1993
AP Physics B Examination
with Key



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$x = 0.075m$
$F = kx \quad k = \frac{F}{x} \frac{5N}{0.075} = 66$

1. In which of the following situations would an object be accelerated?

   I. It moves in a straight line at constant speed.
   II. It moves with uniform circular motion.
   III. It travels as a projectile in a gravitational field with negligible air resistance.

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

2. A ball falls straight down through the air under the influence of gravity. There is a retarding force F on the ball with magnitude given by $F = bv$, where v is the speed of the ball and b is a positive constant. The magnitude of the acceleration a of the ball at any time is equal to which of the following?

   (A) $g - b$
   (B) $g - \frac{bv}{m}$
   (C) $g + \frac{bv}{m}$
   (D) $\frac{g}{b}$
   (E) $\frac{bv}{m}$



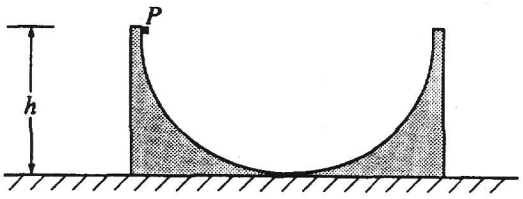
$mg - bv = ma$

$a = \frac{mg - bv}{m}$

$= g - \frac{bv}{m}$

3. An ideal spring obeys Hooke's law, $\mathbf{F} = -k\mathbf{x}$. A mass of 0.50 kilogram hung vertically from this spring stretches the spring 0.075 meter. The value of the force constant for the spring is most nearly

   (A) 0.33 N/m
   (B) 0.66 N/m
   (C) 6.6 N/m
   (D) 33 N/m
   (E) 66 N/m



4. The figure above shows a rough semicircular track whose ends are at a vertical height h. A block placed at point P at one end of the track is released from rest and slides past the bottom of the track. Which of the following is true of the height to which the block rises on the other side of the track?

   (A) It is equal to $h/2\pi$.
   (B) It is equal to $h/4$.
   (C) It is equal to $h/2$.
   (D) It is equal to h.
   (E) It is between zero and h; the exact height depends on how much energy is lost to friction.

$d = 3m \quad v_i = 0 \quad d = \frac{1}{2}at^2 \quad a = \frac{2d}{t^2} = \frac{6}{1} = 6$
$t = 1s$

5. An object is released from rest on a planet that has no atmosphere. The object falls freely for 3.0 meters in the first second. What is the magnitude of the acceleration due to gravity on the planet?

(A) 1.5 m/s^2
(B) 3.0 m/s^2
(C) 6.0 m/s^2
(D) 10.0 m/s^2
(E) 12.0 m/s^2

6. If Spacecraft X has twice the mass of Spacecraft Y, then true statements about X and Y include which of the following?

I. On Earth, X experiences twice the gravitational force that Y experiences.
II. On the Moon, X has twice the weight of Y.
III. When both are in the same circular orbit, X has twice the centripetal acceleration of Y.

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

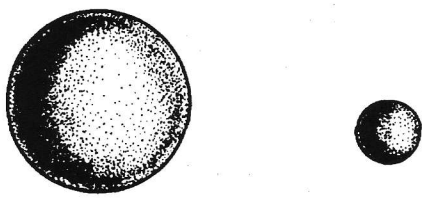
$F_G = ma_c$
$\frac{GM_1M_2}{r^2} = ma_c$



7. Two pucks are attached by a stretched spring and are initially held at rest on a frictionless surface, as shown above. The pucks are then released simultaneously. If puck I has three times the mass of puck II, which of the following quantities is the same for both pucks as the spring pulls the two pucks toward each other?

(A) Speed
(B) Velocity
(C) Acceleration
(D) Kinetic energy
(E) Magnitude of momentum

Conservation of momentum



8. The two spheres pictured above have equal densities and are subject only to their mutual gravitational attraction. Which of the following quantities must have the same magnitude for both spheres?

(A) Acceleration
(B) Velocity
(C) Kinetic energy
(D) Displacement from the center of mass
(E) Gravitational force

equal & opposite

9. When an object oscillating in simple harmonic motion is at its maximum displacement from the equilibrium position, which of the following is true of the values of its speed and the magnitude of the restoring force?

	Speed	Restoring Force
(A)	Zero	Maximum
(B)	Zero	Zero
(C)	$\frac{1}{2}$ maximum	$\frac{1}{2}$ maximum
(D)	Maximum	$\frac{1}{2}$ maximum
(E)	Maximum	Zero

MUST BE

10. Which of the following is true when an object of mass m moving on a horizontal frictionless surface hits and sticks to an object of mass $M > m$, which is initially at rest on the surface?

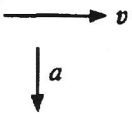
(A) The collision is elastic.
(B) All of the initial kinetic energy of the less-massive object is lost.
(C) The momentum of the objects that are stuck together has a smaller magnitude than the initial momentum of the less-massive object.
(D) The speed of the objects that are stuck together will be less than the initial speed of the less-massive object.
(E) The direction of motion of the objects that are stuck together depends on whether the hit is a head-on collision.

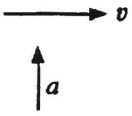
11. Two objects having the same mass travel toward each other on a flat surface, each with a speed of 1.0 meter per second relative to the surface. The objects collide head-on and are reported to rebound after the collision, each with a speed of 2.0 meters per second relative to the surface. Which of the following assessments of this report is most accurate?

(A) Momentum was not conserved, therefore the report is false.
(B) If potential energy was released to the objects during the collision, the report could be true.
(C) If the objects had different masses, the report could be true.
(D) If the surface was inclined, the report could be true.
(E) If there was no friction between the objects and the surface, the report could be true.



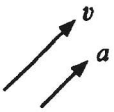
12. An automobile moves at constant speed down one hill and up another hill along the smoothly curved surface shown above. Which of the following diagrams best represents the directions of the velocity and the acceleration of the automobile at the instant that it is at the lowest position, as shown?

(A) 

(B) 

(C) 

(D) 

(E) 

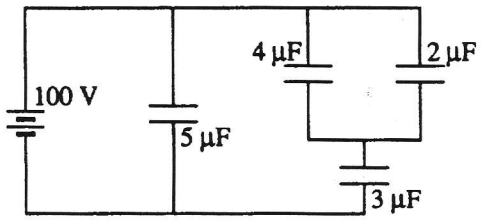
13. Which of the following will cause the electrical resistance of certain materials known as superconductors to suddenly decrease to essentially zero?

(A) Increasing the voltage applied to the material beyond a certain threshold voltage
(B) Increasing the pressure applied to the material beyond a certain threshold pressure
(C) Cooling the material below a certain threshold temperature
(D) Stretching the material to a wire of sufficiently small diameter
(E) Placing the material in a sufficiently large magnetic field

14. Kirchhoff's loop rule for circuit analysis is an expression of which of the following?

(A) Conservation of charge
(B) Conservation of energy
(C) Ampère's law
(D) Faraday's law
(E) Ohm's law

Questions 15-16 refer to the circuit shown below.



15. The equivalent capacitance for this network is most nearly

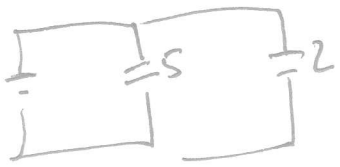
(A) 10/7 μF
(B) 3/2 μF
(C) 7/3 μF
(D) 7 μF
(E) 14 μF

16. The charge stored in the 5-microfarad capacitor is most nearly

(A) 360 μC
(B) 500 μC
(C) 710 μC
(D) 1,100 μC
(E) 1,800 μC

$Q = CV = 5\mu f(100V)$
$= 500\mu C$

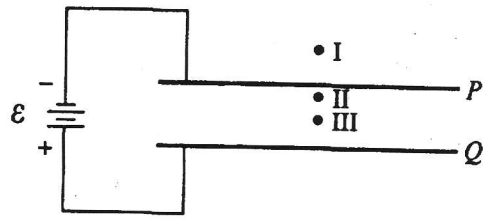




$\frac{1}{6} + \frac{2}{6} = \frac{3}{6}$

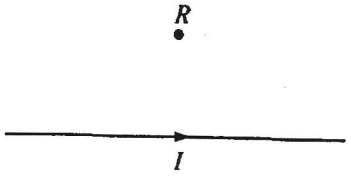
$C_{eq} = 2$





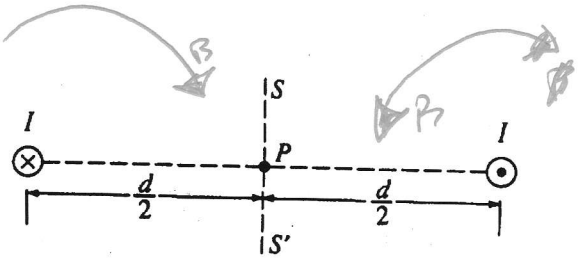
17. Two large parallel conducting plates P and Q are connected to a battery of emf $\mathcal{E}$, as shown above. A test charge is placed successively at points I, II, and III. If edge effects are negligible, the force on the charge when it is at point III is

(A) of equal magnitude and in the same direction as the force on the charge when it is at point I
(B) of equal magnitude and in the same direction as the force on the charge when it is at point II
(C) equal in magnitude to the force on the charge when it is at point I, but in the opposite direction
(D) much greater in magnitude than the force on the charge when it is at point II, but in the same direction
(E) much less in magnitude than the force on the charge when it is at point II, but in the same direction



18. The direction of the magnetic field at point R caused by the current I in the wire shown above is

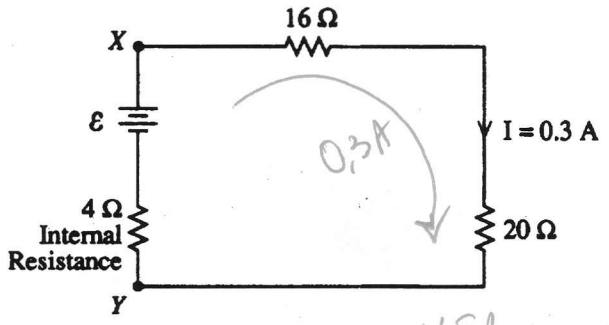
(A) to the left
(B) to the right
(C) toward the wire
(D) into the page
(E) out of the page



19. Two long, parallel wires are separated by a distance d, as shown above. One wire carries a steady current I into the plane of the page while the other wire carries a steady current I out of the page. At what points in the plane of the page and outside the wires, besides points at infinity, is the magnetic field due to the currents zero?

(A) Only at point P
(B) At all points on the line SS'
(C) At all points on the line connecting the two wires
(D) At all points on a circle of radius $2d$ centered on point P
(E) At no points

Questions 20-22 relate to the following circuit diagram, which shows a battery with an internal resistance of 4.0 ohms connected to a 16-ohm and a 20-ohm resistor in series. The current in the 20-ohm resistor is 0.3 amperes.



20. What is the emf of the battery?

(A) 1.2 V
(B) 6.0 V
(C) 10.8 V
(D) 12.0 V
(E) 13.2 V

21. What is the potential difference across the terminals X and Y of the battery?

(A) 1.2 V
(B) 6.0 V
(C) 10.8 V
(D) 12.0 V
(E) 13.2 V

22. What power is dissipated by the 4-ohm internal resistance of the battery?

(A) 0.36 W
(B) 1.2 W
(C) 3.2 W
(D) 3.6 W
(E) 4.8 W

23. If the gas in a container absorbs 275 joules of heat, has 125 joules of work done on it, and then does 50 joules of work, what is the increase in the internal energy of the gas?

(A) 100 J
(B) 200 J
(C) 350 J
(D) 400 J
(E) 450 J

Questions 24-25

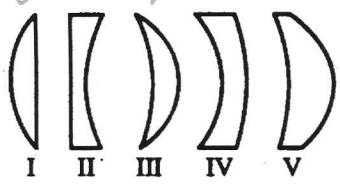
A piece of metal with a mass of 1.50 kilograms, specific heat of 200 J/kg · C°, and initial temperature of 100° C is dropped into an insulated jar that contains liquid with a mass of 3.00 kilograms, specific heat of 1,000 J/kg · C°, and initial temperature of 0° C. The piece of metal is removed after 5 seconds, at which time its temperature is 20° C. Neglect any effects of heat transfer to the air or to the insulated jar.

24. The temperature of the liquid after the metal is removed is

(A) 0° C
(B) 4° C
(C) 8° C
(D) 10° C
(E) 20° C

25. The average rate at which heat is transferred while the piece of metal is in the liquid is

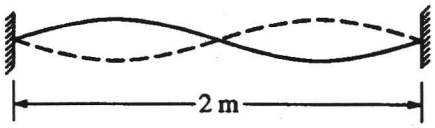
(A) 4,000 J/s
(B) 4,800 J/s
(C) 6,000 J/s
(D) 9,600 J/s
(E) 16,000 J/s



26. Which three of the glass lenses above, when placed in air, will cause parallel rays of light to converge?

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

Questions 27-28



A standing wave of frequency 5 hertz is set up on a string 2 meters long with nodes at both ends and in the center, as shown above.

27. The speed at which waves propagate on the string is

(A) 0.4 m/s
(B) 2.5 m/s
(C) 5 m/s
(D) 10 m/s
(E) 20 m/s

28. The fundamental frequency of vibration of the string is

(A) 1 Hz
(B) 2.5 Hz
(C) 5 Hz
(D) 7.5 Hz
(E) 10 Hz

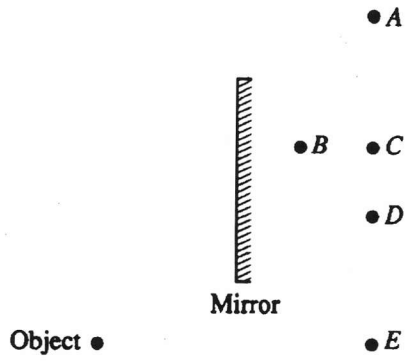
Radio waves
Infrared radiation
Visible light
Ultraviolet radiation
Gamma radiation

29. For the five types of electromagnetic radiation listed above, which of the following correctly describes the way in which wavelength, frequency, and photon energy change as one goes from the top of the list to the bottom?

	Wavelength	Frequency	Photon Energy
(A)	Decreases	Decreases	Increases
(B)	Decreases	Increases	Increases
(C)	Increases	Decreases	Decreases
(D)	Increases	Decreases	Increases
(E)	Increases	Increases	Increases

30. Sound in air can best be described as which of the following types of waves?

(A) Longitudinal
(B) Transverse
(C) Torsional
(D) Electromagnetic
(E) Polarized



31. An object is placed near a plane mirror, as shown above. Which of the labeled points is the position of the image?

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

Questions 32-33 deal with nuclear fission for which the following reaction is a good example.

$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{138}_{56}Ba + {}^{95}_{36}Kr$ + neutrons + released energy

32. The total number of free neutrons in the products of this reaction is

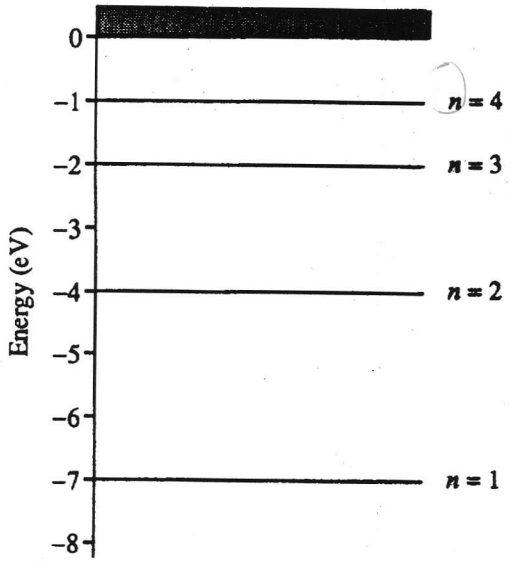
(A) 2
(B) 3
(C) 4
(D) 5
(E) 6

33. Which of the following statements is always true for neutron-induced fission reactions involving $^{235}_{92}U$?

I. The end products always include Ba and Kr.
II. The rest mass of the end products is less than that of $^{235}_{92}U + {}^{1}_{0}n$.
III. The total number of nucleons (protons plus neutrons) in the end products is less than that in $^{235}_{92}U + {}^{1}_{0}n$.

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

Questions 34-35



A hypothetical atom has four energy states as shown above.

34. Which of the following photon energies could NOT be found in the emission spectra of this atom after it has been excited to the $n = 4$ state?

(A) 1 eV
(B) 2 eV
(C) 3 eV
(D) 4 eV
(E) 5 eV

35. Which of the following transitions will produce the photon with the longest wavelength?

(A) $n = 2$ to $n = 1$
(B) $n = 3$ to $n = 1$
(C) $n = 3$ to $n = 2$
(D) $n = 4$ to $n = 1$
(E) $n = 4$ to $n = 3$

36. Cobalt 60 is a radioactive source with a half-life of about 5 years. After how many years will the activity of a new sample of cobalt 60 be decreased to 1/8 its original value?

(A) 2.5 years
(B) 5 years
(C) 10 years
(D) 15 years
(E) It depends on the original amount of cobalt 60.

37. Of the following phenomena, which provides the best evidence that light can have particle properties?

(A) Interference of light in thin films
(B) Electromagnetic radiation
(C) Photoelectric effect
(D) Electron diffraction
(E) X-ray diffraction

38. Of the following phenomena, which provides the best evidence that particles can have wave properties?

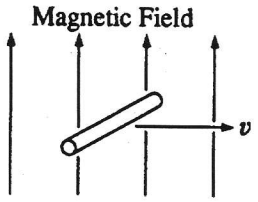
(A) The absorption of photons by electrons in an atom
(B) The α-decay of radioactive nuclei
(C) The interference pattern produced by neutrons incident on a crystal
(D) The production of x-rays by electrons striking a metal target
(E) The scattering of photons by electrons at rest

39. A muon, with a lifetime of 2×10^{-6} second in its frame of reference, is created in the upper atmosphere with a velocity of $0.998c$ toward the Earth. The lifetime of the muon, as measured by an observer on the Earth. is most nearly

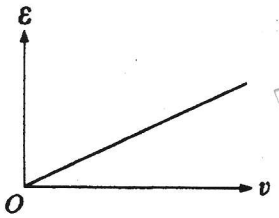
(A) 3×10^{-2} s
(B) 3×10^{-3} s
(C) 3×10^{-4} s
(D) 3×10^{-5} s
(E) 3×10^{-6} s

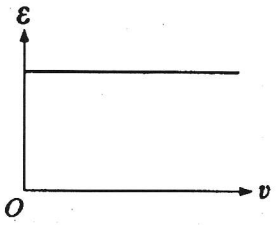
40. The operator of a space station observes a space vehicle approaching at a constant speed v. The operator sends a light signal at speed c toward the space vehicle. The speed of the light signal relative to the space vehicle is

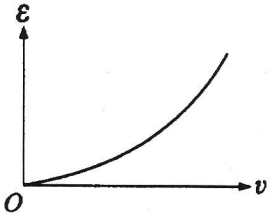
(A) $c + v$
(B) $c - v$
(C) c
(D) $v/\sqrt{1 - v^2/c^2}$
(E) $c\sqrt{1 - v^2/c^2}$

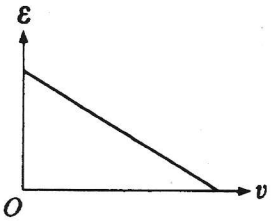


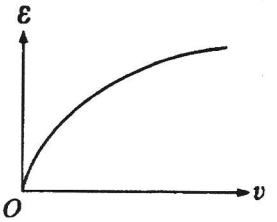
41. A wire of constant length is moving in a constant magnetic field, as shown above. The wire and the velocity vector are perpendicular to each other and are both perpendicular to the field. Which of the following graphs best represents the potential difference $\mathcal{E}$ between the ends of the wire as a function of the speed v of the wire?

(A)


(B)


(C)


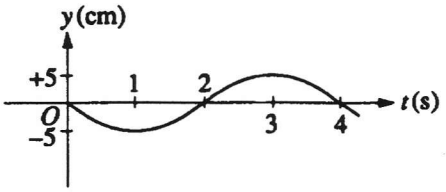
(D)


(E)


42. Forces between two objects which are inversely proportional to the square of the distance between the objects include which of the following?

I. Gravitational force between two celestial bodies
II. Electrostatic force between two electrons
III. Nuclear force between two neutrons

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

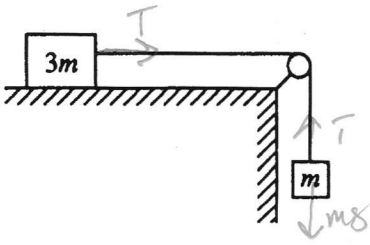


43. A particle oscillates up and down in simple harmonic motion. Its height y as a function of time t is shown in the diagram above. At what time t does the particle achieve its maximum positive acceleration?

(A) 1 s
(B) 2 s
(C) 3 s
(D) 4 s
(E) None of the above, because the acceleration is constant

44. A weight lifter lifts a mass m at constant speed to a height h in time t. What is the average power output of the weight lifter?

(A) mg
(B) mh
(C) mgh
(D) $mght$
(E) mgh/t



45. A block of mass $3m$ can move without friction on a horizontal table. This block is attached to another block of mass m by a cord that passes over a frictionless pulley, as shown above. If the masses of the cord and the pulley are negligible, what is the magnitude of the acceleration of the descending block?

(A) Zero
(B) $g/4$
(C) $g/3$
(D) $2g/3$
(E) g

46. A car initially travels north and then turns to the left along a circular curve. This causes a package on the seat of the car to slide toward the right side of the car. Which of the following is true of the net force on the package while it is sliding?

(A) The force is directed away from the center of the circle.
(B) The force is directed north.
(C) There is not enough force directed north to keep the package from sliding.
(D) There is not enough force tangential to the car's path to keep the package from sliding.
(E) There is not enough force directed toward the center of the circle to keep the package from sliding.

47. A block of mass m slides on a horizontal frictionless table with an initial speed v_0. It then compresses a spring of force constant k and is brought to rest. How much is the spring compressed from its natural length?

(A) $\frac{v_0^2}{2g}$

(B) $\frac{mg}{k} v_0$

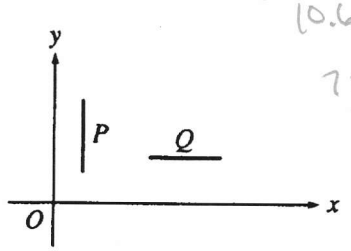
(C) $\frac{m}{k} v_0$

(D) $\sqrt{\frac{m}{k}} v_0$

(E) $\sqrt{\frac{k}{m}} v_0$

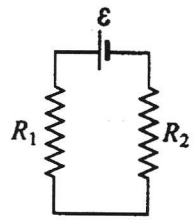
48. The planet Mars has mass 6.4×10^{23} kilograms and radius 3.4×10^6 meters. The acceleration of an object in free-fall near the surface of Mars is most nearly

(A) zero
(B) 1.0 m/s^2
(C) 1.9 m/s^2
(D) 3.7 m/s^2
(E) 9.8 m/s^2

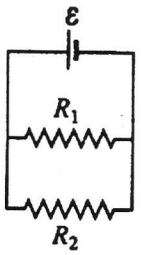


49. Rods P and Q are at rest in an inertial reference frame and oriented as shown above. Both rods have length L in this reference frame. A person moves at a relativistic speed in the y direction. Which of the following would be the lengths, as compared to L, observed for these rods by the person?

	P	Q
(A)	Less than L	Less than L
(B)	Less than L	L
(C)	Less than L	Greater than L
(D)	L	Less than L
(E)	L	L



Series Connection



Parallel Connection

50. In the diagrams above, resistors R_1 and R_2 are shown in two different connections to the same source of emf ε that has no internal resistance. How does the power dissipated by the resistors in these two cases compare?

(A) It is greater for the series connection.
(B) It is greater for the parallel connection.
(C) It is the same for both connections.
(D) It is different for each connection, but one must know the values of R_1 and R_2 to know which is greater.
(E) It is different for each connection, but one must know the value of ε to know which is greater.

51. The product

2 amperes × 2 volts × 2 seconds

is equal to

(A) 8 coulombs
(B) 8 newtons
(C) 8 joules
(D) 8 calories
(E) 8 newton-amperes

52. A radar operates at a wavelength of 3 centimeters. The frequency of these waves is

(A) 10^{-10} Hz
(B) 10^6 Hz
(C) 10^8 Hz
(D) 3×10^8 Hz
(E) 10^{10} Hz

53. In the photoelectric effect, the maximum speed of the electrons emitted by a metal surface when it is illuminated by light depends on which of the following?

I. Intensity of the light
II. Frequency of the light
III. Nature of the photoelectric surface

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

54. Atoms of isotopes of the same element contain the same number of

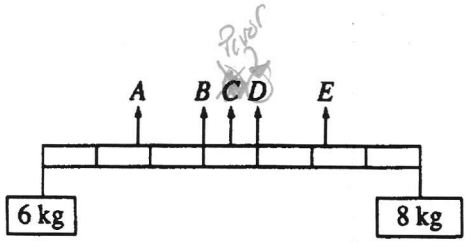
(A) protons but a different number of neutrons
(B) electrons but a different number of protons
(C) neutrons but a different number of protons
(D) neutrons as electrons
(E) protons as neutrons

55. In each cycle of a Carnot engine, 100 joules of heat is absorbed from the high-temperature reservoir and 60 joules is exhausted to the low-temperature reservoir. What is the efficiency of the engine?

(A) 40%
(B) 60%
(C) 67%
(D) 150%
(E) 167%

56. In the Bohr model of the atom, the postulate stating that the orbital angular momentum of the electron is quantized can be interpreted in which of the following ways?

(A) An integral number of electron wavelengths must fit into the electron's circular orbit.
(B) Only one electron can exist in each possible electron state.
(C) An electron has a spin of 1/2.
(D) The atom is composed of a small, positively charged nucleus orbited by electrons.
(E) An incident photon is completely absorbed when it causes an electron to move to a higher energy state.



57. Two objects, of masses 6 and 8 kilograms, are hung from the ends of a stick that is 70 centimeters long and has marks every 10 centimeters, as shown above. If the mass of the stick is negligible, at which of the points indicated should a cord be attached if the stick is to remain horizontal when suspended from the cord?

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

58. In the Doppler effect for sound waves, factors that affect the frequency that the observer hears include which of the following?

I. The speed of the source
II. The speed of the observer
III. The loudness of the sound

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

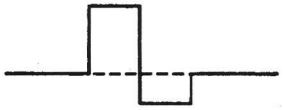


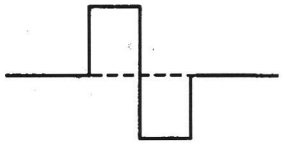
59. The figure above shows two wave pulses that are approaching each other. Which of the following best shows the shape of the resultant pulse when the centers of the pulses, points P and Q, coincide?

(A) 

(B) 

(C) 

(D) 

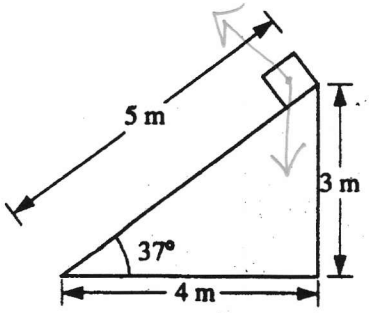
(E) 

60. Observations that indicate that visible light has a wavelength much shorter than a centimeter include which of the following?

I. The colored pattern seen in a soap bubble
II. The colored pattern seen when light passes through a diffraction grating
III. The bending of light when it passes from one medium to another medium

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

Questions 61-63



A plane 5 meters in length is inclined at an angle of 37°, as shown above. A block of weight 20 newtons is placed at the top of the plane and allowed to slide down.

61. The mass of the block is most nearly

(A) 1.0 kg
(B) 1.2 kg
(C) 1.6 kg
(D) 2.0 kg
(E) 2.5 kg

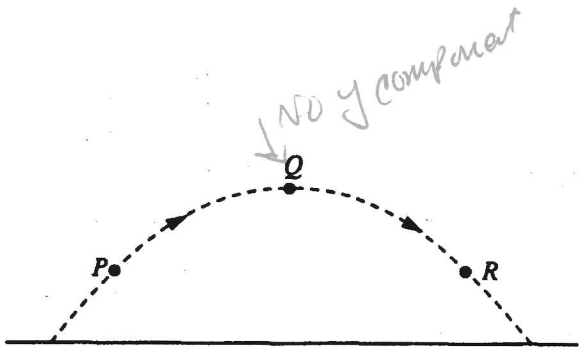
62. The magnitude of the normal force exerted on the block by the plane is most nearly

(A) 10 N
(B) 12 N
(C) 16 N
(D) 20 N
(E) 33 N

63. The work done on the block by the gravitational force during the 5-meter slide down the plane is most nearly

(A) 20 J
(B) 60 J
(C) 80 J
(D) 100 J
(E) 130 J

Questions 64-66



A ball is thrown and follows the parabolic path shown above. Air friction is negligible. Point Q is the highest point on the path. Points P and R are the same height above the ground.

64. How do the speeds of the ball at the three points compare?

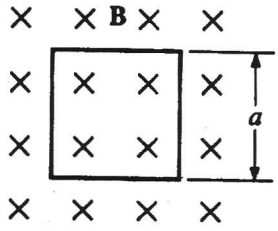
(A) $v_P < v_Q < v_R$
(B) $v_R < v_Q < v_P$
(C) $v_Q < v_R < v_P$
(D) $v_Q < v_P = v_R$
(E) $v_P = v_R < v_Q$

65. Which of the following diagrams best shows the direction of the acceleration of the ball at point P?

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

66. Which of the following best indicates the direction of the net force, if any, on the ball at point Q?

(A)
(B)
(C)
(D) 
(E) There is no net force on the ball at point Q.



67. A square loop of wire of resistance R and side a is oriented with its plane perpendicular to a magnetic field **B**, as shown above. What must be the rate of change of the magnetic field in order to produce a current I in the loop?

(A) IR/a^2
(B) Ia^2/R
(C) Ia/R
(D) Ra/I
(E) IRa



68. The diagram above shows an isolated, positive charge Q. Point B is twice as far away from Q as point A. The ratio of the electric field strength at point A to the electric field strength at point B is

(A) 8 to 1
(B) 4 to 1
(C) 2 to 1
(D) 1 to 1
(E) 1 to 2

69. If the object distance for a converging thin lens is more than twice the focal length of the lens, the image is

(A) virtual and erect
(B) larger than the object
(C) located inside the focal point
(D) located at a distance between f and $2f$ from the lens
(E) located at a distance more than $2f$ from the lens



70. Two conducting spheres of different radii, as shown above, each have charge $-Q$. Which of the following occurs when the two spheres are connected with a conducting wire?

(A) No charge flows.
(B) Negative charge flows from the larger sphere to the smaller sphere until the electric field at the surface of each sphere is the same.
(C) Negative charge flows from the larger sphere to the smaller sphere until the electric potential of each sphere is the same.
(D) Negative charge flows from the smaller sphere to the larger sphere until the electric field at the surface of each sphere is the same.
(E) Negative charge flows from the smaller sphere to the larger sphere until the electric potential of each sphere is the same.