Rajasthan JET Physics Sample Paper-11

Duration: 40 Minutes **Maximum Marks: 160**

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1 mark**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. The dimensional formula of Planck's constant h (where energy $E = h\nu$, ν being frequency) is:

(A) $[ML^2T^{-2}]$

(B) $[ML^2T^{-1}]$

(C) $[MLT^{-1}]$

(D) $[ML^2T^{-3}]$

Q2. A physical quantity is given by $X = \dfrac{a^2\,b^3}{\sqrt{c}}$. If the percentage errors in a, b and c are 1%, 2% and 4% respectively, the maximum percentage error in X is:

(A) 7%

(B) 9%

(C) 14%

(D) 10%

Q3. The velocity of a particle moving along the x-axis varies with time as $v = (6t - 3t^2)$ m/s. The displacement of the particle between the two instants at which it is momentarily at rest is:

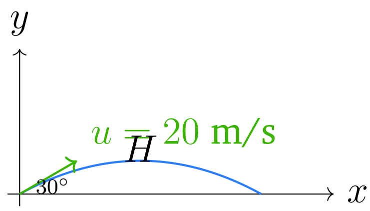
(A) 4 m

(B) 2 m

(C) 8 m

(D) 6 m

Q4. A ball is projected from the ground with a speed of 20 m/s at 30° above the horizontal (take $g = 10$ m/s^2). The maximum height attained by the ball is:



(A) 10 m

(B) 2.5 m

(C) 5 m

(D) 7.5 m

Q5. Rain is falling vertically downward with a speed of 4 m/s. A man walks horizontally with a speed of 3 m/s. At what angle with the vertical should he hold his umbrella to protect himself from the rain?

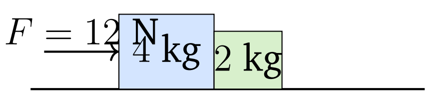
(A) 53°

(B) 30°

(C) 45°

(D) 37°

Q6. Two blocks of masses 4 kg and 2 kg are placed in contact on a smooth horizontal surface. A horizontal force of 12 N is applied to the 4 kg block as shown. The contact force between the two blocks is:



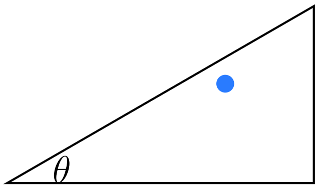
(A) 8 N

(B) 4 N

(C) 12 N

(D) 6 N

Q7. A block placed on a rough inclined plane just begins to slide when the coefficient of static friction between the block and the plane is $\mu = \frac{1}{\sqrt{3}}$. The angle of repose (the inclination at which sliding just starts) is:



(A) 30°

(B) 45°

(C) 60°

(D) 37°

Q8. A variable force $F = (3x^2 + 2x)$ N acts on a body along the x-direction. The work done by this force in moving the body from $x = 0$ to $x = 2$ m is:

(A) 6 J

(B) 10 J

(C) 12 J

(D) 16 J

Q9. A block of mass 0.5 kg is pressed against a horizontal spring of force constant 200 N/m, compressing it by 0.1 m, and then released on a smooth surface. The maximum speed acquired by the block is:

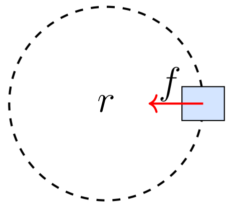
(A) 0.5 m/s

(B) 1 m/s

(C) 4 m/s

(D) 2 m/s

Q10. A car moves on a flat (unbanked) circular track of radius 20 m. If the coefficient of friction between the tyres and the road is 0.5 (take $g = 10$ m/s^2), the maximum speed with which the car can take the turn without skidding is:



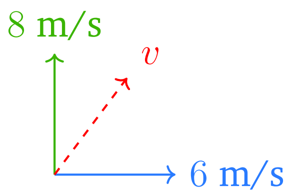
(A) 10 m/s

(B) 5 m/s

(C) 14 m/s

(D) 20 m/s

Q11. Two identical particles, each of mass m, move on a smooth horizontal table: one along the $+x$ direction at 6 m/s and the other along the $+y$ direction at 8 m/s. They collide and stick together. The common speed of the combined mass just after collision is:



(A) 7 m/s

(B) 5 m/s

(C) 10 m/s

(D) 3.5 m/s

Q12. Four point masses, each of mass m, are placed at the corners of a square of side a. The moment of inertia of this system about an axis passing through the centre of the square and perpendicular to its plane is:

(A) ma^2

(B) $4ma^2$

(C) $2ma^2$

(D) $\frac{1}{2}ma^2$

Q13. A solid sphere, a uniform disc and a thin ring, all of the same mass and radius, are released from rest from the top of the same inclined plane and roll down without slipping. Which one reaches the bottom first?

(A) The solid sphere

(B) The disc

(C) The ring

(D) All reach at the same time

Q14. A force $\vec{F} = (3\hat{i} + 2\hat{j})$ N acts at a point whose position vector is $\vec{r} = (2\hat{i} + 3\hat{j})$ m, measured from the origin. The magnitude of the torque of the force about the origin is:

(A) 13 N·m

(B) 7 N·m

(C) 0

(D) 5 N·m

Q15. The acceleration due to gravity at the surface of the Earth is 10 m/s^2. Its value at a depth equal to half the radius of the Earth ($d = R/2$) below the surface is:

(A) 2.5 m/s^2

(B) 5 m/s^2

(C) 7.5 m/s^2

(D) 10 m/s^2

Q16. A satellite revolves around the Earth in a circular orbit. If the radius of the orbit is increased to four times its original value, the orbital speed of the satellite becomes:

(A) doubled

(B) four times

(C) halved

(D) one-fourth

Q17. A stretched wire develops a tensile stress of 2×10^8 Pa and a longitudinal strain of 0.001. The elastic potential energy stored per unit volume of the wire is:

(A) 2×10^5 J/m^3

(B) 0.5×10^5 J/m^3

(C) 1×10^5 J/m^3

(D) 4×10^5 J/m^3

Q18. A soap bubble and a liquid drop have the same radius and are made of liquids of the same surface tension. The ratio of the excess pressure inside the soap bubble to that inside the liquid drop is:

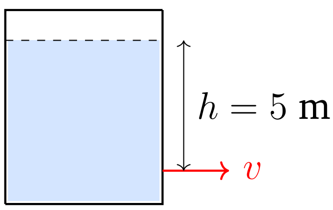
(A) $1 : 1$

(B) $1 : 2$

(C) $4 : 1$

(D) $2 : 1$

Q19. A large open tank is filled with water. A small hole is made on its side wall at a depth of 5 m below the free surface of the water (take $g = 10$ m/s^2). The speed with which water flows out of the hole is:



(A) 5 m/s

(B) 10 m/s

(C) 7.1 m/s

(D) 14.1 m/s

Q20. A refrigerator operates between a cold reservoir at 250 K and a hot reservoir at 300 K. Its (ideal) coefficient of performance is:

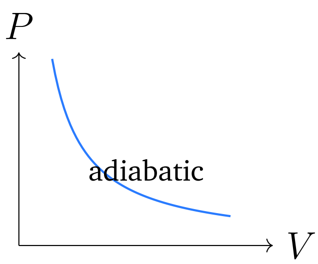
(A) 5

(B) 6

(C) 0.2

(D) 1.2

Q21. A monatomic ideal gas ($\gamma = \frac{5}{3}$) is compressed adiabatically to one-eighth of its initial volume. The ratio of the final absolute temperature to the initial absolute temperature is:



(A) 4

(B) 8

(C) 2

(D) 32

Q22. For a rigid diatomic ideal gas (with translational and rotational degrees of freedom only), the ratio of the specific heats $\gamma = \dfrac{C_p}{C_v}$ is:

(A) 1.67

(B) 1.33

(C) 1.50

(D) 1.40

Q23. A body cools from $62°C$ to $50°C$ in 10 minutes when the surrounding temperature is $26°C$. Assuming Newton's law of cooling, the time it takes to cool further from $50°C$ to $42°C$ is:

(A) 6 min

(B) 8 min

(C) 10 min

(D) 14 min

Q24. A particle executes simple harmonic motion of amplitude A. At the instant its displacement from the mean position is $\frac{A}{2}$, the fraction of its total energy that is kinetic is:

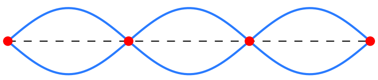
(A) 25%

(B) 75%

(C) 50%

(D) 100%

Q25. A string fixed at both ends vibrates in its third harmonic (three loops), as shown. The total number of nodes (including the two fixed ends) in this mode of vibration is:



(A) 4

(B) 3

(C) 6

(D) 2

Q26. A source of sound emitting a note of frequency 1000 Hz moves directly towards a stationary observer with a speed of 30 m/s. If the speed of sound in air is 330 m/s, the frequency heard by the observer is:

(A) 909 Hz

(B) 1000 Hz

(C) 1090 Hz

(D) 1100 Hz

Q27. Two thin convex lenses of focal lengths 15 cm and 30 cm are placed coaxially in contact with each other. The focal length of the combination is:

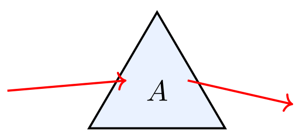
(A) 45 cm

(B) 10 cm

(C) 20 cm

(D) 5 cm

Q28. A thin prism of refracting angle $4°$ is made of glass of refractive index 1.5. The angle of deviation produced by the prism for a ray of light passing through it is:



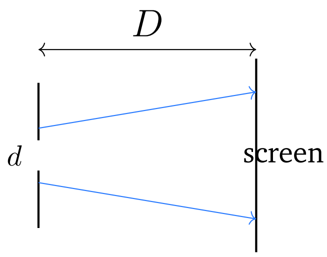
(A) $4°$

(B) $6°$

(C) $2°$

(D) $1°$

Q29. In Young's double-slit experiment, light of wavelength 600 nm is used. The separation between the slits is 0.3 mm and the screen is placed 1.5 m away from the slits. The fringe width on the screen is:



(A) 3 mm

(B) 1.5 mm

(C) 6 mm

(D) 0.3 mm

Q30. Unpolarized light of intensity I_0 is incident on a polaroid. The light then passes through a second polaroid whose axis is at $60°$ to that of the first. The intensity of light emerging from the second polaroid is:

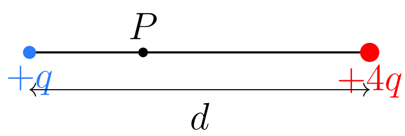
(A) $\frac{I_0}{2}$

(B) $\frac{I_0}{4}$

(C) $\frac{I_0}{8}$

(D) $\frac{I_0}{16}$

Q31. Two point charges $+q$ and $+4q$ are placed a distance d apart. The point P on the line joining them where the net electric field is zero lies at a distance (measured from the charge $+q$):



(A) $\frac{d}{3}$

(B) $\frac{d}{2}$

(C) $\frac{d}{4}$

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

Q32. An electric dipole of dipole moment p is placed in a uniform electric field E with its axis initially aligned along the field. The work done in rotating the dipole through 90° (so that it becomes perpendicular to the field) is:

(A) $2pE$

(B) zero

(C) $-pE$

(D) pE

Q33. A parallel-plate capacitor is charged by a battery and then disconnected from it. A dielectric slab of dielectric constant $\kappa = 4$ is now inserted so as to completely fill the space between the plates. The energy stored in the capacitor:

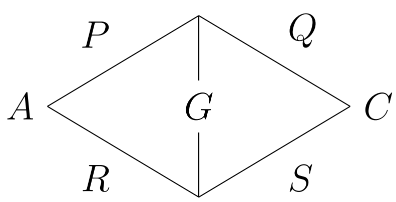
(A) increases to 4 times its initial value

(B) remains unchanged

(C) decreases to one-fourth of its initial value

(D) decreases to one-half of its initial value

Q34. In the Wheatstone bridge shown, each of the four arms P, Q, R, S has a resistance of $2\,\Omega$ and the galvanometer arm G has a resistance of $5\,\Omega$. Since the bridge is balanced, the equivalent resistance between the input terminals A and C is:



(A) $4\,\Omega$

(B) $2\,\Omega$

(C) $5\,\Omega$

(D) $1\,\Omega$

Q35. In a potentiometer experiment, two cells are balanced separately against the potentiometer wire. The balancing lengths obtained are 240 cm for the first cell and 120 cm for the second cell. The ratio of the emf of the first cell to that of the second cell is:

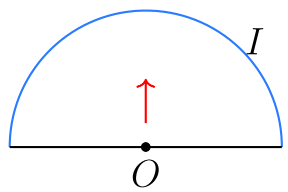
(A) $1 : 2$

(B) $1 : 1$

(C) $3 : 1$

(D) $2 : 1$

Q36. A wire carrying a current I is bent into the shape of a semicircle of radius r. The magnitude of the magnetic field at the centre O of the semicircle (due to the curved part only) is:



(A) $\dfrac{\mu_0 I}{2r}$

(B) $\dfrac{\mu_0 I}{4r}$

(C) $\dfrac{\mu_0 I}{8r}$

(D) $\dfrac{\mu_0 I}{r}$

Q37. A charged particle moving in a plane perpendicular to a uniform magnetic field travels in a circular path. The time period of its revolution is independent of:

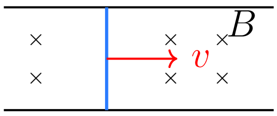
(A) its speed and the radius of the path

(B) the strength of the magnetic field

(C) the charge on the particle

(D) the mass of the particle

Q38. A conducting rod of length 0.5 m slides on two parallel frictionless rails with a constant speed of 5 m/s in a region of uniform magnetic field of 2 T directed perpendicular to the plane of the rails (into the page). The emf induced across the ends of the rod is:



(A) 10 V

(B) 2.5 V

(C) 20 V

(D) 5 V

Q39. A two-input logic gate gives an output $Y = 0$ *only* when both inputs are 1, and gives $Y = 1$ for all the other input combinations, as shown in the truth table. The gate is a:

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

(A) AND gate

(B) NAND gate

(C) NOR gate

(D) OR gate

Q40. Light consisting of photons of energy 5 eV is incident on a metal surface whose work function is 3 eV. The stopping potential required to bring the most energetic emitted photoelectrons to rest is:

(A) 5 V

(B) 8 V

(C) 2 V

(D) 3 V

Detailed Solutions

Q1.

Solution

Planck's constant links the energy of a photon to its frequency through $E = h\nu$, so $h = \dfrac{E}{\nu}$.

Dimensions of the numerator (energy):

$$[E] = [\text{work}] = [\text{force} \times \text{distance}] = (MLT^{-2})(L) = ML^2T^{-2}.$$

Dimensions of the denominator (frequency):

$$[\nu] = \frac{1}{[\text{time}]} = T^{-1}.$$

Therefore:

$$[h] = \frac{[E]}{[\nu]} = \frac{ML^2T^{-2}}{T^{-1}} = ML^2T^{-1}.$$

Why the other options are wrong: ML^2T^{-2} is the dimension of energy itself, not of h (A); MLT^{-1} is the dimension of linear momentum (C); ML^2T^{-3} is the dimension of power (D).

Final Answer: The dimensional formula of Planck's constant is $[ML^2T^{-1}]$, which is the same as that of angular momentum.

Answer: (B) Go Back to Q1

Q2.

Solution

For a quantity expressed as a product or quotient of powers, the maximum fractional error is the sum of the fractional errors, each multiplied by the magnitude of its power.

Given: $X = \dfrac{a^2b^3}{\sqrt{c}} = a^2\, b^3\, c^{-1/2}$.

Rule for combination of errors:

$$\frac{\Delta X}{X} = 2\frac{\Delta a}{a} + 3\frac{\Delta b}{b} + \frac{1}{2}\frac{\Delta c}{c}.$$

Substitute the percentage errors $(1\%, 2\%, 4\%)$:

$$\frac{\Delta X}{X} = 2(1\%) + 3(2\%) + \tfrac{1}{2}(4\%).$$

$$\frac{\Delta X}{X} = 2\% + 6\% + 2\% = 10\%.$$

Why the other options are wrong: 7% ignores the power of b; 9% forgets the contribution of c; 14% wrongly adds 4% for c without halving it for the square root.

Final Answer: The maximum percentage error in X is 10%.

Answer: (D) Go Back to Q2

Q3.

Solution

The particle is momentarily at rest where its velocity is zero.

Find the instants of rest by setting $v = 0$:

$$6t - 3t^2 = 0 \;\Rightarrow\; 3t(2-t) = 0 \;\Rightarrow\; t = 0 \text{ s and } t = 2 \text{ s}.$$

Displacement is the integral of velocity between these instants:

$$s = \int_0^2 (6t - 3t^2)\, dt.$$

$$s = \left[3t^2 - t^3\right]_0^2.$$

$$s = (3 \times 4 - 8) - 0 = 12 - 8 = 4 \text{ m}.$$

Why the other options are wrong: 2 m and 6 m come from arithmetic slips in evaluating the limits; 8 m is the value of the single term t^3 alone and ignores the $3t^2$ term.

Final Answer: The displacement between the two rest instants is 4 m.

Answer: (A) Go Back to Q3

Q4.

Solution

The maximum height of a projectile depends only on the vertical component of the launch velocity.

Vertical component of velocity:

$$u_y = u \sin\theta = 20 \times \sin 30^\circ = 20 \times \tfrac{1}{2} = 10 \text{ m/s}.$$

Maximum height formula:

$$H = \frac{u_y^2}{2g} = \frac{u^2 \sin^2\theta}{2g}.$$

Substitute the values:

$$H = \frac{(10)^2}{2 \times 10} = \frac{100}{20} = 5 \text{ m}.$$

Why the other options are wrong: 10 m doubles the correct result; 2.5 m uses $u \sin\theta$ once too few; 7.5 m mixes the height and range expressions.

Final Answer: The maximum height attained is 5 m.

Answer: (C) Go Back to Q4

Q5.

Solution

To stay dry, the man must hold the umbrella along the direction of the rain's velocity *relative to himself*.

Velocity of rain relative to the man: the rain has a downward velocity of 4 m/s, and relative to the man it acquires a horizontal component equal and opposite to the man's velocity, i.e. 3 m/s (backward).

Angle with the vertical:

$$\tan\theta = \frac{\text{horizontal component}}{\text{vertical component}} = \frac{3}{4}.$$

$$\theta = \tan^{-1}\left(\frac{3}{4}\right) = 37^\circ.$$

Why the other options are wrong: 53° is the complementary angle ($\tan^{-1}\frac{4}{3}$), which is the angle measured from the horizontal, not the vertical; 30° and 45° do not satisfy $\tan\theta = 3/4$.

Final Answer: The umbrella should be tilted at 37° to the vertical, towards the direction of motion.

Answer: (D) Go Back to Q5

Q6.

Solution

Both blocks move together with a common acceleration because they are in contact on a smooth surface.

Common acceleration of the system:

$$a = \frac{F}{m_1 + m_2} = \frac{12}{4+2} = \frac{12}{6} = 2\ \text{m/s}^2.$$

The contact force is the only horizontal force acting on the 2 kg block, so it produces its acceleration:

$$N = m_2\, a = 2 \times 2 = 4\ \text{N}.$$

Why the other options are wrong: 12 N is the applied force on the whole system, not the inter-block force; 8 N would be $m_1 a$ (the net force on the 4 kg block); 6 N has no physical basis here.

Final Answer: The contact force between the blocks is 4 N.

Answer: (B) Go Back to Q6

Q7.

Solution

The angle of repose is the inclination at which a block on a rough surface is on the verge of sliding; at that angle the limiting friction exactly balances the component of gravity along the incline.

Condition at the angle of repose θ:

$$mg \sin\theta = \mu\, mg \cos\theta.$$

$$\tan\theta = \mu.$$

Substitute $\mu = \dfrac{1}{\sqrt{3}}$:

$$\tan\theta = \frac{1}{\sqrt{3}} \;\Rightarrow\; \theta = 30^\circ.$$

Why the other options are wrong: $\tan 45^\circ = 1$, $\tan 60^\circ = \sqrt{3}$ and $\tan 37^\circ \approx 0.75$, none of which equals $\frac{1}{\sqrt{3}} \approx 0.577$.

Final Answer: The angle of repose is 30°.

Answer: (A) Go Back to Q7

Q8.

Solution

For a force that varies with position, the work done is the integral of the force over the displacement.

Work integral:

$$W = \int_0^2 F\,dx = \int_0^2 (3x^2 + 2x)\,dx.$$

Carry out the integration:

$$W = \left[x^3 + x^2\right]_0^2.$$

$$W = (2^3 + 2^2) - 0 = 8 + 4 = 12 \text{ J}.$$

Why the other options are wrong: 6 J and 16 J arise from integrating only one term; 10 J comes from an arithmetic error in evaluating the limits.

Final Answer: The work done by the variable force is 12 J.

Answer: (C) Go Back to Q8

Q9.

Solution

On a smooth surface, all the elastic potential energy stored in the compressed spring is converted into the kinetic energy of the block.

Elastic potential energy stored in the spring:

$$U = \frac{1}{2}kx^2 = \frac{1}{2} \times 200 \times (0.1)^2.$$

$$U = \frac{1}{2} \times 200 \times 0.01 = 1 \text{ J}.$$

Energy conservation ($U =$ kinetic energy at maximum speed):

$$\frac{1}{2}mv^2 = 1 \text{ J}.$$

$$v^2 = \frac{2 \times 1}{0.5} = 4 \;\Rightarrow\; v = 2 \text{ m/s}.$$

Why the other options are wrong: 1 m/s and 0.5 m/s come from dropping the factor of 2 or mis-handling the mass; 4 m/s is the value of v^2, not v.

Final Answer: The maximum speed acquired by the block is 2 m/s.

Answer: (D) Go Back to Q9

Q10.

Solution

On a flat circular road, the necessary centripetal force is provided entirely by static friction. The car is on the verge of skidding when friction reaches its limiting value.

Condition for maximum speed:

$$\frac{mv_{\max}^2}{r} = \mu mg.$$

$$v_{\max} = \sqrt{\mu r g}.$$

Substitute $\mu = 0.5$, $r = 20$ m, $g = 10$ m/s^2:

$$v_{\max} = \sqrt{0.5 \times 20 \times 10} = \sqrt{100} = 10 \text{ m/s}.$$

Why the other options are wrong: 5 m/s and 20 m/s come from dropping or doubling a factor inside the root; 14 m/s ($\approx \sqrt{200}$) forgets the factor μ.

Final Answer: The maximum safe speed for the turn is 10 m/s.

Answer: (A) Go Back to Q10

Q11.

Solution

Linear momentum is conserved in each perpendicular direction during the collision. After sticking, the combined mass is $2m$.

Momentum along x:

$$p_x = m \times 6 = 6m.$$

Momentum along y:

$$p_y = m \times 8 = 8m.$$

Resultant momentum:

$$p = \sqrt{p_x^2 + p_y^2} = \sqrt{(6m)^2 + (8m)^2} = \sqrt{36 + 64}\, m = 10m.$$

Common speed of the combined mass $2m$:

$$v = \frac{p}{2m} = \frac{10m}{2m} = 5 \text{ m/s}.$$

Why the other options are wrong: 10 m/s forgets to divide by the total mass $2m$; 7 m/s wrongly averages the two speeds; 3.5 m/s halves the average.

Final Answer: The combined mass moves off at 5 m/s.

Answer: (B) Go Back to Q11

Q12.

Solution

The moment of inertia of a system of point masses is $I = \sum m_i r_i^2$, where r_i is the perpendicular distance of each mass from the axis.

Distance of each corner from the centre of a square of side a: half the diagonal,

$$r = \frac{\text{diagonal}}{2} = \frac{a\sqrt{2}}{2} = \frac{a}{\sqrt{2}}.$$

So $r^2 = \frac{a^2}{2}$ for every mass.

Total moment of inertia (four equal masses):

$$I = 4 \times m \times r^2 = 4 \times m \times \frac{a^2}{2} = 2ma^2.$$

Why the other options are wrong: ma^2 and $\frac{1}{2}ma^2$ use the wrong distance; $4ma^2$ would require each mass to be at distance a from the axis, which is not the case here.

Final Answer: The moment of inertia about the central perpendicular axis is $2ma^2$.

Answer: (C) Go Back to Q12

Q13.

Solution

For a body rolling down an incline without slipping, the linear acceleration is

$$a = \frac{g \sin\theta}{1 + \frac{I}{mR^2}},$$

where $\frac{I}{mR^2}$ is the shape factor k.

Shape factors:

- Solid sphere: $k = \frac{2}{5} = 0.4$
- Disc: $k = \frac{1}{2} = 0.5$

- Ring: $k = 1$

Interpretation: the smaller the shape factor, the larger the acceleration. The solid sphere has the smallest k, hence the greatest acceleration, and so reaches the bottom first.

Why the other options are wrong: the disc and the ring have larger shape factors, giving smaller accelerations; they arrive later, so the three do not arrive together.

Final Answer: The solid sphere reaches the bottom first.

Answer: (A) Go Back to Q13

Q14.

Solution

Torque about the origin is the cross product $\vec{\tau} = \vec{r} \times \vec{F}$.

Compute the cross product (both vectors lie in the xy-plane, so the torque is along $\hat{k}$):

$$\vec{\tau} = (2\hat{i} + 3\hat{j}) \times (3\hat{i} + 2\hat{j}).$$

$$\tau_z = r_x F_y - r_y F_x = (2)(2) - (3)(3).$$

$$\tau_z = 4 - 9 = -5.$$

Magnitude of the torque:

$$|\vec{\tau}| = |-5| = 5 \text{ N} \cdot \text{m}.$$

Why the other options are wrong: 13 N·m comes from adding the products instead of subtracting; 7 N·m is another arithmetic slip; 0 would require $\vec{r}$ and $\vec{F}$ to be parallel, which they are not.

Final Answer: The magnitude of the torque about the origin is 5 N·m.

Answer: (D) Go Back to Q14

Q15.

Solution

The variation of gravity with depth below the Earth's surface is

$$g_d = g\left(1 - \frac{d}{R}\right),$$

assuming the Earth has uniform density.

Substitute $d = \frac{R}{2}$**:**

$$g_d = g\left(1 - \frac{R/2}{R}\right) = g\left(1 - \frac{1}{2}\right) = \frac{g}{2}.$$

Numerical value:

$$g_d = \frac{10}{2} = 5\ \text{m/s}^2.$$

Why the other options are wrong: $10\ \text{m/s}^2$ is the surface value (no decrease); $2.5\ \text{m/s}^2$ wrongly uses $d/R = 3/4$; $7.5\ \text{m/s}^2$ uses the height formula $g(1 - d/R)$ with the wrong sign convention.

Final Answer: At a depth of $R/2$, the value of g is $5\ \text{m/s}^2$.

Answer: (B) Go Back to Q15

Q16.

Solution

The orbital speed of a satellite in a circular orbit of radius r is obtained by equating gravitational force to the required centripetal force:

$$\frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{GM}{r}}.$$

Dependence on radius: $v \propto \frac{1}{\sqrt{r}}$.

When the radius becomes 4 **times:**

$$\frac{v'}{v} = \sqrt{\frac{r}{r'}} = \sqrt{\frac{r}{4r}} = \frac{1}{2}.$$

$$v' = \frac{v}{2}.$$

Why the other options are wrong: the speed decreases (not doubles or quadruples) with larger orbit; one-fourth would require $v \propto 1/r$, but the dependence is

$1/\sqrt{r}$.

Final Answer: Increasing the orbital radius four-fold halves the orbital speed.

Answer: (C) Go Back to Q16

Q17.

Solution

The elastic potential energy stored per unit volume of a stretched wire is

$$u = \frac{1}{2} \times \text{stress} \times \text{strain}.$$

Substitute stress $= 2 \times 10^8$ Pa and strain $= 0.001 = 10^{-3}$:

$$u = \frac{1}{2} \times (2 \times 10^8) \times (10^{-3}).$$

$$u = \frac{1}{2} \times 2 \times 10^5 = 1 \times 10^5 \text{ J/m}^3.$$

Why the other options are wrong: 2×10^5 J/m^3 omits the factor $\frac{1}{2}$; 0.5×10^5 and 4×10^5 result from mishandling the powers of ten.

Final Answer: The elastic energy density stored in the wire is 1×10^5 J/m^3.

Answer: (C) Go Back to Q17

Q18.

Solution

A soap bubble has *two* liquid surfaces (inner and outer), whereas a liquid drop has only *one*.

Excess pressure inside a soap bubble:

$$\Delta P_{\text{bubble}} = \frac{4T}{r}.$$

Excess pressure inside a liquid drop:

$$\Delta P_{\text{drop}} = \frac{2T}{r}.$$

Ratio for the same radius and same T:

$$\frac{\Delta P_{\text{bubble}}}{\Delta P_{\text{drop}}} = \frac{4T/r}{2T/r} = \frac{4}{2} = 2 : 1.$$

Why the other options are wrong: $1:1$ ignores the two surfaces of the bubble; $1:2$ inverts the ratio; $4:1$ confuses the numerator $4T/r$ with the whole ratio.

Final Answer: The excess pressure in the soap bubble is twice that in the drop, i.e. $2:1$.

Answer: (D) Go Back to Q18

Q19.

Solution

By Bernoulli's theorem, the speed of efflux of a liquid from a small hole at depth h below the free surface is given by Torricelli's law.

Torricelli's law:

$$v = \sqrt{2gh}.$$

Substitute $g = 10 \text{ m/s}^2$ and $h = 5$ m:

$$v = \sqrt{2 \times 10 \times 5} = \sqrt{100} = 10 \text{ m/s}.$$

Why the other options are wrong: 5 m/s drops the factor $2g$; 7.1 m/s ($\approx \sqrt{50}$) forgets a factor of 2; 14.1 m/s ($\approx \sqrt{200}$) doubles h erroneously.

Final Answer: The water flows out of the hole with a speed of 10 m/s.

Answer: (B) Go Back to Q19

Q20.

Solution

The (ideal) coefficient of performance of a refrigerator working between absolute temperatures T_{hot} and T_{cold} is

$$\text{COP} = \frac{T_{\text{cold}}}{T_{\text{hot}} - T_{\text{cold}}}.$$

Substitute $T_{\text{cold}} = 250$ K and $T_{\text{hot}} = 300$ K:

$$\text{COP} = \frac{250}{300 - 250} = \frac{250}{50} = 5.$$

Why the other options are wrong: 6 uses T_{hot} in the numerator (that is the COP of a heat pump); 0.2 inverts the expression; 1.2 is the ratio $T_{\text{hot}}/T_{\text{cold}}$.

Final Answer: The coefficient of performance of the refrigerator is 5.

Answer: (A) Go Back to Q20

Q21.

Solution

For an adiabatic process, $TV^{\gamma-1} = \text{constant}$.

Relate initial and final states:

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}.$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}.$$

Here $\frac{V_1}{V_2} = 8$ (volume becomes one-eighth) and $\gamma - 1 = \frac{5}{3} - 1 = \frac{2}{3}$:

$$\frac{T_2}{T_1} = 8^{2/3} = \left(2^3\right)^{2/3} = 2^2 = 4.$$

Why the other options are wrong: 8 uses an exponent of 1 instead of $2/3$; 2 uses an exponent of $1/3$; 32 uses $8^{5/3}$, i.e. the wrong power.

Final Answer: The final absolute temperature is 4 times the initial temperature.

Answer: (A) Go Back to Q21

Q22.

Solution

A rigid diatomic gas has $f = 5$ degrees of freedom (3 translational $+$ 2 rotational).

Molar specific heats:

$$C_v = \frac{f}{2}R = \frac{5}{2}R, \qquad C_p = C_v + R = \frac{7}{2}R.$$

Ratio of specific heats:

$$\gamma = \frac{C_p}{C_v} = \frac{\frac{7}{2}R}{\frac{5}{2}R} = \frac{7}{5} = 1.40.$$

Why the other options are wrong: $1.67 = \frac{5}{3}$ is for a monatomic gas; $1.33 = \frac{4}{3}$ corresponds to a polyatomic gas; 1.50 does not correspond to any simple gas with integer degrees of freedom.

Final Answer: For a rigid diatomic gas, $\gamma = 1.40$.

Answer: (D) Go Back to Q22

Q23.

Solution

Newton's law of cooling (in its average form) states

$$\frac{\theta_1 - \theta_2}{t} = k\left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right),$$

where θ_0 is the surrounding temperature.

First interval ($62°C \to 50°C$ in 10 min, $\theta_0 = 26°C$):

$$\frac{62-50}{10} = k\left(\frac{62+50}{2} - 26\right).$$

$$\frac{12}{10} = k(56-26) = k(30) \Rightarrow k = \frac{1.2}{30} = 0.04 \text{ min}^{-1}.$$

Second interval ($50°C \to 42°C$, time t):

$$\frac{50-42}{t} = k\left(\frac{50+42}{2} - 26\right).$$

$$\frac{8}{t} = 0.04 \times (46-26) = 0.04 \times 20 = 0.8.$$

$$t = \frac{8}{0.8} = 10 \text{ min}.$$

Why the other options are wrong: the body cools more slowly as it approaches the surroundings, so the time for the second $8°$ drop must exceed the first interval's rate; 6 or 8 min underestimate this slowing.

Final Answer: The body takes 10 minutes to cool from $50°C$ to $42°C$.

Answer: (C) Go Back to Q23

Q24.

Solution

In SHM, the total energy is constant: $E = \frac{1}{2}kA^2$. The potential energy at displacement x is $\frac{1}{2}kx^2$.

Fraction that is potential energy at $x = \dfrac{A}{2}$:

$$\frac{U}{E} = \frac{\frac{1}{2}kx^2}{\frac{1}{2}kA^2} = \frac{x^2}{A^2} = \left(\frac{A/2}{A}\right)^2 = \frac{1}{4}.$$

Fraction that is kinetic energy:

$$\frac{K}{E} = 1 - \frac{U}{E} = 1 - \frac{1}{4} = \frac{3}{4} = 75\%.$$

Why the other options are wrong: 25% is the potential-energy fraction, not the kinetic; 50% holds at $x = A/\sqrt{2}$, not $A/2$; 100% holds only at the mean position.

Final Answer: At $x = A/2$, 75% of the total energy is kinetic.

Answer: (B) Go Back to Q24

Q25.

Solution

For a string fixed at both ends, the n-th harmonic contains n loops (antinodes). The fixed ends are always nodes.

Counting for the third harmonic ($n = 3$, three loops):

- Number of antinodes (loops) $= n = 3$.
- Number of nodes $= n + 1 = 3 + 1 = 4$.

The nodes occur at both ends and at the two internal points separating the three loops, as marked in the figure.

Why the other options are wrong: 3 counts the loops (antinodes), not the nodes; 6 and 2 do not match the node count of the third harmonic.

Final Answer: The third harmonic of a string fixed at both ends has 4 nodes.

Answer: (A) Go Back to Q25

Q26.

Solution

When a source approaches a stationary observer, the observed frequency rises. The Doppler formula for an approaching source is

$$f' = f\left(\frac{v}{v - v_s}\right),$$

where v is the speed of sound and v_s the source speed.

Substitute $f = 1000$ Hz, $v = 330$ m/s, $v_s = 30$ m/s:

$$f' = 1000 \times \frac{330}{330 - 30}.$$

$$f' = 1000 \times \frac{330}{300} = 1000 \times 1.1 = 1100 \text{ Hz}.$$

Why the other options are wrong: 909 Hz uses $v+v_s$ in the denominator (the case of a *receding* source); 1000 Hz ignores the Doppler shift; 1090 Hz is an arithmetic slip.

Final Answer: The observer hears a frequency of 1100 Hz.

Answer: (D) Go Back to Q26

Q27.

Solution

When two thin lenses are placed in contact, their powers add.

Power of each lens ($P = 1/f$, with f in metres):

$$P_1 = \frac{1}{0.15} = \frac{100}{15} \text{ D}, \qquad P_2 = \frac{1}{0.30} = \frac{100}{30} \text{ D}.$$

It is easier to add reciprocals directly (with f in cm):

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{15} + \frac{1}{30}.$$

$$\frac{1}{F} = \frac{2}{30} + \frac{1}{30} = \frac{3}{30} = \frac{1}{10}.$$

$$F = 10 \text{ cm}.$$

Why the other options are wrong: 45 cm and 20 cm come from adding the focal lengths instead of their reciprocals; 5 cm halves the result incorrectly.

Final Answer: The focal length of the combination is 10 cm (converging).

Answer: (B) Go Back to Q27

Q28.

Solution

For a *thin* prism (small refracting angle), the angle of deviation is given by

$$\delta = (\mu - 1)A,$$

where A is the refracting angle and μ the refractive index.

Substitute $\mu = 1.5$ and $A = 4^\circ$:

$$\delta = (1.5 - 1) \times 4^\circ.$$

$$\delta = 0.5 \times 4^\circ = 2^\circ.$$

Why the other options are wrong: 4° forgets the factor $(\mu - 1)$; 6° uses μ instead of $(\mu - 1)$; 1° halves the correct result.

Final Answer: The angle of deviation produced by the thin prism is 2°.

Answer: (C) Go Back to Q28

Q29.

Solution

The fringe width in Young's double-slit experiment is

$$\beta = \frac{\lambda D}{d},$$

where λ is the wavelength, D the slit-to-screen distance and d the slit separation.

Convert and substitute: $\lambda = 600$ nm $= 6 \times 10^{-7}$ m, $D = 1.5$ m, $d = 0.3$ mm $= 3 \times 10^{-4}$ m.

$$\beta = \frac{(6 \times 10^{-7})(1.5)}{3 \times 10^{-4}}.$$

$$\beta = \frac{9 \times 10^{-7}}{3 \times 10^{-4}} = 3 \times 10^{-3} \text{ m} = 3 \text{ mm}.$$

Why the other options are wrong: 1.5 mm and 6 mm arise from doubling or halving d; 0.3 mm confuses the fringe width with the slit separation.

Final Answer: The fringe width on the screen is 3 mm.

Answer: (A) Go Back to Q29

Q30.

Solution

Step 1 – after the first polaroid: unpolarized light loses half its intensity:

$$I_1 = \frac{I_0}{2}.$$

Step 2 – after the second polaroid (Malus's law, axis at $60°$):

$$I_2 = I_1 \cos^2 60°.$$

$$I_2 = \frac{I_0}{2} \times \left(\frac{1}{2}\right)^2 = \frac{I_0}{2} \times \frac{1}{4} = \frac{I_0}{8}.$$

Why the other options are wrong: $I_0/2$ ignores the second polaroid; $I_0/4$ forgets that $\cos^2 60° = 1/4$ (not $1/2$); $I_0/16$ wrongly squares the factor again.

Final Answer: The intensity emerging from the second polaroid is $\frac{I_0}{8}$.

Answer: (C) Go Back to Q30

Q31.

Solution

Between two like charges, the electric fields point in opposite directions, so a null point exists on the line joining them, nearer the smaller charge.

Let the null point be at a distance x from $+q$. Equate the field magnitudes:

$$\frac{kq}{x^2} = \frac{k(4q)}{(d-x)^2}.$$

Take the square root of both sides:

$$\frac{1}{x} = \frac{2}{d-x}.$$

$$d - x = 2x \;\Rightarrow\; d = 3x \;\Rightarrow\; x = \frac{d}{3}.$$

Why the other options are wrong: $d/2$ would be correct only for equal charges; $d/4$ and $2d/3$ do not satisfy the field-balance equation (the null point must be closer to the smaller charge $+q$).

Final Answer: The field is zero at a distance $\frac{d}{3}$ from the charge $+q$.

Answer: (A) Go Back to Q31

Q32.

Solution

The potential energy of a dipole in a uniform field is $U(\theta) = -pE\cos\theta$, where θ is the angle between $\vec{p}$ and $\vec{E}$.

Initial position (aligned, $\theta = 0$):

$$U_i = -pE\cos 0^\circ = -pE.$$

Final position (perpendicular, $\theta = 90^\circ$):

$$U_f = -pE\cos 90^\circ = 0.$$

Work done equals the change in potential energy:

$$W = U_f - U_i = 0 - (-pE) = pE.$$

Why the other options are wrong: $2pE$ is the work to rotate fully from 0° to 180°; zero would mean no energy change; $-pE$ has the wrong sign (work must be done *on* the dipole to turn it away from alignment).

Final Answer: The work done in rotating the dipole to the perpendicular position is pE.

Answer: (D) Go Back to Q32

Q33.

Solution

The capacitor is *disconnected* from the battery, so the charge Q on the plates stays constant.

Effect of the dielectric on capacitance:

$$C' = \kappa C_0 = 4C_0.$$

Energy stored in terms of constant charge:

$$U = \frac{Q^2}{2C}.$$

Since Q is fixed and C increases 4 times:

$$U' = \frac{Q^2}{2(4C_0)} = \frac{1}{4}\cdot\frac{Q^2}{2C_0} = \frac{U_0}{4}.$$

Why the other options are wrong: the energy would increase 4 times only if the battery stayed connected (constant voltage); it does not remain unchanged, nor does it merely halve.

Final Answer: The stored energy decreases to one-fourth of its initial value.

Answer: (C) Go Back to Q33

Q34.

Solution

In a *balanced* Wheatstone bridge, no current flows through the galvanometer arm, so that arm can be removed without affecting the currents. The bridge then reduces to two series branches in parallel.

Each series branch (two $2\,\Omega$ arms in series):

$$P+Q=2+2=4\,\Omega, \qquad R+S=2+2=4\,\Omega.$$

The two branches are in parallel between A and C:

$$R_{AC}=\frac{4\times 4}{4+4}=\frac{16}{8}=2\,\Omega.$$

Why the other options are wrong: $4\,\Omega$ counts only one branch; $5\,\Omega$ wrongly includes the galvanometer resistance (which carries no current); $1\,\Omega$ treats all four arms as a simple parallel set.

Final Answer: The equivalent resistance between A and C is $2\,\Omega$.

Answer: (B) Go Back to Q34

Q35.

Solution

In a potentiometer, the emf of a cell is directly proportional to its balancing length (the current through the potentiometer wire being constant):

$$\frac{E_1}{E_2}=\frac{\ell_1}{\ell_2}.$$

Substitute $\ell_1=240$ cm and $\ell_2=120$ cm:

$$\frac{E_1}{E_2}=\frac{240}{120}=2.$$

$$E_1:E_2=2:1.$$

Why the other options are wrong: $1 : 2$ inverts the ratio; $1 : 1$ ignores the different balancing lengths; $3 : 1$ does not match $240 : 120$.

Final Answer: The ratio of the emfs is $2 : 1$.

Answer: (D) Go Back to Q35

Q36.

Solution

The magnetic field at the centre of a circular arc of radius r that subtends an angle ϕ (in radians) at the centre is

$$B = \frac{\mu_0 I}{4\pi r}\,\phi.$$

For a semicircle, the arc subtends $\phi = \pi$ radians:

$$B = \frac{\mu_0 I}{4\pi r} \times \pi = \frac{\mu_0 I}{4r}.$$

Why the other options are wrong: $\frac{\mu_0 I}{2r}$ is the field at the centre of a *full* circular loop; $\frac{\mu_0 I}{8r}$ corresponds to a quarter circle ($\phi = \pi/2$); $\frac{\mu_0 I}{r}$ has no factor accounting for the geometry.

Final Answer: The field at the centre of the semicircular wire is $\frac{\mu_0 I}{4r}$.

Answer: (B) Go Back to Q36

Q37.

Solution

For a charged particle moving perpendicular to a uniform magnetic field, the magnetic force provides the centripetal force:

$$qvB = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{qB}.$$

Time period of one revolution:

$$T = \frac{2\pi r}{v} = \frac{2\pi}{v} \cdot \frac{mv}{qB} = \frac{2\pi m}{qB}.$$

Observation: T depends on m, q and B, but the speed v has cancelled out. Hence the period (and the cyclotron frequency) is independent of the particle's speed and of the radius of its path.

Why the other options are wrong: T explicitly contains B, q and m, so it does depend on each of these.

Final Answer: The time period is independent of the particle's speed and orbital radius.

Answer: (A) Go Back to Q37

Q38.

Solution

A conducting rod moving with velocity v perpendicular to a magnetic field B, with its length L perpendicular to both, develops a motional emf.

Motional emf formula:

$$\varepsilon = BLv.$$

Substitute $B = 2$ T, $L = 0.5$ m, $v = 5$ m/s:

$$\varepsilon = 2 \times 0.5 \times 5.$$

$$\varepsilon = 5 \text{ V}.$$

Why the other options are wrong: 10 V and 20 V come from omitting the length or doubling a factor; 2.5 V drops the speed term.

Final Answer: The emf induced across the rod is 5 V.

Answer: (D) Go Back to Q38

Q39.

Solution

We identify the gate from its truth table. The output Y is 1 for the input combinations $(0, 0), (0, 1), (1, 0)$ and becomes 0 only for $(1, 1)$.

Compare with standard gates:

- An AND gate gives $Y = 1$ only when both inputs are 1 – the exact opposite of this table.
- A NAND gate is an AND gate followed by a NOT, so $Y = \overline{A \cdot B}$. It gives $Y = 0$ *only* when both inputs are 1, which matches the table exactly.
- A NOR gate gives $Y = 1$ only for $(0, 0)$.
- An OR gate gives $Y = 0$ only for $(0, 0)$.

The Boolean expression of the given table is $Y = \overline{A \cdot B}$, the NAND operation.

Final Answer: The gate is a NAND gate.

Answer: (B) Go Back to Q39

Q40.

Solution

By Einstein's photoelectric equation, the maximum kinetic energy of the emitted photoelectrons is the photon energy minus the work function.

Maximum kinetic energy:

$$K_{\text{max}} = E_{\text{photon}} - \phi = 5 \text{ eV} - 3 \text{ eV} = 2 \text{ eV}.$$

Stopping potential V_0 is defined so that $eV_0 = K_{\text{max}}$:

$$eV_0 = 2 \text{ eV} \;\Rightarrow\; V_0 = 2 \text{ V}.$$

Why the other options are wrong: 5 V uses the photon energy alone; 8 V adds the energies; 3 V uses the work function alone.

Final Answer: The stopping potential is 2 V.

Answer: (C) Go Back to Q40

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	D	3	A	4	C	5	D
6	B	7	A	8	C	9	D	10	A
11	B	12	C	13	A	14	D	15	B
16	C	17	C	18	D	19	B	20	A
21	A	22	D	23	C	24	B	25	A
26	D	27	B	28	C	29	A	30	C
31	A	32	D	33	C	34	B	35	D
36	B	37	A	38	D	39	B	40	C