Astronomy 101 Final Exam Form Akey

Name: _____

Lab section number: _____

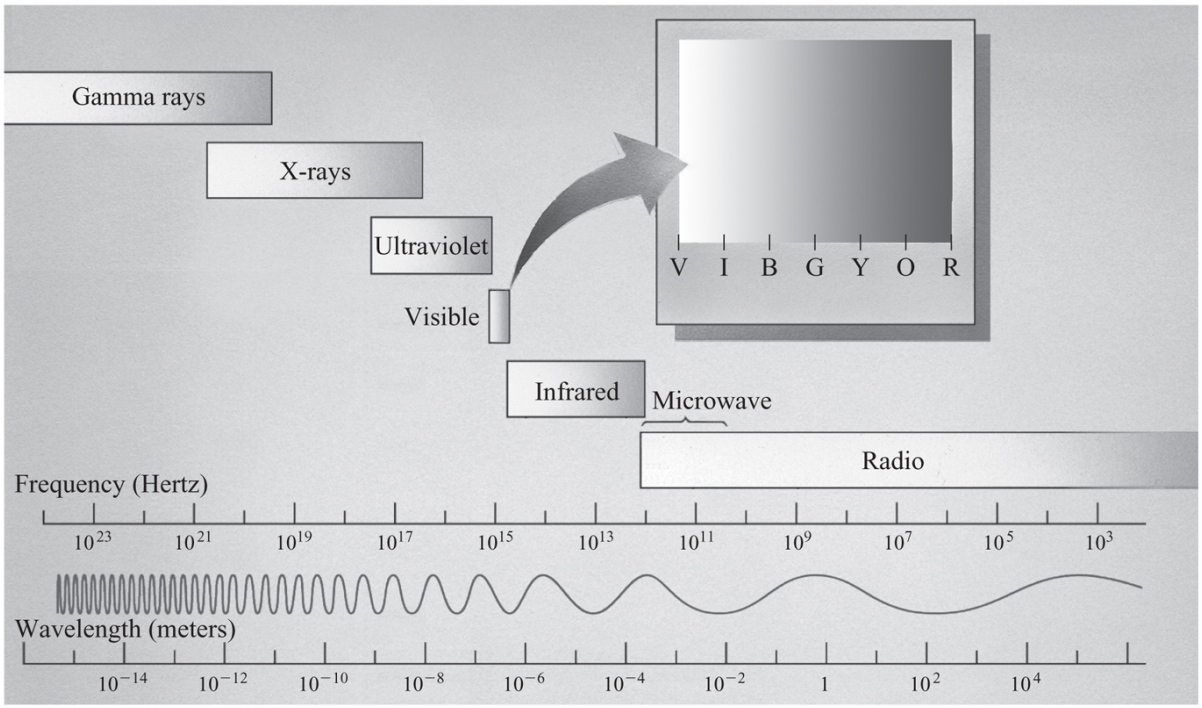
- Exam time: two hours
- Please put bags under your seats to allow proctors to move around the room.
- Please choose the **best** answer to each question.
- You may use up to four single-sided or two double-sided pages of notes on this exam. You may not use a cellphone or smartwatch for any reason and must put these away.
- If you have a question, raise your hand, and a proctor will assist you.
- Do not attempt to communicate with anyone other than teaching staff during the exam.

Good luck!

Lab Schedule

Section	Instructor	Time
M024	Jiaxin Sun	Monday 8:00AM-9:20AM
M003	Pan Dong	Monday 9:30AM-10:50AM
M004	Pan Dong	Monday 11:00AM-12:20PM
M005	Pan Dong	Monday 12:45PM-2:05PM
M006	Pan Dong	Monday 2:15PM-3:35PM
M007	Suman Kundu	Monday 3:45PM-5:05PM
M008	Suman Kundu	Monday 5:15PM-6:35PM
M009	Suman Kundu	Monday 6:45PM-8:05PM
M010	Suman Kundu	Monday 8:15PM-9:35PM
M027	Julian Georg	Tuesday 3:30PM-4:50PM
M028	Julian Georg	Tuesday 5:00PM-6:20PM
M029	Julian Georg	Tuesday 6:30PM-7:50PM
M030	Julian Georg	Tuesday 8:00PM-9:20PM
M025	Ohana Benevides Rodrigues	Wednesday 8:00AM-9:20AM
M011	Ohana Benevides Rodrigues	Wednesday 9:30AM-10:50AM
M012	Ohana Benevides Rodrigues	Wednesday 11:00AM-12:20PM
M013	Scott Bassler	Wednesday 12:45PM-2:05PM
M014	Jiaxin Sun	Wednesday 2:15PM-3:35PM
M015	Sarthak Gupta	Wednesday 3:45PM-5:05PM
M016	Sarthak Gupta	Wednesday 5:15PM-6:35PM
M017	Elizabeth Lawson-Keister	Wednesday 6:45PM-8:05PM
M018	Elizabeth Lawson-Keister	Wednesday 8:15PM-9:35PM
M019	Sarthak Gupta	Thursday 5:00PM-6:20PM
M020	Sarthak Gupta	Thursday 6:30PM-7:50PM
M031	Ohana Benevides Rodrigues	Thursday 8:00PM-9:20PM
M026	Elizabeth Lawson-Keister	Friday 8:00AM-9:20AM
M021	Elizabeth Lawson-Keister	Friday 9:30AM-10:50AM
M022	Jiaxin Sun	Friday 11:00AM-12:20PM
M023	Jiaxin Sun	Friday 12:45PM-2:05PM

Reference



Newton's laws of motion state:

1. An object in motion will continue to move in a straight line at a constant speed unless acted on by an external force.
2. An object's acceleration is equal to the sum of the forces acting on it divided by its mass; in symbols, $a = F/m$ or $F = ma$.
3. If object A exerts a force on object B, then object B exerts a force back on A of equal size and in the opposite direction.

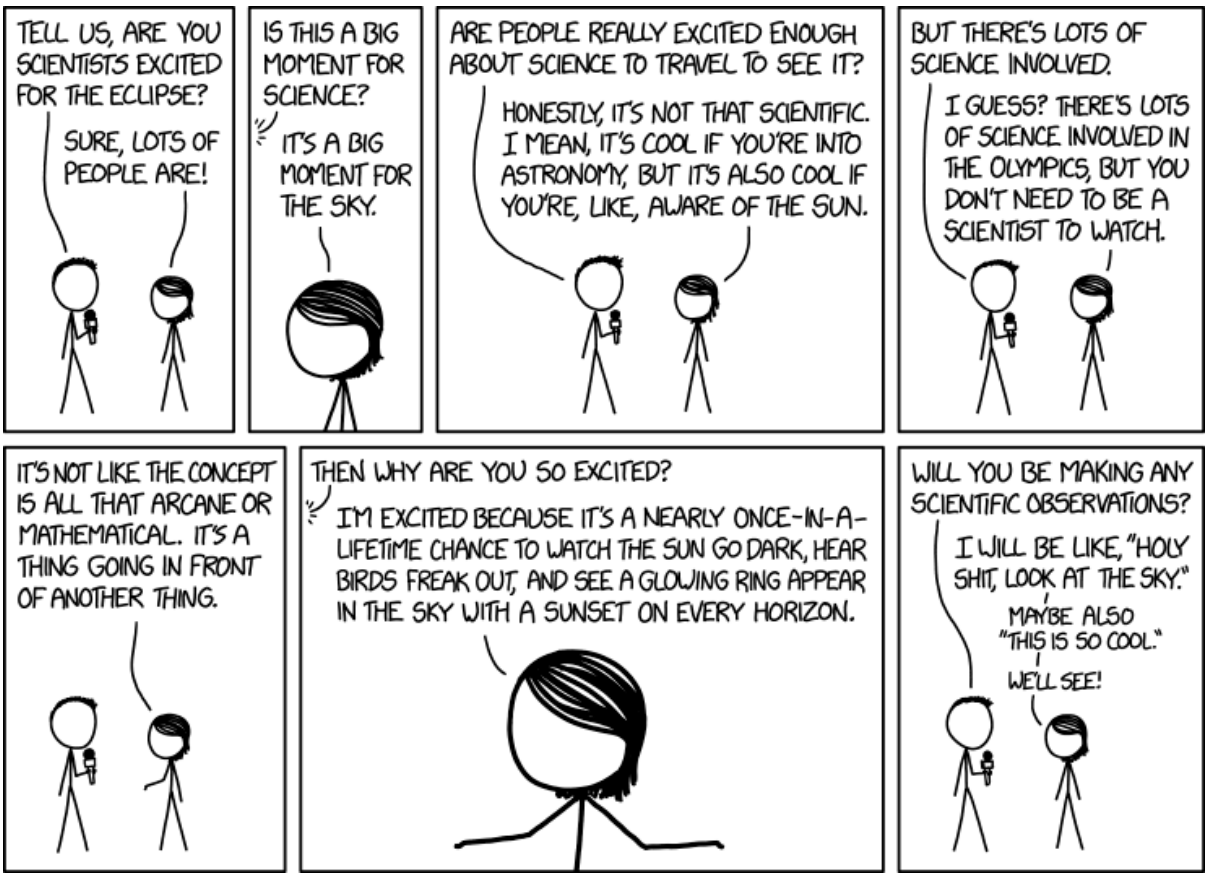
Newton's law of gravity says that the gravitational force between two objects is given by

$$F_g = \frac{Gm_1m_2}{r^2},$$

where m_1 and m_2 are their masses and r is the distance between their centers/

Kepler's laws of orbital motion state:

1. Planets orbit the Sun in ellipses with the Sun at one focus
2. The line connecting the Sun to a planet sweeps out equal areas in equal times
3. The orbital period is proportional to the 3/2 power of the semimajor axis of the orbit; in symbols, $T \propto a^{3/2}$.



(xkcd #1877, by Randall Munroe. Used under the CC-BY-NC license.)

`(Question formid)`

1. What form is your exam?

   (A) Form A
   (B) Form B
   (C) Form C
   (D) Form D
   (E) Form E

`(Question cold-war)`

2. The primary motivation for the rapid developments of rocketry in the late 1950's was:

   (A) Traveling to the Moon
   (B) **Producing intercontinental ballistic missiles**
   (C) Sending robotic probes to the planets, like the US *Viking* series
   (D) Launching communication satellites into orbit

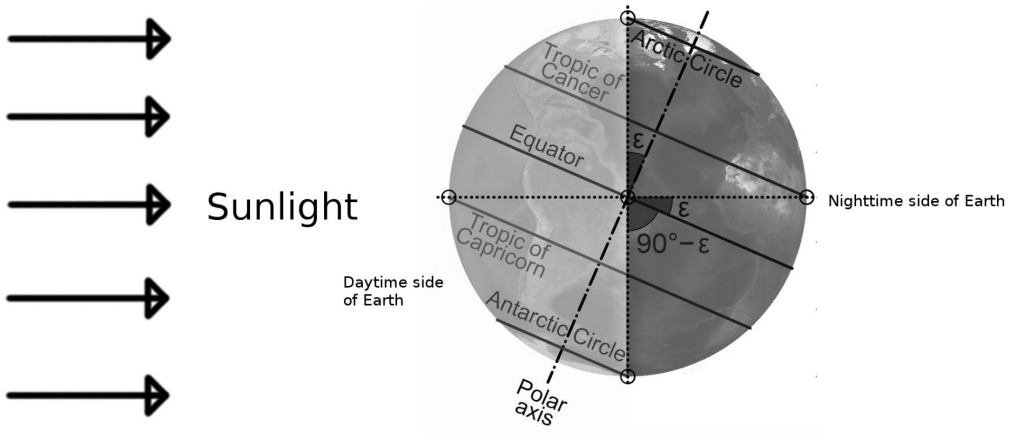
`(Question alpha-centauri)`

3. Suppose that in the far future humans send a spaceprobe to Alpha Centauri. We send it a radio signal telling it to take a picture of the planet it is orbiting. How long will it be until we get the return signal?

   (A) About a month
   (B) About ten thousand years
   (C) **About a decade**
   (D) About a century
   (E) About a year

(Question solstice)

4. Consider the following image, showing Earth at a particular point in its orbit:



What is the most specific thing you can conclude about the time of year in this picture? *(Adapted from a question suggested by Scott; thanks!)*

(A) **It is the December solstice (around December 21)**

(B) It is sometime in November, December, or January, but you can't tell exactly when

(C) It is sometime in May, June, or July, but you can't tell exactly when

(D) It is the June solstice (around June 21)

(E) The time of year here depends on which part of Earth's surface you are concerned with

`(Question kepler-model)`

5. Consider two objects: the moon Titan in its orbit around Saturn, and the *Cassini* spacecraft as it used its rocket motor to explore various objects near Saturn.

   Which of the following are true?

   (I) Newton's laws of motion describe the motion of Titan

   (II) Newton's laws of motion describe the motion of *Cassini*

   (III) Kepler's laws of orbital motion describe the motion of Titan

   (IV) Kepler's laws of orbital motion describe the motion of *Cassini*

   (A) III only
   (B) II, III, and IV
   (C) II and III
   (D) I, II, III, and IV
   (E) **I, II, and III**

`(Question atmosphere-thick)`

6. Which of the following objects has the *thickest atmosphere*?

   (A) **Venus**
   (B) Mercury
   (C) Earth
   (D) Mars
   (E) Enceladus

`(Question coalescence)`

7. How did the planets in our Solar System form?

   (A) They came from outside the Solar System and were captured by the Sun's gravity and brought into orbits around the Sun

   (B) **They coalesced from small bits of dust and ice that stuck together by static electricity and, as they grew, gravity**

   (C) They coalesced from solar wind particles emitted by the Sun over its lifetime

   (D) They are pieces of the Sun that broke off during its early life, when nuclear fusion first started in its core

   (E) None of the above

`(Question ice-planet)`

8. A star similar to our Sun has a planet orbiting it that is made principally of ice. Which of the following is a possible description of its orbit?

   (A) A strongly elliptical orbit with perihelion of 0.7 AU and aphelion of 30 AU

   (B) A nearly circular orbit with radius 1.5 AU

   (C) **A nearly circular orbit with radius 20 AU**

   (D) A nearly circular orbit with radius 0.5 AU

   (E) More than one of the above are possible orbits for an ice planet

`(Question light-travel)`

9. The amount of time required for light to travel from Earth to the *Voyager I* probe, located at the edge of the solar system, is closest to:

   (A) Ten minutes

   (B) One year

   (C) One month

   (D) **One day**

   (E) One second

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(Question copernican-accuracy)
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10. Which is true about the Copernican heliocentric model of the Solar System, compared to the Ptolemaic geocentric model?

    (A) **The Copernican model provided a better description of the arrangements of the objects in the Solar System, but its predictions about the apparent motion of planets in the sky were not as precise as the Ptolemaic model**

    (B) The Copernican model was less correct in regard to the arrangements of the objects in the Solar System, but its predictions about the apparent motion of planets in the sky were more precise than the Ptolemaic model

    (C) The Copernican heliocentric model introduced elliptical orbits for the planets and thus paved the way for the discovery of the laws of orbital motion

    (D) The Copernican heliocentric model required more complex mathematics to describe the motion of planets like Mars than the Ptolemaic model

    (E) None of the above are true

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(Question stove-burner)
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11. Blacksmiths use the visible appearance of the thermal radiation of hot metal to judge its temperature.

    Suppose a metal is heated to the point where its glow is barely visible to the human eye, around 1000 Kelvin. What type of light is it mostly emitting?

    (A) Ultraviolet light

    (B) Blue light

    (C) White light

    (D) **Infrared light**

    (E) Red light

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(Question earth-rotate-sidereal-day)
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12. How many degrees does the Earth rotate on its axis during a sidereal day?

    (A) Around 359 degrees

    (B) Around 361 degrees

    (C) Around 1 degree

    (D) **Exactly 360 degrees**

    (E) The Earth does not rotate on its axis! What are you, some kind of heretic?

(Question halley-orbit)

13. The diagram below shows the orbital path for Halley's comet, along with Earth's orbit (the small circle on the far left). Why is Halley's comet only visible about 10 days out of every 76 years? *(Thanks to Scott Bassler for writing this question!)*

(A) Halley's comet moves fastest when it is near the Earth, and so it exits our region of space quickly

(B) Only a small part of Halley's comet's orbit is near enough to the Earth to be seen.

(C) Most of the time, Halley's comet is behind the Sun, making it impossible to observe.

(D) **Both (A) and (B) are true**

(E) During most of its orbit, the lit side of Halley's comet is facing away from us, as with the new moon

(Question atmosphere-thin)

14. Which of the following objects has the *thinnest atmosphere*?

(A) Jupiter

(B) **Mercury**

(C) Earth

(D) Mars

(E) Venus

(Question kepler-ellipse)

15. In trying to make sense of Tycho Brahe's data, Kepler was stymied by a small deviation – a small fraction of a degree – in the position of Mars. What caused this deviation?

(A) **At that time, Kepler was assuming that Mars moved in a circular path**

(B) The precession of the equinoxes meant that Mars was not where the *Almagest* predicted it to be

(C) Kepler had not corrected Tycho's data for the refraction of the atmosphere

(D) Tycho's pet moose kicked his instruments and knocked them out of alignment

(E) They had not considered Jupiter's gravitational influence on the orbit of Mars

`(Question mars-volcano)`

16. There is an extremely large mountain that looks like a volcano on Mars. Which of the following is true about it?

    (A) **It hasn't been active in billions of years, but it was active long ago**
    (B) Its eruptions dredge up material from the interior of Mars that we can use to determine its age
    (C) Mars has never had volcanic activity, so it must have been created by a meteorite impact
    (D) Its eruptions create the dust storms that have covered the solar panels of *Spirit*
    (E) None of the above

`(Question habitable-zone)`

17. Over billions of years, how is the location of the circumstellar habitable zone of the Sun changing?

    (A) It is moving closer in
    (B) It is not moving at all
    (C) **It is moving further out**
    (D) It is expanding on both edges
    (E) I skipped the lab on this

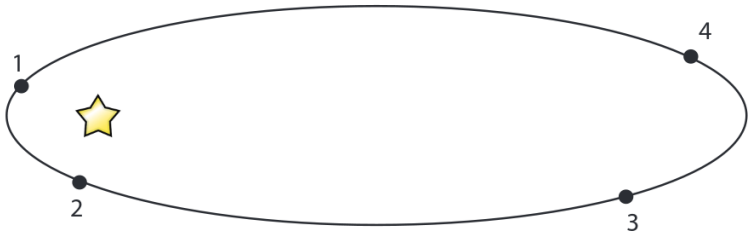
`(Question ice-fishers)`

18. In the Syracuse Vocal Ensemble concerts last weekend, we sang a piece describing people fishing during mid-December, but they only have "an hour or two" of sunlight per day. Where might they be located?

    (A) The North Pole
    (B) The southern tip of Argentina
    (C) **Canada**
    (D) Syracuse
    (E) None of the above

`(Question comet)`

19. Consider the orbit of the following comet, which is traveling counterclockwise around the Sun:



At which location is the comet *traveling slowly*, but *speeding up*?

(A) 1
(B) 2
(C) 3
(D) **4**
(E) None of the above

`(Question earth-rotate-solar-day)`

20. How many degrees does the Earth rotate on its axis during a solar day?

(A) Exactly 360 degrees
(B) Around 359 degrees
(C) **Around 361 degrees**
(D) Around 1 degree
(E) The Earth does not rotate on its axis! What are you, some kind of heretic?

`(Question sun-motion)`

21. Suppose you note the position of the Sun at solar noon today, and then again at solar noon tomorrow, while observing from the same point in Syracuse. What will be true?

    ("Today" and "tomorrow" refer to the actual date you are taking this exam.)

    (A) The Sun will be very near the zenith at noon today, and will be slightly closer to the zenith at noon tomorrow

    (B) **The Sun will be low in the southern sky at noon today, and slightly lower in the southern sky at noon tomorrow**

    (C) The Sun will be low in the northern sky at noon today, and slightly lower in the northern sky at noon tomorrow

    (D) The Sun will be low in the southern sky at noon today, and slightly higher in the southern sky at noon tomorrow

    (E) The Sun will be low in the northern sky at noon today, and slightly higher in the northern sky at noon tomorrow

`(Question moon-gravity)`

22. The Earth is 96 times more massive than the Moon, and its radius is four times as large as the Moon's.

    If a rock weighs 10 pounds on the surface of the Moon, how much does it weigh on Earth?

    (A) **60 pounds**

    (B) 2.5 pounds

    (C) 10 pounds

    (D) 240 pounds

    (E) In order to answer this problem, we would need to know the mass of the rock

`(Question kelvin-temperature)`

23. The temperature of the Earth is most nearly:

    (A) **300 Kelvin**

    (B) 80 Kelvin

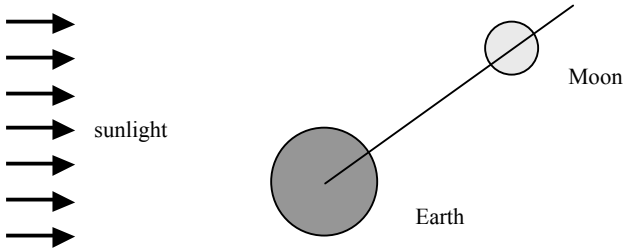
    (C) 3000 Kelvin

    (D) 30 Kelvin

    (E) 3 Kelvin

`(Question moon-bisect)`

24. This diagram appeared on the lab about Moon phases, showing the Earth and Moon as seen from above the North Pole.



During that lab, you were asked to:

- Draw the line through the center of the Moon perpendicular to the direction of incoming sunlight.
- Shade the half of the Moon that does NOT receive sunlight.
- Draw the line perpendicular to the line that connects the Earth and the Moon.
- Determine the Moon phase.

Based on these steps, what phase would an observer on Earth observe the Moon to be in in the above diagram? *(Thanks to Scott Bassler for the question!)*

(A) New moon
(B) Full moon
(C) Waxing half moon ("first quarter")
(D) **Waning gibbous**
(E) Waxing crescent

`(Question rock-in-box)`

25. Three rocks are floating in space, 1 AU from the Sun, far from any planets, as follows:

    - Rock α is enclosed in a box that absorbs visible light, but allows other types to pass through.
    - Rock β is enclosed in a box that absorbs infrared light, but allows other types to pass through.
    - Rock γ is not enclosed in anything.

    Which of the following is a correct description of their temperatures?

    (A) $\gamma > \beta > \alpha$ ("γ is hotter than β, which is hotter than α")
    (B) $\gamma > \beta = \alpha$ ("γ is hotter than β and α, which are the same temperature")
    (C) $\alpha > \beta > \gamma$ ("α is hotter than β, which is hotter than γ")
    (D) $\gamma = \beta > \alpha$ ("γ and β are the same temperature, and are hotter than α")
    (E) $\beta > \alpha > \gamma$ ("β is hotter than α, which is hotter than γ")

`(Question star-motions)`

26. In Syracuse, you observe a star low on the horizon, due north of you. Where will you find that star six hours later?

    (A) In the northwestern sky
    (B) High in the northern sky, nearly at the zenith
    (C) Below the horizon – you won't be able to see it
    (D) **In the northeastern sky**
    (E) The answer depends on the time of the year

`(Question far-from-earth)`

27. Which of the following has traveled the *least far* from Earth?

    (A) Spacecraft that the USSR built as part of their effort to go to the Moon
    (B) *Viking 1*
    (C) Spacecraft that were part of the *Apollo* program
    (D) **Any of the Space Shuttles**
    (E) *Pioneer 10*

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(Question life-necessity)
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28. Which of the following is most likely to be necessary for life?

    (A) Atmospheric pressure similar to Earth's
    (B) Gravity similar to Earth's
    (C) **Liquid water**
    (D) A temperature below 50° C/122° F
    (E) Molecular oxygen (O_2)

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(Question rocket-push)
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29. Which is an explanation of how rockets push themselves forward?

    (A) They convert energy into thrust without applying a force on any other object
    (B) **They push back against their own exhaust**
    (C) They push back against the medium that surrounds them
    (D) They convert energy into heat, and that heat pushes them forward
    (E) None of the above are correct.

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(Question parallax-baseline)
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30. Recall that when discussing parallax, your baseline is the distance between the two points you observed the object from.

    If you want to use parallax to determine the distances to the stars, but are confined to the surface of the Earth, what is the largest baseline you have access to? *(Thanks to Scott Bassler for the question!)*

    (A) The radius of the Earth's orbit around the Sun
    (B) The diameter of the Earth
    (C) The circumference of the Earth
    (D) **The diameter of the Earth's orbit around the Sun**
    (E) The radius of the Earth

`(Question climate-change-timeline)`

31. Without action to mitigate CO_2 emissions, which of the following is likely to happen within a century? For comparison, the difference between Earth's temperature now and its temperature during the last Ice Age is about 5 degrees C.

    (A) Earth will warm by 12-18 C, reaching temperatures higher than during the time of the dinosaurs

    (B) **Earth will warm by 5-7 C**

    (C) Earth will warm by 50-200 C, with a runaway greenhouse effect transforming it into a state like Venus, incapable of supporting life

    (D) Earth will warm by 1.5-2 C

    (E) Earth will warm by 20-30 C, becoming hot enough that living things will only be able to live near the poles

`(Question star-composition)`

32. How can we most readily measure what chemical elements are in stars?

    (A) By examining the positions of the bright lines in their spectra

    (B) By examining the slight motions they make in the sky

    (C) **By examining the positions of the dark lines in their spectra**

    (D) By examining the peak wavelengths of the continuous spectra that they emit

    (E) We have no way to measure the composition of stars

`(Question earth-age)`

33. The age of the Earth is most nearly:

    (A) 4.2 million years

    (B) **4.5 billion years**

    (C) 14 billion years

    (D) 750 million years

    (E) 6200 years

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(Question sputnik)
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34. When the Soviet Union launched their first artifical satellite *Sputnik 1* in 1957, what was the status of the American space program?

    (A) **It was essentially nonexistent; NASA had not been created yet**

    (B) The Americans had flown the first person to space, Alan Shepard, in 1956; *Sputnik 1* was thus not that great of a leap forward

    (C) The Americans were slightly behind the Soviets, and would launch their first satellite a month afterward

    (D) The Americans were in the middle of testing the *Apollo* hardware that would eventually be used for the trip to the Moon and back

    (E) None of the above are correct

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(Question chemical-reaction)
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35. Which of the following would result in the greatest advance in rocketry for interplanetary travel?

    (A) The discovery of a new type of rocket fuel whose molecules have only half of the mass per molecule as those used today, but which is exhausted out of the rocket at the same speed when burned

    (B) **The discovery of a new type of rocket fuel that would result in a 30% increase in the exhaust speed of the gases ejected from a rocket**

    (C) The discovery of a new alloy of titanium allowing the construction of fuel tanks, structural components, and the like that weighs only 60% as much as current materials

    (D) An enormously successful Kickstarter by Elon Musk, allowing him to fund rockets twice as big as any that have been built so far

    (E) Advances in computer graphics technology allowing NASA to create compelling Martian landscapes in a Hollywood basement, in addition to the lunar ones that they already have.

`(Question elements)`

36. Rattlesnakes make use of their ability to see infrared light to hunt their prey at night. Which of the following animals is *least* likely to be detected by a hungry diamondback rattlesnake on a dark night in Arizona using its infrared vision?

    Assume that the desert rocks are all brown, and that the temperature at night is 30° C.

    (A) **A blue and yellow lizard whose body temperature is 30° C**
    (B) A grey-colored toad that has just hopped out of cool water, and whose skin is 24° C
    (C) A black phainopepla (a kind of American desert bird) whose body temperature is 40° C
    (D) A brown-colored kangaroo rat whose body temperature is 39° C
    (E) It depends on which critter speaks Parseltongue most fluently

`(Question moon-phase-cause)`

37. Which is the best explanation of moon phases?

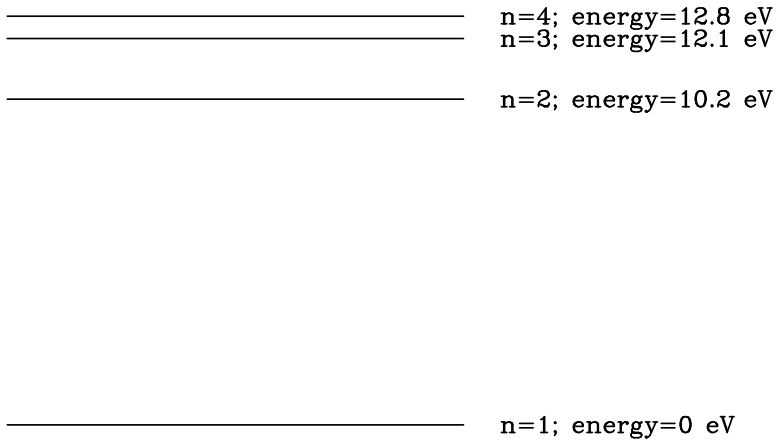
    (A) As the Earth rotates, observers on different parts of the Earth are able to see different fractions of the Moon's surface above the horizon.
    (B) **The Moon is always half lit, but depending on its position we may see more or less of its lit face.**
    (C) The Earth casts shadows on the face of the Moon that vary in size and location as the Moon moves around the Earth.
    (D) The fraction of the the Moon's surface that is lit by the Sun changes depending on its position.
    (E) None of the above is correct.

(Question hydrogen-spectrum)

38. Here is an energy-level diagram showing the first four energy levels of hydrogen.

Suppose that you run an electric current through hydrogen gas in a discharge tube (like you used in lab) and looked at it through one of the handheld spectrometers you used in lab. What would you see?

(Visible light photons have energies from 1.6-3.2 eV. Note that I'm only asking you to think about the first four energy levels, shown here. There is an additional piece of the spectrum resulting from energy levels above $n = 4$, but don't worry about that for this problem.)



(A) A continous band of color ranging from red to blue

(B) One red, one orange, one yellow, one green, one blue, and one purple line

(C) **One red line and one blue-green line**

(D) One red line

(E) Three ultraviolet lines

`(Question climate-change-future)`

39. In Lab 8, you estimated the temperatures of planets by balancing the incoming thermal radiation from the Sun and the outgoing thermal radiation from the planet. You found that your estimate wasn't accurate for Venus and Earth, planets that have an atmosphere that causes a greenhouse effect. How does the greenhouse effect change this radiation balance?

    (A) The greenhouse effect increases the amount of infrared thermal radiation reaching from the planet at any given temperature.

    (B) **The greenhouse effect reduces the amount of infrared thermal radiation escaping from the planet at any given temperature.**

    (C) The greenhouse effect increases the amount of visible thermal radiation reaching the planet at any given temperature.

    (D) The greenhouse effect reduces the amount of visible thermal radiation escaping from the planet at any given temperature.

    (E) None of the above are correct.

`(Question equinox-day-length)`

40. On the September equinox, which location will experience a longer day?

    (A) Quito, Ecuador (on the Equator)

    (B) McMurdo Station, Antarctica (78°S latitude)

    (C) Syracuse, NY (43° N latitude)

    (D) Tallinn, Estonia (59° N latitude)

    (E) **All of the above will experience days that are the same length**

`(Question capricorn-motion)`

41. A person looks up and sees the constellation Capricorn high overhead at midnight on a given day.

    When will Capricorn be located behind the sun?

    (A) One day from then

    (B) **Six months from then**

    (C) One month from then

    (D) One sidereal year from then

    (E) More than one of the above

(Question liquid-water)

42. Other than Earth, where could liquid water be found in our solar system, either now or in the past?

    (A) On the surface of Mars, now

    (B) On the surface of Venus, now

    (C) Below the surface of Saturn's moon Enceladus

    (D) On the surface of Mars, in the distant past

    (E) **More than one of the above**

(Question transitions-1)

43. Suppose that an atom has energy levels of 0 eV, 2.5 eV, 3.5 eV, and 4 eV. It has one electron which is currently in the $n = 3$ state (with energy 3.5 eV). Which of the following can this atom do?

    (A) **It can emit photons with energy 1 eV or 3.5 eV, or absorb a photon of energy 0.5 eV**

    (B) It can absorb photons with energy 1 eV or 3.5 eV, or emit a photon of energy 0.5 eV

    (C) It can emit a photon with energy 2.5 eV or absorb a photon of energy 4 eV

    (D) It can absorb a photon with energy 2.5 eV or emit a photon of energy 4 eV

(Question calendar-solstice)

44. In a fictional culture in a series of novels, the principal religious observation of the people is the "Longest Night" – the winter solstice. Which sort of calendar are these people most likely to use?

    (A) **A solar calendar, like the Gregorian calendar**

    (B) A lunar calendar, like the Islamic calendar

    (C) A lunisolar calendar, like the Chinese or Jewish calendar

    (D) A sidereal calendar, like the Egyptian calendar

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(Question greenhouse-effect)
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45. Which of the following has the strongest greenhouse effect?

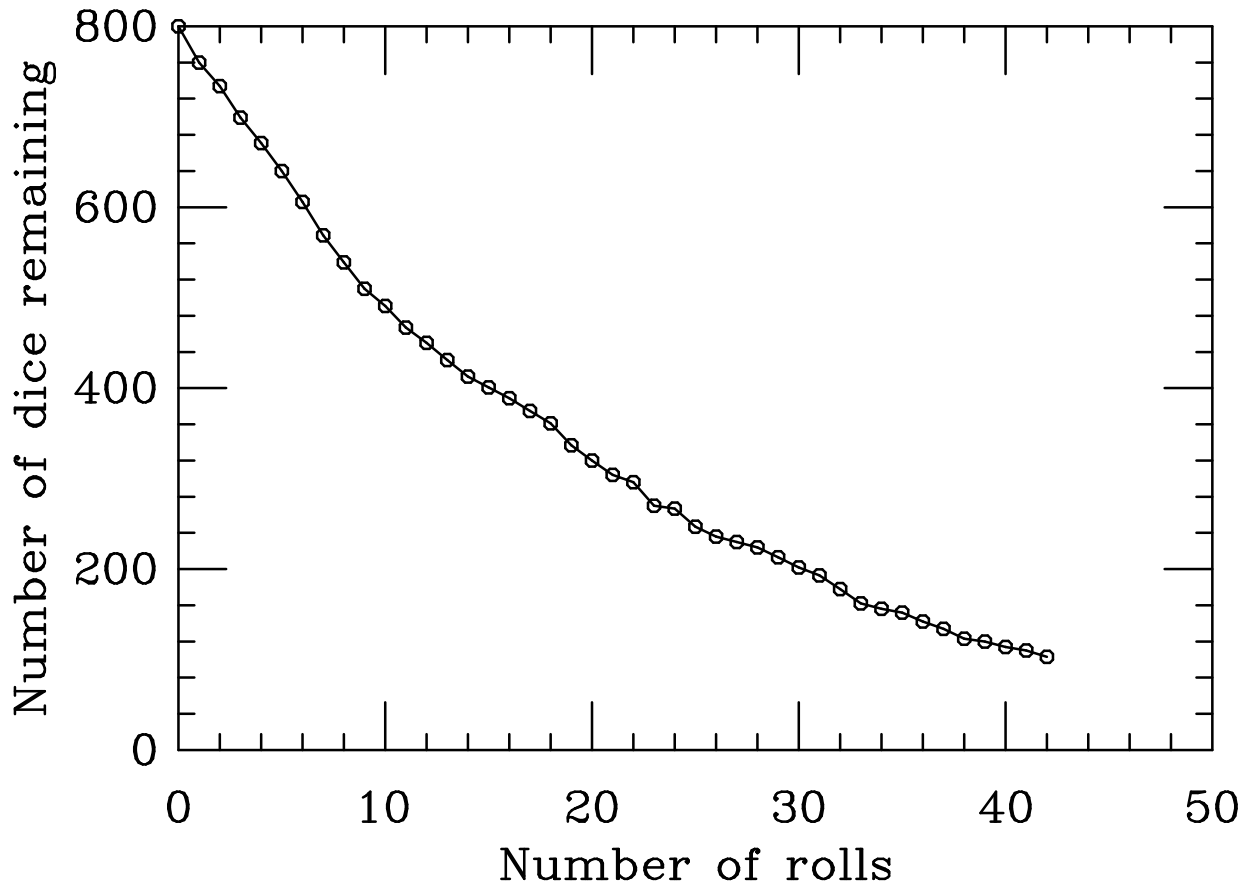
    (A) Earth (now)
    (B) The Moon
    (C) Mercury
    (D) **Earth; 80 million years ago, when non-bird dinosaurs walked the earth**
    (E) Mars (now)

(Question dice-rolls)

46. You have eight hundred twenty-sided dice. Being a superstitious sort, you want to see which one can go the longest before rolling a 1; this is the die you're going to use for your important *Dungeons and Dragons* game over the holidays.

    You roll all of the dice and remove all of the ones that came up "1". Then you repeat the procedure, each time rolling all the dice and removing all the 1's.

    After you do this for a while, you decide to start keeping track of how many rolls you've made vs. how many dice are left. You gather the following data. (This is very similar to what you did in lab, except you are using twenty-sided dice rather than six-sided ones.)



    Based on this chart, what is the "half-life" of the number of dice remaining? (*Adapted from a question written by Scott Bassler; thanks!*)

    (A) **About 15 rolls**
    (B) About 25 rolls
    (C) About 10 rolls
    (D) About 20 rolls
    (E) About 30 rolls

`(Question distance-scales)`

47. The distance from the Earth to Saturn is most nearly:

    (A) 100 AU
    (B) **10 AU**
    (C) 0.1 AU
    (D) 1 AU
    (E) 1000 AU

`(Question life-earth-origin)`

48. When did life first appear on Earth?

    (A) Six thousand years ago
    (B) About two billion years ago
    (C) **About four billion years ago**
    (D) About two hundred million years ago
    (E) We don't know when life appeared on Earth with any precision

`(Question seasons-cause)`

49. Which of the following is the best explanation of why we have seasons?

    (A) During the summer the Earth is closer to the Sun, and during the winter it is further away, due to the eccentricity of the Earth's orbit.
    (B) **The tilt of the Earth's axis does not change over one year, but when it is combined with the Earth's motion around the Sun, sometimes we (in the Northern Hemisphere) are tilted toward the Sun, but six months later we are on the other side of the Sun and are thus tilted away from it**
    (C) The tilt of the Earth's axis changes twice per year, so sometimes we (in the Northern Hemisphere) are tilted toward the Sun, and sometimes we are tilted away from it
    (D) None of the above are good explanations for the seasons.

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(Question climate-change-now)
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50. During the last ice age, the Earth was about 5 degrees C colder than it was around 1800. (This information is provided only as a comparison, to help you understand the scale of Earth's recent natural climate change.)
How much warmer has the Earth been in recent years than it was around 1800?

    (A) **1 degree C**
    (B) 8 degrees C
    (C) 3 degrees C
    (D) 5 degrees C
    (E) It is the same temperature as it was around 1800

```
(Question absorb-emit)
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51. Which principle of physics explains why atoms must emit light when their electrons transition to a lower energy level, and why they transition to a higher energy level when they absorb light?

    (A) Newton's law of universal gravitation
    (B) **The conservation of energy**
    (C) The conservation of angular momentum
    (D) The Heisenberg uncertainty principle
    (E) Kepler's second law of orbital motion

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(Question hottest-planet)
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52. Which of the following objects has the *hottest* surface?

    (A) Mars
    (B) The Moon
    (C) Earth
    (D) **Venus**
    (E) Mercury

`(Question earth-age-origin)`

53. How do we know how old the Earth is?

    (A) By measuring the amount of heat left in its core compared to when it was formed

    (B) By examining gases trapped in ice core samples in Antarctica

    (C) By examinations of the decay of the orbit of the Moon

    (D) **By using radioisotope dating on the oldest rocks we can find**

    (E) We do not know how old the Earth is

`(Question planet-age-dating)`

54. When humans launched *Voyager 1* into space, we included a sample of uranium-238 with the famous *Voyager Golden Record*, designed to carry information about Earth and humans in case any exterrestrial intelligence should find it.

    Uranium-238 decays into lead-206 with a half-life of around 4.5 billion years. In the future, suppose that someone were to find *Voyager 1* and observe that the sample consists of 25% uranium and 75% lead.

    How far in the future was *Voyager 1* discovered?

    (A) **About 9 billion years**

    (B) About 18 billion years

    (C) About 1.1 billion years

    (D) About 3.4 billion years

    (E) About 4.5 billion years

`(Question galilean-telescope)`

55. What was an immediate consequence of Galileo's application of the telescope to astronomy?

    (A) It led quickly to the discovery of new planets, Uranus and Neptune

    (B) It allowed people to make more precise measurements of the motion of Mars, leading to the development of Kepler's laws of motion

    (C) It allowed Tycho to measure the parallax of the supernova he observed and determine its distance

    (D) **It allowed people to see moons orbiting other planets for the first time**

    (E) It allowed people to make more precise measurements of the motion of Mars, leading to the correction of errors in the *Almagest* on the properties of epicycles

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(Question angular-momentum)
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56. The conservation of angular momentum explains:

    (A) Why the early solar system spun faster as it collapsed

    (B) Why planets closer to the Sun are hotter

    (C) Why an object falling off of a shelf gains speed as it falls

    (D) Why comets move faster when they are closer to the Sun

    (E) **More than one of the above is a consequence of the conservation of angular momentum**

Scratch Paper

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