JEE Main 2026 April 8 Shift 1 Physics

Question Paper with Solutions

Conducted by National Testing Agency (NTA)

General Instructions

(i) The test is of 3 hours duration.

(ii) This test paper consists of 75 questions. Each subject (PCM) has 25 questions. The maximum marks are 300.

(iii) This question paper contains Three Parts. Part-A is Physics, Part-B is Chemistry and Part-C is Mathematics. Each part has only two sections: Section-A and Section-B.

(iv) Section - A : Attempt all questions.

(v) Section - B : Attempt all questions.

(vi) Section - A (01 – 20) contains 20 multiple choice questions which have only one correct answer. Each question carries +4 marks for correct answer and –1 mark for wrong answer.

(vii) Section - B (21 – 25) contains 5 Numerical value based questions. The answer to each question should be rounded off to the nearest integer. Each question carries +4 marks for correct answer and –1 mark for wrong answer.

1. There are two projectiles thrown at angles θ_1 & θ_2 such that their ranges are same. Their speeds of projection are also same and time periods are 10 sec and 5 sec respectively. Find the range.

(1) 250 m

(2) 300 m

(3) 650 m

(4) 100 m

Correct Answer: (1) 250 m

Solution:

Concept:

For projectiles having the same speed but producing the same range, the angles of projection must be **complementary**.

Important projectile formulas:

$$T = \frac{2u\sin\theta}{g}$$

$$R = \frac{u^2\sin 2\theta}{g}$$

Also,

$$\sin 2\theta = 2\sin\theta\cos\theta$$

These relations help express range in terms of the time of flight expressions.

Step 1: Using the time of flight for the first projectile.

$$T_1 = \frac{2u\sin\theta}{g} = 10$$

$$u\sin\theta = \frac{10g}{2} = 5g$$

Step 2: Using the time of flight for the second projectile.

Since the angles are complementary, the second projectile involves $\cos\theta$:

$$T_2 = \frac{2u\cos\theta}{g} = 5$$

$$u\cos\theta = \frac{5g}{2}$$

Step 3: Finding the range.

$$R = \frac{u^2\sin 2\theta}{g}$$

$$R = \frac{2(u\sin\theta)(u\cos\theta)}{g}$$

Substitute the obtained values:

$$R = \frac{2(5g)\left(\frac{5g}{2}\right)}{g}$$

$$R = \frac{25g^2}{g} = 25g$$

Taking $g = 10 \text{ m/s}^2$:

$$R = 25 \times 10 = 250 \text{ m}$$

$$\boxed{R = 250 \text{ m}}$$

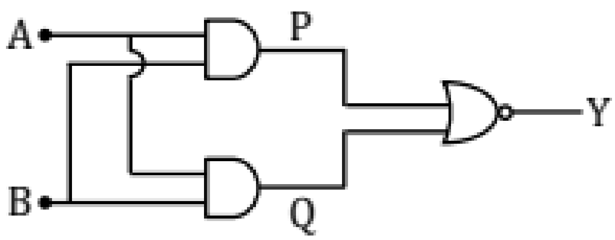
Quick Tip: If two projectiles have the same speed and same range, their angles of projection are complementary:

$$\theta_1 + \theta_2 = 90^\circ$$

This allows us to use $u\sin\theta$ and $u\cos\theta$ directly from the time of flight formulas to quickly compute the range.

---

2. For the logic gate shown in the diagram, find the output Y for the given inputs A and B.



(1) $A \cdot \overline{B}$

(2) $\overline{A} + \overline{B}$

(3) $A + B$

(4) $\overline{A \cdot B}$

Correct Answer: (2) $\overline{A} + \overline{B}$

Solution:

Concept:

In digital electronics:

- An **AND gate** gives output $A \cdot B$.
- A **NOR gate** gives output $\overline{A+B}$.
- **De Morgan's Theorem** states:

$$\overline{A+B} = \overline{A} \cdot \overline{B}, \qquad \overline{AB} = \overline{A} + \overline{B}$$

Using these relations, complex logic circuits can be simplified.

Step 1: Identify the outputs of the AND gates.

From the circuit,

$$P = A \cdot B$$

$$Q = A \cdot B$$

Both gates are AND gates producing the same output.

Step 2: Determine the final gate operation.

The outputs P and Q are fed into a **NOR gate**.

$$Y = \overline{P+Q}$$

Substitute P and Q:

$$Y = \overline{(A \cdot B) + (A \cdot B)}$$

Step 3: Simplify the Boolean expression.

$$Y = \overline{A \cdot B}$$

Using De Morgan's theorem:

$$\overline{A \cdot B} = \overline{A} + \overline{B}$$

$$\boxed{Y = \overline{A} + \overline{B}}$$

Quick Tip: Remember De Morgan's laws for simplifying logic circuits:

$$\overline{AB} = \overline{A} + \overline{B}$$

$$\overline{A+B} = \overline{A} \cdot \overline{B}$$

These identities are extremely useful when analyzing circuits involving NAND and NOR gates.

---

3. A block is attached to a spring and it oscillates with natural frequency f_1. If the spring is cut into two half and only one of the half spring is connected to the block then the frequency becomes f_2. Find $\frac{f_2}{f_1}$.

(1) $\sqrt{2}$

(2) $\frac{1}{\sqrt{2}}$

(3) 2

(4) $\frac{1}{2}$

Correct Answer: (1) $\sqrt{2}$

Solution:

Concept:

The frequency of oscillation of a spring-block system is

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where k = spring constant m = mass attached to the spring

When a spring is cut into equal halves, the spring constant of each half becomes **twice** the original.

Step 1: Write the original frequency of the spring-block system.

$$f_1 = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Step 2: Determine the new spring constant after cutting the spring.

When the spring is cut into two equal parts,

$$k' = 2k$$

Step 3: Calculate the new frequency.

$$f_2 = \frac{1}{2\pi}\sqrt{\frac{2k}{m}}$$

$$f_2 = \sqrt{2}\left(\frac{1}{2\pi}\sqrt{\frac{k}{m}}\right)$$

$$f_2 = \sqrt{2}f_1$$

Step 4: Find the required ratio.

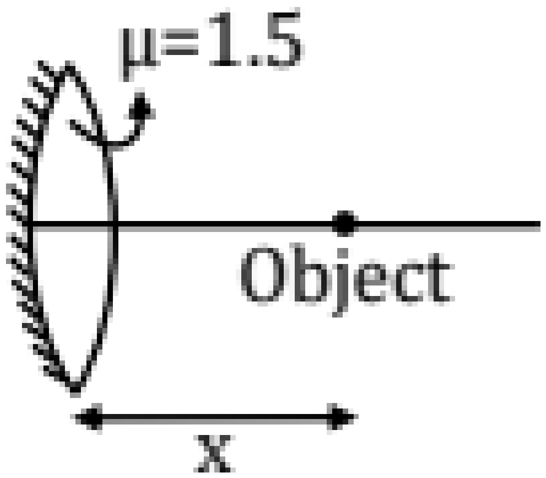
$$\frac{f_2}{f_1} = \sqrt{2}$$

$$\boxed{\frac{f_2}{f_1} = \sqrt{2}}$$

Quick Tip: If a spring of constant k is cut into n equal parts, the spring constant of each part becomes nk. Thus cutting a spring into two halves doubles the spring constant.

---

4. A biconvex lens having radius of curvature 20 cm for both surfaces and one side of the lens is silvered as shown in the figure. Object is at distance x cm from the lens. Find x such that image is on the object itself. Given $\mu = 1.5$.



Correct Answer: $x = 10$ cm

Solution:

Concept:

This system acts as a **combination of a lens and a mirror**. The light first passes through the lens, reflects from the silvered surface (mirror), and again passes through the lens.

Key relations:

Mirror focal length:

$$f_m = \frac{R}{2}$$

Lens maker formula for symmetric biconvex lens:

$$f_L = \frac{R}{2(\mu - 1)}$$

Equivalent focal length for lens–mirror combination:

$$\frac{1}{F} = \frac{1}{f_m} - \frac{2}{f_L}$$

Step 1: Find focal length of the mirror.

$$f_m = \frac{R}{2} = \frac{20}{2} = 10$$

Since reflection occurs,

$$f_m = -10\,\text{cm}$$

Step 2: Find focal length of the lens.

$$f_L = \frac{R}{2(\mu - 1)}$$

$$f_L = \frac{20}{2(1.5 - 1)}$$

$$f_L = \frac{20}{1} = 20\,\text{cm}$$

Step 3: Find equivalent focal length of the system.

$$\frac{1}{F} = \frac{1}{f_m} - \frac{2}{f_L}$$

$$\frac{1}{F} = \frac{1}{-10} - \frac{2}{20}$$

$$\frac{1}{F} = -\frac{1}{10} - \frac{1}{10}$$

$$\frac{1}{F} = -\frac{1}{5}$$

$$F = -5\,\text{cm}$$

Step 4: Condition for image to coincide with object.

For image to form at the same position as the object:

$$u = 2|F|$$

$$u = 2 \times 5 = 10\,\text{cm}$$

$$\boxed{x = 10\,\text{cm}}$$

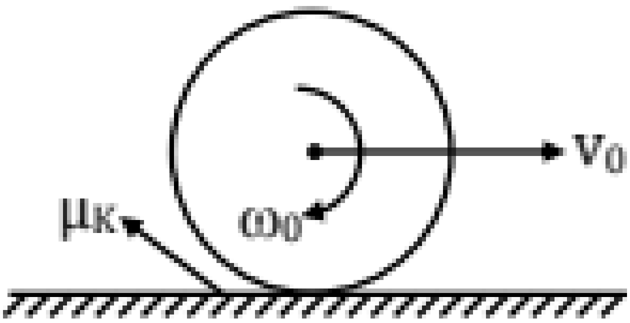
Quick Tip: For a lens with one side silvered, treat the system as a **lens–mirror combination**. Use the relation:

$$\frac{1}{F} = \frac{1}{f_m} - \frac{2}{f_L}$$

to find the equivalent focal length.

---

5. A solid cylinder of mass m and radius R is projected on a rough surface having kinetic friction coefficient μ_k with velocity v_0 and angular velocity ω_0 as shown in the figure. Find out time after which rolling starts. $(\omega_0 = \frac{v_0}{4R})$



(1) $\dfrac{3\omega_0 R}{\mu_k g}$

(2) $\dfrac{2\omega_0 R}{\mu_k g}$

(3) $\dfrac{\omega_0 R}{\mu_k g}$

(4) $\dfrac{\omega_0 R}{3\mu_k g}$

Correct Answer: (3) $\dfrac{\omega_0 R}{\mu_k g}$

Solution:

Concept:

When a body slides on a rough surface, kinetic friction acts opposite to motion. For a rolling body:

- Linear deceleration is caused by friction.
- Friction also produces torque that changes angular velocity.
- Pure rolling begins when

$$v = \omega R$$

For a solid cylinder:

$$I = \frac{1}{2}MR^2$$

Step 1: Find linear acceleration due to friction.

Friction force:

$$f = \mu_k mg$$

Using Newton's second law:

$$a = \frac{f}{m} = \mu_k g$$

Since friction opposes motion,

$$v = v_0 - \mu_k g t$$

Step 2: Find angular acceleration produced by friction.

Torque due to friction:

$$\tau = \mu_k mgR$$

Using rotational equation:

$$\tau = I\alpha$$

$$\mu_k mgR = \frac{MR^2}{2}\alpha$$

$$\alpha = \frac{2\mu_k g}{R}$$

Thus angular velocity becomes

$$\omega = \omega_0 + \frac{2\mu_k g}{R}t$$

Step 3: Apply rolling condition.

Pure rolling begins when

$$v = \omega R$$

Substitute expressions:

$$v_0 - \mu_k g t = (\omega_0 + \frac{2\mu_k g}{R} t)R$$

$$v_0 - \mu_k g t = \omega_0 R + 2\mu_k g t$$

Step 4: Use given relation $\omega_0 = \frac{v_0}{4R}$.

$$v_0 = 4\omega_0 R$$

Substitute:

$$4\omega_0 R - \omega_0 R = 3\mu_k g t$$

$$3\omega_0 R = 3\mu_k g t$$

$$t = \frac{\omega_0 R}{\mu_k g}$$

$$\boxed{t = \frac{\omega_0 R}{\mu_k g}}$$

Quick Tip: For sliding to rolling problems:

$$v = v_0 - at, \qquad \omega = \omega_0 + \alpha t$$

and rolling begins when

$$v = \omega R$$

Always apply this condition to find the transition time.

6. A new unit (α) of length is chosen such that it is equal to the distance travelled by light in vacuum in 1 second. What is the distance between Venus and Earth in terms of this new unit. If light takes 6 min 40 sec to cover the distance.

Correct Answer: 400

Solution:

Concept:

The speed of light in vacuum is

$$c = 3 \times 10^8 \text{ m/s}$$

The new unit of length α is defined as the distance travelled by light in 1 second.

$$1\alpha = c \times 1\,\text{s}$$

Thus,

$$1\alpha = 3 \times 10^8 \text{ m}$$

Step 1: Calculate the total time taken by light.

$$t = 6 \text{ min } 40 \text{ s}$$

$$t = 6 \times 60 + 40 = 360 + 40 = 400 \text{ s}$$

Step 2: Find the actual distance between Venus and Earth.

$$d = vt$$

$$d = (3 \times 10^8)(400)$$

$$d = 12 \times 10^{10} \text{ m}$$

Step 3: Convert the distance into the new unit.

Since

$$1\alpha = 3 \times 10^8 \text{ m}$$

$$n\alpha = 12 \times 10^{10}$$

$$n(3 \times 10^8) = 12 \times 10^{10}$$

$$n = 400$$

$$\boxed{400\alpha}$$

Quick Tip: Whenever a new unit is defined using physical constants, first convert the unit into SI units and then express the required quantity in terms of that unit.

---

7. Find dipole moment of a system consisting of charge $q_1 = 3\,\mu C$ and $q_2 = -9\,\mu C$ with position coordinates $\vec{r}_1 = 2\hat{i} + 3\hat{j} + 3\hat{k}$ and $\vec{r}_2 = \hat{i} + \hat{j} + \hat{k}$ respectively.

(1) $-3\hat{i}\ \mu C$-m

(2) $-9\hat{i}\ \mu C$-m

(3) $-6\hat{i}\ \mu C$-m

(4) $-5\hat{i}\ \mu C$-m

Correct Answer: (1) $-3\hat{i}\ \mu C$-m

Solution:

Concept:

The electric dipole moment of a system of charges is given by

$$\vec{p} = \sum q_i \vec{r}_i$$

where q_i = charge $\vec{r}_i$ = position vector of charge

Step 1: Write the given quantities.

$$q_1 = 3\,\mu C$$

$$q_2 = -9\,\mu C$$

$$\vec{r}_1 = 2\hat{i} + 3\hat{j} + 3\hat{k}$$

$$\vec{r}_2 = \hat{i} + \hat{j} + \hat{k}$$

Step 2: Use the dipole moment formula.

$$\vec{p} = q_1\vec{r}_1 + q_2\vec{r}_2$$

Step 3: Substitute the values.

$$\vec{p} = 3(2\hat{i} + 3\hat{j} + 3\hat{k}) - 9(\hat{i} + \hat{j} + \hat{k})$$

$$\vec{p} = (6\hat{i} + 9\hat{j} + 9\hat{k}) - (9\hat{i} + 9\hat{j} + 9\hat{k})$$

$$\vec{p} = -3\hat{i}$$

$$\boxed{\vec{p} = -3\hat{i}\ \mu C\text{-m}}$$

Quick Tip: For multiple charges, dipole moment is simply the vector sum $\vec{p} = \sum q_i\vec{r}_i$. Always multiply each charge with its position vector and then add vectorially.

---

8. If $H = \dfrac{\varepsilon^r E^p x^q}{t^s}$ find p, q, r and s.

$$H \rightarrow \text{Magnetic field}$$

$$\varepsilon \rightarrow \text{Permittivity of medium}$$

$$E \rightarrow \text{Electric field}$$

$$x \rightarrow \text{distance}$$

$$t \rightarrow \text{time}$$

(1) $r = 0,\ p = 1,\ q = -1,\ s = 1$
(2) $r = 1,\ p = -1,\ q = -1,\ s = 1$
(3) $r = 1,\ p = 1,\ q = +1,\ s = 1$
(4) $r = 0,\ p = -1,\ q = -1,\ s = 1$

Correct Answer: (1)

Solution:

Concept:
Using the **principle of dimensional homogeneity**, the dimensions on both sides of a physical equation must be equal.
Dimensions used:

$$[H] = [MLT^{-2}A^{-1}]$$

$$[\varepsilon] = [M^{-1}L^{-3}T^{4}A^{2}]$$

$$[E] = [MLT^{-3}A^{-1}]$$

$$[x] = [L]$$

$$[t] = [T]$$

Step 1: Write the dimensional equation.

$$[H] = [\varepsilon]^r [E]^p [x]^q [t]^{-s}$$

Step 2: Substitute dimensions.

$$[MLT^{-2}A^{-1}] = [M^{-1}L^{-3}T^4A^2]^r [MLT^{-3}A^{-1}]^p [L]^q [T]^{-s}$$

Step 3: Equate powers of fundamental quantities.

For M:

$$-p + r = 1$$

For L:

$$-3r + p + q = 0$$

For T:

$$4r - 3p + s = -2$$

For A:

$$2r - p = -1$$

Step 4: Solve the equations.

From the equations,

$$r = 0$$

$$p = 1$$

$$q = -1$$

$$s = 1$$

$$\boxed{r = 0,\ p = 1,\ q = -1,\ s = 1}$$

Quick Tip: In dimensional analysis, always equate powers of M, L, T, and A separately to form simultaneous equations.

---

9. Two photons of wavelength λ and 2λ are incident on a metal surface and emit photoelectrons of maximum kinetic energies $3k$ and k. Find work function of the metal.

(1) $\frac{hc}{4\lambda}$

(2) $\frac{hc}{2\lambda}$

(3) $\frac{2hc}{3\lambda}$

(4) $\frac{hc}{\lambda}$

Correct Answer: (1)

Solution:

Concept:

According to the **photoelectric equation**,

$$\frac{hc}{\lambda} = W + K_{\text{max}}$$

where

$$W = \text{work function}$$

$$K_{\text{max}} = \text{maximum kinetic energy}$$

Step 1: Apply equation for wavelength λ.

$$\frac{hc}{\lambda} = W + 3k$$

Step 2: Apply equation for wavelength 2λ.

$$\frac{hc}{2\lambda} = W + k$$

Step 3: Solve the equations.

Subtract the second equation from the first:

$$\frac{hc}{\lambda} - \frac{hc}{2\lambda} = 2k$$

$$\frac{hc}{2\lambda} = 2k$$

$$k = \frac{hc}{4\lambda}$$

Substitute in

$$\frac{hc}{2\lambda} = W + k$$

$$\frac{hc}{2\lambda} = W + \frac{hc}{4\lambda}$$

$$W = \frac{hc}{4\lambda}$$

$$\boxed{W = \frac{hc}{4\lambda}}$$

Quick Tip: For photoelectric problems with two wavelengths, write two photoelectric equations and subtract them to eliminate the work function or kinetic energy.

---

10. A solenoid having length 30 cm. If there are 10 turns/cm and current through solenoid

changes from 2A to 4A in 3.14 sec. Find emf induced. (Area is A)

(1) $0.24A$ volt

(2) $0.40A$ volt

(3) $0.80A$ volt

(4) $0.20A$ volt

Correct Answer: (1)

Solution:

Concept:

Induced emf in a coil is given by

$$\varepsilon = L\frac{di}{dt}$$

where L is the inductance of the solenoid.

For a long solenoid

$$L = \mu_0 n^2 A\ell$$

where

$$n = \text{turns per unit length}, \quad A = \text{area}, \quad \ell = \text{length of solenoid}$$

Step 1: Convert given quantities to SI units.

$$\ell = 30\,\text{cm} = 0.3\,\text{m}$$

$$n = 10\,\text{turns/cm} = 1000\,\text{turns/m}$$

Total turns

$$N = n\ell = 1000 \times 0.3 = 300$$

Step 2: Calculate rate of change of current.

$$\frac{di}{dt} = \frac{4-2}{3.14}$$

$$\frac{di}{dt} = \frac{2}{3.14}$$

Step 3: Find inductance of the solenoid.

$$L = \mu_0 n^2 A\ell$$

$$L = (4\pi \times 10^{-7})(1000)^2 A(0.3)$$

$$L = 1.2\pi \times 10^{-1} AH$$

Step 4: Calculate induced emf.

$$\varepsilon = L\frac{di}{dt}$$

$$\varepsilon = (1.2\pi \times 10^{-1} A)\left(\frac{2}{3.14}\right)$$

$$\varepsilon \approx 0.24A \text{ volt}$$

$$\boxed{\varepsilon = 0.24A \text{ volt}}$$

Quick Tip: For a solenoid, inductance depends on turns per unit length:

$$L = \mu_0 n^2 A\ell$$

Always convert turns/cm into turns/m before substituting.

---

11. 1 mole of ideal diatomic gas is enclosed in a cylinder piston arrangement having cross-sectional area of piston $4\,\text{cm}^2$. If gas has only rotational modes and $P_{atm} = 100$ kPa, some

amount of heat is added to the system as a result piston moves up slowly by $2.5\,$cm. If temperature change is $1.2^\circ C$. Find heat given to gas.

(1) $19.9\,J$

(2) $23.5\,J$

(3) $14.6\,J$

(4) $10\,J$

Correct Answer: (1)

Solution:

Concept:

Since the piston moves slowly, the process is **isobaric** (pressure constant).

Heat supplied:

$$Q = nC_p\Delta T$$

For a diatomic gas with only rotational modes:

$$f = 2$$

$$C_p = \left(\frac{f}{2} + 1\right)R$$

Step 1: Find molar heat capacity at constant pressure.

$$C_p = \left(\frac{2}{2} + 1\right)R$$

$$C_p = 2R$$

Step 2: Calculate heat supplied.

$$Q = nC_p\Delta T$$

$$Q = 1 \times 2R \times 1.2$$

$$Q = 2 \times 8.314 \times 1.2$$

$$Q = 19.95\,J$$

$$\boxed{Q \approx 19.9\,J}$$

Quick Tip: For isobaric processes:

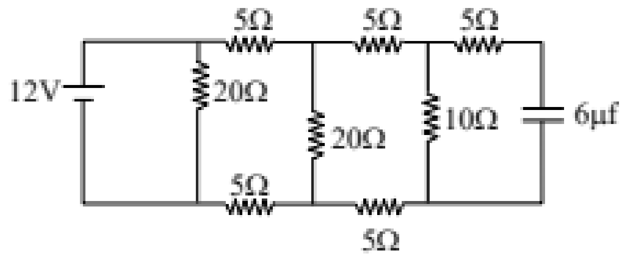
$$Q = nC_p\Delta T$$

and for diatomic gas with only rotational degrees of freedom:

$$C_p = 2R$$

---

12. Find charge on capacitor at steady state.



(1) $18\,\mu C$

(2) $16\,\mu C$

(3) $10\,\mu C$

(4) $8\,\mu C$

Correct Answer: (1)

Solution:

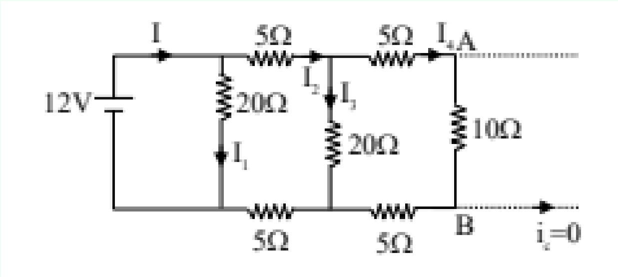
Concept:

At steady state in a DC circuit:

- Capacitor behaves as an **open circuit.**

- No current flows through the capacitor branch.
- First solve the resistive network to find the potential difference across the capacitor.
- Then use

$$q = C\Delta V$$



Step 1: Open the capacitor branch.

Since steady state is reached,

$$i_C = 0$$

Thus the remaining circuit contains only resistors.

Step 2: Find equivalent resistance of the network.

After simplification,

$$R_{eq} = 10\Omega$$

Step 3: Find total current from the battery.

$$I = \frac{V}{R}$$

$$I = \frac{12}{10}$$

$$I = 1.2A$$

Step 4: Determine branch currents.

Current divides equally through the two 20Ω resistors:

$$I_1 = I_2 = \frac{I}{2} = 0.6A$$

Further current division gives

$$I_3 = I_4 = \frac{I_2}{2} = 0.3A$$

Step 5: Find potential difference across the capacitor.

Voltage across the 10Ω resistor:

$$\Delta V = IR$$

$$\Delta V = 0.3 \times 10$$

$$\Delta V = 3\,V$$

Step 6: Calculate charge on the capacitor.

$$q = C\Delta V$$

$$q = 6\mu F \times 3$$

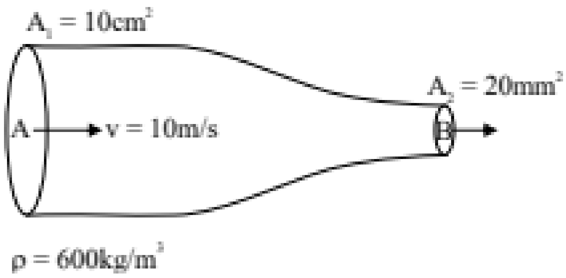
$$q = 18\,\mu C$$

$$\boxed{q = 18\,\mu C}$$

Quick Tip: In steady state DC circuits, capacitors act as open circuits. Always remove the capacitor branch first and solve the resistive network.

---

13. Find pressure difference between A and B.



(1) $75\,MPa$

(2) $85\,MPa$

(3) $95\,MPa$

(4) $65\,MPa$

Correct Answer: (1)

Solution:

Concept:

Using **Bernoulli's theorem** for fluid flow at same height:

$$P + \frac{1}{2}\rho v^2 = \text{constant}$$

Also apply **continuity equation**:

$$A_A v_A = A_B v_B$$

Step 1: Apply continuity equation.

Convert areas:

$$A_A = 10\,cm^2 = 10 \times 10^{-4} m^2$$

$$A_B = 20\,mm^2 = 20 \times 10^{-6} m^2$$

$$A_A v_A = A_B v_B$$

$$(10 \times 10^{-4})(10) = (20 \times 10^{-6}) v_B$$

$$v_B = 500\,m/s$$

Step 2: Apply Bernoulli's equation.

$$P_A + \frac{1}{2}\rho v_A^2 = P_B + \frac{1}{2}\rho v_B^2$$

Step 3: Find pressure difference.

$$P_A - P_B = \frac{1}{2}\rho(v_B^2 - v_A^2)$$

$$P_A - P_B = \frac{1}{2}(600)\left(500^2 - 10^2\right)$$

$$P_A - P_B = 7.497 \times 10^7\,Pa$$

$$P_A - P_B \approx 75\,MPa$$

$$\boxed{75\,MPa}$$

Quick Tip: In fluid flow problems:

- Use continuity equation to relate velocities.
- Then apply Bernoulli's equation to find pressure differences.

---

14. A car is moving in a circular path of radius $20\,m$ with speed $54\,km/hr$. A pendulum is hanging from the roof of the car. Find the angle made by pendulum with vertical. (Take $g = 10\,m/s^2$).

(1) $\tan^{-1}\left(\frac{9}{8}\right)$

(2) $\tan^{-1}\left(\frac{8}{9}\right)$

(3) $\tan^{-1}\left(\frac{4}{3}\right)$

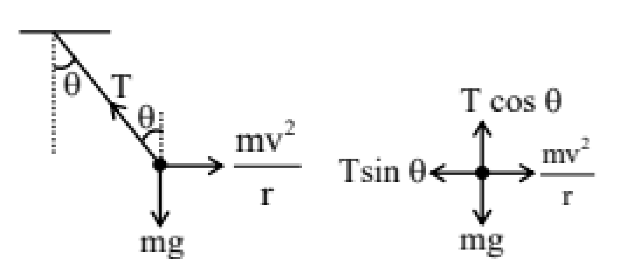
(4) $\tan^{-1}\left(\frac{3}{4}\right)$

Correct Answer: (1)

Solution:

Concept:

When a car moves in a circular path, the pendulum experiences a horizontal pseudo force due to centripetal acceleration.



Resolving forces on the bob:

$$T\cos\theta = mg$$

$$T\sin\theta = \frac{mv^2}{r}$$

Dividing the two equations,

$$\tan\theta = \frac{v^2}{rg}$$

Step 1: Convert speed into SI units.

$$v = 54 \times \frac{5}{18}$$

$$v = 15\,m/s$$

Step 2: Substitute values in the equation.

$$\tan\theta = \frac{v^2}{rg}$$

$$\tan\theta = \frac{15^2}{20 \times 10}$$

$$\tan\theta = \frac{225}{200}$$

$$\tan\theta = \frac{9}{8}$$

$$\boxed{\theta = \tan^{-1}\left(\frac{9}{8}\right)}$$

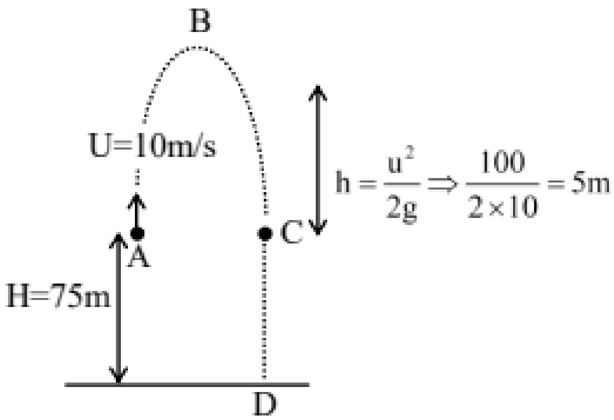
Quick Tip: For a pendulum inside a turning vehicle:

$$\tan\theta = \frac{v^2}{rg}$$

because horizontal pseudo force balances the horizontal component of tension.

---

15. A balloon is moving with speed $10\,m/s$ in upward direction. At height $75\,m$ a stone is released then find distance travelled by stone in air.



(1) $70\,m$

(2) $80\,m$

(3) $90\,m$

(4) $85\,m$

Correct Answer: (3)

Solution:

Concept:

When the stone is released from the balloon, it already has the **initial upward velocity** of the balloon.

The motion occurs in three stages:

- Upward motion until velocity becomes zero
- Downward motion back to release point
- Further fall to the ground

Step 1: Find maximum additional height reached.

$$h = \frac{u^2}{2g}$$

$$h = \frac{10^2}{2 \times 10}$$

$$h = 5\,m$$

Step 2: Calculate total distance travelled.

Upward distance:

$$AB = 5\,m$$

Downward back to release point:

$$BC = 5\,m$$

Height of balloon above ground:

$$CD = 75\,m$$

Step 3: Total distance travelled in air.

$$\text{Distance} = AB + BC + CD$$

$$= 5 + 5 + 75$$

$$= 85\,m$$

$$\boxed{85\,m}$$

Quick Tip: When an object is released from a moving body, it retains the initial velocity of that body at the moment of release.

---

16. Two nuclei $A(200\,amu)$ and $B(212\,amu)$ undergoes α-decay and Q-value is same and equal to $1\,MeV$. Find ratio of KE of α-particle.

(1) $\dfrac{2597}{2600}$
(2) $\dfrac{2600}{2597}$
(3) $\dfrac{5200}{2597}$
(4) $\dfrac{2597}{5200}$

Correct Answer: (1)

Solution:

Concept:

During α-decay,

$$M \rightarrow (M-4) + \alpha$$

Due to conservation of momentum:

$$p_\alpha = p_{\text{daughter}}$$

Thus kinetic energy distribution becomes

$$\frac{KE_{\text{daughter}}}{KE_\alpha} = \frac{m_\alpha}{m_d}$$

Energy of the α-particle is

$$KE_\alpha = \frac{M-4}{M}Q$$

Step 1: Write expression for kinetic energy.

For nucleus M,

$$KE_\alpha = \frac{M-4}{M}Q$$

Step 2: Write ratio for the two nuclei.

$$\frac{(KE_\alpha)_1}{(KE_\alpha)_2} = \frac{\frac{200-4}{200}}{\frac{212-4}{212}}$$

Step 3: Substitute values.

$$= \frac{\frac{196}{200}}{\frac{208}{212}}$$

$$= \frac{196}{200} \times \frac{212}{208}$$

$$= \frac{2597}{2600}$$

$$\boxed{\frac{2597}{2600}}$$

Quick Tip: In α-decay the kinetic energy of the α-particle is

$$KE_\alpha = \frac{M-4}{M}Q$$

where M is the mass number of the parent nucleus.

---

17. At $t = 0$ two particles A of mass $3.4\,kg$ and B of mass $2.5\,kg$ are moving along x-axis with

initial velocities $5\,m/s$ and $10\,m/s$ respectively starting from $x = 0$. At $t = 5s$ position of A is $x = 104\,m$ and of B is $x = 137\,m$. Find ratio of momentum at $t = 10s$.

(1) 2.17

(2) 0.17

(3) 3.17

(4) 1.17

Correct Answer: (4)

Solution:

Concept:

Use kinematic equation:

$$s = ut + \frac{1}{2}at^2$$

Then velocity at time t:

$$v = u + at$$

Momentum:

$$p = mv$$

Step 1: Find acceleration of particle A.

$$104 = 5 \times 5 + \frac{1}{2}a(25)$$

$$104 = 25 + \frac{25a}{2}$$

$$79 = \frac{25a}{2}$$

$$a = \frac{79 \times 2}{25}$$

Velocity at $t = 10s$:

$$v_A = u + at$$

$$v_A = 5 + \frac{79 \times 2}{25} \times 10$$

$$v_A = \frac{341}{5}$$

Step 2: Find acceleration of particle B.

$$137 = 10 \times 5 + \frac{1}{2}a(25)$$

$$137 = 50 + \frac{25a}{2}$$

$$87 = \frac{25a}{2}$$

$$a = \frac{87 \times 2}{25}$$

Velocity at $t = 10s$:

$$v_B = u + at$$

$$v_B = 10 + \frac{87 \times 2}{25} \times 10$$

$$v_B = \frac{398}{5}$$

Step 3: Find ratio of momenta.

$$\frac{p_A}{p_B} = \frac{m_A v_A}{m_B v_B}$$

$$= \frac{3.4 \times \frac{341}{5}}{2.5 \times \frac{398}{5}}$$

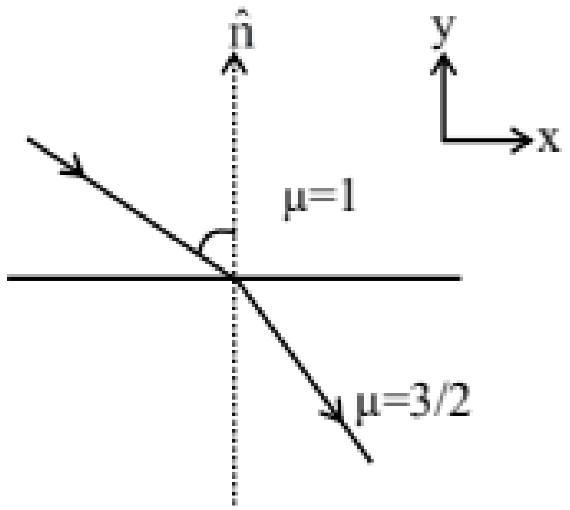
$$= 1.165$$

$$\boxed{1.17}$$

Quick Tip: First determine acceleration using displacement equation, then calculate velocity at required time before finding momentum.

---

18. Incident ray is along $3\hat{i} - 2\hat{j}$ and refracted ray is along $c\hat{i} - 4\hat{j}$. Find c.



(1) 1.6

(2) 0.6

(3) 2.6

(4) 4

Correct Answer: (3)

Solution:

Concept:

According to **Snell's law,**

$$\mu_1 \sin i = \mu_2 \sin r$$

Angle with the normal can be obtained using the cross product of the ray direction with the unit normal vector.

Normal to the surface is along the y-axis.

Step 1: Find unit vector along incident ray.

$$\hat{e} = \frac{3\hat{i} - 2\hat{j}}{\sqrt{3^2 + (-2)^2}}$$

$$\hat{e} = \frac{3\hat{i} - 2\hat{j}}{\sqrt{13}}$$

Step 2: Find unit vector along refracted ray.

$$\hat{r} = \frac{c\hat{i} - 4\hat{j}}{\sqrt{c^2 + 16}}$$

Step 3: Use Snell's law in vector form.

$$\mu_1 |\hat{e} \times \hat{n}| = \mu_2 |\hat{r} \times \hat{n}|$$

where $\hat{n}$ is unit vector along normal.

Given

$$\mu_1 = 1, \qquad \mu_2 = \frac{3}{2}$$

Step 4: Substitute values.

$$\frac{3}{\sqrt{13}} = \frac{3}{2} \frac{c}{\sqrt{c^2 + 16}}$$

Step 5: Solve the equation.

$$\frac{3}{\sqrt{13 + 2^2}} = \frac{3c}{2\sqrt{c^2 + 16}}$$

$$13c^2 = 4c^2 + 64$$

$$9c^2 = 64$$

$$c = \frac{8}{3}$$

$$c \approx 2.6$$

$$\boxed{c = 2.6}$$

Quick Tip: When rays are given as vectors, first convert them to unit vectors and use cross product with the normal to obtain $\sin\theta$.

---

19. A water droplet falls in air and attains terminal velocity v_1. If it splits into 64 identical droplets each having terminal velocity v_2. Find $\frac{v_2}{v_1}$.

(1) $\frac{1}{2}$
(2) $\frac{1}{4}$
(3) $\frac{1}{16}$
(4) $\frac{1}{32}$

Correct Answer: (3)

Solution:

Concept:
Terminal velocity of a small spherical drop in a viscous medium is given by

$$v_T = \frac{2r^2 g}{9\eta}(\rho_s - \rho_f)$$

Thus

$$v_T \propto r^2$$

Step 1: Relate terminal velocity and radius.

$$v \propto r^2$$

$$\frac{v_2}{v_1} = \left(\frac{r_2}{r_1}\right)^2$$

Step 2: Use conservation of volume.

When the droplet splits into 64 identical droplets:

$$\frac{4}{3}\pi r_1^3 = 64 \times \frac{4}{3}\pi r_2^3$$

$$r_1^3 = 64 r_2^3$$

$$r_1 = 4 r_2$$

$$\frac{r_2}{r_1} = \frac{1}{4}$$

Step 3: Find velocity ratio.

$$\frac{v_2}{v_1} = \left(\frac{1}{4}\right)^2$$

$$\frac{v_2}{v_1} = \frac{1}{16}$$

$$\boxed{\frac{1}{16}}$$

Quick Tip: For droplets breaking into n identical droplets:

$$r_2 = \frac{r_1}{n^{1/3}}$$

and since $v_T \propto r^2$,

$$v_2 = v_1\left(\frac{1}{n^{1/3}}\right)^2$$

---

20. Initial pressure and volume of monoatomic gas is P and V. It is expanded adiabatically to

27 times of initial volume. Find magnitude of change in internal energy.

(1) $\frac{3}{2}PV$

(2) PV

(3) $\frac{4}{3}PV$

(4) $\frac{PV}{2}$

Correct Answer: (3)

Solution:

Concept:

For an **adiabatic process**

$$PV^{\gamma} = \text{constant}$$

For a monoatomic gas

$$\gamma = \frac{5}{3}$$

Internal energy change:

$$\Delta U = nC_v\Delta T$$

Using ideal gas relation this becomes

$$\Delta U = \frac{P_2V_2 - P_1V_1}{\gamma - 1}$$

Step 1: Use adiabatic relation.

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

Given

$$V_2 = 27V$$

$$PV^{5/3} = P_2(27V)^{5/3}$$

$$P_2 = \frac{P}{27^{5/3}}$$

$$27^{5/3} = (3^3)^{5/3} = 3^5$$

$$P_2 = \frac{P}{3^5}$$

Step 2: Calculate change in internal energy.

$$\Delta U = \frac{P_2V_2 - P_1V_1}{\gamma - 1}$$

$$= \frac{\left(\frac{P}{3^5}\right)(27V) - PV}{\frac{5}{3} - 1}$$

Step 3: Simplify the expression.

$$= \frac{\frac{P \cdot 27V}{3^5} - PV}{\frac{2}{3}}$$

$$= \frac{\frac{PV}{9} - PV}{\frac{2}{3}}$$

$$= \frac{-\frac{8}{9}PV}{\frac{2}{3}}$$

$$\Delta U = -\frac{4}{3}PV$$

Since magnitude is required,

$$\boxed{|\Delta U| = \frac{4}{3}PV}$$

Quick Tip: For adiabatic processes:

$$PV^{\gamma} = \text{constant}$$

and internal energy change can be written as

$$\Delta U = \frac{P_2V_2 - P_1V_1}{\gamma - 1}$$

which avoids calculating temperature explicitly.
