Introductory Astronomy **NAME:**

Homework 11: The Earth: 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 tests.

Answer Table

	a	b	c	d	e
1.	O	O	O	O	O
2.	O	O	O	O	O
3.	O	O	O	O	O
4.	O	O	O	O	O
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16.	O	O	O	O	O
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18.	O	O	O	O	O
19.	O	O	O	O	O
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21.	O	O	O	O	O
22.	O	O	O	O	O
23.	O	O	O	O	O
24.	O	O	O	O	O
25.	O	O	O	O	O
26.	O	O	O	O	O
27.	O	O	O	O	O
28.	O	O	O	O	O
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36.	O	O	O	O	O

Name:

	a	b	c	d	e
37.	O	O	O	O	O
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71.	O	O	O	O	O
72.	O	O	O	O	O

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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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011 qmult 00080 1 4 1 easy deducto-memory: gravity and sphere

2. "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

   SUGGESTED ANSWER: (a)

   Notice I exclude macroscopic kinetic energy from being dominating. A lot of kinetic energy can result in disk structure like galaxies.

   Wrong answers:
   e) I can't recall ever having eaten a snow cone: I'm sure I don't want to.

   Redaction: Jeffery, 2001jan01

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011 qmult 00082 1 4 4 easy deducto-memory: Earth oblate sphere

3. 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.

   SUGGESTED ANSWER: (d)

   Wrong answers:
   e) If the difference were this large, the Earth would not look nearly as spherical as it does in pictures or in globe representations.

   Redaction: Jeffery, 2001jan01

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011 qmult 00100 1 1 5 easy memory: Earth hot near formation

4. 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.

   SUGGESTED ANSWER: (e) The point should have been reinforced a lot.

   Wrong answers:
   c) Stone Cold Steve Austin, super-wrestler. Despite all our modernism, there is still a place for selected champions who engage in ritual combat in which the posturing is most of the fun.

   Redaction: Jeffery, 2001jan01

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011 qmult 00300 1 1 1 easy memory: internal structure of Earth

5. 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.

SUGGESTED ANSWER: (a) Getting the right answer may depend mostly on the reading lectures, not on attending the lectures.

Wrong answers:
b) Biology hasn't really played much of a role.
c) Cryptology is the study of crypts.
d) Oddly cosmology and cosmetics derive from the same Greek kosmos that originally meant an adornment, particularly to beautiful orderliness (Fu-59–60).
e) Well, no.

Redaction: Jeffery, 2001jan01

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011 qmult 00310 1 4 1 easy deducto-memory: central region of Earth

6. 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.

SUGGESTED ANSWER: (a) Solid iron with substantial amounts of nickel and sulfur (FMW-149).

Wrong answers:
c) There's gold in them there core.

Redaction: Jeffery, 2001jan01

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011 qmult 00400 1 1 3 easy memory: water coverage of Earth

7. Of the Earth's surface, liquid water covers about:

a) 10 %. b) 30 %. c) 71 %. d) 95 %. e) 99 %.

SUGGESTED ANSWER: (c)

An easy memory question from general knowledge if not from the book. Even from remembering what a globe looks like the answer can be deduced. Col-38 says 70.8 % covered by water.

Wrong answers:
e) We'd all be Tahitian then.

Redaction: Jeffery, 2001jan01

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011 qmult 00450 2 4 2 moderate deducto-memory: crust composition

8. 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.

SUGGESTED ANSWER: (b)

Silicates are mostly SiO_2 (silica) which is not a molecule but simply a compound that forms in different crystal arrangements. The atomic mass of Si is about 28 and of O is about 16. Evidently, the crust is a bit more rich in O than the SiO_2 formula suggests.

Wrong answers:
a) The surface isn't that radioactive.
c) No the crust is not mostly rust which also has hydrogen in it.
d) No the crust is not mostly water either in liquid or solid form.
e) Kryptonite! Superman beware.

Redaction: Jeffery, 2001jan01

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011 qmult 00500 2 4 2 moderate deducto-memory: Earth's crust

9. 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.

   SUGGESTED ANSWER: (b)

   See Se-433, FMW-148. The thickness of crust estimates varies from book to book. It's probably just that the values are uncertain and depend on varying definition.

   Wrong answers:
   a) The Earth's mean radius is 6371 km thick and the students know there is a substantial mantle and core.
   c) Ireland is not a privileged domain of the Earth and negative thickness is blarney.
   d) Nevada is not a privileged domain of the Earth and negative thickness is the con.
   e) The Earth's mean radius is 6371 km thick and the students know there is a substantial mantle and core.

   Redaction: Jeffery, 2001jan01

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011 qmult 00510 2 4 3 moderate deducto-memory: lithosphere defined

10. The upper rigid layer of the Earth 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

    SUGGESTED ANSWER: (c) See Se-433.

    Wrong answers:
    d) The asthenosphere is the plastic lower mantle. It is the region below the lithosphere

    Redaction: Jeffery, 2001jan01

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011 qmult 00512 2 4 2 moderate deducto-memory: Earth's surface warmth

11. 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.

    SUGGESTED ANSWER: (b)

    The mean solar heat flux to the Earth's surface is about 170 W/m**2 and the geothermal heat flux is only 0.008 W/m**2 (CW-46).

    Wrong answers:
    a) Geothermal heat is vital to geology, but it doesn't keep most of the surface warm.
    d) The first "natural" is an adjective modifying "natural gas fires." There is no "natural natural gas" that I know of.

    Redaction: Jeffery, 2001jan01

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011 qmult 00520 1 4 2 easy deducto-memory: crustal plates

12. 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.

SUGGESTED ANSWER: (b)

Wrong answers:
e) We live on the surface of plates. They arn't that hot.

Redaction: Jeffery, 2001jan01

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011 qmult 00522 1 4 5 easy deducto-memory: tectonic plate boundaries

13. "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

SUGGESTED ANSWER: (e)

Wrong answers:
b) Earthquakes are events not features.

Redaction: Jeffery, 2001jan01

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011 qmult 00600 1 4 4 easy deducto-memory: plate tectonics driver

14. 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.

SUGGESTED ANSWER: (d)

Wrong answers:
c) Not very likely is it.

Redaction: Jeffery, 2001jan01

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011 qmult 00610 1 4 3 easy deducto-memory: Earth resurfacing

15. 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.

SUGGESTED ANSWER: (c) See Lissauer 1993, ARA&A, 31, 129, p. 132 for typical Earth rock ages.

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

Redaction: Jeffery, 2001jan01

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011 qmult 00700 1 4 4 easy deducto-memory: crust add and subtract

16. 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

SUGGESTED ANSWER: (d) Se-435 uses ocean trenches in the figure caption.

Wrong answers:
a) Impactors arn't a big influence on current Earth geology.

Redaction: Jeffery, 2001jan01

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011 qmult 00710 1 4 1 easy deducto-memory: tectonic plate boundaries
17. 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).

SUGGESTED ANSWER: (a)

Wrong answers:
e) Mifault, yurfault—ha, ha, ha, good one eh.

Redaction: Jeffery, 2001jan01

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011 qmult 00900 1 4 2 easy deducto-memory: volcano defined defined
18. 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.

SUGGESTED ANSWER: (b)

Ba-1364 says that volcanoes are vents. They don't necessarily have to have formed a mountain although they often do so.

Wrong answers:
e) *Star Trek* never figured out if Spock should be called a Vulcanian or a Vulcan. The former is consistent with usual practice, but the later just tripped off the tongue. But how would you feel about being called an Earth.

Redaction: Jeffery, 2001jan01

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011 qmult 01110 1 4 2 easy deducto-memory: Pangaea
19. In the Permian period about 250 million years ago, the Earth is believed to have had one large supercontinent called:

a) Panama. b) Pangaea. c) Pangloss. d) Pan-Am. e) Panic.

SUGGESTED ANSWER: (b)

WB-92 says 300 to 250 million years ago and other sources say 225 million years ago. Obviously some discussion is going on. It was a long time ago anyway.

Wrong answers:

c) Candide's tutor, Dr. Pangloss: "This is the best of all possible worlds."

Redaction: Jeffery, 2001jan01

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011 qmult 01200 2 4 2 moderate deducto-memory: Earth atmosphere gases

20. 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.

SUGGESTED ANSWER: (b) See Se-439, CW-296, and Cox-258, but note Cox has got the wrong exponents for some numbers.

Wrong answers:
a) The Earth would be warm if there were as much carbon dioxide as argon, of course, the answer doesn't imply that there is.

Redaction: Jeffery, 2001jan01

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011 qmult 01210 1 4 5 easy deducto-memory: trace gas carbon dioxide

21. "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)

SUGGESTED ANSWER: (e)

Wrong answers:
a) Oxygen gas is a product of photosynthesis and I believe plants do need it for respiration, but it is not an important greenhouse gas it seems (SWT-507).
d) Argon is 1.29 % by mass and is the 3rd most abundant gas in the atmosphere. But Argon is a noble gas and is chemically almost completely inert.

Redaction: Jeffery, 2001jan01

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011 qmult 01500 1 1 3 easy memory: O_2 for breathing

22. 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.

SUGGESTED ANSWER: (c)

Wrong answers:
a) I don't think we could breathe atomic oxygen. It's a highly reactive gas, but probably in the wrong way. In any case, its molecular oxygen (O_2) that we breathe.
b) Carbon monoxide is toxic. See Keenan, p. 181.
d) Krypton is an inert gas. Maybe bad for Superman.
e) Neon is an inert gas.

Redaction: Jeffery, 2001jan01

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011 qmult 01700 1 5 1 easy thinking: albedo and heating

23. 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.

SUGGESTED ANSWER: (a)

The surface temperature must depend on the interior heat content and transport properties if no heat gets in from above.

Wrong answers:
b) Why should surface temperature be zero in all cases when we know that some planets have interior heat.
c) Why should the surface temperature be exactly the freezing point of of water.
d) Why the boiling point of N_2. Clark p. 54 gives 273.15-195.8=77.35 for the boiling point of N_2.
e) There are no negative temperatures on the absolute scale.

Redaction: Jeffery, 2001jan01

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011 qmult 01800 1 5 1 easy thinking: greenhouse effect defined
24. 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.

SUGGESTED ANSWER: (a)

Even on general knowledge answer (a) should be deducible. The point of the question is really to give a succinct and correct (to the best of my understanding) account of the greenhouse effect for the benefit of the students.

The greenhouse effect is a partial misnomer. The effect as described does play a secondary role in heating greenhouses–the glass windows acting as the atmosphere—but the main heating effect is that cooling upward convection can't happen in a confined building. See "Greenhouse: How Do Greenhouses Work?" by Sue Ann Bowling.

`http://www.gi.alaska.edu/ScienceForum/ASF8/817.html .`

Wrong answers:
b) Everyone knows the greenhouse effect heats, not cools.
d) Is this true about the orchids?

Redaction: Jeffery, 2001jan01

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011 qmult 01900 1 4 2 easy deducto-memory: greenhouse effect on planets
25. 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.

SUGGESTED ANSWER: (b)

The only thing that may make it hard is if someone confuses the greenhouse effect with the anthropogenic increase in the Earth's greenhouse effect that is currently under debate. When speaking loosely the later is just called the former, but I think allowed answers preclude confusion.

Wrong answers:
b) As discussed in class we need some and Seeds makes this point briefly.
c) Why should it be?
d) The consensus view is that it does happen. This should be clear from the lectures, Seeds, and even general knowledge.
e) Just to see who's been on Mars for the last 30 years.

Redaction: Jeffery, 2001jan01

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011 qmult 02000 1 4 4 easy deducto-memory: heat flow direction
26. 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

SUGGESTED ANSWER: (d)

Everyone knows insulation decreases heat flow. Most everyone should guess, increasing temperature difference increases heat flow.

Wrong answers:
a) Exactly wrong.

Redaction: Jeffery, 2001jan01

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011 qmult 02100 2 4 4 moderate deducto-memory: greenhouse and heat balance
27. 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.

SUGGESTED ANSWER: (d)

Wrong answers:

a) There isn't a continual heating of the Earth due to lack of balance of inflow and outflow.

b) The earth's atmosphere has practically no H_2.

c) The earth's atmosphere has practically no H_2.

e) It would be a mighty hot day in Vegas if the Earth's mean temperature were 80°C. It is about 15°C.

Redaction: Jeffery, 2001jan01

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011 qmult 02200 1 3 1 easy math: increasing CO_2

28. 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!!!

SUGGESTED ANSWER: (a)

The answer requires a rate calculation and then an exhaustion time calculation. First, the rate of increase averaged over 40 years is

$$R = \frac{A}{t} = \frac{55}{40} = 1.375 \approx 1.4 \quad \text{ppm per year} .$$

Second, to increase by another 430 ppm requires

$$t = \frac{A}{R} = \frac{430}{1.4} = 307 \approx 300 \quad \text{years} .$$

Actually, the rate of increase for the last few years (circa 2015) has been about 2.2 ppm per year. The rate of increase could go higher still as countries around the world increase their use of carbon fuels. But hopefully we stop releasing carbon dioxide to the atmosphere.

Wrong answers:

e) Now wouldn't this be lovely.

Redaction: Jeffery, 2001jan01

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011 qmult 02300 1 1 2 easy memory: rising ocean levels

29. 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.

SUGGESTED ANSWER: (b) See Se-440.

Wrong answers:
d) A rather incoherent answer.
e) It won't necessarily increase rainfall and even if it did that won't increase sea level

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011 qmult 02400 1 4 4 easy deducto-memory: rising Earth temperature

30. 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.

SUGGESTED ANSWER: (d)

Wrong answers:
e) Not likely, but global climate is tricky with all kinds of strange feedbacks. Thus, almost anything could happen due to unexpected processes. But likely global average temperature will rise.

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011 qmult 03000 2 4 3 moderate deducto-memory: Earth's permanent atmosphere

31. 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.

SUGGESTED ANSWER: (c)

Note this question avoids the primeval-secondary atmosphere question that Seeds discusses.

In a sense, the atmosphere is always coming into being and always passing away, and *a fortiori* this was more true of the early atmosphere when outgassing, comet impacts, and escape to space probably happened much more furiously than at present: "This is my grandfather's axe: my father replaced the axe head; I've replaced the haft."

Wrong answers:

a) this answer is not the right one for the "permanent" atmosphere. It may be the source for an early atmosphere of gases. See Se-420.
b) a red herring.
d) biological activity certainly has modified the "permament" atmosphere creating oxygen, but it wasn't the original source.
e) the solar wind is actually thought to be the cause of extremely weak atmospheres on Mercury and the Moon, but not on Earth. The part about Comet Hale-Bopp is correct, however.

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011 qmult 03200 1 4 1 easy deducto-memory: Earth's oxygen

32. 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.

SUGGESTED ANSWER: (a)

Wrong answers:

d) Well the oxygen atoms come from outgassing in the form of water vapor and carbon dioxide, but molecular oxygen (O_2) probably mostly came from photosynthesis.

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011 qmult 03500 2 5 3 moderate thinking: escaping molecules

33. 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.

SUGGESTED ANSWER: (c)

Moderate: A moderate thinking question. Neither Seeds nor I have discussed in a coherent fashion gas escape from a planet, but general grounds should allow students to deduce the right answer.

Wrong answers:

a) Why should surface factors necessarily affect upper atmosphere escape? Through interconnectedness, of course, but in principal there need not be any.
b) why should the presence of a particular gas affect anything?
d) why should biological activity affect anything?
e) why should surface biological activity affect anything?

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