Astronomy 101A: 2nd Exam
2005 Mar08 Tuesday

Instructions: There are 50 multiple-choice questions and the test is out of 50 marks. Choose the BEST answer, completion, etc., and darken fully the appropriate circle on the TABLE provided on page 2. Read all responses carefully. NOTE that long, detailed responses won’t depend on hidden keywords: keywords in such responses are BOLD-FACED capitalized.

This is a CLOSED-BOOK exam. NO cheat sheets allowed. Calculators are permitted. This a 75 minute exam. Remember your name (and write it down on the exam too). DO NOT discuss the test with those in any section who have not taken it.

You must show a photo id when handing in the exam.
### NAME:

#### Answer Table for the Multiple-Choice Questions

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005 qmult 00100 1 5 5 easy thinking: victory of Newtonian heliocentrism

1. 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. Heliocentrism 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:


SUGGESTED ANSWER: (e) An easy thinking question after the long harangue.

Wrong answers:

a) Aristotle was the patron of the old physics and system.

b) He started the contest, he didn’t end it.

c) Galileo obviously didn’t triumph and he wasn’t the completer of the victory—
he was a great intermediate figure.

d) Kepler wasn’t able to convince most of the world of heliocentric system and
didn’t invent much anyway of the new physics.
e) Newton was born 1642dec25 on the Julian calendar used in England all of this life. This 1643jan04 on the modern Gregorian calendar that was used in most of the rest of Europe at that time.

**Redaction:** Jeffery, 2001jan01

005 qmult 00300 1 1 4 easy memory: speed and velocity

2. 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.

**SUGGESTED ANSWER:** (d) Velocity is vector. Vectors specify both a magnitude and a direction.

**Wrong answers:**

   e) A nonsense answer.

**Redaction:** Jeffery, 2001jan01

005 qmult 00200 1 1 4 easy memory: hammer and feather on Moon

3. Drop a feather and hammer at the same time on the Earth and then on the Moon.

   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 at about the same time as the **hammer** on the Moon.
   e) The **feather** lands second on Earth and first by a large margin on the Moon.

**SUGGESTED ANSWER:** (d)

**Wrong answers:**

   a) The air resistance on Earth slows down the feather.
   b) On the Moon, the air resistance is negligible.

**Redaction:** Jeffery, 2001jan01

005 qmult 00310 1 1 4 easy memory: mass defined

**Extra keywords:** CK-61-8

4. _______ 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
SUGGESTED ANSWER: (d) The fact that the mass that occurs in the gravity law is the same as the mass in the 2nd law was always a bit of a mysterious coincidence in Newtonian physics. In formulating general relativity, Einstein took it as a fundamental fact and not as a coincidence.

Wrong answers:
   e) Emass is to mass as email is to mail.

Redaction: Jeffery, 2001 jan 01

005 qmult 00402 1 4 5 easy deducto-memory: Newton’s 1st law
5. “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

SUGGESTED ANSWER: (e) The 1st law is actually a special case of the 2nd law. Thus it would create an ambiguity to use the 2nd law as wrong answer.

Wrong answers:
   b) No. The 3rd law is the law of reaction.

Redaction: Jeffery, 2001 jan 01

005 qmult 00410 1 4 5 easy deducto memory: Newton’s 2nd law
6. 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).

SUGGESTED ANSWER: (e) The right answer is also the longest answer.

Wrong answers:
   b) This is the 3rd law.
   c) This is the 1st law.

Redaction: Jeffery, 2001 jan 01
005 qmult 00510 1 5 3 easy thinking: Newton’s 3rd law and accelerations

7. 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.

SUGGESTED ANSWER: (c)

Wrong answers:
b) It is probably wrong to believe that Parmenides really did not believe that motion occurred. Rather he was presenting a philosophic argument based on premises that led to that conclusion. Philosophy, among other things, is the search for true premises and valid means of deriving conclusions from them.
d) This answer (which isn’t an answer to the question) just makes the fallacy explicit by saying the equal and opposite forces do have to be on the same body.
e) Did you ever, ever here me mention such an exception. Actually there are forces that are exceptions to the third law, but I didn’t talk about them. But the exceptions are not the reason why the argument is fallacious.

Redaction: Jeffery, 2001 jan 01

005 qmult 00570 3 1 3 tough thinking: rotating frame

8. A rotating frame (i.e., rotating with respect to an inertial frame) is:

a) NOT an inertial frame. Nevertheless, there CAN BE NO accelerations in such a frame without a force.
b) an inertial frame.
c) NOT an inertial frame. There CAN BE accelerations in such a frame without a force.
d) BOTH an exact inertial frame and an exact non-inertial frame at the same time.
e) a practical impossibility.
SUGGESTED ANSWER: (c) A tough memory question on a test, but not so tough on a homework.

Wrong answers:
e) So much for all those years spend on playground merry-go-rounds.

Redaction: Jeffery, 2001 jan01

005 qmult 00900 2 5 5 moderate thinking: gravitation law
9. 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.

SUGGESTED ANSWER: (e) It can be just a straight memory question, but some thought can narrow the answers down. The students have to grasp the additivity of gravitation. This is seldom explicitly discussed in elementary classes, but it is sort of implied.
In general relativity a repulsive gravitational force can arise in theory and there is evidence that such a repulsive gravity force is accelerating the expansion of the universe. But the Newtonian gravity force is always attractive: i.e., within Newton’s theory of gravity, gravity is always attractive.

**Wrong answers:**

a) This violates Newton’s 3rd law of motion.

b) The gravitational force is always attractive and inverse cube law is wrong from the formula itself, but some students may be weak on cubes. But they could recall that the law does apply to spherical bodies.

c) They could recall that the law does apply to spherical bodies.

d) Gravity is obviously doesn’t vanish for nonspherical bodies: even that apple was not perfectly spherical.

**Redaction:** Jeffery, 2001 jan01

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005 qmult 01010 1 5 4 easy thinking: inverse-square law of gravity redux

**10.** 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

**SUGGESTED ANSWER:** (d) People do have to understand what an inverse square law means.

**Wrong answers:**

a) This would be the result of just an inverse law.

**Redaction:** Jeffery, 2001 jan01

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005 qmult 01102 1 5 4 easy thinking: Galileo and balls

**11.** 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.

**SUGGESTED ANSWER:** (d) This seems pretty obvious to me.
Wrong answers:
a) There are stronger perturbations that Jupiter I’d think.

Redaction: Jeffery, 2001 Jan 01

005 qmult 01200 1 4 4 easy deducto-memory: centripetal acceleration
12. 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**.

SUGGESTED ANSWER: (d)

Wrong answers:
a) Oh, c’mon.

Redaction: Jeffery, 2001 Jan 01

005 qmult 01210 1 4 2 easy deducto-memory: circular orbital velocity
13. 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.

SUGGESTED ANSWER: (b)

Wrong answers:
d) Coulomb’s law is the electrostatic force law.
e) Oh, c’mon.

Redaction: Jeffery, 2001 Jan 01

005 qmult 01270 1 4 4 easy deducto-memory: orbital free fall
14. 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.

SUGGESTED ANSWER: (d)

Wrong answers:

a) Gravity doesn’t vanish in space. Why do the planets keep orbiting the Sun.
b) Gravity is always attractive.
c) But they are always falling towards the Earth.
e) The answer is plausible nonsense. There is, of course, some air resistance in low orbit, but that doesn’t account for free fall.

Redaction: Jeffery, 2001 Jan 01

005 qmult 01402 1 3 2 easy math: kinetic energy and velocity
15. 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).

SUGGESTED ANSWER: (b)

Wrong answers:

e) As Lurch would say: “Aaarr.”

Redaction: Jeffery, 2001 Jan 01

005 qmult 01410 1 1 3 easy memory: energy conversions
16. 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, and quantum mechanics, but **NOT** 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, quantum mechanics, **AND** thermodynamics.
d) comes in the form of kinetic and heat energy only.
e) comes in the form of rest mass energy only.

**SUGGESTED ANSWER: (c)**

**Wrong answers:**
b) Thermodynamics through the 2nd law puts definite constraints on how energy can be converted.

**Redaction:** Jeffery, 2001Jan01

005 qmult 01420 1 5 5 easy thinking: Einstein equation $E=mc^2$

17. 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.

**SUGGESTED ANSWER: (e)**

**Wrong answers:**
a) The vacuum speed of light is a dynamical condition not an energy form.
c) Oh c’mon
d) If this were so, we would have no energy problems and also would probably have blown ourselves to smithereens long ago.

**Redaction:** Jeffery, 2001jan01

005 qmult 01450 1 5 1 easy thinking: 2nd law of thermodynamics

18. 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.

**SUGGESTED ANSWER:** (a)

**Wrong answers:**

b) Everyone knows heat flows.

c) Hot coffee gets cold; cold coffee never gets hot.

d) Heat and coolness are not fluids.

e) Coolness may be a relative absence of heat, but heat is not a fluid.

**Redaction:** Jeffery, 2001jan01

006 qmult 00050 1 4 4 easy deducto-memory: speed of light

19. “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 an effect or 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

**SUGGESTED ANSWER:** (d)

**Wrong answers:**

b) Physically no, but in imagination yes, but we’re talking physics.

e) Well yes, but I’m not going to accept it as a right answer anyway.

**Redaction:** Jeffery, 2001jan01

006 qmult 00052 1 4 2 easy deducto-memory: firework sound and flash

20. At firework displays, the explosions produce a light flash and sound.

a) The sound is heard before the flash is seen.

b) The flash is seen before the sound is heard.

b) Sound and flash come simultaneously.

d) The sound is seen before the flash is heard.

b) Neither effect is noticed by the spectators.
SUGGESTED ANSWER: (b)

Wrong answers:

b) No.
d) Sound seen? Flash heard?
e) The old pointless firework display.

Redaction: Jeffery, 2001 Jan 01

006 qmult 00300 2 1 2 easy memory: electromagnetic radiation
21. 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) 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 LOWER.

c) a 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) a 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) a PARTICLE PHENOMENON only.

SUGGESTED ANSWER: (b)

Wrong answers:

a) The speed of light in a vacuum is the absolute highest speed in our philosophy.

c) Einstein dispatched the ether to the realm of useless concepts.
e) Well EM radiation actually has some particle properties, but it can never be called a particle phenomenon unqualified.

**Redaction:** Jeffery, 2001jan01

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006 qmult 00500 2 1 3 moderate memory: EMR spectrum

22. 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.

**SUGGESTED ANSWER:** (c) You know, defining electromagnetic spectrum is trickier than it seems.

**Wrong answers:**
b) This is the definition of a blackbody spectrum which is a particular example of an electromagnetic spectrum. It is not definition of the electromagnetic spectrum.

**Redaction:** Jeffery, 2001jan01

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006 qmult 00510 2 1 2 moderate memory: EMR does not include protons

23. The electromagnetic spectrum includes all forms of electromagnetic radiation. Which of the following is **NOT** a form of electromagnetic radiation.

a) gamma-rays b) protons c) radio waves d) visible light
e) ultraviolet light

**SUGGESTED ANSWER:** (b)

**Wrong answers:**
a) These are a high-energy photon kind of electromagnetic radiation.

**Redaction:** Jeffery, 2001jan01

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006 qmult 00530 2 1 3 moderate memory: visible light range

**Extra keywords:** CK-91-key-3

24. 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 microns.

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
e) This is, more or less, the infrared band.
Redaction: Jeffery, 2001Jan01

006 qmult 00540 1 1 4 easy memory: opaque bands

Extra keywords: CK-92-14

25. 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

SUGGESTED ANSWER: (d)

Wrong answers:
   e) Cold?

Redaction: Jeffery, 2001Jan01

006 qmult 00610 1 1 5 easy memory: photons

Extra keywords: CK-91-photon

26. The quantum or “particle” of light is called a/an:
   a) proton.   b) electron.   c) quarkon.   d) lighton.   e) photon.

SUGGESTED ANSWER: (e)

Wrong answers:
   c) For some reason, it’s quarks rather than quarkons. Well I know why actually: Murray Gell-mann knew *Finnegan’s Wake* somewhat and somewhere in there the seagulls call “Three quarks for Muster Mark” whatever that means.

Redaction: Jeffery, 2001Jan01

007 qmult 00010 1 1 3 easy memory: ion defined

Extra keywords: CK-110-ion

27. An ion is a:
   a) synonym for an atom.   b) neutral atom.   c) charged atom.
   d) molecule.   e) proton.

SUGGESTED ANSWER: (c)

Wrong answers:
   e) Well a bare proton is the hydrogen ion, but an ion is not a proton.

Redaction: Jeffery, 2001Jan01

007 qmult 00400 2 4 4 moderate deducto-memory: hot bodies radiate

28. Any body (including a cloud of dilute gas) at a finite temperature or range of temperatures will radiate (in addition to any reflected light):
   a) a pure line spectrum.   b) a perfect blackbody spectrum.   c) only X-rays.
   d) electromagnetic radiation.   e) nothing at all.
SUGGESTED ANSWER: (d) It’s just a wee bit tricky I think to rule out perfect blackbody spectrum.

Wrong answers:
a) In strictest sense I doubt that anything emits a pure line spectrum, but obviously some things are close enough.
b) In strictest sense I doubt that anything emits a perfect blackbody spectrum, but obviously some things are close enough. But a dilute gas doesn’t: it emits a line spectrum.
c) Obviously not.
e) Nah.

Redaction: Jeffery, 2001 jan01

007 qmult 00600 2 1 5 moderate memory: blackbody spectrum and temperature
29. 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 universal spectrum that depends on NO PROPERTIES of the radiating body.
e) radiate a blackbody spectrum which is a universal spectrum that depends ONLY on the absolute (i.e., Kelvin scale) temperature of the radiating body.

SUGGESTED ANSWER: (e)

Wrong answers:
d) It depends on temperature.

Redaction: Jeffery, 2001 jan01

007 qmult 00660133easy math: using Wien’s law for a human
30. Wien’s law for blackbody spectra is

$$\lambda_{\text{micron}}^{\text{max}} \approx \frac{2898 \text{ micron-K}}{T}.$$ 

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

SUGGESTED ANSWER: (c)

Wrong answers:
d) We don’t look all red do we?

Redaction: Jeffery, 2001 jan01
31. The line spectrum of an atom, ion, or molecule is:

a) an almost unique identifier of the atom, ion, or molecule.
b) the radiation emitted when the temperature of the atom, etc., goes over 1000 K.
c) the radiation emitted when the temperature of the atom, etc., goes over 10,000 K.
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.

**SUGGESTED ANSWER:** (a)

**Wrong answers:**
e) If this were true, we wouldn’t know what the universe was made of.

**Redaction:** Jeffery, 2001 jan01

32. “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 ____________, Alex?

a) nuclear-burning core  
b) photosphere  
c) chromosphere  
d) corona  
e) stellar wind

**SUGGESTED ANSWER:** (b)

**Wrong answers:**
c) Probably lots of stars have chromospheres, but we can only observe the Sun’s in detail anyway.  
d) Probably lots of stars have coronas, but we can only observe the Sun’s in detail anyway.  
e) We know many stars have stellar winds. Some much stronger than the Sun’s.

**Redaction:** Jeffery, 2001 jan01

33. 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.
SUGGESTED ANSWER: (b)

Wrong answers:
  a) not an emission line spectrum: this takes memory for most students.
  c) this isn’t likely and was denied in book and (one hopes) in the lectures.
  d) No it isn’t. This should be memorable from several points of view. We don’t ordinarily see the huge corona right.
  e) a red herring.

Redaction: Jeffery, 2001 Jan01

007 qmult 010100 2 4 4 moderate deducto-memory: H alpha line wavelength
34. The Hα 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

SUGGESTED ANSWER: (d)

Wrong answers:
  e) This not logically possible, unless one starts making special qualifications: e.g., consider strongly Doppler shifted versions of the line. But special cases are not best answers.

Redaction: Jeffery, 2001 Jan01

007 qmult 01300 1 1 1 easy memory: Doppler effect defined
35. 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.

SUGGESTED ANSWER: (a) One does have to understand that relative motion is the key thing.

Wrong answers:
  e) Nah.

Redaction: Jeffery, 2001 Jan01

007 qmult 01310 1 1 1 easy memory: redshift of receding source
36. A source of light is moving away from you, and thus the light is:
   a) redshifted.    b) blueshifted.    c) greenshifted.    d) yellowshifted.
   e) turquoise shifted.
SUGGESTED ANSWER: (a)

Wrong answers:
   e) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001 jan 01

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007 qmult 01400 2 4 1 moderate deducto-memory: Doppler shift
37. 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.

SUGGESTED ANSWER: (a)

Wrong answers:
   e) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001 jan 01

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038 qmult 00200 1 4 5 easy deducto-memory: solar composition
Extra keywords: Sun-question
38. The Sun’s surface composition by mass (which approximates the average cosmic composition and is typical of non-ancient stars) is about:

   a) 100 % helium.
   b) 71 % hydrogen, 27 % nitrogen, and 20 % everything else.
   c) 71 % carbon, 27 % nitrogen, and 2 % everything else.
   d) 71 % hydrogen, 27 % nitrogen, and 2 % everything else.
   e) 71 % hydrogen, 27 % helium, and 2 % everything else.

SUGGESTED ANSWER: (e) The solar composition is pretty close to the average cosmic composition. The values come from Cox-28, but are rounded-off to whole numbers.

Wrong answers:
   a) Well word helium is derived from the Greek word for the Sun and the Sun god: Helios
   b) This composition doesn’t add up to 100 %.
Redaction: Jeffery, 2001Jan01

038 qmult 00310 111 easy memory: stellar parallax for distance

Extra keywords: CK-272,277

39. 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.

Suggested answer: (a)

Wrong answers:
b) In principle, this could be done, but it is not sensible since it is much more difficult that using the Earth-Sun distance.
c) In principle, the distance to the Sun can be measured this way.
e) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001Jan01

038 qmult 00320 133 easy math: stellar parallax calculation I, Van M.'s star

Extra keywords: CK-278-12, Van Maanen’s star

40. 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

\[ d_{\text{parsec}} = \frac{1}{\theta_{\text{arcsecond}}} , \]

where \( \theta_{\text{arcsecond}} \) is the parallax angle in arcseconds and \( d_{\text{parsec}} \) is the distance in parsecs.

a) 0.232 pc. b) 1 pc. c) 4.3 pc. d) 2.32 pc. e) 10 pc.

Suggested answer: (c) The solution is

\[ d_{\text{parsec}} = \frac{1}{\theta_{\text{arcsecond}}} = \frac{1}{0.232} = 4.31 \text{ pc} \]

where \( d \) is distance in parsec and \( p \) is the stellar parallax (CK-273).

Fortran code

```
print*
theta=.232
dd=1./theta
print*,’distance d’,dd ! 4.310345
```

Wrong answers:
e) As Lurch would say: “Aaaarh.”
**Redaction:** Jeffery, 2001 jan 01

038 qmult 00340 2 1 5 moderate memory: closest star to Earth, not Sun

**Extra keywords:** CK-277-2

41. 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.

**SUGGESTED ANSWER:** (e) See (FK-A-6) for the data.

**Wrong answers:**
   d) This 2nd closest at 1.34 pc.

**Redaction:** Jeffery, 2001 jan 01

038 qmult 00352 2 5 2 mod. thinking: decreasing stellar parallaxes

42. 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.

**SUGGESTED ANSWER:** (b)

**Wrong answers:**
   e) Exactly wrong.

**Redaction:** Jeffery, 2001 jan 01

038 qmult 00400 2 1 5 moderate math: AU to parsec conversion

**Extra keywords:** CK-278-14

43. A dim star is located at about 2 million astronomical units from Earth. Recall 1 AU = $1.496 \times 10^{11}$ m and 1 pc = $3.09 \times 10^{16}$ m. Approximately, what is the distance to the star in parsecs?
   a) $1.5 \times 10^{11}$ pc. b) $2 \times 10^6$ pc. c) $3 \times 10^{17}$ pc. d) 3 pc. e) 10 pc.

**SUGGESTED ANSWER:** (e) Behold

$$2 \times 10^6 \text{AU} \times \frac{1.496 \times 10^{11} \text{m}}{1 \text{AU}} \times \frac{1 \text{pc}}{3.09 \times 10^{16} \text{m}} \approx 10 \text{pc}.$$

**Wrong answers:**
   b) This is the distance in AU.
   c) This is the distance in meters.

**Redaction:** Jeffery, 2001 jan 01

038 qmult 00510 1 1 2 easy memory: star gravitational interactions

44. Because gravity is a long-range, inverse-square-law force, significant gravitational interactions between two stars:
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.

**SUGGESTED ANSWER:** (b)

**Wrong answers:**
e) As Lurch would say: “Aaarh.”

**Redaction:** Jeffery, 2001\_jan\_01

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038 qmult 00602 1 1 3 easy memory: luminosity defined II

**Extra keywords:** CK-276,277, Sun-question

45. 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.

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
d) A star does have a neutrino power or luminosity, but that is not usually considered part of its luminosity.
e) This usually the state of being white hot.

**Redaction:** Jeffery, 2001\_jan\_01

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038 qmult 00620 1 4 4 easy deducto-memory: range of star luminosities

**Extra keywords:** CK-277-3, FK-414

46. 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^{-4}; 10^{6}  b) 1/2; 2  c) infinite; zero  d) 10^{6}; 10^{-4}  e) 2; 1/2

**SUGGESTED ANSWER:** (d) The values differ a bit between CK-277-3 and FK-414. But (d) is more or less right either way.

**Wrong answers:**
c) This is impossible, except speaking metaphorically.

**Redaction:** Jeffery, 2001\_jan\_01

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038 qmult 00800 2 1 5 mod memory: flux inverse-square behavior

**Extra keywords:** CK-276,277

47. 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.
SUGGESTED ANSWER: (e)
Wrong answers:
  b) A nonsense answer.

Redaction: Jeffery, 2001 jan01

038 qmult 00810 2 4 5 mod. deducto-memory: flux inverse-square law proof
48. “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) principle of equivalence  b) cosmological principle  c) perfect cosmological principle  d) relativity postulate  e) conservation of energy principle

SUGGESTED ANSWER: (e)
Wrong answers:
  a) This is a principle Einstein invoke to guide him to general relativity.
  b) This is a principle guiding cosmological modeling. It seems to be true.
  c) This is a principle that was invoked to justify the steady-state universe model.

It has been proven false pretty decisively in its original meaning, but it may have a reformulation in the eternal inflation theory.
  a) This is a principle Einstein invoke to guide him to special relativity.

Redaction: Jeffery, 2001 jan01

038 qmult 00830 1 3 1 easy math: Earth-Sun luminosity distance
Extra keywords: this question can easily be solved by deduction
49. According to one standard reference, the solar luminosity \( L_\odot = 3.845 \times 10^{26} \text{ W} \) and the solar constant (i.e., the solar flux at the mean distance of the Earth) \( f = 1367, \text{ W/m}^2 \). 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 \( d = 1.496 \times 10^{11} \text{ m} \).
  b) \( d = \sqrt{L/f} \) and \( d = 1.496 \times 10^{11} \text{ m} \).
  c) \( d = \sqrt{L} \) and \( d = 1.496 \times 10^2 \text{ m} \).
  d) \( d = \sqrt{L/(4\pi f)} \) and \( d = 1.496 \times 10^{12} \text{ m} \).
  e) \( d = \sqrt{1/f} \) and \( d = 1.496 \times 10^{11} \text{ m} \).

SUGGESTED ANSWER: (a) The given formula is obviously the correct inverse formula. One could do the math to get the value, but since all the other answer formulae are wrong, except one that puts the Sun at 150 m, one doesn’t really have to. The value one computes is accurate to only 4 digits.
According Cox-12, the mean Earth-Sun distance is $1.4959787066 \times 10^{11}$ m. The solar luminosity and solar constant are from Cox-340, but similar values come from AB-14-2.

Fortran Code

```fortran
print*
pi=acos(-1.)
xlum=3.86e26
solconst=1373.
dd=sqrt(xlum/(4.*pi*solconst))
print*, 'The calculated Earth-Sun distance is ', dd, & ' m' ! 1.49573E+11
```

Wrong answers:
c) The Sun is only about 150 m away?

Redaction: Jeffery, 2001jan01

038 qmult 00900 1 4 5 easy deducto-memory: distance ladder defined
50. “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 distaff c) distance adder d) distance viper e) distance ladder

SUGGESTED ANSWER: (e)

Wrong answers:
a) Oh, c’mon.

Redaction: Jeffery, 2001jan01