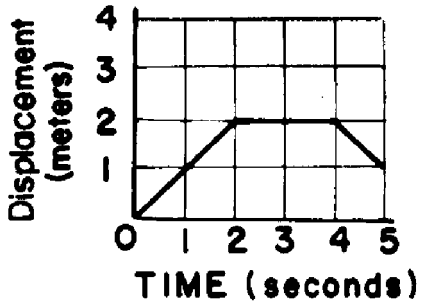
1.



The graph above represents the motion of an object traveling in a straight line as a function of time. What is the average speed of the object during the first four seconds?

(A) 0 m/s
(B) 0.2 m/s
(C) 0.5 m/s
(D) 1 m/s
(E) 2 m/s

2. A train starts at rest and accelerates at a uniform rate of 4 m/s^2. Which of the following is closest to its speed after it has traveled 25 meters?

(A) 10 m/s
(B) 14 m/s
(C) 70 m/s
(D) 100 m/s
(E) 200 m/s

3. Which of the following is a scalar unit?

(A) Acceleration
(B) Speed
(C) Displacement
(D) Average Velocity
(E) Instantaneous Velocity

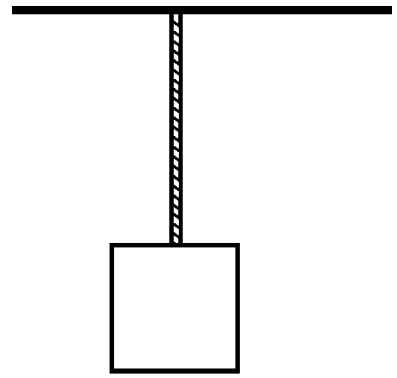
4. A street car driver is traveling at a speed of 25 m/s when he sees a road block. He applies the brakes causing a magnitude of deceleration of 5 m/s^2. If the roadblock is 70 m away, which of the following will happen?

(A) The car will hit the road block.
(B) The car will stop immediately before the roadblock.
(C) The car will stop 2.5 m before the roadblock.
(D) The car will stop 5 m before the roadblock.
(E) The car will stop 7.5 m before the roadblock.

5. A cannon fires a projectile with an initial speed v at an angle θ above the horizon. What is the horizontal distance traveled by the projectile?

(A) $\frac{v^2 \sin\theta}{g}$
(B) $\frac{2v^2 \sin\theta}{g}$
(C) $\frac{v^2 \sin 2\theta}{g}$
(D) $\frac{2v^2 \sin 2\theta}{g}$
(E) $\frac{2v^2 \sin^2\theta}{g}$

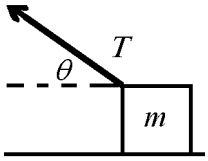
6.



A uniform rope of weighing 30 N hangs from a ceiling as shown above. A box of weight 50 N hangs from the rope. What is the tension in the rope?

(A) 50 N throughout the rope.
(B) 65 N throughout the rope.
(C) 80 N throughout the rope.
(D) It varies from 50 N at the bottom of the rope to 80 N at the top.
(E) It varies from 80 N at the bottom of the rope to 50 N at the top.

7. Base your answer to the following question on the diagram below which shows a box of mass m being pulled across a rough horizontal floor by a force of magnitude T at an angle . The coefficient of friction between the box and the floor is μ.



The normal force on the box has magnitude

(A) $mg + T\sin\theta$
(B) $mg - T\sin\theta$
(C) $mg + T\cos\theta$
(D) $mg - T\cos\theta$
(E) mg

8. A dog that weighs 500 N at rest on the Earth's surface is standing on a scale on the floor of an elevator. The elevator is accelerating upward in the Earth's gravitational field at a rate of 9.8 m/s^2. What does the scale read?

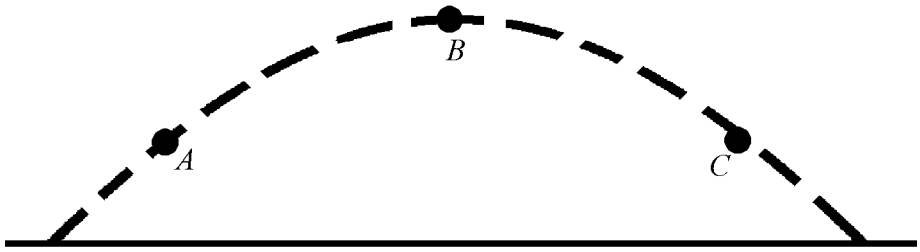
(A) 0 N
(B) 250 N
(C) 500 N
(D) 1000 N
(E) 2000 N

9. How much energy is required to stop a car of mass 100 kg traveling at 25 m/s?

(A) 1,150 J
(B) 21,150 J
(C) 31,250 J
(D) 32,250 J
(E) 42,250 J

Base your answers to questions **10** through **14** on the following information.

A cannonball is fired and follows the parabolic path shown below. Air resistance is negligible. Point *B* is the highest point on the path and points *A* and *C* are at the same height.



10. How do the speeds of the cannonball at the there points compare?
    (A) $v_A < v_B < v_C$ (B) $v_C < v_B < v_A$ (C) $v_B < v_A < v_C$ (D) $v_A < v_B = v_C$ (E) $v_B < v_A = v_C$

11. How do the accelerations of the ball at the three points compare?
    (A) $a_A < a_B < a_C$ (B) $a_B < a_A < a_C$ (C) $a_A = a_B = a_C$ (D) $a_A = a_B < a_C$ (E) $a_B < a_A = a_C$

12. Which of the following best describes the direction of the acceleration of the ball at point *C*?
    (A) to the right
    (B) down and to the right
    (C) down
    (D) up and to the right
    (E) up and to the left

13. Which of the following best describes the direction of the velocity of the cannonball at point *B*?
    (A) to the right
    (B) up and to the right
    (C) down and to the right
    (D) up
    (E) down

14. Which of the following best describes the direction of the net force on the ball at point *A*?
    (A) up and to the right
    (B) to the right
    (C) down and to the right
    (D) down
    (E) There is no net force on the cannonball at point *A*

15. A bullet is fired horizontally at a velocity of 200 m/s at a height of 1 m. At the same time, another bullet is dropped 1 m from rest. The difference between t_1, the time it takes the fired bullet to hit the ground, and t_2, the time it takes the dropped bullet to hit the ground is
    (A) 0 s
    (B) 1 s
    (C) 2 s
    (D) 4 s
    (E) 8 s

16. Base your answer to the following question on the following situation.

    A proton and an anti-proton, each of mass 1.67×10^{-27} kilogram are in the same general vicinity and have very small initial speeds. They then annihilate each other, producing two photons.

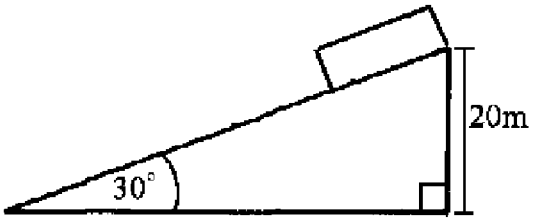
    What is the angle between the paths of the emerging photons?
    (A) 0º
    (B) 45º
    (C) 60º
    (D) 90º
    (E) 180º

17. A rocket engine acquires motion by ejecting hot gases in the opposite direction. This is an example of the law of
    (A) conservation of heat
    (B) conservation of energy
    (C) conservation of linear momentum
    (D) conservation of mass
    (E) conservation of angular momentum

18. An 40 kg object is being pushed along a surface at a constant velocity by a force of 80 N. What is the coefficient of kinetic friction between the object and the surface?
    (A) 0.1
    (B) 0.2
    (C) 0.25
    (D) 0.4
    (E) 0.5

19. An object with a mass of 2 kg increases in speed from 4 m/s to 12 m/s in 3 s. The total work performed on the object during this time is
    (A) 16 J
    (B) 64 J
    (C) 128 J
    (D) 256 J
    (E) 512 J

Base your answers to questions **20** through **22** on the following diagram, which shows a block that started at the top of a frictionless ramp and is sliding down.



20. How long does it take to block to slide to the bottom of the ramp?
    (A) 4 s
    (B) 8 s
    (C) 10 s
    (D) 16 s
    (E) There is insufficient information to answer the question.

21. With what speed will the block reach the bottom if it was released from rest at the top?
    (A) 10 m/s
    (B) 20 m/s
    (C) 25 m/s
    (D) 30 m/s
    (E) 40 m/s

22. If the mass of the block is 5 kg, how much work is done by gravity as the block slides down the full length of the incline?
    (A) 10 J
    (B) 100 J
    (C) 200 J
    (D) 1000 J
    (E) 2000 J

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23. A 30 N block is being pulled along a horizontal surface with an acceleration of 6 m/s^2 by a rope. The coefficient of kinetic friction between the block and the surface is 0.5. What is the force applied by the rope?
    (A) 3 N
    (B) 15 N
    (C) 30 N
    (D) 33 N
    (E) 66 N

24. A block of mass 5.0 kg is hung from a vertical spring stretching it 0.40 m. The amount of energy stored in the spring is most nearly
    (A) 0.40 J
    (B) 0.80 J
    (C) 8.0 J
    (D) 10 J
    (E) 20 J

25. An object at rest splits into 3 particles, each with mass m, traveling with velocity v. The angle between the velocity vectors of any two of these particles is
    (A) 30º
    (B) 60º
    (C) 90º
    (D) 120º
    (E) 150º

26. A person pushes an object with a mass of 50 kg across a surface with a coefficient of friction of 0.2. If the box moves with a constant velocity of 2.0 m/s, the power supplied to the box by the person is
    (A) 20 W
    (B) 25 W
    (C) 50 W
    (D) 100 W
    (E) 200 W

27. Two isolated objects collide in an inelastic collision. Which of the following statements are correct?
    I) Total energy is conserved
    II) Kinetic energy is conserved
    III) Linear Momentum is conserved
    (A) I only
    (B) III only
    (C) I and III only
    (D) II and III only
    (E) I, II, and III

Base your answers to questions **28** and **29** on the following situation.

An object with a mass of 5 kg is attached to a 1 meter long rope and whirled in a vertical circle.

28. At the bottom of its path, the rope has a tension of 95 N. The object is moving most nearly
    (A) 2 m/s
    (B) 3 m/s
    (C) 6 m/s
    (D) 9 m/s
    (E) 15 m/s

29. Of the following, which is the greatest speed of the object for which the rope would become slack at the top of its circular path?
    (A) 20 m/s
    (B) 15 m/s
    (C) 10 m/s
    (D) 5 m/s
    (E) 2m/s

---

30. A particle travels in a circular path at constant speed with a constant kinetic energy of 20 J. If the net force on the particle is 40 N, what is the radius of the path the particle takes?
    (A) 0.2 m
    (B) 0.5 m
    (C) 1 m
    (D) 1.5 m
    (E) 2 m

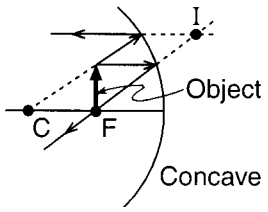
31. A 5 kg ball hangs from a 10 m string. The ball is swung horizontally outward 90º from its equilibrium position. Assuming the system behaves as a simple pendulum, find the maximum speed of the ball during its swing.
    (A) 50 m/s
    (B) 14 m/s
    (C) 10 m/s
    (D) 5 m/s
    (E) 2 m/s

32. What is the frequency of a gamma ray whose wavelength is 20 nm?
    (A) 6.7×10^{-17} Hz
    (B) 1.5×10^{-14} Hz
    (C) 1.5×10^{16} Hz
    (D) 6.7×10^{17} Hz
    (E) 3.5×10^{24} Hz

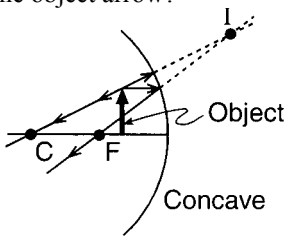
33. An object arrow is placed in front of a concave mirror having center of curvature *C* and principal focus *F*.

Which diagram best shows the location of point *I,* the image of the tip of the object arrow?

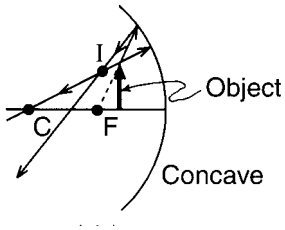
(A)



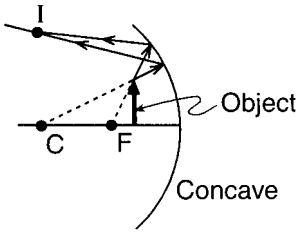
(C)



(B)

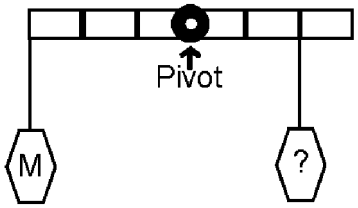


(D)



(E) none of the above

34. A wooden board of mass 10 *M* is held up by a nail hammered into a wall. A block of mass *M* rests $\frac{L}{2}$ away from the pivot. Another block of a certain mass is hung a distance $\frac{L}{3}$. The system is in static equilibrium.



What is the measure of the mass labeled "***?***" ?

(A) $\frac{M}{2}$

(B) $\frac{M}{3}$

(C) M

(D) $\frac{3M}{2}$

(E) $2M$

35. An object weighs 10 N on the earth's surface. What is the weight of the object on a planet which has one tenth the earth's mass and one half the earth's radius?

(A) 1 N
(B) 2 N
(C) 4 N
(D) 10 N
(E) 20 N

36. An object with density of 3000 kg/m^3 is dropped in water. The magnitude of its acceleration is most nearly

(A) 6.5 m/s^2.
(B) 7.0 m/s^2.
(C) 10.0 m/s^2.
(D) 13.0 m/s^2.
(E) 13.5 m/s^2.

37. Bernoulli's equation is an expression which represents

(A) the conservation of energy for ideal water flow
(B) the conservation of fluid pressure throughout a system
(C) the direct proportion between viscosity and fluid flow
(D) the inverse proportion of cross-sectional area and fluid flow
(E) the conservation of linear momentum in a fluid system

Base your answers to questions **38** through **40** on a piece of metal with a mass of 3.0 kg specific heat of 400 J/kg•K and an initial temperature of 500 K that is dropped into an insulated jar that contains a liquid with a mass of 10 kg, specific heat of 1200 J/kg•K and initial temperature of 300 K. The piece of metal is removed after 10 seconds, at which time its temperature is 450 K. Neglect any effects of heat transfer to the air or to the insulated jar.

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

(A) 300 K
(B) 305 K
(C) 350 K
(D) 365 K
(E) 450 K

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

(A) 2,000 J/s
(B) 3,000 J/s
(C) 6,000 J/s
(D) 8,000 J/s
(E) 12,000 J/s

40. If the metal were left in the liquid for a much longer time, the final temperature of the metal would be most nearly

(A) 305 K
(B) 310 K
(C) 320 K
(D) 340 K
(E) 350 K

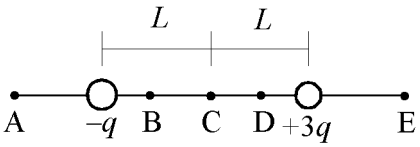
41. A uniform rod of a length of 2.0 m at 5ºC has a coefficient of linear expansion of $5.0 \times 10^{-4}\ K^{-1}$. How much longer is it when the temperature is 35ºC?
(A) 0.010 m
(B) 0.015 m
(C) 0.030 m
(D) 0.0 45 m
(E) .060 m

42. Which of the following is always a characteristic of an adiabatic process?
(A) The temperature does not change.
(B) The internal energy does not change.
(C) The pressure does not change.
(D) The entropy does not change
(E) No work is done on or by the system.

43. What is the maximum efficiency of an engine operating between a heat source at 327ºC and a heat sink at 27ºC?
(A) 15%
(B) 33%
(C) 50%
(D) 67%
(E) 94%

44. The operation of any thermodynamic process will always result in
(A) positive work being done.
(B) the energy of a system decreasing.
(C) total entropy increasing.
(D) the pressure of a system remaining constant.
(E) the energy of a system increasing.

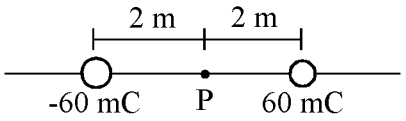
45. Base your answer on the following picture (not to scale), with charges of $-q$ and $+3q$ a distance $2L$ apart along the x-axis.



In the diagram above, at which of the points would a positive test charge most likely feel no electrostatic force?
(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

46. A parallel-plate capacitor has capacitance *C*. A second parallel-plate capacitor has plates with twice the area and half the separation. The capacitance of this second capacitor is most nearly
(A) $\frac{1}{4}C$
(B) $\frac{1}{2}C$
(C) C
(D) $2C$
(E) $4C$

47.



What is the strength of the electric field at the point *P* in the above diagram?
(A) 0 N/C
(B) 1.35×10^8 N/C
(C) 2.7×10^8 N/C
(D) 5.4×10^8 N/C
(E) 1.08×10^9 N/C

Base your answers to questions **48** and **49** on the following. A point *P* is located 3.0 m from a point charge of –5.0 C and the point *Q* is located 5.0 m from the same charge.

48. What is the electric potential at point *P*?
(A) -1.8×10^9
(B) -5.0×10^9
(C) -5.4×10^9
(D) -9.0×10^9
(E) -15×10^9

49. What is the electric potential at point *Q*?
(A) -1.8×10^9
(B) -5.0×10^9
(C) -5.4×10^9
(D) -9.0×10^9
(E) -15.0×10^9

50. The diagram below represents oppositely charged plates in an evacuated glass tube.

Which diagram below represents the path of free electrons between the charged plates?
(A)

(B)

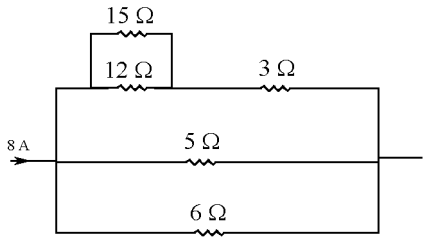
(C)

(D)

(E) None of the above

51. If the potential difference between two oppositely charged parallel metal plates is doubled, the electric field intensity at a point between them is
(A) quartered
(B) halved
(C) unchanged
(D) doubled
(E) quadrupled

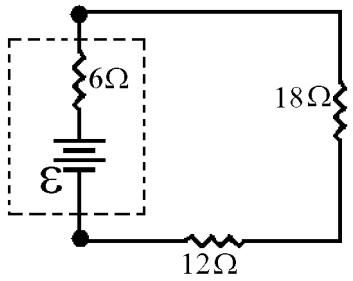
52.



The voltage drop across the 5 Ω resistor in the portion of the circuit shown above is most nearly

(A) 12 V
(B) 18 V
(C) 24 V
(D) 40 V
(E) 48 V

53. Base your answer to the following question on the circuit diagram below which shows a battery with an internal resistance of 6.0 Ω connected to a 12-Ω and 18-ohm resistor in series. The current in the 12-Ω resistor is 0.2 A.



What is the total power dissipated by the external resistors in this circuit?

(A) 1.0 W
(B) 1.2 W
(C) 1.44 W
(D) 1.728 W
(E) 2.0 W

54. Which quantities are needed to calculate the amount of energy supplied to an operating toaster?

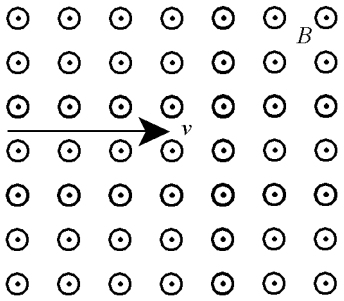
I. resistance
II. applied voltage
III. operating time

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

55. According to Faraday's Law, the induced EMF is equal to which of the following?

(A) the change in electric flux
(B) the change in magnetic flux
(C) the negative change in electric flux
(D) the rate of change in magnetic flux
(E) the negative rate of change in magnetic flux

56.



A particle with charge $+q$ is traveling through a uniform magnetic field B that points out of the page in the direction indicated by the arrow in the plane of the page. In what direction is the force on the particle?

(A) towards the bottom of the page
(B) towards the top of the page
(C) up out of the page
(D) down into the page
(E) towards the left of the page

57. A particle executes uniform circular motion with speed v due to the influence of a magnetic force within a uniform magnetic field B. If the particle's charge is q, and the radius of the path of the particle is r, find an expression for the mass of the particle.

(A) $\frac{rq\mathrm{B}}{v}$
(B) $\frac{rq\mathrm{B}}{v^2}$
(C) $rqv\mathrm{B}$
(D) $\frac{v}{rq\mathrm{B}}$
(E) $\frac{v^2}{rq\mathrm{B}}$

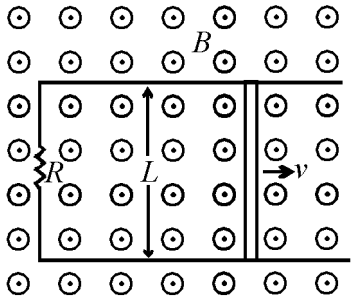
58. Which of the following statements is true about magnetic forces and fields?

(A) The magnetic field lines are always parallel to the magnetic force lines.
(B) The magnetic field lines are always parallel to the velocity vector.
(C) The magnetic force can never change the velocity vector of a particle.
(D) The magnetic field from a current-carrying wire is related to the inverse square of the distance from the wire.
(E) A charged particle can move through a magnetic field without feeling a magnetic force.

59. A car siren has a frequency of 500 hertz as heard by the driver of the car. Assume that the velocity of sound in air is 330 meters per second. If the car is approaching a stationary listener at 60 meters per second, the siren frequency that the listener hears is

(A) 409 Hz
(B) 423 Hz
(C) 590 Hz
(D) 611 Hz
(E) 650 Hz

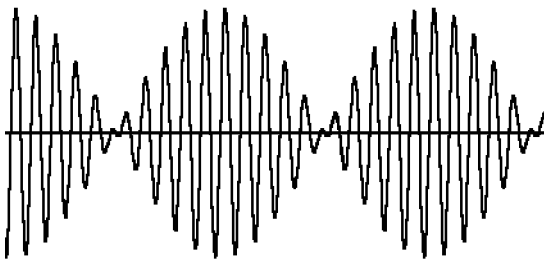
Base your answers to questions **60** and **61** on the diagram below of a metal rod with length L pushed along a set of conducting rails that completes a circuit with a total resistance R at a constant velocity v to the right. The circuit is in a magnetic field B that points out of the page.



60. What is the current induced in the circuit?
    (A) $RBLv$ clockwise
    (B) $BLv \times \frac{1}{R}$ counterclockwise
    (C) $BLv \times \frac{1}{R}$ clockwise
    (D) $BLv \times \frac{1}{2R}$ counterclockwise
    (E) $BLv \times \frac{1}{2R}$ clockwise

61. The power supplied by an external force to keep the rod moving at a constant velocity is
    (A) $RBlv$
    (B) $\frac{Blv}{R}$
    (C) $R(Blv)^2$
    (D) $\frac{(Blv)^2}{R}$
    (E) $(RBlv)^2$

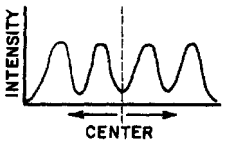
62.

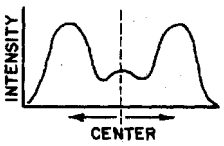


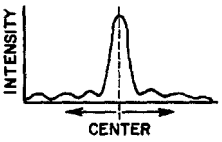
Two sinusoidal waves are combined to obtain the result in the figure above. Which of the following can best be explained by this figure?
(A) Doppler shift
(B) diffraction
(C) polarization
(D) beats
(E) refraction

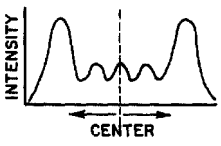
63. If the critical angle of a material against air is 30°, what is the index of refraction of the material?
    (A) 0.5
    (B) 0.6
    (C) 1.33
    (D) 1.5
    (E) 2

64. In Young's double slit interference experiment, which of the following affect the pattern of light and dark bands seen on the projection screen?
    I. The color of the light.
    II. The size of the slits.
    III. The distance between the slits.
    (A) I only
    (B) III only
    (C) I and II only
    (D) I and III only
    (E) I, II, and III

65. Which graph best represents the light intensity of the single-slit diffraction pattern for monochromatic light?
    (A)


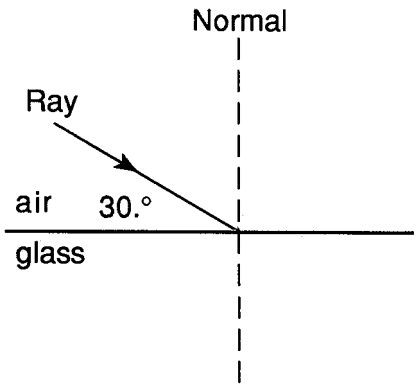
    (B)


    (C)


    (D)


    (E) None of the above

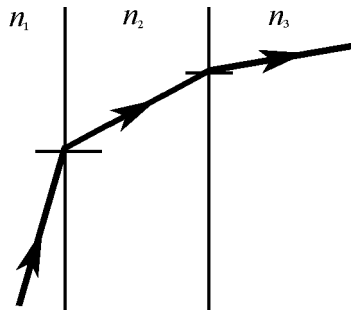
66.



In the above diagram, a ray of light in air is incident upon the smooth surface of glass with an index of refraction of $\sqrt{3}$. What is the smallest angle between the incident ray and it's reflected ray?
(A) 15º
(B) 30º
(C) 60º
(D) 120º
(E) 150º

67. An object is placed 50 cm from a plane mirror. Which of the following describes the image?
    (A) 50 cm from the object and upright
    (B) 50 cm from the object and inverted
    (C) 100 cm from the object and upright
    (D) 100 cm from the object and inverted
    (E) 150 cm from the object and upright

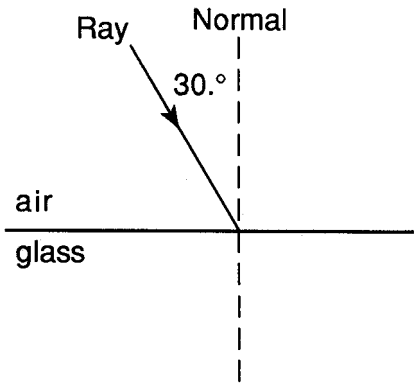
68.



The figure above shows the path of a beam of light travels through three different media. Which of the following is true?

(A) $n_1 > n_2 > n_3$
(B) $n_1 > n_3 > n_2$
(C) $n_3 > n_2 > n_1$
(D) $n_3 > n_1 > n_2$
(E) $n_2 > n_3 > n_1$

69.



In the above diagram, a ray of light in air is incident upon the smooth surface of glass. If the angle between the reflected and refracted rays is 105º, find the index of refraction of the glass.

(A) $\frac{1}{2}$
(B) $\frac{\sqrt{3}}{2}$
(C) $\frac{\sqrt{2}}{2}$
(D) $\sqrt{2}$
(E) $2\sqrt{2}$

70. What causes chromatic aberration in a lens?

(A) Each wavelength of light reflects from the surface of the lens.
(B) Each wavelength of light is refracted a different amount by the lens.
(C) White light waves interfere inside the lens.
(D) White light waves diffract around the edge of the lens.
(E) The surfaces of the lens are not smooth.

71. ${}_{1}^{2}\mathrm{H} + {}_{20}^{43}\mathrm{Ca} \rightarrow {}_{21}^{42}\mathrm{Sc} + X$

In the above reaction, X is most likely

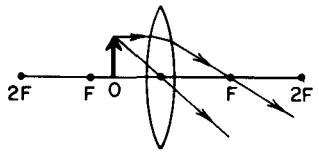
(A) protons
(B) neutrons
(C) neutrinos
(D) electrons
(E) alpha particles

72. An image of an object produced by a mirror is enlarged, virtual and erect. The object was

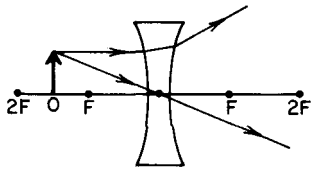
(A) outside of the focal length of a concave mirror
(B) outside of the focal length of a convex mirror
(C) inside the focal length of a convex mirror
(D) inside the focal length of a concave mirror
(E) at the focal length of a convex mirror

73. Which diagram best represents a lens being used to produce a real, enlarged image of object *O*?

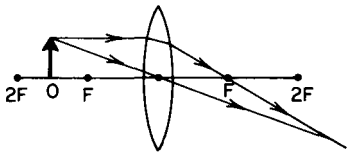
(A)



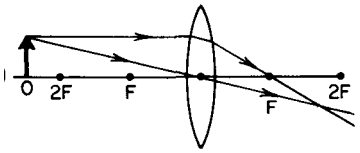
(B)



(C)



(D)



(E) none of the above

74. Photons with a kinetic energy of 8 eV strike a metal surface with a work function of 3 eV. If photons with twice the wavelength as the initial ones strike the surface

(A) no electrons will be emitted.
(B) electrons will be emitted with a maximum kinetic energy of 1 eV.
(C) electrons will be emitted with a maximum kinetic energy of 2 eV.
(D) electrons will be emitted with a maximum kinetic energy of 5 eV.
(E) electrons will be emitted with a maximum kinetic energy of 13 eV.

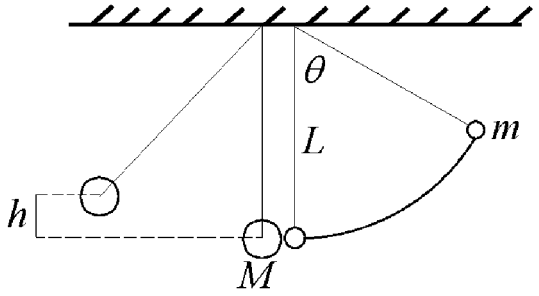
75. An object is placed 1.5 m from a plane mirror. How far is the image from the object?

(A) 50 cm
(B) 100 cm
(C) 150 cm
(D) 200 cm
(E) 300 cm

76. A radioactive of sample of mass 600 kg has a half-life of 2 days. A second sample of mass m has a half-life of 2.5 days. After 10 days, the samples have the same mass. The original mass of the second sample is

(A) 150 kg
(B) 175 kg
(C) 187 kg
(D) 200 kg
(E) 300 kg

77. Two balls are set on the end of strings of length L so that they hit at the bottom of their arcs. The first ball has a mass m. It is pulled back to a point where it makes an angle θ with the horizontal, then is released. It strikes the second ball in a perfectly elastic collision and bounces back . The second ball, with mass M, travels an upward distance of h before coming back down.



a) Calculate the velocity of the ball of mass M just after the collision.
b) Calculate the velocity of the ball of mass m
i) just before the collision.
ii) just after the collision.
c) Determine the maximum height that the ball of mass m will reach after the collision.

78. An object with a height of 15 cm is placed 1.2 m in front of a spherical concave mirror. An image is formed 40 cm in front of the mirror.
a) What is the nature of the image, real or virtual?
b) Determine whether the image will be upright or inverted.
c) Determine the height of the image.
d) Calculate the mirror's radius of curvature.
e) Draw a ray diagram, with a minimum of two rays, showing the mirror, labeling its focal point, the object, and the formation of the image.

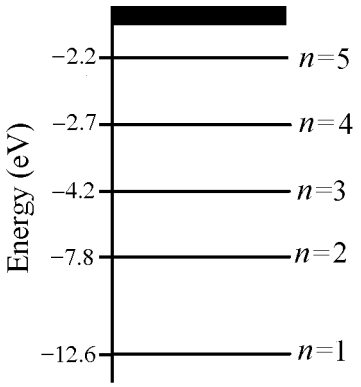
79. A heat engine operates on a Carnot cycle with a hot reservoir temperature of 1200 K and a cold reservoir temperature of 500 K. It is used to lift a mass with a weight of 7500.0 N at a constant velocity of 0.030 m/s for 5 minutes.

(a) What is the total work done by the heat engine?
(b) What is the amount of heat absorbed from the hot reservoir?
(c) The waste heat is then pumped into a room with 40 kilograms of air in it. If the specific heat of air is 700 J/kg•K, what is the temperature change in the room?

80. You want to determine the spring constant k of a spring that can be assumed to be ideal that hangs vertically from a stand. You have the following materials:
• A ruler
• An object of unknown mass
• A beaker containing a liquid of unknown density
• A stop watch
• A spring of known constant K

(a) List the steps of a procedure that can be used to determine the unknown spring constant.
(b) List all measurements you would need to make, and assign a variable to each of them (for example: t = time).
(c) Show explicitly, using equations, how k can be determined from these measurements.
(d) What is one possible source of experimental error, and how would it affect your value of the spring constant?

81.



The illustration above depicts the energy levels for a single electron atom.

(a) Determine the wavelength of a photon emitted as the electron drops from n = 5 to n = 2.
(b) Determine the magnitude of the momentum for the photon.

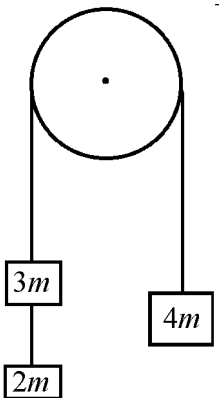
This photon then hits a photoelectric surface with a work function of 2.5 eV.

(c) Determine the maximum velocity of the emitted electron.
(d) Determine the maximum kinetic energy of an electron that could be emitted from the photoelectric cell as a result of an energy level transition in the single electron atom.

82. A student walks directly towards a plane mirror with a speed of 1.0 m/s. Relative to the student, how fast is the image moving?

(A) 0.25 m/s
(B) 0.50 m/s
(C) 1.0 m/s
(D) 2.0 m/s
(E) 4.0 m/s

83.



Three blocks of masses 2*m*, 3*m*, and 4*m* are connected by massless strings, one of which passes over a massless, frictionless pulley, as shown above.

(a) Draw a free body diagram indicating and labeling all forces on the 3*m* block.

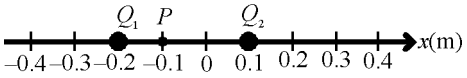
Express each of the following in terms of *m* and *g*.

(b) The acceleration of the 4*m* block.
(c) The tension in the string supporting the 4*m* block.
(d) The tension in the string supporting the 2*m* block.

The string supporting the 2*m* block is now cut. Determine the following in terms of *m* and *g*.

(e) The acceleration of the 4*m* block.
(f) The tension in the string supporting the 4*m* block.

84.



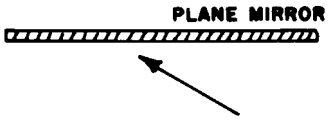
Two point charges, Q_1 and Q_2, are located a distance of 0.30 meter apart, as shown above. Charge $Q_1 = -12.0$ μC. The electric potential is zero at point *P*, located 0.10 meter from Q_1 and 0.20 meter from Q_2.

(a) Determine the magnitude and sign of charge Q_2.
(b) Determine the magnitude and direction of the net force on charge Q_1.
(c) Calculate the electrostatic potential energy of the system.
(d) Determine the coordinates of the point *R* on the *x*-axis to the left of Q_1 at which the net electric field is zero.
(e) How much work is needed to bring an electron from infinity to point *P*?

85. A heat engine is built to operate between temperatures of 1200 K and 300 K. It is used to lift a 30 kg mass at a constant velocity of 4 m/s.

(a) Determine the power that the heat engine must supply to lift the mass.
(b) Determine the maximum possible efficiency of the heat engine.
(c) If the heat engine operates at its maximum efficiency, at what rate is heat removed from the hot reservoir.
(d) The heat from the cold reservoir is pumped into a tank containing 30 kg of water. If the engine operates at its maximum efficiency, how long would it take to raise the temperature of the water 2 K.

86.

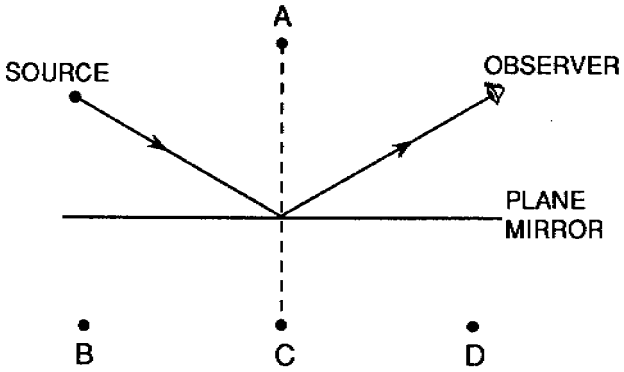


The diagram represents an object located on the reflecting side of a plane mirror.

Which arrow below best represents the image produced by the mirror?

(A) 
(B) 
(C) 
(D) 
(E) none of the above

87. In the diagram below, a light ray leaves a light source and reflects from a plane mirror.



At which point does the image of the source appear to be located?

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

Answer Key

1.	C	31.	B
2.	B	32.	C
3.	B	33.	C
4.	E	34.	D
5.	C	35.	C
6.	D	36.	A
7.	B	37.	A
8.	D	38.	B
9.	C	39.	C
10.	E	40.	C
11.	C	41.	C
12.	C	42.	B
13.	A	43.	C
14.	D	44.	C
15.	A	45.	A
16.	E	46.	E
17.	C	47.	C
18.	B	48.	E
19.	C	49.	D
20.	A	50.	A
21.	B	51.	D
22.	D	52.	B
23.	D	53.	B
24.	D	54.	E
25.	D	55.	E
26.	E	56.	A
27.	C	57.	A
28.	B	58.	E
29.	E	59.	D
30.	C	60.	C

Answer Key

61. D

62. D

63. E

64. D

65. C

66. E

67. C

68. C

69. D

70. B

71. B

72. D

73. C

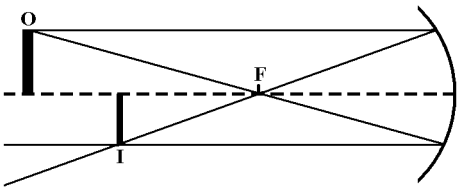
74. B

75. E

76. E

77. a) $\sqrt{(2gh)}$
b) $\sqrt{(2gL(1-\cos\theta))}$
c) $\dfrac{m\sqrt{(2gL(1-\cos\theta))} - M\sqrt{(2gh)}}{m}$
d) $\dfrac{mL(1-\cos\theta)-Mh}{m}$

78. e)



a) real
b) inverted
c) 5 cm
d) 60 cm

79. (a) 67,500 J
(b) 115,714 J
(c) 1.72 K

80. (a) Hang the object of unknown mass from the spring of known constant and note the change in length, then hang it from the spring of unknown constant and note change in length.
(b) Original length of known spring L_1
Final length of known spring L_2
Original length of unknown spring l_1
Final length of unknown spring l_2
(c) since the force on the object by the spring is the same in both cases
$k(l_2 - l_1) = K(L_2 - L_1)$
$k = K(L_2 - L_1)/(l_2 - l_1)$
(d) The springs are not ideal. Since we do not know how each spring differs from being ideal, we cannot say how this will affect the calculation. Various answers.

81. (a) 221.8 nm
(b) 2.986×10^{-27} kg • m/s
(c) 1.04×10^{6} m/s
(d) 7.9 eV

82. D

83. (b) $\frac{1}{9}g$, (c) $\frac{40}{9}mg$, (d) $\frac{16}{9}mg$,
(e) $-\frac{1}{7}g$, (f) $\frac{24}{7}mg$

84. (a) 24 μC
(b) 28.8 N to the right
(c) 8.64 J
(d) –0.924
(e) 0 eV

85. (a) 1,200 W
(b) 75%
(c) 1600 W
(d) 6285 s

86. C

87. B

Eduware Genealogy by Question

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3. I. NEWTONIAN MECHANICS / A. Kinematics / 1. One-Dimensional Motion / b. Questions without graphs : 0000535
4. I. NEWTONIAN MECHANICS / A. Kinematics / 1. One-Dimensional Motion / b. Questions without graphs : 0000529
5. I. NEWTONIAN MECHANICS / A. Kinematics / 2. Two-Dimensional Motion / a. Projectile motion : 0000033
6. I. NEWTONIAN MECHANICS / B. Newton's Laws / 1. Static Equilibrium (First Law) / a. Tension in a string : 0001082
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9. I. NEWTONIAN MECHANICS / C. Work, Energy, and Power / 1. Work and Kinetic Energy / b. Work-energy theorem : 0000585
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19. I. NEWTONIAN MECHANICS / C. Work, Energy, and Power / 1. Work and Kinetic Energy / b. Work-energy theorem : 0001047
20. I. NEWTONIAN MECHANICS / B. Newton's Laws / 2. Dynamics (Second Law) / b. Dynamics on an inclined plane : 0000952
21. I. NEWTONIAN MECHANICS / B. Newton's Laws / 2. Dynamics (Second Law) / b. Dynamics on an inclined plane : 0000953
22. I. NEWTONIAN MECHANICS / B. Newton's Laws / 2. Dynamics (Second Law) / b. Dynamics on an inclined plane : 0000954
23. I. NEWTONIAN MECHANICS / B. Newton's Laws / 4. Friction / b. Kinetic friction : 0000676
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26. I. NEWTONIAN MECHANICS / C. Work, Energy, and Power / 4. Power / b. P = F·v : 0000167
27. I. NEWTONIAN MECHANICS / D. Linear Momentum / 2. One-Dimension / b. Inelastic collisions : 0000731
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29. I. NEWTONIAN MECHANICS / E. Circular Motion and Rotations / 1. Uniform Circular Motion / b. Centripetal forces : 0000693
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33. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 2. Mirrors / c. Concave : 0001268
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39. II. FLUID MECHANICS AND THERMAL PHYSICS [B] / B. Temperature and Heat / 2. Specific and Latent Heat / a. Specific heat capacity : 0000335
40. II. FLUID MECHANICS AND THERMAL PHYSICS [B] / B. Temperature and Heat / 2. Specific and Latent Heat / a. Specific heat capacity : 0000336
41. II. FLUID MECHANICS AND THERMAL PHYSICS [B] / B. Temperature and Heat / 3. Thermal Expansion / a. Thermal expansion : 0000263
42. II. FLUID MECHANICS AND THERMAL PHYSICS [B] / C. Thermodynamics / 2. First Law of Thermodynamics / b. No diagrams : 0001093
43. II. FLUID MECHANICS AND THERMAL PHYSICS [B] / C. Thermodynamics / 3. Second Law of Thermodynamics / b. Heat engines : 0000987
44. II. FLUID MECHANICS AND THERMAL PHYSICS [B] / C. Thermodynamics / 3. Second Law of Thermodynamics / a. Entropy : 0001294
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49. III. ELECTRICITY AND MAGNETISM / A. Electrostatics / 2. Electrostatic Potential / a. Calculating potential : 0000132

Eduware Genealogy by Question

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53. III. ELECTRICITY AND MAGNETISM / C. Electric Circuits / 4. Energy and Power / a. Power dissipated by a resistor : 0000331
54. III. ELECTRICITY AND MAGNETISM / C. Electric Circuits / 4. Energy and Power / a. Power dissipated by a resistor : 0001275
55. III. ELECTRICITY AND MAGNETISM / E. Electromagnetism / 2. Electromagnetic Induction / a. Induced EMF : 0002121
56. III. ELECTRICITY AND MAGNETISM / D. Magnetostatics / 1. Force on a Moving Charge / a. Force on a moving point charge : 0001340
57. III. ELECTRICITY AND MAGNETISM / D. Magnetostatics / 1. Force on a Moving Charge / a. Force on a moving point charge : 0000845
58. III. ELECTRICITY AND MAGNETISM / D. Magnetostatics / 2. Current Carrying Wires / b. Field from a long straight wire : 0000837
59. IV. WAVES AND OPTICS [B] / A. Wave Motion / 2. Wave Phenomena / a. Doppler shift : 0000528
60. III. ELECTRICITY AND MAGNETISM / E. Electromagnetism / 2. Electromagnetic Induction / a. Induced EMF : 0000855
61. III. ELECTRICITY AND MAGNETISM / E. Electromagnetism / 2. Electromagnetic Induction / a. Induced EMF : 0000856
62. IV. WAVES AND OPTICS [B] / A. Wave Motion / 2. Wave Phenomena / b. Superposition : 0001065
63. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 1. Reflection and Refraction / c. Total internal refection : 0002027
64. IV. WAVES AND OPTICS [B] / B. Physical Optics / 1. Diffraction / a. Diffraction : 0000892
65. IV. WAVES AND OPTICS [B] / B. Physical Optics / 1. Diffraction / a. Diffraction : 0001204
66. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 1. Reflection and Refraction / a. Reflection : 0000894
67. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 2. Mirrors / a. Planar : 0001040
68. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 1. Reflection and Refraction / b. Refraction : 0000466
69. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 1. Reflection and Refraction / b. Refraction : 0000893
70. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 1. Reflection and Refraction / b. Refraction : 0001236
71. V. ATOMIC AND NUCLEAR PHYSICS [B] / B. Nuclear Physics / 1. Nuclear Reactions / a. Isotopes, Radiation and Transmutation : 0000933
72. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 2. Mirrors / c. Concave : 0001738
73. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 3. Lenses / a. Converging : 0001216
74. V. ATOMIC AND NUCLEAR PHYSICS [B] / A. Atomic Physics and Quantum Effects / 1. Wave/Particle Duality / d. Photoelectric effect : 0000299
75. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 2. Mirrors / a. Planar : 0001039
76. V. ATOMIC AND NUCLEAR PHYSICS [B] / B. Nuclear Physics / 3. Half-life / a. Half-life : 0001834
77. I. NEWTONIAN MECHANICS / D. Linear Momentum / 4. Free Response Questions / a. Free Response Questions : 0000735
78. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 4. Free Response Questions / a. Free Response Questions : 0000913
79. II. FLUID MECHANICS AND THERMAL PHYSICS [B] / C. Thermodynamics / 4. Free Response Questions / a. Free Response Questions : 0000223
80. VI. LAB [B] / A. Lab / 1. Lab / a. Lab : 0001329
81. V. ATOMIC AND NUCLEAR PHYSICS [B] / A. Atomic Physics and Quantum Effects / 3. Free Response Questions / a. Free Response Questions : 0001844
82. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 2. Mirrors / a. Planar : 0000416
83. I. NEWTONIAN MECHANICS / B. Newton's Laws / 5. Free Response Questions / a. Free Response Questions : 0000234
84. III. ELECTRICITY AND MAGNETISM / A. Electrostatics / 4. Free Response Questions / a. Free Response Questions : 0000194
85. II. FLUID MECHANICS AND THERMAL PHYSICS [B] / C. Thermodynamics / 4. Free Response Questions / a. Free Response Questions : 0000231
86. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 2. Mirrors / a. Planar : 0001210
87. IV. WAVES AND OPTICS [B] / C. Geometric Optics / 2. Mirrors / a. Planar : 0001219

Eduware Genealogy by Category

1: I. NEWTONIAN MECHANICS\A. Kinematics\1. One-Dimensional Motion\a. Graphs of motion - (1)
3: I. NEWTONIAN MECHANICS\A. Kinematics\1. One-Dimensional Motion\b. Questions without graphs - (2, 3, 4)
6: I. NEWTONIAN MECHANICS\A. Kinematics\2. Two-Dimensional Motion\a. Projectile motion - (5, 10, 11, 12, 13, 14)
1: I. NEWTONIAN MECHANICS\B. Newton's Laws\1. Static Equilibrium (First Law)\a. Tension in a string - (6)
1: I. NEWTONIAN MECHANICS\B. Newton's Laws\1. Static Equilibrium (First Law)\c. Other statics problems - (7)
2: I. NEWTONIAN MECHANICS\B. Newton's Laws\2. Dynamics (Second Law)\a. One - dimensional dynamics - (8, 15)
1: I. NEWTONIAN MECHANICS\B. Newton's Laws\3. Multiple Body Systems (Third Law)\a. Action-reaction pairs - (17)
2: I. NEWTONIAN MECHANICS\C. Work, Energy, and Power\1. Work and Kinetic Energy\b. Work-energy theorem - (9, 19)
2: I. NEWTONIAN MECHANICS\B. Newton's Laws\4. Friction\b. Kinetic friction - (18, 23)
3: I. NEWTONIAN MECHANICS\B. Newton's Laws\2. Dynamics (Second Law)\b. Dynamics on an inclined plane - (20, 21, 22)
1: I. NEWTONIAN MECHANICS\C. Work, Energy, and Power\2. Potential Energy\b. Stored in a spring - (24)
1: I. NEWTONIAN MECHANICS\C. Work, Energy, and Power\4. Power\b. P = F·v - (26)
1: I. NEWTONIAN MECHANICS\D. Linear Momentum\2. One-Dimension\a. Elastic collisions - (16)
1: I. NEWTONIAN MECHANICS\D. Linear Momentum\2. One-Dimension\b. Inelastic collisions - (27)
1: I. NEWTONIAN MECHANICS\B. Newton's Laws\5. Free Response Questions\a. Free Response Questions - (83)
1: I. NEWTONIAN MECHANICS\D. Linear Momentum\4. Free Response Questions\a. Free Response Questions - (77)
1: I. NEWTONIAN MECHANICS\E. Circular Motion and Rotations\2. Rotational Statics\a. Torque - (34)
1: I. NEWTONIAN MECHANICS\F. Oscillations and Gravitation\2. Forces and Energies\c. Pendulum - (31)
1: I. NEWTONIAN MECHANICS\F. Oscillations and Gravitation\3. Gravitation\a. Gravitational force - (35)
3: I. NEWTONIAN MECHANICS\E. Circular Motion and Rotations\1. Uniform Circular Motion\b. Centripetal forces - (28, 29, 30)
1: I. NEWTONIAN MECHANICS\D. Linear Momentum\3. Two-Dimensions\b. Inelastic collisions - (25)
1: II. FLUID MECHANICS AND THERMAL PHYSICS [B\A. Fluid Mechanics\2. Buoyancy\a. Magnitude of buoyant force - (36)
1: II. FLUID MECHANICS AND THERMAL PHYSICS [B\A. Fluid Mechanics\3. Fluid Flow Continuity\a. Change in velocity - (37)
3: II. FLUID MECHANICS AND THERMAL PHYSICS [B\B. Temperature and Heat\2. Specific and Latent Heat\a. Specific heat capacity - (38, 39, 40)
1: II. FLUID MECHANICS AND THERMAL PHYSICS [B\B. Temperature and Heat\3. Thermal Expansion\a. Thermal expansion - (41)
1: II. FLUID MECHANICS AND THERMAL PHYSICS [B\C. Thermodynamics\2. First Law of Thermodynamics\b. No diagrams - (42)
1: II. FLUID MECHANICS AND THERMAL PHYSICS [B\C. Thermodynamics\3. Second Law of Thermodynamics\a. Entropy - (44)
1: II. FLUID MECHANICS AND THERMAL PHYSICS [B\C. Thermodynamics\3. Second Law of Thermodynamics\b. Heat engines - (43)
2: II. FLUID MECHANICS AND THERMAL PHYSICS [B\C. Thermodynamics\4. Free Response Questions\a. Free Response Questions - (79, 85)
1: III. ELECTRICITY AND MAGNETISM\A. Electrostatics\1. Coulomb's law\b. Electric fields - (47)
2: III. ELECTRICITY AND MAGNETISM\A. Electrostatics\2. Electrostatic Potential\a. Calculating potential - (48, 49)
1: III. ELECTRICITY AND MAGNETISM\A. Electrostatics\1. Coulomb's law\a. Force between charges - (45)
1: III. ELECTRICITY AND MAGNETISM\B. Conductors, Capacitors, and Resistors\2. Capacitors\a. Capacitance - (46)
2: III. ELECTRICITY AND MAGNETISM\B. Conductors, Capacitors, and Resistors\2. Capacitors\b. Electric fields in capacitors - (50, 51)
1: III. ELECTRICITY AND MAGNETISM\C. Electric Circuits\2. Resistor Only Circuits\b. Currents and ohm's law - (52)
2: III. ELECTRICITY AND MAGNETISM\D. Magnetostatics\1. Force on a Moving Charge\a. Force on a moving point charge - (56, 57)
1: III. ELECTRICITY AND MAGNETISM\D. Magnetostatics\2. Current Carrying Wires\b. Field from a long straight wire - (58)
2: III. ELECTRICITY AND MAGNETISM\C. Electric Circuits\4. Energy and Power\a. Power dissipated by a resistor - (53, 54)
3: III. ELECTRICITY AND MAGNETISM\E. Electromagnetism\2. Electromagnetic Induction\a. Induced EMF - (55, 60, 61)
1: III. ELECTRICITY AND MAGNETISM\A. Electrostatics\4. Free Response Questions\a. Free Response Questions - (84)
2: IV. WAVES AND OPTICS [B]\B. Physical Optics\1. Diffraction\a. Diffraction - (64, 65)
1: IV. WAVES AND OPTICS [B]\C. Geometric Optics\1. Reflection and Refraction\a. Reflection - (66)
3: IV. WAVES AND OPTICS [B]\C. Geometric Optics\1. Reflection and Refraction\b. Refraction - (68, 69, 70)
1: IV. WAVES AND OPTICS [B]\C. Geometric Optics\1. Reflection and Refraction\c. Total internal refection - (63)
1: IV. WAVES AND OPTICS [B]\A. Wave Motion\1. Properties of Waves\c. Electromagnetic waves - (32)
1: IV. WAVES AND OPTICS [B]\C. Geometric Optics\3. Lenses\a. Converging - (73)
5: IV. WAVES AND OPTICS [B]\C. Geometric Optics\2. Mirrors\a. Planar - (67, 75, 82, 86, 87)
1: IV. WAVES AND OPTICS [B]\C. Geometric Optics\4. Free Response Questions\a. Free Response Questions - (78)
1: IV. WAVES AND OPTICS [B]\A. Wave Motion\2. Wave Phenomena\a. Doppler shift - (59)
2: IV. WAVES AND OPTICS [B]\C. Geometric Optics\2. Mirrors\c. Concave - (33, 72)
1: IV. WAVES AND OPTICS [B]\A. Wave Motion\2. Wave Phenomena\b. Superposition - (62)
1: V. ATOMIC AND NUCLEAR PHYSICS [B]\A. Atomic Physics and Quantum Effects\3. Free Response Questions\a. Free Response Questions - (81)
1: V. ATOMIC AND NUCLEAR PHYSICS [B]\B. Nuclear Physics\3. Half-life\a. Half-life - (76)
1: V. ATOMIC AND NUCLEAR PHYSICS [B]\B. Nuclear Physics\1. Nuclear Reactions\a. Isotopes, Radiation and Transmutation - (71)
1: V. ATOMIC AND NUCLEAR PHYSICS [B]\A. Atomic Physics and Quantum Effects\1. Wave/Particle Duality\d. Photoelectric effect - (74)
1: VI. LAB [B]\A. Lab\1. Lab\a. Lab - (80)

AP Physics B Sample Exam

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