

# Astronomy Multiple Choice

1. Evidence that the universe is expanding is best provided by the

- (1) red shift in the light from distant galaxies
- (2) change in the swing direction of a Foucault pendulum on Earth
- (3) parallelism of Earth's axis in orbit
- (4) spiral shape of the Milky Way Galaxy

2. In New York State, summer is warmer than winter because in summer New York State has

- (1) fewer hours of daylight and receives low angle insolation
- (2) fewer hours of daylight and receives high angle insolation
- (3) more hours of daylight and receives low-angle insolation
- (4) more hours of daylight and receives high angle insolation

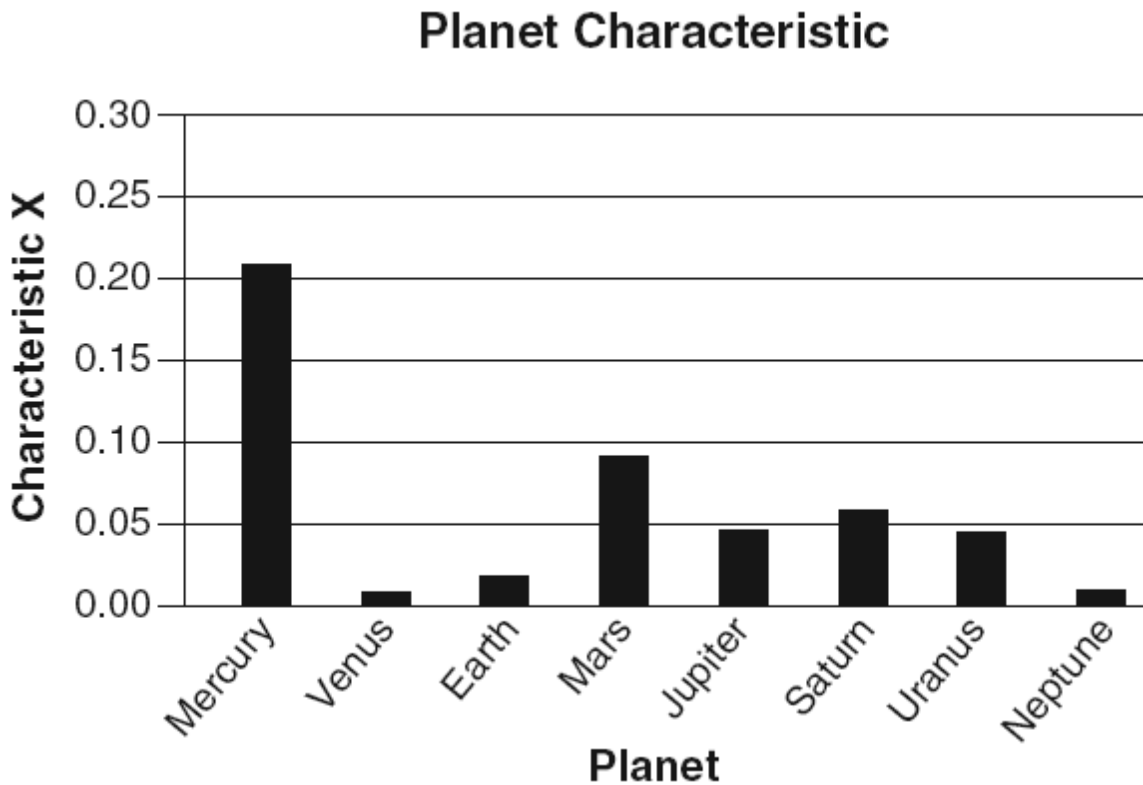
3. Which object forms by the contraction of a large sphere of gases causing the nuclear fusion of lighter elements into heavier elements?

- (1) comet
- (2) planet
- (3) star
- (4) moon

4. Which statement best describes the position of the Sun at sunrise and sunset as seen by an observer in New York State on June 21?

- (1) The Sun rises north of due east and sets north of due west.
- (2) The Sun rises south of due east and sets south of due west.
- (3) The Sun rises north of due east and sets south of due west.
- (4) The Sun rises

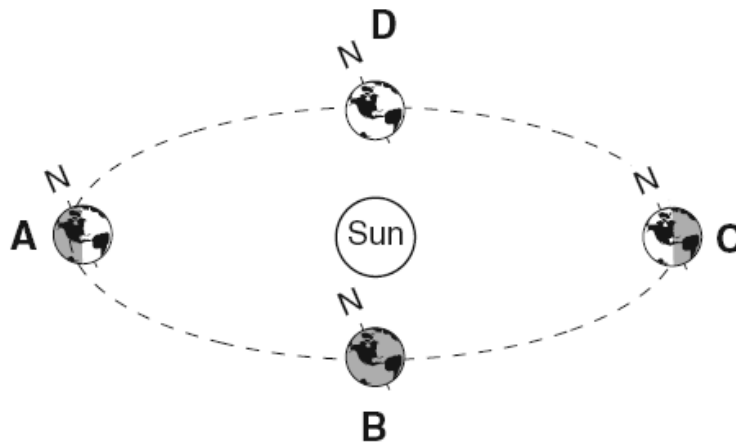
The bar graph below shows one planetary characteristic, identified as X, plotted for the planets of our solar system.



5. Which characteristic of the planets in our solar system is represented by X?

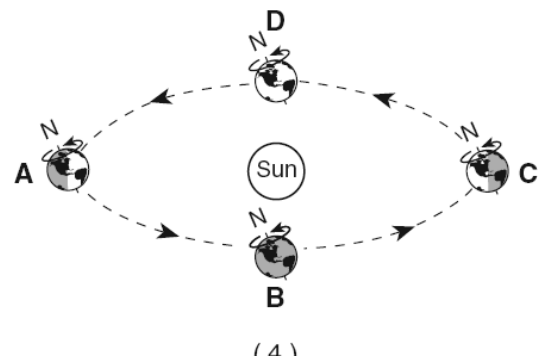
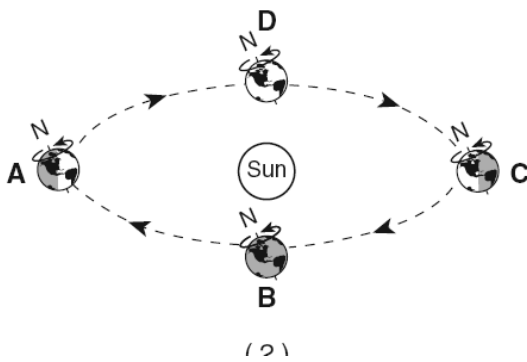
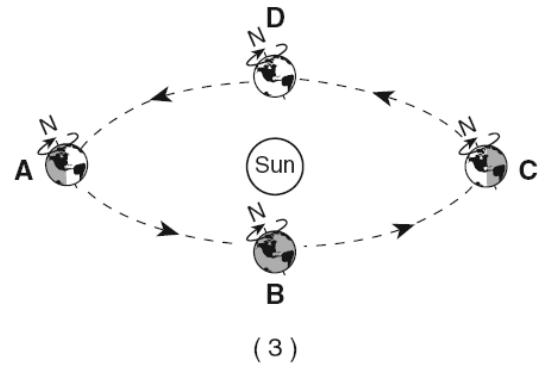
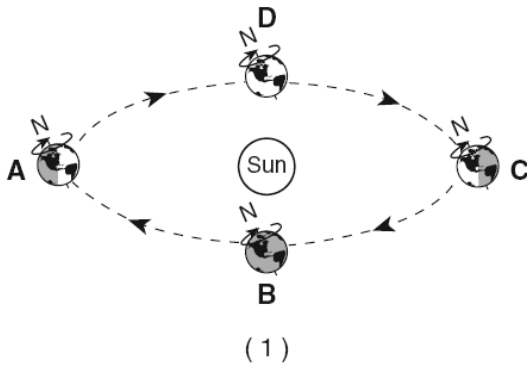
- (1) mass
- (2) density
- (3) eccentricity of orbit
- (4) period of rotation

Base your answers to questions 6 through 9 on the diagram below, which represents Earth in its orbit around the Sun. The position of Earth on the first day of each season is labeled A, B, C, and D.



(Not drawn to scale)

6. Which diagram correctly shows the directions of Earth's revolution and rotation?



7. At which location are the Sun's noontime rays perpendicular to Earth's surface at the Tropic of Cancer ( $23.5^\circ$  N)?

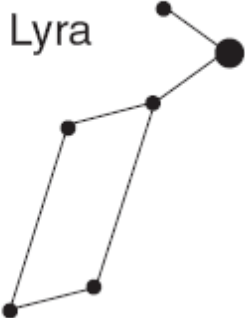
- (1) A                      (3) C  
 (2) B                      (4) D

8. What is the approximate rate of Earth's revolution around the Sun?

- (1)  $1^\circ$  per day                      (3)  $15^\circ$  per day  
 (2)  $1^\circ$  per year                      (4)  $15^\circ$  per year

9. Which event is caused by Earth's revolution?

- (1) the apparent shift in the path of a Foucault pendulum  
 (2) deflection of planetary winds to the right in the Northern Hemisphere  
 (3) the apparent rising and setting of the Sun  
 (4) different constellations observed in the night sky throughout the year

<p>10. As viewed from Earth, most stars appear to move across the sky each night because</p> <p>(1) Earth revolves around the Sun  (2) Earth rotates on its axis  (3) stars orbit around Earth  (4) stars revolve around the center of the galaxy</p>	<p>13. The star <i>Algol</i> is estimated to have approximately the same luminosity as the star <i>Aldebaran</i> and approximately the same temperature as the star <i>Rigel</i>. <i>Algol</i> is best classified as a</p> <p>(1) main sequence star  (2) red giant star  (3) white dwarf star  (4) red dwarf star</p>
<p>11. The explosion associated with the Big Bang theory and the formation of the universe is inferred to have occurred how many billion years ago?</p> <p>(1) less than 1                      (3) 4.6  (2) 2.5                                (4) over 10</p>	<p>14. The best evidence that Earth spins on its axis is the motion of</p> <p>(1) tectonic plates  (2) <i>Polaris</i>  (3) a wind vane  (4) a Foucault pendulum</p>
<p>The diagram below represents the constellation Lyra.</p>  <p>12. Which statement best explains why Lyra is visible to an observer in New York State at midnight in July but <i>not</i> visible at midnight in December?</p> <p>(1) Earth spins on its axis.  (2) Earth orbits the Sun.  (3) Lyra spins on its axis.  (4) Lyra orbits Earth.</p>	<p>15. When viewed from Earth, the light from very distant galaxies shows a red shift. This is evidence that these distant galaxies are</p> <p>(1) revolving around the Sun  (2) revolving around the Milky Way  (3) moving away from Earth  (4) moving toward Earth</p>

The diagram below shows the spectral lines for an element.



16. Which diagram best represents the spectral lines of this element when its light is observed coming from a star that is moving away from Earth?

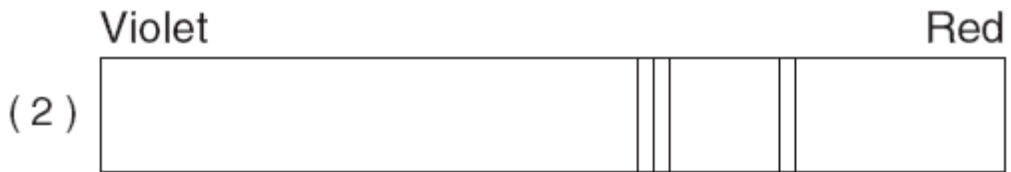
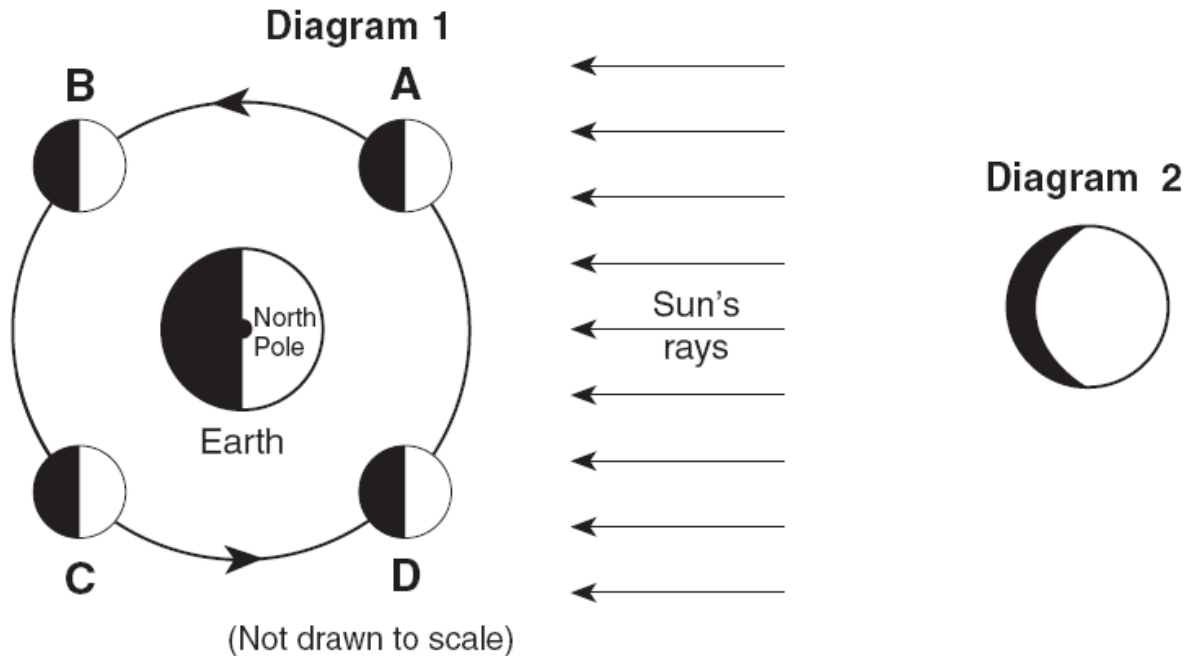


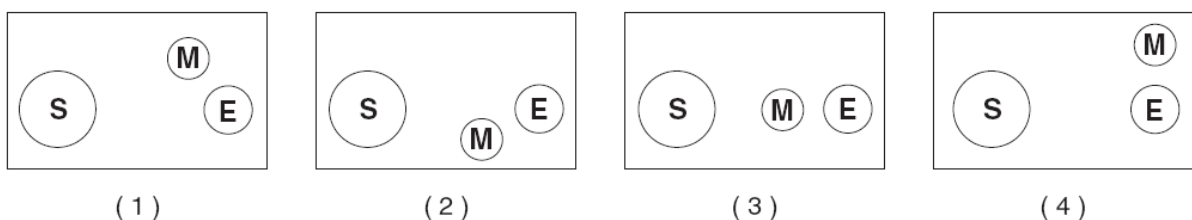
Diagram 1 shows the Moon in its orbit at four positions labeled *A*, *B*, *C*, and *D*. Diagram 2 shows a phase of the Moon as viewed from New York State.



17. At which labeled Moon position would the phase of the Moon shown in diagram 2 be observed from New York State?

- (1) *A*                      (3) *C*  
 (2) *B*                      (4) *D*

18. Which arrangement of the Sun, the Moon, and Earth results in the highest high tides, and the lowest low tides on Earth? (Diagrams are not drawn to scale.)



Base your answers to questions 19 through 22 on the passage and diagram below. The diagram shows the orbits of the four inner planets and the asteroid Hermes around the Sun. Point *A* represents a position along Hermes' orbit.

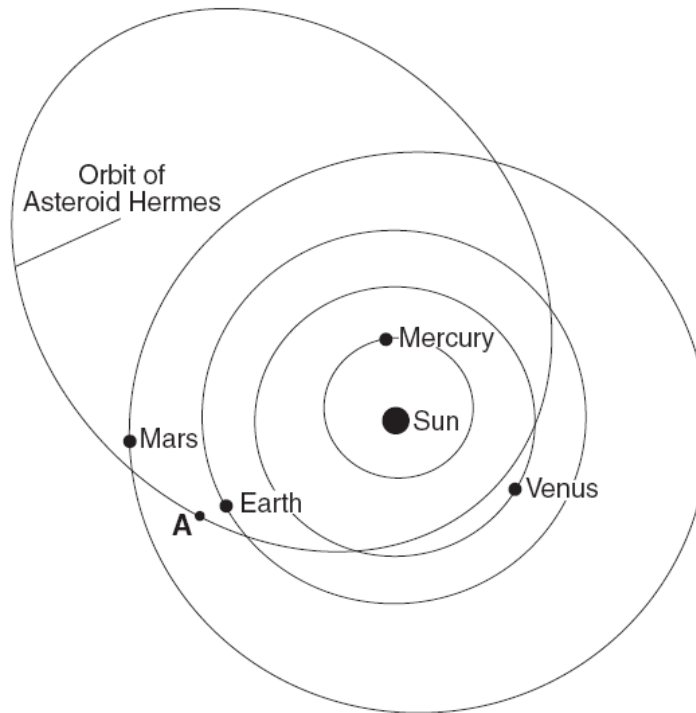
### The Curious Tale of Asteroid Hermes

It's dogma [accepted belief] now: an asteroid hit Earth 65 million years ago and wiped out the dinosaurs. But in 1980 when scientists Walter and Luis Alvarez first suggested the idea to a gathering at the American Association for Advancement of Sciences, their listeners were skeptical. Asteroids hitting Earth? Wiping out species? It seemed incredible. At that very moment, unknown to the audience, an asteroid named Hermes halfway between Mars and Jupiter was beginning a

long plunge toward our planet. Six months later it would pass 300,000 miles from Earth's orbit, only a little more than the distance to the Moon....

Hermes approaches Earth's orbit twice every 777 days. Usually our planet is far away when the orbit crossing happens, but in 1937, 1942, 1954, 1974 and 1986, Hermes came harrowingly [dangerously] close to Earth itself. We know about most of these encounters only because Lowell Observatory astronomer Brian Skiff rediscovered Hermes on Oct. 15, 2003. Astronomers around the world have been tracking it carefully ever since....

Excerpted from "The Curious Tale of Asteroid Hermes," Dr. Tony Phillips, Science @ NASA, November 3, 2003



(Not drawn to scale)

19. When Hermes is located at position A and Earth is in the position shown in the diagram, the asteroid can be viewed from Earth at each of the following times *except*

- (1) sunrise
- (2) sunset
- (3) 12 noon
- (4) 12 midnight

21. Why is evidence of asteroids striking Earth so difficult to find?

- (1) Asteroids are made mostly of frozen water and gases and are vaporized on impact.
- (2) Asteroids are not large enough to leave impact craters.
- (3) Asteroids do not travel fast enough to create impact craters.
- (4) Weathering, erosion, and deposition on Earth have destroyed or buried most impact craters.

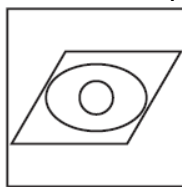
22. According to the diagram, as Hermes and

<p>20. How does the period of revolution of Hermes compare to the period of revolution of the planets shown in the diagram?</p> <p>(1) Hermes has a longer period of revolution than Mercury, but a shorter period of revolution than Venus, Earth, and Mars.</p> <p>(2) Hermes has a shorter period of revolution than Mercury, but a longer period of revolution than Venus, Earth, and Mars.</p> <p>(3) Hermes has a longer period of revolution than all of the planets shown.</p> <p>(4) Hermes has a shorter period of revolution than all of the planets shown.</p>	<p>the planets revolve around the Sun, Hermes appears to be a threat to collide with</p> <p>(1) Earth, only  (2) Earth and Mars, only  (3) Venus, Earth, and Mars, only  (4) Mercury, Venus, Earth, and Mars</p>
<p>23. Which type of electromagnetic energy has the longest wavelength?</p> <p>(1) infrared radiation  (2) radio wave radiation  (3) ultraviolet radiation  (4) x-ray radiation</p>	<p>24. The average temperature at Earth's equator is higher than the average temperature at Earth's South Pole because the South Pole</p> <p>(1) receives less intense insolation  (2) receives more infrared radiation  (3) has less land area  (4) has more cloud cover</p>

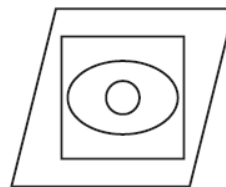
The symbols below are used to represent different regions of space.

Universe =  Earth =  Galaxy =  Solar system = 

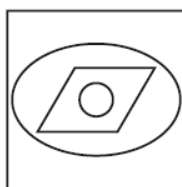
25. Which diagram shows the correct relationship between these four regions? [If one symbol is within another symbol, that means it is part of, or included in, that symbol.]



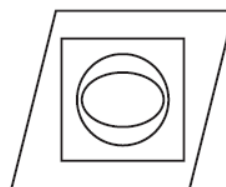
(1)



(3)



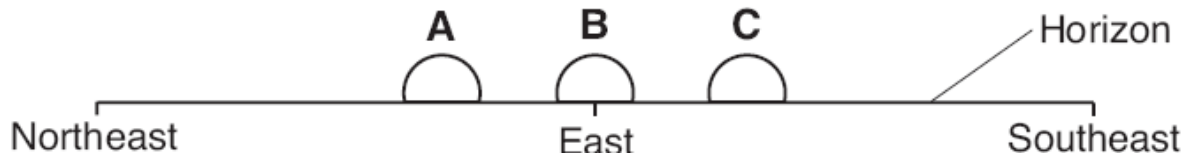
(2)



(4)



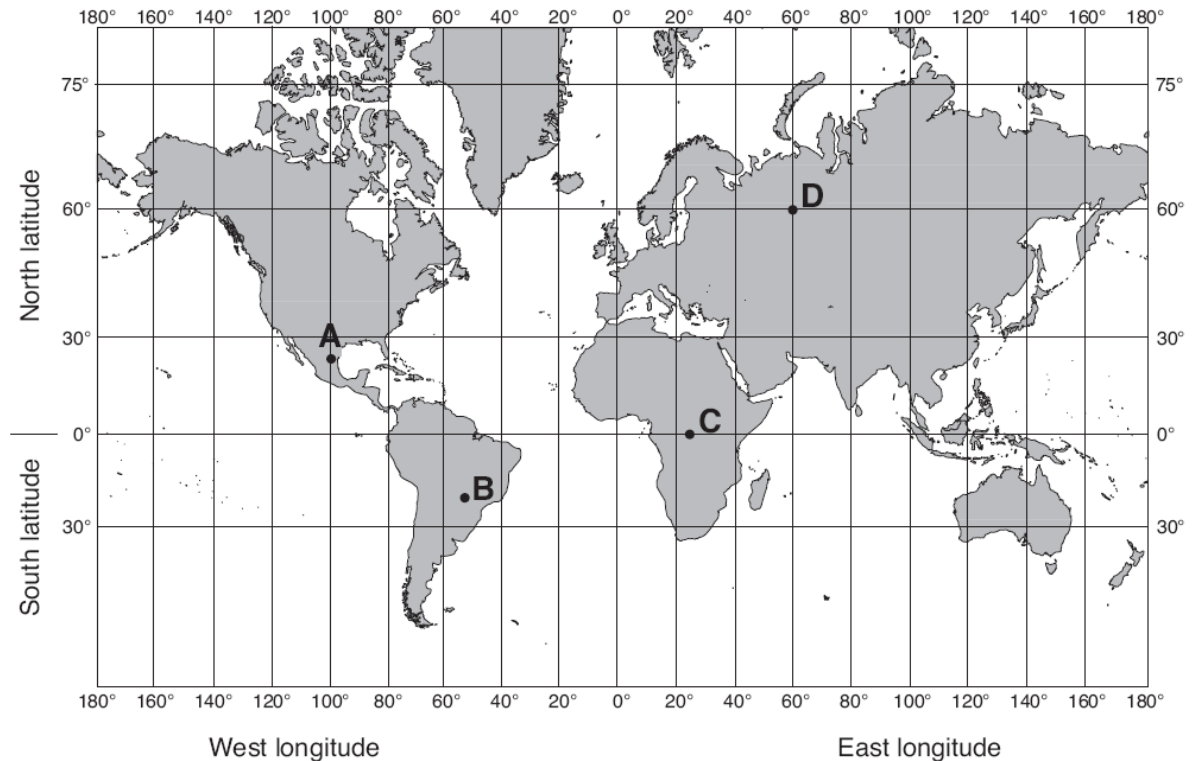
A student in New York State looked toward the eastern horizon to observe sunrise at three different times during the year. The student drew the following diagram that shows the positions of sunrise, *A*, *B*, and *C*, during this one-year period.



26. Which list correctly pairs the location of sunrise to the time of the year?

- (1) *A*—June 21 *B*—March 21 *C*—December 21
- (2) *A*—December 21 *B*—March 21 *C*—June 21
- (3) *A*—March 21 *B*—June 21 *C*—December 21
- (4) *A*—June 21 *B*—December 21 *C*—March 21

Base your answers to questions 27 through 29 on the world map below. Letters *A* through *D* represent locations on Earth's surface.



27 At which location could an observer *not* see *Polaris* in the night sky at any time during the year?

- (1) *A*
- (2) *B*
- (3) *C*
- (4) *D*

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28 Which location receives 12 hours of daylight and 12 hours of darkness on June 21?

- (1) *A*                      (3) *C*  
(2) *B*                      (4) *D*

29 At which location on December 21 is the Sun directly overhead at solar noon?

- (1) *A*                      (3) *C*  
(2) *B*                      (4) *D*

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Base your answers to questions 30 through 33 on the table below, which shows eight inferred stages describing the formation of the universe from its beginning to the present time.

**Data Table**

Stage	Description of the Universe	Average Temperature of the Universe (°C)	Time From the Beginning of Universe
1	the size of an atom	?	0 second
2	the size of a grapefruit	?	$10^{-43}$ second
3	"hot soup" of electrons	$10^{27}$	$10^{-32}$ second
4	Cooling allows protons and neutrons to form.	$10^{13}$	$10^{-6}$ second
5	still too hot to allow the forming of atoms	$10^8$	3 minutes
6	Electrons combine with protons and neutrons, forming hydrogen and helium atoms. Light emission begins.	10,000	300,000 years
7	Hydrogen and helium form giant clouds (nebulae) that will become galaxies. First stars form.	-200	1 billion years
8	Galaxy clusters form and first stars die. Heavy elements are thrown into space, forming new stars and planets.	-270	13.7 billion years

30 How soon did protons and neutrons form after the beginning of the universe?

- (1)  $10^{-43}$  second                      (3)  $10^{-6}$  second  
(2)  $10^{-32}$  second                      (4) 13.7 billion years

31 What is the most appropriate title for this table?

- (1) The Big Bang Theory                      (3) The Law of Superposition  
(2) The Theory of Plate Tectonics                      (4) The Laws of Planetary Motion

32 According to this table, the average temperature of the universe since stage 3 has

- (1) decreased, only                      (3) remained the same  
(2) increased, only                      (4) increased, then decreased

33 Between which two stages did our solar system form?

- (1) 1 and 3                      (3) 6 and 7  
 (2) 3 and 5                      (4) 7 and 8

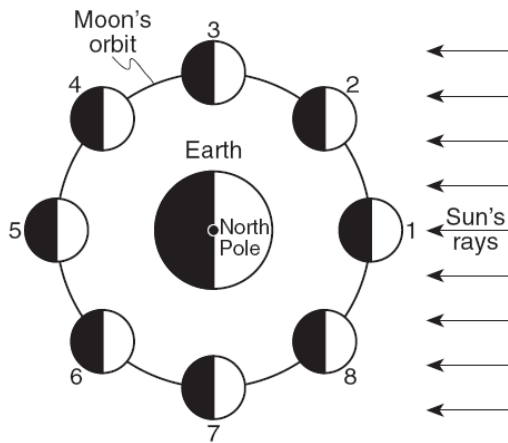
34 Which object is closest to Earth?

- (1) the Sun            (3) the Moon  
 (2) Venus            (4) Mars

37 Compared to other groups of stars, the group that has relatively low luminosities and relatively low temperatures is the

- (1) White Dwarfs    (3) Red Giants  
 (2) Red Dwarfs    (4) Blue Superrgiants

The diagram below shows the Moon orbiting Earth, as viewed from space above Earth's North Pole. The Moon is shown at eight positions in its orbit.



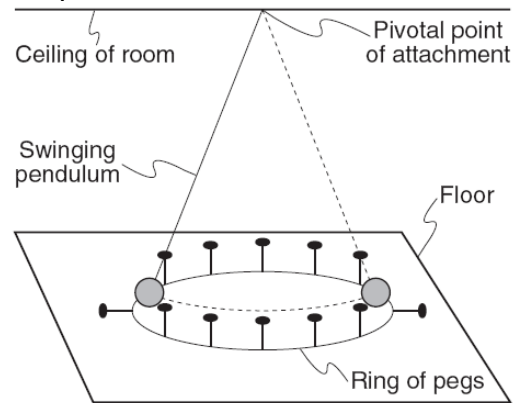
(Not drawn to scale)

Spring ocean tides occur when the difference in height between high tide and low tide is greatest.

35 At which two positions of the Moon will spring tides occur on Earth?

- (1) 1 and 5            (3) 3 and 7  
 (2) 2 and 6            (4) 4 and 8

The diagram below represents a swinging Foucault pendulum.



38 This pendulum will show an apparent change in the direction of its swing due to Earth's

- (1) curved surface            (3) rotation  
 (2) tilted axis                (4) revolution

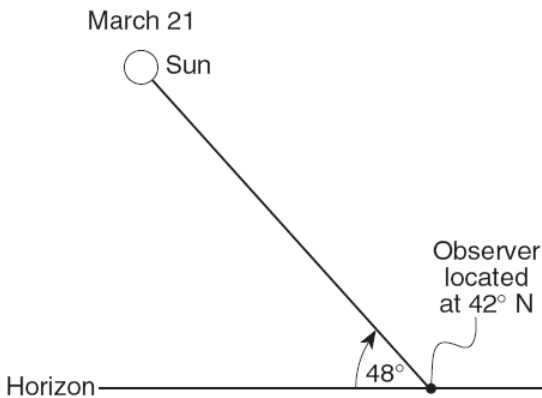
36 Which sequence correctly lists the relative sizes from smallest to largest?

- (1) our solar system, universe, Milky Way Galaxy
- (2) our solar system, Milky Way Galaxy, universe
- (3) Milky Way Galaxy, our solar system, universe
- (4) Milky Way Galaxy, universe, our solar system

39 Which list of three planets and Earth's Moon is arranged in order of increasing equatorial diameter?

- (1) Earth's Moon, Pluto, Mars, Mercury
- (2) Pluto, Earth's Moon, Mercury, Mars
- (3) Mercury, Mars, Earth's Moon, Pluto
- (4) Mars, Mercury, Pluto, Earth's Moon

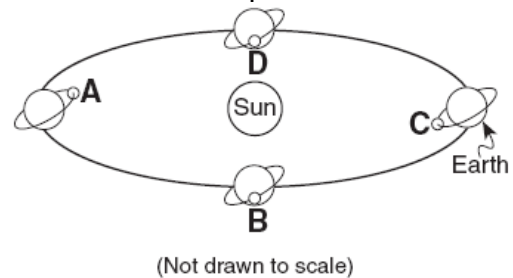
The diagram below shows the altitude of the Sun at solar noon on March 21, as seen by an observer at 42° N latitude.



40 Compared to the altitude of the Sun observed at solar noon on March 21, the altitude of the Sun observed at solar noon on June 21 will be

- (1) 15° higher in the sky
- (2) 23.5° higher in the sky
- (3) 42° higher in the sky
- (4) 48° higher in the sky

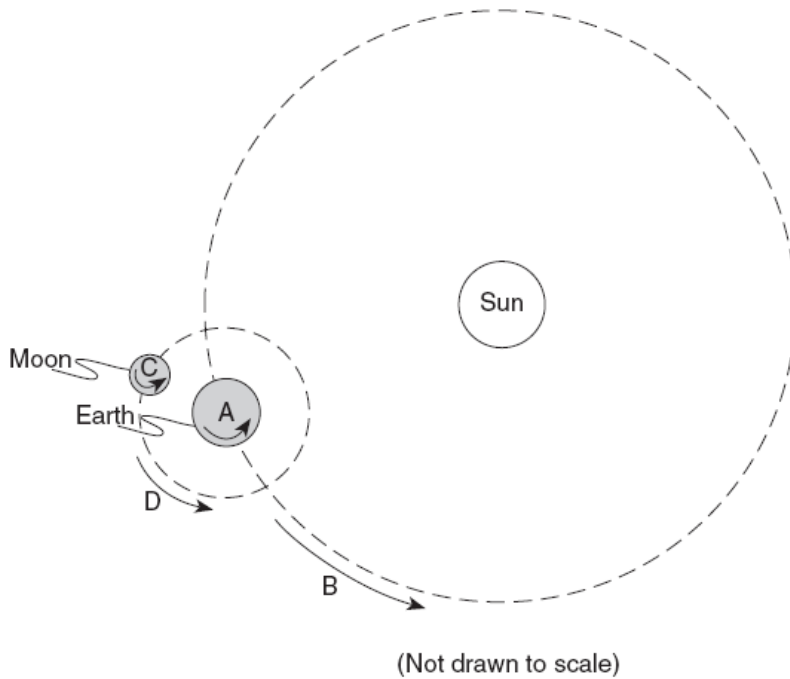
The diagram below shows Earth's orbit around the Sun and different positions of the Moon as it travels around Earth. Letters A through D represent four different positions of the Moon.



41 An eclipse of the Moon is most likely to occur when the Moon is at position

- (1) A
- (2) B
- (3) C
- (4) D

Base your answers to questions 42 through 44 on the diagram below, which has lettered arrows showing the motions of Earth and the Moon.



Key	
Arrow	Motion
A	Earth's rotation on its axis
B	Earth's revolution around the Sun
C	The Moon's rotation on its axis
D	The Moon's revolution around Earth

42 These lettered arrows represent motions that are

- (1) noncyclic and unpredictable
- (2) noncyclic and predictable
- (3) cyclic and unpredictable
- (4) cyclic and predictable

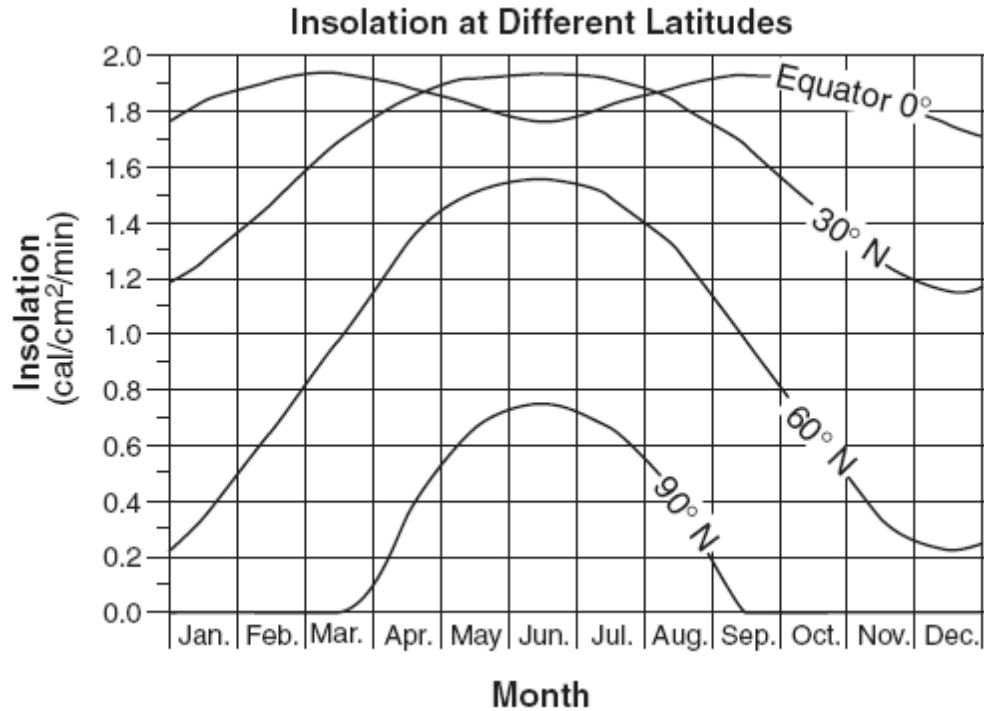
43 Which two motions are completed in about the same amount of time?

- (1) A and B
- (2) B and C
- (3) C and D
- (4) A and D

44 Which lettered arrow represents the motion that causes the Moon to show phases when viewed from Earth?

- (1) A
- (2) B
- (3) C
- (4) D

Base your answers to questions 45 through 47 on the graph below, which shows the amount of insolation during one year at four different latitudes on Earth's surface.



45 This graph shows that insolation varies with

- (1) latitude and time of day
- (2) latitude and time of year
- (3) longitude and time of day
- (4) longitude and time of year

46 Why is less insolation received at the equator in June than in March or September?

- (1) The daylight period is longest at the equator in June.
- (2) Winds blow insolation away from the equator in June.
- (3) The Sun's vertical rays are north of the equator in June.
- (4) Thick clouds block the Sun's vertical rays at the equator in June.

47 Why is insolation 0 cal/cm<sup>2</sup>/min from October through February at 90° N?

- (1) Snowfields reflect sunlight during that time.
- (2) Dust in the atmosphere blocks sunlight during that time.
- (3) The Sun is continually below the horizon during that time.
- (4) Intense cold prevents insolation from being absorbed during that time.

48 Which star has a higher luminosity and a lower temperature than the Sun?

- (1) *Rigel*
- (2) *Barnard's Star*
- (3) *Alpha Centauri*
- (4) *Aldebaran*

51 If Earth's axis were tilted  $35^\circ$  instead of  $23.5^\circ$ , the average temperatures in New York State would most likely

- (1) decrease in both summer and winter
- (2) decrease in summer and increase in winter
- (3) increase in summer and decrease in winter
- (4) increase in both summer and winter

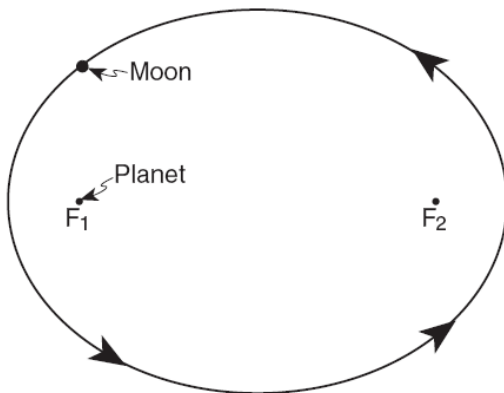
49 Starlight from distant galaxies provides evidence that the universe is expanding because this starlight shows a shift in wavelength toward the

- (1) red-light end of the visible spectrum
- (2) blue-light end of the visible spectrum
- (3) ultraviolet-ray end of the electromagnetic spectrum
- (4) gamma-rays

52 On which day of the year would the intensity of insolation at Kingston, New York, most likely be greatest?

- (1) March 21
- (2) June 21
- (3) September 23
- (4) December 21

The diagram below represents the elliptical orbit of a moon revolving around a planet. The foci of this orbit are the points labeled  $F_1$  and  $F_2$ .

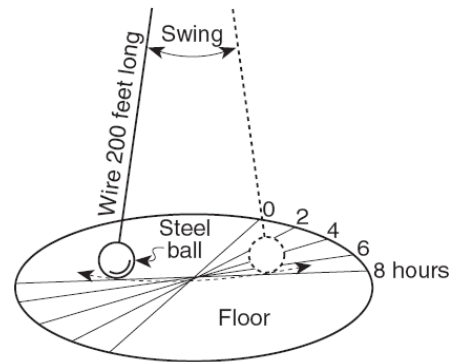


(Drawn to scale)

50 What is the approximate eccentricity of this elliptical orbit?

- (1) 0.3
- (2) 0.5
- (3) 0.7
- (4) 1.4

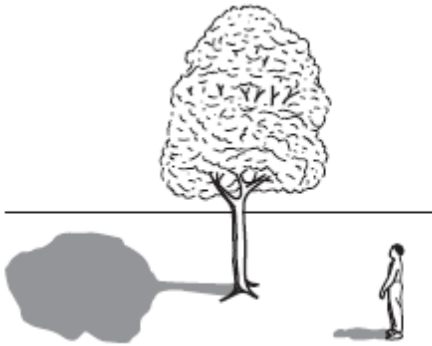
53 The diagram below represents a Foucault pendulum swinging freely for 8 hours.



The Foucault pendulum appears to gradually change its direction of swing due to Earth's

- (1) orbit around the Sun
- (2) curved surface
- (3) tilted axis
- (4) spin on its axis

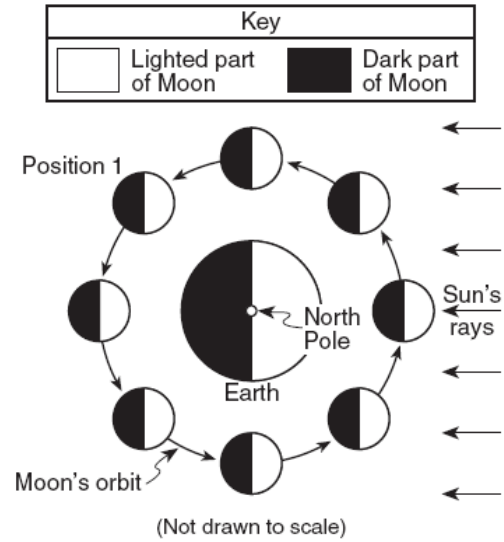
The diagram below shows the noontime shadows cast by a student and a tree.



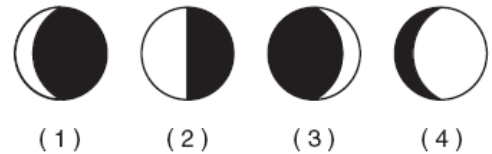
54 If the time is solar noon and the student is located in New York State, in what direction is the student facing?

- (1) north
- (2) south
- (3) east
- (4) west

The diagram below represents the Moon in its orbit, as viewed from above Earth's North Pole. Position 1 represents a specific location of the Moon in its orbit.



56 Which phase of the Moon will be seen from Earth when the Moon is at position 1?



55 During nighttime cooling, most of the energy radiated by Earth's oceans into space is

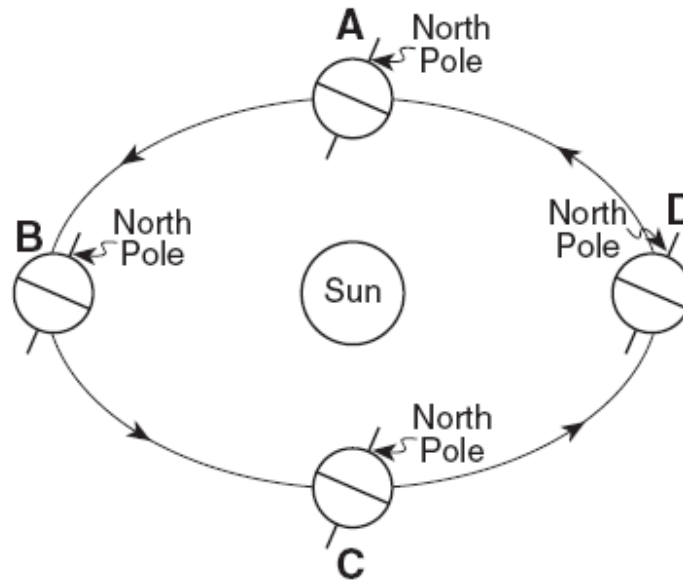
- (1) ultraviolet rays
- (2) gamma rays
- (3) visible light rays
- (4) infrared rays

57 The motion of a Foucault pendulum provides evidence of

- (1) the Sun's rotation
- (2) the Sun's revolution
- (3) Earth's rotation
- (4) Earth's revolution



Base your answers to questions 58 through 60 on the diagram below, which represents an exaggerated view of Earth revolving around the Sun. Letters A, B, C, and D represent Earth's location in its orbit on the first day of each of the four seasons.



(Not drawn to scale)

58 Which location in Earth's orbit represents the first day of fall (autumn) for an observer in New York State?

- (1) A
- (2) B
- (3) C
- (4) D

59 Earth's rate of revolution around the Sun is approximately

- (1) 1° per day
- (2) 360° per day
- (3) 15° per hour
- (4) 23.5° per hour

60 Which observation provides the best evidence that Earth revolves around the Sun?

- (1) Stars seen from Earth appear to circle *Polaris*.
- (2) Earth's planetary winds are deflected by the Coriolis effect.
- (3) The change from high ocean tide to low ocean tide is a repeating pattern.
- (4) Different star constellations are seen from Earth at different times of the year.

61 Which form of electromagnetic radiation has a wavelength of  $1.0 \cdot 10^{-3}$  centimeter?

- (1) ultraviolet
- (2) infrared
- (3) radio waves
- (4) microwaves

62 The time required for the Moon to show a complete cycle of phases when viewed from Earth is approximately

- (1) 1 day
- (2) 1 week
- (3) 1 month
- (4) 1 year

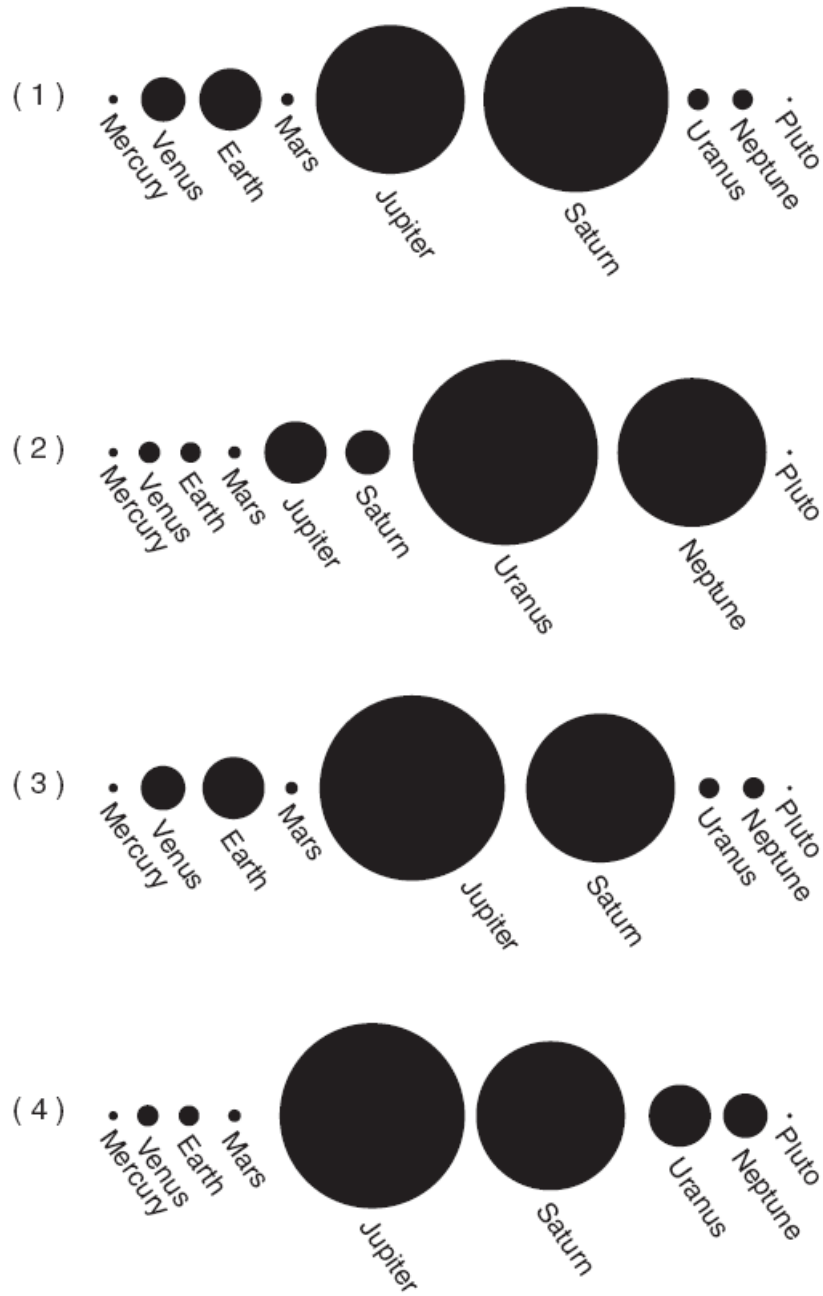
63 Which planet has an orbital eccentricity most like the orbital eccentricity of the Moon?

- (1) Pluto
- (2) Saturn
- (3) Mars
- (4) Mercury

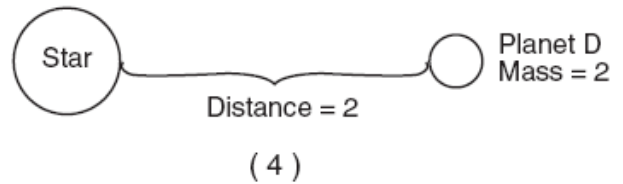
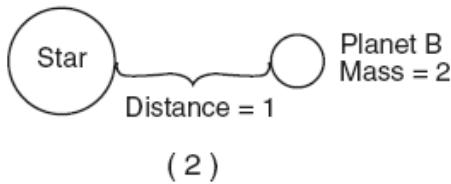
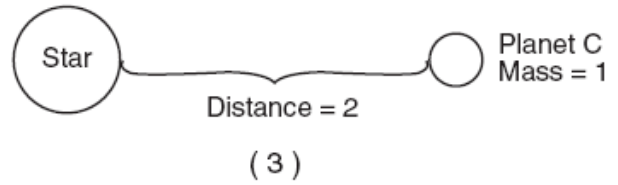
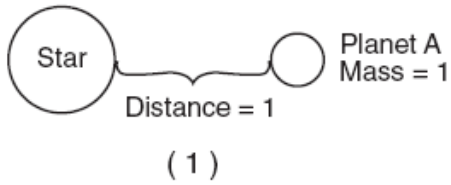
64 On June 21, where will the Sun appear to rise for an observer located in New York State?

- (1) due west
- (2) due east
- (3) north of due east
- (4) south of due east

65 Which sequence correctly shows the relative size of the nine planets of our solar system?

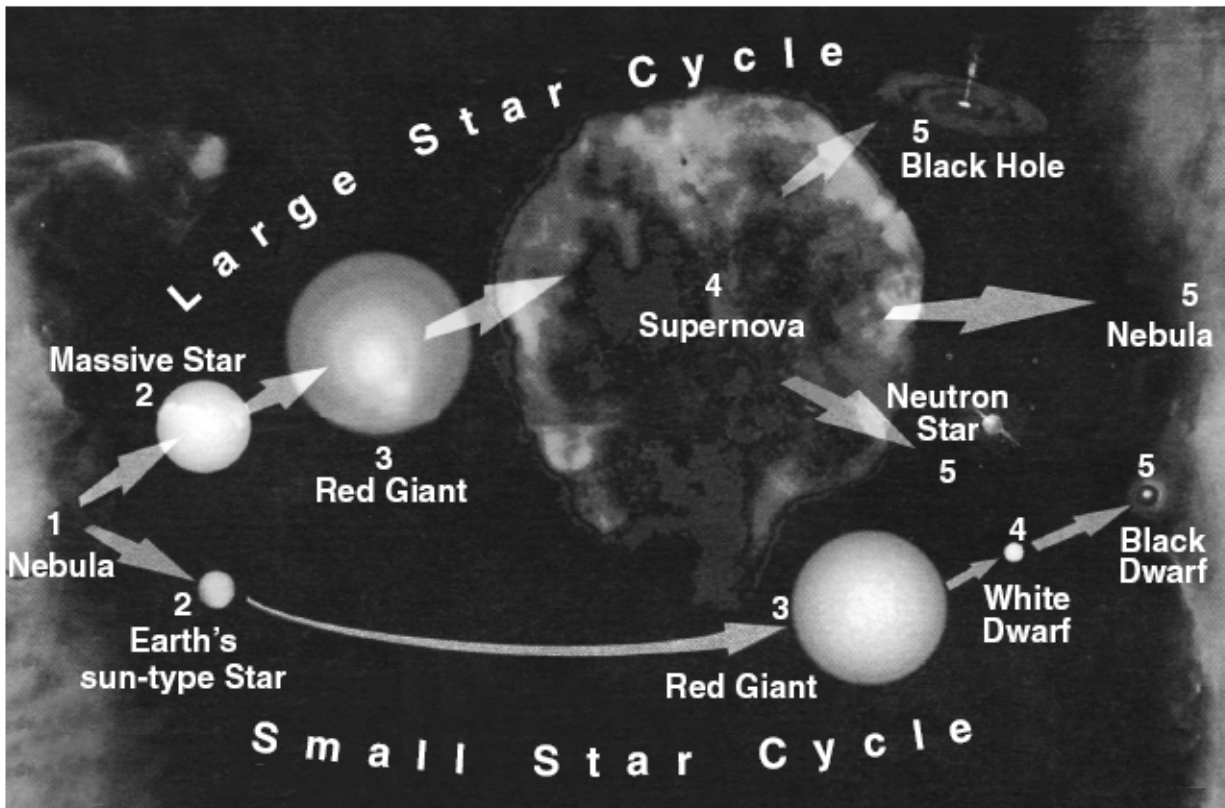


66 In each diagram below, the mass of the star is the same. In which diagram is the force of gravity greatest between the star and the planet shown?



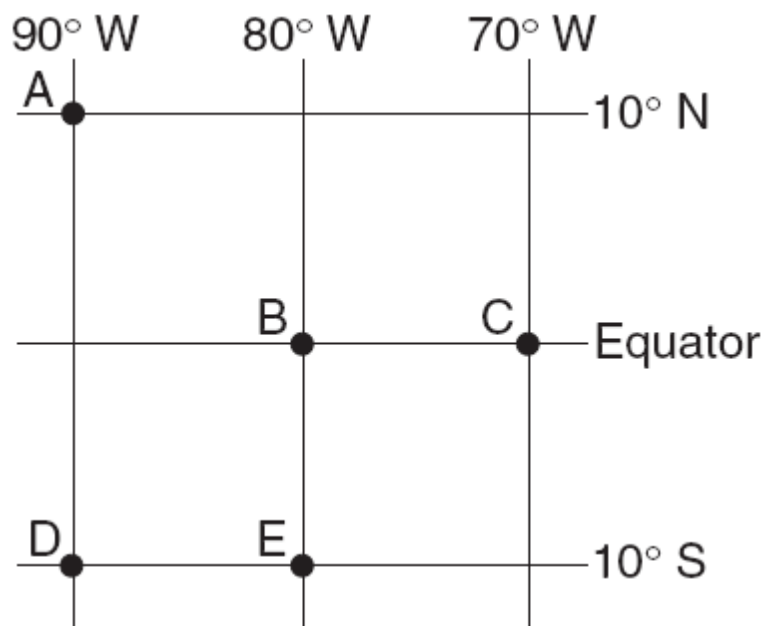
Base your answers to questions 67 through 38 on the diagram below, which shows two possible sequences in the life cycle of stars, beginning with their formation from nebular gas clouds in space.

### The Life Cycles of Stars



<p>67 According to the diagram, the life-cycle path followed by a star is determined by the star's initial</p> <ul style="list-style-type: none"> <li>(1) mass and size</li> <li>(2) temperature and origin</li> <li>(3) luminosity and color</li> <li>(4) luminosity and structure</li> </ul> <p>68 Stars like Earth's Sun most likely formed directly from a</p> <ul style="list-style-type: none"> <li>(1) nebula</li> <li>(2) supernova</li> <li>(3) red giant</li> <li>(4) black dwarf</li> </ul>	<p>69 According to the diagram, a star like Earth's Sun will eventually</p> <ul style="list-style-type: none"> <li>(1) explode in a supernova</li> <li>(2) become a black hole</li> <li>(3) change into a white dwarf</li> <li>(4) become a neutron star</li> </ul>
<p>70 The redshift of light from distant galaxies provides evidence that the universe is</p> <ul style="list-style-type: none"> <li>(1) shrinking, only</li> <li>(2) expanding, only</li> <li>(3) shrinking and expanding in a cyclic pattern</li> <li>(4) remaining the same size</li> </ul>	

Base your answers to questions 71 and 72 on the map below, which shows the latitude and longitude of five observers, A, B, C, D, and E, on Earth.



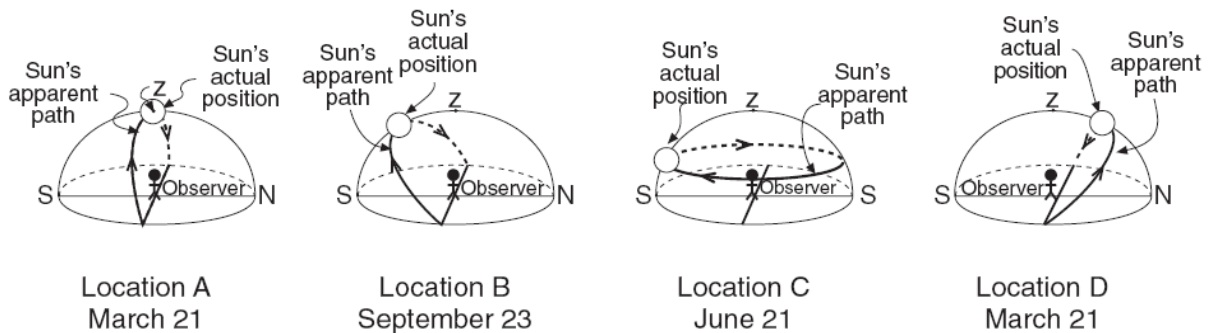
71 What is the altitude of *Polaris* (the North Star) above the northern horizon for observer A?

- (1) 0°
- (2) 10°
- (3) 80°
- (4) 90°

72 Which two observers would be experiencing the same apparent solar time?

- (1) A and C
- (2) B and C
- (3) B and E
- (4) D and E

Base your answers to questions 73 through 75 on the diagram below, which shows a model of the apparent path and position of the Sun in relation to an observer at four different locations, A, B, C, and D, on Earth's surface on the dates indicated. The zenith (z) and the actual position of the Sun in the model at the time of the observation are shown. [The zenith is the point directly over the observer.]



73 According to the Sun's actual position shown in the diagrams, the most intense insolation is being received by the observer at location

- (1) A (3) C
- (2) B (4) D

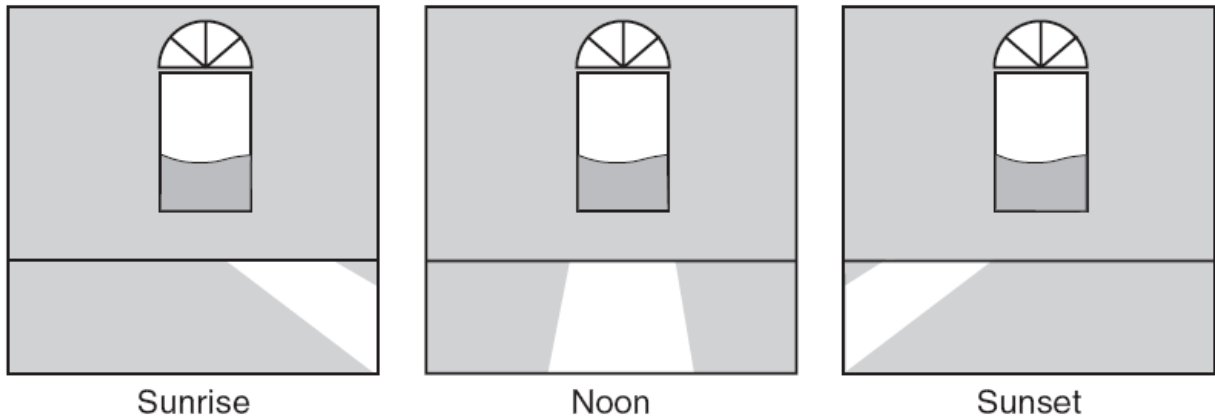
74 Where on Earth's surface is the observer at location C located?

- (1) at the Equator
- (2) at the South Pole
- (3) at the North Pole
- (4) in Oswego, New York

75 From sunrise to sunset at location B, the length of the observer's shadow will

- (1) increase, only
- (2) decrease, only
- (3) increase, then decrease
- (4) decrease, then increase

Base your answers to questions 76 and 77 on the diagram below, which shows sunlight entering a room through the same window at three different times on the same winter day.



76 The apparent change in the Sun's position shown in the diagram is best explained by

- (1) the Sun rotating at a rate of  $15^\circ$  per hour
- (2) Earth rotating at a rate of  $15^\circ$  per hour
- (3) the Sun's axis tilted at an angle of  $23^\circ$
- (4) Earth's axis tilted at an angle of  $23^\circ$

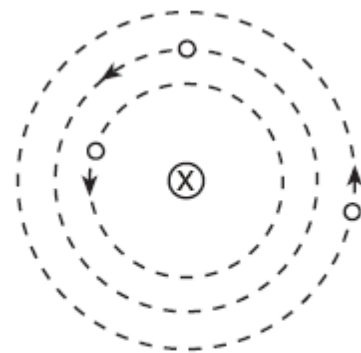
77 This room is located in a building in New York State. On which side of the building is the window located?

- (1) north                      (3) east
- (2) south                     (4) west

78 The Milky Way galaxy is best described as

- (1) a type of solar system
- (2) a constellation visible to everyone on Earth
- (3) a region in space between the orbits of Mars and Jupiter
- (4) a spiral-shaped formation composed of billions of stars

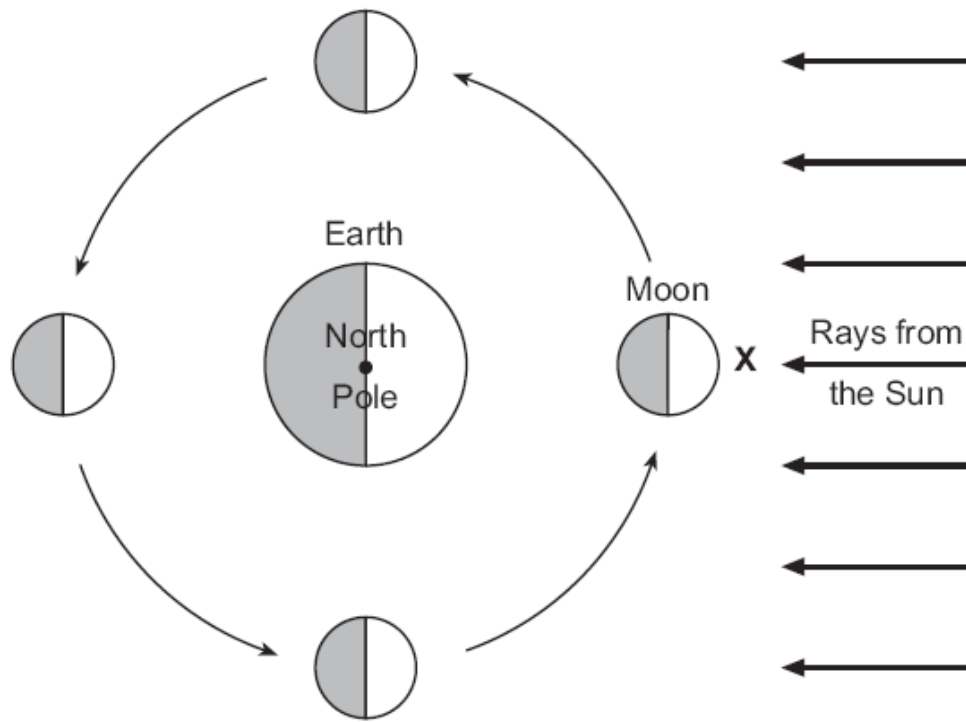
79 The diagram below represents a simple geocentric model. Which object is represented by the letter X?



( Not drawn to scale )

- (1) Earth                      (3) Moon
- (2) Sun                        (4) *Polaris*

The diagram below shows the Moon at four positions in its orbit around Earth as viewed from above the North Pole.



(Not drawn to scale)

80 Beginning with the Moon at position X (the new-Moon phase), which sequence of Moon phases would be seen by an observer on Earth during 1 month?

- (1)
- (2)
- (3)
- (4)

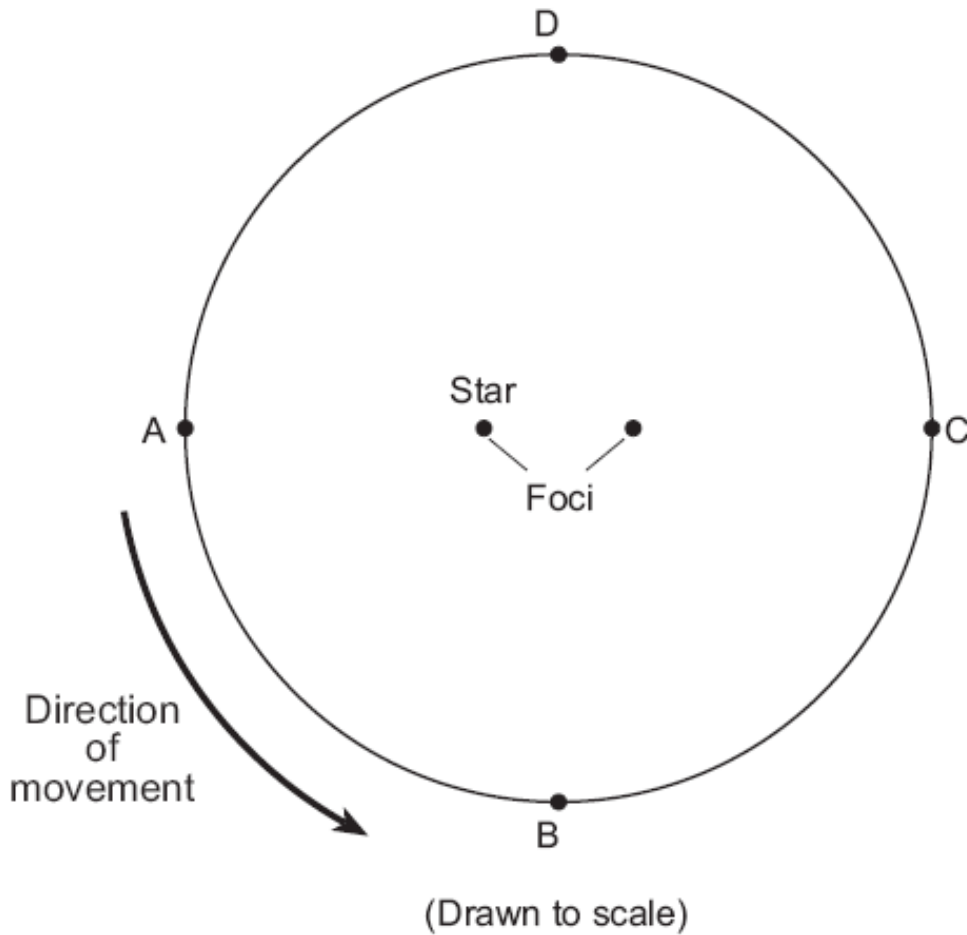
81 In which list are the forms of electromagnetic energy arranged in order from longest to shortest wavelengths?

- (1) gamma rays, x rays, ultraviolet rays, visible light
- (2) radio waves, infrared rays, visible light, ultraviolet rays
- (3) x rays, infrared rays, blue light, gamma rays
- (4) infrared rays, radio waves, blue light, red light

82 Compared to the average density of the terrestrial planets (Mercury, Venus, Earth, and Mars), the average density of the Jovian planets (Jupiter, Saturn, Uranus, and Neptune) is

- (1) less
- (2) greater
- (3) the same

Base your answers to questions 36 through 38 on the diagram below, which represents the elliptical orbit of a planet traveling around a star. Points A, B, C, and D are four positions of this planet in its orbit.





83 The calculated eccentricity of this orbit is approximately

- (1) 0.1                      (3) 0.3
- (2) 0.2                      (4) 0.4

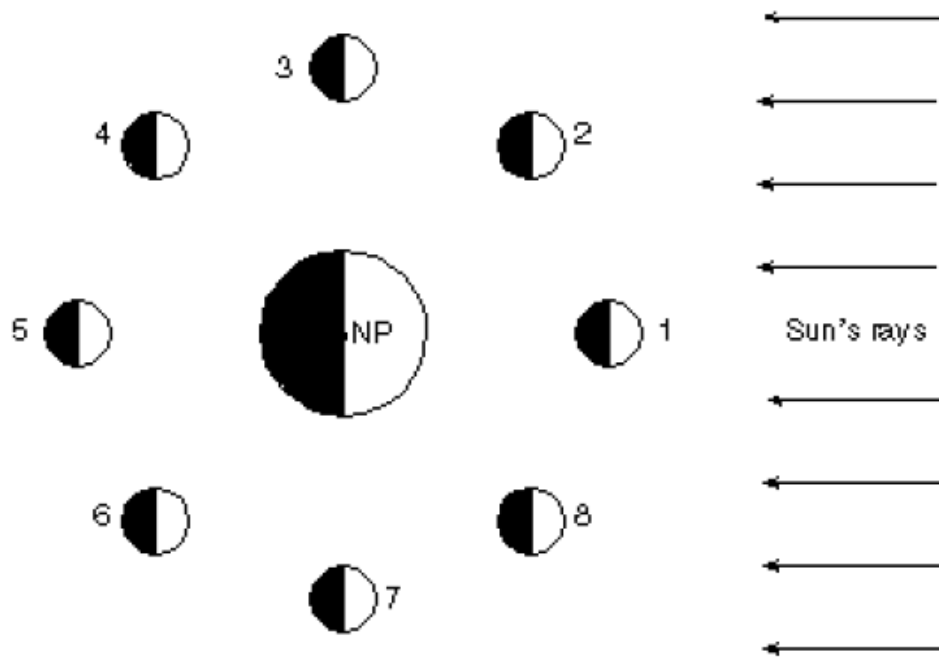
84 The gravitational attraction between the star and the planet will be greatest at position

- (1) A                          (3) C
- (2) B                          (4) D

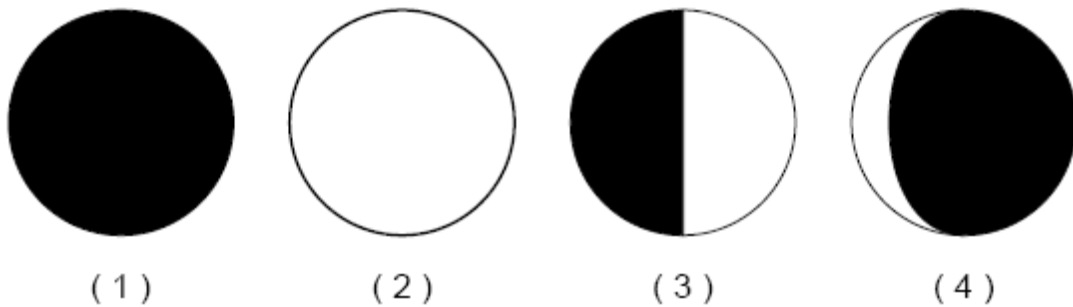
85 As the planet revolves in orbit from position A to position D, the orbital velocity will

- (1) continually decrease
- (2) continually increase
- (3) decrease, then increase
- (4) increase, then decrease

The diagram below shows the Moon in different positions as it revolves around Earth, as observed from above the North Pole (NP).



85 Which image correctly represents the Moon at position 8, as observed from Earth?



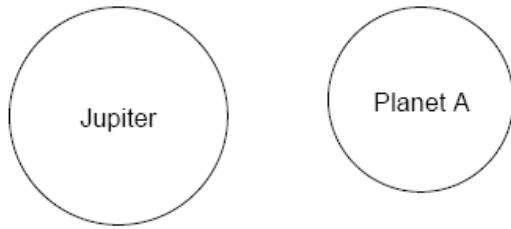
86 The Sun's position in space is best described as the approximate center of

- (1) a constellation
- (2) the universe
- (3) the Milky Way galaxy
- (4) our solar system

89 Compared to Pluto, Mercury moves more rapidly in its orbit because Mercury

- (1) is larger
- (2) is more dense
- (3) is closer to the Sun
- (4) has a more elliptical orbit

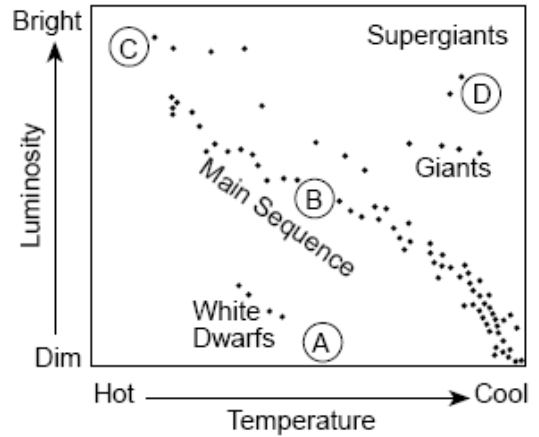
The diagram below represents two planets in our solar system drawn to scale, Jupiter and planet A.



87 Planet A most likely represents

- (1) Earth
- (2) Venus
- (3) Saturn
- (4) Uranus

The graph below represents the brightness and temperature of stars visible from Earth.



90 Which location on the graph best represents a star with average brightness and temperature?

- (1) A
- (2) B
- (3) C
- (4) D

88 The length of an Earth year is based on Earth's

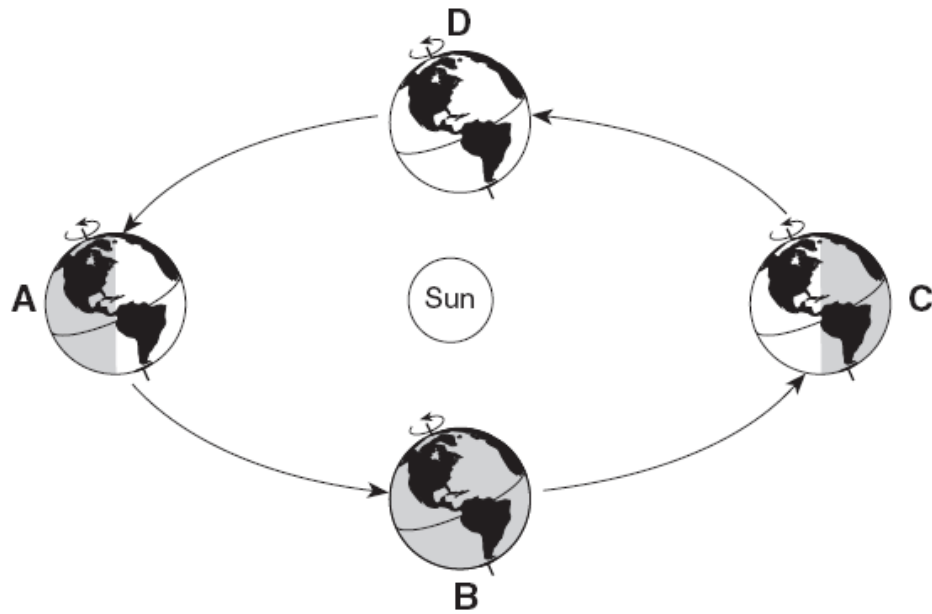
- (1) rotation of 15°/hr
- (2) revolution of 15°/hr
- (3) rotation of approximately 1°/day
- (4) revolution of approximately 1°/day

91 The passage of the Moon into Earth's shadow causes a

- (1) lunar eclipse
- (2) solar eclipse
- (3) new Moon
- (4) full Moon

<p>92 Which statement describes the general relationship between the temperature and the luminosity of main sequence stars?</p> <p>(1) As temperature decreases, luminosity increases.</p> <p>(2) As temperature decreases, luminosity remains the same</p> <p>(3) As temperature increases, luminosity increases.</p> <p>(4) As temperature increases, luminosity remains the same.</p>	<p>95 The path of a Foucault pendulum provides evidence that Earth</p> <p>(1) rotates on its axis  (2) revolves in its orbit  (3) is tilted on its axis  (4) has an elliptical orbit</p>
<p>93 Which planet has the <i>least</i> distance between the two foci of its elliptical orbit?</p> <p>(1) Venus      (3) Mars  (2) Earth      (4) Jupiter</p>	<p>96 Earth's rate of rotation is approximately</p> <p>(1) 1° per day      (3) 180° per day  (2) 15° per day      (4) 360° per day</p>
<p>94 Light and other forms of electromagnetic radiation are given off by stars using energy released during</p> <p>(1) nuclear fusion      (3) convection  (2) conduction      (4) radioactive decay</p>	

Base your answers to questions 97 through 99 on the diagram below, which shows a model of Earth's orbit around the Sun. Letters A, B, C, and D represent Earth's position at the beginning of each season.



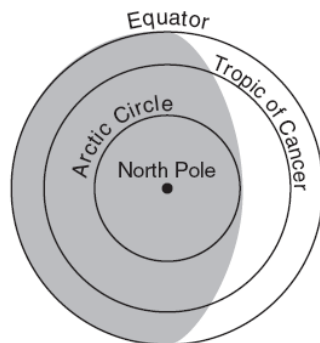
(Not drawn to scale)

97 Which position of Earth represents the first day of summer in the Northern Hemisphere?

- (1) A
- (2) B
- (3) C
- (4) D

98 The diagram below shows how Earth is illuminated [lighted] by the Sun as viewed from above the North Pole. In which orbital position would Earth be illuminated as shown?

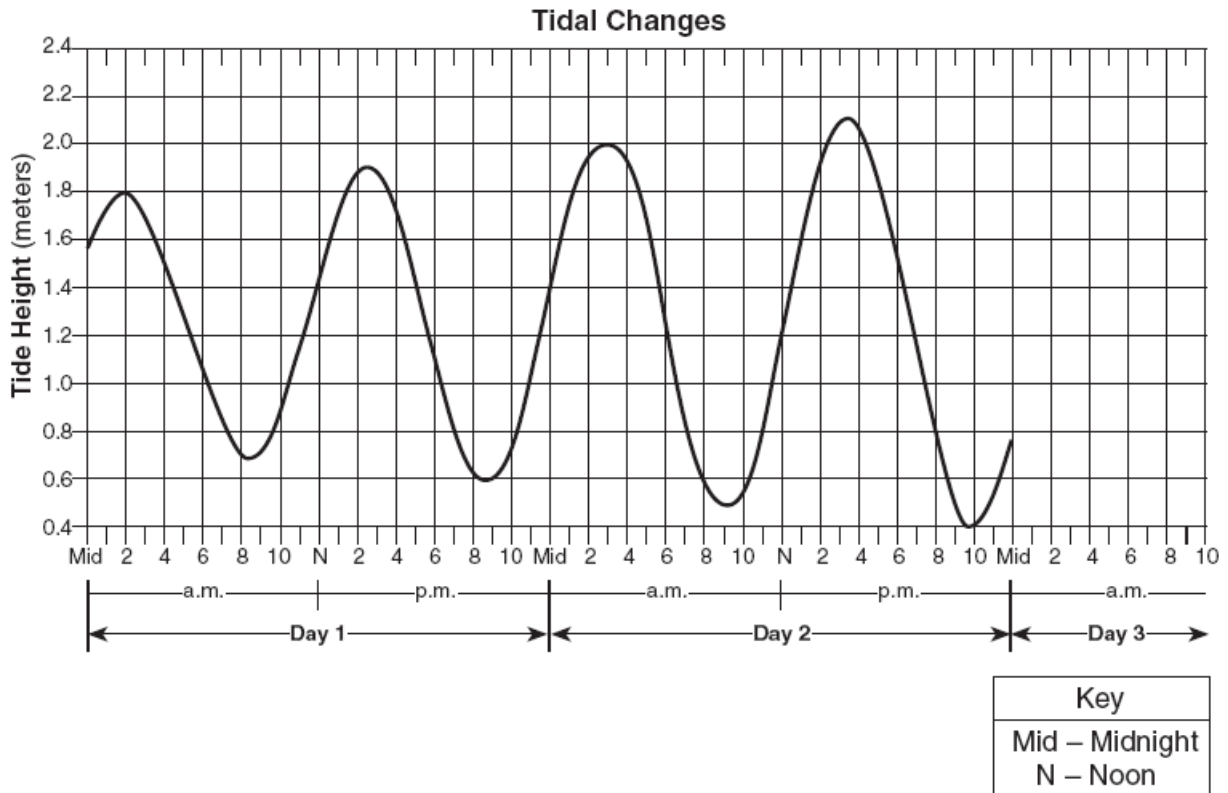
- (1) A
- (2) B
- (3) C
- (4) D



99 How many degrees will the Sun's vertical rays shift on Earth's surface as Earth travels from position C to position D?

- (1) 15°
- (2) 23.5°
- (3) 47°
- (4) 365°

Base your answers to questions 100 and 101 on the graph below, which shows two days of tidal data from a coastal location in the northeastern United States.



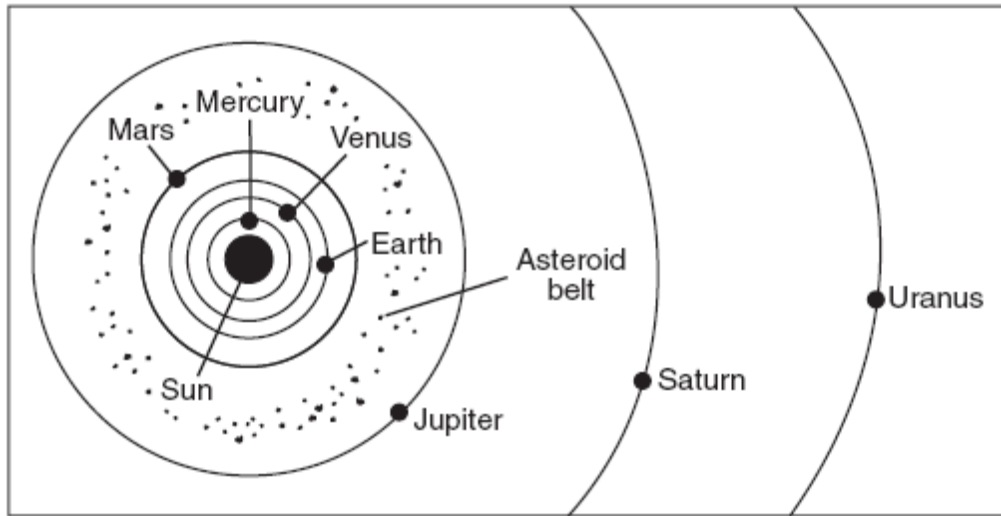
100 The change in the tides as shown on the graph is primarily the result of

- (1) Earth's rotation and the Moon's revolution
- (2) Earth's rotation and revolution
- (3) the Moon's rotation and Earth's revolution
- (4) the Moon's rotation and revolution

101 If the pattern shown continues, the most likely height and time for the first high tide on day 3 would be

- (1) 2.2 meters at 4 a.m.
- (2) 2.3 meters at 4 a.m.
- (3) 2.2 meters at 5 a.m.
- (4) 2.3 meters at 5 a.m.

This diagram shows a portion of the solar system.



(Not drawn to scale)

102 What is the average distance, in millions of kilometers, from the Sun to the asteroid belt?

- (1) 129
- (2) 189
- (3) 503
- (4) 857

103 One factor responsible for the strength of gravitational attraction between a planet and the Sun is the

- (1) degree of tilt of the planet's axis
- (2) distance between the planet and the Sun
- (3) planet's period of rotation
- (4) amount of insolation given off by the Sun

105 Which planet is located approximately ten times farther from the Sun than Earth is from the Sun?

- (1) Mars
- (2) Jupiter
- (3) Saturn
- (4) Uranus

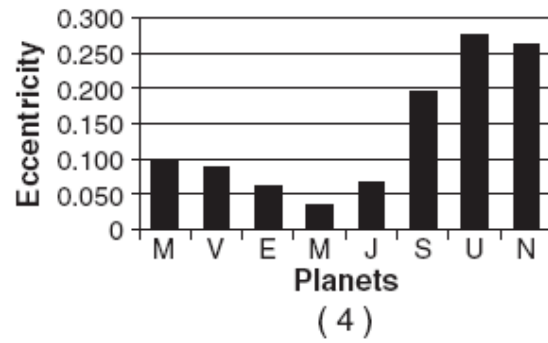
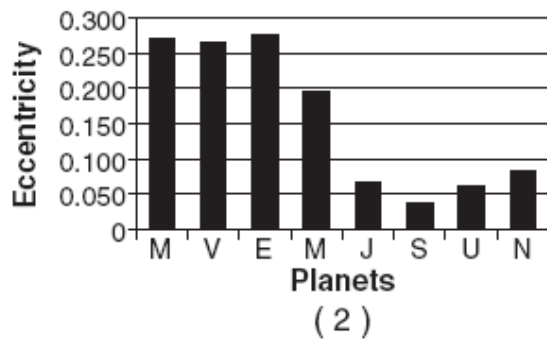
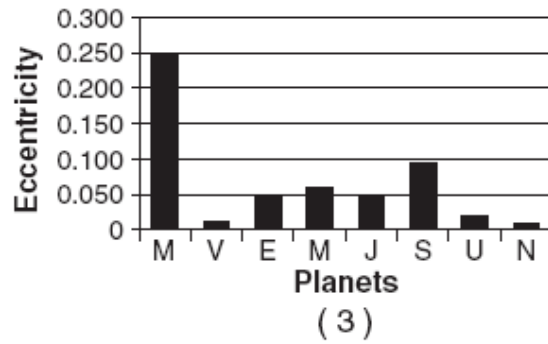
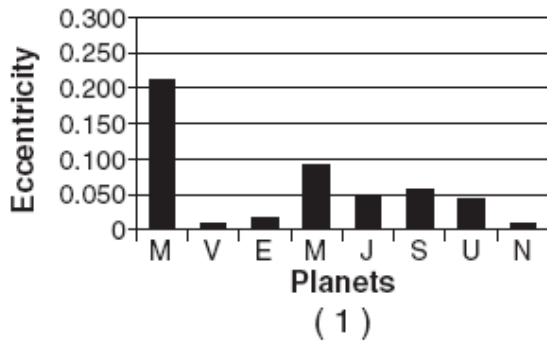
104 Large craters found on Earth support the hypothesis that impact events have caused

- (1) a decrease in the number of earthquakes and an increase in sea level
- (2) an increase in solar radiation and a decrease in Earth radiation
- (3) the red shift of light from distant stars and the blue shift of light from nearby stars
- (4) mass extinctions of life-forms and global climate changes

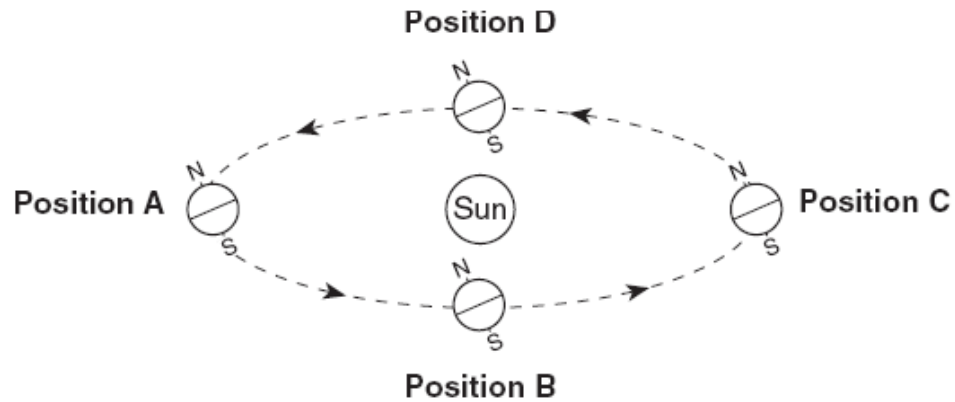
106 What is the inferred age of our solar system, in millions of years?

- (1) 544
- (2) 1300
- (3) 4600
- (4) 10,000

107 Which bar graph correctly shows the orbital eccentricity of the planets in our solar system?



The diagram below shows Earth in its orbit around the Sun. Positions A, B, C, and D represent Earth at the beginning of each season.



(Not drawn to scale)

108 At which lettered position of Earth does New York State experience the first day of summer?

- (1) A
- (2) B
- (3) C
- (4) D

Base your answers to questions 109 through 112 on the diagram below, which represents the Sun's apparent paths and the solar noon positions for an observer at  $42^\circ$  N latitude on December 21, September 23, and June 21.

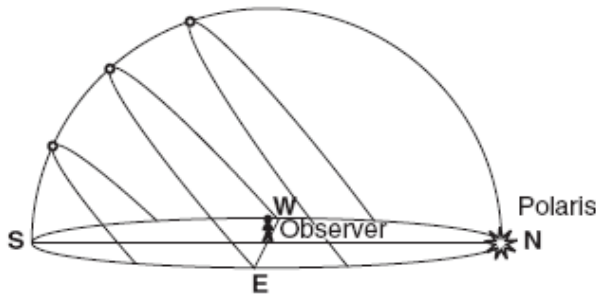
109 In which direction will sunrise occur on June 21?

- (1) north of due west                      (3) south of due west  
 (2) north of due east                      (4) south of due east

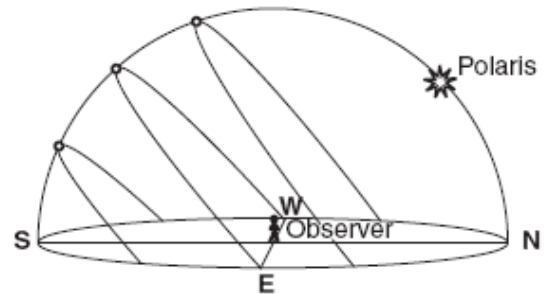
110 How many hours occurred between sunrise and solar noon on September 23?

- (1) 6                      (3) 12  
 (2) 8                      (4) 24

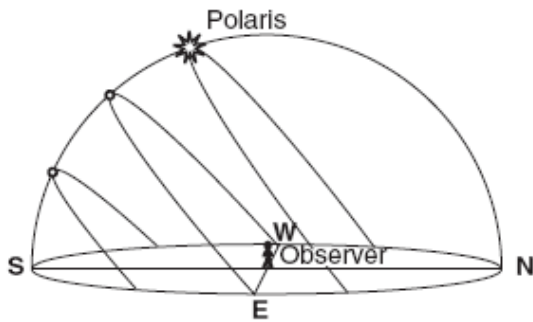
111 Which diagram best shows the location of *Polaris* relative to the observer?



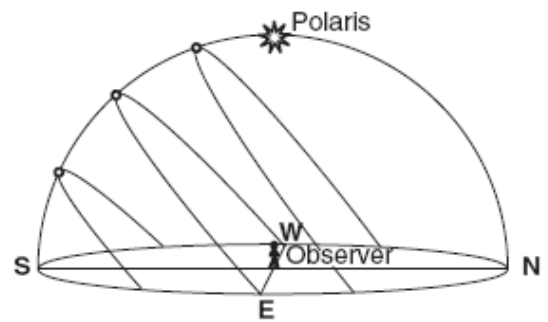
(1)



(3)



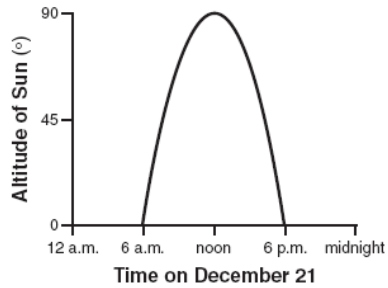
(2)



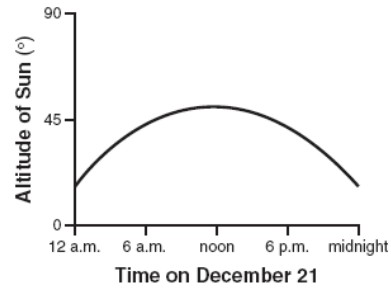
(4)



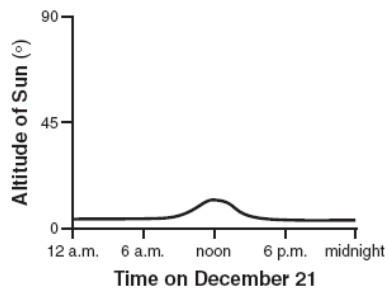
112 Which graph best shows the altitude of the Sun, as measured by the observer located at 42° N, at various times on December 21?



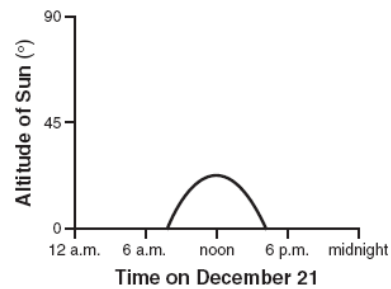
( 1 )



( 3 )



( 2 )



( 4 )

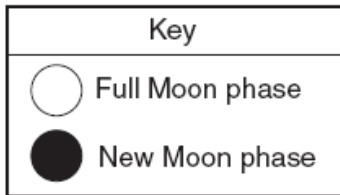
113 Which object in our solar system has the greatest density?

















- (1) Jupiter
- (2) Earth
- (3) the Moon
- (4) the Sun

114 What is the main reason that the gravitational attraction between Earth and the Moon changes each day?

- (1) Earth's axis is tilted at 23.5°.
- (2) Earth's rotational speed varies with the seasons.
- (3) The Moon has an elliptical orbit.
- (4) The Moon has a spherical shape

115 Which sequence of Moon phases could be observed from Earth during a 2-week period?



- (1)  →  →  → 
- (2)  →  →  → 
- (3)  →  →  → 
- (4)  →  →  → 

118 One factor responsible for the strength of gravitational attraction between a planet and the Sun is the

- (1) degree of tilt of the planet's axis
- (2) distance between the planet and the Sun
- (3) planet's period of rotation
- (4) amount of insolation given off by the Sun

116 In the demonstration, a student swings the weight hanging in the pail and then spins the stool. The stool represents

- (1) the revolving Earth
- (2) the rotating Earth
- (3) the Coriolis effect
- (4) convection currents

119 If Earth's axis were tilted *less* than 23.5°, which seasonal average temperature change would occur in New York State?

- (1) Spring and fall would be cooler.
- (2) Spring and fall would be warmer.
- (3) Winter would be cooler.
- (4) Summer would be cooler.

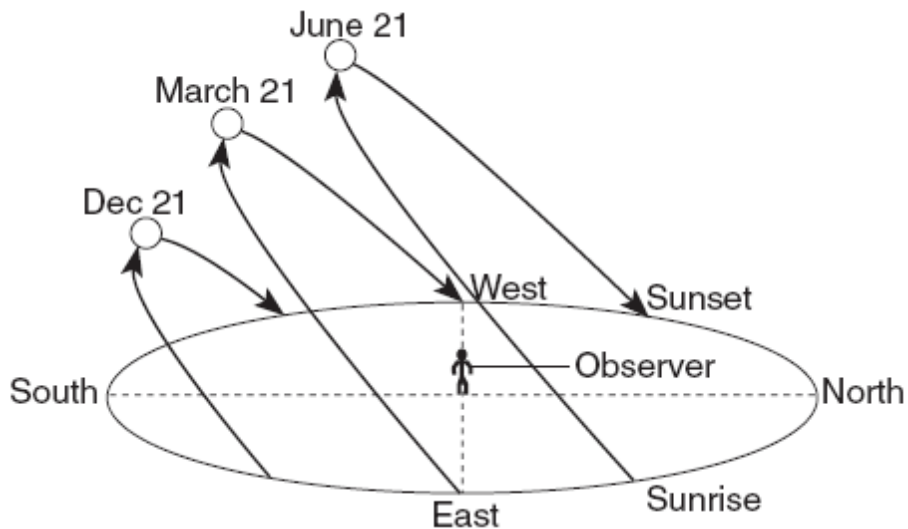
117 Which list shows stars in order of increasing temperature?

- (1) *Barnard's Star, Polaris, Sirius, Rigel*
- (2) *Aldebaran, the Sun, Rigel, Procyon B*
- (3) *Rigel, Polaris, Aldebaran, Barnard's Star*
- (4) *Procyon B, Alpha Centauri, Polaris, Betelgeuse*

120 Which planet is located approximately ten times farther from the Sun than Earth is from the Sun?

- |             |            |
|-------------|------------|
| (1) Mars    | (3) Saturn |
| (2) Jupiter | (4) Uranus |

The diagram below shows the apparent daily path of the Sun, as viewed by an observer at a certain latitude on three different days of the year.



121 At which latitude were these apparent Sun paths most likely observed?

- (1) 0°
- (2) 23.5° N
- (3) 43° N
- (4) 66.5° N

122 Large craters found on Earth support the hypothesis that impact events have caused

- (1) a decrease in the number of earthquakes and an increase in sea level
- (2) an increase in solar radiation and a decrease in Earth radiation
- (3) the red shift of light from distant stars and the blue shift of light from nearby stars
- (4) mass extinctions of life-forms and global climate changes

124 What is the main reason that the gravitational attraction between Earth and the Moon changes each day?

- (1) Earth's axis is tilted at 23.5°.
- (2) Earth's rotational speed varies with the seasons.
- (3) The Moon has an elliptical orbit.
- (4) The Moon has a spherical shape.

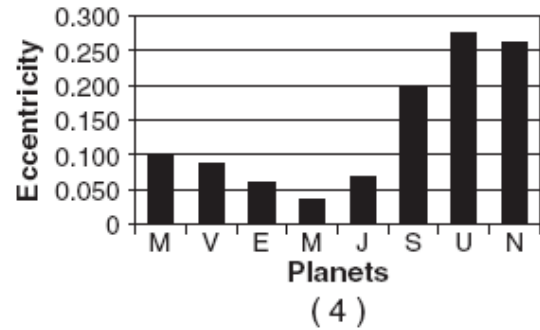
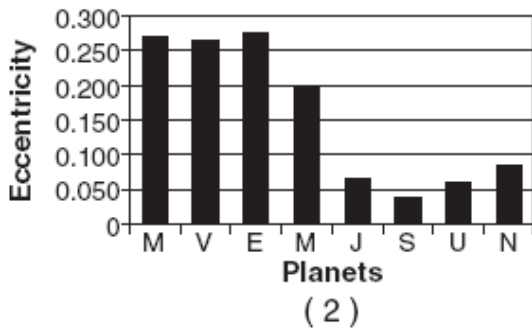
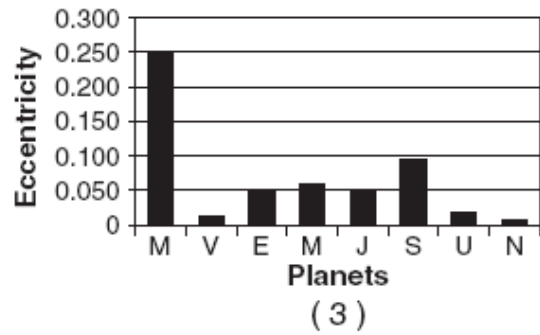
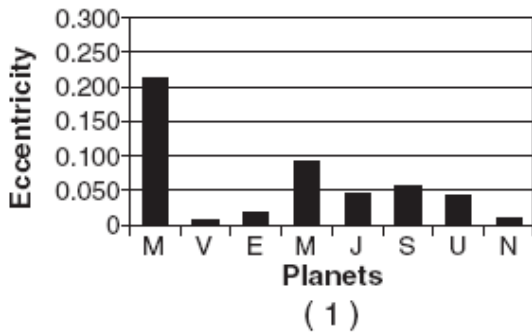
123 What is the inferred age of our solar system, in millions of years?

- (1) 544
- (2) 1300
- (3) 4600
- (4) 10,000

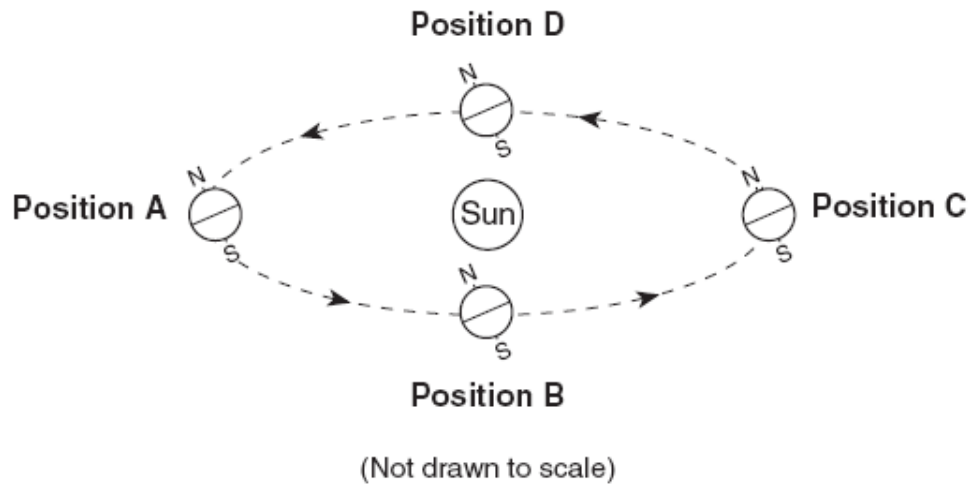
125 Which object in our solar system has the greatest density?

- (1) Jupiter
- (2) Earth
- (3) the Moon
- (4) the Sun

126 Which bar graph correctly shows the orbital eccentricity of the planets in our solar system?



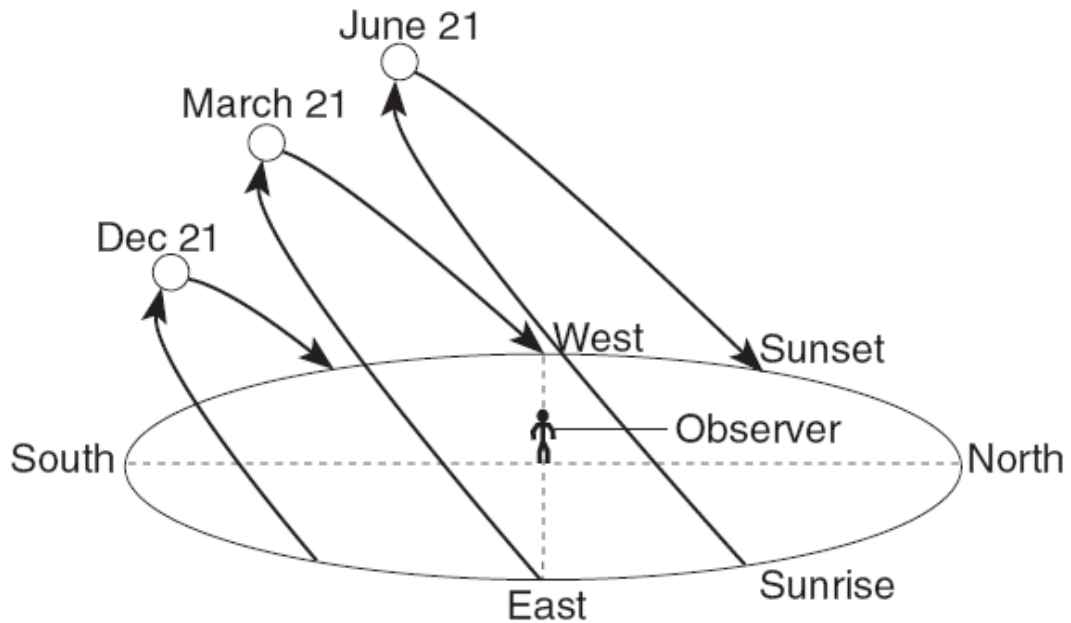
The diagram below shows Earth in its orbit around the Sun. Positions A, B, C, and D represent Earth at the beginning of each season.



127 At which lettered position of Earth does New York State experience the first day of summer?

- (1) A
- (2) B
- (3) C
- (4) D

The diagram below shows the apparent daily path of the Sun, as viewed by an observer at a certain latitude on three different days of the year.



128 At which latitude were these apparent Sun paths most likely observed?

- (1) 0°
- (2) 23.5° N
- (3) 43° N
- (4) 66.5° N

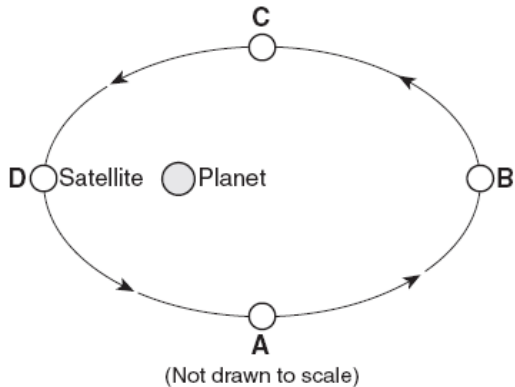
129 Compared to the Jovian planets in our solar system, Earth is

- (1) less dense and closer to the Sun
- (2) less dense and farther from the Sun
- (3) more dense and closer to the Sun
- (4) more dense and farther from the Sun

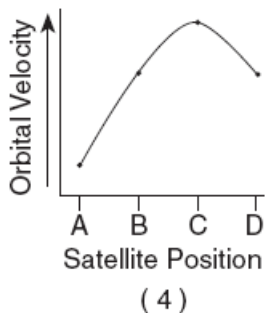
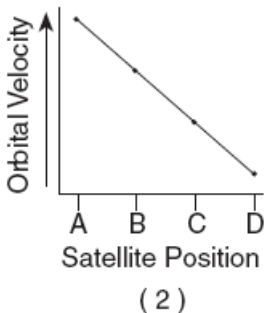
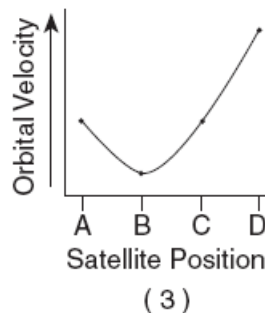
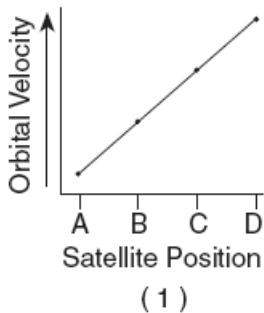
130 A Foucault pendulum appears to change its direction of swing due to the

- (1) tilt of Earth's axis
- (2) spin of Earth on its axis
- (3) deflection of Earth's planetary winds
- (4) movement of Earth in its orbit around the Sun

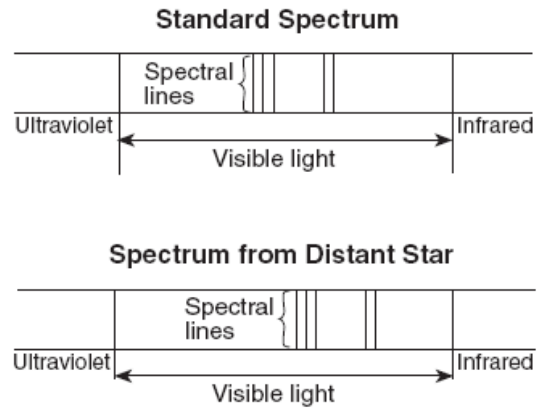
The diagram below shows a satellite in four different positions as it revolves around a planet.



131 Which graph best represents the changes in this satellite's orbital velocity as it revolves around the planet?



132 The diagram below shows a standard spectrum compared to a spectrum produced from a distant star. Which conclusion can be made by comparing the standard spectrum to the spectrum produced from this distant star?



- (1) The star's spectral lines have shifted toward the ultraviolet end of the spectrum and the star is moving toward Earth.
- (2) The star's spectral lines have shifted toward the ultraviolet end of the spectrum and the star is moving away from Earth.
- (3) The star's spectral lines have shifted toward the infrared end of the spectrum and the star is moving toward Earth.
- (4) The star's spectral lines have shifted toward the infrared end of the spectrum and the star is moving away from Earth.

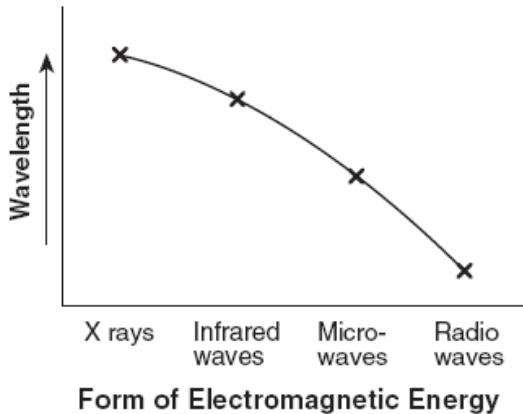
133 Which statement provides evidence that Earth revolves around the Sun?

- (1) Winds at different latitudes are curved different amounts by the Coriolis effect.
- (2) Different star constellations are visible from Earth at different seasons of the year.
- (3) The Sun follows an apparent arc across the sky during the day.
- (4) The stars appear to circle Earth during the night.

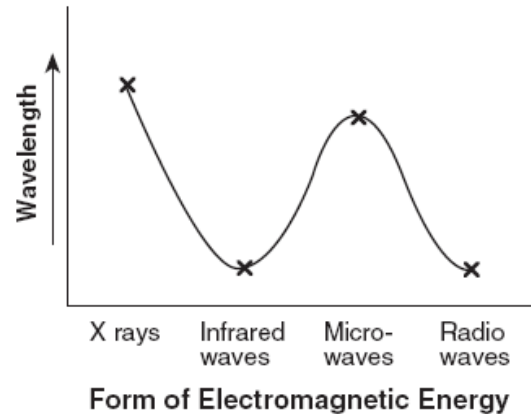
134 Compared to the surface temperature and luminosity of massive stars in the Main Sequence, the smaller stars in the Main Sequence are

- (1) hotter and less luminous
- (2) hotter and more luminous
- (3) cooler and less luminous
- (4) cooler and more luminous

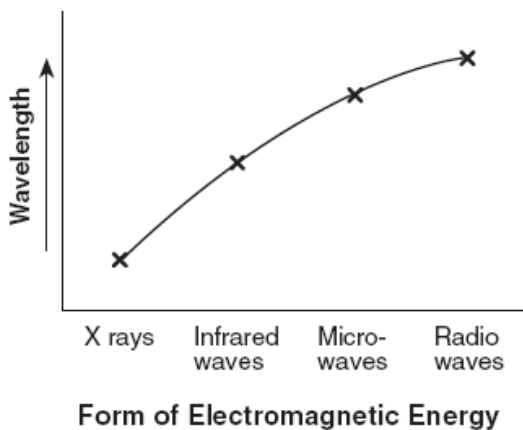
135 Which graph best represents the relative wavelengths of the different forms of electromagnetic energy?



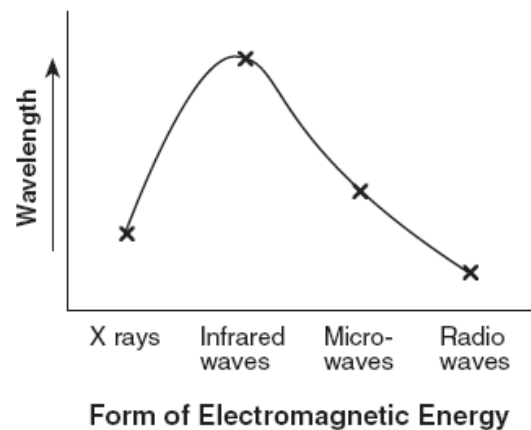
( 1 )



( 3 )

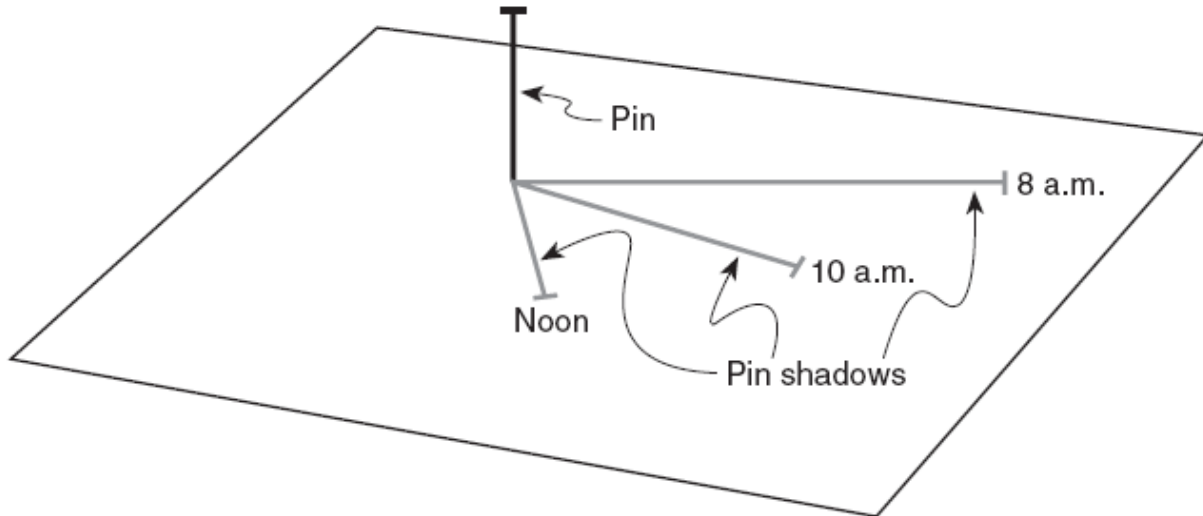


( 2 )



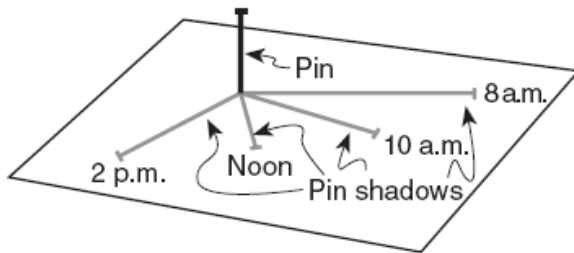
( 4 )

Base your answers to questions 136 through 138 on the diagram below and on your knowledge of Earth science. The diagram shows a pin perpendicular to a card. The card was placed outdoors in the sunlight on a horizontal surface. The positions of the pin's shadow on the card were recorded several times on March 21 by an observer in New York State.

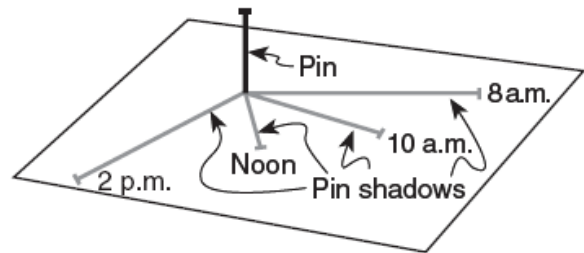


(Drawn to scale)

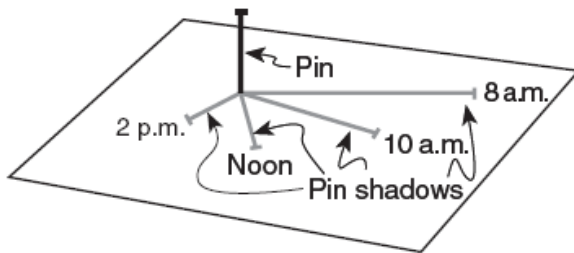
136 Which diagram best represents the length of the pin's shadow at 2 p.m. on March 21?



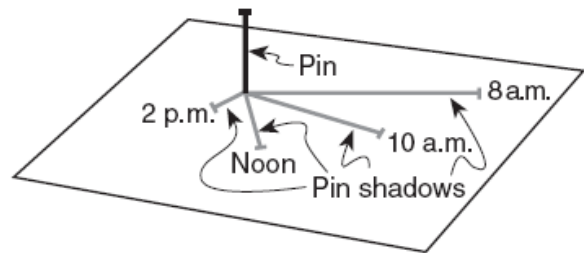
(1)



(3)



(2)



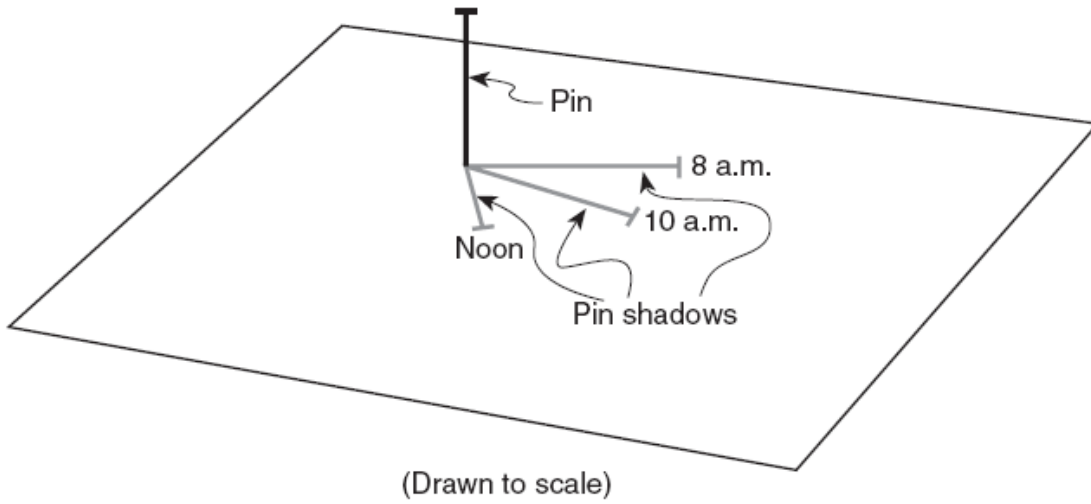
(4)

137 The changing location of the pin's shadow on March 21 is caused by

- |                          |                        |
|--------------------------|------------------------|
| (1) the Sun's rotation   | (3) Earth's rotation   |
| (2) the Sun's revolution | (4) Earth's revolution |



138 On June 21, the card and pin were placed in the same position as they were on March 21. The diagram below shows the positions of the pin's shadow.



Which statement best explains the decreased length of each shadow on June 21?

- (1) The Sun's apparent path varies with the seasons.
- (2) The Sun's distance from Earth varies with the seasons.
- (3) The intensity of insolation is lower on June 21.
- (4) The duration of insolation is shorter on June 21.

139 Which planet's orbit around the Sun is most nearly circular?

- (1) Mercury
- (2) Neptune
- (3) Pluto
- (4) Venus

141 How many times will the Sun's perpendicular rays cross Earth's Equator between March 1 of one year and March 1 of the next year?

- (1) 1
- (2) 2
- (3) 3
- (4) 4

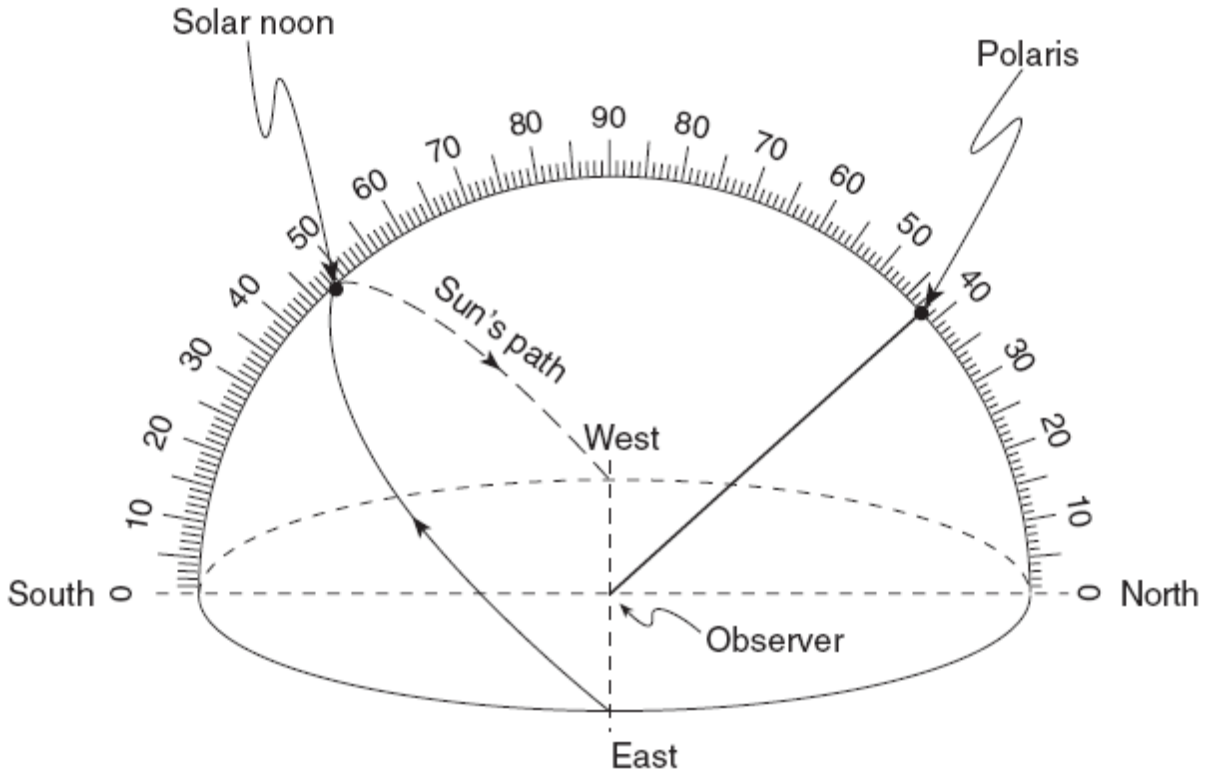
140 Which star's surface temperature is closest to the temperature at the boundary between Earth's mantle and core?

- (1) *Sirius*
- (2) *Rigel*
- (3) the Sun
- (4) *Betelgeuse*

142 Which celestial feature is largest in actual size?

- (1) the Moon
- (2) Jupiter
- (3) the Sun
- (4) the Milky Way

Base your answers to questions 143 through 145 on the diagram below, which represents a model of the sky (celestial sphere) for an observer in New York State. The curved arrow represents the Sun's apparent path for part of one day. The altitude of *Polaris* is also indicated.



143 According to this diagram, what is the Sun's altitude at solar noon?

- (1) 23.5°
- (2) 42°
- (3) 48°
- (4) 90°

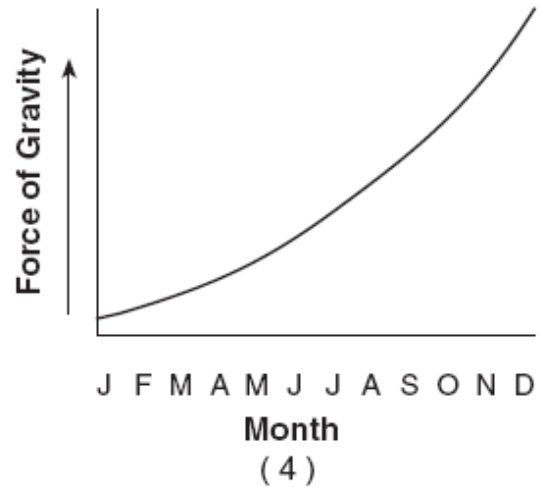
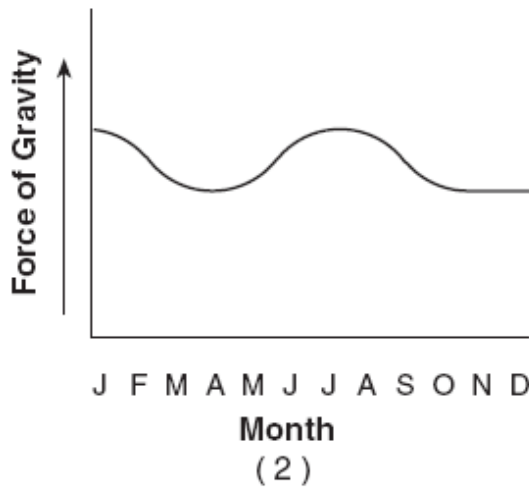
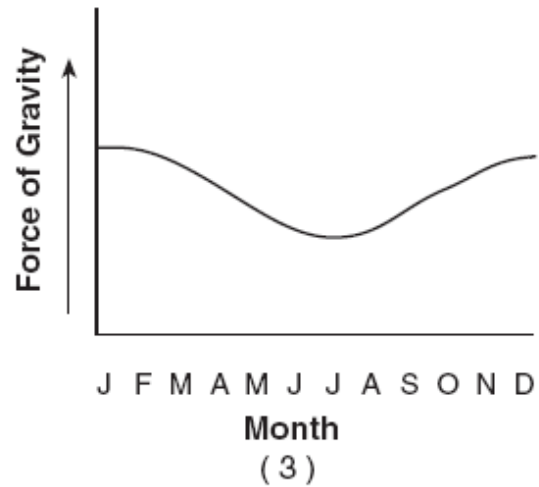
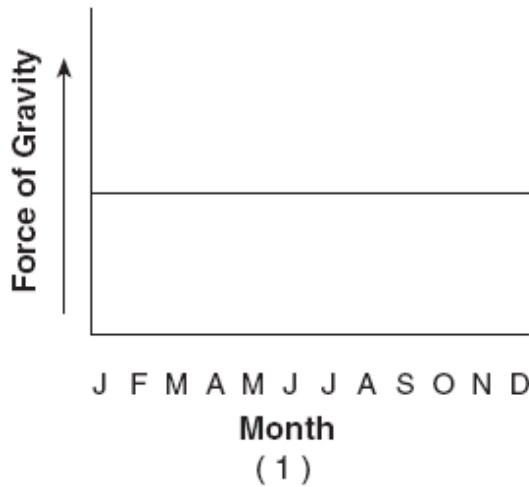
144 Where is this observer most likely located?

- (1) Massena
- (2) Oswego
- (3) Slide Mountain
- (4) Mt. Marcy

145 On which date could this observation of the Sun's apparent path have been made?

- (1) March 21
- (2) July 21
- (3) October 21
- (4) December 21

146 Which graph best represents the force of gravity between Earth and the Sun during one revolution of Earth around the Sun?



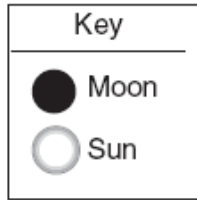
147 The best evidence that Earth rotates is provided by the

- (1) location of mid-oceanic ridge volcanoes and the distribution of index fossils
- (2) movement of Foucault pendulums and the Coriolis effect on air movement
- (3) pattern of changing seasons and the depth of meteor impacts
- (4) rate of uranium-238 decay

148 How do Jupiter's density and period of rotation compare to Earth's?

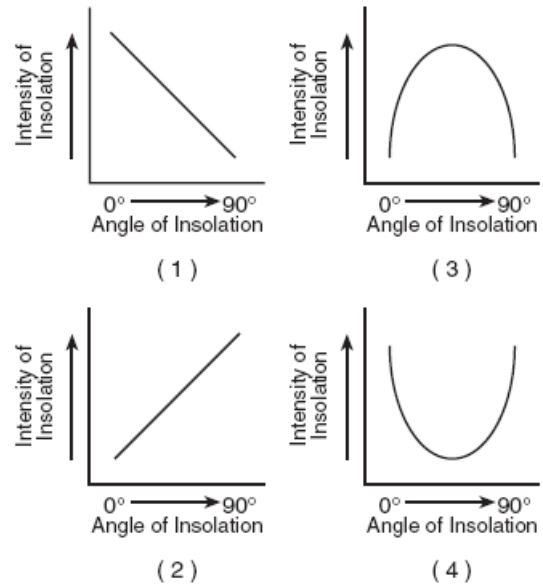
- (1) Jupiter is less dense and has a longer period of rotation.
- (2) Jupiter is less dense and has a shorter period of rotation.
- (3) Jupiter is more dense and has a longer period of rotation.
- (4) Jupiter is more dense and has a shorter period of rotation.

149 What is represented by the diagram below?

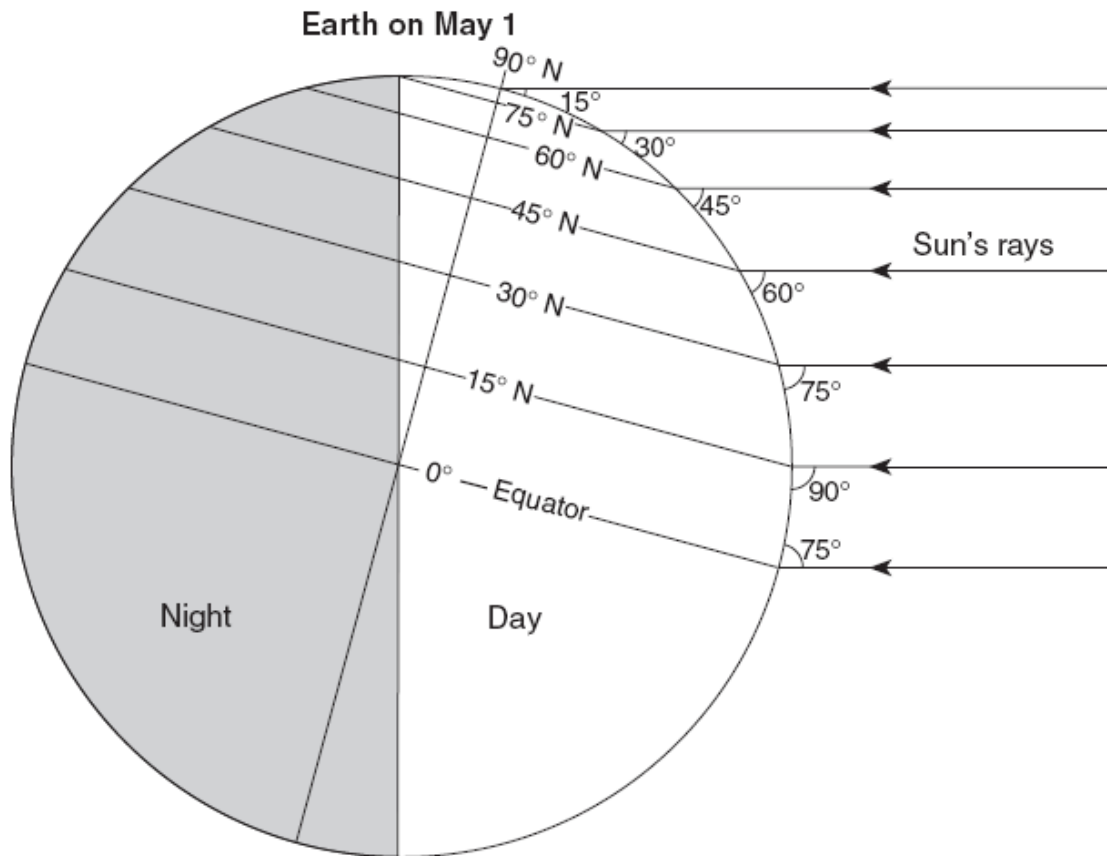


- (1) changing phases of the Sun
- (2) changing phases of the Moon
- (3) stages in an eclipse of the Sun
- (4) stages in an eclipse of the Moon

150 Which graph best represents the relationship between the angle of insolation and the intensity of insolation?



Base your answers to questions 36 and 37 on the diagram below, which shows the angle of the Sun's noontime rays received at different Earth latitudes on May 1.



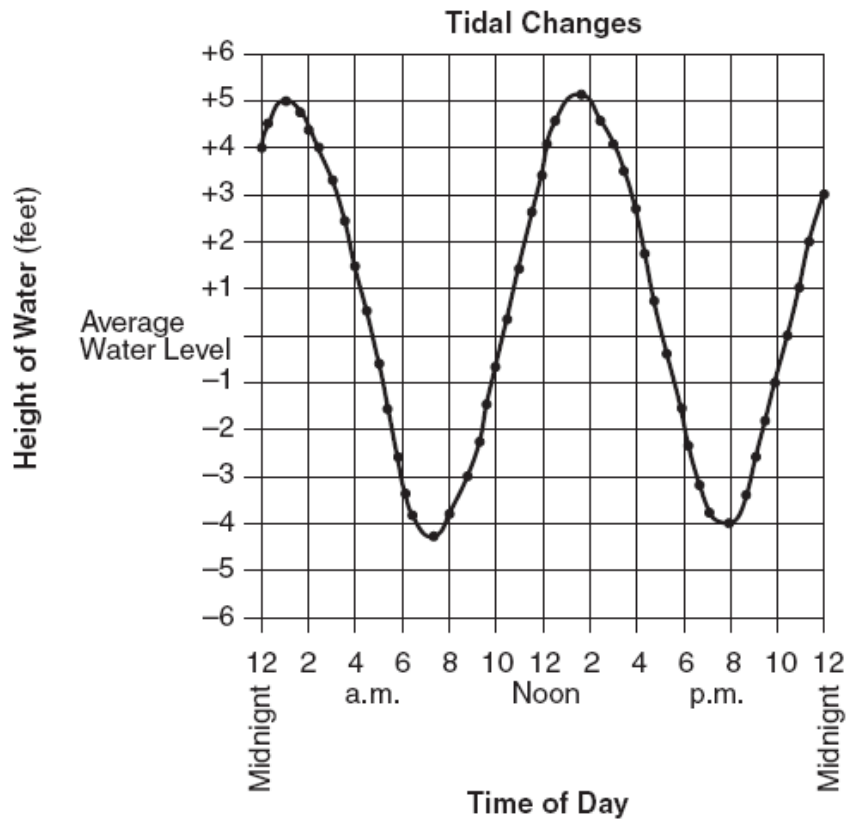
151 Which changes can be expected to occur at 45° N over the next 30 days?

- (1) The duration of insolation will decrease and the temperature will decrease.
- (2) The duration of insolation will decrease and the temperature will increase.
- (3) The duration of insolation will increase and the temperature will decrease.
- (4) The duration of insolation will increase and the temperature will increase.

152 At which latitude can the noontime Sun be observed in the northern part of the sky?

- (1) 0°
- (2) 30° N
- (3) 60° N
- (4) 90° N

Base your answers to questions 153 and 154 on the graph below. The graph shows the recorded change in water level (ocean tides) at a coastal city in the northeastern United States during 1 day.



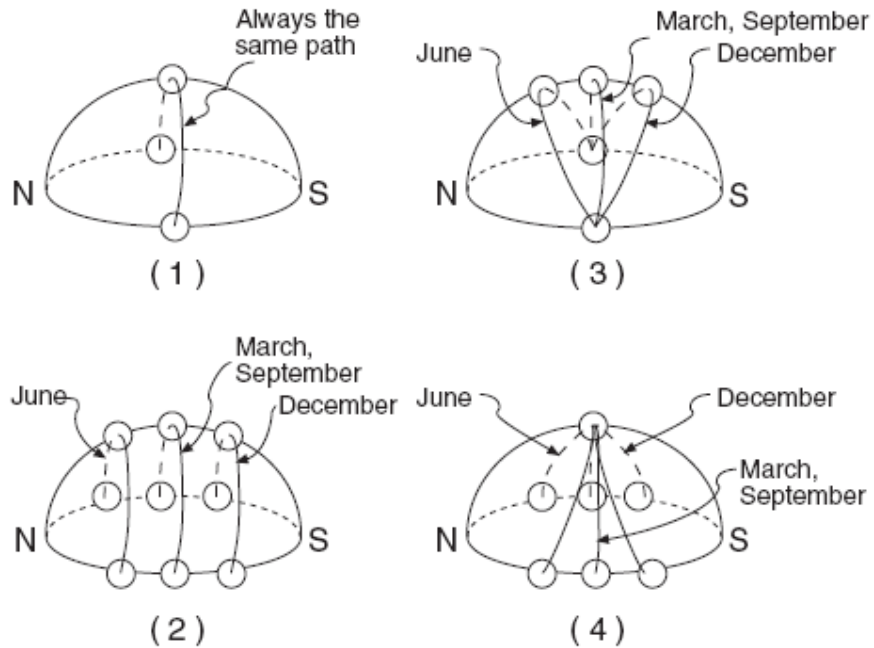
153 Which inference about tides is best made from this graph?

- (1) The hourly rate of tidal change is always the same.
- (2) The rate of tidal change is greatest at high tide.
- (3) The tidal change is a random event.
- (4) The tidal change is cyclic.

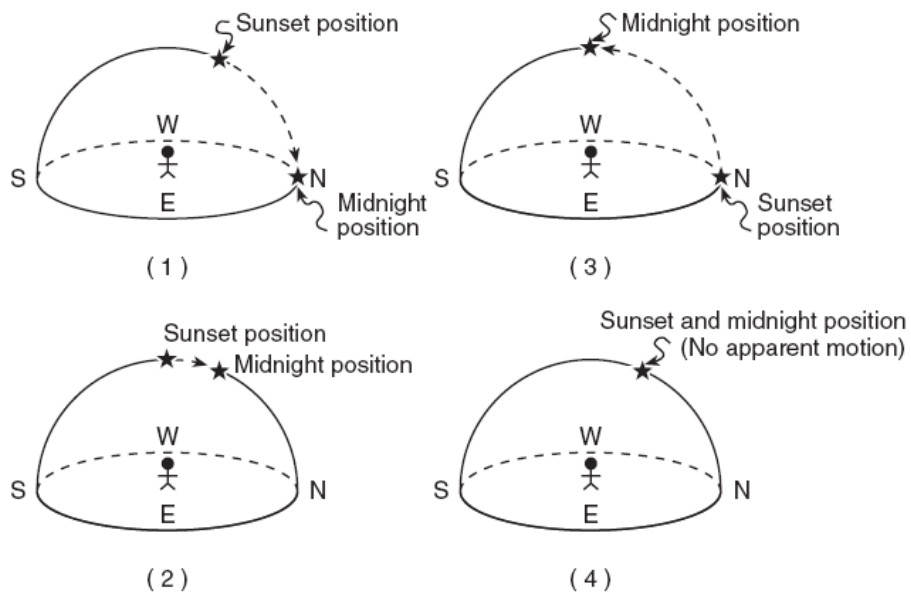
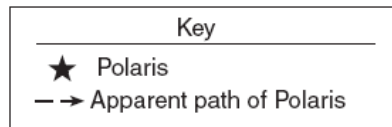
154 According to the pattern shown on the graph, the next high tide will occur on the following day at approximately

- (1) 12:30 a.m.
- (2) 2:00 a.m.
- (3) 3:15 a.m.
- (4) 4:00 a.m.

155 Which model best represents the apparent path of the Sun observed at various times during the year at the Equator?



155 Which diagram correctly shows the apparent motion of *Polaris* from sunset to midnight for an observer in northern Canada?



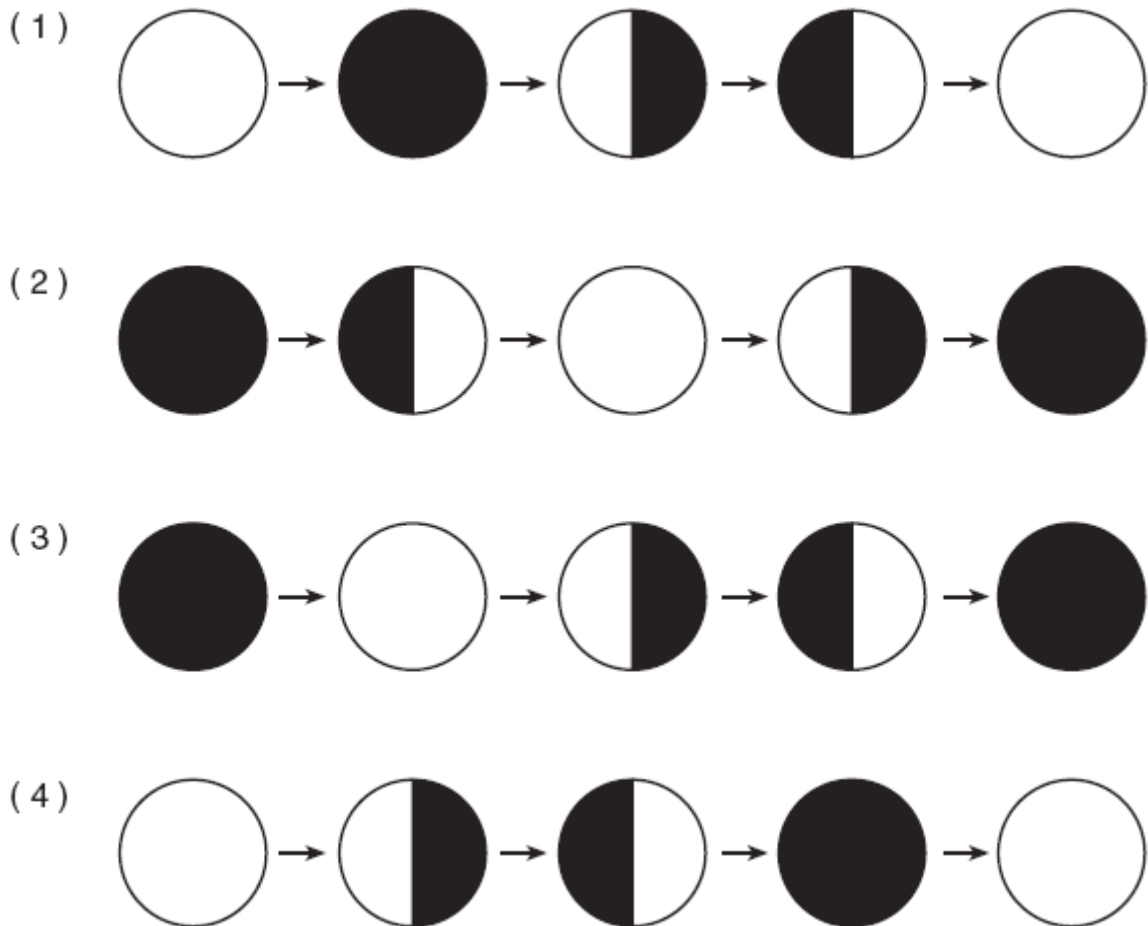
156 Earth's orbital velocity is slowest on July 5 because

- (1) the Moon is closest to Earth
- (2) Earth's distance from the Sun is greatest
- (3) Earth, the Moon, and the Sun are located along a straight line in space
- (4) the highest maximum temperatures occur in the Northern Hemisphere

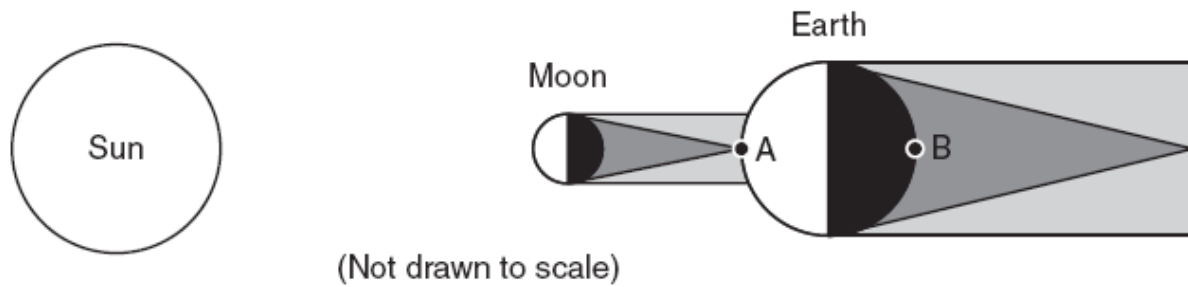
157 Three planets that are relatively large, gaseous, and of low density are

- (1) Mercury, Jupiter, and Saturn
- (2) Venus, Jupiter, and Neptune
- (3) Mars, Jupiter, and Uranus
- (4) Jupiter, Saturn, and Uranus

157 Which diagram sequence correctly shows the order of Moon phases, as viewed from Earth, for a period of 1 month? [Note that some phases have been omitted.]



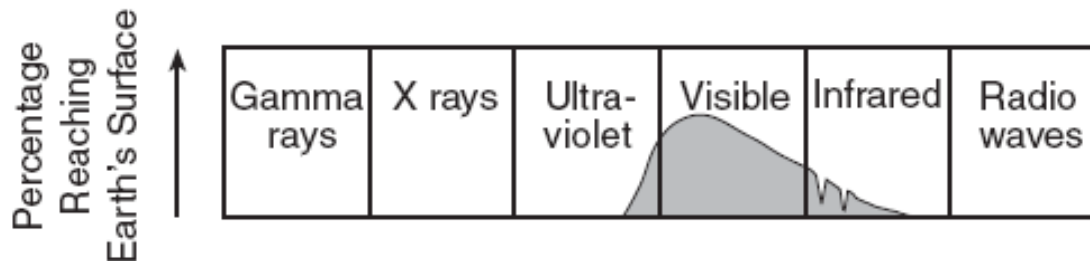
The diagram below shows the relative positions of the Sun, the Moon, and Earth when an eclipse was observed from Earth. Positions *A* and *B* are locations on Earth's surface.



158 Which statement correctly describes the type of eclipse that was occurring and the position on Earth where this eclipse was observed?

- (1) A lunar eclipse was observed from position *A*.
- (2) A lunar eclipse was observed from position *B*.
- (3) A solar eclipse was observed from position *A*.
- (4) A solar eclipse was observed from position *B*

The diagram below shows the types of electromagnetic energy given off by the Sun. The shaded part of the diagram shows the approximate amount of each type actually reaching Earth's surface.



159 Which conclusion is best supported by the diagram?

- (1) All types of electromagnetic energy reach Earth's surface.
- (2) Gamma rays and x rays make up the greatest amount of electromagnetic energy reaching Earth's surface.
- (3) Visible light makes up the greatest amount of electromagnetic energy reaching Earth's surface.
- (4) Ultraviolet and infrared radiation make up the greatest amount of electromagnetic energy reaching Earth's surface.



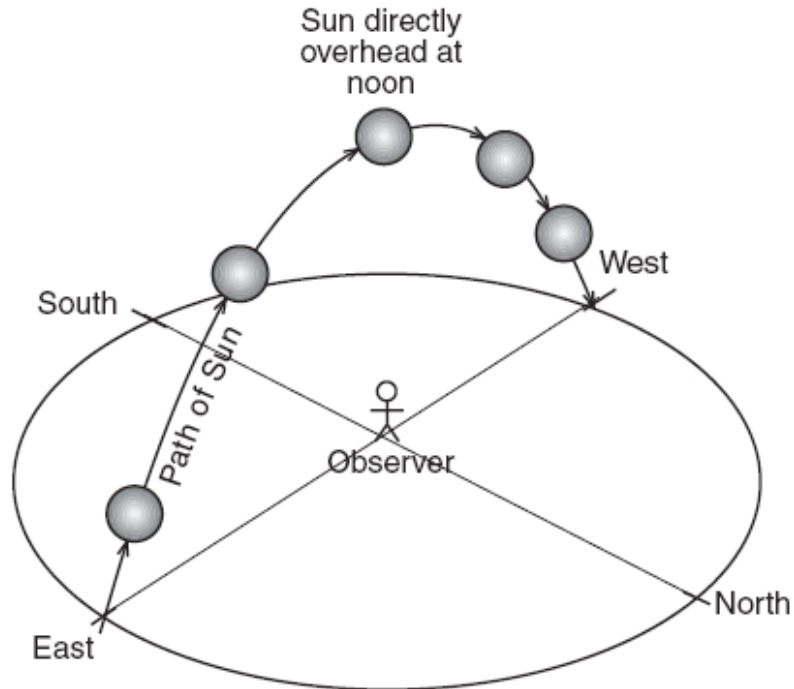
The table below shows the duration of insolation at different latitudes for three different days during the year.

Latitude	Day 1 Duration of Insolation (hours)	Day 2 Duration of Insolation (hours)	Day 3 Duration of Insolation (hours)
90° N	24	12	0
80° N	24	12	0
70° N	24	12	0
60° N	$18\frac{1}{2}$	12	$5\frac{1}{2}$
50° N	$16\frac{1}{4}$	12	$7\frac{3}{4}$
40° N	15	12	9
30° N	14	12	10
20° N	$13\frac{1}{4}$	12	$10\frac{3}{4}$
10° N	$12\frac{1}{2}$	12	$11\frac{1}{2}$
0°	12	12	12

160 Which dates are represented most correctly by Day 1, Day 2, and Day 3, respectively?

- (1) March 21, September 22, December 21
- (2) June 21, September 22, December 21
- (3) September 22, December 21, March 21
- (4) December 21, March 21, June 21

The diagram below shows the apparent path of the Sun as viewed by an observer at a certain Earth location on March 21.



161 At which latitude is the observer located?

- (1) the Equator ( $0^\circ$ )                      (3)  $66^\circ$  N  
 (2)  $23^\circ$  N                                      (4)  $90^\circ$  N

162 Which planet takes more time to complete one rotation on its axis than to complete one revolution around the Sun?

- (1) Mercury                      (3) Mars  
 (2) Venus                         (4) Jupiter

164 Which star is cooler and many times brighter than Earth's Sun?

- (1) *Barnard's Star*                      (3) *Rigel*  
 (2) *Betelgeuse*                         (4) *Sirius*

163 Which observation provides the best evidence that Earth rotates?

- (1) The position of the planets among the stars changes during the year.  
 (2) The location of the constellations in relationship to *Polaris* changes from month to month.  
 (3) The length of the shadow cast by a flagpole at noontime changes from season to season.  
 (4) The direction of swing of a freely swinging pendulum changes during the day.

165 An observer recorded the times of three successive high tides at one Earth location as:

- 7:12 a.m.
- 7:38 p.m.
- 8:04 a.m.

What was the time of the next high tide?

- (1) 8:12 p.m.                      (3) 8:38 p.m.  
 (2) 8:30 p.m.                      (4) 9:04 p.m.

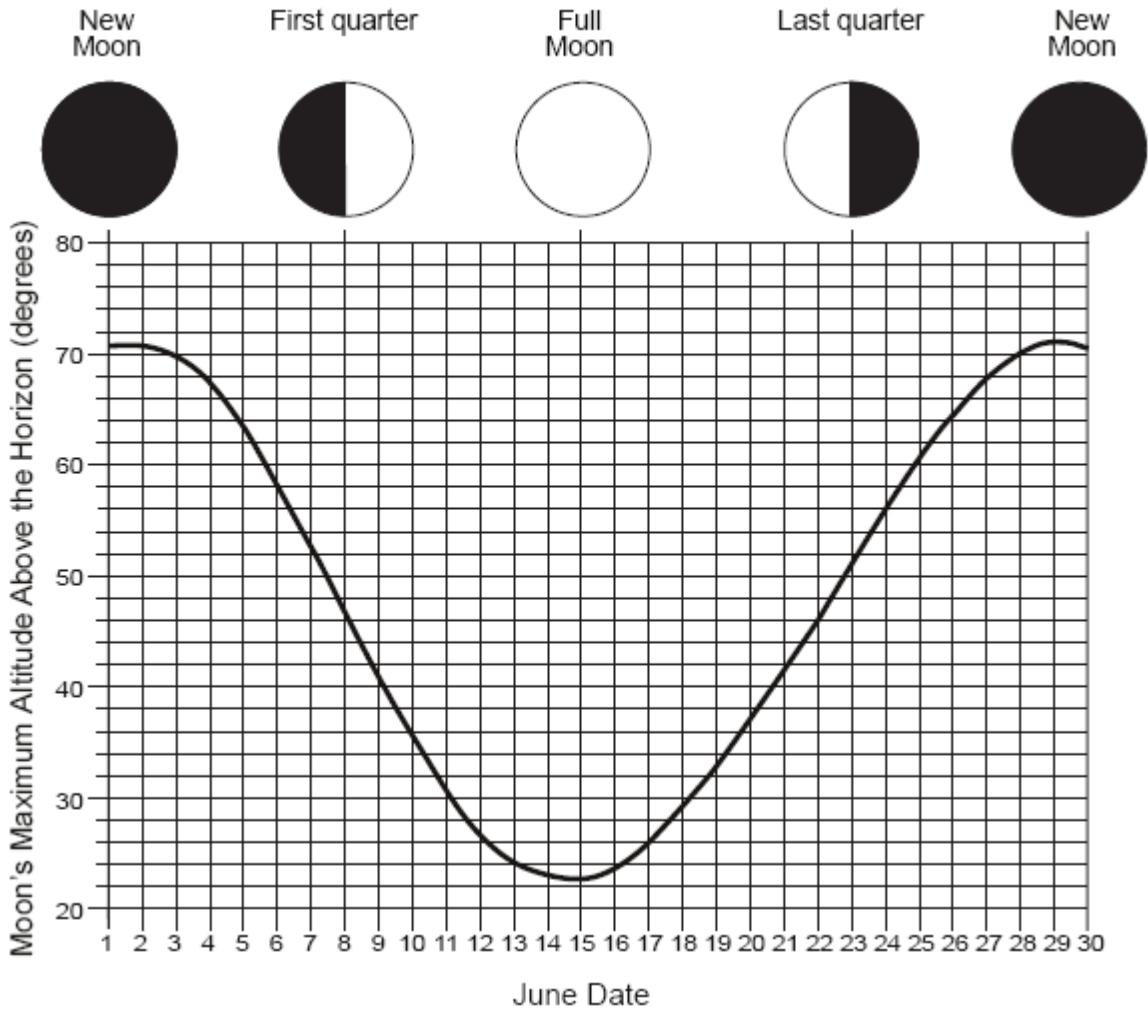
166 Energy is transferred from the Sun to Earth mainly by

- (1) molecular collisions
- (2) density currents
- (3) electromagnetic waves
- (4) red shifts

167 Which planet has an orbit with an eccentricity most similar to the eccentricity of the Moon's orbit around Earth?

- (1) Earth
- (2) Jupiter
- (3) Pluto
- (4) Saturn

Base your answers to questions 168 through 171 on the graph below, which shows the maximum altitude of the Moon, measured by an observer located at a latitude of 43° N during June in a particular year. The names and appearance of the four major Moon phases are shown at the top of the graph, directly above the date on which the phase occurred.



168 What was the maximum altitude of the Moon on June 22?

- (1) 40°
- (2) 43°
- (3) 46°
- (4) 50°

170 Which city is closest in latitude to the location where these observations were made?

- (1) Binghamton
- (2) New York City
- (3) Albany
- (4) Syracuse

169 Which diagram best represents the Moon's phase observed on June 11?



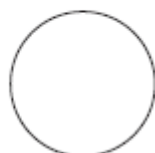
(1)



(3)



(2)

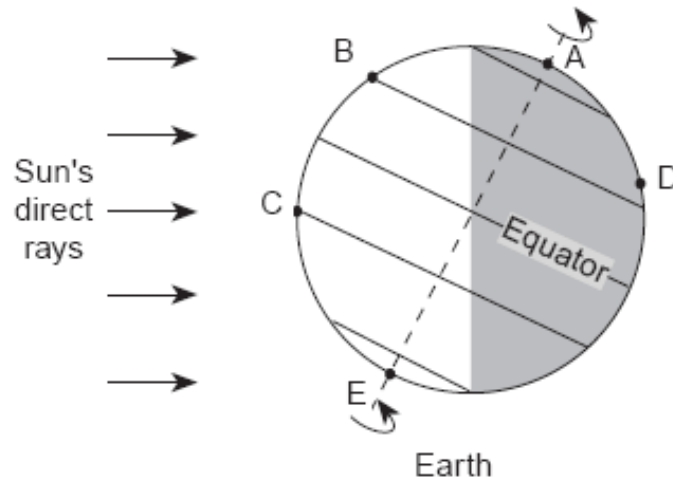


(4)

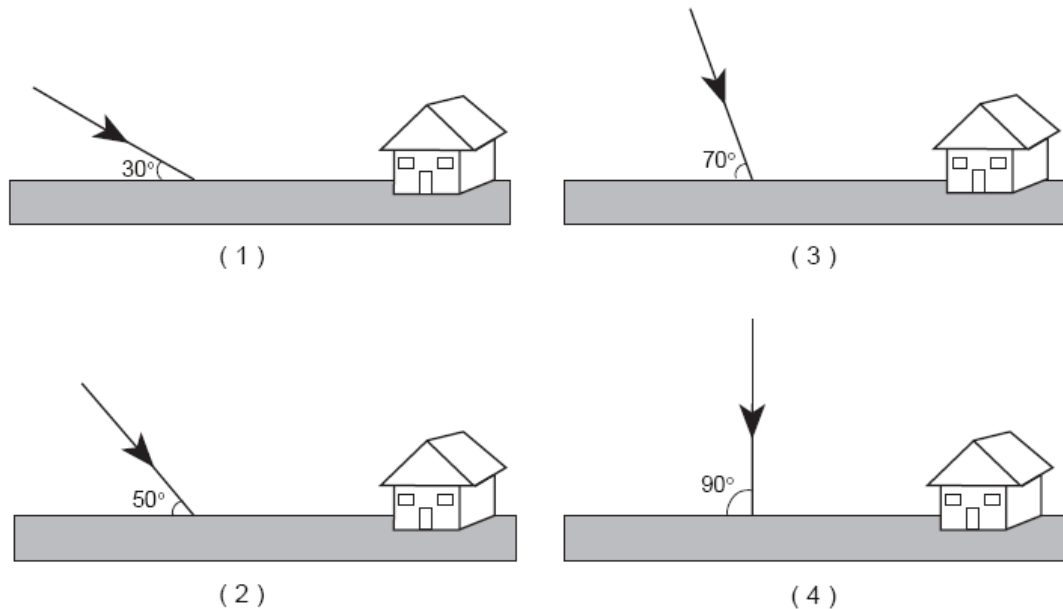
171 Which terms describe both the changes in the maximum altitude of the Moon and the changes in the Moon's phases over a period of several years?

- (1) cyclic and predictable
- (2) cyclic and unpredictable
- (3) noncyclic and predictable
- (4) noncyclic and unpredictable

Base your answers to questions 172 through 174 on the diagram below, which shows the tilt of Earth on its axis in relation to the Sun on one particular day. Points A through E are locations on Earth's surface. Point D is located in New York State. The dashed line represents Earth's axis.



172 Which diagram best represents the angle of the Sun's rays received at location C at noon on this day?



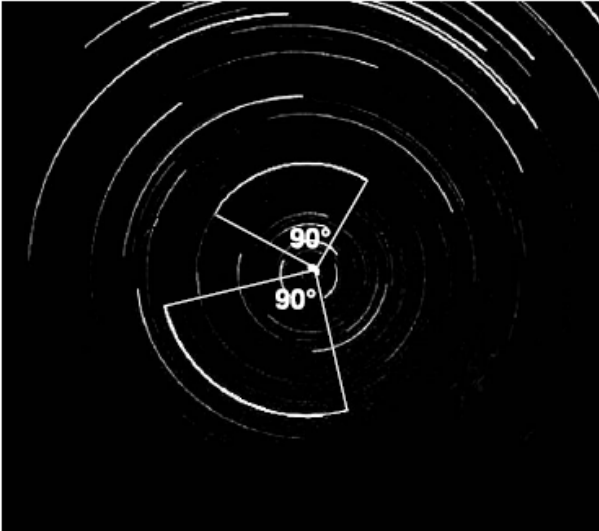
173 What is the latitude of location A?

- (1)  $0^\circ$
- (2)  $23^\circ \text{ N}$
- (3)  $63^\circ \text{ S}$
- (4)  $90^\circ \text{ N}$

174 On this day, which location has the greatest number of hours of daylight?

- (1) E
- (2) B
- (3) C
- (4) D

A camera was placed in an open field and pointed toward the northern sky. The lens of the camera was left open for a certain amount of time. The result is shown in the photograph below. The angle of the arc through which two of the stars appeared to move during this time exposure is shown.



175 How many hours was the lens left open to produce the photograph?

- (1) 12
- (2) 2
- (3) 6
- (4) 4

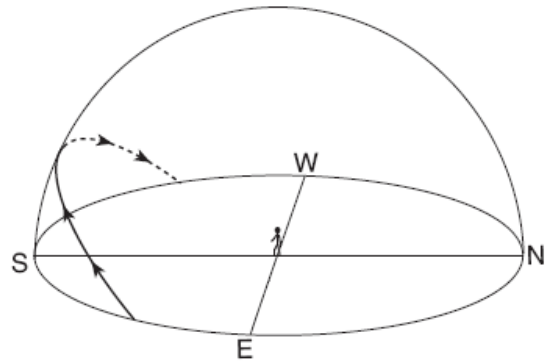
176 At which location is the altitude of *Polaris* approximately  $42^\circ$ ?

- (1) Niagara Falls
- (2) Elmira
- (3) Watertown
- (4) Massena

177 Which motion causes the constellation Orion to be visible at midnight from New York State in winter but not in summer?

- (1) rotation of Earth
- (2) rotation of Orion
- (3) revolution of Earth
- (4) revolution of Orion

The model below shows the Sun's apparent path across the sky for an observer in New York State.



178 On which day of the year was this path observed?

- (1) March 21
- (2) June 21
- (3) September 21
- (4) December 21

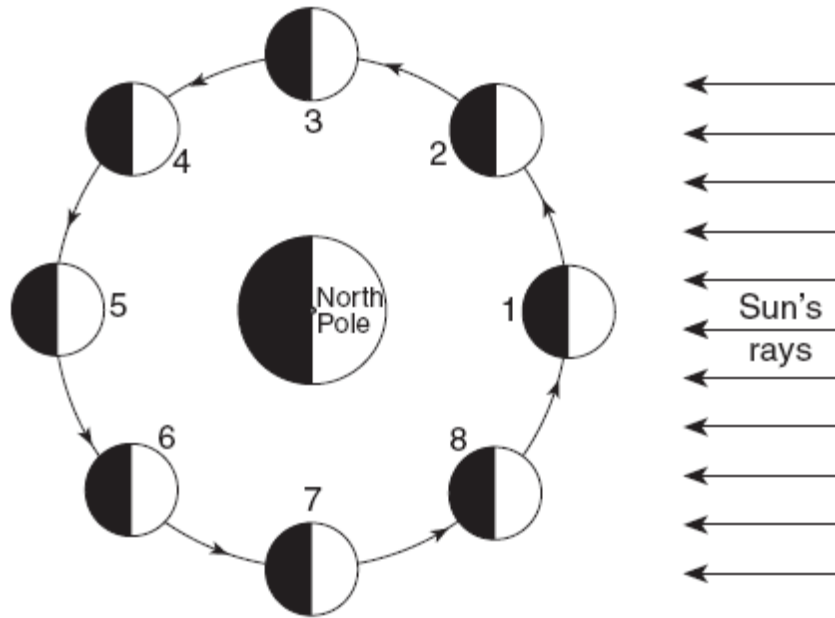
179 At which latitude is the Sun directly overhead on certain days of the year?

- (1)  $23.5^\circ$  N
- (2)  $42^\circ$  N
- (3)  $66.5^\circ$  N
- (4)  $90^\circ$  N

180 What does a red shift in light from distant celestial objects indicate to a scientist on Earth?

- (1) The gravitational force on Earth changes.
- (2) The universe appears to be expanding.
- (3) The Jovian planets are aligned with the Sun.
- (4) Galaxies are becoming more numerous.

The diagram below shows the Moon as it revolves around Earth. The numbered locations represent different positions of the Moon in its orbit.



(Not drawn to scale)

181 Which Moon phase would be seen by an observer in New York State when the Moon is at position 2?



The photographs below show the surface of the Moon as seen from Earth over an 80-minute period during a single night.



182 Which motion is responsible for this changing appearance of the Moon?

- (1) The Moon moves into the shadow of Earth.
- (2) The Moon moves into the shadow of the Sun.
- (3) The Sun moves into the shadow of Earth.
- (4) The Sun moves into the shadow of the Moon.

Base your answers to questions 182 through 184 on the data table below, which shows information about the four largest asteroids found in our solar system.

**Data Table**

<b>Name</b>	<b>Average Diameter (kilometers)</b>	<b>Period of Revolution (years)</b>
Ceres	848.4	4.60
Pallas	498.1	4.61
Juno	247.0	4.36
Vesta	468.3	3.63

182 The asteroids shown in the data table are located between the orbits of

- (1) Venus and Earth
- (2) Earth and Mars
- (3) Mars and Jupiter
- (4) Jupiter and Saturn

183 Compared to the diameter of Earth's Moon, the diameter of Ceres is about

- (1) one-fourth of the Moon's diameter
- (2) one-half of the Moon's diameter
- (3) twice the diameter of the Moon
- (4) four times the diameter of the Moon

184 The surface rocks of Vesta contain significant amounts of the mineral pyroxene. If rocks on Vesta are similar to rocks on Earth, which two igneous rocks would most likely be found on the surface of Vesta?

- (1) basalt and scoria
- (2) dunite and granite
- (3) peridotite and pumice
- (4) rhyolite and pegmatite

185 Which statement best describes the age of our solar system and the universe?

- (1) The universe is at least twice as old as our solar system.
- (2) Our solar system is at least twice as old as the universe.
- (3) Our solar system and the universe are estimated to be 5 billion years old.
- (4) Our solar system and the universe are estimated to be 10 billion years old.

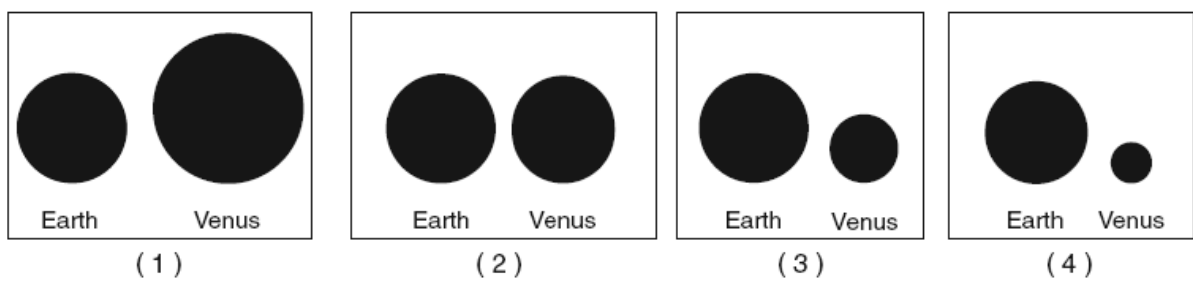
186 A Foucault pendulum is used to prove that

- (1) the Sun rotates on its axis
- (2) the Sun revolves around Earth
- (3) Earth rotates on its axis
- (4) Earth revolves around the Sun

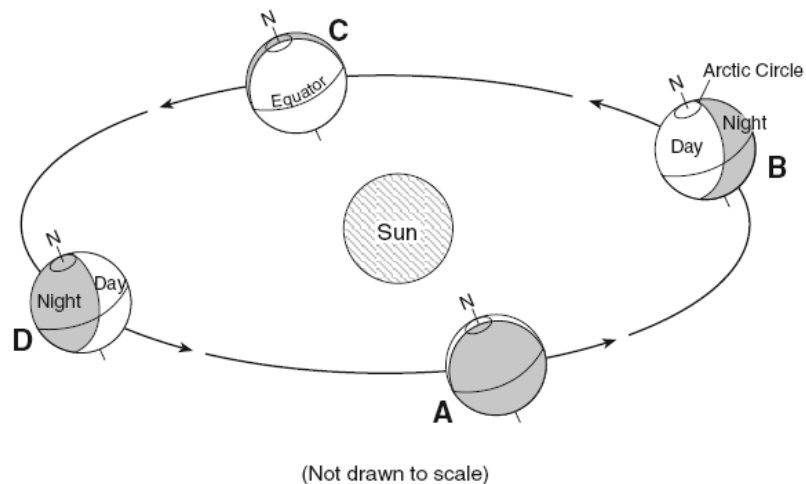


<p>187 The spinning of Earth on its axis causes the apparent rising and setting of the</p> <p>(1) Sun, only (2) Sun and the Moon, only (3) Moon and some stars, only (4) Sun, the Moon, and some stars</p>	<p>189 Compared to the terrestrial planets, the Jovian planets are</p> <p>(1) smaller and have lower densities (2) smaller and have greater densities (3) larger and have lower densities (4) larger and have greater densities</p>
<p>188 Which process produces the energy that allows the stars of the universe to radiate visible light?</p> <p>(1) convection                      (3) insolation (2) nuclear fusion                  (4) radioactive decay</p>	

190 Which pair of shaded circles best represents the relative sizes of Earth and Venus when drawn to scale?



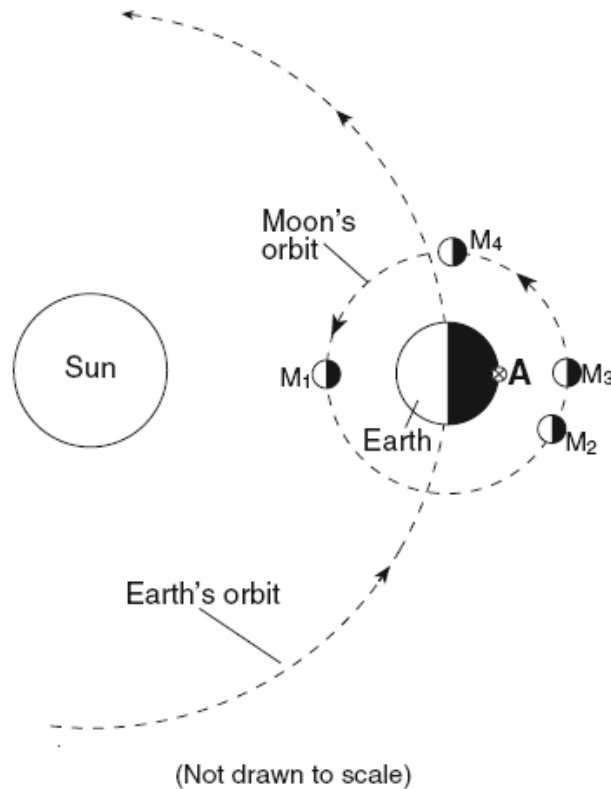
The diagram below shows Earth's orbit around the Sun. Locations A, B, C, and D represent Earth on the first day of each season.



191 Which location represents March 21?

- (1) A                      (3) C  
(2) B                      (4) D

Base your answers to questions 192 through 194 on the diagram below, which shows Earth in orbit around the Sun, and the Moon in orbit around Earth.  $M_1$ ,  $M_2$ ,  $M_3$ , and  $M_4$  indicate positions of the Moon in its orbit. Letter  $A$  indicates a location on Earth's surface.



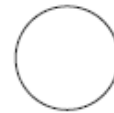
192 An observer at location  $A$  on Earth views the Moon when it is at position  $M_3$ . Which phase of the Moon will the observer see?



( 1 )



( 2 )



( 3 )



( 4 )

193 At which Moon position could a solar eclipse be seen from Earth?

(1)  $M_1$

(3)  $M_3$

(2)  $M_2$

(4)  $M_4$

194 An observer at location  $A$  noticed that the apparent size of the Moon varied slightly from month to month when the Moon was at position  $M_4$  in its orbit. Which statement best explains this variation in the apparent size of the Moon?

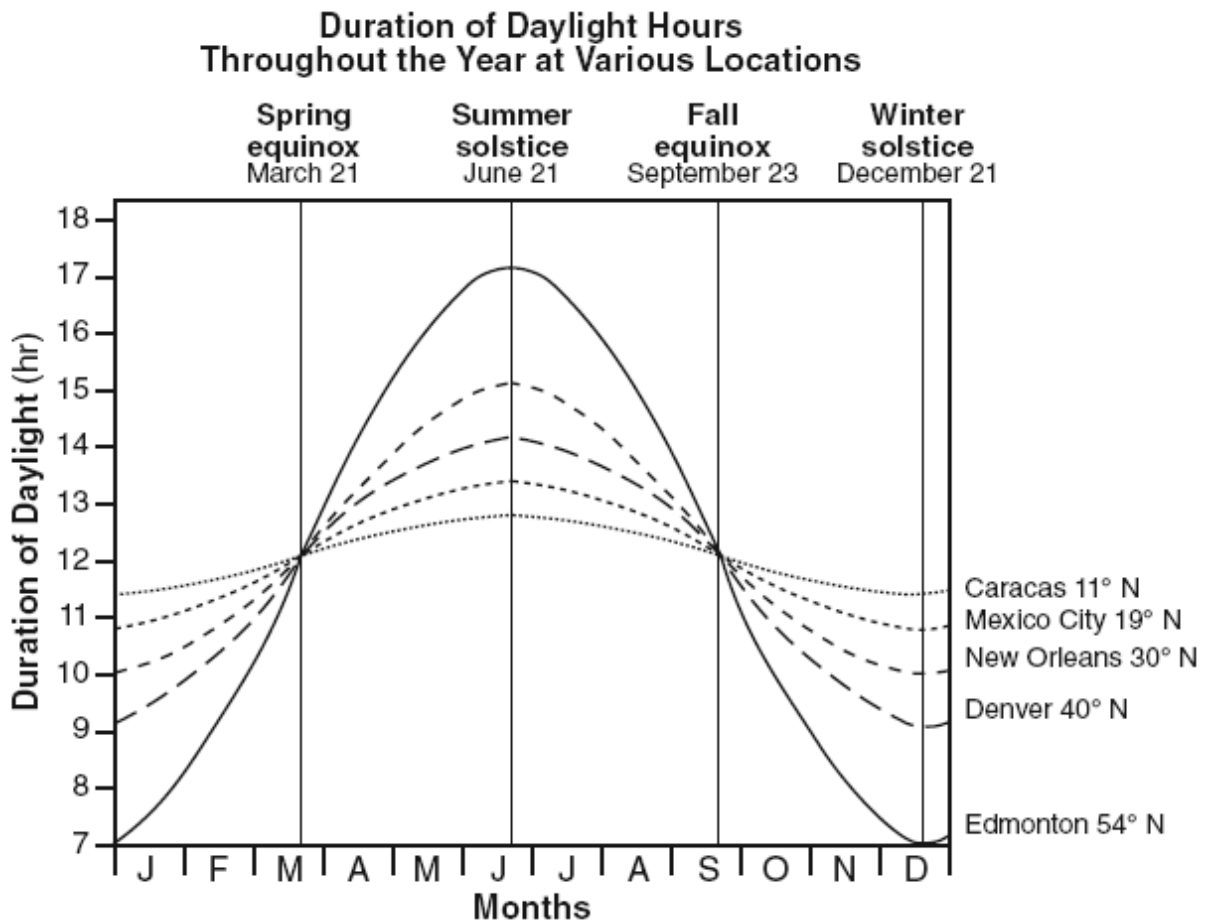
(1) The Moon expands in summer and contracts in winter.

(2) The Moon shows complete cycles of phases throughout the year.

(3) The Moon's period of rotation is equal to its period of revolution.

(4) The Moon's distance from Earth varies in a cyclic manner.

Base your answers to questions 195 and 196 on the graph below, which shows the duration of daylight hours throughout the year for five cities located in the Northern Hemisphere.



195 Which city experiences the greatest variation in daylight hours during one year?

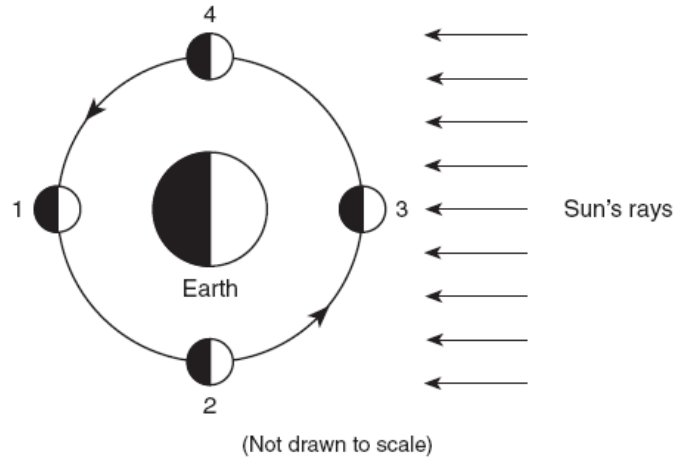
- (1) Caracas
- (2) Mexico City
- (3) New Orleans
- (4) Edmonton

196 What is the primary reason each city's duration of daylight hours changes throughout the year?

- (1) Earth's axis is tilted  $23.5^\circ$  to the plane of its orbit.
- (2) Earth's rotation rate is  $15^\circ$  per day.
- (3) The cities are located at different longitudes.
- (4) The cities are located at different elevations.

<p>197 Scientists can plan to photograph a solar eclipse because most astronomical events are</p> <p>(1) cyclic and predictable  (2) cyclic and unpredictable  (3) random and predictable  (4) random and unpredictable</p>	<p>200 In New York State, the constellation Pisces can be seen in the night sky between the middle of summer and the middle of winter. The constellation Scorpio can be seen in the night sky between early spring and early fall. The reason these two constellations can be viewed only at these times is a direct result of Earth's</p> <p>(1) spin on its axis  (2) movement around the Sun  (3) axis having a 23.5° tilt  (4) distance from the Sun</p>
<p>198 Approximately how many degrees per day does Earth revolve in its orbit around the Sun?</p> <p>(1) 1°                      (3) 15°  (2) 13°                     (4) 23.5°</p>	<p>201 Compared with our Sun, the star <i>Betelgeuse</i> is</p> <p>(1) smaller, hotter, and less luminous  (2) smaller, cooler, and more luminous  (3) larger, hotter, and less luminous  (4) larger, cooler, and more luminous</p>
<p>199 Astronomers viewing light from distant galaxies observe a shift of spectral lines toward the red end of the visible spectrum. This shift provides evidence that</p> <p>(1) orbital velocities of stars are decreasing  (2) Earth's atmosphere is warming  (3) the Sun is cooling  (4) the universe is expanding</p>	

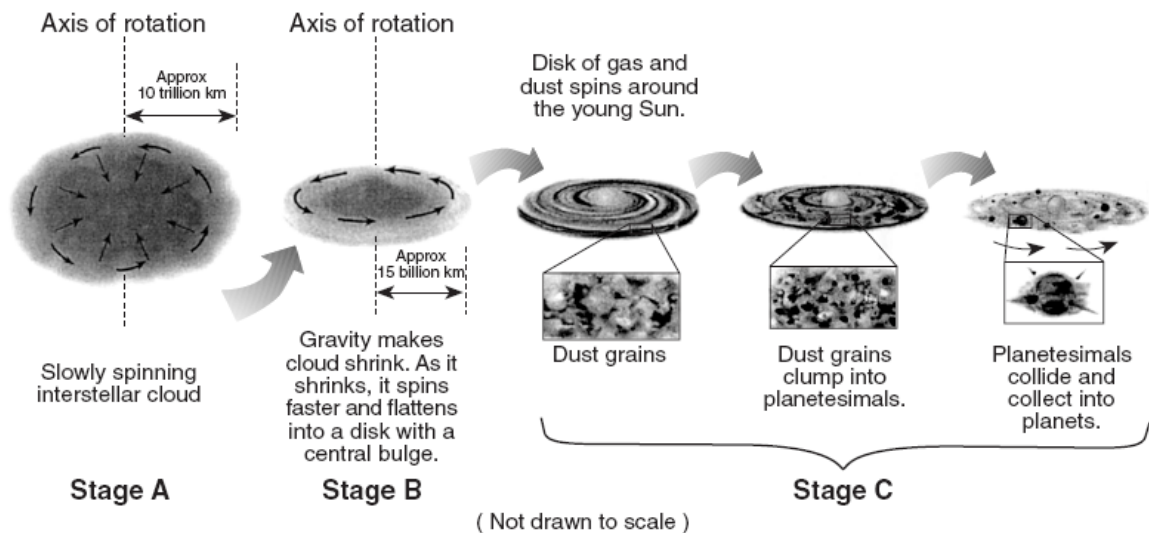
The diagram below represents the Sun's rays striking Earth and the Moon. Numbers 1 through 4 represent positions of the Moon in its orbit around Earth.



202 The highest tides on Earth occur when the Moon is in positions

- (1) 1 and 3
- (2) 2 and 4
- (3) 3 and 2
- (4) 4 and 1

Base your answers to questions 203 and 204 on the diagram below, which shows an inferred sequence in which our solar system formed from a giant interstellar cloud of gas and debris. Stage A shows the collapse of the gas cloud, stage B shows its flattening, and stage C shows the sequence that led to the formation of planets.



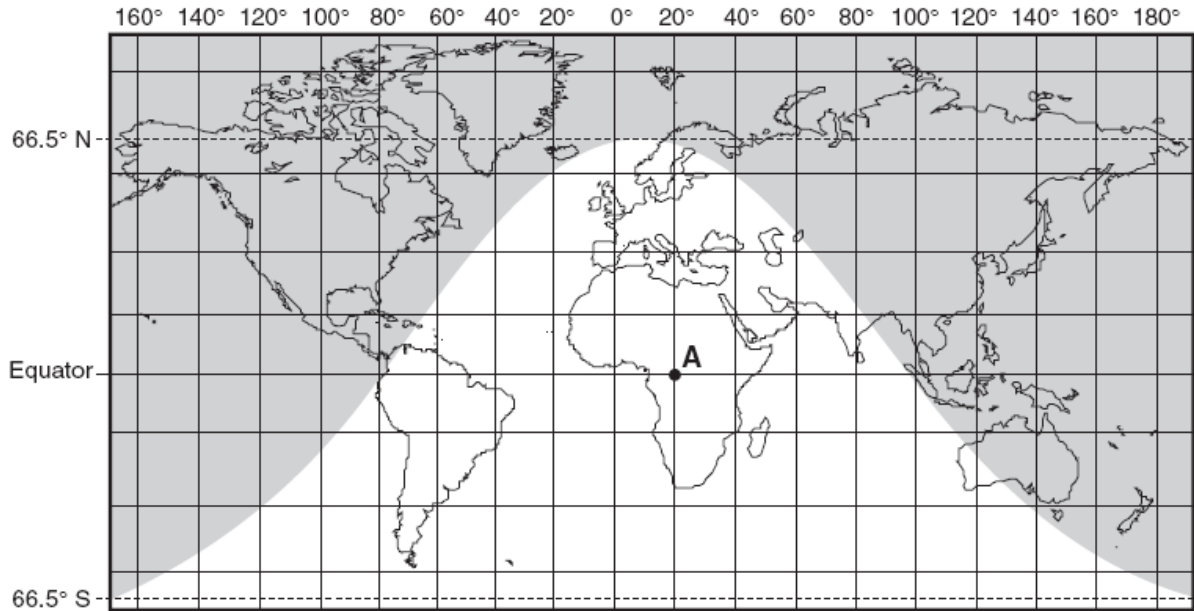
203 From stage B to stage C, the young Sun was created

- (1) when gravity caused the center of the cloud to contract
- (2) when gravity caused heavy dust particles to split apart
- (3) by outgassing from the spinning interstellar cloud
- (4) by outgassing from Earth's interior

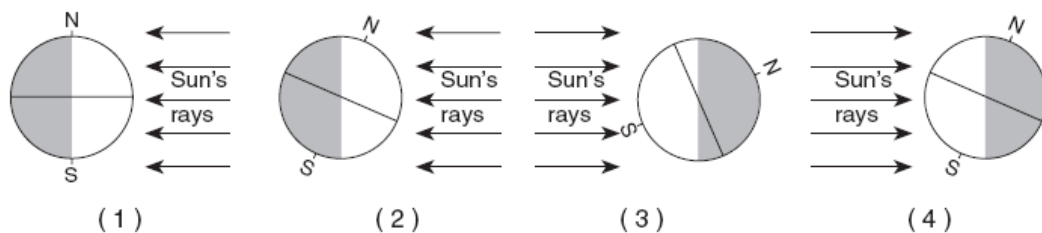
204 After the young Sun formed, the disk of gas and dust

- (1) became spherical in shape
- (2) formed a central bulge
- (3) became larger in diameter
- (4) eventually formed into planets

Base your answers to questions 205 through 207 on the world map below. The shaded portion of the map indicates areas of night, and the unshaded portion indicates areas of daylight on a certain day of the year. Dashed latitude lines represent the Arctic Circle ( $66.5^\circ$  N) and the Antarctic Circle ( $66.5^\circ$  S). Point A is a location on Earth's surface.



205 Which diagram shows the position of Earth relative to the Sun's rays on this day?



206 Approximately how many hours of daylight would occur at position A on this day?

- (1) 6
- (2) 9
- (3) 12
- (4) 15

207 On this day, the duration of daylight from the equator to the Arctic Circle

- (1) decreases, only
- (2) increases, only
- (3) decreases, then increases
- (4) increases, then decreases

208 A Foucault pendulum appears to change its direction of swing over a period of several hours because of Earth's

- (1) rotation
- (2) revolution
- (3) tilted axis
- (4) gravity

211 From which New York State location would *Polaris* be observed to have an altitude closest to  $43^\circ$  above the northern horizon?

- (1) Binghamton
- (2) Utica
- (3) Watertown
- (4) New York City

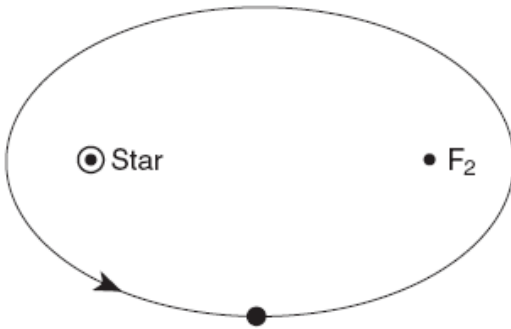
209 The same side of the Moon always faces Earth because the

- (1) Moon's period of rotation is longer than its period of revolution around Earth
- (2) Moon's period of rotation is shorter than its period of revolution around Earth
- (3) Moon rotates once as it completes one revolution around Earth
- (4) Moon does not rotate as it completes one revolution around Earth

212 In October, observers in New York State looking due south at the night sky would see a different group of constellations than they had seen in March. What is the best explanation for this change in the night sky?

- (1) Constellations revolve around Earth.
- (2) Constellations revolve around the Sun.
- (3) The Sun revolves around the center of our galaxy.
- (4) Earth revolves around the Sun.

210 The diagram below shows the elliptical orbit of a planet revolving around a star. The star and  $F_2$  are the foci of this ellipse.

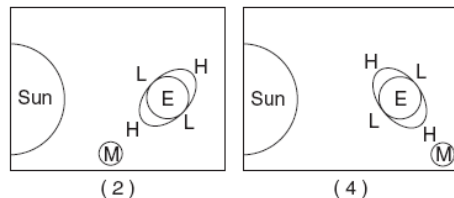
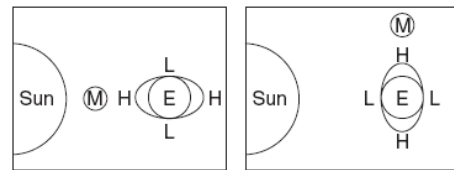


What is the approximate eccentricity of this ellipse?

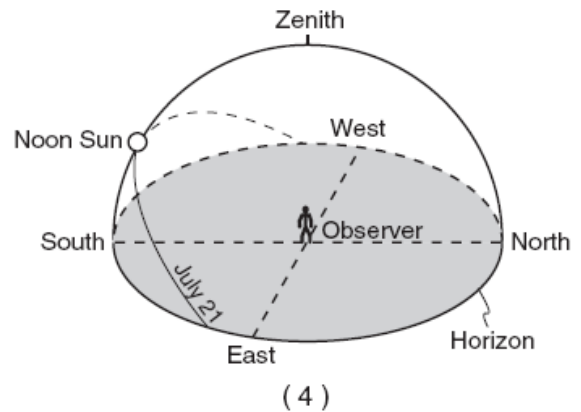
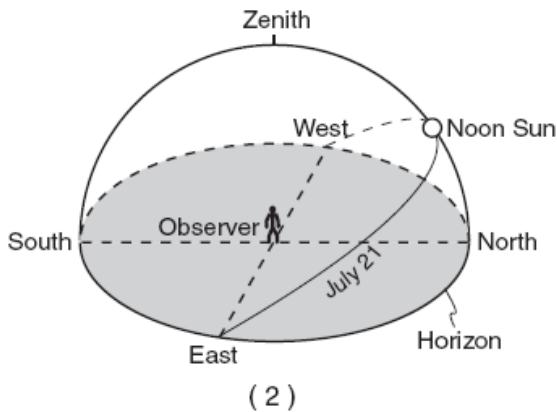
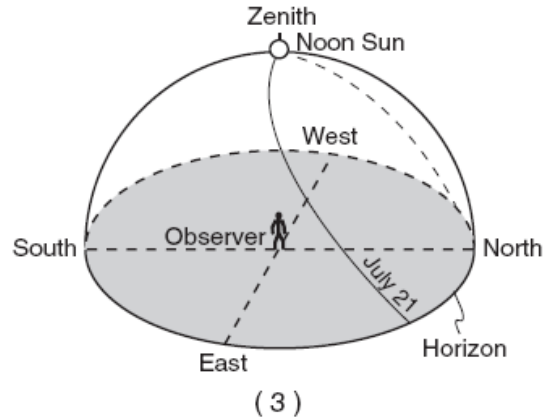
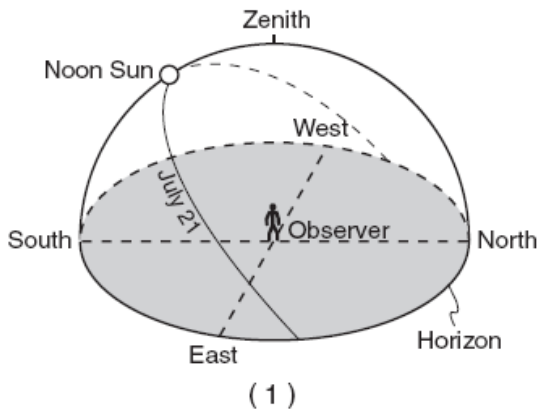
- (1) 0.22
- (2) 0.47
- (3) 0.68
- (4) 1.47

213 The diagrams below represent Earth's ocean tides at four different positions of the Moon. Which diagram shows the Moon position that will produce the highest high tides and the lowest low tides? (The diagrams are not drawn to scale.)

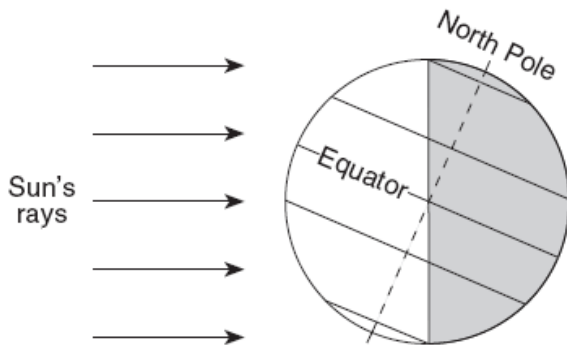
Key	
E = Earth	H = High tide
M = Moon	L = Low tide



214 Which diagram best shows the Sun's apparent path, as seen by an observer on July 21 in New York State?



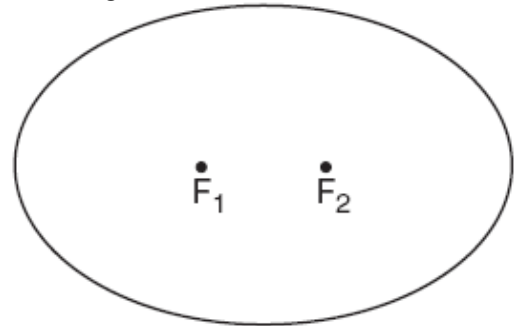
215 The diagram below shows Earth on a particular day in its orbit around the Sun. The dashed line represents Earth's axis.



Which date is represented by the diagram?

- (1) March 21
- (2) June 21
- (3) September 23
- (4) December 21

216 The diagram below is a constructed ellipse.

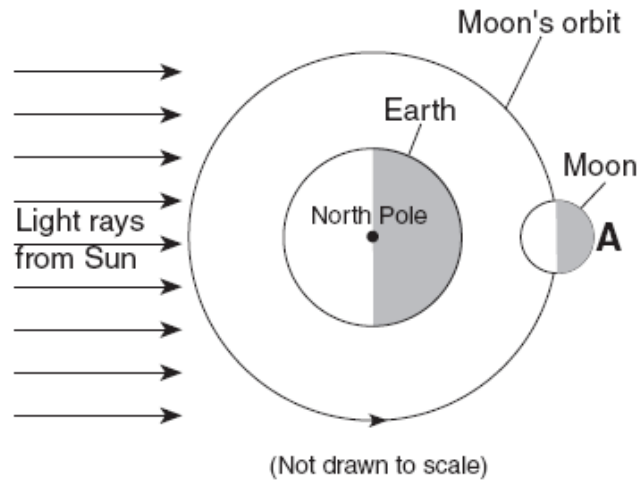


$F_1$  and  $F_2$  are the foci of the ellipse. The eccentricity of this constructed ellipse is closest to the eccentricity of the orbit of which planet?

- (1) Mercury
- (2) Earth
- (3) Saturn
- (4) Pluto

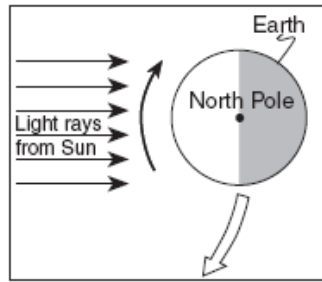


Base your answers to questions 217 and 218 on the diagram below, which shows the Moon, Earth, and the Sun's rays as viewed from space. Letter A indicates a certain position of the Moon in its orbit.

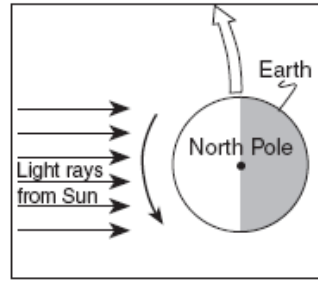


217 Which diagram correctly shows the direction of Earth's rotation and revolution?

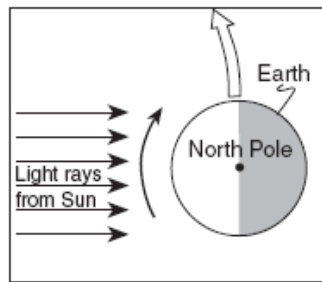
Key	
	Rotation
	Revolution



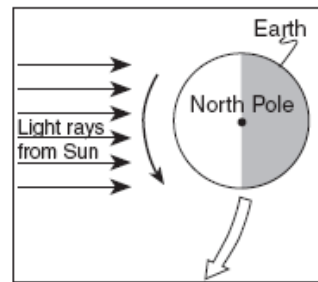
(1)



(3)

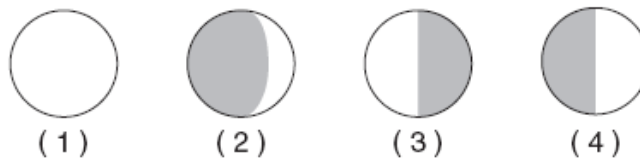


(2)



(4)

218 Which diagram represents the phase of the Moon, as seen by an observer on Earth, when the Moon is located at position A in its orbit?



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Base your answers to questions 219 through 221 on the passage below and on your knowledge of Earth science.

### A Newly Discovered Planet

Scientists studying a Sun-like star named *Ogle-Tr-3* discovered a planet that is, on the average, 3.5 million kilometers away from the star's surface. The planet was discovered as a result of observing a cyclic decrease in the brightness of *Ogle-Tr-3* every 28.5 hours. The changing brightness is the result of the planet blocking some of the starlight when it is between *Ogle-Tr-3* and Earth. This observation allowed scientists to find not only the planet, but also to determine the planet's mass and density. The mass has been calculated to be approximately 159 times the mass of Earth. The planet is only 20% as dense as Jupiter. Scientists think that this low density is the result of being very close to *Ogle-Tr-3*.

219 Compared to the period of revolution of Mercury and Venus, this newly discovered planet's period of revolution is

- (1) shorter than both Mercury's and Venus'
- (2) longer than both Mercury's and Venus'
- (3) shorter than Mercury's but longer than Venus'
- (4) longer than Mercury's but shorter than Venus'

220 The density of the discovered planet has been estimated to be approximately

- (1) 5.5 g/cm<sup>3</sup>
- (2) 2.0 g/cm<sup>3</sup>
- (3) 1.3 g/cm<sup>3</sup>
- (4) 0.3 g/cm<sup>3</sup>

221 The planet was discovered when it passed between Earth and the star *Ogle-Tr-3*. Which event in our solar system results from a similar type of alignment of the Moon between Earth and the Sun?

- (1) summer solstice
- (2) winter solstice
- (3) solar eclipse
- (4) lunar eclipse

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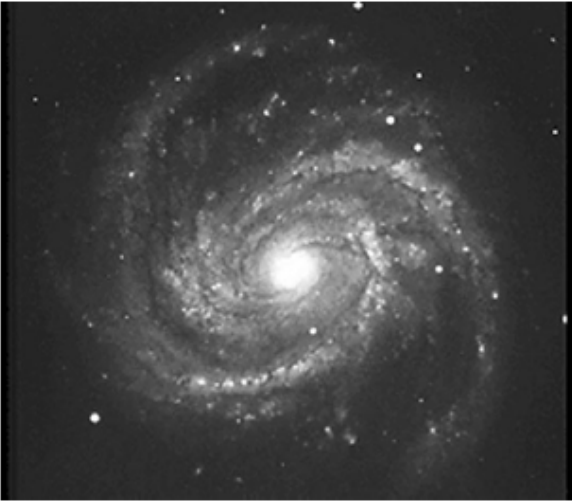
222 Compared to Earth's solar system, the universe is inferred to be

- (1) younger and larger
- (2) younger and smaller
- (3) older and larger
- (4) older and smaller

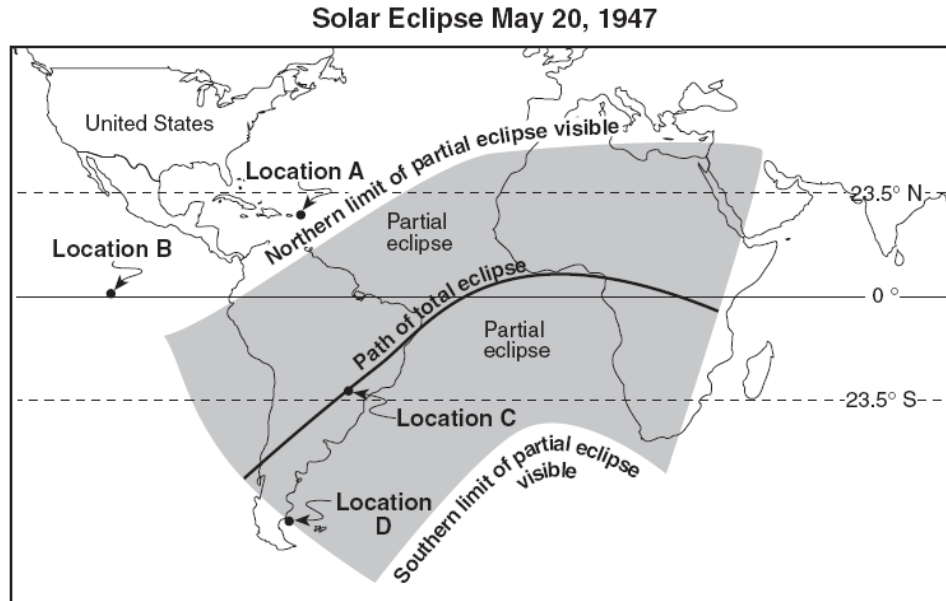
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223 Terrestrial planets move more rapidly in their orbits than the Jovian planets because terrestrial planets are

- (1) rotating on a tilted axis
- (2) more dense
- (3) more massive
- (4) closer to the Sun

<p>224 Which event is a direct result of Earth's revolution?</p> <p>(1) the apparent deflection of winds  (2) the changing of the Moon phases  (3) the seasonal changes in constellations viewed in the night sky  (4) the daily rising and setting of the Sun</p>	<p>227 The cyclic rise and fall of ocean tides on Earth is primarily caused by Earth's rotation and the</p> <p>(1) temperature differences in ocean currents  (2) revolution of Earth around the Sun  (3) direction of Earth's planetary winds  (4) gravitational attraction of the Moon and the Sun</p>
<p>225 The apparent change in direction of a swinging Foucault pendulum is the result of the</p> <p>(1) rotation of Earth  (2) revolution of Earth  (3) tilt of Earth's axis  (4) shape of Earth's orbit</p>	<p>228 Compared to the temperature and luminosity of the star <i>Polaris</i>, the star <i>Sirius</i> is</p> <p>(1) hotter and more luminous  (2) hotter and less luminous  (3) cooler and more luminous  (4) cooler and less luminous</p>
<p>226 The diagram below represents the shape of the Milky Way Galaxy.</p>  <p>The Milky Way Galaxy is best described as</p> <p>(1) elliptical                      (3) circular  (2) irregular                      (4) spiral</p>	<p>229 The Big Bang Theory, describing the creation of the universe, is most directly supported by the</p> <p>(1) redshift of light from distant galaxies  (2) presence of volcanoes on Earth  (3) apparent shape of star constellations  (4) presence of craters on Earth's Moon</p>

Base your answers to questions 230 through 232 on the world map below, which shows regions of Earth where a solar eclipse was visible on May 20, 1947. Locations *A*, *B*, *C*, and *D* are on Earth's surface.



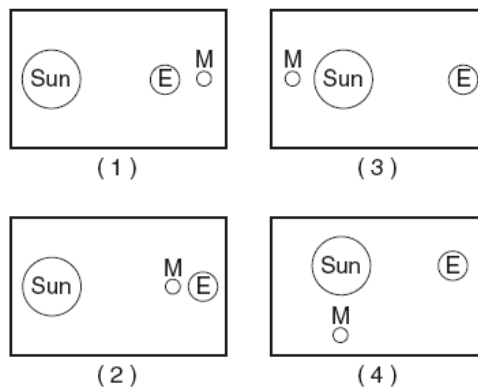
230 At which location could an observer have viewed this total solar eclipse if the skies were clear?

- (1) *A*
- (2) *B*
- (3) *C*
- (4) *D*

231 Which statement best describes the visibility of this eclipse from locations in New York State?

- (1) A total eclipse was visible all day.
- (2) A total eclipse was visible only from noon until sunset.
- (3) A partial eclipse was visible only from noon until sunset.
- (4) Neither a partial nor a total eclipse was visible.

232 Which diagram best represents the positions of Earth (*E*), the Sun, and the Moon (*M*) that created the solar eclipse? (Diagrams are not drawn to scale.)



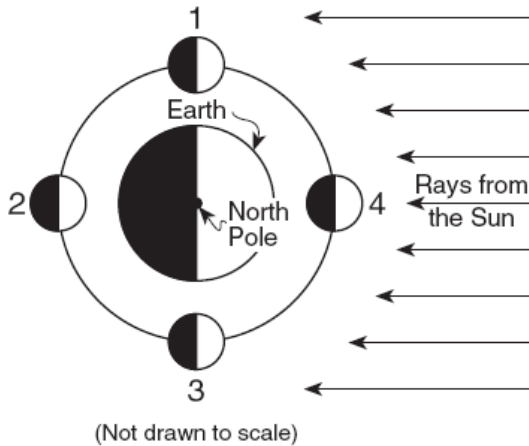
233 One complete cycle of the phases of the Moon takes approximately one

- (1) day (3) month
- (2) week (4) year

237 Which two stars have the most similar luminosity and temperature?

- (1) *Betelgeuse* and *Barnard's Star*
- (2) *Rigel* and *Betelgeuse*
- (3) *Alpha Centauri* and the Sun
- (4) *Sirius B* and *Procyon B*

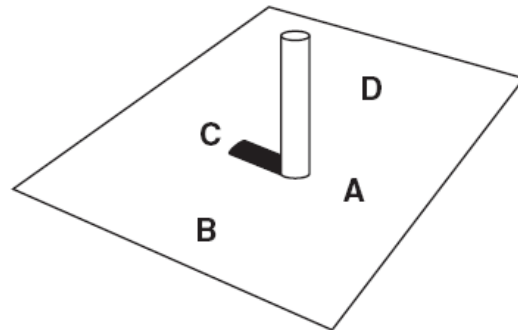
The diagram below shows the Moon at four positions in its orbit around Earth.



234 An observer on Earth could see a solar eclipse when the Moon is at position

- (1) 1 (3) 3
- (2) 2 (4) 4

The diagram below shows the noontime shadow cast by a vertical post located in New York State.



238 Which letter indicates a location west of the post?

- (1) A (3) C
- (2) B (4) D

235 Which planet would float if it could be placed in water?

- (1) Mercury (3) Saturn
- (2) Earth (4) Pluto

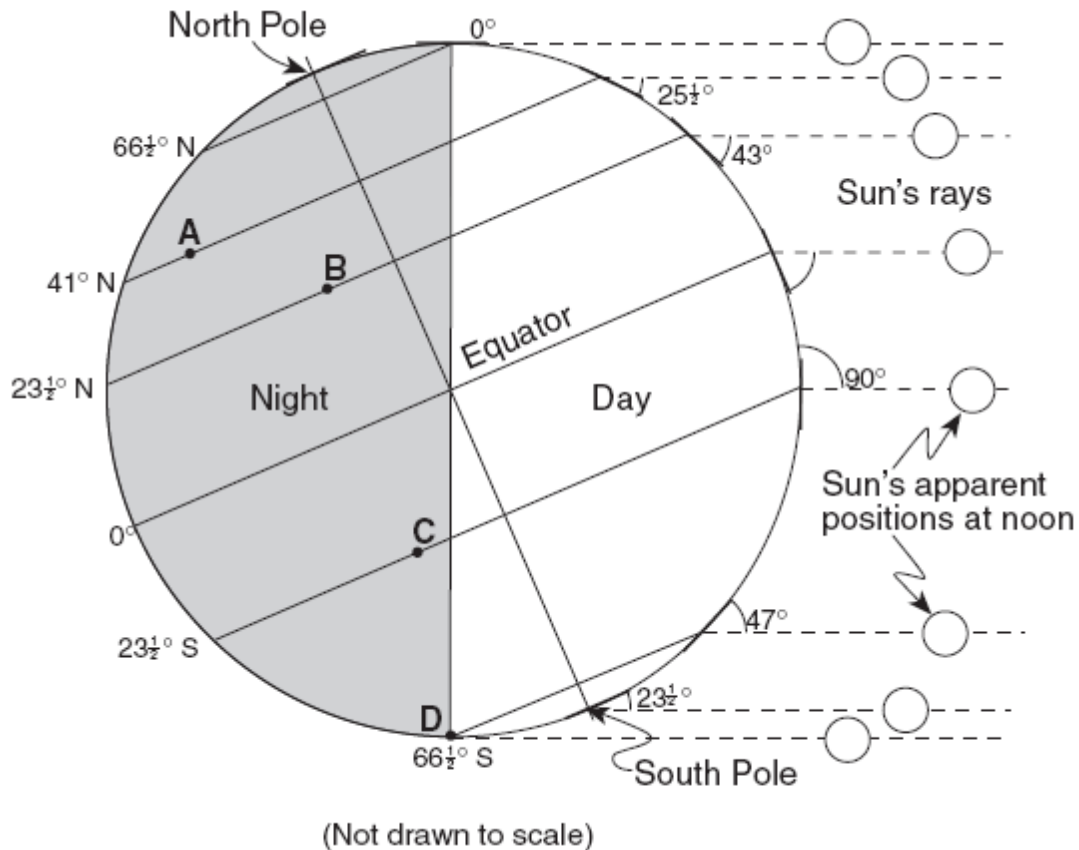
239 On March 21, at which location in New York State would sunrise occur first?

- (1) Riverhead (3) Buffalo
- (2) Syracuse (4) Massena

236 Earth is farthest from the Sun during the Northern Hemisphere's summer, and Earth is closest to the Sun during the Northern Hemisphere's winter. During which season in the Northern Hemisphere is Earth's orbital velocity greatest?

- (1) winter (3) summer
- (2) spring (4) fall

Base your answers to questions 240 through 242 on the diagram below, which shows the altitude and apparent position of the noontime Sun, as seen from various latitudes on Earth on a particular day of the year. Letters *A* through *D* represent locations on Earth's surface.



240 Which lettered location will experience the *shortest* period of daylight during one Earth rotation on this day?

- (1) A
- (2) B
- (3) C
- (4) D

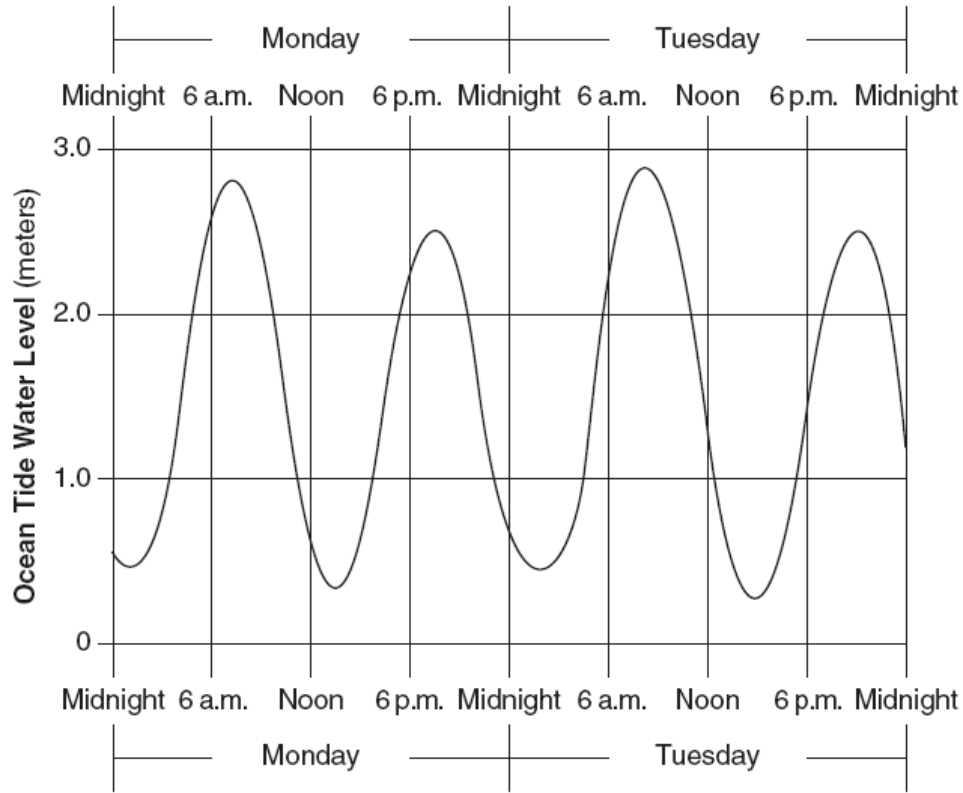
241 What is the altitude of the noontime Sun at the Equator on this date?

- (1)  $23^{\circ}$
- (2)  $43^{\circ}$
- (3)  $66^{\circ}$
- (4)  $90^{\circ}$

242 Which season will begin at  $41^{\circ}$  N latitude, three months after the date represented by this diagram?

- (1) summer
- (2) fall
- (3) winter
- (4) spring

Base your answers to questions 243 through 245 on the graph below, which shows the water levels of ocean tides measured in Boston, Massachusetts, for a 2-day period.



243 The graph shows that high tides at Boston occur approximately every

- (1) 3.5 hours
- (2) 6.0 hours
- (3) 12.5 hours
- (4) 16.0 hours

244 If the trends shown by the graph continue, which statement best describes the next low tide at Boston that is expected to occur on Wednesday?

- (1) It will occur about 3 a.m. with a 0.4-meter water level.
- (2) It will occur about 6 a.m. with a 0.6-meter water level.
- (3) It will occur about 9 p.m. with a 2.6-meter water level.
- (4) It will occur about 10 p.m. with a 2.8-meter water level.

245 The gravitational pull of the Moon has the greatest influence on the water levels of Earth's ocean tides. If the distance between the Moon and Earth were to *decrease* steadily for the week following the time shown on the graph, which water-level changes would be expected to occur?

- (1) High tides would get higher and low tides would get lower.
- (2) High tides would get lower and low tides would get higher.
- (3) Both high tides and low tides would get higher.
- (4) Both high tides and low tides would get lower.

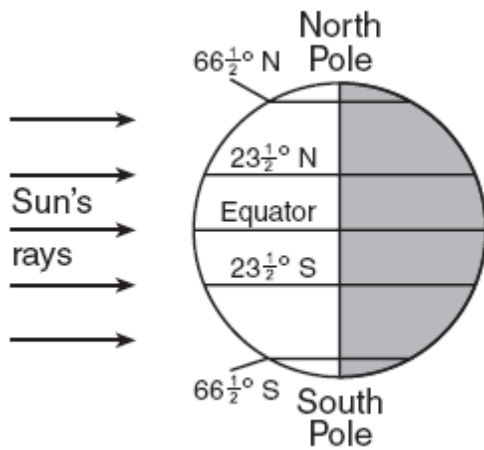
246 Which statement correctly compares the size, composition, and density of Neptune to Earth?

- (1) Neptune is smaller, more gaseous, and less dense.
- (2) Neptune is larger, more gaseous, and less dense.
- (3) Neptune is smaller, more solid, and more dense.
- (4) Neptune is larger, more solid, and more dense.

248 Which star color indicates the hottest star surface temperature?

- (1) blue
- (2) white
- (3) yellow
- (4) red

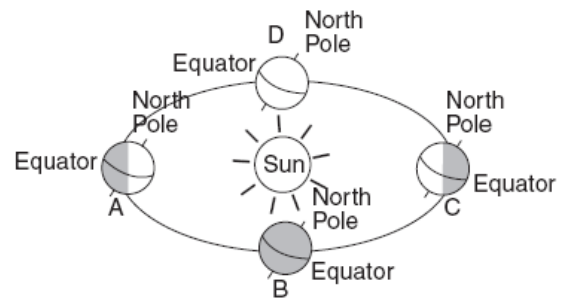
The diagram below represents Earth at a specific position in its orbit as viewed from space. The shaded area represents nighttime.



247 Which Earth latitude receives the greatest intensity of insolation when Earth is at the position shown in the diagram?

- (1) 0°
- (2) 23 °N
- (3) 66 ° N
- (4) 90° N

The diagram below represents Earth at four different positions, A, B, C, and D, in its orbit around the Sun.



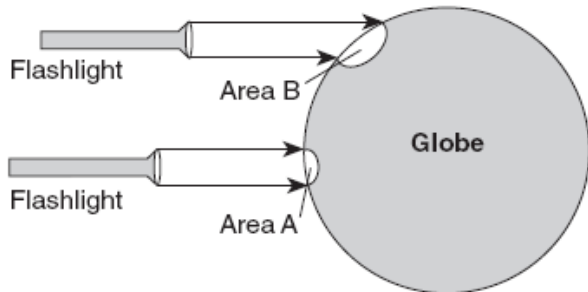
(Not drawn to scale)

249 Between which positions would New York State be experiencing the summer season?

- (1) A and B
- (2) B and C
- (3) C and D
- (4) D and A



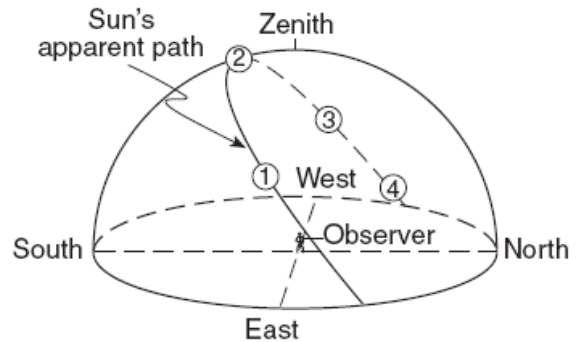
The diagram below shows a classroom demonstration. Two identical flashlights were placed in the positions shown and they illuminated areas of varying size, *A* and *B*, on a classroom globe. Thermometers were then placed at the center of each illuminated area to measure the rate of temperature increase. Readings were taken over a period of 30 minutes.



250 Students most likely observed that the temperature of area *A* increased at a

- (1) slower rate than the temperature of area *B* because area *A* received rays that were less concentrated
- (2) slower rate than the temperature of area *B* because area *A* received rays that were more slanted
- (3) faster rate than the temperature of area *B* because area *A* received rays that were more perpendicular to the surface
- (4) faster rate than the temperature of area *B* because area *A* received rays with less total energy

Base your answers to questions 251 and 252 on the diagram below, which shows numbered positions of the Sun at four different times along the Sun's apparent daily path, as seen by an observer in New York State. Numbers 1 through 4 represent apparent positions of the Sun.



251 The observer had the longest shadow when the Sun was at position

- (1) 1
- (2) 2
- (3) 3
- (4) 4

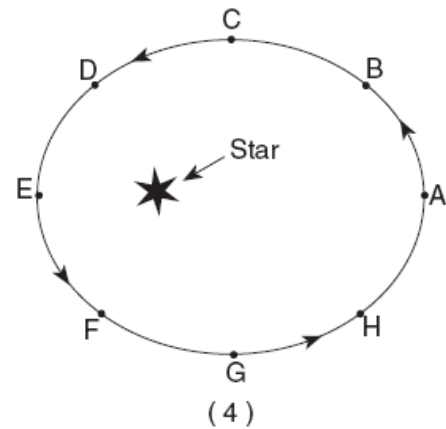
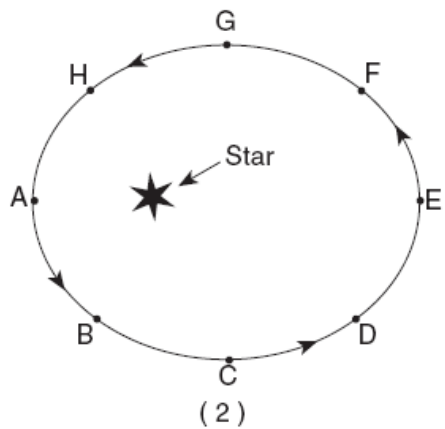
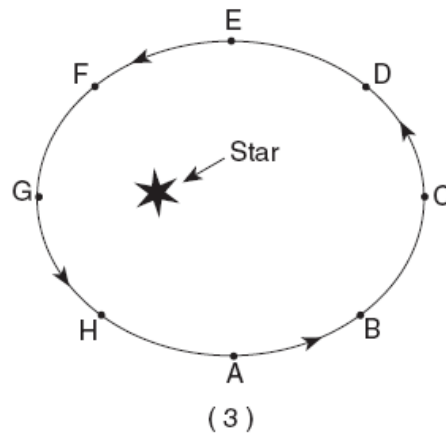
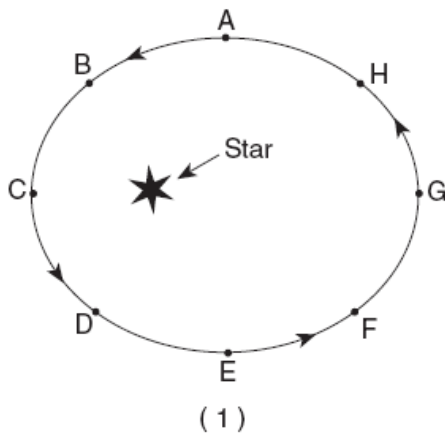
252 During which day of the year is the Sun most likely to follow the apparent path shown?

- (1) March 1
- (2) July 1
- (3) October 1
- (4) December 1

The table below shows gravitational data for a planet traveling in an elliptical orbit around a star. The table shows the relative gravitational force between the star and this planet at eight positions in the orbit (letters *A* through *H*). Higher numbers indicate stronger gravitational attraction.

Planet's Position in the Orbit	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>	<i>G</i>	<i>H</i>
Relative Gravitational Force Between Star and Planet	52	42	25	12	10	12	25	42

253 Which diagram best represents the positions of the planet in its orbit that would produce the gravitational forces shown in the data table?



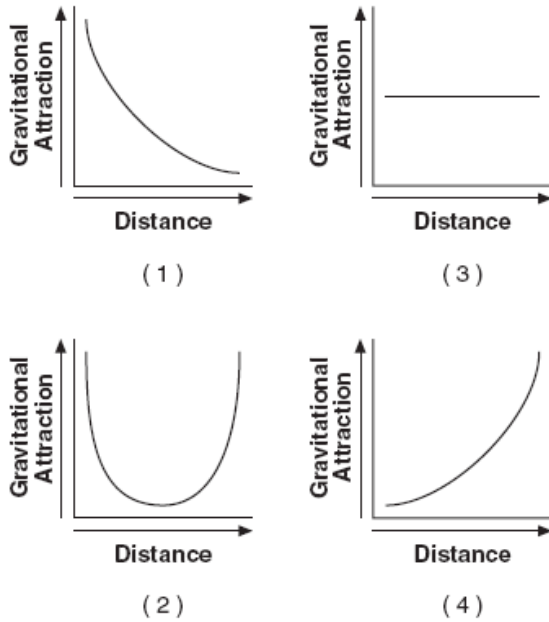
254 The apparent rising and setting of the Sun, as viewed from Earth, is caused by

- (1) Earth's rotation
- (2) Earth's revolution
- (3) the Sun's rotation
- (4) the Sun's revolution

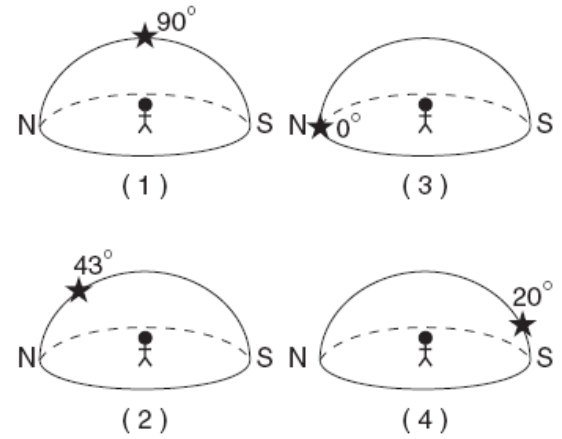
255 In which direction on the horizon does the Sun appear to rise on July 4 in New York State?

- (1) due north
- (2) due south
- (3) north of due east
- (4) south of due east

256 Which graph best represents the change in gravitational attraction between the Sun and a comet as the distance between them increases?



259 Which diagram represents the approximate altitude of *Polaris* as seen by an observer located in Syracuse, New York?



257 The best evidence that Earth spins on its axis is provided by

- (1) variations in atmospheric density
- (2) apparent shifts in the swing of a Foucault pendulum
- (3) changes in the position of sunspots on the Sun
- (4) eclipses of the Moon

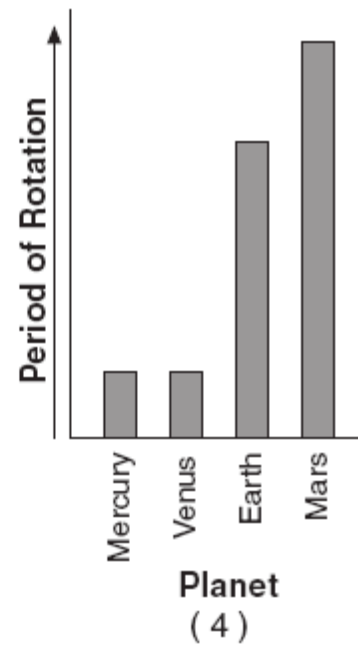
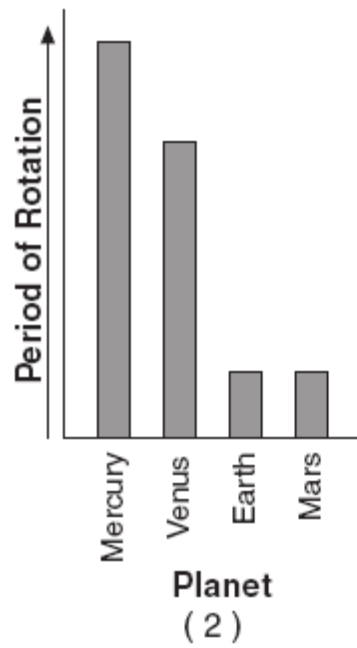
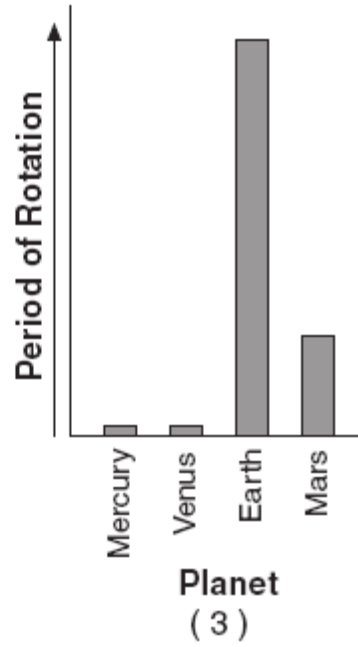
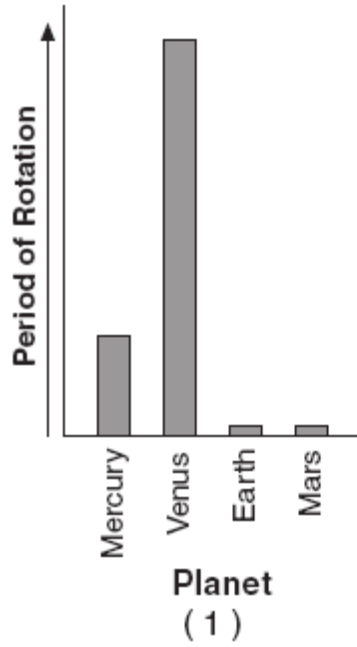
260 A major belt of asteroids is located between Mars and Jupiter. What is the approximate average distance between the Sun and this major asteroid belt?

- (1) 110 million kilometers
- (2) 220 million kilometers
- (3) 390 million kilometers
- (4) 850 million kilometers

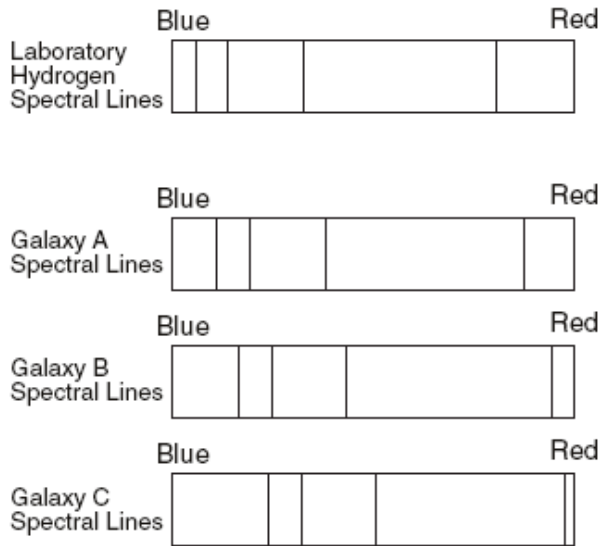
258 A cycle of Moon phases can be seen from Earth because the

- (1) Moon's distance from Earth changes at a predictable rate
- (2) Moon's axis is tilted
- (3) Moon spins on its axis
- (4) Moon revolves around Earth

259 Which graph best represents the relative periods of rotation of Mercury, Venus, Earth, and Mars?

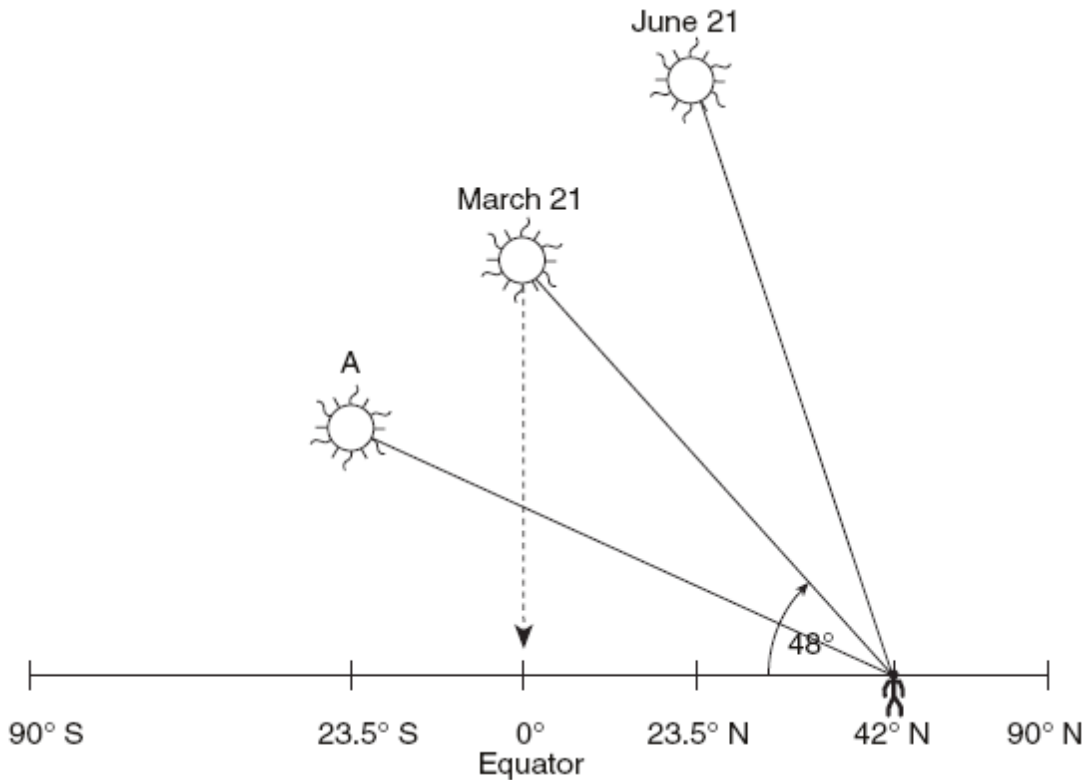


In the diagram below, the spectral lines of hydrogen gas from three galaxies, *A*, *B*, and *C*, are compared to the spectral lines of hydrogen gas observed in a laboratory.



- 260 What is the best inference that can be made concerning the movement of galaxies *A*, *B*, and *C*?
- (1) Galaxy *A* is moving away from Earth, but galaxies *B* and *C* are moving toward Earth.
  - (2) Galaxy *B* is moving away from Earth, but galaxies *A* and *C* are moving toward Earth.
  - (3) Galaxies *A*, *B*, and *C* are all moving toward Earth.
  - (4) Galaxies *A*, *B*, and *C* are all moving away from Earth.

Base your answers to questions 261 through 263 on the diagram below, which represents the position of the Sun with respect to Earth's surface at solar noon on certain dates. The latitudes of six locations on the same line of longitude are shown. The observer is located at 42° N in New York State. The date for the Sun at position A has been deliberately left blank.



261 At which New York State location could the observer be located?

- (1) Plattsburgh      (3) New York City
- (2) Mount Marcy    (4) Slide Mountain

262 When the Sun is at position A, which latitude receives the most direct rays of the Sun?

- (1) Tropic of Cancer (23.5° N)
- (2) Tropic of Capricorn (23.5° S)
- (3) Equator (0°)
- (4) Antarctic Circle (66.5° S)

263 When the Sun is at the March 21 position, New York State will usually have

- (1) longer days than nights
- (2) 12 hours of daylight and 12 hours of darkness
- (3) the lowest annual altitude of the Sun at solar noon
- (4) the highest annual altitude of the Sun at solar noon