Do not use a calculator. To simplify numerical calculations, use $g = 10\ m/s^2$.

PART A

Directions: In this section of the exam, the same lettered choices are used to answer several questions. Each group of questions is preceded by five lettered choices. When answering questions in each group, select the best answer from the available choices and fill in the corresponding bubble on the answer sheet. Each possible answer may be used once, more than once, or not at all.

Questions 1–3

(A) Alpha decay
(B) Beta decay
(C) Gamma ray
(D) Fission
(E) Fusion

Select the term from above that identifies the nuclear reactions described in questions 1 to 3.

1. An isotope of bismuth, ${}^{214}_{83}Bi$, undergoes a transmutation into an isotope of polonium, ${}^{214}_{84}Po$.

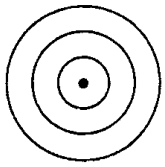
2. ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{90}_{38}Sr + {}^{143}_{54}Xe + 3n + \text{Energy}$

3. An isotope of thorium, ${}^{227}_{90}Th$, undergoes a transmutation into an isotope of radium, ${}^{223}_{88}Ra$.

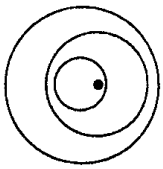
Questions 4–6

The following diagrams depict sound waves moving outward from a sound source.

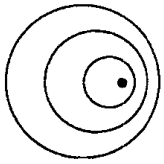
(A)



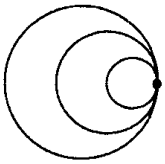
(B)



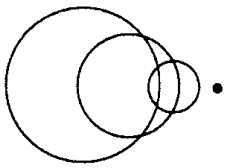
(C)



(D)



(E)



4. Which diagram depicts the sound waves created by a source moving with a speed v that is equal to the speed of sound?

5. Which diagram depicts the sound waves created by a source moving with a speed v that is less than the speed of sound?

6. Which diagram depicts the sound waves created by a source moving with a speed v that is greater than the speed of sound?

Questions 7–9

The following terms relate to circuits. Match the correct term with its definition.

(A) Capacitance
(B) Current
(C) Power
(D) Resistance
(E) Voltage

7. The rate of charge flow.

8. The rate of energy dissipation in a circuit.

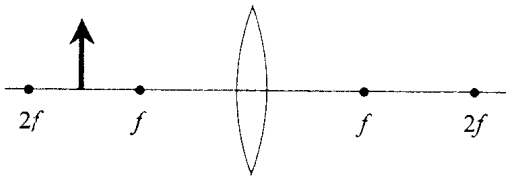
9. The potential difference between the terminals of the battery.

Questions 10–12

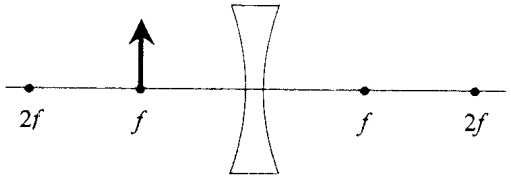
Match the correct image description with the optical instruments depicted in questions 10 to 12.

(A) Real and inverted
(B) Real and upright
(C) No image forms, ray traces never intersect
(D) Virtual and inverted
(E) Virtual and upright

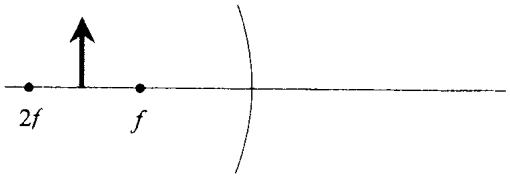
10.



11.



12.

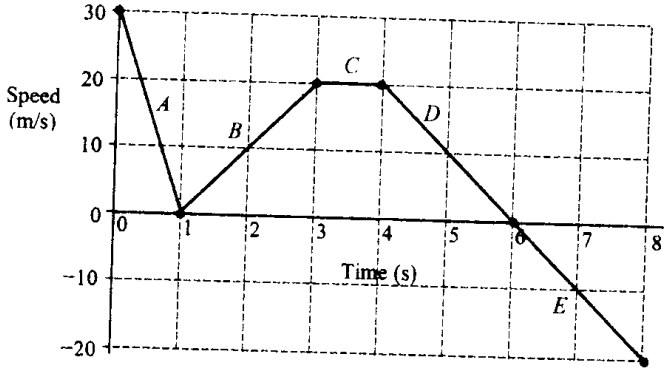


PART B

Directions: This section of the exam consists of questions or incomplete statements followed by five possible answers or completions. Select the best answer or completion, and fill in the corresponding bubble on the answer sheet.

Questions 13–15

Use the following speed-time graph for the motion of an object to solve questions 13 to 15.



13. Determine the displacement during the first second (interval *A*).

(A) 10 m
(B) 15 m
(C) 20 m
(D) 25 m
(E) 30 m

14. During which interval is the object moving with a constant velocity?

(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *A*, *B*, *D*, and *E*

15. Which of the following is true when $t = 6$ seconds?

I. The object is accelerating.
II. The object has an instantaneous speed of zero.
III. The object has returned to the origin.

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

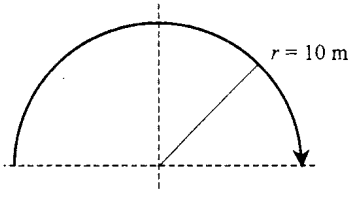
---

16. If a ball is thrown straight upward with an initial velocity of v, it will reach a height of h. If the initial speed of the ball is doubled, what will be the new maximum height?

(A) $\sqrt{2}(h)$
(B) $2h$
(C) $2\sqrt{2}(h)$
(D) $4h$
(E) $4\sqrt{2}(h)$

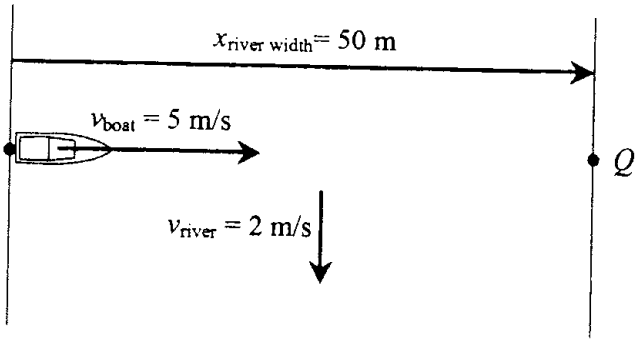
17. A mass, initially at rest, is accelerated uniformly at 5.0 meters per second squared. Determine the displacement and final speed of the mass after 2.0 seconds have passed.

	Displacement	Final speed
(A)	10 m	10 m/s
(B)	20 m	20 m/s
(C)	40 m	20 m/s
(D)	60 m	30 m/s
(E)	80 m	40 m/s



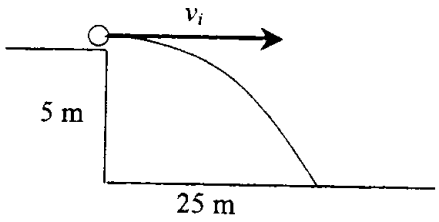
18. During a time of 5.0 seconds, an object moves through a half circle with a radius of 10 meters, as shown above. What is the magnitude of the object's velocity during this motion?

(A) 2 m/s
(B) π m/s
(C) 4 m/s
(D) 2π m/s
(E) 4π m/s



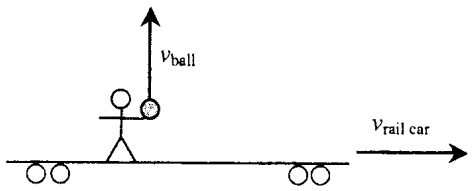
19. A boat capable of moving at 5 meters per second attempts to cross a 50-meter-wide river. The river flows downstream at 2 meters per second. The boat begins at point P and aims for point Q, a point directly across the river. How far downstream, from point Q, will the boat drift?

(A) 0 m
(B) 10 m
(C) 20 m
(D) 30 m
(E) 40 m



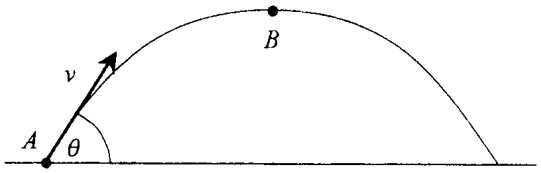
20. A ball is thrown horizontally from the edge of a 5-meter-tall building. It lands 25 meters from the base of the building, as shown in the diagram above. With what initial speed was the ball thrown?

(A) 5 m/s
(B) 10 m/s
(C) 15 m/s
(D) 20 m/s
(E) 25 m/s



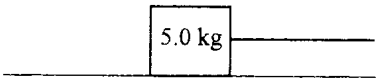
21. A flat railroad car is moving to the right at 5 m/s. A person standing on the car throws a ball straight upward at 20 m/s. If air resistance is negligible, where will the ball be *in relation to the person's new position* at the time when the ball returns to its original starting height?

(A) The ball will land 20 meters in front of the person.
(B) The ball will land 10 meters in front of the person.
(C) The ball will land in the person's hand.
(D) The ball will land 10 meters behind the person.
(E) The ball will land 20 meters behind the person.



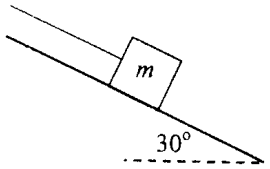
22. The diagram above depicts a projectile launched from point A with a speed of v at angle of θ, above the horizontal. Determine the speed of the projectile when it reaches its maximum height at point B.

(A) 0
(B) v
(C) $\frac{1}{2}v$
(D) $v\cos\theta$
(E) $v\sin\theta$



23. A 5.0-kilogram mass is pulled along a rough horizontal surface by a string, as shown above. The coefficient of kinetic friction between the surface and the object is 0.10. The tension in the string is 30 newtons. Determine the acceleration of the object.

(A) 1 m/s^2
(B) 2 m/s^2
(C) 3 m/s^2
(D) 4 m/s^2
(E) 5 m/s^2



24. Mass m is positioned on a frictionless 30° incline, as shown above. It is kept stationary by a string that is parallel to the incline. Determine the tension in the string.

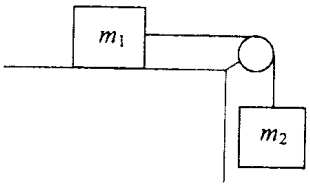
(A) $\frac{1}{4}mg$

(B) $\frac{1}{2}mg$

(C) $\frac{\sqrt{2}}{2}mg$

(D) mg

(E) $2mg$



25. Two masses, $m_1 = 1$ kg and $m_2 = 3$ kg, are connected by a string that is draped over a pulley, as shown above. Mass 1 is positioned on a frictionless horizontal surface, while mass 2 hangs freely. The masses are released from rest. Determine the acceleration of mass 2.

(A) 2.5 m/s^2

(B) 3.3 m/s^2

(C) 5.0 m/s^2

(D) 6.7 m/s^2

(E) 7.5 m/s^2

26. Earth ($m = 5.98 \times 10^{24}$ kilograms) pulls a 60-kilogram person towards it with a force of 600 N. With what amount of force does the person pull Earth towards themselves?

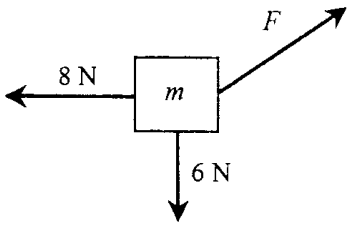
(A) 0 N

(B) $\frac{1}{600}$ N

(C) 60 N

(D) 600 N

(E) 5.98×10^{24} N

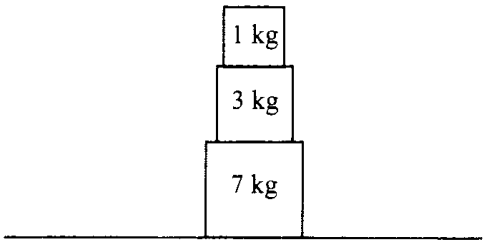


27. Three forces act on a mass, m, as shown in the diagram above. The mass remains at rest. Determine the magnitude of force F.

(A) 6 N
(B) 8 N
(C) 10 N
(D) 12 N
(E) 14 N

28. What is the apparent weight of a 60-kilogram astronaut that is experiencing a rocket launch with an acceleration of 40 meters per second squared?

(A) 600 N
(B) 1,200 N
(C) 1,800 N
(D) 2,400 N
(E) 3,000 N

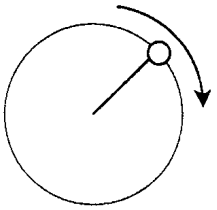


29. Three masses are stacked on top of each other and are resting on the floor, as shown above. Determine the net force acting on the 3-kilogram mass.

(A) 0 N
(B) 10 N
(C) 20 N
(D) 30 N
(E) 40 N

Questions 30–31

A 1.0-kilogram mass is attached to the end of a 1.0-meter-long string. When the apparatus is swung in a vertical circle, the tension in the rope at the very bottom of the circle has a magnitude of 110 newtons.



30. Determine the speed of the mass at the lowest point in the circle.

(A) 5 m/s
(B) 10 m/s
(C) 25 m/s
(D) 55 m/s
(E) 110 m/s

31. Determine the minimum speed needed at the top of the loop in order for the mass to complete one cycle.

(A) 1.0 m/s
(B) 2.5 m/s
(C) $\sqrt{10}$ m/s
(D) $5\sqrt{10}$ m/s
(E) 10 m/s

Questions 32–33

A 5.0-kilogram mass is moving in uniform circular motion with a radius of 1.0 meter and a frequency of 3.0 hertz.

32. Determine the tangential velocity of the mass.

(A) $\frac{1}{6}\pi$ m/s
(B) $\frac{2}{3}\pi$ m/s
(C) $\frac{3}{2}\pi$ m/s
(D) 3π m/s
(E) 6π m/s

33. Determine the centripetal acceleration of the mass.

(A) $3\pi^2$ m/s^2
(B) $6\pi^2$ m/s^2
(C) $12\pi^2$ m/s^2
(D) $36\pi^2$ m/s^2
(E) $72\pi^2$ m/s^2

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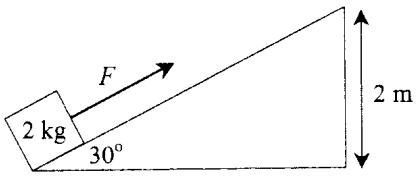
34. A car of mass m makes a turn with a radius of r. The coefficient of friction between the tires and the road is μ. The maximum speed that the car can make the turn *without* skidding is v. If the mass of the car is doubled, what is the new maximum speed in the turn?

(A) $\frac{1}{4}v$
(B) $\frac{1}{2}v$
(C) v
(D) $2v$
(E) $4v$

Questions 35–37

A 2.0-kilogram mass is pulled up a frictionless 30° incline at a constant speed of 0.5 meters per second.



35. Determine the force, F, required to move up the incline at a constant speed of 0.5 m/s.

(A) 5 N
(B) 10 N
(C) 15 N
(D) 20 N
(E) 25 N

36. Determine the work done by force F to move the mass to a vertical height of 2.0 meters.

(A) 0 J
(B) 5 J
(C) 10 J
(D) 20 J
(E) 40 J

37. Determine the power required to move the mass up the incline at constant speed.

(A) 0 W
(B) 2.5 W
(C) 5.0 W
(D) 10 W
(E) 20 W

38. A 3.0-kilogram block is pressed against a spring that has a spring constant of 300 newtons per meter, as shown above. The block is moved to the left until the spring has been compressed 0.10 meters. The block and compressed spring are held in this stationary position for a brief amount of time. Finally, the block is released and the spring pushes the block to the right. What is the maximum speed reached by the block?

(A) 0 m/s
(B) 1 m/s
(C) 2 m/s
(D) 5 m/s
(E) 10 m/s

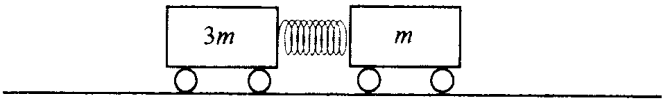
39. What amount of force is required to change the speed of a 1,500-kilogram car by 10 meters per second in a time of 5 seconds?

(A) 500 N
(B) 1,000 N
(C) 2,000 N
(D) 3,000 N
(E) 6,000 N

40. Which of these is true during an inelastic collision, in which no external forces act?

I. Linear momentum is conserved.
II. Kinetic energy is conserved.
III. The system loses energy as heat.

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



41. Two carts with masses $3m$ and m are placed on a horizontal track with a compressed spring positioned between them. The carts are released from rest. The $3m$ cart moves to the left with a speed of v. What is the speed of the cart on the right in the diagram above?

(A) $\frac{1}{3}v$

(B) $\frac{1}{2}v$

(C) v

(D) $2v$

(E) $3v$

42. A satellite of mass m orbits Earth at a height of h and a speed of v. What would the speed be for a satellite of mass $3m$ at a height of h?

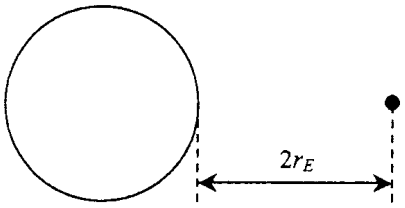
(A) $\frac{1}{3}v$

(B) v

(C) $\sqrt{3}v$

(D) $3v$

(E) $9v$



43. Determine the acceleration of gravity, in terms of g, at a point in space that is located a distance equal to two Earth radii ($2r_E$) above the surface of Earth, shown in the figure above.

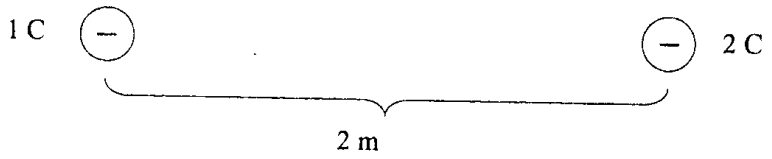
(A) $\frac{1}{9}g$

(B) $\frac{1}{4}g$

(C) $\frac{1}{3}g$

(D) $\frac{1}{2}g$

(E) g



44. Determine the magnitude of the electric force acting on the 1-coulomb charge in the diagram above in terms of the Coulomb's law constant, k.

(A) $\frac{1}{4}k$

(B) $\frac{1}{2}k$

(C) k

(D) $2k$

(E) $4k$

45. The direction of an electric field is

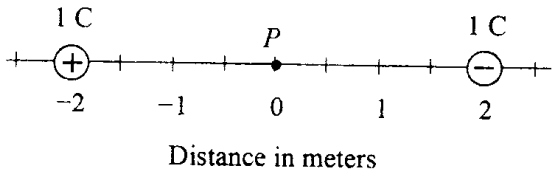
(A) determined by Lenz's law

(B) determined by the right-hand rule

(C) the same as the direction of force acting on any type of charge

(D) the same as the direction of force acting on a negative charge

(E) the same as the direction of force acting on a positive charge



46. In the diagram, a +1-coulomb charge is located 2 meters to the left of the origin. A −1-coulomb charge is located 2 meters to the right of the origin. Determine the electric potential, in terms of the Coulomb's law constant, k, at point P located at the origin.

(A) zero

(B) $\frac{1}{4}k$

(C) $\frac{1}{2}k$

(D) k

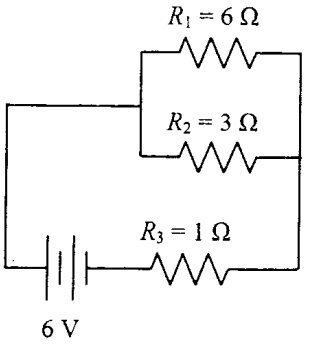
(E) $2k$

47. A conducting sphere with a mass of 1.0 kilograms and a charge of 3.0 coulombs is initially at rest. Determine its speed after being accelerated through a 6.0-volt potential difference.

(A) 2.0 m/s
(B) 3.0 m/s
(C) 4.0 m/s
(D) 5.0 m/s
(E) 6.0 m/s

Questions 48–50

Use the following circuit diagram to answer questions 48 to 50.



48. What current flows through the 1 Ω resistor?

(A) 0.5 A
(B) 1.0 A
(C) 2.0 A
(D) 3.0 A
(E) 4.0 A

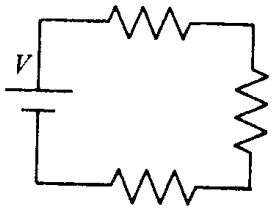
49. What is the voltage drop across the 1 Ω resistor?

(A) 2 V
(B) 4 V
(C) 6 V
(D) 8 V
(E) 10 V

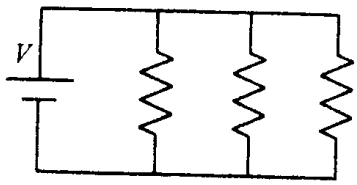
50. How much power is dissipated in the 1 Ω resistor each second?

(A) 4 W
(B) 10 W
(C) 16 W
(D) 20 W
(E) 32 W

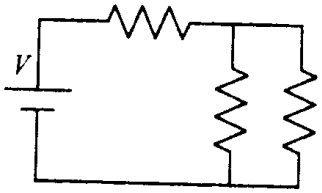
I.



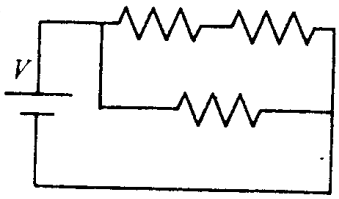
II.



III.

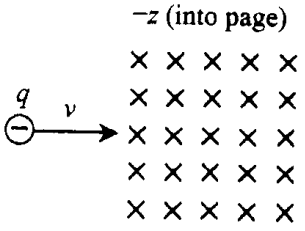


IV.



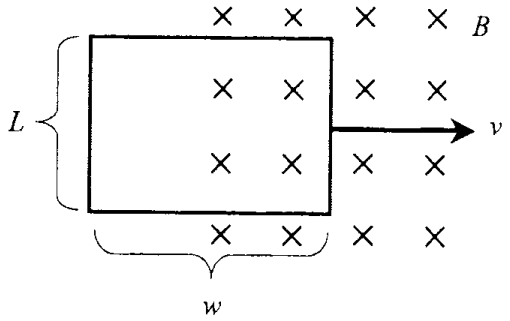
51. In the circuit diagrams above, the resistors represent identical lightbulbs. Which circuit will have the brightest lightbulbs?

(A) I only
(B) II only
(C) III only
(D) IV only
(E) The brightness of the lightbulbs is the same in each circuit.



52. Charge q moving with speed v in the $+x$-direction enters a uniform $-z$ magnetic field, B, as shown in the diagram above. In what direction is the force of magnetism acting on the charge at the instant the charge first enters the magnetic field?

(A) $+x$
(B) $+y$
(C) $-y$
(D) $+z$
(E) $-z$



53. The induced emf in the loop at the instant shown in the diagram above is

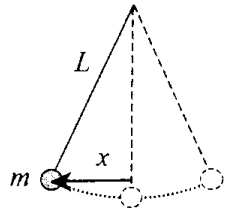
(A) 0

(B) BLv

(C) $\frac{BLv}{w}$

(D) Bwv

(E) $\frac{v}{BLw}$



54. A pendulum is constructed with a string of length L and a mass m, as shown above. When the pendulum bob is displaced a distance x from equilibrium, its period of oscillation is T. What will be the new period if the mass, m, and the displacement from equilibrium, x, are both doubled?

(A) $\frac{1}{4}T$

(B) $\frac{\sqrt{2}}{2}T$

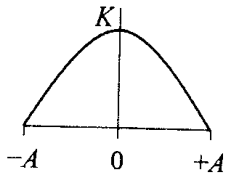
(C) T

(D) $\sqrt{2}T$

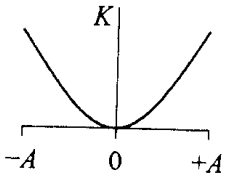
(E) $4T$

55. Which graph correctly depicts the kinetic energy of a mass experiencing simple harmonic motion?

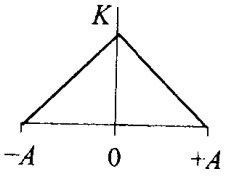
(A)



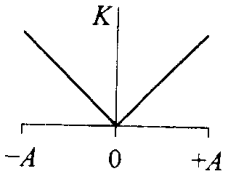
(B)



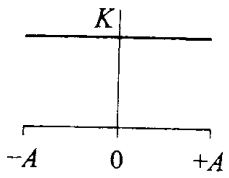
(C)



(D)

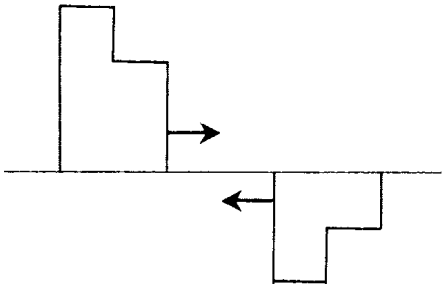


(E)



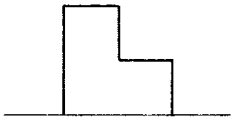
56. A sound wave emitted by a source has a frequency f, a velocity v, and a wavelength λ. If the frequency is doubled, how will the speed and wavelength be affected?

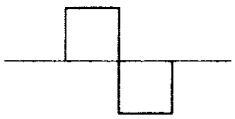
(A) v, λ
(B) $2v, \lambda$
(C) $v, 2\lambda$
(D) $\frac{1}{2}v, \lambda$
(E) $v, \frac{1}{2}\lambda$



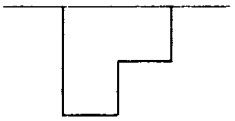
57. The two wave pulses shown above are moving toward one another. Which diagram depicts the waveform at the instant that the waves overlap and superimpose?

(A) 

(B) 

(C) 

(D) 

(E) 

58. A guitar string vibrates in a manner resulting in a standing wave having a wavelength λ being formed in the string. A listener hears the fundamental frequency, f_1, for this particular string. The string is plucked a second time in a manner that produces the second harmonic for this string. How does the wavelength for the second harmonic compare with the wavelength at the fundamental frequency?

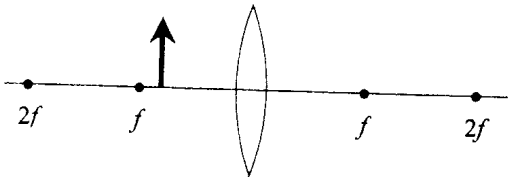
(A) $\frac{1}{2}\lambda$

(B) $\frac{\sqrt{2}}{2}\lambda$

(C) λ

(D) $\sqrt{2}\lambda$

(E) 2λ

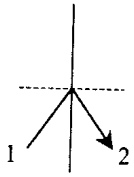


59. The object viewed by a convex lens is positioned just inside of the focus, as shown in the diagram above. Which of the following correctly describes the image?

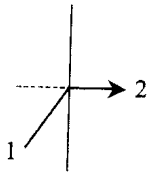
(A) No image is formed
(B) Real and upright
(C) Real and inverted
(D) Virtual and upright
(E) Virtual and inverted

60. Which diagram below correctly illustrates the path of a light ray moving from point 1 in air (to the left of the solid line) to point 2 in glass (to the right of the solid line)?

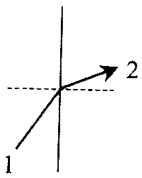
(A)



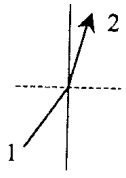
(B)



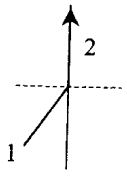
(C)



(D)



(E)



61. An image formed by a convex mirror is

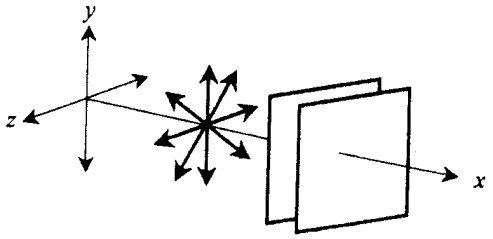
(A) real and upright
(B) real and inverted
(C) virtual and upright
(D) virtual and inverted
(E) No image is formed by this mirror.

62. Monochromatic light with wavelength λ passes through two narrow slits that are a distance d apart. The resulting interference pattern appears as a series of alternating bright and dark regions on a screen located a length L meters behind the slits. How could the experiment be altered so that the spacing between bright regions on the screen is decreased?

(A) Use light with a shorter wavelength.
(B) Decrease the distance from the slits to the screen.
(C) Increase the distance between the slits.
(D) Perform the experiment under water.
(E) All of the above.

63. The bending of light as it passes through a narrow opening, or slit, is known as

(A) absorption
(B) diffraction
(C) interference
(D) polarization
(E) refraction



64. Unpolarized light is projected onto two polarizing filters, as shown above. The polarizing filters contain thin threads all oriented parallel to one another. The filters are rotated with respect to each other, and two key positions are identified. In one position, no light is transmitted through the filter. In the other position, the maximum amount of light is transmitted. How must the microscopic threads in the two filters be oriented so that these results are witnessed?

	No light transmitted	Maximum light transmitted
(A)	Parallel	Parallel
(B)	Parallel	Perpendicular
(C)	Perpendicular	Parallel
(D)	Perpendicular	Perpendicular

(E) No solution exists that allows for these observations.

65. A gas is trapped in a cylinder with a movable piston. How is the temperature, T, of the gas affected if the pressure of the gas doubles while the piston is moved inward, reducing the volume by half?

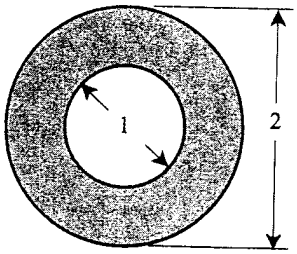
(A) $\frac{1}{4}T$

(B) $\frac{1}{2}T$

(C) T

(D) $2T$

(E) $4T$



66. A metal washer is a flat, circular piece of metal with a hole through its center, as pictured above. What will be the effect of heating this washer?

(A) No change occurs as the effects on the diameters cancel.

(B) Diameter 1 will decrease, and diameter 2 will decrease.

(C) Diameter 1 will decrease, and diameter 2 will increase.

(D) Diameter 1 will increase, and diameter 2 will decrease.

(E) Diameter 1 will increase, and diameter 2 will increase.

67. The specific heat of a liquid is 2,000 joules/kilogram • kelvin. How much heat is required to raise the temperature of 3.0 kilograms of this liquid from 10°C to 30°C?

(A) 300 J
(B) 13,333 J
(C) 30,000 J
(D) 60,000 J
(E) 120,000 J

68. During an isothermal process, 600 joules of heat are removed from a trapped gas. Determine the work done on or by the gas and the change in internal energy of the system.

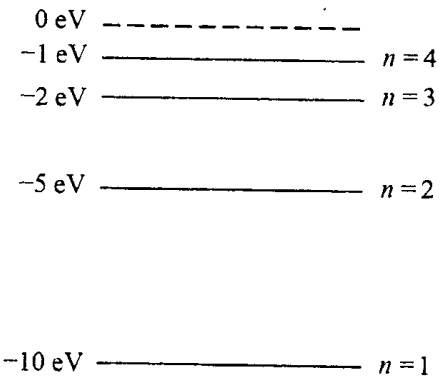
(A) $W = 0$ J; $\Delta U = -600$ J
(B) $W = 0$ J; $\Delta U = +600$ J
(C) $W = -600$ J; $\Delta U = 0$ J
(D) $W = +600$ J; $\Delta U = 0$ J
(E) None of the above.

69. Which of the following is true about an isometric process?

(A) No work is done.
(B) No change in volume occurs.
(C) No heat is exchanged.
(D) Both A and B.
(E) Both A and C.

70. A heat engine operates between 100°C and 500°C. The theoretical efficiency is most nearly

(A) 10%
(B) 20%
(C) 50%
(D) 70%
(E) 80%



71. The energy level diagram above shows a sample of atoms initially in the ground state. The atoms are radiated by photons having 9 electron volts of energy. After the absorption, photons are emitted by the sample of atoms. Several energies for the emitted photons are listed below. Which of these energies is NOT possible for photons emitted by the atom diagrammed above?

(A) 1 eV
(B) 2 eV
(C) 3 eV
(D) 5 eV
(E) 8 eV

72. In a photoelectric experiment, the frequency of light is steadily increased. Which statement below is NOT correct?

(A) Below the threshold frequency, no electrons are emitted.
(B) Above the threshold frequency, electrons are emitted.
(C) Increasing the frequency of light increases the energy of the emitted electrons.
(D) Increasing the frequency of light increases the potential difference of the photocell.
(E) Increasing the frequency of light increases the induced current.

73. A radioactive sample with a half-life of 25 days is analyzed after 100 days. The amount of remaining radioactive material as a fraction of the original sample is most nearly

(A) $\frac{1}{32}$
(B) $\frac{1}{16}$
(C) $\frac{1}{8}$
(D) $\frac{1}{4}$
(E) $\frac{1}{2}$

74. A spacecraft with a speed of $0.99c$ in the $+x$-direction passes by a stationary observer. The dimensions of the spacecraft will appear altered along which axis/axes?

(A) x only
(B) y only
(C) z only
(D) y and z only
(E) x, y, and z

75. Which scientist proposed three laws of planetary motion based upon observations of the orbit of Mars?

(A) Galileo Galilei
(B) Johann Kepler
(C) James Maxwell
(D) Albert Michelson
(E) Isaac Newton