JEE Main 2026 April 4 Shift 1 Physics

Question Paper with Solutions

Conducted by National Testing Agency (NTA)

NATIONAL TESTING AGENCY
Excellence in Assessment

General Instructions

(i) **Duration:** The total duration of the examination is 3 hours (180 minutes).

(ii) **Total Marks:** The complete paper carries a maximum of 300 marks.

(iii) **Structure:** The paper has 3 part and each consists of two sections:

- **Section A:** 20 Multiple Choice Questions (MCQs).
- **Section B:** 5 Numerical Value Type Questions.

(iv) **Compulsory Questions:** All 25 questions are compulsory.

(v) Each question has four options. Only **one** option is correct.

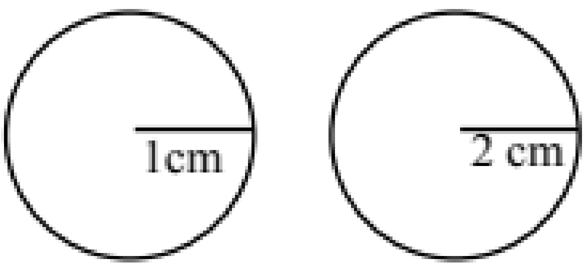
(vi) **Right Answer:** +4 marks.

(vii) **Incorrect Answer:** −1 mark (Negative marking).

(viii) **Unanswered/Marked for Review:** 0 marks.

Physics

1. Find the work done in expanding a soap bubble from radius $1\,$cm to $2\,$cm. Surface tension is $\gamma = 7.2 \times 10^{-2}\,$N/m.



(A) 542.6×10^{-6} J

(B) 543.6×10^{-6} J

(C) 542.6×10^{-5} J

(D) 545.6×10^{-6} J

Correct Answer: (1) 542.6×10^{-6} J

Solution:

Concept:

For a soap bubble, there are **two surfaces** (inner and outer). Therefore, the work done in expanding the bubble equals the increase in surface energy of both surfaces.

Surface energy:

$$U = 2\gamma A$$

Work done in expansion:

$$W = \Delta U = 2\gamma(A_2 - A_1)$$

Area of a sphere:

$$A = 4\pi r^2$$

Thus,

$$W = 2\gamma\left[4\pi r_2^2 - 4\pi r_1^2\right]$$

Step 1: Write the expression for work done.

$$W = 2\gamma\left[4\pi(r_2^2 - r_1^2)\right]$$

$$W = 8\pi\gamma(r_2^2 - r_1^2)$$

Step 2: Substitute the given values.

$$\gamma = 7.2 \times 10^{-2}\,\text{N/m}$$

$$r_1 = 1\,\text{cm} = 1 \times 10^{-2}\,\text{m}$$

$$r_2 = 2\,\text{cm} = 2 \times 10^{-2}\,\text{m}$$

$$W = 8\pi \times 7.2 \times 10^{-2}\left[(2 \times 10^{-2})^2 - (1 \times 10^{-2})^2\right]$$

Step 3: Simplify the expression.

$$(2 \times 10^{-2})^2 = 4 \times 10^{-4}$$

$$(1 \times 10^{-2})^2 = 1 \times 10^{-4}$$

$$r_2^2 - r_1^2 = 3 \times 10^{-4}$$

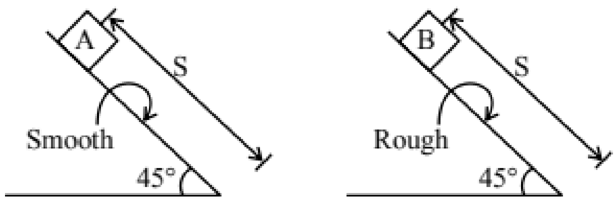
$$W = 8\pi \times 7.2 \times 10^{-2} \times 3 \times 10^{-4}$$

$$W = 542.6 \times 10^{-6}\,\text{J}$$

Quick Tip: For a **soap bubble**, two surfaces exist (inside and outside), so the surface energy is $U = 2\gamma A$. Always multiply by 2 when calculating work done due to surface tension in soap bubbles.

---

2. Two blocks A and B are released from rest on two inclined planes of the same inclination. One inclined plane is smooth while the other is rough as shown in the figure. If block B takes 50% more time to reach the bottom than block A, find the coefficient of friction (μ). The inclination of the plane is $45°$.



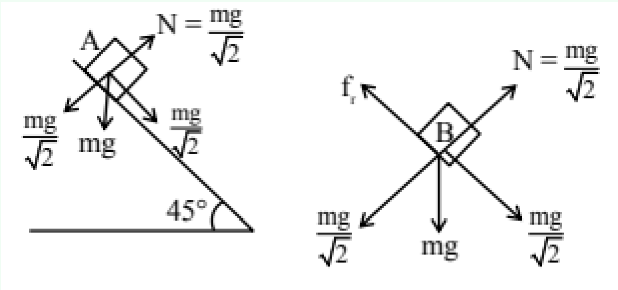
(A) $\frac{5}{9}$
(B) $\frac{13}{9}$
(C) $\frac{3}{9}$

(D) $\frac{7}{9}$

Correct Answer: (1) $\frac{5}{9}$

Solution:

Concept:



For motion down an inclined plane:

Acceleration on a **smooth incline**

$$a = g\sin\theta$$

Acceleration on a **rough incline**

$$a = g(\sin\theta - \mu\cos\theta)$$

If a body starts from rest and moves a distance S,

$$S = \frac{1}{2}at^2$$

Thus,

$$t = \sqrt{\frac{2S}{a}}$$

Hence time is inversely proportional to the square root of acceleration.

$$t \propto \frac{1}{\sqrt{a}}$$

Step 1: Acceleration of block A (smooth plane).

$$a_A = g\sin 45^\circ$$

$$a_A = \frac{g}{\sqrt{2}}$$

Step 2: Acceleration of block B (rough plane).

$$a_B = g(\sin 45^\circ - \mu \cos 45^\circ)$$

$$a_B = g\left(\frac{1}{\sqrt{2}} - \mu\frac{1}{\sqrt{2}}\right)$$

$$a_B = \frac{g}{\sqrt{2}}(1-\mu)$$

Step 3: Using the relation between time and acceleration.

$$t \propto \frac{1}{\sqrt{a}}$$

$$\frac{t_B}{t_A} = \sqrt{\frac{a_A}{a_B}}$$

Given B takes 50% more time:

$$t_B = 1.5\, t_A$$

$$\frac{t_B}{t_A} = \frac{3}{2}$$

Step 4: Substitute accelerations.

$$\frac{3}{2} = \sqrt{\frac{\frac{g}{\sqrt{2}}}{\frac{g}{\sqrt{2}}(1-\mu)}}$$

$$\frac{3}{2} = \sqrt{\frac{1}{1-\mu}}$$

Step 5: Solve for μ.

$$\left(\frac{3}{2}\right)^2 = \frac{1}{1-\mu}$$

$$\frac{9}{4} = \frac{1}{1-\mu}$$

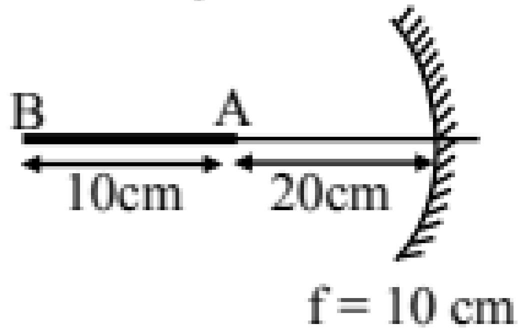
$$1-\mu = \frac{4}{9}$$

$$\mu = \frac{5}{9}$$

Quick Tip: For bodies starting from rest on an inclined plane, $S = \frac{1}{2}at^2$. If distances are same, $t \propto \frac{1}{\sqrt{a}}$. This relation greatly simplifies comparison problems involving different accelerations.

---

3. Find the length of image of rod AB. The rod is placed in front of a concave mirror of focal length $f = 10$ cm. End A is 20 cm from the mirror and the length $AB = 10$ cm.



(A) 10 cm

(B) 5 cm

(C) 15 cm

(D) 20 cm

Correct Answer: (2) 5 cm

Solution:

Concept:

For mirrors, the mirror formula relates object distance u, image distance v, and focal length f:

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

Using the mirror sign convention:

- Object distance u is negative.
- Focal length f is negative for a concave mirror.

The image length of the rod equals the difference between the image positions of its two ends.

Step 1: Image position of point A.

Distance of A from mirror:

$$u_A = -20\,\text{cm}, \quad f = -10\,\text{cm}$$

Using mirror formula:

$$\frac{1}{v_A} + \frac{1}{u_A} = \frac{1}{f}$$

$$\frac{1}{v_A} + \frac{1}{-20} = \frac{1}{-10}$$

$$\frac{1}{v_A} = -\frac{1}{10} + \frac{1}{20}$$

$$\frac{1}{v_A} = -\frac{1}{20}$$

$$v_A = -20\,\text{cm}$$

Step 2: Image position of point B.

Since $AB = 10\,\text{cm}$,

$$u_B = -30\,\text{cm}$$

Applying mirror formula:

$$\frac{1}{v_B} + \frac{1}{u_B} = \frac{1}{f}$$

$$\frac{1}{v_B} + \frac{1}{-30} = \frac{1}{-10}$$

$$\frac{1}{v_B} = -\frac{1}{10} + \frac{1}{30}$$

$$\frac{1}{v_B} = -\frac{2}{30}$$

$$v_B = -15\,\text{cm}$$

Step 3: Length of the image of the rod.

$$\text{Image length} = |v_A - v_B|$$

$$= |-20-(-15)|$$

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

Thus, the length of the image of the rod is:

$$\boxed{5\,\text{cm}}$$

Quick Tip: When an extended object is placed along the principal axis of a mirror, calculate the image position of both ends separately using the mirror formula. The difference between their image positions gives the length of the image.

---

4. Nuclei A and B form a nucleus C. Binding energy per nucleon for A, B and C are $3\,\text{MeV}, 7\,\text{MeV}$ and $6\,\text{MeV}$ respectively. Find the energy produced in the reaction:

$$2A^3 + B^4 \rightarrow C^{10}$$

(A) $12\,\text{MeV}$

(B) $14\,\text{MeV}$

(C) $13\,\text{MeV}$

(D) $15\,\text{MeV}$

Correct Answer: (2) 14 MeV

Solution:

Concept:

Energy released in a nuclear reaction equals the difference between the total binding energy of the products and the total binding energy of the reactants.

$$Q = BE_{\text{products}} - BE_{\text{reactants}}$$

Binding energy of a nucleus:

$$BE = (\text{Binding energy per nucleon}) \times (\text{Number of nucleons})$$

Step 1: Calculate total binding energy of reactants.

For nucleus A^3:

$$BE = 3 \times 3 = 9\,\text{MeV}$$

Since there are two A nuclei:

$$BE_A = 2 \times 9 = 18\,\text{MeV}$$

For nucleus B^4:

$$BE_B = 4 \times 7 = 28\,\text{MeV}$$

Total binding energy of reactants:

$$BE_{\text{LHS}} = 18 + 28 = 46\,\text{MeV}$$

Step 2: Calculate total binding energy of product.

For nucleus C^{10}:

$$BE_{\text{RHS}} = 10 \times 6 = 60\,\text{MeV}$$

Step 3: Calculate energy released.

$$Q = BE_{\text{RHS}} - BE_{\text{LHS}}$$

$$Q = 60 - 46$$

$$Q = 14\,\text{MeV}$$

Quick Tip: Energy released in nuclear reactions is calculated using binding energies: $Q = BE_{\text{products}} - BE_{\text{reactants}}$. If the result is positive, energy is released.

---

5. If force $\vec{F} = 2t\,\hat{i} + 3t^2\,\hat{j}$ acts on a particle of mass $m = 2\,\text{kg}$, find the power at $t = 2\,\text{s}$ if the particle was initially at rest.

(A) $54\,\text{W}$

(B) $58\,\text{W}$

(C) $56\,\text{W}$

(D) $52\,\text{W}$

Correct Answer: (3) $56\,\text{W}$

Solution:

Concept:

Power delivered by a force is given by the dot product of force and velocity.

$$P = \vec{F} \cdot \vec{v}$$

Acceleration is related to force by Newton's second law:

$$\vec{a} = \frac{\vec{F}}{m}$$

Velocity can be obtained by integrating acceleration.

Step 1: Find acceleration.

$$\vec{a} = \frac{\vec{F}}{m}$$

$$\vec{a} = \frac{2t}{2}\hat{i} + \frac{3t^2}{2}\hat{j}$$

$$\vec{a} = t\,\hat{i} + \frac{3t^2}{2}\hat{j}$$

Step 2: Find velocity by integrating acceleration.

$$\vec{v} = \int \vec{a}\,dt$$

$$\vec{v} = \int t\,dt\,\hat{i} + \int \frac{3t^2}{2}\,dt\,\hat{j}$$

$$\vec{v} = \frac{t^2}{2}\hat{i} + \frac{t^3}{2}\hat{j}$$

Step 3: Compute power.

$$P = \vec{F} \cdot \vec{v}$$

$$P = (2t\,\hat{i} + 3t^2\,\hat{j}) \cdot \left(\frac{t^2}{2}\hat{i} + \frac{t^3}{2}\hat{j}\right)$$

$$P = t^3 + \frac{3}{2}t^5$$

Step 4: Substitute $t = 2s$.

$$P = 2^3 + \frac{3}{2}(2^5)$$

$$P = 8 + \frac{3}{2} \times 32$$

$$P = 8 + 48$$

$$P = 56\,\mathrm{W}$$

Quick Tip: Instantaneous power delivered by a force is $P = \vec{F} \cdot \vec{v}$. First find velocity by integrating acceleration obtained from $\vec{F} = m\vec{a}$, then take the dot product.

---

6. Two projectiles A and B are launched with the same speed at angles 15° and 30° respectively. Find the ratio of range A to range B.

(A) $\frac{2}{\sqrt{3}}$

(B) $\frac{1}{\sqrt{3}}$

(C) $\sqrt{3}$

(D) $2\sqrt{3}$

Correct Answer: (2) $\frac{1}{\sqrt{3}}$

Solution:

Concept:

The horizontal range of a projectile launched with speed u at an angle θ with the horizontal is given by

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

Thus, when the initial speeds are the same, the ratio of ranges depends only on $\sin 2\theta$.

Step 1: Write the range expressions for both projectiles.

$$R_A = \frac{u^2 \sin 2\theta_A}{g}$$

$$R_B = \frac{u^2 \sin 2\theta_B}{g}$$

Step 2: Take the ratio of ranges.

$$\frac{R_A}{R_B} = \frac{\frac{u^2 \sin 2\theta_A}{g}}{\frac{u^2 \sin 2\theta_B}{g}}$$

$$\frac{R_A}{R_B} = \frac{\sin 2\theta_A}{\sin 2\theta_B}$$

Step 3: Substitute the given angles.

$$\theta_A = 15^\circ, \qquad \theta_B = 30^\circ$$

$$\frac{R_A}{R_B} = \frac{\sin 30^\circ}{\sin 60^\circ}$$

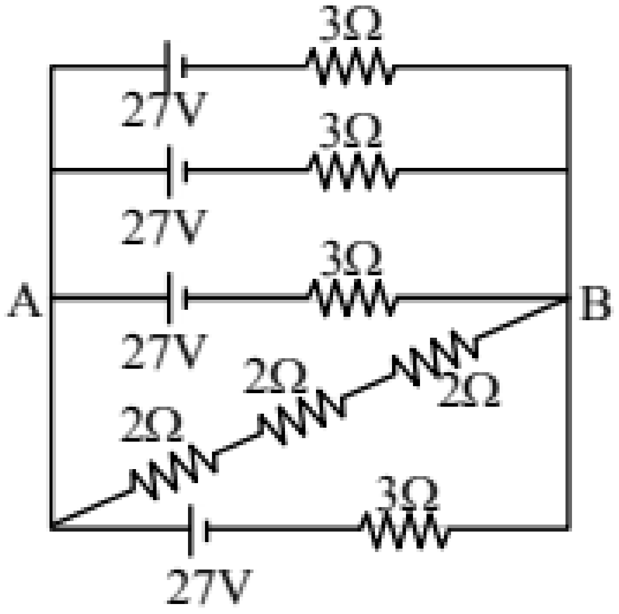
$$= \frac{\frac{1}{2}}{\frac{\sqrt{3}}{2}}$$

$$\frac{R_A}{R_B} = \frac{1}{\sqrt{3}}$$

Quick Tip: For projectiles with the same initial speed, the range depends on $\sin 2\theta$. Angles θ and $(90^\circ - \theta)$ produce the same range.

---

7. Find the voltage V_{AB} and the current i_{BA} in the given circuit.



(A) 24 V, 2 A

(B) 24 V, 1 A

(C) 18 V, 2 A

(D) 18 V, 1 A

Correct Answer: (2) 24 V, 1 A

Solution:

Concept:

When several cells with internal resistances are connected in parallel, the equivalent emf and equivalent resistance are given by

$$E_{\text{eq}} = \frac{\sum \frac{E_i}{r_i}}{\sum \frac{1}{r_i}}$$

$$r_{\text{eq}} = \frac{1}{\sum \frac{1}{r_i}}$$

This allows the complex network between A and B to be reduced to a single equivalent source.

Step 1: Write the equivalent emf expression.

$$E_{\text{eq}} = \frac{\frac{27}{3} + \frac{27}{3} + \frac{27}{3} + \frac{0}{6} + \frac{27}{3}}{\frac{1}{3} + \frac{1}{3} + \frac{1}{3} + \frac{1}{6} + \frac{1}{3}}$$

$$E_{\text{eq}} = \frac{36}{9/6}$$

$$E_{\text{eq}} = 24\,\text{V}$$

Thus,

$$V_{AB} = 24\,\text{V}$$

Step 2: Find equivalent resistance.

$$r_{\text{eq}} = \frac{1}{\frac{1}{3} + \frac{1}{3} + \frac{1}{3} + \frac{1}{6} + \frac{1}{3}}$$

$$r_{\text{eq}} = \frac{2}{3}\,\Omega$$

Step 3: Find current i_{BA}.

The external resistor between the equivalent source and point B is $3\,\Omega$.

Total resistance:

$$R_{\text{total}} = 3 + \frac{2}{3}$$

Using Ohm's law:

$$i_{BA} = \frac{E_{\text{eq}}}{R_{\text{total}}}$$

$$i_{BA} = \frac{24}{3 + \frac{2}{3}}$$

$$i_{BA} = \frac{24}{\frac{11}{3}}$$

$$i_{BA} \approx 1\,\text{A}$$

Thus,

$$V_{AB} = 24\,\text{V}, \qquad i_{BA} = 1\,\text{A}$$

Quick Tip: For cells connected in parallel with internal resistances, use $E_{\text{eq}} = \frac{\sum(E/r)}{\sum(1/r)}$ and $r_{\text{eq}} = \frac{1}{\sum(1/r)}$. This converts a complicated network into a single equivalent source.

---

8. In an AC circuit a resistor 100Ω, inductor $0.1\,\text{mH}$ and a capacitor are connected in series across an AC source of $220\,\text{V}$, $50\,\text{Hz}$. If the power factor of the circuit is $\frac{1}{2}$ and $|X_L - X_C| = \alpha\sqrt{3}\,\Omega$, find α.

(A) $100\sqrt{3}$

(B) 100

(C) $\frac{100}{\sqrt{3}}$

(D) 1000

Correct Answer: (2) 100

Solution:

Concept:

For a series AC circuit, the power factor is

$$\cos\phi = \frac{R}{Z}$$

where Z is the impedance. Also,

$$\tan\phi = \frac{|X_L - X_C|}{R}$$

These relations allow determination of the net reactance.

Step 1: Use the given power factor.

$$\cos\phi = \frac{1}{2}$$

$$\phi = 60^\circ$$

Step 2: Use the tangent relation.

$$\tan\phi = \frac{|X_L - X_C|}{R}$$

$$\tan 60^\circ = \frac{|X_L - X_C|}{100}$$

$$\sqrt{3} = \frac{|X_L - X_C|}{100}$$

Step 3: Calculate net reactance.

$$|X_L - X_C| = 100\sqrt{3}$$

Given

$$|X_L - X_C| = \alpha\sqrt{3}$$

Thus,

$$\alpha = 100$$

Quick Tip: In a series AC circuit, power factor relations are very useful: $\cos\phi = R/Z$ and $\tan\phi = (X_L - X_C)/R$. These directly connect reactance with resistance.

---

9. A solid sphere of mass M and radius R is split into two pieces of masses $\frac{7M}{8}$ and $\frac{M}{8}$. The piece of mass $\frac{7M}{8}$ is converted into a disc of radius $2R$ and thickness t whose moment of inertia is I_1. The other piece is made into a solid sphere with moment of inertia I_2. Find $\frac{I_1}{I_2}$.

(A) 150

(B) 140

(C) 130

(D) 120

Correct Answer: (2) 140

Solution:

Concept:

Moment of inertia formulas:

$$I_{\text{disc}} = \frac{1}{2}MR^2$$

$$I_{\text{sphere}} = \frac{2}{5}MR^2$$

Mass and volume relations are used to determine the radius of the smaller sphere.

Step 1: Find density of the original sphere.

$$M = \frac{4}{3}\pi R^3\rho$$

$$\rho = \frac{3M}{4\pi R^3}$$

Step 2: Find radius of smaller sphere of mass $M/8$.

$$\frac{M}{8} = \frac{4}{3}\pi r^3\rho$$

Substitute ρ:

$$\frac{M}{8} = \frac{4}{3}\pi r^3 \left(\frac{3M}{4\pi R^3}\right)$$

$$\frac{M}{8} = M\frac{r^3}{R^3}$$

$$r^3 = \frac{R^3}{8}$$

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

Step 3: Moment of inertia of disc formed from mass $7M/8$.

$$I_1 = \frac{1}{2}\left(\frac{7M}{8}\right)(2R)^2$$

$$I_1 = \frac{7MR^2}{4}$$

Step 4: Moment of inertia of smaller sphere.

$$I_2 = \frac{2}{5}\left(\frac{M}{8}\right)\left(\frac{R}{2}\right)^2$$

$$I_2 = \frac{MR^2}{80}$$

Step 5: Find the ratio.

$$\frac{I_1}{I_2} = \frac{\frac{7MR^2}{4}}{\frac{MR^2}{80}}$$

$$\frac{I_1}{I_2} = 140$$

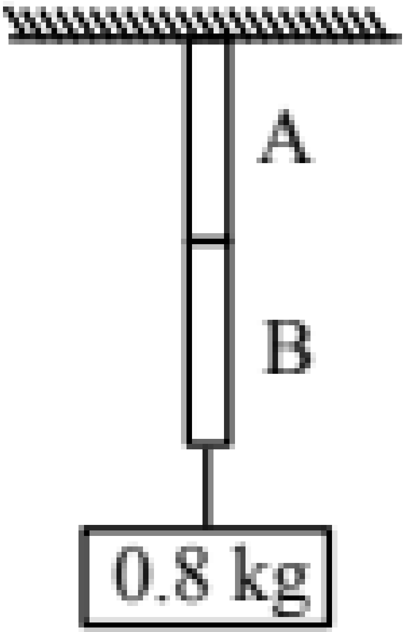
Quick Tip: When objects are reshaped, mass remains constant but geometry changes. Use density and volume relations to determine new dimensions before applying moment of inertia formulas.

---

10. Length of rods are ℓ and 2ℓ respectively and their Young's modulus are γ and 2γ respectively.

Given:

$$\ell = 0.314\,\text{m}, \quad R = 0.2\,\text{mm}\,(\text{same}), \quad \gamma = 2 \times 10^9$$



Find the total extension $\Delta\ell$.

(A) $0.4\,\text{mm}$

(B) $0.1\,\text{mm}$

(C) $0.2\,\text{mm}$

(D) $0.3\,\text{mm}$

Correct Answer: (3) $0.2\,\text{mm}$

Solution:

Concept:

Extension of a wire under load is given by

$$\Delta L = \frac{FL}{AY}$$

where F = applied force, L = length of wire, A = cross-sectional area, Y = Young's modulus.

For rods connected in series, total extension equals the sum of individual extensions.

$$\Delta\ell = \Delta\ell_1 + \Delta\ell_2$$

Step 1: Write extension expressions for both rods.

$$\Delta\ell_1 = \frac{MgL_1}{A\gamma}$$

$$\Delta\ell_2 = \frac{MgL_2}{A(2\gamma)}$$

Step 2: Add the extensions.

$$\Delta\ell = \frac{MgL}{A\gamma} + \frac{Mg(2L)}{A(2\gamma)}$$

$$\Delta\ell = \frac{Mg}{A}\left(\frac{L}{\gamma} + \frac{2L}{2\gamma}\right)$$

$$\Delta\ell = \frac{2MgL}{A\gamma}$$

Step 3: Substitute numerical values.

Mass $m = 0.8\,\text{kg}$

$$A = \pi R^2$$

$$R = 0.2\,\text{mm} = 2 \times 10^{-4}\,\text{m}$$

$$A = \pi(2 \times 10^{-4})^2$$

Substitute:

$$\Delta\ell = \frac{0.8 \times 10}{\pi \times 4 \times 10^{-6}}\left(\frac{2 \times 0.314}{2 \times 10^{9}}\right)$$

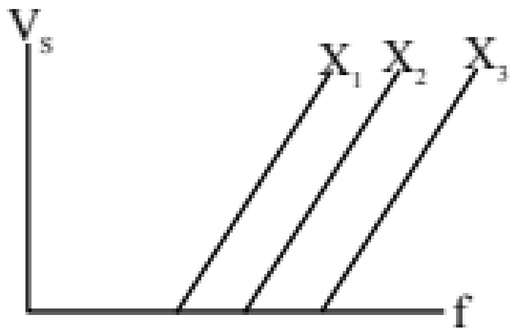
$$\Delta\ell = 2 \times 10^{-4}\,\text{m}$$

$$\Delta\ell = 0.2\,\text{mm}$$

Quick Tip: For rods connected in series under the same load, total extension is simply the sum of individual extensions: $\Delta L_{total} = \Delta L_1 + \Delta L_2$.

---

11. The graph shows stopping potential V_s versus frequency f of incident light for three different metals X_1,X_2, and X_3. Choose the metal which will eject photoelectrons with maximum kinetic energy for a given frequency.



(A) X_1

(B) X_2

(C) X_3

(D) can't be predicted

Correct Answer: (1) X_1

Solution:

Concept:

According to Einstein's photoelectric equation,

$$K_{\max} = eV_s = hf - \phi$$

where $K_{\max}$ = maximum kinetic energy of emitted electrons, V_s = stopping potential, h = Planck's constant, f = frequency of incident light, ϕ = work function of the metal.

The threshold frequency f_0 is related to work function as:

$$\phi = hf_0$$

Thus,

$$K_{max} = h(f - f_0)$$

For a fixed incident frequency, the metal with the **lowest threshold frequency** (or lowest work function) will give the **maximum kinetic energy**.

Step 1: Interpret the graph.

In a stopping potential vs frequency graph:

- All metals have the same slope $\frac{h}{e}$.
- The intercept on the frequency axis represents the threshold frequency.

Step 2: Identify the smallest threshold frequency.

From the graph, the line corresponding to X_1 intersects the frequency axis first.

Thus,

$$f_{0(X_1)} < f_{0(X_2)} < f_{0(X_3)}$$

Step 3: Determine which metal gives maximum kinetic energy.

Since

$$K_{max} = h(f - f_0)$$

smaller f_0 gives larger K_{max}.

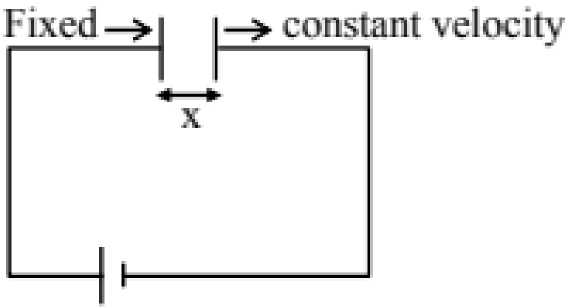
Therefore,

$$X_1 \text{ produces the maximum kinetic energy.}$$

Quick Tip: In a stopping potential vs frequency graph, the slope is constant h/e. The metal with the **smallest threshold frequency** (leftmost intercept) produces electrons with the **maximum kinetic energy**.

---

12. If the right plate of a parallel plate capacitor is pulled with constant velocity as shown in the figure, find how the rate of change of energy stored in the capacitor depends on the separation x.



(A) x^{-2}

(B) x^{-3}

(C) x^{-1}

(D) x^{2}

Correct Answer: (1) x^{-2}

Solution:

Concept:

Capacitance of a parallel plate capacitor is given by

$$C = \frac{\varepsilon_0 A}{x}$$

where x is the separation between the plates.

Energy stored in a capacitor connected to a constant voltage source is

$$U = \frac{1}{2}CV^2$$

Since the capacitor remains connected to the battery, the voltage V remains constant.

Step 1: Substitute the capacitance expression into energy formula.

$$U = \frac{1}{2}\left(\frac{\varepsilon_0 A}{x}\right)V^2$$

$$U = \frac{1}{2}\frac{\varepsilon_0 A V^2}{x}$$

Step 2: Differentiate with respect to time.

$$\frac{dU}{dt} = \frac{1}{2}\varepsilon_0 A V^2 \frac{d}{dt}\left(\frac{1}{x}\right)$$

$$\frac{dU}{dt} = \frac{1}{2}\varepsilon_0 AV^2 \left(-\frac{1}{x^2}\right)\frac{dx}{dt}$$

Step 3: Use constant velocity condition.

Since the plate moves with constant velocity,

$$\frac{dx}{dt} = \text{constant}$$

Thus,

$$\frac{dU}{dt} \propto \frac{1}{x^2}$$

Quick Tip: For a capacitor connected to a battery, voltage remains constant. Since $C = \frac{\varepsilon_0 A}{x}$, the stored energy $U = \frac{1}{2}CV^2$ varies inversely with plate separation.

---

13. Two 4-bit binary numbers $A = 1101$ and $B = 1010$ are given in the input logic circuit. Find the output Y.

(A) 1000

(B) 1101

(C) 0010

(D) 0111

Correct Answer: (2) 1101

Solution:

Concept:

From the circuit:

- Input B first passes through a NOT gate giving $\overline{B}$.
- The output then enters a NAND gate with A.

Thus,

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

Using De Morgan's theorem:

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

Step 1: Write the given binary numbers.

$$A = 1101$$

$$B = 1010$$

Step 2: Find complement of B.

$$\overline{B} = 0101$$

Step 3: Apply the Boolean expression.

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

Performing OR operation:

$$\begin{array}{cccc} A & = & 1 & 1 \\ 0 & 1 & & \\ \overline{B} & = & 0 & 1 \\ 0 & 1 & & \\ \hline Y & = & 1 & 1 \\ 0 & 1 & & \end{array}$$

$$Y = 1101$$

Quick Tip: A NAND gate with one complemented input often simplifies using De Morgan's theorem. $\overline{A \cdot B} = \overline{A} + \overline{B}$.

---

14. Resolving power of a telescope is 5×10^{-7} rad. If wavelength of incident light is $500\,\text{nm}$, find the diameter of the aperture of the telescope.

(A) $1.22\,\text{m}$

(B) 4.66 m

(C) 2.33 m

(D) 0.56 m

Correct Answer: (1) 1.22 m

Solution:

Concept:

Resolving power of a telescope is given by Rayleigh's criterion:

$$\theta = \frac{1.22\lambda}{D}$$

where θ = angular resolution, λ = wavelength of light, D = diameter of the objective lens.

Step 1: Substitute the given values.

$$\theta = 5 \times 10^{-7}\,\text{rad}$$

$$\lambda = 500\,\text{nm} = 500 \times 10^{-9}\,\text{m}$$

$$5 \times 10^{-7} = \frac{1.22 \times 500 \times 10^{-9}}{D}$$

Step 2: Solve for D.

$$D = \frac{1.22 \times 500 \times 10^{-9}}{5 \times 10^{-7}}$$

$$D = 1.22\,\text{m}$$

Quick Tip: Rayleigh's criterion for telescope resolution is $\theta = \frac{1.22\lambda}{D}$. Smaller θ (better resolution) requires a larger aperture D.

15. An ideal gas has number of moles $n = 2$, initial volume V_0 and pressure

$$P = P_0\left[1 + \left(\frac{V_0}{V}\right)^2\right]^{-1}.$$

The gas goes from state A (initial) to B (final) such that volume becomes $3V_0$. Find $T_A - T_B$.

(A) $\frac{11P_0V_0}{10R}$

(B) $\frac{5P_0V_0}{11R}$

(C) $\frac{11P_0V_0}{5R}$

(D) $\frac{10P_0V_0}{11R}$

Correct Answer: (1) $\frac{11P_0V_0}{10R}$

Solution:

Concept:

For an ideal gas,

$$PV = nRT$$

Here $n = 2$. Thus temperature can be found from

$$T = \frac{PV}{2R}$$

Step 1: Find temperature at state A.

At $V = V_0$,

$$P = \frac{P_0}{1 + (V_0/V_0)^2} = \frac{P_0}{2}$$

Using ideal gas equation:

$$\frac{P_0}{2} \times V_0 = 2R\,T_A$$

$$T_A = \frac{P_0V_0}{4R}$$

Step 2: Find temperature at state B.

At $V = 3V_0$,

$$P = \frac{P_0}{1 + \left(\frac{V_0}{3V_0}\right)^2} = \frac{P_0}{1 + \frac{1}{9}} = \frac{9P_0}{10}$$

Using ideal gas equation:

$$\frac{9P_0}{10} \times 3V_0 = 2R\,T_B$$

$$T_B = \frac{27P_0V_0}{20R}$$

Step 3: Find temperature difference.

$$T_B - T_A = \frac{27P_0V_0}{20R} - \frac{P_0V_0}{4R}$$

$$= \frac{27P_0V_0}{20R} - \frac{5P_0V_0}{20R}$$

$$= \frac{11P_0V_0}{10R}$$

Quick Tip: Whenever pressure is given as a function of volume, substitute the specific volume into the relation first to obtain P, then use the ideal gas law $PV = nRT$ to find the temperature.

---

16. A slit of width a is illuminated by light of wavelength λ. The linear separation between the 1st and 3rd minima in the diffraction pattern produced on a screen placed at a distance D from the slit is:

(A) $\frac{3D\lambda}{a}$

(B) $\frac{3D\lambda}{2a}$

(C) $\frac{D\lambda}{a}$

(D) $\frac{2D\lambda}{a}$

Correct Answer: (4) $\frac{2D\lambda}{a}$

Solution:

Concept:

For single slit diffraction, the position of minima on the screen is

$$y_n = \frac{nD\lambda}{a}, \qquad n = 1, 2, 3, \ldots$$

Step 1: Position of the first minima.

$$y_1 = \frac{D\lambda}{a}$$

Step 2: Position of the third minima.

$$y_3 = \frac{3D\lambda}{a}$$

Step 3: Find the separation.

$$\text{Separation} = y_3 - y_1$$

$$= \frac{3D\lambda}{a} - \frac{D\lambda}{a}$$

$$= \frac{2D\lambda}{a}$$

Quick Tip: For single slit diffraction minima, use $y_n = \frac{nD\lambda}{a}$. The separation between two minima is simply the difference of their positions.

---

17. In a screw gauge, when the circular scale is given five complete rotations, it moves linearly by 2.5 mm. If the circular scale has 100 divisions, the least count of the screw gauge is:

(A) 1×10^{-2} mm

(B) 5×10^{-3} mm

(C) 1×10^{-3} mm

(D) 4×10^{-2} mm

Correct Answer: (2) 5×10^{-3} mm

Solution:

Concept:

Least count of a screw gauge is given by

$$\text{Least Count} = \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

Pitch is the linear distance moved by the screw in one complete rotation.

Step 1: Find the pitch.

Given 5 rotations move the screw by 2.5 mm:

$$\text{Pitch} = \frac{2.5}{5}$$

$$\text{Pitch} = 0.5\,\text{mm}$$

$$= 5 \times 10^{-4}\,\text{m}$$

Step 2: Calculate the least count.

Number of divisions on circular scale = 100

$$\text{L.C.} = \frac{\text{Pitch}}{\text{Number of divisions}}$$

$$= \frac{5 \times 10^{-4}}{100}\,\text{m}$$

$$= 5 \times 10^{-6}\,\text{m}$$

Step 3: Convert into millimetres.

$$5 \times 10^{-6}\,\text{m} = 5 \times 10^{-3}\,\text{mm}$$

Quick Tip: For screw gauges, always remember: Pitch = distance moved in one rotation, and Least Count = $\frac{\text{Pitch}}{\text{Number of circular scale divisions}}$.

18.

Find the magnetic moment of the spiral.**There is a spiral which has $r_i = 3\,$cm, $r_{ext} = 6\,$cm, $I = 20\,$mA and $N = 200$, where r_i : internal radius r_{ext} : external radius N : number of turns I : current.**

Find the magnetic moment of the spiral.

(A) 2.64×10^{-2} **A m**^{2}

(B) 4.87×10^{-2} **A m**^{2}

(C) 3.65×10^{-2} **A m**^{2}

(D) 6.67×10^{-2} **A m**^{2}

Correct Answer: **(1)** 2.64×10^{-2} **A m**^{2}

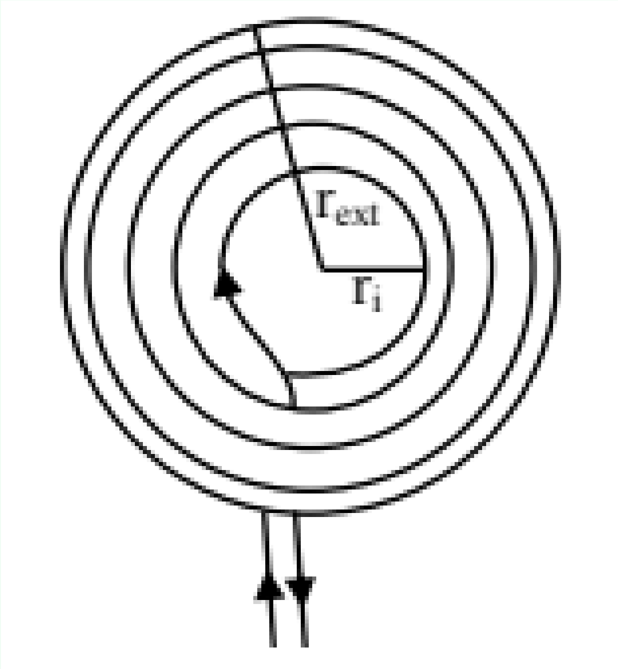
Solution:

Concept:

Magnetic moment of a current loop is

$$M = I \times A$$

For a spiral coil with continuously varying radius, the total magnetic moment is obtained by integrating the contribution of small circular loops.



Step 1: **Magnetic moment of a small ring.**

For a small ring of radius r,

$$dM = I\,dA$$

$$dM = I(\pi r^2)$$

If the number of turns changes continuously,

$$dM = I(dN)\pi r^2$$

Step 2: **Relate dN with radius.**

Since N turns are distributed between r_i and r_{ext},

$$dN = \frac{N}{r_{ext} - r_i} dr$$

Substitute:

$$dM = I\pi r^2 \frac{N}{r_{ext} - r_i} dr$$

Step 3: **Integrate between the limits.**

$$M = \int_{r_i}^{r_{ext}} I\pi r^2 \frac{N}{r_{ext} - r_i} dr$$

$$M = \frac{I\pi N}{r_{ext} - r_i} \int_{r_i}^{r_{ext}} r^2 dr$$

$$M = \frac{I\pi N}{r_{ext} - r_i} \left[\frac{r^3}{3} \right]_{r_i}^{r_{ext}}$$

$$M = \frac{I\pi N}{3(r_{ext} - r_i)} (r_{ext}^3 - r_i^3)$$

Step 4: Substitute numerical values.

$$I = 20 \times 10^{-3} A$$

$$N = 200$$

$$r_{ext} = 6 \times 10^{-2} m$$

$$r_i = 3 \times 10^{-2} m$$

$$M = \frac{20 \times 10^{-3} \times 3.14 \times 200}{3(6-3) \times 10^{-2}} (6^3 - 3^3) \times 10^{-6}$$

$$M = 2.64 \times 10^{-2} \textbf{ A m}^2$$

Quick Tip: **Magnetic moment of a loop is $M = IA$. For spiral coils with varying radius, integrate $I\pi r^2$ over the turns.**

---

19. Two forces are acting on a body:

$$\vec{F}_1 = 3\hat{i} - 5\hat{j} + 2\hat{k}$$

$$\vec{F}_2 = 8\hat{i} + 2\hat{j} - 3\hat{k}$$

The displacement of the body is $25\,\text{m}$ along the direction $3\hat{i} - 4\hat{j}$. Find the work done.

(A) 225 **J**

(B) 200 **J**

(C) 125 **J**

(D) 325 **J**

Correct Answer: **(1)** 225 **J**

Solution:

Concept:

Work done by a force is given by the dot product of force and displacement.

$$W = \vec{F} \cdot \vec{S}$$

If multiple forces act simultaneously, the resultant force is

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$$

Step 1: **Find the resultant force.**

$$\vec{F}_{net} = (3+8)\hat{i} + (-5+2)\hat{j} + (2-3)\hat{k}$$

$$\vec{F}_{net} = 11\hat{i} - 3\hat{j} - \hat{k}$$

Step 2: **Find the displacement vector.**

Direction vector:

$$3\hat{i} - 4\hat{j}$$

Magnitude of this direction:

$$\sqrt{3^2 + 4^2} = 5$$

Unit vector:

$$\frac{3\hat{i}-4\hat{j}}{5}$$

Since displacement magnitude is $25\,m$**,**

$$\vec{S} = 25\left(\frac{3\hat{i}-4\hat{j}}{5}\right)$$

$$\vec{S} = 15\hat{i}-20\hat{j}$$

Step 3: Calculate the work done.

$$W = \vec{F}_{net}\cdot\vec{S}$$

$$= (11\hat{i}-3\hat{j}-\hat{k})\cdot(15\hat{i}-20\hat{j})$$

$$W = 11\times 15+(-3)(-20)+(-1)(0)$$

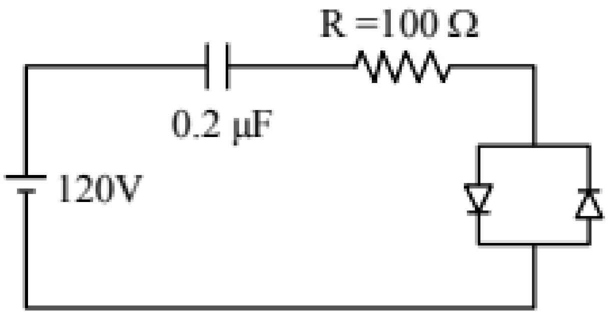
$$W = 165+60$$

$$W = 225\,\mathbf{J}$$

Quick Tip: **When displacement is given along a direction, first convert the direction into a unit vector and multiply it by the magnitude to obtain the displacement vector.**

---

20. Each diode in the circuit has 10Ω **resistance in forward bias and infinite resistance in reverse bias. Find the time constant of the circuit. Given:** $R = 100\Omega$, $C = 0.2\,\mu F$.



(A) $20\,\mu s$

(B) $22\,\mu s$

(C) $18\,\mu s$

(D) $5\,\mu s$

Correct Answer: **(2)** $22\,\mu s$

Solution:

Concept:

The time constant of an RC circuit is

$$\tau = RC$$

where R is the effective resistance in the circuit and C is the capacitance.

Step 1: Determine effective resistance.

The circuit contains a resistor $R = 100\Omega$ and a diode. Only one diode conducts in forward bias, contributing a resistance of 10Ω.

Thus,

$$R_{eq} = 100 + 10 = 110\Omega$$

Step 2: Calculate the time constant.

$$\tau = RC$$

$$\tau = 110 \times 0.2 \times 10^{-6}$$

$$\tau = 22 \times 10^{-6}\,s$$

$$\tau = 22\,\mu s$$

Quick Tip: Time constant of an RC circuit is $\tau = RC$. When diodes are present, first determine which diode is forward biased and include its resistance in the effective resistance.

21. Find the final temperature of a mixture of two gases. If one gas has pressure P_1, temperature T_1, number of moles n_1 and volume V_1; and the second gas has pressure P_2, temperature T_2, number of moles n_2 and volume V_2. If the final pressure is P and final volume is V, find the final temperature of the mixture.

(A) $\dfrac{PV}{\frac{P_1V_1}{T_1}+\frac{P_2V_2}{T_2}}$

(B) $\dfrac{PV(T_1+T_2)}{P_1V_1+P_2V_2}$

(C) $\dfrac{(P_1V_1+P_2V_2)(T_1+T_2)}{PV}$

(D) $\dfrac{PV}{P_1V_1}T_1+\left(\dfrac{PV}{P_2V_2}\right)T_2$

Correct Answer: **(1)** $\dfrac{PV}{\frac{P_1V_1}{T_1}+\frac{P_2V_2}{T_2}}$

Solution:

Concept:

For an ideal gas,

$$PV = nRT$$

Thus,

$$n = \frac{PV}{RT}$$

When two gases mix, the total number of moles is conserved.

$$n = n_1 + n_2$$

Step 1: Write number of moles for each gas.

$$n_1 = \frac{P_1V_1}{RT_1}$$

$$n_2 = \frac{P_2V_2}{RT_2}$$

Step 2: Write total number of moles after mixing.

$$n = \frac{PV}{RT_f}$$

Step 3: Use mole conservation.

$$\frac{PV}{RT_f} = \frac{P_1V_1}{RT_1} + \frac{P_2V_2}{RT_2}$$

Cancel R:

$$\frac{PV}{T_f} = \frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_2}$$

Step 4: Solve for T_f.

$$T_f = \frac{PV}{\frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_2}}$$

Quick Tip: For mixing of ideal gases, total number of moles remains conserved. Always express moles using $n = \frac{PV}{RT}$ and then apply $n = n_1 + n_2$.

---

22. A particle is moving along the x-axis where the speed varies as

$$v^2 = 100 - x^2$$

Determine the time period.

(A) 4π

(B) 8π

(C) 2π

(D) π

Correct Answer: (3) 2π

Solution:

Concept:

For simple harmonic motion (SHM), velocity as a function of displacement is

$$v = \omega\sqrt{A^2 - x^2}$$

where A = amplitude, ω = angular frequency.

Step 1: Rewrite the given equation.

$$v^2 = 100 - x^2$$

$$v = \sqrt{100 - x^2}$$

Step 2: Compare with SHM velocity relation.

$$v = \omega\sqrt{A^2 - x^2}$$

Comparing,

$$A^2 = 100$$

$$A = 10$$

and

$$\omega = 1$$

Step 3: Find the time period.

$$T = \frac{2\pi}{\omega}$$

$$T = \frac{2\pi}{1}$$

$$T = 2\pi$$

Quick Tip: **In SHM, velocity-displacement relation is $v = \omega\sqrt{A^2 - x^2}$. Comparing the given equation with this form directly gives amplitude and angular frequency.**