron content

516. Based on the theory of planet formation we would expect Mercury to be richer in **RELATIVE** iron abundance than:

a) Jupiter, but not Earth. b) icy planetesimals, but not Earth. c) Earth.
d) Earth, but not the Sun. e) Mars, but not the Sun.

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012 qmult 10400 1 4 4 easy deducto-memory: Mercury's atmosphere

517. Mercury has:

a) a thick, dry, carbon dioxide atmosphere.
b) a water vapor atmosphere which is thick enough to to cause clouds that are sometimes seen from Earth.

c) a thin, but nearly breathable, oxygen-nitrogen atmosphere.
d) almost no atmosphere.
e) a thick atmosphere of nearly transparent molecular hydrogen gas.

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012 qmult 10410 1 4 1 easy deducto-memory: Mercury's lava plains

518. Mercury has lava plains somewhat like the Moon's maria, but these Mercurian plains:

a) are not so dark and noticeable. b) cover all the Mercurian impact craters. c) are very much darker than the lunar maria. d) are green. e) are green because they are covered with vegetation.

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012 qmult 10500 2 4 2 moderate deducto-memory: weird terrain

519. "Let's play *Jeopardy*! For $100, the answer is: The focusing of siesmic waves at the antipodal point from Caloris Basin impactor impacted on Mercury is believed to have caused this geological feature at the antipodal point."

What is ____________, Alex?

a) an impact basin b) jumbled weird terrain c) a lobate scarp
d) a normal scarp e) a magnetic field

---

012 qmult 10600 2 4 4 moderate deducto-memory: Mercury's lobate scarps

520. Features that are prominent on Mercury, but are comparatively small and inconspicuous on the Moon, are:

a) giant lava-flooded impact basins such as the Orientale Basin. b) geysers. c) impact craters of tens of kilometers in diameter. d) lobate scarps that can stretch over hundreds of kilometers. e) volcanic craters.

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012 qmult 11000 3 1 3 tough memory: Mercury's rotation Doppler effect

521. The rotational period of Mercury was measured in 1965 by reflecting a radio pulse with a range of frequencies (i.e., a frequency band) off of Mercury's surface. But what physical effect allows the measurement of rotation from the reflection of a radio pulse that is sent with a particular intensity and frequency band?

a) The time interval for a pulse to return increases as a planet's rotation increases.
b) The intensity of a returning pulse decreases as a planet's rotation rate increases. This is caused by the Doppler effect.
c) The width of the frequency band of a returning pulse increases as a planet's rotation rate increases. This is caused by the Doppler effect.
d) A returning pulse is divided into three frequency bands if there is rotation. The size of the frequency difference between the bands increases as a planet's rotation rate increases. This is caused by the Doppler effect.
e) If there is rotation, a returning radio pulse makes a gobble-gobble sound.

Chapt. 12 Venus

Multiple-Choice Problems

013 qmult 00010 1 4 2 easy deducto-memory: Venus radius

522. Venus' radius is:

a) 0.01 Earth radii. b) 0.95 Earth radii. c) 11.2 Earth radii.
d) 100.2 Earth radii. e) 0.7233 AU.

013 qmult 00020 2 4 3 moderate deducto-memory: Venus rotation

523. The period for Venus' axial rotation relative to the observable universe is unusually long for planet (243.0226 days) and the rotation is retrograde (i.e., clockwise as viewed from the north ecliptic pole) which is unlike the other planets except Uranus. These unusual rotation characteristics may be due to:

c) a **SMALL** impactor that randomly altered the rotation characteristic imposed at formation. Those formation characteristics may have been more like those of Earth and Mars.
b) **SYNCHRONOUS TIDAL LOCKING** to the Sun. Recall the Venusian year (i.e., revolution period) relative to the fixed stars is 224.695 days.
c) a **GIANT** impactor that randomly altered the rotation characteristic imposed at formation. Those formation characteristics may have been more like those of Earth and Mars.
d) **NON-SYNCHRONOUS TIDAL LOCKING** to the Sun exactly like the tidal locking of Mercury to the Sun. Recall that the ratio of the Mercurian rotation period to Mercurian revolution period is 2/3 nearly exactly.
e) a gravitational perturbation by Jupiter.

013 qmult 00100 1 1 5 easy memory: Venus is hot

524. Compared to Earth's surface, the surface of Venus is:

a) cold. b) unbelievably cold. c) middling cold. d) lukewarm. e) hot.

013 qmult 00200 1 4 3 easy deducto-memory: Venus surface temperature

525. The surface of temperature of Venus is about:

a) 273.15 K. b) 15 K. c) 740 K. d) 15×10^6 K. e) 20° C.

013 qmult 00220 2 1 2 moderate memory: Venus seasons

526. Venus has virtually no seasons because:

a) of **SMALL** eccentricity and axis inclination, and **HIGHLY VARIABLE,** heat-transport-**INEFFICIENT** global atmospheric circulation.
b) of **SMALL** eccentricity and axis inclination, and **HIGHLY STABLE,** heat-transport-**EFFICIENT** global atmospheric circulation.
c) Venus is **CLOSER TO** the Sun than Earth.
d) of **LARGE** eccentricity and axis inclination, and **HIGHLY STABLE,** heat-transport-**EFFICIENT** global atmospheric circulation.
e) Venus is **FARTHER FROM** the Sun than Earth.

013 qmult 00300 1 1 2 easy memory: Venus atmosphere

527. Venus has a:

a) **THICK**, carbon-dioxide-**RICH** atmosphere, and so has virtually **NO** greenhouse effect.
b) **THICK**, carbon-dioxide-**RICH** atmosphere, and so has an **EXTREME** greenhouse effect.
c) **THIN**, carbon-dioxide-**POOR** atmosphere, and so has an **EXTREME** greenhouse effect.
d) **THIN**, carbon-dioxide-**POOR** atmosphere, and so has virtually **NO** greenhouse effect.
e) **THICK** carbon-dioxide-**POOR** atmosphere, and so has a **REVERSE** greenhouse effect: i.e., the surface is cooled far below what it would be if there were no atmosphere at all.

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013 qmult 00305 2 4 4 moderate deducto-memory: Venus atmosphere history

528. The super-dense, CO_2-dominated atmosphere of Venus (and consequently Venus' extreme greenhouse effect) developed because of continuing ____________ outgassing by volcanic activity and the ____________ of liquid water.

a) O_2; abundance b) N_2; abundance c) N_2; absence d) CO_2; absence
e) CO_2; abundance

---

013 qmult 00310 2 4 5 moderate deducto-memory: Venus illumination

529. The daytime illumination on the surface of Venus is ____________, because the ____________ light is strongly absorbed by the thick ____________-dominated atmosphere.

a) bluish; reddish; CO_2 b) bluish; reddish; N_2 c) orangy; bluish; water-vapor
d) orangy; bluish; N_2 e) orangy; bluish; CO_2

---

013 qmult 00320 2 4 2 moderate deducto-memory: Venus not red hot

530. The surface of Venus is very hot (i.e., about 470°C or 740 K). To the human eye, it is:

a) obviously red hot. b) not quite red hot at least not obviously so. Red hotness begins at about 500°C. c) blue hot. d) still many hundreds of degrees celsius below the temperature for being red hot. e) X-ray hot.

---

013 qmult 00500 2 4 1 moderate deducto-memory: Venus geological processes

531. Venus has:

a) **NO** liquid water erosion, **NO** micrometeoritic erosion, and **NO** evidence of full plate tectonics. Geological activity is mainly volcanic and tectonic due to **INTERNAL HEAT** with some wind erosion. But large-scale impactor geology (i.e., impactor cratering) is more important on Venus than on Earth because of the low level of erosion compared to the Earth and, perhaps, because of a lower level of internal-heat-driven geology.
b) **NO** liquid water erosion, **NO** micrometeoritic erosion, and **NO** evidence of full plate tectonics. There is **NO INTERNAL-HEAT-DRIVEN** geological activity at all. There is probably some solar tidal force geological activity and large impactors occasionally hit. Like the Moon and Mercury, Venus is nearly a dead world.
c) liquid water erosion, micrometeoritic erosion, and full plate tectonics. There is also **INTERNAL-HEAT-DRIVEN** geological activity. Except for the micrometeoritic erosion, Venus geology is **MUCH** like the Earth's.
d) liquid water erosion, micrometeoritic erosion, and full plate tectonics. There is also **INTERNAL-HEAT-DRIVEN** geological activity. Venus geology is **EXACTLY** like the Earth's.
e) no impact craters.

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013 qmult 00600 2 4 2 moderate deducto-memory: Venus and Earth similar?

532. Why might one expect Venus and Earth to be similar?

a) They are nearly at the same distance from the Sun.

b) They have nearly the same mass and mean density, and the difference in their distances from the Sun isn't huge.
c) Because Venus is closer to the Sun than Earth.
d) They have nearly the same color.
e) They have nearly the same rotation period relative to the Sun (i.e., day period).

---

013 qmult 00610 2 4 1 moderate deducto-memory: terrae of Venus
533. The terrae of Venus are:

a) uplands: they are perhaps similar to Earth's continents. b) lowlands: they are perhaps similar to Earth's continents. c) lowlands: they are perhaps similar to Earth's ocean basins. d) lowlands: they are perhaps similar to Earth's mid-ocean ridges. e) little Earths embedded in Venus' surface.

---

013 qmult 00620 2 4 2 moderate deducto-memory: Ishtar and Aphrodite
534. The Ishtar and Aphrodite are:

a) Venusian impact craters. b) Venusian terrae. c) Martian impact craters. d) Martian volcanoes. e) dear friends of Santa.

---

013 qmult 00700 2 4 5 moderate deducto-memory: Venus' craters
535. So far about 900 impact craters have been found on Venus by radar mapping. This is far more than on Earth, but far fewer than on the Moon. None of the discovered craters is smaller than about 3 km in diameter. Explain these facts.

a) The Venus surface is renewed more slowly than the Earth surface. This is perhaps because Venus **HAS** plate tectonics and water erosion. On the other hand, the Venus surface is renewed more quickly than the Moon surface since on the Moon geological activity is very slow and mostly due to impacts themselves. Thus Venus craters last longer than Earth craters, but not as long as Moon craters. This explains Venus' intermediate crater population. The lack of small impact craters is due to Venus' **LOCATION IN THE SOLAR SYSTEM**. Smaller impactors do not get closer to the Sun than the orbit of Earth.
b) The Venus surface is renewed more slowly than the Earth surface. This is perhaps because Venus **LACKS** full plate tectonics (as far as we know circa 2004) and water erosion. On the other hand, the Venus surface is renewed more quickly than the Moon surface since on the Moon geological activity is very slow and mostly due to impacts themselves. Thus Venus craters last longer than Earth craters, but not as long as Moon craters. This explains Venus' intermediate crater population. The lack of small impact craters is due to Venus' **LOCATION IN THE SOLAR SYSTEM**. Smaller impactors do not get closer to the Sun than the orbit of Earth.
c) Venus has fewer craters than the Moon and more than the Earth mainly because its intermediate size between Moon and Earth sizes. The small craters on Venus are mainly **FULLY FLOODED BY LIQUID WATER,** and so are not seen.
d) Venus formed **AFTER THE HEAVY BOMBARDMENT PHASE** of the Solar System ($\sim$ 4.6–3.8 billion years ago), and so missed most of the early cratering that the Moon and Mercury received. On the other hand, Venus has slower geological activity than the Earth, and so it has more craters than the Earth: the Earth's craters from the heavy bombardment have all been destroyed since then. The lack of small craters is caused by rapid **LIQUID WATER EROSION** on Venus that removes the small features first.
e) The Venus surface is renewed more slowly than the Earth surface. This is perhaps because Venus **LACKS** full plate tectonics (as far as we know circa 2004) and water erosion. On the other hand, the Venus surface is renewed more quickly than the Moon surface since on the Moon geological activity is very slow and mostly due to impacts themselves. Thus Venus craters last longer than Earth craters, but not as long as Moon craters. This explains Venus' intermediate crater population. The lack of small impact craters is probably due

to Venus' **THICK ATMOSPHERE**. Smaller impactors tend to burn up in the Venus atmosphere more than in the Earth atmosphere.

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013 qmult 00800 2 4 4 moderate deducto-memory: shield volcano

536. Shield volcanoes such ones finds on Venus, Earth, and Mars have slopes that:

a) rise very steeply. b) fall-off quickly into volcanic depressions. c) rise very steeply and are topped by impact craters. d) rise at very low angle (i.e., a low grade). e) fall-off quickly into a salt-water lake.

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013 qmult 00900 1 4 4 easy deducto-memory: Venus corona
Extra keywords: CM-168–169

537. "Let's play *Jeopardy*! For $100, the answer is: These geological features on Venus consist of raised or depressed roughly circular regions with circular and radial fractures: they have volcanoes on them and are sometimes flooded with lava. They are probably due to rising mantle plumes of magma."

What are ____________, Alex?

a) terrae b) maria c) tectonic plates d) coronas e) moons

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013 qmult 01000 2 4 4 moderate deducto-memory: Venusian magnetic field

538. Venus has no significant magnetic field. Although somewhat puzzling this lack is probably at least partially due to Venus':

a) abundant coronas. b) lack of coronas. c) very fast rotation rate. d) very slow rotation rate. e) very variable rotation rate.

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013 qmult 01100 1 4 3 easy deducto-memory: fate of Venus

539. The final fate of Venus is probably to:

a) collide with the Earth.
b) collide with Mars.
c) be evaporated in the Sun during a red giant phase in about 5 Gyr.
d) be evaporated in the Sun during a red giant phase in about 5 million years.
e) be left as cold rocky world with a cold CO_2 atmosphere and no internal heat. A layer of CO_2 ice might condense out on the surface. This will happen billions of years from now after the Sun has become a white dwarf star.

Chapt. 13 Mars: The Red Planet

Multiple-Choice Problems

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014 qmult 00100 1 4 1 easy deducto-memory: Mars order from Sun
540. Going outward from the Sun, Mars is the:

a) 4th planet. b) 3rd planet. c) 10th planet. d) 1st planet. e) 3rd and 5th planet.

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014 qmult 00110 1 4 4 easy deducto-memory: Mars' name
541. The planet Mars gets its name from:

a) a candy bar. b) Cinq-Mars, a close friend of Louis XIII. c) the Greek god of peace. d) the Roman god of war. e) Santa's chief elf.

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014 qmult 00200 1 4 5 easy deducto-memory: Mars discovery
542. Mars was discovered in:

a) 1610 by Galileo Galilei (1564–1642). b) 1655 by Christiaan Huygens (1629–1695). c) 1869 by Pietro Angelo Secchi (1818–1878). d) 1877 by Giovanni Schiaparelli (1835–1910). e) in prehistory by numerous persons no doubt.

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014 qmult 00300 1 5 1 easy thinking: Martian canals
543. The Martian canals:

a) were first widely introduced (but not first "discovered") by Giovanni Schiaparelli (1835–1910) in **1877** as explanations for features he saw on Mars. His Italian word *canale* (which does not necessarily imply artificial water channel in Italian) was misleadingly translated as canal in English. Percival Lowell (1855–1916) picked up the idea of canals and believed that they proved intelligent life on Mars. He mapped out the canals in detail using his Lowell Observatory in Flagstaff, Arizona. With the probable exception of Valles Marineris, all his canals were apparently illusions: one supposes artifacts of the eye trying to see shapes in unresolvable or barely resolvable markings.
b) were first widely introduced (but not first "discovered") by Giovanni Schiaparelli (1835–1910) in **1877** as explanations for features he saw on Mars. His Italian word *canale* (which does not necessarily imply artificial water channel in Italian) was misleadingly translated as canal in English. Percival Lowell in **1980** picked up the idea of canals and believed that they proved intelligent life on Mars. He mapped out the canals in detail using his Lowell Observatory in Flagstaff, Arizona. Despite the recent NASA probes to Mars showing no canals, Lowell still maintains the canals are really there. Supermarket tabloids thoroughly support him and ascribe NASA's contrary findings to government cover-up.
c) were first widely introduced (but not first "discovered") by H.G. Wells (1866–1946) in **1898** in his book *The War of the Worlds*. In that book they were the handiwork of intelligent Martian octopuses: evolution had made the Martians all brain and fingers. Wells's son Orson Welles (1915–1985) (who had Americanized his surname) based his Mars invasion Halloween radio show of 1938, *The War of the Worlds,* on his father's book. The radio show caused considerable panic (especially in New Jersey) among people who were perhaps

predisposed by various 20th century events to believe in remorseless, faceless invaders. In any case, in his later years Welles revealed that the canals had always been a hoax.

d) are now dry, but once they carried water from the polar caps to Valles Marineris which was then a long narrow sea. Although the canals are almost certainly natural, the idea that extinct Martians built them to supply water to their cities (Martian versions of Las Vegas) is still held by some noted scientists such a Percival Lowell, Orson Welles, and Liberace.

e) include the Suez, Panama, and Welland Canals.

---

014 qmult 00310 1 4 2 easy deducto-memory: Martian seasons

544. Mars has seasons principally because:

a) it is red. b) its axis is tilted by about 25° to the pole perpendicular to Mars' orbital plane. c) its orbit is super-highly elliptical. d) of its volcanoes. e) of its impact craters.

---

014 qmult 00312 1 4 4 easy deducto-memory: Mars size

545. The Mars' diameter in units of Earth's diameter is about:

a) 10. b) 5. c) 1. d) 1/2. e) 1/1000.

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014 qmult 00320 1 4 5 easy deducto-memory: Mars seasonal color variations

546. Briefly describe the seasonal color variations of one hemisphere of Mars' surface. (The basic color of Martian soil is reddish probably due to high iron oxide [rust] content).

a) In the spring, increasing warmth causes green **PLANT LIFE** to flourish and this plant life covers much of the red soil surface. Hence a hemisphere surface becomes greener in spring. In the fall, the plant life declines and the hemisphere surface becomes redder again.

b) In the spring, increasing warmth causes **PLANT LIFE** to change from red to green, greening the appearance of the surface of a hemisphere. In the fall, the plant life turns red again, reddening the appearance of the surface.

c) In the spring a hemisphere's white polar cap, which extends to the **EQUATOR** in winter, retreats leaving a red soil surface. In the fall, white polar cap grows back to the equator turning the hemisphere white again.

d) Dust storms cover some of the Martian surface with **GREEN DUST**. In the spring, apparently the winds strip away some of the dust leaving a **REDDER** soil surface. Thus a hemisphere appears greener in the winter and redder in the summer.

e) Dust storms tend to cover Martian surfaces with **RED DUST**. In the spring, apparently the winds strip away some of the dust. Some of the underlying surface is dark rather than red, and so the surface becomes darker in appearance when the dust is blown away. The darker surface appears greenish in comparison to the overall red of the Martian surface. Thus a hemisphere appears redder in the winter and greener in the summer.

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014 qmult 00330 1 4 3 easy deducto-memory: Martian geological features

547. On Mars:

a) Valles Marineris is an alluvial plain, Olympus Mons is a dry ocean, Syrtis Major is a large canal, and Hellas Planitia is a large impact basin.

b) Valles Marineris is a smile, Olympus Mons is a wart, Syrtis Major is a *Star Trek* character, and Hellas Planitia is a plantation.

c) Valles Marineris is a large canyon, Olympus Mons is a large volcano, Syrtis Major is a large dark region, and Hellas Planitia is a large impact basin.

d) Valles Marineris is a large volcano, Olympus Mons is a large canyon, Syrtis Major is a large impact basin, and Hellas Planitia is a large dark region.

e) Valles Marineris is a large impact basin, Olympus Mons is a large dark region, Syrtis Major is a large canyon, and Hellas Planitia is a large volcano.

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014 qmult 00400 1 4 4 easy deducto-memory: largest Martian volcano

548. The largest volcano on Mars and perhaps in the Solar System is:

a) Valles Marineris. b) Phobos. c) Ishtar Terra. d) Olympus Mons. e) Kitt Peak.

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014 qmult 00500 1 4 4 easy deducto-memory: Valles Marineris

549. Valles Marineris is a:

a) Hibernian bog.
b) small valley on Venus.
c) small valley on Mars that was probably formed by a huge river, now of course completely dry.
d) large valley on Mars that was probably formed by the Martian crust cracking and subsiding somehow.
e) large valley on Mars that was probably formed by a long drought early in Martian history.

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014 qmult 00600 1 1 3 easy memory: Mars and Venus different atmospheres

550. Venus and Mars have atmospheres which are 96 % and 95 % carbon dioxide (CO_2) by number, respectively. So why are the Venus and Mars atmospheres so different?

a) Venus' atmosphere has **SULFURIC ACID DROPLET CLOUDS** and Mars' atmosphere has clouds of **GREEN** dust.
b) Venus has no moons and almost no inclination of its rotation axis from the ecliptic pole. Mars has two moons and an axis inclination of about 25° from the perpendicular pole to its orbit.
c) The surface pressure of Venus is **ABOUT 90** times Earth's surface pressure: Mars' surface pressure is about a **HUNDRETH** of Earth's surface pressure. Thus, the CO_2 atmosphere of **VENUS** is much, much thicker than that of Mars.
d) The surface pressure of Venus is **ABOUT 1/90** times Earth's surface pressure: Mars' surface pressure is about a **HUNDRED TIMES** Earth's surface pressure. Thus, the CO_2 atmosphere of **MARS** is much, much thicker than that of **VENUS**.
e) The surface pressure of Venus is about the **SAME** as Earth's surface pressure: Mars' surface pressure is about a **HUNDRETH** of Earth's surface pressure. Thus, the CO_2 atmosphere of **VENUS** is much, much thicker than that of **MARS**.

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014 qmult 00700 3 4 2 tough deducto-memory: Martian polar ice caps

551. The Martian polar ice caps are:

a) possibly permanent **CARBON DIOXIDE** ice covered in winter by a layer of **WATER** ice. In the spring, the water ice layer **MELTS** and the water quickly evaporates. The carbon dioxide ice remains through the summer. Remember, at a given pressure, carbon dioxide ice **MELTS** at a higher temperature than water ice. In the fall, water vapor condenses on the polar caps again.
b) possibly permanent **WATER** ice covered in winter by a layer of **CARBON DIOXIDE** ice. In the spring, some or all of the carbon dioxide (all at the northern cap it seems) **SUBLIMES** (i.e., passes directly to gas phase): the atmospheric pressure on Mars is too low to for a liquid carbon dioxide phase to exist. In the fall, carbon dioxide condenses on the polar caps again.
c) possibly permanent **CARBON DIOXIDE** ice covered in winter by a layer of **WATER** ice. In the spring, the water ice **SUBLIMES** (i.e., passes directly to gas phase): the atmospheric pressure on Mars is too low to for a liquid water phase to exist. Remember, at a given pressure, carbon dioxide ice **SUBLIMES** at a higher temperature than water ice. In the fall, water vapor condenses on the polar caps again.
d) made of whitish rock.
e) ordinary water snow. They melt totally in the spring and then are reconstituted by large snow storms in the late fall and winter.

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014 qmult 00800 1 4 3 easy deducto-memory: recent gullies on Mars
Extra keywords: This question needs fixing up for Gwen's discoveries

552. "Let's play *Jeopardy*! For $100, the answer is: Analysis of these features has led to the conclusion that liquid water has flowed temporarily (perhaps for very brief periods) on Mars within geologically recent times."

What are ____________, Alex?

a) ocean basins b) tidal shoals c) gullies d) canals e) bathtubs

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014 qmult 00830 2 1 3 moderate memory: rain-fed run-off channels

553. Circa 2003, analysis of dendritic channels on Mars based on Mars Global Surveyor data led to the conclusion that in some cases at least these channels were very probably:

a) glacial melt ponds. b) glacial melt oceans. c) rain-fed run-off channels. d) rain-fed canals. e) snow-fed canals.

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014 qmult 00850 2 4 4 moderate deducto-memory: delta or distributary fan on Mars

554. "Let's play *Jeopardy*! For $100, the answer is: The discovery in 2003 of this feature on Mars proves that at some time in the past there was continuous liquid water flow on Mars."

What is a ____________, Alex?

a) glacier b) tidal shoal c) gully d) river delta or distributary fan (which is closely related to, but not the same thing as, a river delta) e) rotary fan (which was likely a river delta)

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014 qmult 00870 1 4 5 easy deducto-memory: flowing water on Mars

555. Why is it thought that there was once flowing liquid water on Mars?

a) The water ice at the **POLAR CAPS** suggests this.
b) The two kinds of dry channels found on Mars. The first kind are runoff-like channels which are meandering and dendritic (branchy), and are thought to have been rain-fed rivers. They are found in the old Martian highland and are perhaps older than 3.9 billion years. They are tens of meters in width and perhaps 10 to 20 km long. The second kind are the **MARTIAN CANALS** which also suggest that there was once intelligent life of on Mars.
c) The two kinds of dry channels found on Mars. The first kind are runoff-like channels which are meandering and dendritic (branchy), and are thought to have been rain-fed rivers. They are found in the old Martian highland and are perhaps older than 3.9 billion years. They are tens of meters in width and perhaps 10 to 20 km long. The second kind are the circular channels that are concentric around large impact craters. There are usually between 3 and 7 of these circular channels. It is hypothesized that they were constructed by the **MARTIANS** in order to make dart board patterns.
d) The two kinds of dry channels found on Mars. The first kind are runoff-like channels which are meandering and dendritic (branchy), and are thought to have been rain-fed rivers. They are found in the old Martian highland and are perhaps older than 3.9 billion years. They are tens of meters in width and perhaps 10 to 20 km long. The second kind are are called **OUTFLOW CHANNELS OR ARROYOS**. The largest are 10 km or more in width and hundreds of kilometers long. It is hypothesized that these outflow channels were produced **TECTONIC PLATES** grinding against each other. The liquid water in outflow channels was an inconsequential and inconspicuous later incident.
e) The three kinds of dry channels found on Mars. The first kind are runoff-like channels which are meandering and dendritic (branchy), and are thought to have been rain-fed rivers. They are found in the old Martian highland and are perhaps older than 3.9 billion years. They are tens of meters in width and perhaps 10 to 20 km long. The second kind are are called **OUTFLOW CHANNELS OR ARROYOS**. These are 10 km or more in width and hundreds of kilometers long. It is hypothesized that these outflow channels

were produced by **SUDDEN, LARGE FLOODS**. The floods occurred when an impact or volcano suddenly melted a large amount of frozen water in the soil (i.e., permafrost). The **THIRD KIND** are river delta formations. These formations are considered absolute proof that there was continuous liquid water flow on Mars at some time in its history.

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014 qmult 00900 2 4 5 moderate deducto-memory: Allan Hills 84001

556. "Let's play *Jeopardy*! For $100, the answer is: NASA researchers in 1996 proposed that this object possibly contained fossilized Martian microbes."

What is ____________, Alex?

a) Pathfinder b) Viking 1 c) Beagle 2 d) star Cary Grant 1904
e) meteorite Allan Hills 84001

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014 qmult 01000 1 4 2 easy deducto-memory: no Mars surface life

557. Why is life as we know it not possible (without some extreme adaptions) on the surface of present-day Mars?

a) The surface of Mars is relatively **UNPROTECTED** from sterilizing UV radiation because of its thin atmosphere which in particular has no UV-absorbing ozone layer. But there is, however, **PLENTY** of liquid water (which is necessary for life) in the deep bottoms craters where the atmospheric pressure is high.
b) First, the surface of Mars is relatively **UNPROTECTED** from sterilizing UV radiation because of its thin atmosphere which in particular has no UV-absorbing ozone layer. Second, liquid water (which is necessary for life as we know it) **CANNOT** exist for long on the Martian surface due to the low atmospheric pressure.
c) First, the surface of Mars is relatively **PROTECTED** from sterilizing UV radiation because of its thin atmosphere which in particular has no UV-absorbing ozone layer. Second, liquid water (which is necessary for life as we know it) **CANNOT** exist on the Martian surface due to the low atmospheric pressure.
d) First, the surface of Mars is relatively **PROTECTED** from sterilizing UV radiation because of its thin atmosphere which in particular has no UV-absorbing ozone layer. But there is, however, **PLENTY** of liquid water in the deep bottoms craters where the atmospheric pressure is high.
e) We've never found any life, so there isn't any.

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014 qmult 01100 2 4 4 moderate deducto-memory: Mars subsurface life

558. Life (as we know it) on Mars' surface appears impossible. It is speculated that subsurface life may exist. Why?

a) The Viking and Pathfinder probes detected abundant traces of **ORGANIC MOLECULES** when they drilled **SEVERAL HUNDREDS** of meters below the surface. Organic molecules are necessary for life, but are not sufficient evidence of it.
b) Below the surface the temperature is much **LOWER** and conditions much **DRYER,** and this would allow life to exist.
c) Below the surface there may be **SUFFICIENT WARMTH** from the Mars interior to sustain life. (Mars probably still has significant though it is insufficient for very obvious geological activity.) The heat and higher subsurface pressure could allow liquid water to exist (in rock pores), and liquid water is also needed for life. Additionally, below the surface, life would be protected from ultraviolet radiation. The **LACK** of any deep crustal life (i.e., life deeper than a few meters) on Earth, however, makes the idea of subsurface life on Mars very speculative.
d) Below the surface there may be **SUFFICIENT WARMTH** from the Mars interior to sustain life. (Mars probably still has significant though it is insufficient for very obvious geological activity.) The heat and higher subsurface pressure could allow liquid water to exist (in rock pores, etc.), and liquid water is also needed for life. Additionally, below

the surface, life would be protected from ultraviolet radiation. The **PRESENCE** of deep crustal life (i.e., life to down to perhaps a few kilometers: i.e., a deep biosphere) on Earth lends credence to the idea of subsurface Martian life. In fact, some people now wonder if subsurface life may the commonest form of life in the Universe.

e) The exo-biology people will grasp at any straw.

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014 qmult 02000 2 4 3 moderate deducto-memory: weathering to carbonate rock
Extra keywords: Rethink this question before you use it again.

559. The Urey (silicate-rock) weathering process can be important in determining the nature of planet atmospheres. Discuss how this process affects the atmospheres of Venus, Earth, and Mars.

a) The process causes **ATMOSPHERIC SULFURIC ACID** to be locked up in sedimentary rock. On Venus the process does not operate since it requires liquid water. Consequently, Venus has sulfuric acid droplet clouds, and thus cannot sustain life. On Earth the Urey weathering process is operative because of the abundant liquid water. Outgassing from volcanic activity keeps ejecting sulfuric acid into Earth's atmosphere, and so without the Urey weathering process life could not exist on Earth. The process does not happen on Mars despite the moderately abundant liquid water since there is no outgassing.

b) The process, which locks **ATMOSPHERIC CARBON DIOXIDE** (CO_2) up in sedimentary rock, requires liquid water to occur. On Venus, the liquid water was eliminated somehow and the process turned off. Volcanic outgassing then flooded (over hundreds of millions of years probably) the atmosphere with CO_2. An extreme greenhouse effect ensued. On Earth outgassing and the Urey weathering process both occur. Basically because of the two effects, the Earth atmosphere's CO_2 content has stayed at a level (but not a constant level) such that CO_2 along with water vapor have created a greenhouse effect sufficient to keep Earth comfortably warm for life over billions of years. Of course, CO_2 is also needed for photosynthesis. On Mars the Urey weathering process probably removed **ALL** CO_2 from the atmosphere after volcanic outgassing effectively stopped. Today Mars has only a **THIN NITROGEN ATMOSPHERE** and virtually no greenhouse effect. As a result the surface of Mars is too cold overall to sustain life.

c) The process, which locks **ATMOSPHERIC CARBON DIOXIDE** (CO_2) up in sedimentary rock, requires liquid water to occur. On Venus, the liquid water was eliminated somehow and the process turned off. Volcanic outgassing then flooded (over hundreds of millions of years probably) the atmosphere with CO_2. An extreme greenhouse effect ensued. On Earth outgassing and the Urey weathering process both occur. Basically because of the two effects, the Earth atmosphere's CO_2 content has stayed at a level (but not a constant level) such that CO_2 along with water vapor have created a greenhouse effect sufficient to keep Earth comfortably warm for life over billions of years. Of course, CO_2 is also needed for photosynthesis. On Mars the Urey weathering process may have removed **MUCH** of the CO_2 from the atmosphere after volcanic outgassing effectively stopped. Also the solar wind probably blew away some CO_2 (maybe a lot of CO_2) after Mars' supposed early magnetic field turned off. The magnetic field would have protected Mars' atmosphere from solar wind blasting. Today Mars has only a thin atmosphere **DOMINATED BY** $\mathbf{CO_2}$. There is a small greenhouse effect, but it is probably insufficient to keep the **SURFACE** warm enough overall for life as we know it. Moreover, liquid water is impossible on Mars because of the low atmospheric pressure and the lack of an ozone layer allows a lot of ultraviolet light to reach the surface. These are both negative factors for life (as we know it).

d) The process, which locks **ATMOSPHERIC SULFURIC ACID** up in sedimentary rock, requires liquid water to occur. Thus it does not occur on either Venus or Mars despite their **ABUNDANT** liquid water. But on Earth **ABSENCE** of liquid water causes the process to occur furiously.

e) The process causes **ATMOSPHERIC SULFURIC ACID** to be locked up into sedimentary rock. On Venus the process does not operate since it requires CO_2. Consequently, Venus has sulfuric acid droplet clouds and cannot sustain life. On Earth the Urey weathering process is operative because of the abundant CO_2. Outgassing from volcanic activity keeps ejecting sulfuric acid into Earth's atmosphere, and so without the Urey weathering process life could not exist on Earth. The process does not happen on Mars for two basic reasons: there is **NO** CO_2 and there is **NO** outgassing.

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014 qmult 03110 1 1 4 easy memory: Mars moons

560. The moons of Mars are:

a) Tycho and Kepler. b) Io and Europe. c) Titan and Iapetus.
d) Phobos and Deimos. e) Fear and Terror.

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014 qmult 03120 1 1 4 easy memory: Mars moons discovered

561. Mars' two moons were discovered in ____________. The larger one has a mean diameter of 22 km and the smaller one has a mean diameter of 12 km.

a) prehistory b) the 4th century BCE by Democritus (460?–370? BCE)
c) the 10th century by al-Sufi (903–986) d) 1877 by Asaph Hall (1829–1907)
e) 1992 by Fred Whipple (1906–2004)

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014 qmult 03200 1 4 3 easy deducto-memory: Mars moon shapes

562. Why are Mars' moons Phobos and Deimos so nonspherical?

a) Excessive cratering constantly stops the "spherizing" effect of gravity.
b) Volcanic effects continually distort their shapes.
c) Their mass is small, and thus their self-gravity is insufficient to force them to be spherical by overcoming the structural electromagnetic forces of their material and, perhaps, their centrifugal force due to their rotation.
d) Their mass is small, and thus their self-gravity is insufficient to force them to be spherical against the effect of the solar wind.
e) The tidal force of Mars has pulled them into football shapes.

---

014 qmult 03300 2 5 3 moderate thinking: Mars moons tidally locked

563. Mars' moons Phobos and Deimos are small, nonspherical bodies with triaxial dimensions in kilometers of about $27 \times 21.6 \times 18.8$ and $15 \times 12.2 \times 11$, respectively. Their mean distances from Mars center are 2.761 and 6.906 Mars radii (1.470 and 3.678 Earth radii). Their eccentricities are 0.015 and 0.0005. Their orbital periods and rotational periods are the same length: the periods for Phobos are 0.31891023 days and for Deimos are 1.2624407 days. They both orbit eastward. Because Phobos' orbital period is shorter than Mars' rotational period (1.02595675 days), Phobos rises west and sets east. Deimos rises east and sets west, but moves relatively slowly across the sky relative to a local sky coordinate system. The moons are probably captured asteroids. The exact sameness (on average) of moons's orbital and rotational periods shows that they are tidally locked to Mars. Why would this be expected?

a) Because of the strength of the solar wind.
b) They are close to Mars, and so Mars' tidal force is probably quite **STRONG**. Moreover, their small size meant that they probably had **INCREDIBLY HUGE ROTATIONAL KINETIC ENERGY** when they started orbiting Mars. The **MORE** the initial rotational kinetic energy, the easier it was to get rid of enough of it to have slowed them down to the tidally locked situation. Thus their probably huge initial rotational kinetic energy also helped tidal locking to occur.
c) They are close to Mars, and so Mars' tidal force is probably quite **STRONG**. Moreover, their small size meant that they probably had **LOW ROTATIONAL KINETIC ENERGY** when they started orbiting Mars, unless they were rotating incredibly quickly. The **LOWER** the initial rotational kinetic energy (provided it was greater than needed for tidally locking), the easier it was to get rid of enough of it to have slowed them down

to the tidally locked situation. If they had insufficient initial rotational kinetic energy for tidal locking, the Martian tidal force would have had to speed them up: but since they are small bodies, that added amount of rotational kinetic energy was probably relatively small. Thus because of their small size, it was probably relatively easy to change their rotational kinetic energy to just the amount needed for tidal locking.

d) They are close to Mars, and so Mars' tidal force is probably quite **WEAK**. Moreover, their small size meant that they probably had **INCREDIBLY HUGE ROTATIONAL KINETIC ENERGY** when they started orbiting Mars. The **MORE** the initial rotational kinetic energy, the easier it was to get rid of enough of it to have slowed them down to the tidally locked situation. Thus their probably huge initial rotational kinetic energy also helped tidal locking to occur.

e) They are close to Mars, and so Mars' tidal force is probably quite **WEAK**. Moreover, their small size meant that they probably had **LOW ROTATIONAL KINETIC ENERGY** when they started orbiting Mars, unless they were rotating incredibly quickly. The **LOWER** the initial rotational kinetic energy (provided it was greater than needed for tidally locking), the easier it was to get rid of enough of it to have slowed them down to the tidally locked situation. If they had insufficient initial rotational kinetic energy for tidal locking, the Martian tidal force would have had to speed them up: but since they are small bodies, that added amount of rotational kinetic energy was probably relatively small. Thus because of their small size, it was probably relatively easy to change their rotational kinetic energy to just the amount needed for tidal locking.

Chapt. 14 Gas Giant Planets

Multiple-Choice Problems

015 qmult 00100 1 4 4 easy deducto-memory: gas giant planets

564. "Let's play *Jeopardy*! For \$100, the answer is: These planets are:

 1) massive;
 2) powerful gravity sources;
 3) compartively low in density;
 4) in outer Solar System beyond 5 AU where it is generally pretty cold;
 5) have compositions dominated by hydrogen and helium;
 6) have extensive moon systems;
 7) have complex ring systems."

 What are the ____________, Alex?

 a) rocky planets b) Bullwinkle and Rocky c) Kuiper Belt objects d) gas giant or **JOVIAN** planets e) gas giant or **JOVIAL** planets

015 qmult 00110 1 4 2 easy deducto-memory: gas giant planet sizes

565. The gas giant planets in order of decreasing diameter are:

 a) Saturn, Jupiter, Uranus, Neptune. b) Jupiter, Saturn, Uranus, Neptune. c) Uranus, Neptune, Jupiter, Saturn. d) Jupiter, Saturn, Earth, Venus. e) Ganymede, Callisto, Io, Europa.

015 qmult 00200 1 1 1 easy memory: gas giant elements

566. The most abundant elements in the gas giants are

 a) hydrogen and helium. b) carbon and nitrogen. c) carbon and helium. d) silicon, oxygen, and iron. e) hydrogen and iron.

015 qmult 00300 2 1 3 moderate memory: gas giant moon formation

567. The moons of the gas giants probably mainly formed by two processes. One of these is formation from a miniature protoplanetary disk that formed around the gas giant. The other is:

 a) fission of material from the gas giant due to high rotation. The material then coalesced into moons.
 b) by giant impactors that knocked material off the gas giants. The material then coalesced into moons.
 c) gravitational capture of small bodies such as planetesimals, protoplanets, asteroids, icy bodies, and maybe comets.
 d) close encounters with passing stars that pulled material out of the planets. The material then coalesced into moons.
 e) ejection of material from giant volcanoes on the gas giants. The material then coalesced into moons.

015 qmult 00400 2 4 3 moderate deducto-memory: liquid metallic hydrogen

568. What is a substance does **NOT** ordinarily exist on Earth, but likely is a major component of Jupiter and Saturn and perhaps all the gas giants.

a) Molecular hydrogen gas. b) Helium gas. c) Liquid metallic hydrogen. d) Solid metallic hydrogen. e) Methane gas.

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015 qmult 00500 2 4 1 moderate deducto-memory: gas giant bands

569. The gas giant planet atmospheres exhibit a band structure because of ________________ from their ________ interiors combined with ____________ rotation.

a) convection; hot; rapid b) radiative transport of heat; hot; rapid c) convection; hot; slow d) radiative transport of heat; cold; slow e) radiative transport of heat; cold; slow

---

015 qmult 00600 1 4 3 easy deducto-memory: rings maintained

570. "Let's play *Jeopardy*! For $100, the answer is: These orbiting structures are maintained around planets because the planet tidal force is too strong to allow them to coalesce under their self gravity into moons."

What are ____________, Alex?

a) planets b) comets c) rings d) toroids e) clumps

---

015 qmult 00700 2 4 1 moderate deducto-memory: ring flatness

571. Why are the ring systems of the gas giants flat?

a) There is a **COLLISIONAL PROCESS** that eventually causes the ring particles to orbit in a disk and the alignment of the disk favored by the gravity of the oblate planet is alignment with the planet's **EQUATORIAL PLANE**.
b) There is a **COLLISIONAL PROCESS** that eventually causes the ring particles to orbit in a disk and the alignment of the disk favored by the gravity of the oblate planet is alignment with the planet's **POLAR PLANE**.
c) There is a **MAGNETIC PROCESS** that eventually causes the ring particles to orbit in a disk and the alignment of the disk favored by the gravity of the oblate planet is alignment with the planet's **EQUATORIAL PLANE**.
d) There is a **MAGNETIC PROCESS** that eventually causes the ring particles to orbit in a disk and the alignment of the disk favored by the gravity of the oblate planet is alignment with the planet's **POLAR PLANE**.
e) The tenth planet from the Sun, Planet X, gravitationally perturbs the rings particles into disk in the planet's **POLAR PLANE**.

---

015 qmult 00800 2 4 3 moderate deducto-memory: ring complexity

572. What is a major reason why the ring systems of the gas giants are so complex with knots and arcs, etc.?

a) The perfectly spherical shapes of the particles.
b) The cubical shapes of the particles.
c) Subtle gravitational perturbations by the gas giant moons.
d) Subtle magnetic perturbations by the gas giant moons.
e) The tenth planet from the Sun, Planet X, gravitationally perturbs the rings.

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015 qmult 00100 1 1 1 easy memory: Jupiter's order number

573. Jupiter is:

a) the fifth planet from the Sun. b) the fourth planet from the Sun.
c) the sixth planet from the Sun. d) a comet.
e) the tenth planet from the Sun. It is often called Planet X.

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015 qmult 00200 1 1 1 easy memory: Jupiter's order number and mass

574. In our Solar System, Jupiter is:

a) the **MOST** massive planet and the **FIFTH** planet from the Sun.
b) the **MOST** massive planet and the **SIXTH** planet from the Sun.
c) the **SECOND MOST** massive planet and the **FOURTH** planet from the Sun.
d) the **FIFTH MOST** massive planet and the **THIRD** planet from the Sun.
e) a large asteroid that crosses both the orbits of Mars and Earth. It represents a perennial hazard to all life on Earth.

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015 qmult 00300 1 1 3 easy memory: Jupiter impact craters
575. Jupiter's observable surface is:

a) **uncratered** by impacts because of its extreme **volcanic activity**.
b) **heavily impact cratered** because of its extreme **volcanic activity**.
c) **uncratered** by impacts because it is a **gas**.
d) **uncratered** by impacts because it is **solid**.
e) bright green cheese due to impact cratering.

---

015 qmult 00400 2 4 3 moderate deducto-memory: Jupiter composition
576. Jupiter's composition by mass is estimated to be dominated by:

a) methane (**90** percent) and ammonia (**9** percent).
b) carbon dioxide (**55** percent) and molecular nitrogen (**36** percent).
c) hydrogen in liquid molecular and liquid metallic form (**78** percent) and helium (**19** percent).
d) hydrogen in liquid molecular and metallic form (**19** percent) and helium (**78** percent).
e) methane (**9** percent) and ammonia (**90** percent).

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015 qmult 00500 2 4 3 moderate deducto-memory: Jupiter's colors
577. The source of Jupiter's colors (reds, browns, oranges, etc.):

a) is various forms of hydrogen and helium. b) is iodine. c) has not yet been determined. The source is probably trace chemicals of sort or another: perhaps organic molecules, sulfur, or phosphorus. d) is iron. e) is vegetation.

---

015 qmult 00600 1 4 1 easy deducto-memory: Jupiter's Great Red Spot
578. Jupiter's Great Red Spot is:

a) a long-lasting storm.
b) a remnant of the impacts of the cometary fragments of comet Shoemaker-Levy 9.
c) a red iceberg floating on molecular hydrogen gas.
d) a storm that has existed only a few years and will likely dissipate in another ten years or so.
e) actually on Saturn.

---

015 qmult 00700 1 4 2 easy deducto-memory: Jupiter's bands
579. On Jupiter the rising and sinking convective flows at the surface are:

a) organized into bright and dark bands that are **PERPENDICULAR** to the equator and meet at the poles.
b) organized into bright and dark bands that are **PARALLEL** to the equator.
c) organized into **GRANULES** and intergranule surroundings as on the Sun.
d) completely undetectable. Their existence is known only from modeling.
e) completely green in color.

---

015 qmult 00800 2 4 2 moderate deducto-memory: Jupiter's bands in detail
580. On Jupiter the rising and sinking convective flows at the surface are:

a) organized into bright and dark bands that are **PERPENDICULAR** to the equator and meet at the poles. The bright bands are the **HOT, HIGH-PRESSURE RISING GAS** and dark bands are **COOLER, LOW-PRESSURE SINKING GAS**. The dark bands are at lower elevation and receive less solar illumination.

b) organized into bright and dark bands that are **PARALLEL** to the equator. The bright bands are the **HOT, HIGH-PRESSURE RISING GAS** and dark bands are **COOLER, LOW-PRESSURE SINKING GAS**. The dark bands are at lower elevation and receive less solar illumination.

c) organized into bright and dark bands that are **PARALLEL** to the equator. The bright bands are the **COOLER, LOW-PRESSURE SINKING GAS** and dark bands are **HOT, HIGH-PRESSURE RISING GAS**. The dark bands are at lower elevation and receive less solar illumination.

d) organized into bright and dark bands that are **PERPENDICULAR** to the equator. The bright bands are the **COOLER, LOW-PRESSURE SINKING GAS** and dark bands are **HOT, HIGH-PRESSURE RISING GAS**. The dark bands are at lower elevation and receive less solar illumination.

e) completely green in color.

---

015 qmult 00900 2 4 4 moderate deducto-memory: Jupiter's radiation

581. Jupiter radiates:

a) about **100 TIMES** the energy it absorbs from the Sun. This energy comes from a cold hydrogen fusion in its center.

b) about **100 TIMES** the energy it absorbs from the Sun. Most of this energy comes from primordial heat from time of formation and radiogenic heat both stored in its interior.

c) about **2 TIMES** the energy it absorbs from the Sun. Most of this energy comes from primordial heat from time of formation and radiogenic heat both stored in its interior. The emitted radiation heats **Io,** and thus causes Io's extensive **VOLCANIC ACTIVITY**.

d) about **2 TIMES** the energy it absorbs from the Sun. Most of this energy comes from primordial heat from time of formation and radiogenic heat both stored in its interior.

e) about **4 TIMES** the energy it absorbs from the Sun. Most of this energy comes from primordial heat from time of formation and radiogenic heat both stored in its interior. The emitted radiation heats **Io,** and thus causes Io's extensive **VOLCANIC ACTIVITY**.

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015 qmult 01000 3 1 3 tough memory: Jupiter's magnetic field

582. Jupiter probably has a strong magnetic field because of the dynamo effect. Why should Jupiter have a strong dynamo effect? It rotates ____________ and probably has a deep convective layer of ____________.

a) rapidly; hydrogen ice b) rapidly; liquid molecular hydrogen c) rapidly; liquid metallic hydrogen d) slowly; helium oxide e) rapidly; helium oxide

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015 qmult 01100 1 4 1 easy deducto-memory: Galilean moons

583. The 4 Galilean moons of Jupiter are:

a) Callisto, Ganymede, Europa, Io. b) Callisto, Ares, Iolaus, Pseudolus. c) Callisto, Ganymede, Europa, Phobos. d) Callisto, Ganymede, Asia, Io. e) Callisto, Ganymede, Africa, Io.

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015 qmult 01200 1 4 4 easy deducto-memory: number of Jupiter moons

584. How many moons does Jupiter have?

a) 4 known moons circa 2011. There may be other undiscovered, small moons. The 4 moons are, of course, the Galilean satellites discovered by **REMBRANDT**.

b) 4 known moons circa 2011. There may be other undiscovered, small moons. The 4 moons are, of course, the Galilean satellites discovered by **GALILEO**.

c) 1001.

d) 63 known moons circa 2011. There may be other undiscovered, small moons.

e) 6 known moons circa 2011. These moons include the 4 Galilean satellites and the two small moons, **PHOBOS** and **DEIMOS**. There may be other undiscovered, small moons.

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015 qmult 01300 1 4 4 easy deducto-memory: Galilean moon orbital plane

585. The Galilean moons of Jupiter orbit more or less in a single plane probably because:

a) the early solar nebular magnetic field forced them to form in a plane.
b) of pure luck.
c) of pure bad luck.
d) they formed out of the disk of material that formed about the early Jupiter.
e) a passing giant protoplanet pulled them into a plane long after their formation.

---

015 qmult 01400 2 4 3 deducto-moderate memory: Galilean moon surfaces
Extra keywords: DON'T capitalize keywords here. Too messy looking.

586. The surfaces of the Jupiter's Galilean satellites can be summarized as follows:

a) Callisto (old dark icy), Ganymede (old dark icy in parts; newer icy in parts), Europa (sulfurous and volcanic), Io (**methane ice**).
b) **Triton** (methane ice), Ganymede (sulfurous icy), Europa (sulfurous and volcanic), Io (**methane ice**).
c) Callisto (old dark icy), Ganymede (old dark icy in parts; newer icy in parts), Europa (newer brighter icy), Io (**sulfurous and volcanic**).
d) **Triton** (old dark icy), Ganymede (old dark icy in parts; newer icy in parts), Europa (newer brighter icy), Io (**sulfurous and volcanic**).
e) Callisto (old dark icy), Ganymede (old dark icy in parts; newer icy in parts), Europa (newer brighter icy), Io (**iron oxide**).

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015 qmult 01500 1 4 5 easy deducto-memory: Io uncratered

587. Why has Io perhaps been especially heavily impacted for a Solar System body? Why is Io relatively uncratered by impacts compared to most Solar System moons?

a) It has perhaps been especially heavily impacted because of its **GREAT VOLCANIC ACTIVITY**. The closeness to Jupiter explains the lack of cratering.
b) It has perhaps been especially heavily impacted because **JUPITER'S STRONG GRAVITA-
TIONAL FIELD** attracts impactors. Io's **LIQUID SURFACE** cannot, of course, be cratered.
c) It has perhaps been especially heavily impacted because **JUPITER'S STRONG GRAVITATIONAL FIELD** attracts impactors. Io's **ICE SURFACE** cannot, of course, be cratered.
d) It has perhaps been especially heavily impacted because **JUPITER'S FAST ROTATION RATE** attracts impactors. Io's **SNOW SURFACE** cannot, of course, be cratered.
e) It has perhaps been especially heavily impacted because **JUPITER'S STRONG GRAVITATIONAL FIELD** attracts impactors. Io's **GREAT VOLCANIC ACTIVITY** constantly renews its surface and relatively quickly eliminates any traces of impacts.

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015 qmult 01600 2 4 4 moderate deducto-memory: Io's colors

588. The striking (garish?) colors of Io are caused by:

a) rainbows. b) molecular oxygen gas. c) volatile gases such as molecular hydrogen, helium, and water vapor. d) sulfur and sulfur compounds. e) orange-colored water ice.

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015 qmult 01700 2 4 2 moderate deducto-memory: Io's geology driver

589. The cause of Io's great geological activity is:

a) Jupiter's tidal force. Because of its **CIRCULAR ORBIT,** the tidal force continually flexes Io's interior leading to internal heating. The heat causes volcanism.
b) Jupiter's tidal force. Because of its **ECCENTRIC ORBIT,** the tidal force continually flexes Io's interior leading to internal heating. The heat causes volcanism.
c) the great flux of impactors attracted by Jupiter. The impactors plunge deeply into Io and cause **INTENSE SHOCK FORCES** that cause heat. The heat causes volcanism.
d) the great flux of impactors attracted by Jupiter. The impactors plunge deeply into Io and release **RADIOACTIVE MATERIAL**. The radioactive material decays and so generates heat. The heat causes volcanism.
e) **LEFTOVER INTERNAL HEAT** from the time of formation. The heat causes volcanism.

---

015 qmult 01800 2 4 2 moderate deducto-memory: Io's ejected matter

590. The volcanoes on Io eject a lot of:

a) carbon in various forms. b) sulfur in various forms. c) helium gas. d) molecular oxygen. e) sulfur dioxide ice crystals.

---

015 qmult 04000 2 4 2 moderate deducto-memory: Saturn's ring material

591. The Saturnian rings (i.e., the bright rings of Saturn) consist mainly of:

a) carbon in various forms.
b) **WATER ICE** chunks in a range of sizes from billiard ball size to house size. Their icy content makes the rings highly **REFLECTIVE** and this is a main reason why the Saturnian rings are so much brighter than other gas giant rings.
c) **HELIUM ICE** chunks in a range of sizes from billiard ball size to house size. Their icy content makes the rings highly **REFLECTIVE** and this is a main reason why the Saturnian rings are so much brighter than other gas giant rings.
d) **WATER ICE** chunks in a range of sizes from billiard ball size to house size. Their icy content makes the rings highly **LIGHT-ABSORBING** and this is a main reason why the Saturnian rings are so much brighter than other gas giant rings.
e) **HELIUM ICE** chunks in a range of sizes from billiard ball size to house size. Their icy content makes the rings highly **LIGHT-ABSORBING** and this is a main reason why the Saturnian rings are so much brighter than other gas giant rings.

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015 qmult 08000 1 4 4 easy deducto-memory: Cassini division

592. "Let's play *Jeopardy*! For $100, the answer is: It is an apparent gap in the rings of Saturn."

What is the ____________, Alex?

a) Verdi vacancy b) Vivaldi separation c) Puccini gap d) Cassini division e) Salieri split

Chapt. 15 Asteroids, Meteoroids, and Target Earth

Multiple-Choice Problems

016 qmult 00100 1 4 3 easy deducto-memory: meteor/oid/rite
Extra keywords: Do NOT capitalize the boldface words. It would look bad.

593. Let's get the terminology straight once and for all.

a) **METEORS** travel in space, **METEOROIDS** shoot in the sky, and **METEORITES** hit the Earth.
b) **METEOROIDS** travel in space, **METEORITES** shoot in the sky, and **METEORS** hit the Earth.
c) **METEOROIDS** travel in space, **METEORS** shoot in the sky, and **METEORITES** hit the Earth.
d) **METEOROLOGY** travels in space, **METEORLIGHTS** shoot in the sky, and **METEOREALIS** hits the Earth.
e) **METEOROLOGY** travels in space, **METEORLIGHTS** shoot in the sky, and **MONTREAL** hits the Earth.

016 qmult 00200 3 4 2 tough deducto-memory: carbonaceous chondrites

594. Carbonaceous chondrites are:

a) a tribe of Martians in Edgar Rice Burroughs' Mars novels. John Carter thought them hostile, but they were probably just indifferent.
b) a rare kind of stony meteorite. They are dark in appearance and contain a **large (by meteorite standards) amount of water and carbon compounds**. They may be made of material that since it was by formed by condensation and accretion out of the primordial Solar System nebula has never been over 500 K. The carbonaceous chondrites may be the most primitive solar-system objects of which we have samples. Consequently, they are of **great scientific interest**.
c) a rare kind of stony meteorite. They are dark in appearance and contain a **large (by meteorite standards) amount of water and carbon compounds.** They may be made of material that since it was by formed by condensation and accretion out of the primordial Solar System nebula has never been over 500 K. The carbonaceous chondrites may be the most primitive solar-system objects of which we have samples. They are of **no scientific interest,** but they are curiosities and are often made into jewelry.
d) a common kind of stony meteorite. They are **without volatiles** and probably formed from lava on asteroids. Although asteroids are too small to have retained enough formation heat or heat from slow-decaying radioactive isotopes for geological activity, fast decaying radioactive isotopes might have heated their interiors and caused melting before the heat could leak out by conduction. The culprit is thought to be ^{26}Al (aluminum-26) which decays to stable ^{26}Mg (magnesium-26) with a half-life of 0.717 Myr. This ^{26}Al could have caused volcanism as well as elemental differentiation.
e) black and white and read all over.

016 qmult 00300 1 4 4 easy deducto-memory: largest asteroid Ceres 1

595. The largest asteroid (i.e., non-comet minor planet confined within about the orbit of Jupiter) is:

a) Uranus. b) Io. c) Comet Halley. d) Ceres. e) Chicago.

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016 qmult 00400 1 4 5 easy deducto-memory: largest asteroid Ceres 2

596. The largest asteroid (i.e., non-comet minor planet confined within about the orbit of Jupiter) is:

a) Pluto. b) Pittsburgh. c) 1997 XF11 which will impact the Earth (near Pittsburgh) in 2028. d) Phobos. e) Ceres.

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016 qmult 00500 2 4 4 moderate deducto-memory: asteroid orbits
Extra keywords: Too hard to get certain data as of 2010.

597. Of order how many asteroids with known orbits are there?

a) 4 circa 2004. b) 10 circa 2004. c) 10 billion circa 2004. d) Between 200,000 and a million circa 2004. e) none.

---

016 qmult 00510 1 1 4 easy memory: asteroid size distribution

598. The size distribution of asteroids is given in the following table.

Table: Approximate Number of Asteroids N Larger than Mean Diameter D

D (km)	N	D (km)	N
900	1	10.0	10,000
500	3	5.0	90,000
300	6	3.0	X
200	28	1.0	750,000
100	200	0.5	2×10^6
50	600	0.3	4×10^6
30	1100	0.1	25×10^6

NOTE.—The numbers for diameters larger than 500 km are exact counts. The numbers for diameters larger than 300 km and 200 km are nearly exact counts. The only source of uncertainty is that the mean diameters of asteroids are a bit uncertain and asteroids near the diameter bin boundaries lines may be marginally in the wrong diameter bin. It is likely that all asteroids larger than about 100 km have been discovered, but the table only gives approximate numbers for the bins from 100 km down in mean diameter. As the mean diameter get smaller, the number of asteroids become more and more uncertain. The sources are Wikipedia articles *Asteroid* and *List of Notable Asteroids*. The asteroids are the small rocky bodies inward of about Jupiter's orbits that are not moons. Below about 10 meters in size scale, small bodies are considered meteroids rather than asteroids, but there seems to be no exact lower cut-off for asteroid mean diameter.

The **UNSPECIFIED** asteroid number X in the table must be:

a) 2. b) 20. c) 200. d) 200,000. e) 20×10^6.

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016 qmult 00600 1 4 3 moderate deducto-memory: asteroid origin

599. Asteroids (i.e., minor planets confined within about the orbit of Jupiter) are probably mainly:

a) icy planetesimals left over from the formation of the Solar System.
b) fragmented or unfragmented icy planetesimals or protoplanets left over from the formation of the Solar System.
c) fragmented or unfragmented rocky planetesimals or protoplanets left over from the formation of the Solar System.

d) star-like objects beyond the orbit of Pluto.
e) star-like objects closer to the Sun than the orbit of Mars.

---

016 qmult 00700 1 4 1 moderate deducto-memory: Asteroid Belt location
600. The Asteroid Belt is located:

a) between the orbits of Mars and Jupiter. b) between the orbits of Mercury and Venus. c) beyond the orbit of Pluto. d) inside the Sun. e) between the Sun and the orbit of Vulcan.

---

016 qmult 00710 1 4 2 easy deducto-memory: asteroid asymmetry
601. An asteroid less than 300 km in size scale:

a) must be spherical. b) can be asymmetric. c) must be cubical. d) must be green. e) must tetrahedral.

---

016 qmult 00800 3 3 4 tough math: meteoroid kinetic energy
602. The kinetic energy of a body of speed v and mass m is given by the formula

$$E_{\rm kin} = \frac{1}{2}mv^2 \ .$$

A typical meteoroid (a small body in space: it becomes a meteor in precise speech only when it penetrates the Earth's atmosphere) has a speed of order $30\,{\rm km/s} = 30,000\,{\rm m/s}$ relative to the Earth. Given that it has a mass of **1 g (note: 1 gram)**, what is the kinetic energy of this typical meteoroid? (Note that a 1 kg mass falling 1 m under the force of gravity near the Earth's surface acquires about 10 J of kinetic energy.)

a) 10 J. b) 4.5×10^8 J. c) 9×10^8 J. d) 4.5×10^5 J. e) 9×10^5 J.

---

016 qmult 00900 2 5 2 moderate thinking: asteroid discovery
603. The asteroids (i.e., minor planets confined within about the orbit of Jupiter) which were discovered early on are much larger than typical asteroids we discover today. Why?

a) The biggest asteroids are more easily resolved. Thus they were found first.
b) The biggest asteroids tend to reflect the most sunlight, and thus they are brighter and more obvious. Therefore they were found first.
c) The biggest asteroids are simply much more numerous. Thus, the odds are that the biggest asteroids would be discovered first.
d) The biggest asteroids were found first just by accident.
e) The biggest asteroids cause huge gravitational perturbations of Jupiter's orbit. Early 17th century mathematical astronomers were able to deduce the approximate positions of the biggest asteroids. Subsequent searches quickly found these bodies.

---

016 qmult 01000 2 4 2 moderate deducto-memory: asteroid radioactive
604. Why couldn't radioactive potassium-40 (^{40}K: half-life 1.251(3) Gyr), thorium-232 (^{232}Th: half-life 14.05 Gyr), uranium-235 (^{235}U: half-life 0.7038 Gyr) uranium-238 (^{238}U: half-life 4.468 Gyr) have melted the rocky planetesimals (which were the parent bodies for the asteroids) and caused them to chemically differentiate?

a) Because of their small size, the planetesimals will lose heat **SLOWLY** through their surface to space. Thus the heat from radioactive species with long half-lives cannot accumulate sufficiently to melt the planetesimals. It has been hypothesized that radioactive aluminum-26 (^{26}Al: half-life 0.717 Myr), which releases heat relatively quickly, accounts for heat accumulation sufficiently rapid to cause planetesimal melting.
b) Because of their small size, the planetesimals will lose heat **RAPIDLY** through their surface to space. Thus the heat from radioactive species with long half-lives cannot accumulate sufficiently to melt the planetesimals. It has been hypothesized that radioactive

aluminum (^{26}Al: half-life 0.717 Myr), which releases heat relatively quickly, accounts for heat accumulation sufficiently rapid to cause planetesimal melting.

c) None of these radioactive isotopes were contained in the material that formed the planetesimals in the Asteroid Belt area of the Solar System. The radioactive isotopes are all highly **NON-VOLATILE**, and so **ONLY** condensed in the **INNER REGION** of the Solar System where almost all the material got incorporated into rocky planets. The radioactive isotopes in the rocky planets, of course, help to melt and elementally differentiate them.

d) None of these radioactive isotopes were contained in the material that formed the planetesimals in the Asteroid Belt area of the Solar System. The radioactive isotopes are all highly **VOLATILE**, and so **ONLY** condensed in the **FAR OUTER REGION** of the Solar System where almost all the material got incorporated into Uranus, Neptune, and icy planetesimals (Pluto being considered the largest of these). The radioactive isotopes in these gas giant planets and icy planetesimals, of course, help to melt and elementally differentiate them.

e) There is no known reason why they couldn't have. That they didn't is a mystery.

---

016 qmult 01400 1 4 2 easy deducto-memory: Tunguska event

605. In 1908, an impactor (perhaps a small asteroid of order 30 m in scale) hit the Earth in:

a) Flagstaff, Arizona. b) the Tunguska region in Siberia. c) Sudbury, Ontario.
d) Oak Ridge, Tennessee. e) Chicxulub on the Yucatán Peninsula.

---

016 qmult 01500 1 4 5 easy deducto-memory: dinosauricidal Chicxulub

606. The supposed dinosauricidal impactor hit near:

a) the Tunguska region in Siberia. b) Flagstaff, Arizona. c) Sudbury, Ontario.
d) Oak Ridge, Tennessee. e) Chicxulub on the Yucatán Peninsula.

---

016 qmult 01510 1 4 3 easy deducto-memory: shoemaker-levy 9

607. "Let's play *Jeopardy*! For $100, the answer is: This fragmented comet impacted on Jupiter in 1994."

What is Comet ____________, Alex?

a) Tunguska b) Halley c) Shoemaker-Levy 9 d) Cobbler-Dam IX
e) Hale-Bopp

---

016 qmult 01600 2 4 3 easy deducto-memory: impactor cube-law

608. Why is a 100-meter diameter Earth-bound impactor much more worrisome than a 10-meter diameter one?

a) Mass and kinetic energy tend to be proportional to **DIAMETER**. The 100-meter impactor will thus tend to be ten times more devastating than the 10-meter one.

b) Mass and kinetic energy tend to be proportional to the **SQUARE OF DIAMETER**. The 100-meter impactor will thus tend to be a hundred times more devastating than the 10-meter one.

c) Mass and kinetic energy tend to be proportional to the **CUBE OF DIAMETER**. The 100-meter impactor will thus tend to be a thousand times more devastating than the 10-meter one.

d) It is not more worrisome. The bigger the impactor, the less effect on the target.

e) The smaller impactors always land in the oceans.

---

016 qmult 01700 1 4 1 easy deducto-memory: asteroid 1950 DA

609. "Let's play *Jeopardy*! For $100, the answer is: On date 2880 Mar16, this asteroid has a very small probabilty ($\sim 1/34000$ as of 2022) of making a continentally devastating impact on Earth."

What is ____________, Alex?

a) 1950 DA b) Ceres c) Shoemaker-Levy 9 d) Sedna e) Eros

---

016 qmult 03000 1 5 2 easy thinking: why support Spacewatch

610. Why might a person support the search by Spacewatch (or whoever) for Solar System bodies that could impact the Earth?

a) Never in human history has there been significant harm from an impact event. Annie Hodges of Sylacauga, Alabama in 1954 November was awoke from a nap by a meteorite coming through her roof and bouncing off her radio set and then her arm and leg. Probably it left nasty bruises. Wanda and Robert Donahue of Wethersfield, Connecticut in 1982 November (November is the cruelest month) were disturbed (while watching M*A*S*H) when a 3 kg meteorite came through their roof, bounced up into the attic, and came to rest under the dining room table. Michelle Knapp of Peekskill, New York in 1992 October woke up to find her 1980 Chevy Malibu (just bought from her grandmother) had its rear end smashed by a 1.5 kg meteorite that cratered the driveway. These and other impact events on the human condition, totaling 61 recorded incidents in the period $\sim$ 1790–1990, havn't amounted to much compared to other tribulations.

b) Although that the risk of significant harm is small, it is real. Tunguska-like events probably happen once a century or so (or maybe every two thousand years or so), but usually in oceans or relatively uninhabited and out-of-world locations. With the world more populated today and more connected, a Tunguska-like event with heard-of tragic consequences could happen any century. Widespread or global devastation events (as the Chicxulub event was supposed to have been) are extremely rare, but they can happen too. So it is probably worthwhile to support a modest public program to discover dangerous Solar System bodies. We could could prepare for them if needed. Still we'll probably never be able to protect our cars from Peekskill-like events.

c) To prevent ozone loss.

d) To prevent coffee stains.

e) For peace on Earth, goodwill toward humankind.

Chapt. 16 Pluto, Icy Bodies, Kuiper Belt, Oort Cloud, and Comets

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Multiple-Choice Problems

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017 qmult 00100 1 4 4 easy deducto-memory: Herschel Uranus

611. "Let's play *Jeopardy*! For \$100, the answer is: He/she discovered the planet Uranus."

Who is ____________, Alex?

a) Nicolaus Copernicus (1473–1543) b) Galileo Galilei (1564–1642) c) Isaac Newton (1643–1727) d) William Herschel (1738–1822) e) Caroline Herschel (1750–1848).

---

017 qmult 00200 1 4 4 easy deducto-memory: Neptune discovery

612. The existence and location of ____________ was predicted (with a certain amount of good luck) on the basis of deviations of the orbits of other planets before its observational discovery.

a) Vulcan. b) Mars. c) Uranus. d) Neptune. e) Pluto.

---

017 qmult 00300 1 4 4 easy deducto-memory: Pluto discovery

613. Pluto was discovered on 1930 February 18 by:

a) Percival Lowell (1855–1916). b) Henrietta Swan Leavitt (1868–1921). c) Edwin Hubble (1889–1953). d) Clyde Tombaugh (1906–1997). e) Fred Hoyle (1915–2001).

---

017 qmult 00310 1 4 1 easy deducto-memory: blink comparison

614. The actual method of Pluto's discovery was:

a) blink comparison of sky photographs taken at different times. b) radar ranging. c) just visual searching of the sky. d) by X-ray observations. e) by psychic power.

---

017 qmult 00320 2 4 2 moderate deducto-memory: Charon discovery

615. Pluto's moon, discovered 1978 July 2 by James Christy of the U.S. Naval Observatory, is called:

a) Sedna. b) Charon. c) Persephone. d) Dante. e) Virgil.

---

017 qmult 00330 1 1 4 easy memory: Pluto's distance

616. Pluto's mean distance from the Sun is about:

a) 0.39 AU. b) 1 AU. c) 1.52 AU. d) 39 AU. e) $100,000$ AU.

---

017 qmult 00390 1 1 5 easy deducto-memory: Pluto's planet status

617. Pluto's status is disputable because it is:

a) too far from the Sun. b) too close to the Sun. c) not a gas giant. d) a gas giant. e) probably just a very large Kuiper Belt object. Comparable or larger Kuiper Belt objects may be discovered.

---

017 qmult 01100 1 4 5 easy deducto-memory: icy body reservoirs

618. The Solar System seems to have two reservoirs of icy bodies from which comets originate:

a) Valles Marineris and Olympus Mons. b) Phobos and Deimos. c) Ishtar Terra and Aphrodite Terra. d) the Asteroid Belt and the rings of Saturn. e) the Kuiper Belt and the Oort Cloud.

---

017 qmult 01200 1 4 1 easy deducto-memory: Kuiper Belt

619. The Kuiper Belt is a reservoir of icy planetesimals. Some of these planetesimals it is believed become short-period comets. The Kuiper Belt is named for Gerard Kuiper, a Dutch astronomer, who proposed the existence of the reservoir in a 1951 paper. He seems to have been anticipated by Irish amateur astronomer Kenneth Edgeworth in the 1940's: the Irish think the Kuiper Belt should be named the Edgeworth-Kuiper Belt: some of us think that's too long-winded. The first Kuiper Belt object was discovered in 1992 September and, circa 2004 December, there about 840 known Kuiper Belt objects. These discovered Kuiper Belt objects range from $\sim$ 50–1500 km in length scale: the smaller ones arn't likely to be exactly spherical, and so the word diameter is not appropriate. Probably most Kuiper Belt objects smaller than this, but the small ones are hard to detect. The Kuiper Belt objects also fall into the category of:

a) Trans-Neptunian Objects (TNOs). b) Infra-Mercury Objects (IMOs). c) Sub-Lunar Objects (SLOs). d) Alpha Centauri Objects (ACOs). e) Lost Vega Objects (LVOs).

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017 qmult 01500 1 4 1 easy deducto-memory: Sedna

620. "Let's play *Jeopardy*! For \$100, the answer is: This trans-Neptunian object is named for the Inuit goddess of the underworld sea, aquatic mammals, and the dead."

a) What is ____________, Alex?

a) Sedna, discovered in 2003nov b) Quaoar, discovered in 2002 c) 1950 DA (asteroid 29075), discovered in 1950 d) Pluto's moon Charon, discovered in 1978 e) Alpha Centauri, discovered in 1996

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017 qmult 02000 1 4 5 easy deducto-memory: comet components

621. The usual main components of a comet (a comet in the inner solar system to be precise) are:

a) Callisto, Ganymede, Europa, and Io.
b) **small** metallic nucleus, **large** gas and dust coma (the comet head seen in sky), gas tail, and dust tail.
c) **large icy** (dirty icy) nucleus, **minute** gas and dust coma (the comet head seen in the sky), gas tail, and dust tail.
d) **small icy** (dirty icy) nucleus, **large** gas and dust coma (the comet head seen in the sky), gas tail, and large **Saturn-like dust ring**.
e) **small icy** (dirty icy) nucleus, **large** gas and dust coma (the comet head seen in the sky), gas tail, and dust tail.

Chapt. 17 Extrasolar Planets

Multiple-Choice Problems

018 qmult 00080 1 4 5 easy deducto-memory: number of extrasolar planets
Extra keywords: This question needs updating periodically.

622. As of 2004, the number of extrasolar planets known is about:

a) 10,000.
b) 10^6.
c) -3.
d) 0.
e) 110.

018 qmult 00100 1 4 3 easy deducto-memory: extrasolar planetary systems

623. Extrasolar planetary systems discovered so far:

a) are exactly like our Solar System.
b) have no planets.
c) have **MASSIVE JUPITER-SCALE PLANETS** with mean distances to their parent stars that range from as low as 0.1 AU to several AU and often have very eccentric orbits.
d) have **SMALL MERCURY-SCALE PLANETS** with mean distances to their parent stars that range from as low as 0.1 AU to several AU and often have very eccentric orbits.
e) have **EARTH-SIZE, INHABITED PLANETS** with mean distances to their parent stars that range from as low as 0.1 AU to several AU and often have very eccentric orbits.

018 qmult 00200 2 4 1 moderate deducto-memory: our Solar System typical

624. The Solar System:

a) may or may not be typical. The so-far discovered extrasolar planetary systems are rather different from ours, but they represent a biased sample in that our discovery technique favors finding **MASSIVE** planets that are **CLOSE** to their parent stars.
b) is typical as the so-far discovered extrasolar planetary systems show.
c) is absolutely untypical in the universe as the so-far discovered extrasolar planetary systems prove absolutely.
d) may or may not be typical. The so-far discovered extrasolar planetary systems are rather different from ours, but they represent a biased sample in that our discovery technique favors finding **TINY** planets that are **FAR** to their parent stars.
e) is unlike the so-far discovered extrasolar planetary systems, and therefore cannot exist.

Chapt. 18 Star Basics I

Multiple-Choice Problems

019 qmult 00100 1 4 1 easy deducto-memory: stars are hot gas spheres
Extra keywords: Sun-question

625. Stars are spheres:

a) of hot gas. b) with a core of solid iron and a hydrogen outer layer. c) with a core of liquid iron and a hydrogen outer layer. d) with a core of pure helium gas and a hydrogen outer layer. e) of hot rock.

019 qmult 00200 1 4 4 easy deducto-memory: solar composition
Extra keywords: Sun-question

626. The Sun's surface (i.e., photosphere) composition by mass (which approximates the average cosmic composition and is typical of non-ancient stars Population I stars) is, by a 2009 determination (which is very precise, but not necessarily as accurate):

a) 100 % helium.
b) 73.81 % hydrogen, 24.85 % nitrogen, and 20 % metals.
c) 73.81 % carbon, 24.85 % nitrogen, and 1.34 % metals.
d) 73.81 % hydrogen, 24.85 % helium, and 1.34 % metals.
e) 73.81 % helium, 24.85 % hydrogen, and 1.34 % metals.

019 qmult 00300 1 4 3 easy deducto-memory: stellar parallax defined 2
Extra keywords: CK-277-stellar parallax, CK-278-2, the definition is in ch-04

627. "Let's play *Jeopardy*! For $100, the answer is: The angular motion of stars on the sky as seen against the background of more distant stars due to the Earth's motion around the Sun."

What is ____________, Alex?

a) the Doppler shift b) planetary parallax c) stellar parallax
d) stellar paradox e) stellar motion

019 qmult 00310 1 1 1 easy memory: stellar parallax for distance
Extra keywords: CK-272,277

628. A sensible and straightforward surveyor's way of measuring the distance to a star is to use:

a) stellar parallax with the Earth-Sun distance as a baseline.
b) stellar parallax with the Earth-Moon distance as a baseline.
c) solar parallax with the Earth radius as a baseline.
d) solar parallax with the Earth-Sun distance as a baseline.
e) a tape measure.

019 qmult 00320 1 3 3 easy math: stellar parallax calculation 1, Van Maanen's star
Extra keywords: CK-278-12, Van Maanen's star

629. Van Maanen's star has a stellar parallax of 0.232 arcseconds. About how far away is this star?
Recall the distance formula for stellar parallax is

$$d_{\rm parsec} = \frac{1}{\theta_{\rm arcsecond}} ,$$

where $\theta_{\rm arcsecond}$ is the parallax angle in arcseconds and $d_{\rm parsec}$ is the distance in parsecs.

a) 0.232 pc. b) 1 pc. c) 4.3 pc. d) 2.32 pc. e) 10 pc.

---

019 qmult 00330 2 3 3 moderate math: stellar parallax calculation 2

630. If a star exhibits 0.5 arcseconds of stellar parallax using the Earth-Sun distance as a baseline (which is conventional), how far is the star in parsecs?

a) 0.5 pc. b) 1 pc. c) 2 pc. d) 4 pc. e) 10 pc.

---

019 qmult 00340 2 1 5 moderate memory: closest star to Earth , not Sun
Extra keywords: CK-277-2

631. The closest star to Earth (not counting the Sun) is ____________ at 1.30 pc (4.22 ly).

a) Barnard's Star b) Jeffery's Star c) Sirius A d) Alpha Centauri A
e) Proxima Centauri

---

019 qmult 00350 2 5 5 mod. thinking: increasing stellar parallaxes
Extra keywords: CK-279-18

632. If all the stellar parallaxes (i.e., parallax angles measured during a half revolution of the Sun) were **INCREASING** with time, this would mean that the stars were all:

a) getting smaller. b) moving away. c) getting dimmer. d) getting redder.
e) moving closer.

---

019 qmult 00352 2 5 2 mod. thinking: decreasing stellar parallaxes

633. If all the stellar parallaxes (i.e., parallax angles measured during a half revolution of the Sun) were **DECREASING** with time, this would mean that the stars were all:

a) getting smaller. b) moving away. c) getting intrinsically less luminous.
d) getting intrinsically redder. e) moving closer.

---

019 qmult 00400 2 1 5 moderate math: AU to parsec conversion
Extra keywords: CK-278-14

634. A dim star is located at about 2 million astronomical units from Earth. Recall $1\,\mathrm{AU} = 1.496 \times 10^{11}\,\mathrm{m}$ and $1\,\mathrm{pc} = 3.09 \times 10^{16}\,\mathrm{m}$. Approximately, what is the distance to the star in parsecs?

a) 1.5×10^{11} pc. b) 2×10^{6} pc. c) 3×10^{17} pc. d) 3 pc. e) 10 pc.

---

019 qmult 00500 1 1 3 easy memory: matter star-star collisions

635. In galaxy collisions, direct star-star collisions in which star matter impacts star matter occur:

a) for only about 10 % of stars in the colliding galaxies because interstellar distances are very large compared to star sizes. b) with high frequency. c) very rarely because interstellar distances are very large compared to star sizes. d) never: such collisions are physically impossible. e) for all stars in the colliding galaxies.

---

019 qmult 00510 1 1 2 easy memory: star gravitational interactions

636. Because gravity is a long-range, inverse-square-law force, significant gravitational interactions between two isolated stars (i.e., stars not in multiple star systems):

a) almost never occur. b) are relatively common. c) never occur. d) occur only when the star matter impacts on star matter. e) occur only when star matter does not impact on star matter.

---

019 qmult 00600 1 1 4 easy memory: luminosity defined 1
Extra keywords: CK-276,277, Sun-question

637. The total power of a star (i.e., energy output per unit time) is called:

a) brightness. b) rightness. c) lightness. d) luminosity. e) incandescence.

---

019 qmult 00602 1 1 3 easy memory: luminosity defined 2
Extra keywords: CK-276,277, Sun-question

638. A star's luminosity is its:

a) apparent magnitude. b) spectrum. c) total power (energy per unit time) in electromagnetic radiation. d) total power (energy per unit time) in neutrinos. e) incandescence.

---

019 qmult 00620 1 4 1 easy deducto-memory: range of star luminosities
Extra keywords: CK-277-3, FK-414

639. The brightest stars are of order ________ times more luminous than the Sun and the dimmest are of order ________ times the Sun's luminosity.

a) 10^6; 10^{-4} b) 1/2; 2 c) infinite; zero d) 10^{-4}; 10^6 e) 2; 1/2

---

019 qmult 00700 1 4 5 easy deducto-memory: flux defined
Extra keywords: Sun-question

640. "Let's play *Jeopardy*! For $100, the answer is: This is the energy per unit time per unit area **OR** the energy per unit time per unit area in some wavelength band **OR** the energy per unit time per unit area per unit wavelength (or frequency) from some light source (e.g., a star or the Sun)."

What is ____________, Alex?

a) fugue b) flow c) luminosity d) light e) flux

---

019 qmult 00710 1 1 4 easy memory: photometry defined
Extra keywords: CK-283,295

641. The light from astronomical bodies is often studied by observering their light flux in **BROAD** wavelength bands using colored filters. (The emission is usually reported in astronomical magnitudes, but one doesn't need to know that.) The study of emission in this way is called:

a) spectroscopy. b) optometry. c) trigonometry. d) photometry. e) geometry.

---

019 qmult 00800 2 1 5 mod memory: flux inverse-square behavior
Extra keywords: CK-276,277

642. The flux (energy per unit time per unit area perhaps in a wavelength band or per wavelength) of light from a star as a function of distance from the star in the absence of extinction by the interstellar medium obeys a/an:

a) inverse-cube law. b) reverse-cube law. c) gravity law. d) force law. e) inverse-square law.

---

019 qmult 00810 2 4 1 mod. deducto-memory: flux inverse-square law proof

643. "Let's play *Jeopardy*! For $100, the answer is: The inverse-square law describing how the light flux from a star decreases with distance is proven from **THIS** general physical principle when applied to a star and its surrounding vacuum space in a steady state condition."

What is the ____________, Alex?

a) conservation of energy principle b) cosmological principle
c) perfect cosmological principle d) relativity postulate
e) principle of energy equivalence

---

019 qmult 00820 2 1 3 easy memory: inverse-square law luminosity distances

644. If you knew the luminosity of a star, then it distance could be determined directly:

a) from its luminosity alone.

b) a measurement of its flux using the inverse-cube law.
c) a measurement of its flux using the inverse-square law.
d) a measurement of its flux using any inverse power formula.
e) in no known way.

---

019 qmult 00830 1 3 1 easy math: Earth-Sun luminosity distance
Extra keywords: this question can easily be solved by deduction

645. According to one standard reference, the solar luminosity $L_\odot = 3.846 \times 10^{26}\,\text{W}$ http://nssdc.gsfc.nasa.gov/planetary/factsheet/sunfact.html 2013 and the solar constant (i.e., the solar flux at the mean distance of the Earth) $f = 1367.6\,\text{W/m}^2$. Stellar luminosity L and flux f are related by the inverse-square law

$$f = \frac{L}{4\pi d^2} ,$$

where d is the distance from the center of the star to the location where f is measured. Solve for d analytically and then find mean Earth-Sun distance.

a) $d = \sqrt{L/(4\pi f)}$ and $d = 1.496 \times 10^{11}$ m. b) $d = \sqrt{L/f}$ and $d = 1.496 \times 10^{11}$ m.
c) $d = \sqrt{L}$ and $d = 1.496 \times 10^{2}$ m. d) $d = \sqrt{L/(4\pi f)}$ and $d = 1.496 \times 10^{2}$ m.
e) $d = \sqrt{1/f}$ and $d = 1.496 \times 10^{11}$ m.

---

019 qmult 00900 1 4 4 easy deducto-memory: distance ladder defined

646. "Let's play *Jeopardy*! For \$100, the answer is: This metaphorical expression is the name for the collection of distance measurement techniques used to establish cosmic distances on all scales."

What is the ____________, Alex?

a) Gandalf distaff b) distance formulation c) distance derivative
d) distance ladder e) distance scaling

---

019 qmult 00910 1 1 1 easy memory: 1st rung of distance ladder

647. The first rung of the distance ladder is uses the distance measurement technique of:

a) stellar parallax. b) spectroscopic parallax. c) Cepheids.
d) the Tully-Fisher relation. e) Type Ia supernovae.

---

019 qmult 06000 1 1 3 easy memory: faintest magnitude of antiquity
Extra keywords: CK-273

648. The ancient Greeks specified 6 stellar magnitudes. Which was the **FAINTEST**?

a) 2nd. b) 1st. c) 6th. d) 10th. e) 0th.

---

019 qmult 06010 1 1 2 easy memory: brightest magnitude of antiquity
Extra keywords: CK-273

649. The ancient Greeks specified 6 stellar magnitudes. Which was the **BRIGHTEST**?

a) 2nd. b) 1st. c) 6th. d) 10th. e) 0th.

---

019 qmult 06020 2 1 1 easy memory: a lot about magnitude system
Extra keywords: CK-273–276

650. You know a lot about the astronomical magnitude system if you know that:

a) the higher the magnitude the **FAINTER** the object, 5 magnitudes corresponds to a factor of **100** in brightness, and absolute magnitude is apparent magnitude at **10** parsecs.
b) the higher the magnitude the **FAINTER** the object, 5 magnitudes corresponds to a factor of **1** in brightness, and absolute magnitude is apparent magnitude at **10** parsecs.
c) the higher the magnitude the **BRIGHTER** the object, 5 magnitudes corresponds to a factor of **100** in brightness, and absolute magnitude is apparent magnitude at **10** parsecs.

d) the higher the magnitude the **FAINTER** the object, 5 magnitudes corresponds to a factor of **100** in brightness, and absolute magnitude is apparent magnitude at **1000** parsecs.
e) the higher the magnitude the **BRIGHTER** the object, 5 magnitudes corresponds to a factor of **1** in brightness, and absolute magnitude is apparent magnitude at **1000** parsecs.

---

019 qmult 06030 2 4 5 moderate deducto-memory: 1 magnitude difference
Extra keywords: CK-273

651. Star X is 2nd magnitude and star Y is 3rd magnitude. Thus:

a) X is 10 times brighter than Y. b) X is 10 times fainter than Y. c) X and Y are the same brightness. d) X and Y are in the Zodiac constellations. e) X is 2.512 times brighter than Y.

---

019 qmult 06040 3 4 2 hard deducto memory: 5 magnitudes
Extra keywords: CK-273

652. Five magnitudes is:

a) a) a factor of 2.512 in intensity, b) a factor of 100 in intensity, c) a factor of a 1000 in intensity.
d) the magnitude difference between the Sun and the Moon.
e) the magnitude difference between the Sun and Sirius.

---

019 qmult 06050 3 4 2 hard deducto-memory: 4 magnitudes

653. Four magnitudes is:

a) a factor of 2.512 in intensity.
b) more than a factor 2.512 and less than a factor of 100 in intensity.
c) a factor of a 1000 in intensity.
d) the magnitude difference between the Sun and the Moon.
e) the magnitude difference between the Sun and Sirius.

---

019 qmult 06060 2 4 4 moderate deducto-memory: apparent magnitude

654. If star X is 14 in apparent magnitude and star Y is 4 in apparent magnitude, which star is intrinsically more luminous (i.e., puts out more energy per unit time)?

a) Star X.
b) Star Y.
c) One cannot tell since the two stars could be orbiting each other.
d) One cannot tell since apparent magnitude is determined by distance as well as luminosity and the distances have not been specified.
e) They are obviously equally luminous.

---

019 qmult 06070 1 4 3 easy deducto-memory: Betelgeuse-Pollux
Extra keywords: CK-278-9

655. Betelgeuse (the eastern shoulder star of Orion) has apparent visual magnitude 0.45 and Pollux (the brightest star in Gemini) has apparent visual magnitude 1.16. Which of the two stars is brighter on the sky?

a) Neither. b) Pollux. c) Betelgeuse. d) Either. e) Sirius A.

Chapt. 19 Star Basics II

Multiple-Choice Problems

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020 qmult 00100 1 1 4 easy memory: stellar surface temperature
Extra keywords: CK-286,296

656. The surface (i.e., photosphere) temperature of an ordinary star can be determined from:

a) the shape of its **NON-BLACKBODY** spectrum (particularly the location of the peak).
b) an analysis of its **EMISSION** line spectrum.
c) no known means.
d) the shape of its approximately **BLACKBODY** spectrum (particularly the location of the peak) and/or an analysis of its **ABSORPTION** line spectrum.
e) thermometers.

---

020 qmult 00200 1 1 3 easy memory: spectral type temperature

657. The surface (i.e., photosphere) temperature of an ordinary star can be determined by:

a) measuring its mass. b) identifying its luminosity class.
c) identifying its spectral type. d) any means at all. e) no means.

---

020 qmult 00210 2 1 3 moderate memory: OBAFGKM spectral types
Extra keywords: CK-286,295

658. The main sequence spectral star types in descending effective temperature order are:

a) ABCDEFGHIJKLMNOP. b) OBIWANKEN. c) OBAFGKM.
d) OBGKMAF. e) OAGKMAO.

---

020 qmult 00220 1 4 4 easy deducto-memory: spectral subtypes

659. "Let's play *Jeopardy*! For $100, the answer is: Each stellar spectral types is divided into these subtypes."

What are ____________, Alex?

a) 0 Ia, Ib, II, III, IV, V, VI, VII b) Chico, Groucho, Gummo, Harpo, Karlo, Zeppo
c) Larry, Curly, and Moe d) $0, 1, 2, \ldots, 9$ e) a,b,c,d,e, . . . ,x,y,z

---

020 qmult 00230 1 4 5 easy deducto-memory: Sun spectral type
Extra keywords: CK-286

660. The Sun's spectral type is:

a) K2. b) red giant. c) A−. d) Z9. e) G2.

---

020 qmult 00300 2 4 2 moderate deducto memory: hydrogen line strength
Extra keywords: CK-285

661. The hydrogen Balmer lines in main sequence stars:

a) always increase in strength with increasing temperature.
b) are strongest at surface temperature of order $10,000\,\mathrm{K}$.
c) always decrease in strength with increasing temperature.
d) cannot be seen at all.

e) have constant strength with varying temperature.

---

020 qmult 00310 2 4 2 moderate deducto-memory: Balmer line colors

662. The approximate colors of the hydrogen Balmer lines Hα, Hβ, Hγ, and Hδ are, respectively:

a) blue-green, red, violet, and blue-violet. b) red, blue-green, blue-violet, and violet. c) red, white, blue, and mauve. d) rouge, mauve, lime, and tangerine. e) rot, nasal, grunge, and exhaust.

---

020 qmult 00400 1 4 5 easy deducto-memory: Hertzsprung-Russell diagram
Extra keywords: CK-295

663. "Let's play *Jeopardy*! For $100, the answer is: It is a plot of stellar luminosity (or absolute magnitude) versus star temperature (or spectral type)."

What is a ____________, Alex?

a) butterfly diagram b) Hertz-Avis (HA) diagram c) mass-luminosity diagram d) Feynman diagram e) Hertzsprung-Russell (HR) diagram

---

020 qmult 00410 1 1 2 easy memory: main sequence stars on HR diagram
Extra keywords: CK-287,295

664. Most obviously luminous stars, at least in stellar environments like that surrounding the Sun, burn hydrogen in their core and lie in a Hertzsprung-Russell (HR) diagram on a band called the:

a) horizontal branch. b) main sequence. c) sub-giant branch. d) asymptotic giant branch. e) secondary sequence.

---

020 qmult 00420 1 1 2 easy memory: main sequence curve on HR diagram
Extra keywords: CK-295

665. The main sequence on a Hertzsprung-Russell (HR) diagram is a curve (actually a narrow band) of ____________ luminosity with increasing ____________.

a) decreasing; surface temperature b) increasing; surface temperature c) constant; surface temperature d) increasing; hydrogen content e) decreasing; hydrogen content

---

020 qmult 00430 1 1 1 easy memory: star types on HR diagram

666. Main sequence stars, giants, supergiants, and white dwarfs all give rise to easily identifiable groups on a:

a) Hertzsprung-Russell (HR) diagram. b) butterfly diagram. c) Zipf plot. d) Harley-Davidson (HD) diagram. e) x-y diagram.

---

020 qmult 00500 2 4 4 moderate deducto-memory: HR diagram stellar radii

667. On a Hertzsprung-Russell diagram contours of constant radii run:

a) linearly **UPWARD** to the right. b) horizontally across the diagram. c) vertically up the diagram. d) linearly **DOWNWARD** to the right. e) in a spiral to the center.

---

020 qmult 00510 1 4 5 easy deducto-memory: resolving stars

668. Stars:

a) can always be resolved. b) can never be resolved. c) usually cannot be resolved, but with special techniques remote, small ones can be. d) usually are resolved. e) usually cannot be resolved, but with special techniques close, large ones can be.

---

020 qmult 00600 1 1 4 easy memory: luminosity classes
Extra keywords: CK-288,295

669. The luminosity classes of stars are:

a) Chico, Groucho, Gummo, Harpo, Karlo, Zeppo. b) bright, very bright, super-bright, unbelievable. c) 1, 2, 3, 4, 5, 6. d) 0, Ia, Ib, II, III, IV, V, VI, VII. e) OBAFGKM.

---

020 qmult 00610 2 1 4 moderate memory: hypergiant luminosity class
Extra keywords: CK-288,289,296

670. They are the most luminous stars (i.e., luminosities of order $10^6\,L_\odot$) and put in luminosity class 0. They are called:

a) giants. b) dwarfs. c) horizontal branch stars. d) hypergiants. e) red dwarfs.

---

020 qmult 00620 2 4 2 easy deducto-memory: white dwarf luminosity class VII

671. "Let's play *Jeopardy*! For $100, the answer is: These objects appear on Hertzsprung-Russell diagrams and they are assigned a luminosity class VII."

What are ____________, Alex?

a) hypergiants b) white dwarfs c) black holes d) green giants
e) green dwarfs

---

020 qmult 00700 1 4 4 easy deducto-memory: mass-luminosity relation: main sequence
Extra keywords: CK-296-11

672. "Let's play *Jeopardy*! For $100, the answer is: They are the kind of stars to which the mass-luminosity relation applies."

What are ____________ stars, Alex?

a) supergiant b) red giant c) red dwarf d) main-sequence e) Hollywood

---

020 qmult 00710 1 1 1 easy memory: mass-luminosity relation behavior for mass ranges

673. On a log-log plot, the mass-luminosity relation for four mass ranges approximates a:

a) straight line that increases with mass. b) horizontal line. c) vertical line. d) quadratic curve. e) straight line that decreases with mass.

---

020 qmult 00800 1 4 1 easy deducto-memory: binary system
Extra keywords: CK-295

674. Two stars gravitationally bound to each other and orbiting their mutual center of mass constitute a:

a) binary star system. b) triple star system. c) single star. d) galaxy.
e) universe.

---

020 qmult 00810 1 4 2 easy deducto-memory: close binary system
Extra keywords: CK-295

675. The evolution of stars in a close binary systems have additional complexity beyond single single star systems because the binary stars:

a) are always very massive. b) can interact. c) are unbound gravitationally. d) are always very far apart. e) cannot interact.

---

020 qmult 00820 1 4 3 easy deducto-memory: open clusters

676. "Let's play *Jeopardy*! For $100, the answer is: These are loosely-bound, irregularly-shaped groups of stars consisting of order 100 to 1000 stars and having size scales of order 4 to 20 pc."

What are ____________, Alex?

a) singles b) binaries c) open clusters d) globular clusters e) galaxies

---

020 qmult 00830 1 4 5 easy deducto-memory: Pleiades

677. "Let's play *Jeopardy*! For \$100, the answer is: A physical group of stars in the constellation Taurus, sometimes called the Seven Sisters or, in Japan, Subaru, of which at least 7 stars (which are the Seven Sisters) are usually readily visible to the naked eye under reasonably good seeing conditions."

What are the ____________, Alex?

a) Toyotas b) Wives of Chauntecleer c) Brides of Dracula d) Hyades e) Pleiades

---

020 qmult 00840 1 4 3 easy deducto-memory: star associations

678. "Let's play *Jeopardy*! For \$100, the answer is: These are structures of a few to a few hundred stars and span of order 10 to 100 pc. They are generally gravitationally unbound though gravitationally interacting."

What are ____________, Alex?

a) singles b) binaries c) associations d) globular clusters e) galaxies

---

020 qmult 00860 1 4 4 easy deducto-memory: globular clusters

679. "Let's play *Jeopardy*! For \$100, the answer is: These are compact, dense, spherical, gravitationally-bound systems of stars. They can have from of order 20,000 to several million stars and their central concentrations have diameters of order to 5 to 25 pc.

What are ____________, Alex?

a) singles b) binaries c) associations d) globular clusters e) galaxies

---

020 qmult 00870 1 1 1 easy memory: globular cluster ages

680. The ages of globular clusters put a lower limit on the age of the observable universe. The calculated ages of globular clusters do have a range, but typically are about:

a) 12.5 Gyr. b) 12.5 million years. c) 100 million years. d) 4.6 Gyr. e) zero.

---

020 qmult 00900 1 1 1 easy memory: Population I and II

681. Although there is in fact a continuum of star ages and metallicities, the distribution of core-hydrogen-burning stars for convenience breaks two main groups: 1) relatively young and metal rich (metallicity of order mass fraction 0.001–0.03) and 2) relatively old and metal poor (typical metallicity of order mass fraction $\lesssim 0.001$, but going down to as low as mass fraction $\lesssim 10^{-6}$). These two groups are called, respectively:

a) Population I and Population II. b) Population A and Population B. c) dwarfs and giants. d) white dwarfs and red giants. e) giants and supergiants.

---

020 qmult 00920 1 4 5 easy deducto-memory: Population III stars

682. "Let's play *Jeopardy*! For \$100, the answer is: These stars with very nearly zero metallicity are either exceedingly rare or non-existent in the present-day observable universe."

What are ____________, Alex?

a) white dwarfs b) red giants c) Population I stars d) Baade stars e) Population III stars

Chapt. 20 Star Formation

Multiple-Choice Problems

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021 qmult 00100 1 4 2 easy deducto-memory: life history of Sun
Extra keywords: Sunlife
683. The life history of our own star, the Sun, is known to us by:

a) direct observations of all of its stages.
b) direct observations of its current stage plus observations of other stars in all their stages and modeling.
c) direct observations of most of its stages plus observations of other stars in all their stages and modeling.
d) modeling alone.
e) sheer guesswork.

---

021 qmult 00110 1 4 3 easy deducto-memory: life history of stars
Extra keywords: Sunlife
684. The life history of stars is known to us by:

a) direct observations of the evolution of individual stars from the beginning of formation to final demise.
b) direct observations of the evolution of individual stars from the beginning of formation to final demise plus modeling.
c) direct observations of many stars at different stages of their evolution, some episodes of rapid individual star evolution, and modeling.
d) modeling alone.
e) sheer guesswork.

---

021 qmult 00200 1 1 4 easy memory: interstellar medium (ISM) defined 1
Extra keywords: CK-299,321, Sunlife
685. The interstellar medium (ISM) consists of:

a) planets. b) molecular clouds only. c) stars. d) gas and dust.
e) dust only.

---

021 qmult 00210 1 1 4 easy memory: interstellar medium (ISM) defined 2
Extra keywords: CK-299,321, Sunlife
686. Gas and dust in the space inside galaxies is:

a) made of antimatter. b) completely negligible for all purposes.
c) the intergalactic medium (IGM). d) the interstellar medium (ISM).
e) completely invisible.

---

021 qmult 00310 1 4 5 easy deducto-memory: nebula defined
Extra keywords: CK-302,321, Sunlife
687. In modern astronomy, a nebula (plural nebulae) is a:

a) another name for a galaxy b) large main sequence star. c) small main sequence star. d) bright star. e) cloud of a gas in space.

---

021 qmult 00320 1 1 5 easy memory: molecular cloud and stars
Extra keywords: CK-321, Sunlife

688. The dense, cold component of the interstellar medium from which stars are believed to form is made of:

a) H II (ionized hydrogen) regions. b) white dwarfs. c) protostars. d) Lyman-Alpha forests. e) molecular clouds.

---

021 qmult 00330 2 1 5 moderate memory: molecular cloud composition
Extra keywords: CK-300, Sunlife

689. The composition of molecular clouds in the interstellar medium is dominated by:

a) carbon dioxide. b) molecular oxygen only. c) helium gas only.
d) amino acids. e) molecular hydrogen gas and helium gas.

---

021 qmult 00410 3 4 1 tough deducto-memory: molecular clouds and their dust
Extra keywords: Sunlife , long question

690. Molecular clouds are probably about 1 per cent dust by mass.

a) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
b) The dust is **VERY IMPORTANT** to these clouds. It is **COMPLETELY TRANSPARENT** to visible and ultraviolet light, and allows plenty of hard electromagnetic radiation into the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
c) The dust is **COMPLETELY UNIMPORTANT** to these clouds. True, the dust is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless, there are plenty of molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.
d) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless, there are plenty of molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.
e) The presence of this dust is just coincidental. It just happens that where there is dust there are molecular clouds, and where there is no dust there arn't. Things could be entirely otherwise; they just arn't.

---

021 qmult 00420 2 4 3 moderate deducto-memory: molecular cloud dust described

Extra keywords: Sunlife

691. Interstellar dust probably varies widely in composition, size scale, and structure. But there some ideas about typical dust that are generally accepted.

a) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **VOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **NONVOLATILES** condense out on the cores.

b) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.

c) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **NONVOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **VOLATILES** condense out on the cores.

d) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.

e) The dust is found under sofas and on other untouched surfaces. It gets there by settling out the air. One often sees dust in air the reflecting bright sunlight.

---

021 qmult 00510 1 4 5 easy deducto-memory: movement on HR diagram

Extra keywords: CK-322-12

692. "Let's play *Jeopardy*! For \$100, the answer is: It happens whenever a star changes its luminosity and/or its surface temperature."

What is ____________, Alex?

a) explodes b) collapses c) turns green d) becomes a white dwarf
e) movement on the Hertzsprung-Russell (HR) diagram

---

021 qmult 00610 2 4 1 moderate deducto-memory: star formation triggers
Extra keywords: CK-302, Sunlife

693. Star formation in a dusty molecular cloud probably requires some triggering event to initiate the collapse to dense cores that will become stars. Two possible trigger mechanisms are:

a) **SUPERNOVAE** which compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.
b) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.
c) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **PROTOSTAR-PROTOSTAR COLLISIONS** which also compress the molecular clouds.
d) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.
e) **WHITE HOBBITS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.

---

021 qmult 00710 2 4 2 moderate deducto-memory: free-fall molecular cloud
Extra keywords: Sunlife

694. In a **FREE-FALL** contraction of part of molecular cloud:

a) the part starts fall to toward a high density point because of gravitational attraction. Pressure forces slow the fall from the beginning.
b) the part starts fall to toward a high density point because of gravitational attraction. Pressure forces are negligible in slowing the fall because it is a free-fall contraction.
c) the entire molecular cloud collapses to form a black hole.
d) the part collapses to form a black hole.
e) planetesimals collide and break apart.

---

021 qmult 00720 1 4 1 easy deducto-memory: dense core defined sort of
Extra keywords: CK-303,321, Sunlife

695. The collapsing dense regions that develop into stars and initially have temperatures of order 10 K are called:

a) dense cores. b) dilute cores. c) main sequence stars. d) white dwarfs.
e) rotten cores.

---

021 qmult 00800 2 4 3 moderate deducto-memory: protostar defined
Extra keywords: CK-303 but no mention of IR part, Sunlife

696. A protostar is sometimes conveniently defined to be a:

a) star that can no longer burn hydrogen to produce heat energy.
b) white dwarf.
c) dense core of gas contracting to become a star that is hot enough to radiate in the infrared, but not yet sufficiently hot for nuclear burning.
d) molecular cloud that will become a star.
e) giant molecular cloud that will become a star.

---

021 qmult 00810 2 4 2 moderate deducto-memory: protostar contraction 1
Extra keywords: FK-451 agree with this, Sunlife

697. The contraction of a protostar is halted eventually by:

a) the thermal energy generated by the contraction which **DECREASES** the gas pressure inside the protostar.
b) the heat generated by the turning on of nuclear burning which **INCREASES** the gas pressure inside the protostar.
c) the action of magnetic fields.

d) the action of the dynamo effect.
e) the thermal energy generated by the contraction which **INCREASES** the gas pressure inside the protostar.

---

021 qmult 00812 2 4 4 moderate deducto-memory: protostar contraction 2
Extra keywords: CK-304, FK-451, Sunlife

698. After a young star starts nuclear burning, it:

a) stops contracting and explodes. b) collapses. c) becomes violently unstable. d) stops contracting and achieves hydrostatic equilibrium. e) cools off to near absolute zero temperature.

---

021 qmult 01000 1 4 2 easy deducto memory: H II region defined
Extra keywords: CK-307,321,322-3

699. Star formation in giant molecular clouds often results in the formation of OB associations: collections of hot, bright OB stars that ionize the surrounding molecular cloud and evaporate dust because of their strong ultraviolet emission. The gas region ionized by an OB associations is called a/an:

a) small molecular cloud. b) H II region. c) black hole. d) dark dusty molecular cloud. e) giant molecular clouds.

---

021 qmult 01500 1 4 3 easy deducto-memory: disk defined
Extra keywords: Sunlife

700. "Let's play *Jeopardy*! For $100, the answer is: They are relatively thin, round objects consisting of gas and/or dust and/or particles: the material goes around some large astro-body in nearly circular orbits of varying radii in the same direction."

What are ____________, Alex?

a) CDs b) planets c) disks d) satellites e) projectiles

---

021 qmult 01510 2 4 2 moderate deducto-memory: disk formation frequency
Extra keywords: CK-304, Sunlife

701. Disk formation is:

a) a unique event that happened only in the case of the formation of the Sun.
b) a common event in star formation as far as astronomers can tell.
c) a process in nuclear burning.
d) never observed in star formation.
e) responsible for the heating up of the protostar.

---

021 qmult 01512 3 5 2 hard thinking: disk formation 1
Extra keywords: seems ok now

702. Disk formation is believed to happen fairly generally:

a) in star formation, in the formation of accretion disks about putative black holes, and in the **FORMATION OF SPIRAL GALAXIES**. In the case of black holes, matter is **SPRAYED OUT** of the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk.
b) in star formation, in the formation of accretion disks about black holes, and in the **FORMATION OF SPIRAL GALAXIES**. In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **GRAVITATIONALLY CAPTURED** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **HEATS**

UP due to infall kinetic energy being transformed into heat. Consequently, the infalling material radiates electromagnetic radiation.

c) in star formation, in the formation of accretion disks about black holes, and in the **FORMATION OF SPIRAL GALAXIES**. In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **GRAVITATIONALLY CAPTURED** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **COOLS DOWN**.

d) in star formation, in the formation of accretion disks about black holes, and in the **FORMATION OF IMPACT CRATERS**. In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **GRAVITATIONALLY CAPTURED** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **COOLS DOWN**.

e) in star formation, in the formation of accretion disks about black holes, and in the **FORMATION OF IMPACT CRATERS** In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **GRAVITATIONALLY CAPTURED** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **HEATS UP** due to infall kinetic energy being transformed into heat. Consequently, the infalling material radiates electromagnetic radiation. The object Sgr A* near or at the dynamical center of the Milky Way, thought to be a black hole of mass of order $3 \times 10^6\,M_\odot$, is a strong radio source.

---

021 qmult 01514 3 1 2 tough memory: disk formation 2

Extra keywords: Needs rethinking; the right answer is not all right. Sunlife

703. Disk formation in the gas and dust surrounding a protostar happens:

a) principally because of magnetic fields.

b) because randomly orbiting elements (think of them as clumps) of gas and dust keep running into each other, and **losing bulk kinetic energy to heat** and canceling some of their mutual angular momentum. This collisional process keeps happening until it cannot happen any more: i.e., when the elements are all rotating in a plane in circular orbits: i.e., when they are in a disk. The gas and dust system can be said to have relaxed to a disk.

c) because randomly orbiting elements (think of them as clumps) of gas and dust keep running into each other, and **losing heat energy to bulk kinetic energy** and adding to their angular momentum. This collisional process keeps happening until it cannot happen any more: i.e., when the elements are all rotating in a plane in circular orbits: i.e., when they are in a disk. The gas and dust system can be said to have relaxed to a disk.

d) for totally unknown reasons.

e) because a passing star pulls the gas and dust into a disk.

---

021 qmult 01516 3 4 3 hard deducto-memory: disk formation 3

Extra keywords: for intro-astro this is hard: needs work maybe, Sunlife

704. In disk formation about a forming star, some randomly orbiting gas and dust material gets organized into a disk.

a) This is a **clear violation** of the 2nd law of thermodynamics which implies that disorder always increases.

b) This is a **clear violation** of the 2nd law of thermodynamics which implies that disorder always increases **overall**.

c) This is **not a violation** of the 2nd law of thermodynamics. Order has indeed increased in the bulk motions of the gas and dust surrounding the forming star: before the orbits of "clumps" of gas had random angle and direction of revolution; after the "clumps" are in a disk and revolving in the same direction. But **considerable bulk kinetic energy** (i.e., energy of the macroscopic motions of gas) has been turned into randomized microscopic heat energy during the collisions that caused the increased bulk ordering. Thus disorder has **increased microscopically**. Some of this heat energy is radiated away spreading out over distant space. This is also an increase in **disorder**. Consequently, overall the **disorder** (entropy) has increased.

d) This is **probably a violation** of the 2nd law of thermodynamics. Order has indeed increased in the bulk motions of the gas and dust surrounding the forming star: before the orbits of "clumps" of gas had random angle and direction of revolution; after the "clumps" are in a disk and revolving in the same direction. But also a **considerable heat energy** (i.e., random microscopic energy) has been turned into bulk kinetic energy (i.e., energy of the macroscopic motions of gas) during the collisions that caused the increased bulk ordering. Thus disorder has **decreased microscopically**. Some of this heat energy is radiated away spreading out over distant space. This is also an increase in **order**. Consequently, overall the **order** has increased.

e) This is **certainly a violation** of the 2nd law of thermodynamics. Order has indeed increased in the bulk motions of the gas and dust surrounding the forming star: before the orbits of "clumps" of gas had random angle and direction of revolution; after the "clumps" are in a disk and revolving in the same direction. But also a **considerable heat energy** (i.e., random microscopic energy) has been turned into bulk kinetic energy (i.e., energy of the macroscopic motions of gas) during the collisions that caused the increased bulk ordering. Thus disorder has **decreased microscopically**. Some of this heat energy is radiated away spreading out over distant space. This is also an increase in **order**. Consequently, overall the **order** has increased.

Chapt. 21 Main Sequence Star Evolution

Multiple-Choice Problems

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022 qmult 00100 1 1 1 easy memory: observationally on MS

705. A star lying on the main sequence on a Hertzsprung-Russell diagram is a:

 a) main-sequence star. b) pre-main-sequence star. c) post-main-sequence star. d) white dwarf. e) red giant.

---

022 qmult 00110 1 4 5 easy deducto-memory: main sequence star physically
 Extra keywords: CK-310 Sun-question

706. "Let's play *Jeopardy*! For $100, the answer is: It is a star that as observed over relatively short times scales (e.g., all of human history) is burning hydrogen to helium in its core at a constant rate and is in hydrostatic equilibrium."

 What is a/an ____________, Alex?

 a) dense core b) protostar c) pre-main-sequence star d) H II region e) main-sequence star

---

022 qmult 00120 1 4 4 easy-deducto memory: MS energy balance
 Extra keywords: Sun-question

707. For a main sequence star, the energy radiated away as electromagnetic radiation is almost exactly compensated by:

 a) gravitational energy converted to heat energy during rapid collapse. b) neutrinos from space being absorbed by the star. c) energy produced by nuclear burning on the surface. d) energy produced by nuclear burning in the deep interior. e) nothing at all.

---

022 qmult 00200 1 1 2 easy memory: nuclei made of protons, neutrons
 Extra keywords: Sun-question

708. Atomic nuclei are made up of:

 a) protons and electrons. b) protons and neutrons. c) positrons and electrons. d) positrons and neutrals. e) ponytrons and nuggets.

---

022 qmult 00210 1 1 2 easy memory: nucleus small and massive
 Extra keywords: Sun-question

709. The nucleus is occupies ____________ of the volume of an atom and has ____________ of the atomic mass.

 a) a small part; none b) a small part; almost all c) most; almost all d) most; none e) most; half

---

022 qmult 00220 1 1 2 easy memory: isotopes defined
 Extra keywords: Sun-question

710. Nuclei with the same number of protons, but different number of neutrons are ____________ of each other.

a) isochrones b) isotopes c) isobars d) isotropics e) Isoldes

---

022 qmult 00230 1 4 4 easy deducto-memory: deuteron and triton
Extra keywords: Sun-question

711. "Let's play *Jeopardy*! For $100, the answer is: These isotopes of hydrogen have 1 and 2 neutrons, respectively."

What are ____________, Alex?

a) uranium-235 ($^{235}_{92}$U) and uranium-238 ($^{238}_{92}$U) b) helium-3 ($^{3}_{2}$He) and helium-4 ($^{4}_{2}$He) c) the deuteronomy (D or $^{2}_{1}$H) and trident (T or $^{3}_{1}$H) d) the deuteron (D or $^{2}_{1}$H) and triton (T or $^{3}_{1}$H) e) carbon ($^{12}_{6}$C) and oxygen ($^{16}_{8}$O)

---

022 qmult 00240 1 1 2 easy memory: strong nuclear force binds nuclei
Extra keywords: Sun-question

712. Nuclei are bound together by:

a) gravity. b) the strong nuclear force. c) the electromagnetic force. d) the centrifugal force. e) the weak nuclear force.

---

022 qmult 00250 1 1 2 easy memory: nuclear fusion defined
Extra keywords: CK-261,266 Sun-question

713. Nuclear fusion is the ____________ bonding of nuclei to form ____________ nuclei.

a) chemical; larger b) nuclear; larger c) nuclear; smaller d) chemical; smaller e) gravitational; smaller

---

022 qmult 00260 2 1 3 moderate memory: 4 hydrogen nuclei to 1 helium
Extra keywords: CK-262,267 Sun-question

714. In hydrogen burning, how many hydrogen nuclei are **CONSUMED** in producing one helium-4 nucleus (i.e., one $^{4}_{2}$He nucleus)?

a) 1. b) 2. c) 4. d) 10. e) 6.5.

---

022 qmult 00270 2 4 3 moderate deducto-memory: H fusion mass loss
Extra keywords: Sun-question

715. In stellar hydrogen fusion to helium, the rest mass energy of the products is ________ less than that of the reactants. The missing rest mass energy went mostly into ____________.

a) 70 %; heat energy b) 170 %; magnetic field energy c) 0.7 %; heat energy d) 70 %; magnetic field energy e) 0 %; chemical binding energy

---

022 qmult 00280 1 3 2 easy math: E=mc**2 calculation 1 kg
Extra keywords: Sun-question

716. A mass of 1 kg is equivalent to about how much energy? Recall that the speed of light is 3.00×10^8 m/s.

a) 8×10^{16} J. b) 9×10^{16} J. c) 9×10^{8} J. d) 3×10^{8} J. e) 2×10^{8} J.

---

022 qmult 00282 1 3 5 easy math: E=mc**2 calculation 2/9 kg
Extra keywords: Sun-question

717. A mass of (2/9) kg is equivalent to how much energy? Recall that the speed of light is 3.00×10^8 m/s.

a) 8×10^{16} J. b) 9×10^{16} J. c) 9×10^{8} J. d) 3×10^{8} J. e) 2×10^{16} J.

---

022 qmult 00300 1 1 2 easy memory: MS hydrogen burning 1
Extra keywords: Sun-question

718. The energy emitted as electromagnetic energy from main sequence stars is supplied by the:

a) nuclear burning of helium to hydrogen. b) nuclear burning of hydrogen to helium. c) nuclear burning of hydrogen to carbon. d) nuclear burning of helium to carbon. e) chemical burning of hydrogen to carbon.

---

022 qmult 00310 1 1 5 easy memory: MS hydrogen burning 2
Extra keywords: CK-310 Sun-question

719. Main sequence stars burn (in the nuclear sense):

a) helium to carbon in their cores. b) helium to carbon on their surfaces. c) helium to hydrogen on their surfaces. d) helium to hydrogen in their cores. e) hydrogen to helium in their cores.

---

022 qmult 00320 1 1 3 easy memory: thermonuclear reactions in star cores
Extra keywords: CK-267-12 Sun-question

720. Thermonuclear reactions happen only in a star's core (which for the Sun is the region within about 0.25 solar radii of the Sun's center) because only there is it ____________ enough.

a) cold and dilute b) hot and dilute c) hot and dense d) cold and opaque e) fissionable

---

022 qmult 00330 1 1 1 easy memory: nuclear burning on star surface 1
Extra keywords: CK-322-4 Sun-question

721. Why don't thermonuclear reactions happen on the surface of main sequence stars?

a) Not hot and not dense enough. b) Too hot and too dense. c) Too green. d) Too bad. e) Too late.

---

022 qmult 00340 1 4 2 easy deducto-memory:nuclear fusion on a star surface 2
Extra keywords: Sun-question

722. Hydrogen fusion does not happen near the surface of main sequence stars like the Sun because:

a) the gravity is too high there. b) the temperature and density are too low there. c) there is insufficient hydrogen near the surface. d) of comet impacts. e) of X-rays.

---

022 qmult 00400 1 5 3 easy thinking: detailed star modeling 1
Extra keywords: Sun-question

723. In addition to observations of a star and physics theory, in order to understand the star in detail one needs:

a) a few calculations on a scrap of paper. b) analytic exact solutions. c) detailed computer modeling. d) analytic inexact solutions requiring many pages. e) experiments with hydrogen bombs.

---

022 qmult 00410 1 5 4 easy thinking: detailed star modeling 2
Extra keywords: CK-263 Sun-question

724. The interior structure of a star is determined by observation, physics theory, and:

a) back-of-the-envelope calculations. b) exact analytic math. c) guesswork. d) computer modeling. e) horseplay.

---

022 qmult 00420 1 4 3 easy deducto-memory: star model described
Extra keywords: CK-267-11 Sun-question

725. "Let's play *Jeopardy*! For $100, the answer is: This is a set of calculated distributions of temperature, density, luminosity, and other physical quantities for a star."

What is ____________, Alex?

a) the star mass b) the star itself c) a model of the star d) the star luminosity e) the astronomical unit

---

022 qmult 00430 1 4 1 easy deducto-memory: radial variation in a star
Extra keywords: Sun-question

726. In a main sequence star (e.g., the Sun) temperature, density, and pressure:

   a) vary strongly from center to surface (i.e., photosphere).
   b) are constant throughout the star.
   c) are never higher than about 6000 K, 2×10^{-7} g/cm^3, and 0.8 Earth atmospheres, respectively.
   d) are all equal to 6000 in MKS units.
   e) are completely unknown.

---

022 qmult 00500 1 4 3 easy deducto-memory: hydrostatic equilibrium
Extra keywords: Sun-question

727. Hydrostatic equilibrium means that:

   a) pressure and other forces in a fluid are **UNBALANCED**, but the fluid is exhibiting a **SMOOTH FLOW** (at least in the inertial frame of the fluid center of mass).
   b) pressure and other forces in a fluid are **UNBALANCED** and the fluid is exhibiting a **TURBULENT FLOW** (at least in the inertial frame of the fluid center of mass).
   c) pressure and other forces in a fluid are **BALANCED** and there is **NO FLUID MOTION** (at least in the inertial frame of the fluid center of mass).
   d) the temperature is a constant throughout a fluid.
   e) the temperature is not a constant throughout a fluid.

---

022 qmult 00510 1 4 5 easy deducto-memory: everyday hydrostatic
Extra keywords: CK-267-9 Sun-question

728. "Let's play *Jeopardy*! For $100, the answer is: It is an everyday example of hydrostatic equilibrium."

   What is ____________, Alex?

   a) a boat's wake b) stirring coffee c) a river d) a waterfall
   e) water at rest in a cup

---

022 qmult 00520 1 1 2 easy memory: star pressure support
Extra keywords: CK-261, Sun-question

729. Main sequence stars of low mass are mainly supported against collapse ($\gtrsim 90\,\%$ for $M \lesssim 8M_\odot$) by:

   a) the pressure of liquid water. b) the ideal gas pressure of ions and electrons. c) the gravitational force. d) angular momentum. e) the solar wind.

---

022 qmult 00610 1 5 3 easy thinking: radiative transfer everyday
Extra keywords: CK-267-10, Sun-question

730. An everyday example of heat transfer by radiative transport (or radiative transfer) is

   a) boiling water in a pan. b) a spoon in boiling water growing warm. c) sunlight warming. d) a refrigerator cooling. e) a dog barking.

---

022 qmult 00710 1 4 2 easy deducto-memory: convection described
Extra keywords: CK-267-10, Sun-question

731. In convection between a lower hot layer and an upper cold layer (with downward being the direction of gravity):

   a) hot blobs rise and cold blobs rise too. b) hot blobs rise and cold blobs sink. c) hot and cold blobs both sink. d) hot and cold blobs don't form. e) hot and cold blobs madly try to consume the universe.

---

022 qmult 00730 2 1 4 moderate memory: 3-d hydrodynamic effects
Extra keywords: Sun-question

732. A common reason why some astrophysical systems are described as poorly understood is that these systems involve three-dimensional hydrodynamic effects (e.g., convection).

a) Three-dimensional hydrodynamics cannot be **ACCURATELY COMPUTATIONALLY TREATED** at all.
b) Three-dimensional hydrodynamics cannot be **TREATED EVEN QUALITATIVELY**.
c) Three-dimensional hydrodynamics can **ALWAYS** be understood qualitatively and this allows us to **ALWAYS** predict three-dimensional hydrodynamical phenomena, just not their magnitude. Accurate computations of three-dimensional hydrodynamic effects, however, are only possible in some cases. For example, when **electromagnetic effects** are present, they actually simplify three-dimensional hydrodynamic effects and allow accurate computations in all cases.
d) Three-dimensional hydrodynamics can **OFTEN** be understood qualitatively and this **SOMETIMES** allows us to predict three-dimensional hydrodynamical phenomena. Accurate computations of three-dimensional hydrodynamic effects are also possible in some cases.
e) Three-dimensional hydrodynamics can **OFTEN** be understood qualitatively and this **SOMETIMES** allows us to predict three-dimensional hydrodynamical phenomena. Accurate computations of three-dimensional hydrodynamic effects are also possible in some cases. For example, when **ELECTROMAGNETIC EFFECTS** are present, they actually simplify three-dimensional hydrodynamic effects and allow accurate computations in all cases. Maybe someday all three-dimensional hydrodynamic effects will be accurately calculable.

---

022 qmult 01000 2 4 3 moderate deducto-memory: main sequence evolution
Extra keywords: Sun-question, Sunlife

733. During a star's **MAIN SEQUENCE LIFE**, the star is relatively unchanging. But, of course, it is actually changing slowly on the road to its demise. The key change is that:

a) carbon dioxide (CO_2) is being expelled by the star's wind.
b) molecular nitrogen (N_2) is being expelled by the star's wind.
c) hydrogen fuel is being exhausted in its core.
d) hydrogen fuel is being exhausted on its surface.
e) helium fuel is being exhausted in its core.

---

022 qmult 01010 1 1 4 easy memory: main sequence longest phase
Extra keywords: CK-322-6, Sun-question, Sunlife

734. Most nuclear-burning stars are main sequence stars. The reason for this is that the main sequence phase of the nuclear-burning life of star of any mass is the:

a) shortest phase. b) most popular phase. c) wettest phase. d) longest phase.
e) darndest phase.

---

022 qmult 01020 2 4 2 moderate deducto-memory: main sequence brightening
Extra keywords: Sun-question, Sunlife

735. As a **MAIN SEQUENCE STAR** ages, its luminosity (i.e., total energy output):

a) decreases. b) increases. c) oscillates wildly. d) becomes tangential.
e) incinerates.

---

022 qmult 01030 2 4 4 mod. deducto-memory: early Sun luminosity
Extra keywords: Sun-question, Sunlife

736. At the time the Sun first became a main sequence star, its luminosity was probably ____________ than at present.

a) 30 % greater b) 100 % greater c) 50 times greater d) 30 % lower e) 100 % lower

---

022 qmult 01100 1 4 2 easy deducto-memory: red dwarfs
Extra keywords: CK-311,321,322-10

737. These main sequence stars have masses in the range 0.08–0.4 $M_{\odot}$. They have the lowest temperatures and densities in their cores of all main sequence stars and subsequently burn hydrogen to helium most slowly. Convection occurs throughout these stars and eventually they will be converted entirely into helium. They will never burn any other nuclear fuel and eventually must become helium white dwarfs. Their main sequence lifetimes are predicted by models to be hundreds of billions of years. According to our current cosmological theory the age of the universe is only about 14 billion years. Thus, none of these stars has ever left the main sequence. These stars are called:

a) brown dwarfs. b) red dwarfs. c) white dwarfs. d) red giants. e) O stars.

---

022 qmult 01110 1 4 2 easy deducto-memory: convective red dwarfs
Extra keywords: CK-311,321,322-10

738. Red dwarf stars are convective:

a) in no region. b) from center to photosphere. c) only above the photopshere. d) only in the nuclear burning core. e) intermittently.

---

022 qmult 01120 1 4 3 easy deducto-memory: red dwarfs go helium
Extra keywords: CK-311,321,322-10

739. Because red dwarf stars are convective throughout (i.e., from center to photosphere), they will

a) burn helium to hydrogen only in their cores. b) never burn hydrogen at all. c) eventually burn almost all their hydrogen to helium. d) never burn either hydrogen or helium. e) burn carbon before hydrogen.

---

022 qmult 01200 1 4 2 easy deducto-memory: brown dwarf defined
Extra keywords: CK-306,321

740. An object that forms in a star formation region with less than about 0.08 $M_{\odot}$, but more than about 13 Jupiter masses (according to one school of thought), and which never burns ordinary hydrogen is called a:

a) white dwarf. b) brown dwarf. c) red dwarf. d) red giant. e) green giant.

---

022 qmult 01210 1 1 1 easy memory: brown dwarfs are not MS stars
Extra keywords: CK-306,321

741. Brown dwarfs are:

a) not main-sequence stars ever. b) unarguably main-sequence stars. c) main-sequence stars at three different times. d) sometimes main-sequence stars. e) the same things as red giants.

Chapt. 22 Late Star Evolution and Star Death

Multiple-Choice Problems

023 qmult 00100 2 4 2 moderate deducto-memory: main sequence phase ends 1
Extra keywords: Sun-question

742. The end of a star's **MAIN SEQUENCE LIFE** (not its nuclear burning life) comes when it has:

a) exhausted the hydrogen fuel in its corona. b) exhausted the hydrogen fuel in its core region. c) become a white dwarf. d) become a green dwarf. e) exhausted the hydrogen fuel in its sunspots.

023 qmult 00102 1 1 1 easy memory: main sequence phase ends 2
Extra keywords: Sun-question

743. When a star exhausts its core hydrogen fuel its:

a) main sequence phase is ended. b) main sequence phase is at midpoint. c) main sequence phase is beginning. d) red giant phase is ended. e) AGB phase is ended.

023 qmult 00110 2 4 4 moderate deducto-memory: post-main sequence of Sun
Extra keywords: Sun-question

744. After the end of its main sequence lifetime, the Sun will probably go through the following phases in order:

a) red giant, helium flash (a very short stage), horizontal branch star, green giant, cometary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
b) red giant, helium flash (a very short stage), horizontal branch star, jolly green giant, planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
c) red giant, helium flash (a very short stage), vertical branch star, second red giant (i.e., asymptotic [red] giant branch star or ABG star), cometary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
d) red giant, helium flash (a very short stage), horizontal branch star, second red giant (i.e., asymptotic [red] giant branch star or ABG star), planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
e) red giant, Larry, Curly, Moe, black dwarf (very far in the future).

023 qmult 00200 1 4 5 easy deducto-memory: red giants defined sort of
Extra keywords: CK-288,296 Sun-question

745. "Let's play *Jeopardy*! For $100, the answer is: These stars typically have radiii 10 to 100 times that of the Sun and surface temperatures of 2000–4500 K."

What are ____________, Alex?

a) white dwarfs b) green dwarfs c) red dwarfs d) blue giants e) red giants

023 qmult 00210 2 1 2 moderate memory: star to red giant
Extra keywords: Sun-question

746. After its hydrogen-burning life main sequence, a star usually will:

a) expand into a blue supergiant. b) expand into a red giant. c) shrink into a red dwarf. d) just fade out. e) implode to form a protostar.

---

023 qmult 00300 2 4 3 moderate deducto-memory: horizontal branch star defined
Extra keywords: CK-327, Sh-149, Sun-question life

747. Lower mass stars (i.e., those which had main sequence mass $\lesssim 8M_\odot$) when burning helium to carbon and oxygen in their **CORES** are called ____________ stars.

a) red giant b) supergiant c) horizontal branch d) vertical branch e) oblique branch

---

023 qmult 00400 2 4 2 moderate deducto-memory: AGB star defined
Extra keywords: CK-328,346, FK-496,497, Sun-question

748. Lower mass stars (i.e., those which had main sequence mass $\lesssim 4M_\odot$) when burning helium to carbon and oxygen in a shell around an inert carbon-oxygen core, but before they have lost a lot of mass in helium shell flashes (AKA thermal pulses), are called ____________ stars.

a) red dwarf b) asymptotic giant branch (AGB) c) horizontal branch d) vertical branch e) oblique branch

---

023 qmult 00410 1 4 3 easy deducto-memory: AGB Sun vaporizes Earth
Extra keywords: Sun-question

749. If in its AGB (asymptotic red giant) phase (or 2nd red giant phase), the Sun has expanded and enveloped the Earth, the Earth will:

a) very quickly collapse to a black hole.
b) become a red giant star.
c) spiral into the deeper layers of the Sun because of the drag forces of the Sun's outer layers. There the Earth will be totally vaporized. "So the glory of this world passes away": *Sic transit gloria mundi.*
d) gain escape velocity and be ejected from the solar system because of the drag forces of the Sun's outer layers.
e) implode to form a protostar.

---

023 qmult 00500 2 4 2 moderate deducto-memory: helium shell flash defined
Extra keywords: CK-328,346, FK-493, Sun-question

750. "Let's play *Jeopardy*! For $100, the answer is: These short-time scale episodes of explosive helium shell burning in late stellar evolution eject material that become planetary nebulae."

What are ____________, Alex?

a) hydrogen shell flashes b) helium shell flashes (AKA thermal pulses) c) supernovae d) hypernovae e) novae

---

023 qmult 00600 1 4 4 easy deducto-memory: planetary nebula defined
Extra keywords: CK-329,346 FK-493, Sun-question

751. A planetary nebula is:

a) a **cloudy planet**.
b) a cloud that will coalesce into a **planet**.
c) a shell of gas thrown off by a dying star before it becomes a **protostar**.
d) a shell of gas thrown off by a dying star before it becomes a **white dwarf**.
e) a shell of gas thrown off by a dying star before it becomes a **galaxy**.

---

023 qmult 00700 1 1 1 easy memory: core collapse II/Ibc supernovae
Extra keywords: CK-333, 346

752. Stars that are more massive than about $8\,M_\odot$ on the main sequence are believed to burn their cores all the way to iron and to explode as:

a) Type II or Ib/c supernovae. b) planetary nebulae. c) novae.
d) helium shell flashes (AKA thermal pulses). e) black holes.

Chapt. 23 Compact Remnants: White Dwarfs and Neutron Stars

Multiple-Choice Problems

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024 qmult 00100 1 4 1 easy deducto-memory: white dwarf defined
Extra keywords: CK-346,347-5, Sun-question

753. White dwarfs are:

a) the compact remnants of stars. They are **NOT** burning nuclear fuel. They are **COOLING DOWN** forever.
b) giant red stars.
c) the compact remnants of stars. They are **STILL** burning nuclear fuel.
d) the compact remnants of stars. They are **NOT** burning nuclear fuel. But they are **HEATING UP** forever.
e) the compact remnants of stars. They are **NOT** burning nuclear fuel. They have **NEVER** been observed: they are merely predicted theoretically.

---

024 qmult 00200 1 4 5 easy deducto-memory: Chandrasekhar mass limit
Extra keywords: CK-346,347-6

754. "Let's play *Jeopardy*! For $100, the answer is: Above this mass (which is about $1.4\,M_\odot$), a white dwarf cannot support itself against gravitational collapse by electron degeneracy pressure and must collapse to being a neutron star."

What is the ____________, Alex?

a) Behte limit b) Zeldovich limit c) Eddington limit d) Sakharov limit e) Chandrasekhar limit

---

024 qmult 00300 2 1 4 moderate memory: black dwarf defined
Extra keywords: Sun-question

755. A black dwarf is:

a) a black hole.
b) a protostar hidden in a molecular cloud.
c) a protostar after emerging from its cocoon of gas and dust.
d) what a white dwarf becomes when it has cooled off to near absolute zero temperature.
e) a shell of gas thrown off by a dying star before it becomes a galaxy.

---

024 qmult 00310 1 4 5 easy deducto-memory: black dwarfs do not exist
Extra keywords: Sun-question

756. "Let's play *Jeopardy*! For $100, the answer is: If the Big Bang Theory of the universe and our theory of star evolution are correct, then these star remnants do **NOT** currently exist but will some billions of years or more in the future."

What are ____________, Alex?

a) golden bears b) planets c) red giants d) white dwarfs e) black dwarfs

---

024 qmult 00500 1 4 2 easy deducto-memory: white dwarf to SNe Ia
Extra keywords: CK-338,346

757. Isolated white dwarfs are stable objects that just cool off forever. But in a close binary system they can accrete mass from the companion star and increase to nearly the Chandrasekhar limit of about $1.4\,M_\odot$. Before collapse can happen, it is believed that carbon fusion begins in the core in an unstable fashion: a thermonuclear runaway occurs that disrupts the white dwarf on the time scale of a second. The explosion of such a system (which is still somewhat hypothetical) is identified with:

a) Type II supernovae. b) Type Ia supernovae. c) pulsars. d) quasars.
e) novae.

---

024 qmult 01000 1 4 1 easy deducto-memory: neutron star remnant
Extra keywords: CK-339,341,346,347-7

758. "Let's play *Jeopardy*! For $100, the answer is: These compact remnants of core-collapse (Type II/Ib/c) supernovae have diameters of order 20 km and have nuclear density."

What are ____________, Alex?

a) neutron stars b) black holes c) white dwarfs d) supernova remnant nebulae
e) red dwarfs

---

024 qmult 01100 1 1 3 easy memory: pulsars
Extra keywords: CK-341,346

759. Neutron stars that emit radio electromagnetic radiation from rotating north-south magnetic poles are called:

a) centaurs. b) blazers. c) pulsars. d) quasars. e) bursters.

---

024 qmult 01200 2 4 2 moderate deducto-memory: Oppenheimer-Volkov limit
Extra keywords: CK-347-10

760. "Let's play *Jeopardy*! For $100, the answer is: This mass which is theoretically known to be about $3\,M_\odot$ is the upper limit on neutron star mass."

What is the ____________ limit, Alex?

a) Chandrasekhar b) Oppenheimer-Volkov c) Gamow d) neutron star
e) white dwarf

Chapt. 24 Black Holes

Multiple-Choice Problems

025 qmult 00328 1 4 4 easy deducto-memory: two parts of the general relativity

761. "Let's play *Jeopardy*! For \$100, the answer is: How the two parts of it interact is mnemonicked by: "Mass-energy tells spacetime how to curve and curved spacetime tells mass-energy how move."

What is ____________, Alex?

a) special relativity b) Newtonian physics c) quantum mechanics
d) general relativity e) the geodesic equation

025 qmult 00330 1 1 5 easy memory: differential equations and solutions

762. Physical laws (e.g., those of general relativity) are usually formulated as ____________ which tell you what is true at each point in spacetime, but they don't tell you how that truth at each point in spacetime is related to truth at any other point in spacetime The relationships are the ____________ which must be determined separately for every system

a) equalities; inequalities b) integral equations; inequalities
c) integral equations; equalities d) differential equations; equalities
e) differential equations; solutions

025 qmult 00600 1 4 2 easy deducto-memory: Karl Schwarzschild and his solution

763. "Let's play *Jeopardy*! For \$100, the answer is: He/she is the discoverer of the analytically exact solution for the general relativity in massless-space outside of a non-rotating, chargeless, spherically symmetric mass distribution."

Who is ____________, Alex?

a) Henrietta Swan Leavitt (1868–1921) b) Karl Schwarzschild (1873–1916)
c) Albert Einstein (1879–1955) d) Edwin Hubble (1889–1953)
e) Georges Lemaître (1894–1966)

025 qmult 00610 1 1 1 easy memory: Schwarzschild radius defined
Extra keywords: CK-362

764. The radius of the event horizon of a Schwarschild black hole is the ____________ radius.

a) Schwarzschild b) ergoregion c) singularity d) Kerr-Schwarzschild
e) Fermi surface

025 qmult 00650 2 5 5 moderate thinking: Sun black hole
Extra keywords: CK-363-3

765. If the Sun instantaneously and without any other catastrophic effects collapsed to being a black hole, what would happen to the Earth?

a) Nothing: everything would be just as before including the Earth's surface temperature.
b) The Earth would plunge into the solar black hole drawn by its sudden super-gravity.
c) The Earth would suddenly have escape velocity from the Solar System and would fly off into space.

d) Because of strange quantum mechanical effects every possible event would happen to the Earth in infinitely many different parallel universes.
e) The Earth's orbit would be unaffected, but the Earth's surface temperature would soon fall too low to sustain life.

---

025 qmult 00700 1 1 2 easy memory: Schwarzschild and Kerr black holes
Extra keywords: CK-362

766. A black hole that has **NO** angular momentum is a ____________ black hole and one does have angular momentum is a ____________ black hole.

a) Kerr; Schwarzschild b) Schwarzschild; Kerr c) Einstein; Wheeler
d) Wheeler; Einstein e) Tegmark; Wheeler

---

025 qmult 00710 2 4 3 moderate deducto-memory: singularity for Schwarzschild and Kerr black holes
Extra keywords: CK-358,359,362

767. The Schwarzschild and Kerr solutions of general relativity predict a region of infinite density: in the Schwarzschild solution this region is a/an ____________ and in the Kerr solution it is a/an ____________. This region is called the ____________.

a) infinitely thin ring; point; ergoregion b) point; infinitely thin ring; ergoregion
c) point; infinitely thin ring; singularity d) point; infinitely thin ring; event horizon
e) infinitely thin ring; point; singularity

---

025 qmult 00800 1 5 3 easy thinking: black holes exist?

768. Black holes:

a) certainly do **NOT** exist as all absolutely agree.
b) probably do **NOT** exist, but they have caught the popular imagination and astronomers knowing a good thing when they have one keep writing about them.
c) exist. There are multitudinous massive compact objects that are now conventionally called black holes. So conventional black holes exist by convention. But the theoretical defining characteristic of black holes is the event horizon, the surface through which nothing, including light, can escape. Is there evidence for the event horizon? Yes. Many gravitational wave detections since 2015 are very well accounted for by merging black holes with event horizons. Also, in 2019 the Event Horizon Telescope imaged a supermassive black hole with the image being consistent with event horizon existence. So there is now very strong evidence that black holes (with event horizons) do exist. Ovewhelmingly most astronomers now accept their existence. It is always possible that a counter theory to black holes might come along that accounts for the evidence as well or better than black holes. So people will keep an open mind, but without worrying about counter theories much in the meantime.
d) do not exist now, but will billions of years in the future.
e) are redundant.

---

025 qmult 00830 1 4 3 easy deducto-memory: black hole event horizon exists
Extra keywords: CK-358,362

769. "Let's play *Jeopardy*! For \$100, the answer is: The theoretical defining characteristic of a black hole is this surface from which and from below which light cannot escape. From 2015 on, evidence from gravitational waves from the mergers of stellar-mass compact objects and actual imaging of the supermassive compact objects at the centers of galaxies have convinced people beyond almost all doubt that these objects have the aforesaid defining characteristic, and so are black holes. In fact, it is hardly worth mentioning any doubt of the existence of black holes at all, except in being absolutely strict.'

What is the ____________, Alex?

a) singularity b) Earth's horizon c) event horizon d) duality
e) lost horizon

---

025 qmult 00900 2 4 4 moderate deducto-memory: making black holes in general by compression

770. The formula for the Schwarzschild radius is

$$R_{\rm Sch} = \frac{2GM}{c^2} = 2.95318 \left(\frac{M}{M_\odot}\right) \text{ km} ,$$

where $G = 6.67430 \times 10^{-11}$ (in MKS units) is the gravitational constant, M is the mass of an object, c is the speed of light, and $M_\odot = 1.9885 \times 10^{30}$ kg is the mass of the Sun. This formula follows from general relativity for a non-rotating, spherically symmetric mass distribution, but it also accidently can be obtained by setting the escape velocity equal to the speed of light in the Newtonian formula for the escape velocity from a spherically symmetric mass distribution. According to general relativity if any object is compressed within its Schwarzschild radius it:

a) will become Karl Schwarzschild. b) may, but not necessarily will, become a black hole. c) must cease to exist. d) must become a black hole. e) will become a Schwarzschild.

---

025 qmult 01050 1 4 3 easy deducto-memory: X-ray source black holes
Extra keywords: CK-355,362

771. Compact X-ray sources in ____________ where the source seems to have **MORE** than about $2.2\,M_\odot$ are probably ____________.

a) triple systems; neutron stars b) galaxy centers; black holes
c) binary systems; black holes d) galaxy centers; supermassive black holes
e) binary systems; supermassive black holes

---

025 qmult 01060 2 4 1 moderate deducto-memory: X-ray source neutron stars
Extra keywords: CK-355,362

772. Compact, short-wavelength X-ray sources in binary systems where the source seems to have **LESS** than $2.2\,M_\odot$ but more than $1.4\,M_\odot$ are:

a) probably neutron stars. b) certainly black holes. c) white dwarfs.
d) main sequence stars. e) red dwarfs.

---

025 qmult 01090 2 5 4 moderate thinking: black hole binary masses
Extra keywords: CK-363-9

773. The more massive the star is, the faster it evolves in general. But black hole in binary systems (which are the compact remnants of ordinary stars) are sometimes less massive than their ordinary star companions. Resolve this paradox.

a) The paradox **CANNOT** be resolved: such systems are a complete mystery.
b) Companion stars always form much later than the black hole progenitors and are gravitationally captured by the black hole's gravity field.
c) Some mass always just disappears completely from the universe during black hole formation. This non-conservation of energy is a consequence of general relativity.
d) The black hole progenitor was more massive than the companion, but lost significant mass in late stellar evolution and even more mass in the supernova explosion that is believed to have preceded the formation of the black hole.
e) If you have just the right amount of inertial frame and a nearby quasar and add a couple of ad hoc hypotheses, then the masses work out right.

---

025 qmult 01100 2 1 2 moderate memory: black hole jets

774. Probably because of complex magnetic and electric field effects about rotating black holes with accretion disks, these objects perpendicular to their accretion disks exhibit:

a) planes of glowing gas. b) jets of glowing gas. c) jets of ice water. d) stirrups of ice water. e) dendritic patterns.

---

025 qmult 01200 1 1 1 easy memory: supermassive black holes: basic idea
Extra keywords: CK-357

775. These black holes are found in the centers of large galaxies. They have masses of order $10^6\,M_\odot$ to $10^9\,M_\odot$. The name given to this kind of black hole is:

a) supermassive black hole. b) primordial black hole. c) Schwarzschild black hole. d) singularity black hole. e) worst-case black hole.

---

025 qmult 01300 1 1 4 easy memory: Hawking radiation and black hole mass loss
Extra keywords: CK-361,362

776. It is believed that ____________ can lose rest mass energy and thus mass by ____________.

a) only Kerr black holes; Kerr radiation
b) only supermassive black holes; the Hawking field
c) only supermassive black holes; the Schwarschild resonance
d) black holes; Hawking radiation e) black holes; the Kerr field

Chapt. 25 The Discovery of Galaxies

Multiple-Choice Problems

026 qmult 00100 1 4 4 easy deducto-memory: galaxy defined
Extra keywords: CK-370

777. "Let's play *Jeopardy*! For $100, the answer is: They are large, gravitationally-bound systems of stars that range from dwarf versions that are kiloparsec in size scale to the large ones that are tens of kiloparsecs or even a couple hundred kiloparsecs in size scale."

What are ____________, Alex?

a) binaries b) open clusters c) globular clusters d) galaxies e) universes

026 qmult 00110 1 1 2 easy memory: Irregular galaxy type

778. Galaxies come in five main types: ellipticals, lenticular, unbarred spirals, barred spirals, and:

a) globulars. b) irregulars. c) seculars. d) Cepheids. e) Vermeers.

026 qmult 00200 1 4 4 easy deducto-memory: traditional Milky Way
Extra keywords: CK-370

779. "Let's play *Jeopardy*! For $100, the answer is: In the celestial-sphere picture of the sky, this object is luminous band on celestial sphere that straddles a great circle that is at an angle of about 60° to the celestial equator."

What is the ____________, Alex?

a) Zodiac b) celestial axis c) ecliptic d) Milky Way e) Andromeda Nebula

026 qmult 00210 2 1 2 moderate memory: center of Milky Way

780. The center of the Milky Way is in:

a) Orion. b) Sagittarius. c) Virgo. d) Cassiopeia. e) Pegasus.

026 qmult 00310 1 1 1 easy memory: Milk Way stars

781. Democritus (460?–370? BCE) hypothesized that the Milky Way was made of stars unresolvable to the naked eye. Galileo and other observers of circa 1610 verified this hypothesis using the then recently invented:

a) telescope. b) microscope. c) spectroscope. d) astrolabe. e) sundial.

026 qmult 00320 1 4 5 easy deducto memory: Milky Way structure speculators

782. The first three recorded persons, all living in the 18th century, to speculate about the structure of the Milky Way in the context of Newtonian physics were:

a) Larry, Curly, and Moe. b) Voltaire, Talleyrand, and Robespierre. c) Ben Franklin, Thomas Jefferson, and George Washington. d) Thomas Wright, Goethe, and Frederick the Great. e) Thomas Wright, Immanuel Kant, and J. H. Lambert.

026 qmult 00330 1 4 3 easy deducto-memory: Herschel maps the Milky Way

783. "Let's play *Jeopardy*! For $100, the answer is: He/she attempted to map the Milky Way using star counts (or star gauges)."

Who is ____________, Alex?

a) Nicolaus Copernicus (1473–1543) b) Galileo Galilei (1564–1642)
c) William Herschel (1738–1822) d) Isaac Newton (1642/3–1727)
e) Caroline Herschel (1750–1848)

---

026 qmult 00350 1 4 4 easy deducto-memory: Shapley and Milky Way

784. "Let's play *Jeopardy*! For \$100, the answer is: He/she obtained a roughly correct size estimate for the Milky Way and was the first to roughly correctly locate the center of the Milky Way using Cepheid variable stars in globular clusters in the halo of the Milky Way."

Who is ____________, Alex?

a) Henrietta Swan Leavitt (1868–1921) b) Heber Curtis (1872–1942)
c) Edwin Hubble (1889–1953) d) Harlow Shapley (1885–1972)
e) Stephen Hawking (1942–2018)

---

026 qmult 00400 1 4 4 easy deducto-memory: nebulae
Extra keywords: CK-366,370

785. Clouds in space or, when speaking historically, those objects regarded as cloud-like are called:

a) shapleys. b) stars. c) galaxies. d) nebulae. e) curtises.

---

026 qmult 00440 1 4 4 easy deducto-memory: Messier catalog

786. The Messier catalog contains the nebulae that are about the:

a) farthest ones. b) most pointed. c) least visible ones. d) most visible ones.
e) least pointed.

---

026 qmult 00460 1 4 1 easy deducto-memory: Rosse discovers spirals
Extra keywords: CK-366, super-easy deduction question

787. The spiral nature of some nebulae was discovered using visual astronomy and the largest telescope of its time: the 183-cm diameter Leviathan of Parsonstown located at Birr Castle, Parsonstown, Ireland. Because the spiral nebula are rather faint, it takes are large telescope to make out the spiral arms visually. With long-exposure photography it is relatively easy to discover spirals. But visual astronomy beat the recently invented photography by some years in this case: the discovery was made in 1845 April by the builder of the Leviathan:

a) the Earl of Rosse (1800–1867). b) John Herschel (1792–1871).
c) Henrietta Swan Leavitt (1868–1921). d) Harlow Shapley (1885–1972).
e) Edwin Hubble (1889–1953).

---

026 qmult 00500 1 1 4 easy memory: Shapley-Curtis debate
Extra keywords: CK-370

788. On 1920 April 26, a debate about the nature of the spiral nebulae was held at a meeting of the National Academy of Sciences in Washington, D.C. The debaters both made sound points in the printed presentations that they later made if not on the day of. This debate is called the Great Debate or the:

a) Einstein-de Sitter debate. b) Rosse-Hubble debate. c) Shapley-Hubble debate.
d) Shapley-Curtis debate. e) Kant-Einstein debate.

---

026 qmult 06500 1 1 4 easy memory: kapetyn and shapley and Sun in Milky Way

789. In determining the location of the Sun, Jacobus Kapteyn (1851–1922) using star statistics put the Sun ____________ and Harlow Shapley (1885–1972) using Cepheids put it ____________.

a) well away from the Milky Way center; near the Milky Way center
b) well away from the Andromeda Galaxy center; near the Andromeda Galaxy center
c) near the Andromeda Galaxy center; well away from the Andromeda Galaxy center

d) near the Milky Way center; well away from the Milky Way center
e) near the Milky Way center; near the Andromeda Galaxy center

---

026 qmult 00600 1 1 4 easy memory: Hubble proves galaxies exist
Extra keywords: CK-370-2

790. Using Cepheid variable stars as distance indicators and the inverse square law for electromagnetic radiation flux, this famous astronomer was able to prove that M31 (the Andromeda spiral nebulae) was a giant star system (i.e., a galaxy) outside of the Milky Way. His/her name is:

a) Caroline Herschel (1750–1848). b) Henrietta Swan Leavitt (1868–1921). c) Harlow Shapley (1885–1972). d) Edwin Hubble (1889–1953). e) Knut Lundmark (1889–1958).

---

026 qmult 00610 1 4 3 easy memory: Hubble and the 100-inch

791. Edwin Hubble (1889–1953) was able to prove the extragalactic nature of the spiral nebulae because, among other things, he had available the world's:

a) largest telescope of our day. b) second largest telescope of his day. c) largest telescope of his day. d) smallest telescope of our day. e) largest telescope of Newton's day.

---

026 qmult 67124 1 1 3 easy memory: Edwin Hubble's discovery

792. Edwin Hubble (1889–1953) was able to discover ____________ because he had available to him ____________.

a) Cepheids; the world's best spectroscope
b) Cepheids; the world's biggest telescope
c) galaxies; the world's biggest telescope
d) galaxies; the world's best spectroscope
e) nebulae; the world's best spectroscope

Chapt. 26 The Galaxy Alias the Milky Way

Multiple-Choice Problems

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027 qmult 00100 2 1 1 mod. memory: Milky Way center in Sagittarius
Extra keywords: CK-379,385 CM-383

793. The center of the Milk Way is in constellation:

a) Sagittarius. b) Ursa Major. c) Tucana. d) Orion. e) Norma.

---

027 qmult 00150 1 1 1 easy deducto-memory: Milky Way from above
Extra keywords: CK-386-16

794. Say you were located about 8 kpc away from the Galactic center on a line **PERPENDICULAR** to the Galactic disk. What would the Milky Way look like to you?

a) A face-on spiral galaxy: probably rather magnificent. b) An edge-on spiral. c) A globular cluster. d) A supermassive black hole. e) Just the same as it does now.

---

027 qmult 00200 1 4 3 easy deducto-memory: Milky Way disk
Extra keywords: CK-377,385

795. What component of the Milky Way has a diameter and thickness (according to some definitions) of about 50 kpc and 0.6 kpc, respectively?

a) The bulge. b) The halo. c) The disk. d) The horns. e) The heft.

---

027 qmult 00300 1 4 4 easy deducto-memory: halos of galaxies
Extra keywords: CK-382,385

796. "Let's play *Jeopardy*! For $100, the answer is: They are roughly spherical distributions of globular clusters, isolated stars, and probably often dark matter associated with spiral galaxies."

What are ____________, Alex?

a) spiral arms b) horns c) disks d) halos e) nimbuses

---

027 qmult 00400 1 4 5 easy deducto-memory: spiral arm defined
Extra keywords: CK-378,385

797. "Let's play *Jeopardy*! For $100, the answer is: This galactic structure can be observationally characterized as an arc containing concentrations of molecular clouds, H II regions, and hot, young stars that extends from a galactic bulge out to somewhere near the edge of a galaxy disk."

What is a ____________, Alex?

a) globular cluster b) galaxy c) supermassive black hole d) halo e) spiral arm

---

026 qmult 00910 1 3 5 easy math: Sun orbits since formation
Extra keywords: CK-386-10

798. Given that the Sun's orbital period around the center of the Galaxy is about 220 Myr and the age of the Solar System is about 4.6 Gyr, about how many orbits has the Sun completed since formation?

a) 1. b) 0.05. c) 10. d) 46. e) 21.

---

027 qmult 01000 1 4 2 easy deducto-memory: rotation curve defined
Extra keywords: CK-383,385

799. What is a plot of stellar orbital speed versus radial distance from a galactic center?

a) A Hertzsprung-Russell (HR) diagram. b) A rotation curve. c) A light curve. d) A heavy curve. e) A scatter diagram.

---

027 qmult 01010 1 4 1 easy deducto-memory: bulge rotation curve
Extra keywords: CK-386-15

800. In the Galactic bulge the rotation curve rises fairly linear with radius from the Galactic center. This implies:

a) that the mass density in the bulge is fairly constant when averaged over sufficiently LARGE scales. b) that there is supermassive black hole at the center. c) nothing at all. d) almost nothing at all. e) that the mass density in the bulge is fairly constant when averaged over sufficiently SMALL scales.

---

027 qmult 01020 1 1 2 easy memory: flat rotation curve to dark matter
Extra keywords: CK-385-5

801. Because the rotation curves of the Galaxy and many other spiral galaxies stay flat out to distances where the luminous mass has become very rare, it has been concluded that galactic halos must contain:

a) globular clusters. b) dark matter. c) stars. d) dense matter. e) bright matter.

---

027 qmult 01100 1 1 1 easy deducto-memory: dark matter
Extra keywords: CK-384,385

802. The dark matter (aside from a few MACHO observations if indeed MACHOs are a significant form of dark matter) is entirely known from its:

a) gravitational effects. b) blackbody radiation. c) emission line spectra. d) Doppler shift. e) gravitational radiation.

---

027 qmult 01150 2 4 3 moderate deducto-memory: WIMPs

803. If Big Bang nucleosynthesis is correct, most dark matter must be:

a) ordinary matter made of protons, neutrons, and electrons. b) MACHOs (massive compact halo objects) made of ordinary matter. c) some exotic kind of matter possibly WIMPs (weakly interacting massive particles). d) hydrogen. e) helium.

---

027 qmult 01200 1 1 3 easy memory: Sagittarius A* Sag A*
Extra keywords: CK-379, FK-571

804. Very near the gravitational center of the Galaxy is a strong radio source called:

a) Sagittarius B*. b) Norma B*. c) Sagittarius A*. d) Norma A*. e) Aquarius D*.

---

027 qmult 01210 2 4 3 moderate deducto-memory: Sag A* mass
Extra keywords: FK-572

805. The mass of supermassive black hole candidate at the center of the Galaxy is currently calculated to be:

a) $3.7 \times 10^3\,M_\odot$. b) $3.1416 \times 10^{11}\,M_\odot$. c) $3.7 \times 10^6\,M_\odot$. d) $3.1416 \times 10^3\,M_\odot$. e) $1\,M_\odot$.

---

027 qmult 01220 1 1 3 easy memory: Sag A* mass calculated
Extra keywords: CK-386-9

806. The mass of the supermassive black hole candidate at the Galactic center is best calculated from:

a) its X-ray emission. b) its radio emission. c) the velocity of stars in orbit about it. d) its emission in the visible. e) its undetected emission in the visible.

Chapt. 27 Galaxies

Multiple-Choice Problems

028 qmult 00100 1 1 1 easy memory: galaxy nearest neighbor distance
807. A characteristic nearest neighbor distance between galaxies is of order:

a) 1 Mpc. b) 1 kpc. c) 1 pc. d) 1 cm. e) 4283 Mpc.

028 qmult 00200 1 4 5 easy deducto-memory: Hubble types
Extra keywords: CK-388,407
808. In the Hubble sequence of galaxies, the main types are:

a) O0 and G2. b) Sa and SBa. c) spiral and barred spiral. d) elliptical and barred spiral. e) elliptical, lenticular, unbarred spiral, barred spiral, and irregular.

028 qmult 00210 1 4 3 easy deducto-memory: Hubble tuning fork diagram
Extra keywords: CK-394
809. Hubble galaxy types are conveniently displayed by a:

a) Hubble **SPOON** diagram. b) Hertzsprung-Russell (HR) diagram.
c) Hubble **TUNING FORK** diagram. d) Hertzsprung-Hubble **SPOON** diagram.
e) Hertzsprung-Russell **KNIFE** diagram.

028 qmult 00230 2 4 2 moderate deducto-memory: barred spiral subtypes
Extra keywords: CK-394 FK-585
810. "Let's play *Jeopardy*! For $100, the answer is: They are the subtypes of the Hubble type barred spiral."

What are ____________, Alex?

a) Sa, Sb, and Sc b) SBa, SBb, and SBc c) E0, E1, E2, E3, E4, E5, E6, and E7
d) SO and SBO e) Irr I and Irr II

028 qmult 00240 1 4 4 easy deducto-memory: Hubble's galaxy evolution idea not
811. "Let's play *Jeopardy*! For $100, the answer is: It's a common misconception that he/she originally theorized that galaxies evolved from ellipticals to unbarred spirals or barred spirals. In fact, he/she emphasized that his/her classification scheme was entirely empirical."

Who is ____________, Alex?

a) Henrietta Swan Leavitt (1868–1921) b) Adriaan van Maanen (1884–1946)
c) Knut Lundmark (1889–1958) d) Edwin Hubble (1889–1953)
e) Georges Lemaître (1894–1966)

028 qmult 00300 1 4 5 easy deducto-memory: ellipticals
Extra keywords: CK-393,395,407
812. "Let's play *Jeopardy*! For $100, the answer is: Galaxies of this Hubble type range in size from about $10^5\,M_\odot$ (small dwarfs) to $10^{13}\,M_\odot$ (large giants), consist mainly of Population II and old Population I stars, and have relatively little dust and star formation."

What is the ____________ type, Alex?

a) irregular b) lenticular c) spiral d) barred spiral e) elliptical

---

028 qmult 00310 2 4 2 moderate deducto-memory: ellipitcal E0-7 significance

813. The 8 elliptical subtypes E0 through E7 do **NOT** give unambiguous information about the intrinsic properties of the ellipticals because they are assigned:

a) on the basis of the 3-dimensional shape of the galaxy. b) just on the basis of the shape of the galaxy projected on the sky. c) arbitrarily. d) randomly. e) whimsically.

---

028 qmult 00400 1 4 2 easy deducto-memory: lenticular galaxies

Extra keywords: CK-394,407

814. Lenticular (SO and SBO) galaxies have:

a) spiral arms, but no well-defined disks. b) disks, but no well-defined spiral arms. c) bulges, but no disks. d) no bulges, disks, spiral arms, or halos. e) no size whatsoever.

---

028 qmult 00500 1 4 1 easy deducto-memory: spirals and barred spirals

Extra keywords: CK-388,392,407

815. Spiral galaxies are divided into ordinary spirals (or just spirals without qualification) and:

a) barred spirals. b) haloed spirals. c) disked spirals. d) bulgeless spirals. e) unbarred spirals.

---

028 qmult 00510 1 4 5 easy deducto-memory: grand-design and flocculent

Extra keywords: CK-389,407

816. Based on the appearance of their spiral arms, spiral galaxies are divided into grand-design spirals and:

a) sheeplike spirals. b) sheepish spirals. c) woolly spirals. d) fleecy spirals. e) flocculent spirals.

---

028 qmult 00520 1 1 1 easy memory: trailing spiral arm direction

817. The spiral arms rotate in the same sense as the disk stars around the center of the galaxy. The arms, however, rotate more slowly than the stars and gas. The ends of the spiral arms:

a) point opposite the direction of rotation: i.e., the arms are trailing. b) point in the direction of rotation. c) point exactly radially. d) curl back and point toward the galaxy center. e) are knotted together.

---

028 qmult 00530 1 4 1 easy deducto-memory: edge-on, face-on

818. To see a spiral or lenticular galaxy parallel to the disk is to see it ____________ and to see it perpendicular to the disk is to see it ____________.

a) edge-on; face-on b) face-on; edge-on c) edge-on; obliquely d) face-on; obliquely e) obliquely; opaquely

---

028 qmult 00540 1 4 4 easy deducto-memory: spiral subtype from bulge

Extra keywords: CK-388

819. One can usually tell the subtype of a spiral or barred spiral seen **EDGE-ON** because a subtype indication is provided by:

a) the tightness of the winding of the spiral arms. b) the darkness of the disk dust lane. c) the relative size of the halo. d) the relative size of the bulge. e) the galaxy brightness on the sky.

---

028 qmult 00800 2 4 1 moderate deducto-memory: irregular galaxy LMC

820. A well known example of an irregular galaxy (of subtype Irr I) is the:

a) Large Magellanic Cloud (LMC). b) Sombrero Galaxy (M104).
c) Whirlpool Galaxy (M51). d) Milk Way (i.e., the Galaxy).
e) Andromeda Galaxy (M31).

---

028 qmult 00900 1 1 1 easy memory: spiral density waves and SPSF
Extra keywords: CK-391,407 CK-408-3

821. Grand-design and flocculent spiral arms are believed to be caused by, respectively, ____________ and ____________.

a) spiral density waves; self-propagating star formation plus differential rotation.
b) self-propagating star formation plus differential rotation; spiral density waves
c) spiral density waves; flocculent waves d) grand-design waves; flocculent waves
e) galactic cannibalism; gravitational lensing

---

028 qmult 00910 1 1 1 easy memory: star formation in spiral density waves
Extra keywords: CK-408-key

822. The compression of gas and dust in the spiral density wave spiral arms leads directly to these **OBSERVATIONALLY OBVIOUS** spiral arm features:

a) star formation, hot young, blue stars (i.e., OB stars), and H II regions. b) white dwarfs, neutron stars, and black holes. c) brown dwarfs and planets. d) Venus and Mars. e) the Moon and Mercury.

---

028 qmult 02000 1 4 1 easy deducto-memory: naked-eye galaxies
Extra keywords: CK-409-7

823. The Andromeda galaxy (M31), the Large Magellanic Cloud (LMC), and the Small Magellanic Cloud (SMC) are all:

a) naked-eye objects: i.e., they can all be seen by the naked eye. b) dwarf elliptical galaxies.
c) irregular galaxies. d) spiral galaxies. e) elliptical galaxies.

Chapt. 28 The Large-Scale Structure of the Universe

Multiple-Choice Problems

029 qmult 00120 1 4 2 easy deducto-memory: galaxy groups
Extra keywords: CK-408-key

824. "Let's play *Jeopardy*! For $100, the answer is: These objects are themselves grouped into larger structures: clusters (poor and rich), superclusters, filaments, sheets and, in a zero or near-zero population sense, voids."

What are ____________, Alex?

a) spiral arms b) galaxies c) H II regions d) black holes e) bulges

029 qmult 00130 1 4 4 easy deducto-memory: Local Group
Extra keywords: CK-407,408-key

825. The Milky Way belongs to a poor irregular group called the:

a) Great Void Group. b) Virgo supercluster. c) Virgo cluster. d) Local Group. e) Andromeda Group.

029 qmult 00140 1 4 3 easy deducto-memory: undiscovered dwarf galaxies
Extra keywords: CK-408-6

826. Some galaxies close to the Milky Way may be undiscovered because:

a) they are too large. b) located in the southern hemisphere of the celestial sphere. c) they are hidden by the Milky Way dusty disk. d) emit only **RED** light. e) emit only **GREEN** light.

029 qmult 00150 1 1 3 easy deducto-memory: Virgo cluster

827. The nearest rich cluster contains over 2000 galaxies, covers about $10^\circ \times 12^\circ$ on the sky in the constellation Virgo, is about 15 Mpc away, and has a diameter of about 3 Mpc. It is an irregular cluster. It is called the:

a) Local Group. b) Solar System. c) Virgo Cluster. d) Coma Cluster. e) Norma Cluster.

029 qmult 00160 2 5 2 moderate thinking: superclusters unbound
Extra keywords: FK-594

828. Superclusters in most cases do not seem to be gravitationally bound systems. If this is so, then in most cases their component clusters will:

a) progressively move **TOGETHER** with the expansion of the universe. b) progressively move **APART** with the expansion of the universe. c) collapse to form supermassive black holes. d) collapse to form a single supermassive black hole. e) empty into the Void.

029 qmult 00170 1 4 2 easy deducto-memory: voids defined
Extra keywords: CK-396,407

829. These structures, which are roughly spherical, are of order 30 Mpc to 120 Mpc in diameter. They are rather empty, but contain some hydrogen gas and dim galaxies. They are called:

a) dark matter regions. b) voids. c) dark energy regions. d) dim regions. e) zones of avoidance.

---

029 qmult 00180 1 4 2 easy deducto-memory: large-scale structure web-like or foamy
Extra keywords: CK-396

830. "Let's play *Jeopardy*! For $100, the answer is: The large-scale structure of galaxy groupings is often described by this adjective."

What is ____________, Alex?

a) snowy b) web-like c) nebula-like d) creamy e) joky

---

029 qmult 00330 1 1 2 easy memory: elliptical formation
Extra keywords: FK-602

831. In the formation of elliptical galaxies, the orbits of the stars are randomized (almost always by mergers it seems) and the galaxy becomes quenched (i.e., star formation turns off or nearly off) typically on the time scale of gigayears. Gas in quenched elliptical galaxies:

a) has collapsed to form a supermassive black hole. b) is too hot to form stars. c) vanished into thin air. d) mutually annihilated. e) dissolved into helium.

Chapt. 29 Cosmology

Multiple-Choice Problems

---

030 qmult 00100 1 1 5 easy memory: cosmology defined
Extra keywords: physci

832. The science of the universe as a whole is called:

a) proctology. b) universology. c) cosmetology. d) inflation. e) cosmology.

---

030 qmult 00110 1 1 4 easy memory: cosmology defined 2
Extra keywords: physci

833. Cosmology is the science of the universe with emphasis on the observable universe including as a main feature:

a) stars. b) star clusters. c) supernovae. d) the large-scale structure.
e) the cosmic X-ray background.

---

030 qmult 00120 1 1 2 easy memory: general relativity in cosmology
Extra keywords: cosmology

834. By the reckoning of almost any cosmologist, the main physics theory ingredient to cosmology is:

a) planetary systems. b) general relativity. c) special relativity.
d) the quantum theory of solids. e) helioseismology.

---

030 qmult 00130 1 1 3 easy memory: the large-scale structure determined by gravity
Extra keywords: cosmology

835. The large-scale structure (taken as a given the initial conditions from the Big Bang) is determined primarily and overwhelmingly by:

a) the electric force. b) the magnetic force. c) gravity. d) gas pressure.
e) radiation pressure.

---

030 qmult 00200 1 1 1 easy memory: cosmology concerns itself with nature of
Extra keywords: cosmology

836. Modern physical cosmology concerns itself primarily with the universe in regard to:

a) nature of. b) purpose. c) meaning. d) mythology. e) consciousness.

---

030 qmult 00220 1 1 2 easy memory: philosophical cosmology as a source for hypotheses
Extra keywords: cosmology

837. Using philosophical ideas as a source of interesting cosmological hypotheses in research using the scientific method is valid as long as the hypotheses are taken as:

a) dogma. b) things to be tested empirically. c) truth. d) mythology.
e) false.

---

030 qmult 00330 1 4 4 easy deducto-memory: Democritus and Democritian cosmology

838. "Let's play *Jeopardy*! For $100, the answer is: The Pre-Socratic philosopher who proposed a universe full atoms moving in an infinite, eternal void. Occasionally, vortices formed by chance

in the void. In brief, the evolution of a vortex is as follows. The vortex developed a membrane surrounding a region where an up-and-down axis developed (not necessarily aligned with the axis of rotation of the vortex). The lower part of the vortex became solid ground and ocean and the upper part air. Stars rotated with the membrane and planets (including maybe moons, and suns) moved relative to the rotation in some way. The vortex worlds or cosmoses were not eternal, they came and went. Humankind lives in a vortex cosmos with one moon, one sun, and a rotation axis not aligned with the up-and-down axis."

Who was ____________, Alex?

a) Hesiod (circa late 8th century BCE) b) Anaximander (c.610–c.546 BCE)
c) Socrates (c.469–399 BCE) d) Democritus (c.460–c.370 BCE)
e) Aristarchos of Samos (c.310–c.230 BCE)

---

030 qmult 00370 1 1 3 easy memory: Newton, cosmology, absolute space

839. Isaac Newton (1643–1727) in unpubished work did try to contruct a Newtonian cosmology using Newtonian physics. In fact, he didn't try very hard it seems. In any case, he could not find a way to make his cosmological model stable against continual graviational collapses under self gravity. One limitation in his thinking, as we now see it, was that he assumed the stars were at rest on average in his postulated fundamental inertial frame which he called:

a) the Sun frame. b) the Milky Way. c) absolute space. d) absolute time.
e) the Moon frame.

---

030 qmult 00450 1 1 3 easy memory: Hubble's law
Extra keywords: physci

840. Given v as recession velocity and r as cosmological physical distance, Hubble's law is:

a) $r = Hv$. b) $r = H/v$. c) $v = Hr$. d) $v = H/r$. e) $v = Hr^2$.

---

030 qmult 00460 1 4 3 easy deducto-memory: discoverer of Hubble's law
Extra keywords: physci

841. "Let's play *Jeopardy*! For \$100, the answer is: He/she is the person who observationally discovered Hubble's law."

Who is ____________, Alex?

a) Henrietta Swan Leavitt (1868–1921) b) Knut Lundmark (1889–1958)
c) Edwin Hubble (1889–1953) d) Georges Lemaître (1894–1966)
e) Adriaan van Maanen (1884–1946)

---

030 qmult 00470 1 4 1 easy deducto-memory: Hubble time
Extra keywords: physci KB-668-26

842. The current value of the Hubble time and the Λ-CDM model (AKA the concordance model) value for the age of the universe are both about:

a) 14 Gyr. b) 10^{100} yr. c) 10 years. d) 4.6 Gyr. e) 0.

---

030 qmult 00480 1 1 4 easy memory: Hubble length observable universe
Extra keywords: physci KB-670-22

843. The Hubble length is $4.283h_{70}^{-1}$ Gpc (where h_{70} is the reduced Hubble constant: it is equal to 1 to within a few percent). It is a characteristic size scale for the:

a) quantum of the inflaton. b) Milky Way. c) total universe.
d) observable universe. e) Solar System.

---

030 qmult 00490 1 5 2 easy thinking: reverse Hubble law
Extra keywords: physci KB-670-30

844. Suppose counterfactually that we had discovered a reverse Hubble law:

$$v = -Hr \ ,$$

where the recession velocities v were negative and their absolute values increased linearly with cosmological physical distances r. The negative velocities would be determined from blueshifts of galaxies. The reverse Hubble law would imply a universal:

a) expansion anyway. b) contraction. c) static condition. d) smoothing. e) roughening.

---

030 qmult 00500 1 1 3 easy memory: Einstein universe defined
845. The Einstein universe presented by Einstein in 1917 is a/an ____________ universe model.

a) contracting, hyperspherical b) expanding, hyperspherical
c) static, hyperspherical d) static, hypercritical e) expanding, hypercritical

---

030 qmult 00510 1 1 1 easy memory: Einstein universe finite, but unbounded
846. The Einstein universe is:

a) finite, but unbounded. b) finite and bounded. c) infinite and unbounded.
d) infinite, but bounded. e) quasi-infinite and quasi-bounded.

---

030 qmult 00524 1 1 1 easy memory: Einstein's reason for doing cosmology
847. One of the reasons and probably the main reason for Einstein starting to do cosmology in 1917 was to add support to general relativity as a universally true theory. After all, if general relativity was a universally true theory and gravity determines the largest scale structures of the universe, then general relativity should be able to account for the:

a) **LARGEST** scale structure of the universe. b) **UNIVERSE** in part.
c) universe **NOT** at all. d) **BIG BANG**. e) **COSMIC** microwave background.

---

030 qmult 00600 1 4 2 easy deducto-memory: de Sitter universe defined
848. "Let's play *Jeopardy*! For \$100, the answer is: It is an eternal, exponentially expanding cosmological model with no mass-energy content, but only a cosmological constant."

What is the ____________, Alex?

a) Einstein universe (1917) b) de Sitter universe (1917)
c) Lemaître universe (1931?) d) Eddington-Lemaˆ itre universe (1925)
e) Einstein-de Sitter universe (1932)

---

030 qmult 00700 1 4 3 easy deducto-memory: Friedmann-equation models
849. "Let's play *Jeopardy*! For \$100, the answer is: These models were the first plausible universe models (in that they contained mass-energy) to predict the expansion of the universe."

What are the ____________ models, Alex?

a) Alpher-Behte-Gamow b) Einstein-Lemaître c) Friedmann-equation
d) Einstein-equation e) Gamow-equation

---

030 qmult 00720 1 4 5 easy deducto-memory: Big Bang singularity
Extra keywords: physci KB-668-27
850. "Let's play *Jeopardy*! For \$100, the answer is: It is the singularity (i.e., infinite density) condition at the beginning of cosmic time in the most considered Friedmann-equation models or the time period close to that singularity in most modern usages."

What is the ____________, Alex?

a) big rip b) big crunch c) nullility d) big band e) Big Bang

---

030 qmult 00730 1 4 5 easy deducto-memory: Omega in Friedmann-equation models

851. "Let's play *Jeopardy*! For $100, the answer is: In the Friedmann-equation models, it is the symbol for density parameter which is the parameter that that specifies the geometry of the universe: if less than 1, the universe is hyperbolic and infinite; if equal to 1, the universe is flat and infinite; if greater than 1, the universe is hyperspherical and finite. The symbol name is often used as synonym for density parameter."

What is ____________, Alex?

a) Λ (spelt Lambda) b) Ψ (spelt Psi) c) Δ (spelt Delta) d) Γ (spelt Gamma) e) Ω (spelt Omega)

---

030 qmult 00732 3 4 1 tough deducto-memory: Omega and curvature
Extra keywords: physci KB-670-32

852. The curvature of space in Friedmann-equation models is determined by the total density parameter (i.e., total Ω or Omega), **NOT** counting the curvature density parameter (which does **NOT** represent a real density). The total density parameter is the ratio of total universal average mass-energy density to the critical mass-energy density. The curvature possibilities are:

a) hyperbolic ($\Omega < 1$), flat ($\Omega = 1$), and hyperspherical ($\Omega > 1$).
b) hyperspherical ($\Omega < 1$), flat ($\Omega = 1$), and hyperbolic ($\Omega > 1$).
c) hyperbolic ($\Omega < 1$), hyperspherical ($\Omega = 1$), and flat ($\Omega > 1$).
d) spiral ($\Omega < 1$), elliptical ($\Omega = 1$), and irregular ($\Omega > 1$).
e) hypnotical ($\Omega < 1$), sharp ($\Omega = 1$), and hypercritical ($\Omega > 1$).

---

030 qmult 00800 1 1 5 easy memory: accelerating universe
Extra keywords: physci KB-668-28 but note their answer is wrong.

853. According to observations of several kinds beginning in 1998, it is almost certain that the universal expansion is currently:

a) decelerating. b) stopped. c) negative: i.e., the universe is contracting. d) in doubt. e) accelerating.

---

030 qmult 00810 2 4 5 mod. deducto memory: cosmological constant
Extra keywords: physci

854. The simplest explanation considered for the accelerating expansion of the universe is:

a) planet explosions. b) supernovae. c) stellar winds. d) green energy. e) a cosmological constant.

---

030 qmult 00910 1 1 3 easy memory: dark energy and cosmological constant

855. The acceleration of the universe can most simply be accounted for by a (nonzero) cosmological constant. Alternatively, one can use a constant ____________. The two are conceptionally different, but have exactly the same effect on the time evolution of the cosmic scale factor $a(t)$: i.e., they are effectively the same. Because they are effectively the same, the cosmological constant and constant ____________ are often used as if they were synonyms—which is fine as long as you know what you mean.

a) dark matter b) grey matter c) dark energy d) grey energy e) dark grey

---

030 qmult 01000 1 1 1 easy memory: Lambda-CDM or concordance model defined

856. The Friedmann-equation Λ model (i.e., the Friedmann-equation model with a nonzero cosmological constant Λ or nonzero dark energy but still using the letter Λ since one knows what one means) with parameters adjusted to fit current observations was once often called the concordance model, but nowadays is more usually nowadays called the:

a) Λ-CDM model. b) Ω-CDM model. c) Λ-HDM model. d) Ω-HDM model. e) discord model.

---

030 qmult 01030 1 4 1 easy deducto-memory: dark matter
Extra keywords: physci KB-669-34

857. After the dark energy (whatever that is and assuming it's not just an effect of a true cosmological constant), the most abundant form of mass-energy in the universe is apparently some form of matter known only (at least to circa 2020) through its gravitational effects. We call this matter:

a) dark matter. b) dark energy matter. c) baryonic matter.
d) invisible matter. e) mirror matter.

---

030 qmult 01100 1 1 4 easy memory: cosmological redshift direct observable distance measure

858. A direct observable cosmological distance measure obtainable out to any distance is:

a) physical or proper distance. b) observed light flux. c) recession velocity.
d) the cosmological redshift. e) lookback time.

---

030 qmult 01280 1 1 3 easy memory: heat death of the universe

859. If one wildly extrapolates the Λ-CDM model to cosmic time of order 10^{100} to 10^{1000} years or so after the Big Bang, all black holes will have evaporated and all protons and neutrons will have decayed (if they are indeed unstable). The observable universe will then just consist of photons, electrons, positrons, neutrinos, and dark matter particles (if they are stable), and will be expanding forever, getting ever less dense and ever colder and dimmer due the continual loss of heat energy and photon energy caused by the expansion of the universe. This unhappy fate is named the ____________. In the 19th century in terms of a much simpler cosmology than now, Lord Kelvin (1824–1907) first considered the ____________. However, the name ____________ seems to have been coined by Hermann von Helmholtz (1821–1894), probably in German: i.e., *Hitzetod des Universums*.

a) universal absolute zero b) asymptotic universal absolute zero
c) heat death of the universe d) cold death of the universe
e) fade out of the universe

---

030 qmult 01300 1 1 3 easy memory: Big Bang in brief defined
Extra keywords: physci KB-668-27

860. The Big Bang, in brief, is the:

a) explosion of a supernova. b) explosion of a star. c) origin of the observable universe. d) explosion of a quasar. e) end of the observable universe or our pocket universe.

---

030 qmult 01330 1 1 3 easy memory: H and He from Big Bang nucleosynthesis
Extra keywords: physci KB-669-29

861. In Big Bang nucleosynthesis, the two most abundant products are:

a) hydrogen and iron in about a 1:1 mass ratio. b) hydrogen and helium in about a 1:1 mass ratio. c) hydrogen and helium in about a 3:1 mass ratio. d) hydrogen and iron in about a 3:1 mass ratio. e) helium and iron in equal amounts by mass.

---

030 qmult 01332 1 4 1 easy deducto-memory: origin of the heavy elements
Extra keywords: physci KB-669-30

862. Most of the elements in the observable universe heavier than lithium were formed in:

a) stars and supernovae. b) black holes. c) the Big Bang. d) nuclear reactors.
e) planets.

---

030 qmult 01370 1 4 4 easy deducto memory: CMB defined
Extra keywords: physci KB-669-33

863. The relic primordial electromagnetic radiation field which decoupled from matter in the recombination era circa 400,000 years after the Big Bang when hydrogen became neutral making

the observable universe transparent and which has since free streamed through space and cooled off because of the expansion of the universe is called the:

a) Cosmic Gamma-ray Background (CGB). b) Cosmic X-ray Bare Ground (CXBG). c) Cosmic X-ray Foreground (CXF). d) Cosmic Microwave Background (CMB). e) Cosmic X-ray Background (CXB).

---

030 qmult 01372 1 4 2 easy deducto-memory: CMB temperature present-day

864. "Let's play *Jeopardy*! For \$100, the answer is: It is the temperature of the cosmic microwave background (CMB) in the present-day observable universe."

What is ____________, Alex?

a) 15.7×10^6 K b) 2.72548 K c) 5777 K d) about 3000 K e) 300 K

---

030 qmult 01390 1 4 4 easy deducto memory: 5 evidences for Big Bang
Extra keywords: physci-670-28

865. Five observational evidences are:

1. the expansion of the universe.
2. the abundances of the light elements: H, D, He, and Li.
3. the existence of the cosmic microwave background (CMB).
4. that the fluctuations in the CMB are accounted for by primordial density fluctuations that account adequately so far for the initial conditions for the large-scale structure of the universe.
5. that the oldest stars ($\gtrsim 13.6$ Gyr) are not older than the observable universe.

These evidences strongly support:

a) Inflation cosmology. b) the steady state universe. c) little bang cosmology. d) Big Bang cosmology. e) Eternal Inflation cosmology.

---

030 qmult 01450 1 4 4 easy deducto-memory: Hubble tension

866. The Λ-CDM model is in almost all respects a very adequate cosmological model for the observable universe. But there is one major discrepancy at present. The Hubble constant measured directly from the local universe and the Hubble constant measured indirectly using the cosmic microwave background (and relying on the Λ-CDM model itself) do not agree within observational error. Either one or both measurements are wrong if the Λ-CDM model is correct. However, it seems likely that both measurements are correct, except the indirect measurement cannot actually be a measurement of the Hubble constant if they are both correct as measurements: it must be a measurement of something else. This means the Λ-CDM model probably needs to be revised perhaps to the extent that we need a new name for the revision. The disagreement in the two Hubble constant measurements is called the:

a) Hubble anomaly. b) Hubble dispute. c) Hubble-Lemaître dispute. d) Hubble tension. e) Hubble X problem

---

030 qmult 01500 1 4 5 easy deducto-memory: inflation defined
Extra keywords: CK-446

867. "Let's play *Jeopardy*! For \$100, the answer is: It is name for the super-rapid expansion that the observable universe and maybe beyond may have undergone at very early times.

What is ____________, Alex?

a) inoculation b) infestation c) hybridization d) hydration e) inflation

---

030 qmult 01550 1 4 4 easy deducto-memory: problems solved by inflation
Extra keywords: CK-446

868. "Let's play *Jeopardy*! For \$100, the answer is: This concept offers possible solutions to three problems of cosmology: the magnetic monopole, horizon, and flatness problems."

What is ____________, Alex?

a) the cosmological constant Λ b) the Einstein universe c) Big Bang cosmology d) inflation e) perdition

---

030 qmult 01690 1 4 1 easy deducto-memory: golden age of cosmology

869. "Let's play *Jeopardy*! For \$100, the answer is: The popular name (among astronomers anyway) for the period in cosmological research since circa 1992."

What is the ____________ of cosmology, Alex?

a) golden age b) silver age c) bronze age d) iron age e) dawn age

Chapt. 30 Life in the Universe

Multiple-Choice Problems

031 qmult 00100 1 4 2 easy deducto-memory: extraterrestrial life discovered

870. Has extraterrestrial life been discovered for **CERTAIN**?

a) Yes. b) No. c) Maybe. d) Yes and no. e) Yes: 20 years ago.

031 qmult 00200 1 4 1 easy deducto-memory: Kepler's Somnium

871. "Let's play *Jeopardy*! For $100, the answer is: He/she is the author of the *Somnium* which is arguably the first science fiction story dealing with space travel and aliens."

Who is ____________, Alex?

a) Johannes Kepler (1571–1630) b) Caroline Herschel (1750–1848) c) Percival Lowell (1855–1916) d) Georges Lemaître (1894–1966) e) Fred Hoyle (1915–2001)

031 qmult 00250 1 4 2 easy deducto-memory: Fermi's question

872. "Let's play *Jeopardy*! For $100, the answer is: He/she asked the famous question (re intelligent alien life) 'Don't you ever wonder where everybody is?' which is sometimes apocryphally quoted as the more emphatic 'Where are they?' "

Who is ____________, Alex?

a) Johannes Kepler (1571–1630) b) Enrico Fermi (1901–1954) c) Edwin Hubble (1889–1953) d) Ptolemy (c.100–c.170 CE) e) Caroline Herschel (1750–1848)

031 qmult 00300 1 1 5 easy memory: Drake equation
Extra keywords: CK-456

873. What equation is used to estimate the number of technologically advanced civilizations in the Milky Way?

a) The Mandrake equation. b) The Einstein equation. c) The Dragon equation. d) The Duck equation. e) The Drake equation.

031 qmult 00310 1 1 2 easy memory: technologically advanced civilization

874. For practical reasons in SETI (Search for ExtraTerrestial Intelligence), it is convenient to define a technologically advanced civilization as one:

a) without radio communication. b) with radio communication. c) with agriculture. d) without agriculture. e) with steam engines.

031 qmult 00320 2 4 4 moderate deducto-memory: mean number of civilizations

875. If the birth rate of technologically advanced civilizations in the Milky Way is R and they all have lifetimes L, how many exist at any one time?

a) Zero since as many are being born as are dying. b) The number is indeterminate. c) 10^{RL}. d) RL. e) R/L.

---

031 qmult 00410 1 1 3 easy memory: SETI method
Extra keywords: CK-452

876. SETI is usually carried out by:

a) X-ray observations. b) mechanical probes. c) radio observations. d) optical observations. e) elves.

---

031 qmult 00500 1 1 5 easy memory: alien contact when

877. When are we likely to be contacted by alien intelligence?

a) Tomorrow. b) Never. c) We already have been contacted: that is what UFO stories have proven. d) In a million years. e) We don't know.

Chapt. 31 Special and General Relativity

Multiple-Choice Problems

055 qmult 00100 1 4 2 easy deducto-memory: Einstein and relativity

878. "Let's play *Jeopardy*! For $100, the answer is: He/she is the discoverer of special and general relativity."

Who is ____________, Alex?

a) Henrietta Swan Leavitt (1868–1921) b) Albert Einstein (1879–1955) c) Edwin Hubble (1889–1953) d) Georges Lemaître (1894–1966) e) Adriaan van Maanen (1884–1946)

055 qmult 00200 2 5 4 moderate thinking: special relativity

879. A postulate of special relativity is that the speed of light is:

a) the same for all accelerated observers.
b) different in different inertial frames.
c) independent of the gravitational field.
d) a constant and the same for all inertial-frame observers regardless of their motions.
e) a constant and dependent on the phase of the Moon.

055 qmult 01000 1 1 1 easy memory: general relativity
Extra keywords: CK-362

880. Einstein's general relativity (GR) is primarily a theory of:

a) gravity, mass-energy, and spacetime. b) electromagnetism. c) light. d) Newtonian forces. e) atoms and nuclei.

055 qmult 01100 1 1 3 easy memory: gravitational redshift
Extra keywords: CK-362

881. Electromagnetic radiation that emerges from any gravity well experiences a:

a) gravitational blueshift. b) gravitational greenshift. c) gravitational redshift. d) transcendental moment. e) senior moment.

Appendix 32 Multiple-Choice Problem Answer Tables

Note: For those who find scantrons frequently inaccurate and prefer to have their own table and marking template, the following are provided. I got the template trick from Neil Huffacker at University of Oklahoma. One just punches out the right answer places on an answer table and overlays it on student answer tables and quickly identifies and marks the wrong answers

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
882.	O	O	O	O	O	6.	O	O	O	O	O
883.	O	O	O	O	O	7.	O	O	O	O	O
884.	O	O	O	O	O	8.	O	O	O	O	O
885.	O	O	O	O	O	9.	O	O	O	O	O
886.	O	O	O	O	O	10.	O	O	O	O	O

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e
887.	O	O	O	O	O
888.	O	O	O	O	O
889.	O	O	O	O	O
890.	O	O	O	O	O
891.	O	O	O	O	O
892.	O	O	O	O	O
893.	O	O	O	O	O
894.	O	O	O	O	O
895.	O	O	O	O	O
896.	O	O	O	O	O

	a	b	c	d	e
11.	O	O	O	O	O
12.	O	O	O	O	O
13.	O	O	O	O	O
14.	O	O	O	O	O
15.	O	O	O	O	O
16.	O	O	O	O	O
17.	O	O	O	O	O
18.	O	O	O	O	O
19.	O	O	O	O	O
20.	O	O	O	O	O

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
897.	O	O	O	O	O	16.	O	O	O	O	O
898.	O	O	O	O	O	17.	O	O	O	O	O
899.	O	O	O	O	O	18.	O	O	O	O	O
900.	O	O	O	O	O	19.	O	O	O	O	O
901.	O	O	O	O	O	20.	O	O	O	O	O
902.	O	O	O	O	O	21.	O	O	O	O	O
903.	O	O	O	O	O	22.	O	O	O	O	O
904.	O	O	O	O	O	23.	O	O	O	O	O
905.	O	O	O	O	O	24.	O	O	O	O	O
906.	O	O	O	O	O	25.	O	O	O	O	O
907.	O	O	O	O	O	26.	O	O	O	O	O
908.	O	O	O	O	O	27.	O	O	O	O	O
909.	O	O	O	O	O	28.	O	O	O	O	O
910.	O	O	O	O	O	29.	O	O	O	O	O
911.	O	O	O	O	O	30.	O	O	O	O	O

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
912.	O	O	O	O	O	19.	O	O	O	O	O
913.	O	O	O	O	O	20.	O	O	O	O	O
914.	O	O	O	O	O	21.	O	O	O	O	O
915.	O	O	O	O	O	22.	O	O	O	O	O
916.	O	O	O	O	O	23.	O	O	O	O	O
917.	O	O	O	O	O	24.	O	O	O	O	O
918.	O	O	O	O	O	25.	O	O	O	O	O
919.	O	O	O	O	O	26.	O	O	O	O	O
920.	O	O	O	O	O	27.	O	O	O	O	O
921.	O	O	O	O	O	28.	O	O	O	O	O
922.	O	O	O	O	O	29.	O	O	O	O	O
923.	O	O	O	O	O	30.	O	O	O	O	O
924.	O	O	O	O	O	31.	O	O	O	O	O
925.	O	O	O	O	O	32.	O	O	O	O	O
926.	O	O	O	O	O	33.	O	O	O	O	O
927.	O	O	O	O	O	34.	O	O	O	O	O
928.	O	O	O	O	O	35.	O	O	O	O	O
929.	O	O	O	O	O	36.	O	O	O	O	O

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
930.	O	O	O	O	O	21.	O	O	O	O	O
931.	O	O	O	O	O	22.	O	O	O	O	O
932.	O	O	O	O	O	23.	O	O	O	O	O
933.	O	O	O	O	O	24.	O	O	O	O	O
934.	O	O	O	O	O	25.	O	O	O	O	O
935.	O	O	O	O	O	26.	O	O	O	O	O
936.	O	O	O	O	O	27.	O	O	O	O	O
937.	O	O	O	O	O	28.	O	O	O	O	O
938.	O	O	O	O	O	29.	O	O	O	O	O
939.	O	O	O	O	O	30.	O	O	O	O	O
940.	O	O	O	O	O	31.	O	O	O	O	O
941.	O	O	O	O	O	32.	O	O	O	O	O
942.	O	O	O	O	O	33.	O	O	O	O	O
943.	O	O	O	O	O	34.	O	O	O	O	O
944.	O	O	O	O	O	35.	O	O	O	O	O
945.	O	O	O	O	O	36.	O	O	O	O	O
946.	O	O	O	O	O	37.	O	O	O	O	O
947.	O	O	O	O	O	38.	O	O	O	O	O
948.	O	O	O	O	O	39.	O	O	O	O	O
949.	O	O	O	O	O	40.	O	O	O	O	O

NAME:

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
950.	O	O	O	O	O	26.	O	O	O	O	O
951.	O	O	O	O	O	27.	O	O	O	O	O
952.	O	O	O	O	O	28.	O	O	O	O	O
953.	O	O	O	O	O	29.	O	O	O	O	O
954.	O	O	O	O	O	30.	O	O	O	O	O
955.	O	O	O	O	O	31.	O	O	O	O	O
956.	O	O	O	O	O	32.	O	O	O	O	O
957.	O	O	O	O	O	33.	O	O	O	O	O
958.	O	O	O	O	O	34.	O	O	O	O	O
959.	O	O	O	O	O	35.	O	O	O	O	O
960.	O	O	O	O	O	36.	O	O	O	O	O
961.	O	O	O	O	O	37.	O	O	O	O	O
962.	O	O	O	O	O	38.	O	O	O	O	O
963.	O	O	O	O	O	39.	O	O	O	O	O
964.	O	O	O	O	O	40.	O	O	O	O	O
965.	O	O	O	O	O	41.	O	O	O	O	O
966.	O	O	O	O	O	42.	O	O	O	O	O
967.	O	O	O	O	O	43.	O	O	O	O	O
968.	O	O	O	O	O	44.	O	O	O	O	O
969.	O	O	O	O	O	45.	O	O	O	O	O
970.	O	O	O	O	O	46.	O	O	O	O	O
971.	O	O	O	O	O	47.	O	O	O	O	O
972.	O	O	O	O	O	48.	O	O	O	O	O
973.	O	O	O	O	O	49.	O	O	O	O	O
974.	O	O	O	O	O	50.	O	O	O	O	O

	a	b	c	d	e		a	b	c	d	e
975.	O	O	O	O	O	71.	O	O	O	O	O
976.	O	O	O	O	O	72.	O	O	O	O	O
977.	O	O	O	O	O	73.	O	O	O	O	O
978.	O	O	O	O	O	74.	O	O	O	O	O
979.	O	O	O	O	O	75.	O	O	O	O	O
980.	O	O	O	O	O	76.	O	O	O	O	O
981.	O	O	O	O	O	77.	O	O	O	O	O
982.	O	O	O	O	O	78.	O	O	O	O	O
983.	O	O	O	O	O	79.	O	O	O	O	O
984.	O	O	O	O	O	80.	O	O	O	O	O
985.	O	O	O	O	O	81.	O	O	O	O	O
986.	O	O	O	O	O	82.	O	O	O	O	O
987.	O	O	O	O	O	83.	O	O	O	O	O
988.	O	O	O	O	O	84.	O	O	O	O	O
989.	O	O	O	O	O	85.	O	O	O	O	O
990.	O	O	O	O	O	86.	O	O	O	O	O
991.	O	O	O	O	O	87.	O	O	O	O	O
992.	O	O	O	O	O	88.	O	O	O	O	O
993.	O	O	O	O	O	89.	O	O	O	O	O
994.	O	O	O	O	O	90.	O	O	O	O	O
995.	O	O	O	O	O	91.	O	O	O	O	O
996.	O	O	O	O	O	92.	O	O	O	O	O
997.	O	O	O	O	O	93.	O	O	O	O	O
998.	O	O	O	O	O	94.	O	O	O	O	O
999.	O	O	O	O	O	95.	O	O	O	O	O
1000.	O	O	O	O	O	96.	O	O	O	O	O
1001.	O	O	O	O	O	97.	O	O	O	O	O
1002.	O	O	O	O	O	98.	O	O	O	O	O
1003.	O	O	O	O	O	99.	O	O	O	O	O
1004.	O	O	O	O	O	100.	O	O	O	O	O

Answer Table

	a	b	c	d	e
1005.	O	O	O	O	O
1006.	O	O	O	O	O
1007.	O	O	O	O	O
1008.	O	O	O	O	O
1009.	O	O	O	O	O
1010.	O	O	O	O	O
1011.	O	O	O	O	O
1012.	O	O	O	O	O
1013.	O	O	O	O	O
1014.	O	O	O	O	O
1015.	O	O	O	O	O
1016.	O	O	O	O	O
1017.	O	O	O	O	O
1018.	O	O	O	O	O
1019.	O	O	O	O	O
1020.	O	O	O	O	O
1021.	O	O	O	O	O
1022.	O	O	O	O	O
1023.	O	O	O	O	O
1024.	O	O	O	O	O
1025.	O	O	O	O	O
1026.	O	O	O	O	O
1027.	O	O	O	O	O
1028.	O	O	O	O	O
1029.	O	O	O	O	O
1030.	O	O	O	O	O
1031.	O	O	O	O	O
1032.	O	O	O	O	O
1033.	O	O	O	O	O
1034.	O	O	O	O	O
1035.	O	O	O	O	O
1036.	O	O	O	O	O
1037.	O	O	O	O	O
1038.	O	O	O	O	O
1039.	O	O	O	O	O
1040.	O	O	O	O	O

Name:

	a	b	c	d	e
37.	O	O	O	O	O
38.	O	O	O	O	O
39.	O	O	O	O	O
40.	O	O	O	O	O
41.	O	O	O	O	O
42.	O	O	O	O	O
43.	O	O	O	O	O
44.	O	O	O	O	O
45.	O	O	O	O	O
46.	O	O	O	O	O
47.	O	O	O	O	O
48.	O	O	O	O	O
49.	O	O	O	O	O
50.	O	O	O	O	O
51.	O	O	O	O	O
52.	O	O	O	O	O
53.	O	O	O	O	O
54.	O	O	O	O	O
55.	O	O	O	O	O
56.	O	O	O	O	O
57.	O	O	O	O	O
58.	O	O	O	O	O
59.	O	O	O	O	O
60.	O	O	O	O	O
61.	O	O	O	O	O
62.	O	O	O	O	O
63.	O	O	O	O	O
64.	O	O	O	O	O
65.	O	O	O	O	O
66.	O	O	O	O	O
67.	O	O	O	O	O
68.	O	O	O	O	O
69.	O	O	O	O	O
70.	O	O	O	O	O
71.	O	O	O	O	O
72.	O	O	O	O	O

Answer Table

	a	b	c	d	e
1041.	O	O	O	O	O
1042.	O	O	O	O	O
1043.	O	O	O	O	O
1044.	O	O	O	O	O
1045.	O	O	O	O	O
1046.	O	O	O	O	O
1047.	O	O	O	O	O
1048.	O	O	O	O	O
1049.	O	O	O	O	O
1050.	O	O	O	O	O
1051.	O	O	O	O	O
1052.	O	O	O	O	O
1053.	O	O	O	O	O
1054.	O	O	O	O	O
1055.	O	O	O	O	O
1056.	O	O	O	O	O
1057.	O	O	O	O	O
1058.	O	O	O	O	O
1059.	O	O	O	O	O
1060.	O	O	O	O	O
1061.	O	O	O	O	O
1062.	O	O	O	O	O
1063.	O	O	O	O	O
1064.	O	O	O	O	O
1065.	O	O	O	O	O
1066.	O	O	O	O	O
1067.	O	O	O	O	O
1068.	O	O	O	O	O
1069.	O	O	O	O	O
1070.	O	O	O	O	O
1071.	O	O	O	O	O
1072.	O	O	O	O	O
1073.	O	O	O	O	O
1074.	O	O	O	O	O
1075.	O	O	O	O	O
1076.	O	O	O	O	O
1077.	O	O	O	O	O
1078.	O	O	O	O	O
1079.	O	O	O	O	O
1080.	O	O	O	O	O

Name:

	a	b	c	d	e
41.	O	O	O	O	O
42.	O	O	O	O	O
43.	O	O	O	O	O
44.	O	O	O	O	O
45.	O	O	O	O	O
46.	O	O	O	O	O
47.	O	O	O	O	O
48.	O	O	O	O	O
49.	O	O	O	O	O
50.	O	O	O	O	O
51.	O	O	O	O	O
52.	O	O	O	O	O
53.	O	O	O	O	O
54.	O	O	O	O	O
55.	O	O	O	O	O
56.	O	O	O	O	O
57.	O	O	O	O	O
58.	O	O	O	O	O
59.	O	O	O	O	O
60.	O	O	O	O	O
61.	O	O	O	O	O
62.	O	O	O	O	O
63.	O	O	O	O	O
64.	O	O	O	O	O
65.	O	O	O	O	O
66.	O	O	O	O	O
67.	O	O	O	O	O
68.	O	O	O	O	O
69.	O	O	O	O	O
70.	O	O	O	O	O
71.	O	O	O	O	O
72.	O	O	O	O	O
73.	O	O	O	O	O
74.	O	O	O	O	O
75.	O	O	O	O	O
76.	O	O	O	O	O
77.	O	O	O	O	O
78.	O	O	O	O	O
79.	O	O	O	O	O
80.	O	O	O	O	O

1081.	O	O	O	O	O	81.	O	O	O	O	O

NAME:

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
1082.	O	O	O	O	O	26.	O	O	O	O	O
1083.	O	O	O	O	O	27.	O	O	O	O	O
1084.	O	O	O	O	O	28.	O	O	O	O	O
1085.	O	O	O	O	O	29.	O	O	O	O	O
1086.	O	O	O	O	O	30.	O	O	O	O	O
1087.	O	O	O	O	O	31.	O	O	O	O	O
1088.	O	O	O	O	O	32.	O	O	O	O	O
1089.	O	O	O	O	O	33.	O	O	O	O	O
1090.	O	O	O	O	O	34.	O	O	O	O	O
1091.	O	O	O	O	O	35.	O	O	O	O	O
1092.	O	O	O	O	O	36.	O	O	O	O	O
1093.	O	O	O	O	O	37.	O	O	O	O	O
1094.	O	O	O	O	O	38.	O	O	O	O	O
1095.	O	O	O	O	O	39.	O	O	O	O	O
1096.	O	O	O	O	O	40.	O	O	O	O	O
1097.	O	O	O	O	O	41.	O	O	O	O	O
1098.	O	O	O	O	O	42.	O	O	O	O	O
1099.	O	O	O	O	O	43.	O	O	O	O	O
1100.	O	O	O	O	O	44.	O	O	O	O	O
1101.	O	O	O	O	O	45.	O	O	O	O	O
1102.	O	O	O	O	O	46.	O	O	O	O	O
1103.	O	O	O	O	O	47.	O	O	O	O	O
1104.	O	O	O	O	O	48.	O	O	O	O	O
1105.	O	O	O	O	O	49.	O	O	O	O	O
1106.	O	O	O	O	O	50.	O	O	O	O	O

	a	b	c	d	e		a	b	c	d	e
1107.	O	O	O	O	O	76.	O	O	O	O	O
1108.	O	O	O	O	O	77.	O	O	O	O	O
1109.	O	O	O	O	O	78.	O	O	O	O	O
1110.	O	O	O	O	O	79.	O	O	O	O	O
1111.	O	O	O	O	O	80.	O	O	O	O	O
1112.	O	O	O	O	O	81.	O	O	O	O	O
1113.	O	O	O	O	O	82.	O	O	O	O	O
1114.	O	O	O	O	O	83.	O	O	O	O	O
1115.	O	O	O	O	O	84.	O	O	O	O	O
1116.	O	O	O	O	O	85.	O	O	O	O	O
1117.	O	O	O	O	O	86.	O	O	O	O	O
1118.	O	O	O	O	O	87.	O	O	O	O	O
1119.	O	O	O	O	O	88.	O	O	O	O	O
1120.	O	O	O	O	O	89.	O	O	O	O	O
1121.	O	O	O	O	O	90.	O	O	O	O	O
1122.	O	O	O	O	O	91.	O	O	O	O	O
1123.	O	O	O	O	O	92.	O	O	O	O	O
1124.	O	O	O	O	O	93.	O	O	O	O	O
1125.	O	O	O	O	O	94.	O	O	O	O	O
1126.	O	O	O	O	O	95.	O	O	O	O	O
1127.	O	O	O	O	O	96.	O	O	O	O	O
1128.	O	O	O	O	O	97.	O	O	O	O	O
1129.	O	O	O	O	O	98.	O	O	O	O	O
1130.	O	O	O	O	O	99.	O	O	O	O	O
1131.	O	O	O	O	O	100.	O	O	O	O	O