Introductory Astronomy NAME:

Homework 1: Scientific Notation, Units, Math, Angles, Plots, Motion, Orbits: Homeworks and solutions are posted on the course web site. Homeworks are **NOT** handed in and **NOT** marked. But many homework problems ($\sim$ 50–70 %) will turn up on exams.

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

1. 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!

   SUGGESTED ANSWER: (a),(b),(c),(d)

   Wrong answers:
   e) As Lurch would say AAAARGH.

   Redaction: Jeffery, 2008jan01

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

2. "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

   SUGGESTED ANSWER: (e)

   Wrong answers:
   a) Perspective drawing requires considerable geometry, but painting is not a science as usually understood.
   d) Music is actually very math intensive, but it is not a science as usually understood.

   Redaction: Jeffery, 2008jan01

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

3. 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

   SUGGESTED ANSWER: (c)

   Wrong answers:
   e) This would make sense.

   Redaction: Jeffery, 2008jan01

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001 qmult 00210 1 3 4 easy math: hundred million billion in sci. not.
Extra keywords: physci

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

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

   SUGGESTED ANSWER: (d)

   As Andy Rooney says (or used to say), don't you just hate it when newspapers use expressions like hundred million billion miles. We all know scientific notation or should nowadays.
   Behold:

$$10^2 \times 10^6 \times 10^9 = 10^{17} \ .$$

   Wrong answers:

e) Seems unlikely.

Redaction: Jeffery, 2001jan01

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

5. 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.

SUGGESTED ANSWER: (a)

Wrong answers:

c) The numbers are, of course, equal to the numbers in the problem and are in scientific notation, but not the most conventional form as most people would say.
d) The same remark as for answer (c) applies.

Redaction: Jeffery, 2008jan01

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

6. 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.

SUGGESTED ANSWER: (b) All the student needs to know is scientific notation and units.

Wrong answers:

c) Same number, different units: not the same quantity.
d) It's the speed of light, not sound.

Redaction: Jeffery, 2001jan01

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

7. 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 $3. \times 10^1$.

SUGGESTED ANSWER: (d)

Fortran-95 Code

```
        print*
        x1=3.01d2
        x2=1.1d-1
        sum=x1+x2
        pro=x1*x2
        print*,sum,pro
!     301.110000000000         33.1100000000000
```

Wrong answers:

a) Too many figures for both values.
b) Too many figures for the product.
c) too many figures for the sum.
e) Too few figures in both cases. Significant figures have been dropped. You have lost away information.

Redaction: Jeffery, 2008jan01

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

Extra keywords: physci

8. "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

SUGGESTED ANSWER: (e)

Wrong answers:
d) I think this is a pretty good alternative to units.

Redaction: Jeffery, 2001jan01

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

9. "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

   SUGGESTED ANSWER: (c)

   Wrong answers:
   b) HMS could be hectometers, milligrams, and seconds or Her Majesty's Ship.

   Redaction: Jeffery, 2001jan01

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

10. 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.

    SUGGESTED ANSWER: (d)

    Wrong answers:
    b) I know what you are thinking, but you can find it on a map.

    Redaction: Jeffery, 2008jan01

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

11. MKS stands for:

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

    SUGGESTED ANSWER: (c)

    Wrong answers:
    a) Does this seem likely?

    Redaction: Jeffery, 2008jan01

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

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

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

    SUGGESTED ANSWER: (a)

    Wrong answers:
    e) As Lurch would say: "Aaaarh."

    Redaction: Jeffery, 2001jan01

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001 qmult 00350 1 1 2 easy memory: natural units

13. 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.

SUGGESTED ANSWER: (b)

Wrong answers:
c) They are not low and despised.

Redaction: Jeffery, 2008jan01

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001 qmult 00360 1 1 1 easy memory: astronomical unit
14. 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.

SUGGESTED ANSWER: (a) Super-easy memory question.

Wrong answers:
c) This not in AU.

Redaction: Jeffery, 2001jan01

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001 qmult 00362 1 4 3 easy deducto-memory: Pluto-Sun distance
15. 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.

SUGGESTED ANSWER: (c)

Students do not need to remember the value. They must deduce the right answer based on the facts that the astronomical unit is the natural Solar System distance unit—at least for Earthlings—and that Pluto is far, far out. More exactly Pluto's mean distance from the Sun is 39.44 AU.

Alas, Pluto that degraded astro-body. Once it was a planet, but now know more—the Ninth Planet. Demoted to dwarf planet, a faded glory remains.

Wrong answers:
a) This is the Mercury-Sun distance.
b) This is the Earth-Sun distance.
d) This is the Eris-Sun distance.
e) This Planet Nine distance estimate circa 2020.

Redaction: Jeffery, 2001jan01

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001 qmult 00366 1 1 3 easy memory: Earth equatorial radius natural unit
16. The Earth equatorial radius $R_{\mathrm{eq},\odot} = 6378.1370$ 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 $R_{\mathrm{eq},\odot}$. b) Earth-Moon mean dist. 30.2687 $R_{\mathrm{eq},\odot}$.
c) Earth-Moon mean dist. 60.2687 $R_{\mathrm{eq},\odot}$. d) Earth-Venus mean dist. 30.2687 $R_{\mathrm{eq},\odot}$.
e) Earth-Cruithne mean dist. 30.2687 $R_{\mathrm{eq},\odot}$

SUGGESTED ANSWER: (c)

Wrong answers:
e) Cruithne is an asteroid of ~ 5 km in diameter that orbits the Sun with 1:1 orbital resonance with the Earth which means its year is 1 Earth year.

Redaction: Jeffery, 2008jan01

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001 qmult 00370 1 4 4 easy deducto-memory: light-year definition
17. 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).

SUGGESTED ANSWER: (d) A super easy deducto-memory question: the answer is the definition.

Wrong answers:
b) That's beer not year.
e) That's a sidereal year.

Redaction: Jeffery, 2001jan01

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001 qmult 00374 1 1 2 easy memory: lookback time calculation 1
18. 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.

SUGGESTED ANSWER: (b)

Wrong answers:
a) As Lurch would say AAAARGH.

Redaction: Jeffery, 2001jan01

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001 qmult 00380 1 1 4 easy memory: parsec the pimary natural unit
19. 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

SUGGESTED ANSWER: (d)

Wrong answers:
c) Exactly wrong.

Redaction: Jeffery, 2008jan01

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001 qmult 00384 1 1 1 easy memory: parsec distance in light-years
20. 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.

SUGGESTED ANSWER: (a)

Wrong answers:
d) This is what a light year is.

Redaction: Jeffery, 2001jan01

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

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

SUGGESTED ANSWER: (c)

Wrong answers:
a) Parsecs are used in this case.
d) Intergalactic is for between galaxies while intragalactic is for inside galaxies.
e) Furlongs are used here: a furlong is an eightth of a mile or 220 yards.

Redaction: Jeffery, 2001jan01

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001 qmult 00396 1 4 1 easy deducto-memory: relevant physical scales

22. 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.

SUGGESTED ANSWER: (a)

Wrong answers:
b) A snail's trail!

Redaction: Jeffery, 2001jan01

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001 qmult 00398 1 4 5 easy deducto-memory: Fermi micro-century lecture 1

Extra keywords: mathematical physics

23. "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)

SUGGESTED ANSWER: (e)

HRW-9 gives this factoid. As Marilyn Monroe (1926–1962) said on the flight of time in *Some Like it Hot*, "It makes a girl think."

You can reason out the answer, but the calculation with copious factors of unity is as follows:

$$(50\,\text{min}) \times \frac{1\,\text{h}}{60\,\text{min}} \times \frac{1\,\text{d}}{24\,\text{h}} \times \frac{1\,\text{Jyr}}{365.25\,\text{d}} \times \frac{1\,\text{century}}{100\,\text{Jyr}} \times \frac{10^6\ \text{micro-centuries}}{1\,\text{century}}$$
$$\approx \frac{0.04}{365.25} \times 10^4 \approx 1\ \text{micro-century}\ .$$

Wrong answers:
a) Tempting.
c) This is five minutes.

Redaction: Jeffery, 2008jan01

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

24. 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.

SUGGESTED ANSWER: (c)

Wrong answers:
a) The Rankine scale using Fahrenheit degrees, but its zero is absolute zero. It should be obsolete.
b) The original name for the Celsius scale.
e) Oh, c'mon.

Redaction: Jeffery, 2008jan01

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001 qmult 00410 1 1 5 easy memory: Fahrenheit scale

25. 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.

SUGGESTED ANSWER: (e)

Wrong answers:
a) True, but not the best answer.

Redaction: Jeffery, 2008jan01

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

26. The Kelvin scale degree (symbolized K, but with symbol ° 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.

SUGGESTED ANSWER: (e)

Wrong answers:
a) C'mon.

Redaction: Jeffery, 2008jan01

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001 qmult 00440 1 1 2 easy memory: absolute zero defined

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

SUGGESTED ANSWER: (b)

Wrong answers:
a) C'mon.

Redaction: Jeffery, 2008jan01

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

28. 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

SUGGESTED ANSWER: (a)

Wrong answers:
b) As Lurch would say AAAARGH.

Redaction: Jeffery, 2008jan01

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

29. 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

SUGGESTED ANSWER: (c)

Wrong answers:

e) As Lurch would say AAAARGH.

Redaction: Jeffery, 2008jan01

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

30. 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 $t = A/R$.

SUGGESTED ANSWER: (e)

Wrong answers:
a) Exactly wrong.
c) Exactly wrong too.

Redaction: Jeffery, 2008jan01

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

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

a) $2.9979 \times 10^{10}\,\mathrm{km}$. b) $3 \times 10^{10}\,\mathrm{km}$. c) $1.8 \times 10^{12}\,\mathrm{km}$. d) $1.8 \times 10^{7}\,\mathrm{km}$.
e) $3 \times 10^{7}\,\mathrm{km}$.

SUGGESTED ANSWER: (d)

A light-minute is the distance d light travels in 1 minute. Thus, we find

$$d = ct = (2.99792458 \times 10^{10}\,\mathrm{cm/s}) \times \left(\frac{1\,\mathrm{km}}{10^5\,\mathrm{cm}}\right) \times (1\,\mathrm{min}) \times \left(\frac{60\,\mathrm{s}}{1\,\mathrm{min}}\right) \approx 1.8 \times 10^{7}\,\mathrm{km}\ .$$

Note that we have done the unit conversions using the factors of unity

$$1 = \frac{1\,\mathrm{km}}{10^5\,\mathrm{cm}} \qquad \text{and} \qquad 1 = \frac{60\,\mathrm{s}}{1\,\mathrm{min}}\ .$$

The factors of unity are just equal to 1 as their name shows and as we have shown explicitly. Since you can always multiply by 1, you can insert factors of unity where needed in any equation to do conversions. The unit symbols can be canceled out like algebraic symbols—they really are algebraic symbols.

Wrong answers:
a) C'mon.

Redaction: Jeffery, 2001jan01

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

32. "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

SUGGESTED ANSWER: (c)

Wrong answers:
d) The length of a year in seconds is $\pi \times 10^7$ to within 0.5 %.

Redaction: Jeffery, 2001jan01

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

33. 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.

SUGGESTED ANSWER: (c)

It is just a coincidence, but the length of a year is $\pi \times 10^7$ s to within 0.5 %.

Fortran Code

```
        print*
        xjyr=365.25
        daysec=86400.
        yearsec=xjyr*daysec
        pi=acos(-1.)
        print*,'yearsec,yearsec*1.e-7/pi'
        print*,yearsec,yearsec*1.e-7/pi
*          3.15576E+07    1.00451
```

Wrong answers:
b) This is the length of a day.
d) This is the rounded-off to 1 significant figure length of a day.

Redaction: Jeffery, 2001jan01

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

34. 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.

SUGGESTED ANSWER: (b)

Behold:

$$v = \frac{2\pi r}{t} = \frac{2\pi \times 6378.1370 \times 10^3 \,\mathrm{m}}{86164.0905 \,\mathrm{s}} = 465 \,\mathrm{m/s} = 0.465 \,\mathrm{km/s} \; .$$

The Earth's rotation gives rise to an inertial force, the centrifugal force. The centrifugal force is not a real force. It is the effect of being in a rotating frame: you need a force to keep you in rotation and without that you are being thrown outward which is really just moving in a straight line per Newton's 1st law of motion. The centrifugal force is the thing which tries to throw you off carnival centrifuges: it sure feels like a real force. The centrifugal force field (the force per unit mass) at the equator is

$$g_{\mathrm{cf}} = \frac{v^2}{r} = 0.0339 \,\mathrm{m/s^2} \; .$$

This centrifugal force field is much smaller than the actual equatorial gravitational field. But it is not negligible for accurate work and is usually included without comment in the usually cited fiducial equatorial gravitational field of $9.78033 \,\mathrm{m/s^2}$: i.e., this is the gravitational field with the centrifugal field subtracted off (Wikipedia: Earth's gravity).

Fortran Code

```
        print*
!       pi=acos(-1.0_np)
        pi=3.14159265358979323846264338327950288419716939937510_np
!
!!23456789a123456789b123456789c123456789d123456789e123456789f123456789g12
!           ! % https://en.wikipedia.org/wiki/Pi#Approximate_value_and_digits
51 digits
        radeartheq=6378.1370e+3_np  ! %
https://en.wikipedia.org/wiki/Earth_radius#Equatorial_radius
        daysid=86164.0905e0_np  ! % https://en.wikipedia.org/wiki/Sidereal_time
        veq=2.0_np*pi*radeartheq/daysid
        acf=veq**2/radeartheq
        print*,'veq,acf'
        print*,veq,acf
!    465.10113961660729368        3.391571395733061716580E-0002
```

Wrong answers:
c) This is the speed of light.
d) Wrong units.
e) Wrong units.

Redaction: Jeffery, 2001jan01

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001 qmult 00524 1 5 5 easy thinking: Earth speed at the poles
Extra keywords: Save this one for finals?

35. 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.

SUGGESTED ANSWER: (e)

Wrong answers:
b) This is the speed at the equator.
d) Wrong units.

Redaction: Jeffery, 2001jan01

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

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

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

SUGGESTED ANSWER: (d)

A rate times a time gives an amount. In this case

$$v = gt = 9.8\,\mathrm{m/s^2} \times 3\,\mathrm{s} = 29.4 \approx 30\,\mathrm{m/s}\ .$$

Wrong answers:
a) Wrong units.

Redaction: Jeffery, 2001jan01

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

37. 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.

SUGGESTED ANSWER: (b)

An easy math question. But the students have to understand how speed time and distance relate: $d = vt$, and so

$$t = \frac{d}{v} = \frac{3.844 \times 10^{10}}{2.998 \times 10^{10}} \approx 1.3\,\mathrm{s}\ .$$

Wrong answers:
a) 8 minutes, 20 seconds is about the time it takes light to travel from the Sun to the Earth.
c) Light has a finite speed: this answer is impossible.
e) An arcminute is an angular unit, not a time unit.

Redaction: Jeffery, 2001jan01

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

38. 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.

SUGGESTED ANSWER: (b) A give away easy question, unless something is very wrong.

Wrong answers:
a) Wrong units.

Redaction: Jeffery, 2001jan01

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

39. "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

SUGGESTED ANSWER: (e)

Wrong answers:
d) As Lurch would say AAAARGH.

Redaction: Jeffery, 2008jan01

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

40. 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.

SUGGESTED ANSWER: (d)

Those ancient Babylonians used a sexagesimal system for astronomy although not consistently. Probably, they didn't like complex division and choose a base of 60 because it has 12 whole number factors. This ancient sexagesimal system is also why hours have 60 minutes and minutes have 60 seconds. And probably by extension why standard North American AC has 60 cycles per second.

Wrong answers:
a) All things are wrong.

Redaction: Jeffery, 2001jan01

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

41. 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°.

SUGGESTED ANSWER: (b)

Wrong answers:
c) This is a spread hand.
d) Pretty big fist.

Redaction: Jeffery, 2001jan01

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

42. 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.

SUGGESTED ANSWER: (d)

Wrong answers:
e) Degrees are not spatial units.

Redaction: Jeffery, 2001jan01

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

43. 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.

SUGGESTED ANSWER: (d) See Se-18.

Wrong answers:
a) 100° is more than a quadrant separation. Nobody's fist at arm's length is that large. The spatial separation is indeterminate in this question.
b) Angular separation by 360° is 0° angular separation.
e) One arcsecond separation is really too small.

Redaction: Jeffery, 2001jan01

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001 qmult 00652 1 1 3 easy memory: angular velocity of Moon

44. 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) 12.50°/day. c) 13.18°/day. d) 15.19°/day. e) 27.32°/day.

SUGGESTED ANSWER: (c)

Wrong answers:
e) As Lurch would say AAAAaargh.

Fortran-95 Code

```
        print*
        psid=27.321661547_np
        psol=29.530588853_np
!  <a href="https://en.wikipedia.org/wiki/Lunar_month#Cycle_lengths">
!   mean lunar sidereal month 27.321661547 days (J2000)</a>
! <a href="https://en.wikipedia.org/wiki/Lunar_month#Cycle_lengths">
!   lunar month 29.530588853 days (J2000)</a>,
        angle=360.0_np
        osid=angle/psid
        osol=angle/psol
        print*,'osid,osol'
        print*,osid,osol
! 13.176358230655597689         12.190749117535045450
```

Redaction: Jeffery, 2008jan01

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

45. A straight line on a linear plot represents a/an _____ function.

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

SUGGESTED ANSWER: (a) Line, linear: it makes sense right.

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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

46. 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

SUGGESTED ANSWER: (b)

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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

47. 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.

SUGGESTED ANSWER: (d)

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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

48. 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.

SUGGESTED ANSWER: (b)

An example of a non-standard log plot is any magnitude plot from astronomy—eek.

Wrong answers:
e) As Lurch would say: "Aaaarh." Any power of one is still one.

Redaction: Jeffery, 2001jan01

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

49. 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. What the simplest exact inertial frame 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

SUGGESTED ANSWER: (c)

Wrong answers:
e) As Lurch would say AAAaargh.

Redaction: Jeffery, 2008jan01

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

50. "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

SUGGESTED ANSWER: (e)

Wrong answers:

a) As Lurch would say AAAARGH.

Redaction: Jeffery, 2008jan01

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

51. "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

SUGGESTED ANSWER: (d)

Wrong answers:

a) This question is too ambiguous to be a best answer. A less ambiguous question is, for example, what is less than 1?
e) Zorro!

Redaction: Jeffery, 2001jan01

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

52. 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.

SUGGESTED ANSWER: (d)

To rule out answers in this case one has to remember both that bound orbit eccentricities must be in the range $[0, 1]$ and that a very elliptical orbit means a very eccentric one. Thus a large eccentricity is one that is much larger than zero in a sense, but still less than or equal to 1.

Wrong answers:

a) Exactly wrong.
b) Almost exactly wrong.
c) Some comets may have this eccentricity as nearly as one can ever have an exact value for a quantity that is continuous.
e) This is the hard one to remember is not defined for closed orbits.

Redaction: Jeffery, 2001jan01

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

53. 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.

SUGGESTED ANSWER: (a)

The definitions of aphelion and perihelion can be guessed if they are not known.

Wrong answers:

e) In the 19th century Vulcan was a planet predicted to exist between Mercury and the Sun. Some observers claimed to have seen it. But they were mistaken. *Star Trek* revived Vulcan as Spock's home planet, but presumably it's around some other star than the Sun.

Redaction: Jeffery, 2001jan01

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

54. 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.

SUGGESTED ANSWER: (e)

Wrong answers:
c) An oval is not a definite mathematical description.
d) They could orbit in circles, but not always. How they orbit depends on the initial conditions.

Redaction: Jeffery, 2001jan01

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

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

a) elliptical orbits with the Sun at one focus of the ellipse.
b) circular orbits with the Sun at circle center.
c) 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.)
d) planar orbits with the Sun at plane center.
e) spherical orbits with the Sun at sphere center.

SUGGESTED ANSWER: (a)

Wrong answers:
b) To fair approximation the planets do move in circular orbits with the Sun at circle center. Perhaps, one could even say to good approximation, not very good approximation I'd say. Anyway answer (a) is better.
d) Planar orbits? Well I suppose in the sense that elliptical orbits are confined to a plane. But does a plane have a center?
e) What are spherical orbits?

Redaction: Jeffery, 2001jan01

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

56. 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.

SUGGESTED ANSWER: (b)

Wrong answers:
a) Exactly wrong.
d) If the orbit were circular, this would be true.
e) As Lurch would say: "Aaarrrh."

Redaction: Jeffery, 2001jan01