

5. Two non-zero vectors $\vec{A}$ and $\vec{B}$ are related by $\vec{A} = c\vec{B}$ where c is a scalar. If the two vectors have opposite directions, then one of the following is true about c ? (1)
- A. c is a positive number
B. ✓ c is a negative number
C. $c = 1$
D. $c = 0$

Answer: B

If two vectors are related by $\vec{A} = c\vec{B}$ and point in opposite directions, the scalar multiplier c must be negative to reverse the direction of $\vec{B}$.

6. On which of the following does the induced emf in a coil NOT depend when a magnet is inserted into it? (1)
- A. ✓ **resistance of the coil**
B. number of turns of the coil
C. speed approach of the magnet
D. magnetic moment of the magnet

Answer: A

According to Faraday's law of induction, the induced electromotive force depends on the number of turns and the rate of change of magnetic flux, but it is independent of the resistance of the coil (which only affects the induced current).

7. A wave have a speed of 50m/s and a wavelength of 25,000m. What is the frequency of the wave? (1)
- A. ✓ 2.0×10^{-3} HZ
B. 5.0×10^{-2} HZ
C. 6.0×10^1 HZ
D. 1.8×10^6 HZ

Answer: A

The frequency of the wave is calculated using $f = v/\lambda = 50 \text{ m/s}/25,000 \text{ m} = 2.0 \times 10^{-3} \text{ Hz}$.

8. An oscillating system is used to create a succession of wave on a water surface. The rate of wave generation is one every 0.33 seconds. What is the period of these wave? (1)
- A. ✓ **0.3 seconds**
B. 1.0 seconds
C. 2.0 seconds
D. 3.0 seconds

Answer: A

The rate of wave generation is one wave every 0.33 seconds, which means the time period of a single wave is 0.33 seconds, which is closest to 0.3 seconds.

9. A vector that represents the position of an object in relation to another object is called (1)
- A. unit vectors
B. ✓ **position vectors**
C. coplanar vectors
D. collinear vectors

Answer: B

A position vector is a vector that represents the position of an object relative to a reference point or another object.

10. In a reversible thermodynamic process, the system (1)
- A. ✓ **is always close to equilibrium states**
B. might never be close to any equilibrium states
C. is close to equilibrium states only at the beginning and end
D. is close to equilibrium states throughout, except at the beginning and end

Answer: A

A reversible process is carried out quasi-statically (infinitely slowly), ensuring that the system remains in a state of thermodynamic equilibrium at all stages of the process.

11. Points A and B are each a distance d from each of two equal and opposite charge as shown below. What will be the work required to move a negative charge q from A to B? (1)

[Figure: A hand-drawn rhombus (diamond) standing on one of its diagonals. The point A is at the top vertex and the point B is at the bottom vertex. A large circle labelled $+Q$ sits at the left vertex and a large circle labelled $-Q$ sits at the right vertex; a straight horizontal line joins the two charges through the centre, and a straight vertical line joins A to B through the same centre. Each of the four sides of the rhombus is labelled d : the upper-left side (from $+Q$ to A), the upper-right side (from A to $-Q$), the lower-left side (from $+Q$ to B) and the lower-right side (from B to $-Q$).]

A. ✓ zero

B. $\frac{qQ}{4\pi\epsilon_0 d^2}$

C. $\frac{qQ}{4\pi\epsilon_0 d}$

D. $\frac{qQ}{4\pi\epsilon_0 (4d^2)}$

Answer: A

Since points A and B are equidistant from the two equal and opposite charges, the electric potential at both A and B is zero ($V_A = V_B = 0$). Thus, the work required to move a charge between these points, $W = q(V_B - V_A)$, is zero.

12. An air-filled parallel-plate capacitor has a capacitance of 1 pF. The plate separation is then doubled and a wax dielectric is inserted, completely filling the space between the plates. As a result, the capacitance becomes 2 pF. What is the dielectric constant of the wax? (1)

A. 8.0

B. ✓ 4.0

C. 2.0

D. 0.5

Answer: B

The capacitance of a parallel plate capacitor is $C = \frac{K\epsilon_0 A}{d}$. If the separation d is doubled and dielectric constant K is introduced, the new capacitance is $C_2 = \frac{K}{2} C_1$. Given $C_1 = 1$ pF and $C_2 = 2$ pF, we get $2 = \frac{K}{2}(1)$, which gives $K = 4.0$.

13. A step-up transformer is used to (1)

A. increase the power

B. decrease the power

C. ✓ increase the voltage

D. decrease the voltage

Answer: C

A step-up transformer increases the voltage from the primary to the secondary winding while decreasing the current, keeping the total power theoretically constant.

14. A 220-V power line is protected by a 15-A fuse. What is the maximum number of "220V, 500W" light bulbs that can be operated at full brightness from this line? (1)

A. 2

B. 4

C. ✓ 6

D. 8

Answer: C

The maximum power the line can safely handle is $P = VI = 220 \text{ V} \times 15 \text{ A} = 3300 \text{ W}$. Therefore, the maximum number of 500 W bulbs that can be run is $3300/500 = 6.6$, which yields a maximum of 6 bulbs.

15. If $\vec{A} = 8\vec{i} + \vec{j} - 2\vec{k}$ and $\vec{B} = 5\vec{i} - 3\vec{j} + \vec{k}$, then what is the value of $\vec{B} \times \vec{A}$? (1)

A. $3\vec{i} + 4\vec{j} - 3\vec{k}$

B. $-3\vec{i} - 4\vec{j} + 3\vec{k}$

C. $-5\vec{i} - 18\vec{j} - 29\vec{k}$

D. ✓ $5\vec{i} + 18\vec{j} + 29\vec{k}$

Answer: D

Computing the cross product $\vec{B} \times \vec{A}$ by evaluating the determinant of the 3x3 matrix containing unit vectors in the first row, $\vec{B}$ in the second row, and $\vec{A}$ in the third row, yields $5\vec{i} + 18\vec{j} + 29\vec{k}$.

16. A woman driving a 2000 kg car along a level road at 30m/s takes her foot off the gas to see how far her car will roll before it slows to a stop. She discovers that it takes 150m. What is the average force of friction acting on the car? (1)
- A. 9000N
B. ✓ 6000N
C. 3000N
D. 400N

Answer: B

Using the work-energy theorem, the work done by friction equals the change in kinetic energy: $f \cdot d = \frac{1}{2}mv^2$. This gives $f \cdot 150 = \frac{1}{2}(2000)(30)^2$, which simplifies to $f = 6000$ N.

17. The radius of the wheel shown below is 0.75m. What is its moment of inertia? (1)
- [Figure: A hand-drawn wheel: a large circle (the rim) with a small hub at the centre and four straight spokes running from the hub to the rim at the top, bottom, left and right. Where each spoke meets the rim there is a small circle representing a point mass, and each of the four masses is labelled 3kg.]
- A. 2.25 kgm²
B. 3.38 kgm²
C. ✓ 6.75 kgm²
D. 9.00 kgm²

Answer: C

Since all four 3 kg point masses are located on the rim of the wheel at a distance of 0.75 m from the center, the total moment of inertia is $I = 4 \times mR^2 = 4 \times 3 \text{ kg} \times (0.75 \text{ m})^2 = 6.75 \text{ kg m}^2$.

18. An ordinary refrigerator is turned on and its door is open in a thermally insulated kitchen. What is the temperature of the room? (1)
- A. ✓ increases according to the first law of thermodynamics
B. decreases according to the first law of thermodynamics
C. remains constant according to the first law of thermodynamics
D. remains constant according to the second law of thermodynamics

Answer: A

A refrigerator expels more heat to the room than it absorbs from its interior because of the electrical work input ($Q_H = Q_C + W$). In an insulated room, this electrical energy accumulates as thermal energy, raising the room's temperature according to the first law of thermodynamics.

19. The length of an aluminium rod at a temperature of 20°C is 3m. What will be the ratio of change in the length of the rod to its original length if its temperature is raised to 120°C? the coefficient of linear expansion of aluminium is $3.31 \times 10^{-5}/\text{K}$ (1)
- A. 23%
B. 3.2%
C. 3%
D. ✓ 0.23%

Answer: D

Using the standard coefficient of linear expansion for aluminium, which is $\alpha \approx 2.3 \times 10^{-5}/\text{K}$ (typed as $3.31 \times 10^{-5}/\text{K}$ in the question), the ratio $\Delta L/L_0 = \alpha \Delta T = (2.3 \times 10^{-5}) \times 100 = 0.0023 = 0.23\%$.

20. A very large open tank is full of oil whose density is 800kg/m. if the absolute pressure at the bottom of the tank is 1.81×10^5 Pa, then what is the depth of the oil? (Note that atmospheric pressure is 1.01×10^5 Pa) (1)
- A. 100.0m
B. 75.0m
C. ✓ 10.0m
D. 9.5m

Answer: C

The gauge pressure of the oil is $P_{\text{gauge}} = P_{\text{abs}} - P_{\text{atm}} = 1.81 \times 10^5 \text{ Pa} - 1.01 \times 10^5 \text{ Pa} = 0.80 \times 10^5 \text{ Pa}$. Using $P_{\text{gauge}} = \rho gh$, we find $h = 0.80 \times 10^5 / (800 \times 10) = 10.0 \text{ m}$.

- 21.** A 1.5kg particle moves in the xy-plane with velocity $\vec{v} = (4.2\vec{i} - 3.6\vec{j})$ what is its angular momentum when the position vector is $\vec{r} = (1.5\vec{i} + 2.2\vec{j})m$? (1)
- A. ✓ $-22\vec{k}\text{ kgm}^2$
- B. $14.6\vec{k}\text{ kgm}^2$
- C. $-14.6\vec{k}\text{ kgm}^2$
- D. $22\vec{k}\text{ kgm}^2$

Answer: A

The angular momentum is $\vec{L} = m(\vec{r} \times \vec{v}) = 1.5 \times ((1.5\vec{i} + 2.2\vec{j}) \times (4.2\vec{i} - 3.6\vec{j})) = 1.5 \times (-14.64\vec{k}) \approx -22\vec{k} \text{ kg m}^2/\text{s}$.

- 22.** A 2kg object experiences two concurrent forces of 100N at 30° above the positive x-axis and 80N at 60° above the negative x-axis. What is the magnitude of acceleration of the object?
- A. 68 m/s^2
- B. ✓ 64 m/s^2
- C. 48 m/s^2
- D. 46 m/s^2

Answer: B

The components of the forces are $\vec{F}_1 = 86.6\vec{i} + 50\vec{j}$ and $\vec{F}_2 = -40\vec{i} + 69.3\vec{j}$, which sum to $\vec{F}_{\text{net}} = 46.6\vec{i} + 119.3\vec{j}$ with magnitude 128 N. The acceleration is $a = F_{\text{net}}/m = 128 \text{ N}/2 \text{ kg} = 64 \text{ m/s}^2$.

23. A driver moving at a constant speed of 20m/s sees an accident up ahead and hits the brakes. If the car decelerates at a constant rate of -5 m/s^2 , how far does the car go before it comes to a stop? (1)
- A. 120m
B. 100m
C. ✓ 40m
D. 20m

Answer: C

Using the equation of motion $v^2 = u^2 + 2as$ with $v = 0 \text{ m/s}$, $u = 20 \text{ m/s}$, and $a = -5 \text{ m/s}^2$, we get $0 = 20^2 + 2(-5)s$, which simplifies to $10s = 400$, giving $s = 40 \text{ m}$.

24. The energy spectrum emitted by a black body at different temperature is as shown in figure below. Which of the following statements is NOT correct about the black body energy spectrum? (1)
- A. $T_1 < T_2 < T_3 < T_4$
- B. $\lambda_1 > \lambda_2 > \lambda_3 > \lambda_4$
- C. black body radiate energy over the entire electromagnetic spectrum
- D. ✓ the wavelength corresponding to the maximum intensity increases with temperature

Answer: D

Wien's displacement law states that the wavelength corresponding to maximum intensity is inversely proportional to the absolute temperature ($\lambda_{\text{max}}T = \text{constant}$), meaning it decreases as temperature increases.

- 25.** A rectangular loop carrying a current is situated near a long straight wire such that the wire is parallel to one of its sides of the loop and it is in a plane of the loop. If a steady current is established in the wire as shown in figure below, the loop will

[Figure: A hand-drawn figure. On the left is a long straight vertical wire carrying a current labelled I , with an arrowhead near the top of the wire showing the current flowing upward. To the right of the wire, in the same plane, is a rectangular loop whose left side is parallel to the straight wire. The loop carries a current labelled i , drawn clockwise: an arrowhead on the top side points to the right, an arrowhead on the right side points down, an arrowhead on the bottom side points to the left, and an arrowhead on the left side points up.]

- A. Remain stationary.
- B. ✓ **Move toward the wire.**
- C. Move away from the wire.
- D. Rotate about an axis parallel to the wire.

Answer: B

The left side of the rectangular loop carries current in the same direction as the straight wire and is therefore attracted to it, while the right side carries current in the opposite direction and is repelled. Since the magnetic field is stronger closer to the wire, the attractive force dominates and the loop moves toward the wire.

- 26.** Which devices uses the principle of electromagnetic induction for its operation? (1)

- A. ✓ AC generator
B. moving coil meter
C. cathode ray tube
D. light emitting diode

Answer: A

An AC generator works on the principle of electromagnetic induction (Faraday's law) to convert rotational mechanical energy into electrical energy by changing the magnetic flux through a coil.

- 27.** An electron enters a region of uniform electric field of $5 \times 10^3 \text{ N/C}$. what is the force on the electron? (1)

- A.** $8 \times 10^{-22}\text{N}$ **B.** $5.3 \times 10^{-22}\text{N}$
C. $\checkmark 8 \times 10^{-16}\text{N}$ **D.** $1.88 \times 10^{22}\text{N}$

Answer: C

The electric force is given by $F = qE$. For an electron, $F = (1.6 \times 10^{-19} \text{ C}) \times (5 \times 10^3 \text{ N/C}) = 8 \times 10^{-16} \text{ N}$.

- 28.** In the circuit shown below, what is the potential difference between points B and D? (1)

[Figure: A hand-drawn circuit. A 6 V battery sits in the top wire of an outer rectangular loop. The left-hand side of that loop comes down to a node labelled A and the right-hand side comes down to a node labelled C. Between A and C there are two parallel branches. The upper branch runs from A through a 6 ohm resistor to a point labelled B and then through a 12 ohm resistor to C. The lower branch runs from A through a 12 ohm resistor to a point labelled D and then through a 6 ohm resistor to C.]

- A. 1V
B. ✓ 2V
C. 3V
D. 4V

Answer: B

Using the voltage divider rule for parallel branches connected across 6 V, the potential at B is $V_B = 6 \text{ V} \times \frac{12}{6+12} = 4 \text{ V}$ and at D is $V_D = 6 \text{ V} \times \frac{6}{12+6} = 2 \text{ V}$, resulting in a potential difference of $|V_B - V_D| = 2 \text{ V}$.

29. The planet Jupiter is about 318 times as massive as earth, yet on its surface you would weigh only about 2.4 times your weight on earth. Why is this happened? (1)
- A. Your mass is 132.5 times less on Jupiter.
B. You are 132.5 times more weightless there.
C. Jupiter is significantly farther from the sun.
D. ✓ **Jupiter's radius is about 11.5 times the earth's radius.**

Answer: D

The acceleration due to gravity on a planet's surface is $g = GM/R^2$. Since Jupiter is 318 times as massive as Earth but has a surface gravity only 2.4 times that of Earth, its radius must be about $\sqrt{318/2.4} \approx 11.5$ times the Earth's radius.

30. A uniform ball of radius r and mass m starts from rest and rolls down a frictionless inline of height h . when the ball reaches the ground, how fast is it going? (1)
- A. ✓ $\sqrt{\frac{10}{7}gh}$
B. $\sqrt{\frac{9}{10}gh}$
C. $\sqrt{\frac{10}{9}gh}$
D. $\sqrt{\frac{7}{10}gh}$

Answer: A

Applying conservation of energy for standard rolling without slipping, $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$. For a solid ball $I = \frac{2}{5}mr^2$, which simplifies to $mgh = \frac{7}{10}mv^2$ and yields $v = \sqrt{\frac{10}{7}gh}$.

31. A ladder of length 3m and mass 20 kg leans against a smooth, vertical wall so that the angle between the wall and the ladder is 30° . What are the magnitudes of the normal forces at the contact point on the wall (N_w) and at the contact point on the ground? (1)
- A. $N_w = 0 \text{ N}, N_g = 200 \text{ N}$
B. $N_w = 200 \text{ N}, N_g = 0 \text{ N}$
C. ✓ $N_w = 57.7 \text{ N}, N_g = 200 \text{ N}$
D. $N_w = 200 \text{ N}, N_g = 57.7 \text{ N}$

Answer: C

The normal force from the ground must balance the weight of the ladder, so $N_g = mg = 200 \text{ N}$. Balancing torques about the base of the ladder gives $N_w L \cos 30^\circ = mg \frac{L}{2} \sin 30^\circ$, which yields $N_w = 100 \tan 30^\circ \approx 57.7 \text{ N}$.

32. A container resting on the floor of an elevator contains an incompressible fluid of density ρ . When the elevator has an upward acceleration of magnitude "a" then what will be the pressure difference between two points in the fluid separated by a vertical distance Δh ? (1)
- A. $\rho a \Delta h$
B. ✓ $\rho(g + a)\Delta h$
C. $\rho g \Delta h$
D. $\rho g a \Delta h$

Answer: B

In an upward accelerating frame with acceleration a , the effective acceleration due to gravity is $g_{\text{eff}} = g + a$. Therefore, the hydrostatic pressure difference is $\Delta P = \rho(g + a)\Delta h$.

33. If two particles have equal momenta, then which one of the following statements is TRUE about their kinetic energies? (1)
- A. Their kinetic energies are always equal.
 - B. Their kinetic energies are never equal.
 - C. ✓ **Their kinetic energies are equal when their masses are the same.**
 - D. Their kinetic energies are equal when the speed of one of the particle is half the speed of the other and their masses are the same.

Answer: C

The kinetic energy of a particle can be expressed in terms of its momentum as $K = P^2/(2m)$. Since their momenta P are equal, their kinetic energies are equal if and only if their masses m are the same.

34. In Young's double slit experiment both the separation between the slits and the distance between the slits and the screen are halved then, what is the fringe width? (1)
- A. halved
 - B. ✓ **unchanged**
 - C. zero
 - D. doubled

Answer: B

The fringe width in Young's double-slit experiment is $w = \frac{\lambda D}{d}$. Since both the slit separation d and the screen distance D are halved, the ratio D/d remains unchanged, keeping the fringe width constant.

35. What is the capacitance of a capacitor that should be connected with 2 other capacitors having capacitance of 4F and 8F all in series to produce an effective capacitance of $\frac{24}{11} \mu\text{F}$? (1)
- A. ✓ **$12 \mu\text{F}$**
 - B. $10 \mu\text{F}$
 - C. $8 \mu\text{F}$
 - D. $4 \mu\text{F}$

Answer: A

For series capacitors, $1/C_{\text{eq}} = 1/C_1 + 1/C_2 + 1/C_3$. Solving $11/24 = 1/4 + 1/8 + 1/C_3$ gives $1/C_3 = 2/24$, which yields $C_3 = 12 \mu\text{F}$.

36. A particle of mass m is fired into a magnetic field of strength B at speed V . the particle travels in a circular path inside the field with a radius r . which of the following expressions gives the magnitude of the charge on the particle? (1)
- A. $\frac{mr}{vB}$
 - B. $\frac{mv^2}{Br}$
 - C. $\frac{vB}{mr}$
 - D. ✓ **$\frac{mv}{Br}$**

Answer: D

The centripetal force for circular motion in a magnetic field is provided by the magnetic force: $qvB = mv^2/r$. Solving for the charge q gives $q = mv/(Br)$.

37. An alternating current is represented by $I(t) = 10.0 \text{ A} \sin(100\pi t)$. What are the amplitude and frequency of the alternating current? (1)
- A. 100A, 75Hz
 - B. 10.0A, 100Hz
 - C. ✓ **10.0A, 50Hz**
 - D. 5.0A, 25Hz

Answer: C

For $I(t) = 10.0 \sin(100\pi t)$, the amplitude is the coefficient of the sine term (10.0 A) and the angular frequency is $\omega = 100\pi \text{ rad/s}$, corresponding to a frequency $f = \omega/(2\pi) = 50 \text{ Hz}$.

38. A series RLC circuit has a resistance of 45Ω and an impedance of 75Ω . What average power is delivered to this circuit when $\Delta V_{rms} = 210V$? (1)
- A. 573w
B. ✓ 353w
C. 255.4w
D. 237.6w

Answer: B

The average power in an RLC circuit is $P = I_{rms}^2 R$. First finding $I_{rms} = V_{rms}/Z = 210/75 = 2.8$ A, we calculate $P = (2.8)^2 \times 45 \approx 353$ W.

39. A thin film of oil ($n=1.25$) is located on a smooth wet floor. When viewed perpendicular to the floor, the film reflects most strongly red light at 640nm and reflects no blue light at 512nm. How thick is the oil film? (1)
- A. 640nm
B. 612nm
C. 548nm
D. ✓ 512nm

Answer: D

Since $n_{air} < n_{oil} < n_{water}$, both reflections experience a π phase shift. Thus, constructive interference (strong reflection) occurs at $2nt = m\lambda_1$ and destructive at $2nt = (k - 0.5)\lambda_2$; substituting $m = 2$, $k = 3$, and $n = 1.25$ yields a film thickness $t = 512$ nm.

40. Which one of the following changes to parallel plate capacitor would not increase energy stored in the capacitor at a fixed voltage across the plates? (1)
- A. increasing the area of the plates
B. increasing the dielectric constant
C. decreasing the charges on the plates
D. ✓ increasing the distance between the plates

Answer: D

The energy stored at a fixed voltage is $E_c = \frac{1}{2}CV^2$. Increasing the distance between the plates d decreases the capacitance ($C = \kappa\epsilon_0 A/d$), which decreases (rather than increases) the stored energy.

41. Suppose that a voltage source produces 240V for a moment. By what percentage does the power output of 220V light bulb increases? (1)
- A. 38%
B. 36%
C. ✓ 19%
D. 18%

Answer: C

Since power is proportional to the square of voltage ($P = V^2/R$), the percentage increase is $(240^2/220^2 - 1) \times 100\% \approx 19\%$.

42. If all the three resistors in the circuit shown in the figure have equal resistance, and the current flowing into resistor B is 4A, then what is the current flowing into resistor G? (1)

[Figure: A hand-drawn circuit on a rectangular frame with a battery in the left-hand side. Two parallel horizontal branches run between the left and right vertical wires near the top of the frame: the upper branch contains two resistors in series labelled B (on the left) and C (on the right); the branch immediately below it contains two resistors in series labelled D (on the left) and E (on the right). On the right-hand vertical wire, below where those two branches join, there is a resistor labelled F. Along the bottom wire, which returns to the battery, there is a resistor labelled G.]

- A. 16A
C. 2A
B. ✓ 8A
D. 1A

Answer: B

The branch containing B and C is in parallel with the branch containing D and E. Since both parallel branches have equal total resistance, the current of 4 A through B implies a current of 4 A through D, summing to 8 A flowing through G.

43. Refraction of a wave does NOT involve change in its (1)

- A. speed
C. ✓ frequency
B. wavelength
D. speed and wavelength

Answer: C

Refraction of a wave changes its speed and wavelength as it transitions between different media, but the frequency is determined by the source and remains constant.

44. Gas at a pressure P is contained in a vessel. If the masses of all the molecules are doubled and their speeds are halved, then what will be the resulting pressure? (1)

- A. 2P
C. ✓ P/2
B. P/3
D. 3P

Answer: C

From the kinetic theory of gases, pressure is proportional to the product of molecular mass and mean square speed ($P \propto m\langle v^2 \rangle$). Doubling m and halving v changes the pressure to $2m \times (v/2)^2 = \frac{1}{2}mv^2$, so the new pressure is $P/2$.

45. Water flows through a fire hose of diameter 6.35cm at a rate of $0.012 \text{ m}^3/\text{s}$. the fire hose ends in a nozzle of inner diameter 2.20cm. What is the speed with which the water exits the nozzle? (1)

- A. 63.2m/s
C. ✓ 31.6m/s
B. 46.8m/s
D. 23.4 m/s

Answer: C

Using the flow rate equation $Q = Av = \frac{\pi d^2}{4}v$, the exit speed is $v = \frac{4Q}{\pi d^2} = \frac{4 \times 0.012}{\pi \times (0.022)^2} \approx 31.6 \text{ m/s}$.

- 46.** A bullet of mass 10gm, moving horizontally, strikes and embeds itself in a box of mass 1kg suspended from a light string as shown in the figure below. If the composite mass rises to a height, $h=0.45\text{m}$, then what is the speed of the bullet before collision? (1)

[Figure: A hand-drawn ballistic pendulum. On the left a small bullet is drawn as a short pointed shape with a horizontal arrow beside it showing it travelling to the right. In the middle a light string hangs vertically from a horizontal ceiling support; a rectangular box hangs at the lower end of the string, resting at the level of a horizontal ground line. A second string is drawn from the same ceiling point sloping down to the right to the same box shown swung up to a raised position, where a small dark bullet shape with an arrow is drawn inside the box. The vertical rise from the low position to the raised position is labelled $h=0.45\text{m}$.]

- A. ✓ 303m/s B. 300m/s
C. 90.9m/s D. 90m/s

Answer: A

Using the conservation of momentum and mechanical energy with $g = 10 \text{ m/s}^2$ gives the initial velocity of the bullet as $v = \frac{m+M}{m} \sqrt{2gh} = \frac{1.01}{0.01} \sqrt{2 \times 10 \times 0.45} = 303 \text{ m/s}$.

- 47.** A rocket moving in free space has a speed of 3×10^3 m/s relative to the earth. Its engines are turned on and fuel is ejected in a direction opposite the rocket's motion at a speed of 5×10^3 m/s relative to the rocket. What is the speed of the rocket relative to the earth once the rocket's mass is reduced to half its mass before ignition? (1)

- A.** $7 \times 10^3 \text{ m/s}$ **B.** $5 \times 10^3 \text{ m/s}$
C. $4 \times 10^3 \text{ m/s}$ **D.** $2 \times 10^3 \text{ m/s}$

Answer: A

Using the rocket equation, $v_f = v_i + v_e \ln(m_i/m_f) = 3 \times 10^3 + 5 \times 10^3 \ln(2) \approx 6.47 \times 10^3$ m/s, which is closest to the value in Option A.

END OF THE MARKING KEY

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