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PREVIOUS YEAR PAPER · 2024

OLYMPIAD · STAGE I

NSEP

National Standard Examination in Physics

2024

Question paper, answer key and Zigyan solutions

60	216	120 min	61
Questions	Maximum marks	Time	Paper code

Question paper and official answer key: Indian Association of Physics Teachers (IAPT), NSEP 2024, paper code 61.
Solutions and notes: Zigyan. This booklet is not an IAPT publication.

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Sulokya Bibhuty

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- Aarush Kumar — 1 Year Classroom

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- Sulokya Bibhuty — 3 Years Classroom
- Saksham Bishnoi — 4 Years Classroom

ASTRONOMY

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MATHEMATICS (IOQM)

- Priyanshi — 4 Years Classroom

Saksham Bishnoi qualified the Chemistry Olympiad twice and was selected for the Orientation-cum-Selection Camp at HBCSE, Mumbai.

16 selections	16 of 35	AIR 168
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Given in the question paper

Physical constants you may need....

Magnitude of charge on electron $e = 1.60 \times 10^{-19}\,C$	Avogadro's constant $A = 6.023 \times 10^{23}\,mol^{-1}$
Mass of electron $m_e = 9.11 \times 10^{-31}\,kg$	Speed of light in free space $c = 3 \times 10^{8}\ ms^{-1}$
Mass of proton $m_p = 1.67 \times 10^{-27}\,kg$	Speed of sound in dry air at 0°C $v = 332\ ms^{-1}$
Acceleration due to gravity $g = 9.81\ ms^{-2}$	Permittivity of free space $\varepsilon_0 = 8.85 \times 10^{-12}\,C^2 / Nm^2$
Universal gravitational constant $G = 6.67 \times 10^{-11}\,Nm^2 / kg^2$	Permeability of free space $\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$
Universal gas constant $R = 8.31\ J / mol\,K$	Planck's constant $h = 6.625 \times 10^{-34}\ Js$
Boltzmann constant $k = 1.38 \times 10^{-23}\ J / K$	Faraday constant $= 96,500\ C\,mol^{-1}$
Stefan's constant $\sigma = 5.67 \times 10^{-8}\,W / m^2K^4$	Rydberg constant $R = 1.097 \times 10^{7}\,m^{-1}$
Atmospheric pressure (at STP) = $1.013 \times 10^5\ Nm^{-2}$	Astronomical unit $= 1.50 \times 10^{11}\ m$

PART A-1 · ONE CORRECT OPTION

Q. 1 – 48 · +3 for a correct answer, –1 for a wrong one

1. In the Bohr model of hydrogen atom, the force between the nucleus and the electron is modified as $F = \frac{e^2}{4\pi\epsilon_0}\left(\frac{1}{r^2} + \frac{\delta}{r^3}\right)$ where δ is a small constant. Using the Bohr radius $a_0 = \frac{\epsilon_0 h^2}{\pi m e^2}$, the radius of n^{th} orbit is

(A) $a_0n^2 - \delta$ (B) $a_0n^2 + \delta$ (C) $a_0(n - \delta)^2$ (D) $a_0(n + \delta)^2$

Solution · Q1 **Answer: (A)**

For the circular orbit,

$$\frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_0}\left(\frac{1}{r^2} + \frac{\delta}{r^3}\right)$$

Quantisation of angular momentum:

$$mvr = \frac{nh}{2\pi}$$

Using this in the force equation,

$$\frac{n^2h^2}{4\pi^2m} = \frac{e^2}{4\pi\varepsilon_0}(r + \delta)$$

$$\Rightarrow r + \delta = \frac{n^2h^2\varepsilon_0}{\pi me^2} = a_0n^2$$

$$\therefore r = a_0n^2 - \delta$$

IAPT answer: (A) | **Zigyan answer:** (A)

2. An infinite number of conducting rings having increasing radii r_0, r_1, r_2, r_3 and so on, such that $r_0 = r$, $r_1 = 2r$, $r_2 = 2^2 r$, $r_3 = 2^3 r$ and so on ..... upto ∞, have been placed concentrically on a plane. All the rings carry the same current **i** but the current in consecutive rings is in opposite direction as shown. The magnetic field produced at the common center of the rings is

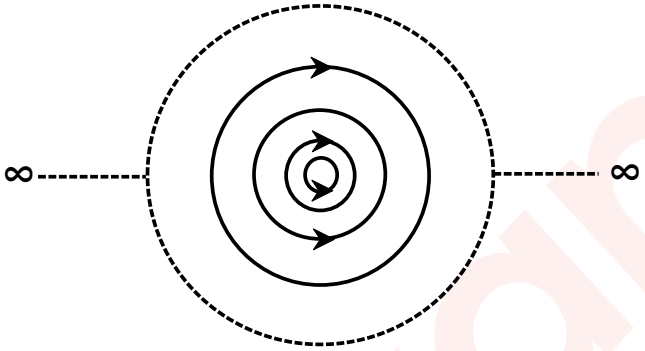


Diagram not to scale

(A) zero

(B) $\frac{\mu_0 i}{4r}$

(C) $\frac{\mu_0 i}{3r}$

(D) $\frac{\mu_0 i}{2r}$

Solution · Q2 **Answer: (C)**

The ring of radius $2^k r$ produces at the centre

$$B_k = \frac{\mu_0 i}{2r} \times \frac{1}{2^k}$$

Successive fields are opposite in direction.

$$B = \frac{\mu_0 i}{2r}\left(1 - \frac{1}{2} + \frac{1}{4} - \frac{1}{8} + \ \ldots\ \right)$$

$$\Rightarrow B = \frac{\mu_0 i}{2r} \times \frac{1}{1 + 1/2}$$

$$\therefore B = \frac{\mu_0 i}{3r}$$

IAPT answer: (C) | **Zigyan answer:** (C)

3. One mole of an ideal monoatomic gas, initially at temperature T, is heated in such a way that its molar heat capacity during the process of heating is C = 2R. The volume of the gas gets tripled (at constant pressure) during the process. The final temperature attained by the gas is

(A) 3 T

(B) 3^2 T

(C) $\frac{1}{3}$T

(D) 3^3 T

Solution · Q3 **As per Zigyan: (B)**

A molar heat capacity of 2R rules out heating this gas at constant pressure, so the given value 2R is used.

By the first law, for one mole,

$$C\,dT = C_V\,dT + P\,dV$$

$$C = 2R,\ C_V = 1.5R$$

$$\Rightarrow P\,dV = 0.5R\,dT$$

Using the gas equation,

$$PV = RT$$

$$\frac{dT}{T} = 2\frac{dV}{V}$$

$$\Rightarrow \frac{T_f}{T} = \left(\frac{3V}{V}\right)^2 = 9$$

$$\therefore T_f = 3^2T$$

Reference: NCERT Physics Class XI (Part II), Chapter 12 'Kinetic Theory', section 12.6.1: for a monatomic gas the molar heat capacity is 1.5R at constant volume and 2.5R at constant pressure. So 2R cannot belong to heating at constant pressure.

Check: in a process with PV^n constant, C exceeds C_V by R divided by (1 – n). So C of 2R makes n equal to –1: P varies as V and T as V^2, and tripling V gives 9T.

IAPT answer: (A) or (B) | **Zigyan answer:** (B)

4. A spring is compressed under the action of a constant force F. The compression of the spring is ξ. Suppose the direction of the force is reversed suddenly as well as its magnitude is doubled. The maximum extension of the spring beyond its natural length will now be (the spring obeys Hook's law).

(A) 2ξ (B) 3ξ (C) 4ξ (D) 5ξ

Solution · Q4 **Answer: (D)**

The compression ξ is taken as the equilibrium value under F.

$$k\xi = F$$

Under the reversed force 2F, the new equilibrium extension is

$$\frac{2F}{k} = 2\xi$$

The end starts from rest at compression ξ, so the amplitude is

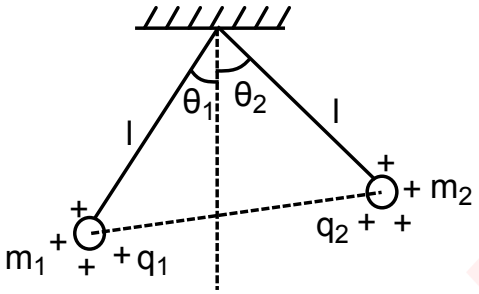
$$A = 2\xi + \xi = 3\xi$$

Maximum extension:

$$2\xi + 3\xi = 5\xi$$

IAPT answer: (D) | **Zigyan answer:** (D)

5. Two small positively charged spherical balls are suspended from a common point at the ceiling by non-conducting massless strings of equal length ℓ. The first ball has mass m_1 and charge q_1 while the second ball has mass m_2 and charge q_2. If the two strings subtend angles θ_1 and θ_2 with the vertical as shown, then



(A) $\frac{\sin\theta_1}{\sin\theta_2} = \frac{q_2}{q_1}$

(B) $\frac{\sin\theta_1}{\sin\theta_2} = \frac{m_2}{m_1}$

(C) $\frac{\tan\theta_1}{\tan\theta_2} = \frac{q_1}{q_2} \times \frac{m_2}{m_1}$

(D) $\frac{\sin\theta_1}{\sin\theta_2} = 1$

Solution · Q5 **Answer: (B)**

The electric forces on the two balls act along the same line with equal magnitude, so they have equal torques about the point of suspension.

Balancing torques for each ball,

$$m_1 g\ell \sin\theta_1 = m_2 g\ell \sin\theta_2$$

$$\Rightarrow \frac{\sin\theta_1}{\sin\theta_2} = \frac{m_2}{m_1}$$

IAPT answer: (B) | **Zigyan answer:** (B)

6. An air filled parallel plate capacitor, with plate area A and plate separation d, is connected to a battery of emf V volt having negligible internal resistance. One of the plates of the capacitor vibrates with amplitude 'a' (a << d) and angular frequency ω. If the instantaneous current in the circuit reaches a maximum value I_0, the amplitude of the vibrations is 'a' equal to

(A) $\frac{I_0 d^2}{\epsilon_0 \omega V A}$

(B) $\frac{2I_0 d}{\epsilon_0 \omega V A}$

(C) $\frac{2I_0 d^2}{\epsilon_0 \omega V A}$

(D) $\frac{I_0 d^2}{2\epsilon_0 \omega V A}$

Solution · Q6 **Answer: (A)**

At time t,

$$q = CV = \frac{\varepsilon_0 AV}{d + a\sin\omega t}$$

$$\Rightarrow i = \frac{dq}{dt} = -\frac{\varepsilon_0 AVa\omega\cos\omega t}{(d + a\sin\omega t)^2}$$

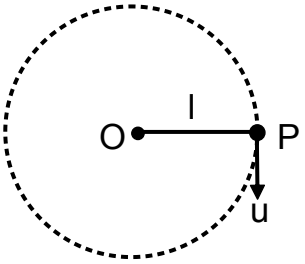
As a is much smaller than d,

$$I_0 = \frac{\varepsilon_0 AVa\omega}{d^2}$$

$$\therefore a = \frac{I_0 d^2}{\varepsilon_0 \omega V A}$$

IAPT answer: (A) | **Zigyan answer:** (A)

7. A small ball of mass m is attached to one end of a massless un-stretchable string of length ℓ and is held at the point P. The other end of the string is fixed to a support at O such that OP is horizontal. The minimum downward speed u, that should be imparted to the ball at the point P so that the ball can complete the vertical circle without any slack in the string, is



(A) $\sqrt{2g\ell}$ (B) $\sqrt{3g\ell}$
(C) $\sqrt{4g\ell}$ (D) $\sqrt{5g\ell}$

Solution · Q7 **Answer: (B)**

For no slack at the highest point,

$$T + mg = \frac{mv^2}{\ell}$$

$$T \geq 0$$

$$\Rightarrow v^2 \geq g\ell$$

By conservation of energy between P and the highest point,

$$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mg\ell$$

$$\Rightarrow u^2 = v^2 + 2g\ell$$

$$\therefore u_{min} = \sqrt{3g\ell}$$

IAPT answer: (B) | **Zigyan answer:** (B)

8. An illuminated point object is placed on the principal axis, in front of an equi-convex glass lens of focal length f = 40 cm, at a distance of u = 1.20 m from the lens. A reflecting plane mirror has been placed behind the lens perpendicular to the principal axis and facing the lens. The nature of the final image and the distance of the plane mirror from the lens, so as to form the final image at the plane mirror itself, is

(A) virtual image, 40 cm (B) real image, 40 cm
(C) virtual image, 50 cm (D) real image, 20 cm

Solution · Q8 **Answer: (A)**

First refraction through the lens (lengths in cm):

$$\frac{1}{v} = \frac{1}{40} - \frac{1}{120} = \frac{1}{60}$$

$$\Rightarrow v = 60$$

Let the plane mirror be at distance x from the lens. Its image lies at a distance from the lens of

$2x - 60$

Second refraction, positive along the returning light:

$$u = -(2x - 60),\ v = -x$$

$$\frac{1}{2x-60} - \frac{1}{x} = \frac{1}{40}$$

$$\Rightarrow x^2 - 10x - 1200 = 0$$

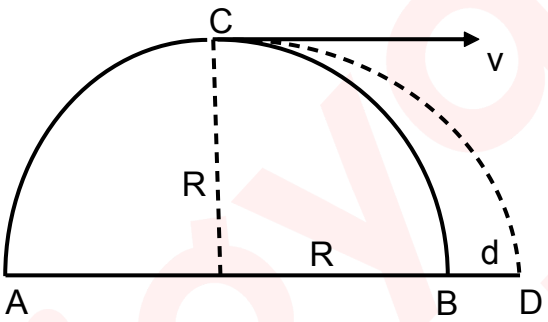
$$\Rightarrow x = 40 \text{ cm}$$

As v is negative, the final image is virtual.

IAPT answer: (A) | **Zigyan answer:** (A)

9. A ball is kicked horizontally from the top C of a hemispherical rock ACB of radius R on a horizontal ground, with a velocity v, so as not to hit the rock at any point during its flight.

Choose the correct statement (see the figure)



(A) The ball will just strike at B

(B) The ball will strike at D where $d = BD = \left(\sqrt{2} - 1\right)R$

(C) The ball will strike at D such that $d = BD = \left(2 - \sqrt{2}\right)R$

(D) The speed v of the ball should always be greater than the critical speed v_0 where v_0 is $\sqrt{\frac{gR}{2}}$

Solution · Q9 **Answer: (B)**

Take the origin at the centre of the base. The ball is at

$$x = vt$$

$$y = R - \frac{gx^2}{2v^2}$$

$$\Rightarrow x^2 + y^2 = R^2 + x^2\left(1 - \frac{gR}{v^2}\right) + \frac{g^2x^4}{4v^4}$$

To clear the rock,

$$x^2 + y^2 \geq R^2$$

$$\Rightarrow v^2 \geq gR$$

For the just-clearing path,

$$v_0 = \sqrt{gR}$$

Time of fall:

$$t = \sqrt{\frac{2R}{g}}$$

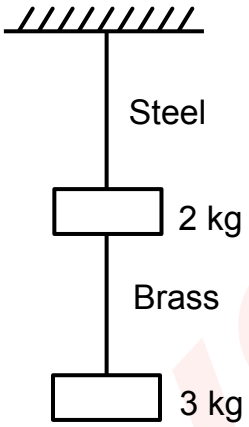
Horizontal range:

$$v_0 t = R\sqrt{2}$$

$$\therefore BD = \left(\sqrt{2} - 1\right)R$$

IAPT answer: (B) | **Zigyan answer:** (B)

10. The ratio of lengths, radii and Young's moduli of steel to brass wires in the figure are α, β and γ, respectively. The corresponding ratio of the increase in their lengths is



(A) $\frac{2\alpha}{3\beta^2\gamma}$ (B) $\frac{5\alpha}{3\beta^2\gamma}$

(C) $\frac{2\alpha\beta^2}{3\gamma}$ (D) $\frac{5\alpha\beta^2}{3\gamma}$

Solution · Q10 **Answer: (B)**

Taking the wires as light, the tension in the brass wire is 3g and in the steel wire is

$$2g + 3g = 5g$$

$$\Delta L = \frac{TL}{\pi r^2 Y}$$

$$\therefore \frac{\Delta L_S}{\Delta L_B} = \frac{5\alpha}{3\beta^2\gamma}$$

IAPT answer: (B) | **Zigyan answer:** (B)

11. A uniform beam of light of intensity 60 mW/m^2 is incident on a totally absorbing sphere of radius 2.0 μm. The density of the material of the sphere is ρ = 5.0 × 10^3 kg/m^3. The sphere is placed in a region of space where gravitational force can be neglected / ignored. The magnitude of acceleration of the sphere due to the incidence of the light is

(A) 1.5 ms^{-2} (B) 3.0 ms^{-2} (C) 7.5 ms^{-2} (D) Zero

Solution · Q11 **As per Zigyan: no option is correct**

Force on a totally absorbing sphere:

$$F = \frac{I\pi r^2}{c}$$

$$m = \rho \times \frac{4}{3}\pi r^3$$

$$\Rightarrow a = \frac{F}{m} = \frac{3I}{4\rho rc}$$

$$\Rightarrow a = \frac{3 \times 0.060}{4 \times 5.0 \times 10^{3} \times 2.0 \times 10^{-6} \times 3 \times 10^{8}}$$

$$\therefore a = 1.5 \times 10^{-8}\ \text{m s}^{-2}$$

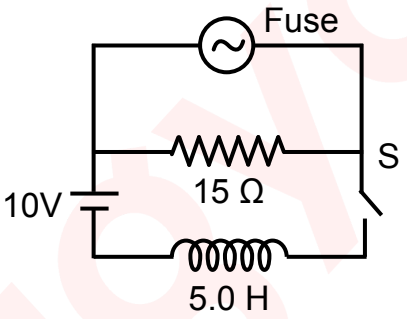
With the data as printed, no option gives this acceleration.

Reference: OpenStax University Physics Volume 2, section 16.4 'Momentum and Radiation Pressure': on a perfect absorber the time-averaged radiation pressure is the intensity divided by c.

Check: the sphere takes in about 7.54×10^{-13} W, which means a force of about 2.51×10^{-21} N. Its mass is about 1.68×10^{-13} kg, so the acceleration is again about 1.5×10^{-8} m s^{-2}.

IAPT answer: question dropped by IAPT | **Zigyan answer:** none of the options is correct

12. The fuse, in the upper branch of the circuit shown, is an ideal 4.0 A fuse. The fuse has zero resistance as long as current through it remains less than 4.0 A. The fuse blows out when the current reaches 4.0 A. Needless to say that the resistance becomes infinite thereafter. Switch S is closed at time t = 0. The fuse blows out at time



(A) t = 2 sec (B) t = 4 sec (C) t = 8 sec (D) It won't blow

Solution · Q12 **Answer: (A)**

The intact fuse has zero resistance and short-circuits the 15 Ω resistor.

By Kirchhoff's loop rule,

$$10 - 5.0\frac{di}{dt} = 0$$

$$i(0) = 0$$

$$\Rightarrow i = 2.0t$$

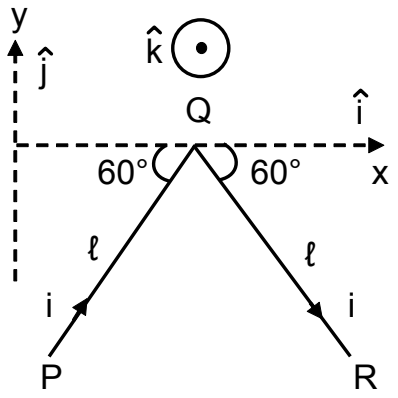
The fuse blows when

$$2.0t = 4.0$$

$$\therefore t = 2.0\ \text{s}$$

IAPT answer: (A) | **Zigyan answer:** (A)

13. The bent wire PQR shown in the figure lies in a uniform magnetic field $\vec{B} = 3.0\hat{i} + 4.0\hat{k}$ T. The direction $\hat{k}$ being normal to the plane of the paper and directed towards the viewer. The two straight sections PQ and QR of the wire each have length 2.0 m and the wire carries a current of 2.5 A. Net force on the wire due to magnetic field $\vec{B}$ is



(A) $40\hat{j}$ N

(B) $-20\hat{j}$ N

(C) $-40\hat{j}$ N

(D) $-20\sqrt{3}\ \hat{j}$ N

Solution · Q13 **Answer: (B)**

In a uniform field the bent wire PQR experiences the same force as a straight wire PR.

$$\vec{PQ} = \hat{i} + \sqrt{3}\ \hat{j}$$

$$\vec{QR} = \hat{i} - \sqrt{3}\ \hat{j}$$

$$\Rightarrow \vec{PR} = 2.0\hat{i}\ \text{m}$$

$$\vec{F} = I\vec{PR} \times \vec{B} = 2.5 \times 2.0\hat{i} \times \left(3.0\hat{i} + 4.0\hat{k}\right)$$

$$\therefore \vec{F} = -20\hat{j}\ \text{N}$$

IAPT answer: (B) | **Zigyan answer:** (B)

14. A charged spherical capacitor consists of two concentric spherical shells of radii a and b (b > a). Half of the stored electrical energy of this system lies within a spherical region of radius r if

(A) $r = \sqrt{ab}$

(B) $r = \dfrac{a+b}{2}$

(C) $r = \dfrac{2ab}{a+b}$

(D) $r = \dfrac{a^2+b^2}{a+b}$

Solution · Q14 **Answer: (C)**

Field between the shells:

$$E = \frac{Q}{4\pi\varepsilon_0 x^2}$$

Energy stored within radius r:

$$U(r) = \int_a^r \frac{1}{2}\varepsilon_0 E^2 4\pi x^2 dx = \frac{Q^2}{8\pi\varepsilon_0}\left(\frac{1}{a} - \frac{1}{r}\right)$$

For half of the total energy,

$$\frac{1}{a} - \frac{1}{r} = \frac{1}{2}\left(\frac{1}{a} - \frac{1}{b}\right)$$

$$\therefore r = \frac{2ab}{a+b}$$

IAPT answer: (C) | **Zigyan answer:** (C)

15. Two stars of masses $M_1 = M_S$ and $M_2 = 15M_S$ (where M_S = mass of the Sun) form a binary system. The stars are revolving round each other, always being at a separation of d = 4 AU between them (1 AU is distance of the Earth from the Sun), move in circular orbits about their center of mass. The period of revolution of each star is

(A) 1 year (B) 2 years (C) 4 years (D) 8 years

Solution · Q15 **Answer: (B)**

For a binary system,

$$T^2 = \frac{4\pi^2 d^3}{G(M_1 + M_2)}$$

In years, AU and solar masses, by comparison with the Earth,

$$T^2 = \frac{d^3}{M_1 + M_2} = \frac{4^3}{16} = 4$$

$$\therefore T = 2 \text{ yr}$$

IAPT answer: (B) | **Zigyan answer:** (B)

16. The total energy released in α decay of a stationary Radium nucleus ^{226}Ra (mass 116 u) is Q = 4.9 MeV (mass of α particle m_α = 4 u) then the

(A) energy of the recoiled daughter nucleus is nearly 8.7 keV

(B) energy of the recoiled daughter nucleus is nearly 4.81 MeV

(C) recoil speed of the daughter nucleus is 2.74×10^5 ms^{-1}

(D) speed of emitted α particle is nearly 1.5×10^6 ms^{-1}

Solution · Q16 **As per Zigyan: (C)**

The printed mass 116 u is a misprint for about 226 u; with 116 u no statement is true.

Daughter nucleus mass:

$$226 \text{ u} - 4 \text{ u} = 222 \text{ u}$$

$$K_d = Q\frac{4}{226} \approx 86.7 \text{ keV}$$

$$\Rightarrow K_\alpha = Q\frac{222}{226} \approx 4.81 \text{ MeV}$$

So (A) and (B) are false.

For the daughter nucleus,

$$v_d = \sqrt{\frac{2K_d}{m_d}} \approx 2.74 \times 10^5 \text{ m s}^{-1}$$

$\therefore$ (C) is true.

By conservation of momentum,

$$v_\alpha = \frac{222}{4} v_d \approx 1.52 \times 10^7 \text{ m s}^{-1}$$

So (D) is false.

Reference: NCERT Physics Class XII (Part II), Chapter 13 'Nuclei', section 13.6: in alpha decay a helium-4 nucleus is emitted. So the daughter of radium-226 has mass number 222.

Check: both fragments carry the same momentum, the square root of 2μQ, where the reduced mass μ is about 3.93 u. Dividing it by 222 u, with u taken as 1.66×10^{-27} kg, gives a daughter speed of about 2.74×10^{5} m s^{-1}.

IAPT answer: (C) | **Zigyan answer:** (C)

17. A listener at rest (with respect to the air and the ground) hears a sound of frequency f_1 from a source moving towards him with a velocity of 15 ms^{-1}, towards East. If the listener now moves towards the approaching source with a velocity of 25 ms^{-1}, towards West, he hears a frequency f_2 that differs from f_1 by 40 Hz. The frequency f of the sound produced by the source is (speed of sound in the air is 340 ms^{-1})

(A) 520 Hz (B) 450 Hz (C) 480 Hz (D) 550 Hz

Solution · Q17 **Answer: (A)**

Listener at rest:

$$f_1 = f\frac{340}{340-15} = f\frac{340}{325}$$

Listener moving towards the source:

$$f_2 = f\frac{340+25}{325} = f\frac{365}{325}$$

$$\Rightarrow f_2 - f_1 = f\frac{25}{325} = 40$$

$$\therefore f = 520 \text{ Hz}$$

IAPT answer: (A) | **Zigyan answer:** (A)

18. A uniform rod of length ℓ swings from a pivot as a physical pendulum. The position of the pivot can be varied along the length of the rod. The minimum time period with which the rod can oscillate with an appropriate position of the pivot is $T = 2\pi\sqrt{\frac{L}{g}}$ where L is equal to

(A) $\frac{\ell}{2}$ (B) $\frac{\ell}{\sqrt{2}}$

(C) $\frac{\ell}{\sqrt{3}}$ (D) $\frac{\ell}{2\sqrt{3}}$

Solution · Q18 **Answer: (C)**

For a physical pendulum, with pivot at distance d from the centre,

$$L = \frac{I}{md} = d + \frac{\ell^2}{12d}$$

For minimum L,

$$1 - \frac{\ell^2}{12d^2} = 0$$

$$\Rightarrow d = \frac{\ell}{2\sqrt{3}}$$

$$\therefore L = \frac{\ell}{\sqrt{3}}$$

Check: by the inequality of arithmetic and geometric means, d plus ℓ^2 divided by 12d is never less than twice the square root of ℓ^2 divided by 12. That least value is ℓ divided by the square root of 3.

IAPT answer: (C) | **Zigyan answer:** (C)

19. The number density of conduction electrons in pure silicon at room temperature is about 10^{16} m^{-3}. The number density of conduction electrons is increased by a factor of 10^6 by doping the silicon lattice with phosphorus. Assume that at room temperature every phosphorus atom contributes one electron to the conduction band. The fraction of silicon atoms replaced by phosphorus atoms is (Given that the density of silicon is 2.33 gm/cm^3 and that the molar mass of silicon M = 28.1 gm)

(A) 1.0×10^{-7} (B) 2.0×10^{-7} (C) 4.0×10^{-7} (D) 5.0×10^{-7}

Solution · Q19 **Answer: (B)**

Final conduction electron density:

$$10^{16} \times 10^6 = 10^{22} \text{ m}^{-3}$$

This is practically the number density of phosphorus atoms.

Silicon atoms per cubic metre:

$$N = \frac{2.33 \times 10^6}{28.1} \times 6.022 \times 10^{23} \approx 4.99 \times 10^{28}$$

Fraction of atoms replaced:

$$\frac{10^{22}}{4.99 \times 10^{28}} \approx 2.0 \times 10^{-7}$$

IAPT answer: (B) | **Zigyan answer:** (B)

20. A soap bubble 10 cm in radius, with a film thickness of $\frac{10}{3} \times 10^{-6}$ cm, is charged to a potential of 80 V. The bubble bursts and converts into a single spherical drop. Assuming that the soap solution is a good conductor, the potential at the surface of the drop is

(A) 2 kV (B) 4 kV (C) 6 kV (D) 8 kV

Solution · Q20 **Answer: (D)**

The volume of the liquid and the charge stay the same.

$$4\pi R^2 t = \frac{4}{3}\pi r^3$$

$$\Rightarrow r^3 = 3R^2 t$$

$$\Rightarrow r^3 = 3 \times 10^2 \times \frac{10}{3} \times 10^{-6} = 10^{-3} \text{ cm}^3$$

$$\Rightarrow r = 0.10 \text{ cm}$$

For the same charge,

$$V'r = VR$$

$$\Rightarrow V' = 80 \times \frac{10}{0.10} \text{ V}$$

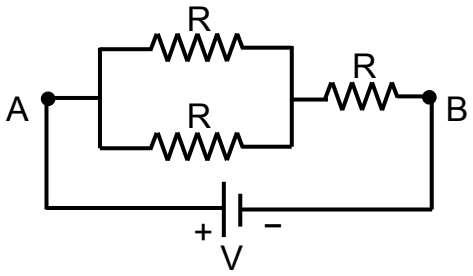
$$\therefore V' = 8 \text{ kV}$$

IAPT answer: (D) | **Zigyan answer:** (D)

21. Three resistances, each of R = 4 Ω rated 16 W, are connected across A and B as shown. Potential difference of V volt is applied between points A and B.

Statement 1: Maximum potential difference V that can be applied is 12 volt.

Statement 2: Maximum power that can be dissipated is 24 watt.



(A) Statements 1 and 2 both are wrong

(B) Statement 1 is correct but statement 2 is wrong

(C) Statement 1 is wrong but statement 2 is correct

(D) Statements 1 and 2 both are correct

Solution · Q21 **Answer: (D)**

Maximum current in one resistor:

$$I = \sqrt{\frac{16}{4}} = 2.0\ A$$

Two resistors in parallel are in series with the third.

$$R_{eq} = 2\ \Omega + 4\ \Omega = 6\ \Omega$$

The single resistor carries the whole current, so it limits the circuit.

$$V_{max} = 2.0\ A \times 6\ \Omega = 12\ V$$

$$P_{max} = 12\ V \times 2.0\ A = 24\ W$$

∴ Both statements are correct.

IAPT answer: (D) | **Zigyan answer:** (D)

22. Water is filled in a vertical cylinder up to a certain height h. The cylinder is made to rotate with an angular velocity ω about a vertical axis coinciding with the axis of the cylinder. The water surface seen from top appears as a/an

(A) ellipsoid (B) hemisphere (C) paraboloid (D) hyperboloid

Solution · Q22 **Answer: (C)**

In steady rotation, the free surface is normal to the resultant of gravity and the centrifugal force.

$$\frac{dy}{dr} = \frac{\omega^2 r}{g}$$

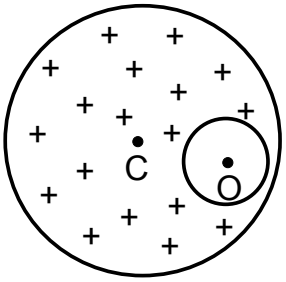
$$\Rightarrow y = y_0 + \frac{\omega^2 r^2}{2g}$$

∴ The surface is a paraboloid.

The name refers to the surface itself; its rim seen from the top is a circle.

IAPT answer: (C) | **Zigyan answer:** (C)

23. A uniformly charged non-conducting sphere with its center at C carries positive charge with uniform charge density + ρ, except in a spherical cavity (inside the sphere) with center O. The electric field **E** at any point inside the cavity is



(A) zero
(B) uniform
(C) directed radially outward
(D) directed radially inward

Solution · Q23 **Answer: (B)**

Superpose a full sphere of density +ρ and a sphere of density −ρ at the cavity. For a point P in the cavity,

$$\vec{E} = \frac{\rho}{3\varepsilon_0}\vec{CP} - \frac{\rho}{3\varepsilon_0}\vec{OP}$$

$$\Rightarrow \vec{E} = \frac{\rho}{3\varepsilon_0}\vec{CO}$$

This is the same at every point, so the field is uniform.

IAPT answer: (B) | **Zigyan answer:** (B)

24. A cylindrical tank with base area A = 0.05 m^2 is filled with water up to a height H = 50 cm. There is a small hole of area a = 0.001 m^2 (a << A) in the bottom of the tank. It takes time t to empty the tank up to a height $\frac{H}{2}$ (i.e to empty half of the water volume). The additional time required to empty the tank completely is

(A) t
(B) $t\sqrt{2}$
(C) $t\left(\sqrt{2}-1\right)$
(D) $t\left(\sqrt{2}+1\right)$

Solution · Q24 **Answer: (D)**

By continuity and Torricelli's law,

$$-A\frac{dx}{dt} = a\sqrt{2gx}$$

With the constant

$$K = \frac{A}{a}\sqrt{\frac{2}{g}}$$

the first half takes

$$t = K\sqrt{H}\left(1 - \frac{1}{\sqrt{2}}\right)$$

The remaining half takes

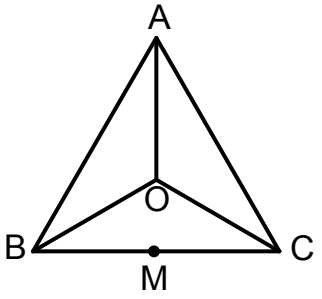
$$t_2 = K\sqrt{H}\,\frac{1}{\sqrt{2}}$$

$$\Rightarrow \frac{t_2}{t} = \frac{1}{\sqrt{2}-1} = \sqrt{2}+1$$

$$\therefore t_2 = t\left(\sqrt{2}+1\right)$$

IAPT answer: (D) | **Zigyan answer:** (D)

25. OABC is a regular tetrahedron, each side of which is made of uniform wire of resistance 4 Ω/m. The length of each side is 2 m. The point M is the midpoint of the side BC. The resistance between O and M is



(A) 5 Ω (B) 4 Ω (C) 10 Ω (D) 15 Ω

Solution · Q25 **Answer: (A)**

Resistance of each edge:

$$R_e = 4 \times 2\ \Omega = 8\ \Omega$$

By symmetry, B and C are at the same potential and can be joined into one node X. Between O and X there are two routes, direct and through A, with resistances

$$4\ \Omega \text{ and } 8\ \Omega + 4\ \Omega = 12\ \Omega$$

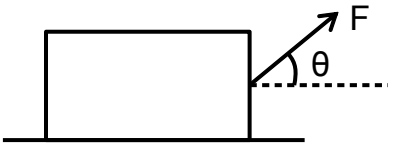
Between X and M the two half edges in parallel give 2 Ω.

$$R_{OM} = \frac{4\times 12}{4+12} + 2$$

$$\therefore R_{OM} = 5\ \Omega$$

IAPT answer: (A) | **Zigyan answer:** (A)

26. A box weighing W is placed on a rough horizontal floor. The coefficient of static friction between the box and the floor is μ. To move the box, a pulling force F is applied along the rope joined to the box at an angle θ with horizontal. By suitable choice of θ, the minimum value of F that can make the box move is



(A) μ W

(B) $\frac{W}{\sqrt{1+\mu^2}}$

(C) $\frac{\mu W}{\sqrt{1+\mu^2}}$

(D) $\frac{W\sqrt{1-\mu^2}}{\mu}$

Solution · Q26 **Answer: (C)**

Normal reaction:

$$N = W - F\sin\theta$$

At limiting equilibrium,

$$F\cos\theta = \mu(W - F\sin\theta)$$

$$\Rightarrow F = \frac{\mu W}{\cos\theta + \mu\sin\theta}$$

The maximum value of the denominator is

$$\sqrt{1+\mu^2}$$

$$\therefore F_{min} = \frac{\mu W}{\sqrt{1+\mu^2}}$$

IAPT answer: (C) | **Zigyan answer:** (C)

27. The external wall of a room measuring 2 m × 3 m consists of a layer of white pine of thickness d_{pine} = 2.0 cm and a layer of rock wool in succession. The external temperature is 36 K below the indoor temperature (Given the thermal conductivity coefficient of white pine K_P = 0.10 Wm^{-1} $kelvin^{-1}$ and that of rock wool K_W= 0.04 Wm^{-1} $kelvin^{-1}$). The thickness of the layer of the rock wool, so that the thermal conduction rate $P_{cond} = \frac{dQ}{dt}$ across the wall does not exceed 120 watt (assuming no loss of heat during conduction and no other way of heat transfer other than conduction), is

(A) 7.2 cm (B) 6.4 cm (C) 4.8 cm (D) 0.8 cm

Solution · Q27 **Answer: (B)**

The two layers are in series. For a heat current of at most 120 W, the least total thermal resistance is

$$R = \frac{36}{120} = 0.30\ K\,W^{-1}$$

White pine:

$$R_P = \frac{0.020}{0.10\times 6} = \frac{1}{30}\ K\,W^{-1}$$

Rock wool:

$$R_w = 0.30 - \frac{1}{30} = \frac{4}{15}\ K\,W^{-1}$$

$$\Rightarrow d_w = R_w K_w A = \frac{4}{15} \times 0.04 \times 6 = 0.064 \text{ m}$$

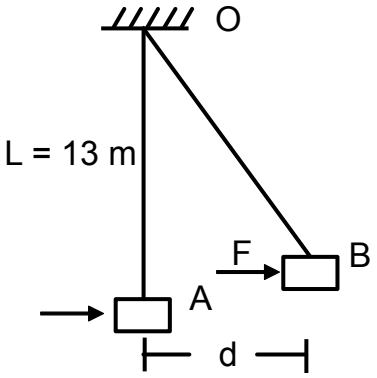
∴ The least thickness needed is 6.4 cm.

IAPT answer: (B) | **Zigyan answer:** (B)

28. A 240 kg block is suspended from a fixed point O, at the end of a long (L = 13 m) massless rope. A horizontal force F slowly pushes the block to move it a horizontal distance d = 5 m sideways, to a position B where it remains stationary as shown in the figure.

Statement 1 Force F at position B is 980 N.

Statement 2 Work done by the force to bring the box from A to B is 2352 J.



(A) Only statement 1 is correct
(B) Only statement 2 is correct
(C) Both statements 1 and 2 are wrong
(D) Both statements 1 and 2 are correct

Solution · Q28 **As per Zigyan: (D)**

At B, the height risen is

$$h = 13 - \sqrt{13^2 - 5^2} = 1 \text{ m}$$

$$\tan\theta = \frac{5}{12}$$

Take the value of g as

$$g = 9.8 \text{ m s}^{-2}$$

Statement 1:

$$F = mg\tan\theta = 240 \times 9.8 \times \frac{5}{12} = 980 \text{ N}$$

Statement 2, by the work-energy theorem:

$$W = mgh = 240 \times 9.8 \times 1 \text{ J} = 2352 \text{ J}$$

∴ Both statements are correct.

Check: adding F dx along the arc gives the work as mgL(1 − cos θ). Here L is 13 m and L cos θ is 12 m, so the work is mg × 1 m, which is 2352 J for g of 9.8 m s^{-2}.

IAPT answer: (C) or (D) | **Zigyan answer:** (D)

29. The number of radioactive nuclei N of a radioactive sample is experimentally measured as a function of time t. At t = 0, N(t = 0) = 50,000 and at t = 10s, N(t = 10s) = 5000 ± 100. The half-life of the sample is estimated from these measurements. The error in the estimation of the half-life is approximately [note that for small values of x, Lt x → 0, ℓn(1 + x) ≈ x]

(A) 0.26 s (B) 0.15 s (C) 0.05 s (D) 0.10 s

Solution · Q29 **As per Zigyan: no option is correct**

From the decay law,

$$T = \frac{t\ln 2}{\ln(N_0/N)}$$

$$\Rightarrow T = \frac{10 \times 0.6931}{2.3026} = 3.010\ \text{s}$$

Taking the time and the initial count as exact, for a small error in N,

$$\frac{\Delta T}{T} = \frac{\Delta N}{N\ln(N_0/N)}$$

$$\Rightarrow \Delta T = 3.010 \times \frac{0.02}{2.3026}\ \text{s}$$

$$\therefore \Delta T \approx 0.026\ \text{s}$$

No option states this error.

Check: using the end counts directly, 4900 nuclei give a half-life of 2.984 s and 5100 give 3.036 s. Each is about 0.026 s away from 3.010 s.

IAPT answer: question dropped by IAPT | **Zigyan answer:** none of the options is correct

30. An amount of heat equal to 10.61 J is given to an ideal gas at constant pressure of one atm (1.01×10^5 Pa). As a result the volume of the gas increases by 30.0 cm^3. The gas is

(A) mono atomic (B) diatomic

(C) tri-atomic (D) mixture of monoatomic and diatomic

Solution · Q30 **Answer: (B)**

Work done by the gas:

$$W = p\Delta V = 1.01 \times 10^5 \times 3.00 \times 10^{-5}\ \text{J} = 3.03\ \text{J}$$

At constant pressure,

$$\frac{C_p}{R} = \frac{Q}{W} = \frac{10.61}{3.03} = 3.50$$

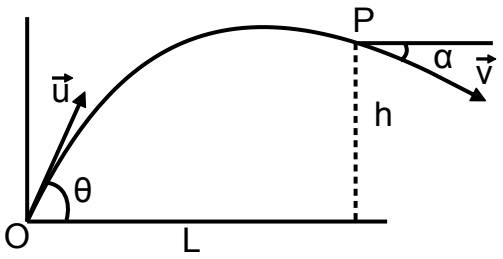
$$\Rightarrow C_V = 2.5R$$

$$\Rightarrow \gamma = 1.4$$

$\therefore$ The gas is diatomic.

IAPT answer: (B) | **Zigyan answer:** (B)

31. A ball is projected from point O on the ground with a certain velocity $\vec{u}$ at angle θ from horizontal. When it reaches point P located at a horizontal distance L from O and is at a height h above the ground, the angle α subtended by the velocity vector $\vec{v}$ with horizontal at this point P is expressed as



(A) $\tan\alpha = \frac{h}{L} - \tan\theta$

(B) $\tan\alpha = \frac{2h}{L} + \tan\theta$

(C) $\tan\alpha = \tan\theta - \frac{2h}{L}$

(D) $\tan\alpha = \frac{2h}{L} - \tan\theta$

Solution · Q31 **As per Zigyan: (C)**

The figure marks α below the horizontal at P, on the falling part of the path.

Equation of the path:

$$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$

Putting the coordinates of P,

$$\frac{gL}{2u^2\cos^2\theta} = \tan\theta - \frac{h}{L}$$

Slope at P:

$$\frac{dy}{dx} = \tan\theta - \frac{gL}{u^2\cos^2\theta} = \frac{2h}{L} - \tan\theta$$

The ball is moving downwards at P, so this slope is negative. The acute angle drawn therefore has

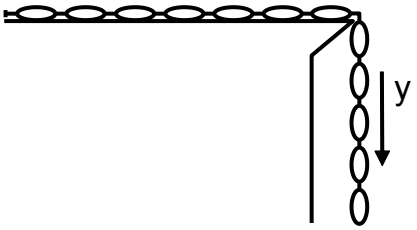
$$\tan\alpha = \tan\theta - \frac{2h}{L}$$

Why Zigyan differs from IAPT: option (D) is the signed slope, negative at P, so it cannot be the tangent of the acute angle drawn.

Check: with constant acceleration, the average vertical velocity (h divided by the time taken to reach P) is the mean of its two end values. So the ratio of v_y to v_x at P is 2h divided by L, minus tan θ. This is negative on the falling part, where α is drawn below the horizontal.

IAPT answer: (D) | **Zigyan answer:** (C)

32. A flexible chain, of length L and uniform mass per unit length λ, slides off the edge of a frictionless table (see figure). Initially a length $y = y_0$ of the chain hangs over the edge, with the chain held at rest. Now the chain is let free. The velocity of the chain when the chain becomes completely vertical (i.e. when the chain is just to leave the edge) is



(A) $v = \sqrt{g\left(L - \frac{y_0^2}{L}\right)}$

(B) $v = \sqrt{2g\left(L - \frac{y_0^2}{L}\right)}$

(C) $v = \sqrt{g\left(L - y_0\right)}$

(D) $v = \sqrt{2g\left(L - y_0\right)}$

Solution · Q32 **Answer: (A)**

Take a smooth edge with no jerk, and potential energy zero at the table top. By conservation of energy,

$$\frac{1}{2}\lambda L v^2 = \frac{\lambda g}{2}\left(L^2 - y_0^2\right)$$

$$\therefore v = \sqrt{g\left(L - \frac{y_0^2}{L}\right)}$$

IAPT answer: (A) | **Zigyan answer:** (A)

33. A Keplerian telescope is adjusted in its normal setting for parallel rays. Mounting of the objective has diameter D and the diameter of the image of that mounting formed by the eye piece of the telescope is d. Magnifying power of the telescope is

(A) $\frac{D}{d} - 1$

(B) $\frac{D}{d} + 1$

(C) $\frac{D + d}{D - d}$

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

Solution · Q33 **Answer: (D)**

In normal adjustment the objective rim is the object for the eyepiece, at

$$u = -(f_o + f_e)$$

Linear magnification of its image:

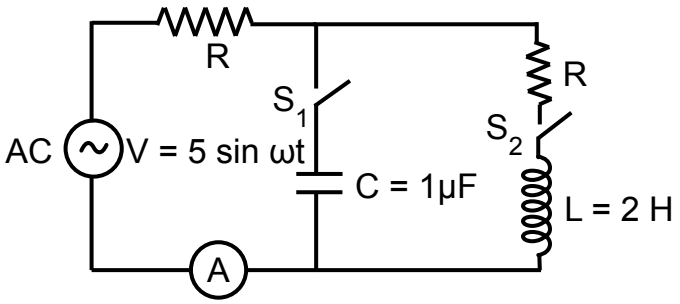
$$\frac{d}{D} = \frac{f_e}{f_o}$$

$$\Rightarrow M = \frac{f_o}{f_e}$$

$$\therefore M = \frac{D}{d}$$

IAPT answer: (D) | **Zigyan answer:** (D)

34. In the circuit shown below, the resistance $R = \sqrt{3} \times 10^3\ \Omega$, the inductance L = 2 H and the capacitance C = 1 μF have been connected to an AC supply of the peak voltage of V_{max} = 5 volt at a frequency ω. Either the switch S_1 or the switch S_2 is closed at a time. In either case, same maximum current (i_{max}) is recorded in the circuit. The frequency of the AC source is nearly



(A) 1.5 kHz (B) 500 Hz (C) 326 Hz (D) 126 Hz

Solution · Q34 **As per Zigyan: (C)**

Equal peak currents mean equal impedances.

$$R^2 + \frac{1}{\omega^2 C^2} = 4R^2 + \omega^2 L^2$$

$$\Rightarrow \frac{1}{\omega^2 C^2} - \omega^2 L^2 = 3R^2$$

Putting x for the square of ω,

$$4x^2 + 9 \times 10^6 x - 10^{12} = 0$$

$$\Rightarrow x = \frac{-9 + \sqrt{97}}{8} \times 10^6$$

$$\Rightarrow \omega \approx 325.7 \text{ rad s}^{-1}$$

The question calls ω the frequency, and the number in (C) is this ω.

The unit hertz in the options is a misprint for rad s^{-1}.

∴ (C) is correct.

Reference: NCERT Physics Class XII (Part I), Chapter 7 'Alternating Current', Example 7.2: for a 50 Hz source the inductive reactance is taken as 2πνL.

Check: at 325.7 rad s^{-1} the impedance is about 3525 Ω with either switch closed, so the two peak currents are equal.

IAPT answer: question dropped by IAPT | **Zigyan answer:** (C)

35. There are two given physical quantities $A = \frac{F}{\rho v^2 D}$ and $B = \frac{\rho v D}{\eta}$ where F is force, ρ is density, D is diameter, v is velocity and η is the Coefficient of viscosity. Which of the two A and B is/are dimensionless?

(A) A (B) B (C) neither A nor B (D) both A and B

Solution · Q35 **Answer: (B)**

Dimensions of force and of viscosity:

$$[F] = MLT^{-2},\ [\eta] = ML^{-1}T^{-1}$$

For A, the dimensions are

$$[A] = \frac{MLT^{-2}}{\left(ML^{-3}\right)\left(L^2T^{-2}\right)(L)} = L$$

For B,

$$[B] = \frac{\left(ML^{-3}\right)\left(LT^{-1}\right)(L)}{ML^{-1}T^{-1}} = M^0L^0T^0$$

∴ Only B is dimensionless.

IAPT answer: (B) | **Zigyan answer:** (B)

36. A uniform inextensible string of length L and mass M is suspended vertically from a rigid support. A transverse pulse is allowed to propagate down through the string from the support. At the same time, a ball of mass m is dropped from the rigid support. The ball will pass the pulse at a distance of (from the top of the string i.e. from the support)

(A) $\frac{15L}{16}$ (B) $\frac{8L}{9}$

(C) $\frac{L}{2}$ (D) $\frac{3L}{4}$

Solution · Q36 **Answer: (B)**

Speed of the pulse at distance x below the support:

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{g(L-x)}$$

So the pulse starts with speed u and has a constant acceleration a, where

$$u = \sqrt{gL}$$

$$a = -\frac{g}{2}$$

The ball and the pulse are level when

$$\sqrt{gL}\ t - \frac{1}{4}gt^2 = \frac{1}{2}gt^2$$

$$\Rightarrow t = \frac{4}{3}\sqrt{\frac{L}{g}}$$

$$\therefore x = \frac{1}{2}gt^2 = \frac{8L}{9}$$

IAPT answer: (B) | **Zigyan answer:** (B)

37. In a positron decay, the radionuclide ^{11}C decays according to $^{11}C \rightarrow {}^{11}B + e^+ + \upsilon$ [the respective atomic masses are ^{11}C = 11.01142 u , ^{11}B = 11.00931 u and the mass of positron = the mass of electron = m_e = 0.00055 u] . The disintegration energy (i.e. the Q value) is approximately

(A) 1.45 MeV (B) 0.94 MeV (C) 0.43 MeV (D) – 1.45 MeV

Solution · Q37 **Answer: (B)**

Using atomic masses, for positron decay,

$$Q = [M(C) - M(B) - 2m_e]c^2$$

$$\Delta m = 11.01142\ u - 11.00931\ u - 2 \times 0.00055\ u = 0.00101\ u$$

$$\Rightarrow Q = 0.00101 \times 931.5\ MeV$$

$$\therefore Q \approx 0.94 \text{ MeV}$$

IAPT answer: (B) | **Zigyan answer:** (B)

38. Two mechanical waves, given by $y_1 = A \sin(8x - 50t)$ and $y_2 = A\sin\left(8x + 50t + \frac{\pi}{3}\right)$ travelling in opposite directions along x - axis, superpose. The position of the node (for x > 0) nearest to the origin is (the displacements y_1 and y_2 are in meter)

(A) 32.7 cm (B) 16.35 cm (C) 6.54 cm (D) 5.45 cm

Solution · Q38 **Answer: (A)**

Adding the two waves,

$$y = 2A\sin\left(8x + \frac{\pi}{6}\right)\cos\left(50t + \frac{\pi}{6}\right)$$

At a node,

$$8x + \frac{\pi}{6} = n\pi$$

For the smallest positive position,

$$n = 1$$

$$\Rightarrow x = \frac{5\pi}{48} \text{ m}$$

$$\therefore x \approx 32.7 \text{ cm}$$

IAPT answer: (A) | **Zigyan answer:** (A)

39. At a certain location on the Earth surface, the intensity of sunlight is 1.00 kW/m^2. A perfectly reflecting concave mirror, of radius of curvature R and aperture radius r, is facing the Sun to produce the light intensity of 100 kW/m^2 at the image. Knowing that the disc of the Sun subtends an angle of 0.01 radian at the Earth surface, the relation between R and r is

(A) R = 10r (B) R = 20r (C) R = 40r (D) r = 20R

Solution · Q39 **Answer: (C)**

The Sun's image lies in the focal plane.

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

Diameter of the image:

$$f \times 0.01 = \frac{R}{2} \times 0.01 = 0.005R$$

Radius of the image:

$$a = \frac{R}{400}$$

All the collected light falls on this image.

$$\frac{I}{I_s} = \frac{\pi r^2}{\pi a^2} = 100$$

$$\Rightarrow r = 10a$$

$$\Rightarrow r = 10 \times \frac{R}{400} = \frac{R}{40}$$

$$\therefore R = 40r$$

Check: an ideal mirror cannot change the brightness of the source. So the intensity at the image rises by the square of the ratio of the cone's half-angle, r divided by f, to the Sun's half-angle, 0.005 rad. A rise of 100 times needs r divided by f to be 0.05, so R is 40r.

IAPT answer: (C) | **Zigyan answer:** (C)

40. A charge Q is uniformly distributed throughout the volume of a non-conducting sphere of radius R. The total electrostatic energy of electric field inside the sphere is $U = \alpha \times \frac{Q^2}{4\pi\epsilon_0 R}$. The value of α is

(A) Zero
(B) $\frac{3}{5}$
(C) $\frac{1}{2}$
(D) $\frac{1}{10}$

Solution · Q40 **Answer: (D)**

Take the permittivity of the material as that of free space. Field inside the sphere:

$$E = \frac{Qr}{4\pi\varepsilon_0 R^3}$$

Energy stored inside:

$$U = \int_0^R \frac{1}{2}\varepsilon_0 E^2 4\pi r^2 dr$$

$$\Rightarrow U = \frac{Q^2}{8\pi\varepsilon_0 R^6}\int_0^R r^4 dr$$

$$\Rightarrow U = \frac{1}{10}\times\frac{Q^2}{4\pi\varepsilon_0 R}$$

$$\therefore \alpha = \frac{1}{10}$$

IAPT answer: (D) | **Zigyan answer:** (D)

41. A long straight vertical wire of circular cross section of radius R contains n conduction electrons per unit volume. A current I flows upward in the wire. The expression for magnetic force on an electron at the surface of the wire is [Assume all the conduction electrons are moving with drift velocity]

(A) $\frac{\mu_0}{4\pi^2}\frac{I^2}{nR^3}$ outward
(B) $\frac{\mu_0}{2\pi}\frac{I^2}{nR^3}$ inward
(C) $\frac{\mu_0}{2\pi^2}\frac{I^2}{nR^3}$ inward
(D) $\frac{\mu_0}{2\pi^2}\frac{I^2}{nR^3}$ outward

Solution · Q41 **Answer: (C)**

Drift speed:

$$v_d = \frac{I}{\pi n e R^2}$$

Magnetic field at the surface:

$$B = \frac{\mu_0 I}{2\pi R}$$

Force on an electron:

$$F = ev_d B = \frac{\mu_0 I^2}{2\pi^2 nR^3}$$

Like parallel currents attract, so this force is directed inward.

IAPT answer: (C) | **Zigyan answer:** (C)

42. In Young's double slit experiment, a bright fringe is observed at y = 1.5 cm from the center of the fringe pattern when monochromatic light of wavelength 612 nm is used. The screen is at 1.4 m from the plane of the two slits, whose separation is 0.4 mm. The number of dark fringes between the center and the said bright fringe at y = 1.5 cm is

(A) 13 (B) 8 (C) 7 (D) 6

Solution · Q42 **Answer: (C)**

Fringe width:

$$w = \frac{\lambda D}{d} = \frac{612 \times 10^{-9} \times 1.4}{0.4 \times 10^{-3}} \approx 2.142 \text{ mm}$$

Order of the given bright fringe:

$$m = \frac{y}{w} = \frac{15}{2.142} \approx 7$$

One dark fringe lies in each gap from the centre up to this fringe.

$\therefore$ There are 7 dark fringes.

IAPT answer: (C) | **Zigyan answer:** (C)

43. An illuminated point object is placed in front of an equi-convex lens of refractive index μ = 1.5 and focal length f = 40 cm, at a distance of u = 1.20 m in front of the lens on its principal axis. Water (μ = 4/3) fills the space behind the lens up to a distance of 40 cm from the lens. The final image is formed on the principal axis beyond the lens at a distance v from the lens. The value of v and the nature of image are

(A) 60 cm, virtual (B) 80 cm, virtual (C) 110 cm, real (D) 130 cm, real

Solution · Q43 **Answer: (D)**

Radius of each face, from the focal length in air:

$$\frac{1}{40} = (1.5 - 1)\frac{2}{R}$$

$$\Rightarrow R = 40 \text{ cm}$$

At each surface (lengths in cm):

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

Air to glass:

$$\frac{1.5}{v_1} - \frac{1}{-120} = \frac{0.5}{40}$$

$$\Rightarrow v_1 = 360$$

Glass to water:

$$\frac{4/3}{v_2} - \frac{1.5}{360} = \frac{4/3 - 1.5}{-40}$$

$$\Rightarrow v_2 = 160$$

The flat surface is at 40 cm. For it, the virtual object distance is

$$160 - 40 = 120$$

$$\frac{1}{v_3} = \frac{4/3}{120}$$

$$\Rightarrow v_3 = 90$$

$$\Rightarrow v = 40 \text{ cm} + 90 \text{ cm} = 130 \text{ cm}$$

The rays meet in air, so the image is real.

IAPT answer: (D) | **Zigyan answer:** (D)

44. A paramagnetic gas at room temperature 27 °C is placed in an external uniform magnetic field of magnitude B = 1.5 tesla . The atoms of the gas have magnetic dipole moment $\mu = 1.0\ \mu_B$ where $1\mu_B = \frac{eh}{4\pi m}$ is Bohr magneton, and m is the mass of electron. The energy difference ΔU_B between the parallel alignment and the antiparallel alignment of the atom's magnetic dipole moment, with respect to the external field B, is $x \times 10^{-4}$ eV where the value of x is

(A) 17.4 (B) 1.74 (C) 34.8 (D) 8.7

Solution · Q44 **Answer: (B)**

$$U = -\mu B \cos\theta$$

$$\Rightarrow \Delta U_B = 2\mu B$$

For the Bohr magneton,

$$\frac{\mu_B}{e} = \frac{h}{4\pi m} \approx 5.79 \times 10^{-5}\ \text{V T}^{-1}$$

$$\Rightarrow \Delta U_B = 2 \times 5.79 \times 10^{-5} \times 1.5 \text{ eV} \approx 1.74 \times 10^{-4} \text{ eV}$$

$$\therefore x = 1.74$$

IAPT answer: (B) | **Zigyan answer:** (B)

45. A glass capillary with inner diameter of 0.40 mm is vertically submerged in water so that the length of its part protruding above the water surface is h = 25 mm. Surface Tension of water is $T = 0.073\ \text{Nm}^{-1}$. Since the water wets the glass completely, it may be concluded that the

(A) length of capillary above the water surface is insufficient so the water will flow out as a fountain

(B) water will rise up to the brim forming a meniscus of radius 1.2 mm at the top

(C) water will rise up to the brim forming a meniscus of radius 0.6 mm at the top

(D) water will rise up to the brim forming a meniscus of radius equal to radius of the capillary

Solution · Q45 **Answer: (C)**

The density of water and g are not given, so we take

$$\rho_w = 1000\ \text{kg m}^{-3},\ g = 9.8\ \text{m s}^{-2}$$

Natural capillary rise:

$$H = \frac{2T}{\rho_w g r} \approx 74.5\ \text{mm}$$

The tube above water is shorter than this. So water rises to the top and the meniscus flattens to a radius b.

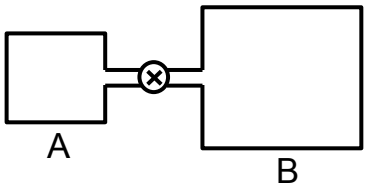
$$\frac{2T}{b} = \rho_w g h$$

$$\Rightarrow b = \frac{2 \times 0.073}{1000 \times 9.8 \times 0.025}\ \text{m}$$

$$\therefore b \approx 0.60\ \text{mm}$$

IAPT answer: (C) | **Zigyan answer:** (C)

46. The container A in the figure holds an ideal gas at a pressure of 5.0×10^5 Pa at 27 °C. It is connected to the container B by a thin tube fitted with a closed valve. Container B with volume four times the volume of A holds the same ideal gas at a pressure 1.0×10^5 Pa at 127 °C. The valve is now opened to allow the pressure to equalize, but the temperature of each container is maintained as before. The common pressure in the two containers (in kPa) is



(A) 200 (B) 300 (C) 320 (D) 180

Solution · Q46 **Answer: (A)**

Neglecting the gas in the thin tube, the total moles remain constant (pressures in kPa).

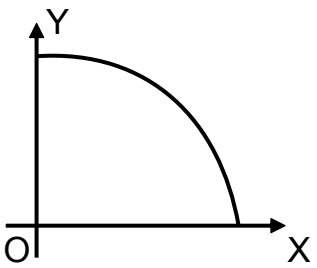
$$\frac{500V}{300R} + \frac{100 \times 4V}{400R} = \frac{pV}{R}\left(\frac{1}{300} + \frac{4}{400}\right)$$

$$\Rightarrow \frac{p}{75} = \frac{8}{3}$$

$$\therefore p = 200 \text{ kPa}$$

IAPT answer: (A) | **Zigyan answer:** (A)

47. A thin plastic disc, which is a quarter of a circle of radius R = 0.6 m, lies in the first quadrant of x-y plane, with the center of curvature at the origin O as shown. It is charged uniformly on one side (one face) with surface charge density σ. Electric potential at point P (0, 0, 0.8 m) is



(A) $\frac{\sigma}{8\epsilon_0}$ (B) $\frac{\sigma}{8\pi\epsilon_0}$

(C) $\frac{\sigma}{20\epsilon_0}$ (D) $\frac{\sigma}{40\epsilon_0}$

Solution · Q47 **Answer: (D)**

Take a quarter ring of radius s and width ds.

$$dq = \frac{\pi\sigma s ds}{2}$$

$$\Rightarrow dV = \frac{dq}{4\pi\epsilon_0\sqrt{s^2 + z^2}}$$

$$\Rightarrow V = \frac{\sigma}{8\epsilon_0}\int_0^R \frac{sds}{\sqrt{s^2 + z^2}}$$

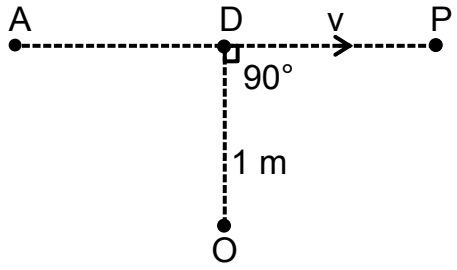
$$\Rightarrow V = \frac{\sigma}{8\varepsilon_0}\left[\sqrt{R^2 + z^2} - z\right]$$

$$R = 0.6\text{ m}, z = 0.8\text{ m}$$

$$\therefore V = \frac{\sigma}{40\varepsilon_0}$$

IAPT answer: (D) | **Zigyan answer:** (D)

48. The charge on a small point object at A produces an electric potential V = 3 volt at a point P. Because of an unavoidable situation, leakage of the charge from the object at A starts at t = 0 at a constant rate of 3 μCs^{-1}. To maintain the potential of 3 volt at the point P, the object is made to move towards P with a certain velocity v. When the point object crosses the point D shown in the figure, it is found to have a charge of 10 μC and the direction of its velocity is perpendicular to OD. The resulting magnetic field **B,** at this instant, at the location O (such that OD = 1.0 m) is



(A) 8.1 nT

(B) $\frac{1}{9}\ \mu T$

(C) 9.9 μT

(D) 9.0 nT

Solution · Q48 **Answer: (D)**

Only the charge moving with the object is considered. For a constant potential at P, at distance x:

$$\frac{kq}{x} = 3$$

$$k = 9 \times 10^9\ \text{N m}^2\ \text{C}^{-2}$$

$$\Rightarrow x = 3 \times 10^9\ q$$

$$\Rightarrow \frac{dx}{dt} = 3 \times 10^9 \times \left(-3 \times 10^{-6}\right) = -9 \times 10^3\ \text{m s}^{-1}$$

So the speed is constant. At D, for a moving point charge,

$$B = \frac{\mu_0}{4\pi}\frac{qv\sin 90^\circ}{r^2}$$

$$\Rightarrow B = \frac{10^{-7} \times 10 \times 10^{-6} \times 9 \times 10^3}{1.0^2}\ \text{T}$$

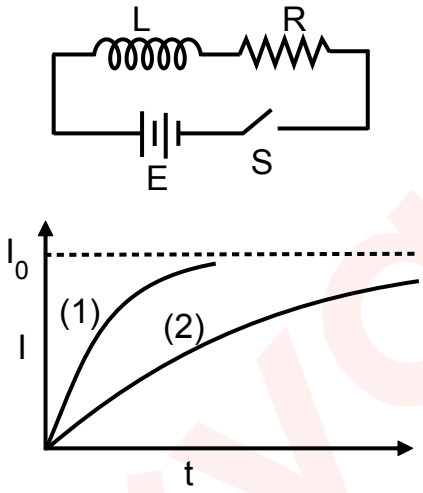
$$\therefore B = 9.0\text{ nT}$$

IAPT answer: (D) | **Zigyan answer:** (D)

PART A-2 · ONE OR MORE CORRECT OPTIONS

Q. 49 – 60 · 6 marks only if all correct options are marked · no negative marking

49. An electric circuit consists of a battery of emf E, an inductance L and a resistance R in series. The switch S is closed at t = 0. The current in the circuit grows exponentially with time as depicted by curve (1). The values of the circuit parameters (E, L or R) are now somehow changed. The circuit is closed second time, the growth of current I follows curve (2). The following conclusion(s) may be drawn



(A) E and R are unchanged but L has increased

(B) $\frac{E}{R}$ is unchanged but $\frac{L}{R}$ has increased

(C) $\frac{E}{R}$ is unchanged but $\frac{L}{R}$ has decreased

(D) Stored magnetic energy has increased

Solution · Q49 — **As per Zigyan: (A), (B), (D)**

For an LR circuit,

$$I = I_0(1 - e^{-t/\tau})$$

$$I_0 = \frac{E}{R}$$

$$\tau = \frac{L}{R}$$

Both curves approach the same final current, so E/R is unchanged.

Curve (2) rises more slowly, so its time constant is larger.

∴ (B) is true and (C) is false.

Only one of E, L and R is changed between the two curves. It must be L, which has increased. So (A) is true.

(D) Stored energy:

$$U = \frac{1}{2}LI_0^2$$

This increases with L, so (D) is true.

Check: changing E alone or R alone would alter the final current, so a single change must be in L.

IAPT answer: (A), (B), (D) | **Zigyan answer:** (A), (B), (D)

50. The Earth is revolving around the Sun (mass M) in a circular orbit of radius r with a period of revolution T = 1 year. Suppose that during the revolution of the Earth, at any instant, the mass of the Sun instantaneously becomes double i.e. 2M. The correct alternative(s) is/are [Assume that the Sun and the Earth are point masses]

(A) The period of revolution of the Earth around the Sun now becomes $\frac{1}{\sqrt{2}}$ year

(B) There is no change in angular momentum of the Earth around the Sun

(C) Minimum distance of the Earth from Sun during revolution is now $\frac{r}{3}$

(D) Maximum speed of the Earth during revolution around the Sun is $3\sqrt{\frac{GM}{r}}$

Solution · Q50 **Answer: (B), (C), (D)**

In the circular orbit,

$$v^2 = \frac{GM}{r}$$

(B) The force remains central, so angular momentum is unchanged. (B) is true.

Just after the change, r is the maximum distance. Total energy:

$$\frac{1}{2}mv^2 - \frac{2GMm}{r} = -\frac{3GMm}{2r} = -\frac{G(2M)m}{2a}$$

$$\Rightarrow a = \frac{2r}{3}$$

(C) $r_{min} = 2a - r$

$$\Rightarrow r_{min} = \frac{r}{3}$$

So (C) is true.

(D) $mvr = mv_{max}\frac{r}{3}$

$$\Rightarrow v_{max} = 3\sqrt{\frac{GM}{r}}$$

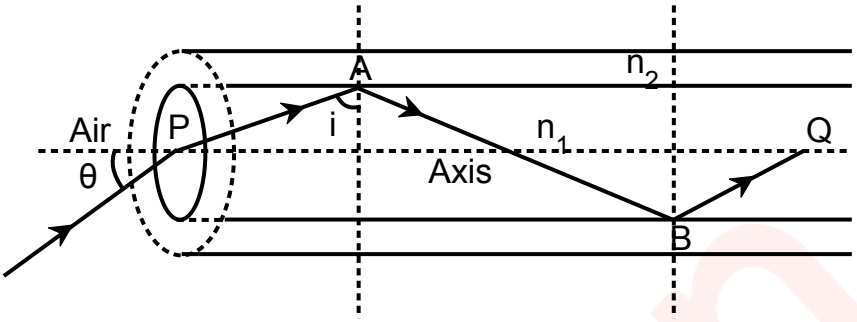
So (D) is true.

(A) $\frac{T'}{T} = \sqrt{\frac{1}{2}\left(\frac{2}{3}\right)^3} = \frac{2}{3\sqrt{3}}$

So (A) is false.

IAPT answer: (B), (C), (D) | **Zigyan answer:** (B), (C), (D)

51. An optical fibre consists of a glass core (refractive index n_1) surrounded by a cladding (refractive index $n_2 < n_1$). A beam of light enters one end of the fibre at P, from air at angle θ, with the axis of fibre as shown in the figure. Choose the correct option(s)



(A) Maximum value of θ for which a ray can travel down the fibre is $\theta = \sin^{-1}\sqrt{n_1^2 - n_2^2}$

(B) Maximum value of θ for which a ray can travel down the fibre is $\theta = \cos^{-1}\sqrt{n_1^2 - n_2^2}$

(C) If θ = 30° (in air) and $n_1 = 1.50$, then for reflection just at the critical angle, the value of n_2 is $\sqrt{2}$

(D) A ray entering at θ = 0 travels a distance L from P to Q, inside the fibre directly along the fibre axis. Another ray travelling through fibre is repeatedly reflected at the critical angle, at interface of glass core and surrounding layer/cladding. Both the rays travel from point P to point Q on the axis. If the two rays started from point P at the same time, the difference Δt in the time taken to reach the point Q by the two rays is $\Delta t = \frac{n_1}{n_2} \times \frac{L}{c}(n_1 - n_2)$ (here c is the speed of light in vacuum)

Solution · Q51 **Answer: (A), (C), (D)**

At the entry face,

$$\sin\theta = n_1 \sin r$$

For total internal reflection inside,

$$\cos r \geq \frac{n_2}{n_1}$$

$$\Rightarrow \sin\theta \leq \sqrt{n_1^2 - n_2^2}$$

So (A) is true (the root being at most 1) and (B) is false.

$$\text{(C) } 0.5 = \sqrt{1.50^2 - n_2^2}$$

$$\Rightarrow n_2 = \sqrt{2}$$

So (C) is true.

(D) At the critical angle, the zigzag path length is

$$\frac{L}{\sin C} = \frac{n_1 L}{n_2}$$

$$\Rightarrow \Delta t = \frac{n_1^2 L}{n_2 c} - \frac{n_1 L}{c} = \frac{n_1}{n_2} \times \frac{L}{c}(n_1 - n_2)$$

∴ (D) is true.

IAPT answer: (A), (C), (D) | **Zigyan answer:** (A), (C), (D)

52. A series LCR circuit fed with AC has resonant angular frequency of $\omega = 2.0 \times 10^4$ rad/s. When the same circuit is driven at an angular frequency of 2.5×10^4 rad/s, it has an impedance of 1.0 kΩ and phase constant of $\phi = 45°$. The values of L, C and R for this circuit may be

(A) R = 707 Ω (B) L = 78.6 mH (C) C = 31.8 nf (D) R = 506 Ω

Solution · Q52 **Answer: (A), (B), (C)**

At resonance,

$$LC = \frac{1}{\omega_0^2} = 2.5 \times 10^{-9}\ s^2$$

(A) $R = Z\cos 45° \approx 707\ \Omega$

So (A) is true and (D) is false.

Net reactance:

$$\omega L - \frac{1}{\omega C} = Z\sin 45° \approx 707\ \Omega$$

$$\Rightarrow \omega L\left(1 - \frac{\omega_0^2}{\omega^2}\right) = 707$$

$$\Rightarrow L = \frac{707}{0.36 \times 2.5 \times 10^4}\ H$$

$$\Rightarrow L \approx 78.6\ mH$$

So (B) is true.

$$C = \frac{1}{\omega_0^2 L} \approx 31.8\ nF$$

∴ (C) is true; the printed unit nf means nanofarad.

IAPT answer: (A), (B), (C) | **Zigyan answer:** (A), (B), (C)

53. A long straight wire, having a radius greater than 4.0 mm, carries a current that is uniformly distributed over its cross - section. The magnitude of magnetic field B due to the current is 0.28 mT at r = 4.0 mm and 0.20 mT at r = 10.0 mm, respectively, from the axis of the wire then the

(A) magnitude of the magnetic field B at a distance r = 2.0 mm from axis is 0.14 mT

(B) magnitude of the magnetic field B at r = 5.0 mm is greater than that at r = 6.0 mm

(C) current flowing in the wire is I = 20 A

(D) current density in the wire is $J \approx 1.1 \times 10^5$ A/m^2

Solution · Q53 **Answer: (A), (B), (D)**

The point at 4.0 mm is inside the wire. If the point at 10.0 mm were also inside, its field would be larger, so it is outside.

(D) $$J = \frac{2B}{\mu_0 r} \approx 1.11 \times 10^5\ A\ m^{-2}$$

So (D) is true.

(C) $$I = \frac{2\pi r B}{\mu_0} = 10\ A$$

So (C) is false.

(A) Inside the wire the field is proportional to r, so

$$B_2 = \frac{0.28}{2} = 0.14\ \text{mT}$$

So (A) is true.

(B) Radius of the wire:

$$a = \sqrt{\frac{I}{\pi J}} \approx 5.35\ \text{mm}$$

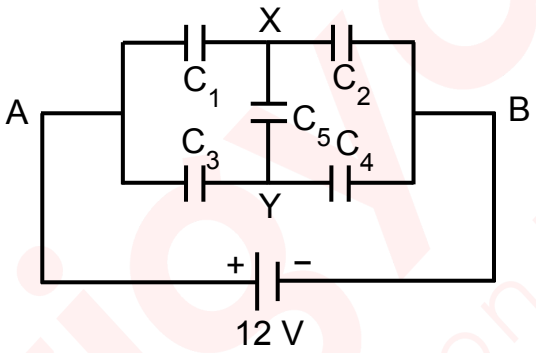
$$B_5 = 0.28 \times \frac{5.0}{4.0} = 0.35\ \text{mT}$$

$$B_6 = 0.20 \times \frac{10.0}{6.0} = 0.333\ \text{mT}$$

∴ (B) is true.

IAPT answer: (A), (B), (D) | **Zigyan answer:** (A), (B), (D)

54. In the given combination of capacitors $C_1 = 4\mu F$, $C_2 = 2\mu F$, $C_3 = 2\mu F$, $C_4 = 4\mu F$ and $C_5 = 3\mu F$, a source of 12 volt is connected across the points A and B. Then the



(A) equivalent capacity between A and B is $\frac{8}{3}\ \mu F$

(B) stored electrical energy of the system is 204 μJ

(C) potential difference between X and Y is $V_{XY} = 2$ volt

(D) potential difference across the capacitor C_2 is 8 volt

Solution · Q54 **Answer: (B), (C)**

Take B at 0 V and A at 12 V, with potentials x and y at X and Y.

At X:

$$4(x - 12) + 2x + 3(x - y) = 0$$

At Y:

$$2(y - 12) + 4y + 3(y - x) = 0$$

$$\Rightarrow x = 7\ \text{V and } y = 5\ \text{V}$$

(C) Potential difference between X and Y:

$$V_{XY} = 2\ \text{V}$$

So (C) is true.

(D) The voltage across C_2 is 7 V, so (D) is false.

(A) Charge supplied:

$$Q = (4 \times 5 + 2 \times 7)\ \mu C = 34\ \mu C$$

$$\Rightarrow C_{eq} = \frac{34}{12} = \frac{17}{6}\,\mu F$$

So (A) is false.

$$\text{(B) } U = \frac{1}{2} \times \frac{17}{6} \times 12^2\,\mu J = 204\,\mu J$$

$\therefore$ (B) is true.

IAPT answer: (B), (C) | **Zigyan answer:** (B), (C)

55. One mole of an ideal monoatomic gas, initially at temperature T, is compressed to $\frac{1}{8}$ of its volume by a piston in a cylinder such that the heat dissipated into the environment is equal to the change in the internal energy of the gas. Then the

(A) molar heat capacity of the gas is $C = \frac{3R}{2}$

(B) final temperature of the gas is 2 T

(C) work done on the gas is 3 RT

(D) equation of state of the process is $PV^{4/3}$ = constant

Solution · Q55 **Answer: (B), (C), (D)**

Here, at every stage,

$$dQ = -dU$$

$$\text{(A) } C = \frac{dQ}{dT} = -\frac{3R}{2}$$

So (A) is false.

Using the first law and the gas equation,

$$3\frac{dT}{T} = -\frac{dV}{V}$$

Hence both of these stay constant:

$TV^{1/3}$ and $PV^{4/3}$

So (D) is true.

$$\text{(B) } T_f = T \times 8^{1/3} = 2T$$

So (B) is true.

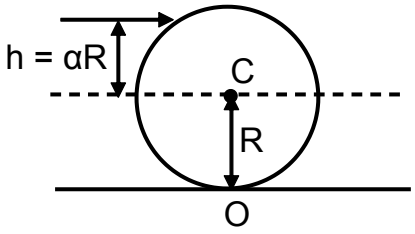
(C) Work done on the gas equals the rise in internal energy plus the heat given out.

$$W = 1.5RT + 1.5RT = 3RT$$

$\therefore$ (C) is true.

IAPT answer: (B), (C), (D) | **Zigyan answer:** (B), (C), (D)

56. A solid ball of mass M and radius R (see figure) is lying on a horizontal table. The ball experiences a short horizontal impulse which imparts a momentum p to the ball. The height of point of impact above the center line is h = α R (0 ≤ α ≤ 1). Choose the correct option/option(s).



(A) Translational energy of the ball is $\frac{p^2}{2M}$

(B) Energy of pure rotational motion of the ball is $\frac{5}{4}\frac{p^2\alpha^2}{M}$

(C) For $\alpha = \frac{2}{5}$, the ball rolls without sliding

(D) For α = 0, pure rotational motion will be observed

Solution · Q56 **Answer: (A), (B), (C)**

Friction has a negligible impulse during the blow.

(A) The impulse gives

$$MV = p$$

$$\Rightarrow K = \frac{p^2}{2M}$$

So (A) is true.

(B) Angular impulse about the centre:

$$I\omega = p\alpha R$$

$$\Rightarrow K_r = \frac{(p\alpha R)^2}{2I} = \frac{5}{4}\frac{p^2\alpha^2}{M}$$

So (B) is true.

(C) Velocity of the contact point:

$$V - \omega R = \frac{p}{M}\left(1 - \frac{5\alpha}{2}\right)$$

This is zero when

$$\alpha = \frac{2}{5}$$

So (C) is true.

(D) For a central blow,

$$\omega = 0$$

The motion is then purely translational, so (D) is false.

IAPT answer: (A), (B), (C) | **Zigyan answer:** (A), (B), (C)

57. According to Bohr theory, in the ground state of hydrogen atom, an electron revolves in circular orbit of radius r with velocity v and circulation frequency f. The magnetic dipole moment of the electronic orbit is p_m. The magnetic field produced by the circulating electron at the center of the atom is B. Then for a He^+ ion in the state n = 2 (electron in the 2^{nd} orbit)

(A) the radius of the orbit is 2r

(B) the magnetic dipole moment of the orbit is 2 p_m

(C) the frequency of circulation is $\frac{f}{2}$

(D) the magnetic field at the center is $\frac{B}{4}$

Solution · Q57 **Answer: (A), (B), (C), (D)**

$$r \propto \frac{n^2}{Z}$$

$$v \propto \frac{Z}{n}$$

(A) For the helium ion in the second orbit, the radius becomes 2r and the speed stays v. So (A) is true.

$$\text{(C) } f = \frac{v}{2\pi r}$$

The frequency becomes half, so (C) is true.

$$\text{(B) } p_m = \frac{evr}{2}$$

The moment doubles, so (B) is true.

$$\text{(D) } B = \frac{\mu_0 ef}{2r}$$

The field becomes one fourth, so (D) is true.

IAPT answer: (A), (B), (C), (D) | **Zigyan answer:** (A), (B), (C), (D)

58. A body of mass m = 0.25 kg is moving along x axis under the action of a conservative force. Its potential energy as a function of position x is given by $U(x) = -\frac{100x}{x^2+4}$ J (x in m). Then

(A) force F(x) acting on the body at x = 0 is 25 N

(B) there is stable equilibrium at x = 2 m

(C) there is unstable equilibrium at x = −2 m

(D) the body executes (small) oscillations with angular frequency ω = 0.5 rad s^{-1}

Solution · Q58 **Answer: (A), (B), (C)**

$$F = -\frac{dU}{dx} = \frac{100(4-x^2)}{(x^2+4)^2}$$

(A) At the origin,

$$F = 25 \text{ N}$$

So (A) is true.

The equilibrium points are at

$$x = \pm 2 \text{ m}$$

Around the positive point the force is restoring, so (B) is true. Around the negative point it pushes the body away, so (C) is true.

(D) For a small shift s from the stable point,

$$F \approx -\frac{400}{64}s$$

$$\Rightarrow k = 6.25 \text{ N m}^{-1}$$

$$\Rightarrow \omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{6.25}{0.25}} = 5.0 \text{ rad s}^{-1}$$

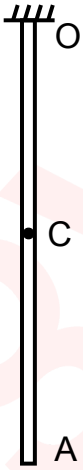
$\therefore$ (D) is false.

IAPT answer: (A), (B), (C) | **Zigyan answer:** (A), (B), (C)

59. A uniform rod OA of length L is freely pivoted at one end O.

Let C be the midpoint (i.e. $OC = \frac{L}{2} = CA$).

Choose the correct statement(s)



(A) The rod can perform small angular oscillations with time period $T = 2\pi\sqrt{\frac{L}{2g}}$

(B) The rod is brought to the horizontal position and then released from rest. The angular velocity of the rod at the instant when it is vertical is $\omega = \sqrt{\frac{3g}{L}}$

(C) When the oscillating rod comes to the vertical position, it breaks at midpoint C without generating any impulsive force, the largest angle from vertical reached by the upper part OC of the rod is 60°.

(D) After breaking, the lower part just falls vertically rotating about its center.

Solution · Q59 **Answer: (B), (C)**

$$\text{(A) } T = 2\pi\sqrt{\frac{I}{Mgd}} = 2\pi\sqrt{\frac{2L}{3g}}$$

So (A) is false.

$$\text{(B) } \frac{MgL}{2} = \frac{1}{2} \times \frac{ML^2}{3}\omega^2$$

$$\Rightarrow \omega = \sqrt{\frac{3g}{L}}$$

So (B) is true.

(C) The rod is taken as released from the horizontal. For the part OC,

$$\frac{1}{2}\times\frac{ML^2}{24}\omega^2=\frac{MgL}{8}(1-\cos\theta)$$
$$\Rightarrow \theta = 60°$$

So (C) is true.

(D) The lower part keeps its horizontal velocity while rotating, so it does not fall vertically. (D) is false.

IAPT answer: (B), (C) | **Zigyan answer:** (B), (C)

60. A boy stands on a stationary ice boat on a frictionless horizontal flat iceberg. The boy and the boat have a combined mass of M = 60 kg. Two balls of masses m_1 = 10 kg and m_2 = 20 kg are placed on the boat. In order to get the boat moving, the boy throws the balls backward horizontally either in succession or both together. In each case the balls are thrown backward with a certain speed v_{rel} = 6 ms^{-1} relative to the boat just when the ball is being thrown. The resulting speed of the system of the boat and the boy is

(A) V = 2.00 ms^{-1} when both the balls m_1 and m_2 are thrown together.

(B) V = 3.00 ms^{-1} when both the balls m_1 and m_2 are thrown together.

(C) V = 2.17 ms^{-1} if the balls are thrown one after the other, first m_1 and then m_2.

(D) V = 2.19 ms^{-1} if the balls are thrown one after the other, first m_2 and then m_1.

Solution · Q60 **Answer: (A), (C), (D)**

The 6 m/s is relative to the boat just after each throw. For one throw of mass m by a system of mass S moving at speed u,

$$V = u + \frac{6m}{S}$$

(A) Both together:

$$V = \frac{6\times 30}{90} = 2.00\ \text{m s}^{-1}$$

So (A) is true and (B) is false.

(C) First m_1, then m_2:

$$V = \frac{6\times 10}{90} + \frac{6\times 20}{80} = \frac{13}{6} \approx 2.17\ \text{m s}^{-1}$$

So (C) is true.

(D) First m_2, then m_1:

$$V = \frac{6\times 20}{90} + \frac{6\times 10}{70} = \frac{46}{21} \approx 2.19\ \text{m s}^{-1}$$

∴ (D) is true.

Check: measured on the ice, the final forward momentum of the boat and boy equals the backward momentum of the two balls: 120 kg m s^{-1} in (A), 130 kg m s^{-1} in (C) and about 131 kg m s^{-1} in (D).

IAPT answer: (A), (C), (D) | **Zigyan answer:** (A), (C), (D)

ANSWER KEY

NSEP 2024 · PAPER CODE 61

60
QUESTIONS · 216 MARKS

IAPT final answer key for paper code 61. ★ marks an answer given as per Zigyan.

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

★ Answers as per Zigyan

- **Q3** — As per Zigyan: (B); IAPT key (A) or (B).
- **Q11** — As per Zigyan: no option is correct; dropped by IAPT.
- **Q16** — As per Zigyan: (C); IAPT key (C).
- **Q28** — As per Zigyan: (D); IAPT key (C) or (D).
- **Q29** — As per Zigyan: no option is correct; dropped by IAPT.
- **Q31** — As per Zigyan: (C); IAPT key (D).
- **Q34** — As per Zigyan: (C); dropped by IAPT.
- **Q49** — As per Zigyan: (A), (B), (D); IAPT key (A), (B), (D).

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OLYMPIADS · 2026

Olympiad results



TOP ACHIEVEMENT · CHEMISTRY

Qualified the Chemistry Olympiad twice, and selected for the HBCSE camp.

Saksham Bishnoi reached the national stage of the Chemistry Olympiad in two consecutive years and was selected for the Orientation-cum-Selection Camp at HBCSE, Mumbai. 4 Years Classroom - the same student who took AIR 168 in JEE Advanced 2026.

Qualified twice | HBCSE selection camp | Only student from Faridabad

Above MAS means above the **Minimum Admissible Score**: clearing it puts a student in the national band for their subject. It is a real threshold, not a participation marker.

CHEMISTRY · ABOVE MAS



Sulokya Bibhuty
Class XII
3 Years Classroom
Above MAS



Anay Gupta
Class XI
3 Years Classroom
Above MAS



Akshat Khator
Class XI
3 Years Classroom
Above MAS



Harshit Goyal
Class XII
4 Years Classroom
Above MAS



Hardik Sharma
Class XI
3 Years Classroom
Above MAS



Aarush Kumar
Class XII
1 Year Classroom
Above MAS

PHYSICS · ASTRONOMY · MATHEMATICS

PHYSICS



Sulokya Bibhuty
Class XII
3 Years Classroom
Above MAS

PHYSICS



Saksham Bishnoi
Class XII
4 Years Classroom
Above MAS

ASTRONOMY



Sulokya Bibhuty
Class XI
3 Years Classroom
Above MAS

MATHEMATICS · IOQM



Priyanshi
Class XI
4 Years Classroom
IOQM Qualifier

OLYMPIADS WE PREPARE STUDENTS FOR

NSEP	NSEC	NSEB	NSEA	IOQM	NSEJS
Physics	Chemistry	Biology	Astronomy	Mathematics	Class X and below

The olympiad pathway starts in Class 8.

NSEJS is open to Class 10 and below - the habit of staying with one hard problem is the one JEE Advanced rewards.

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RESULTS · 2021 – 2026

Our toppers, year by year

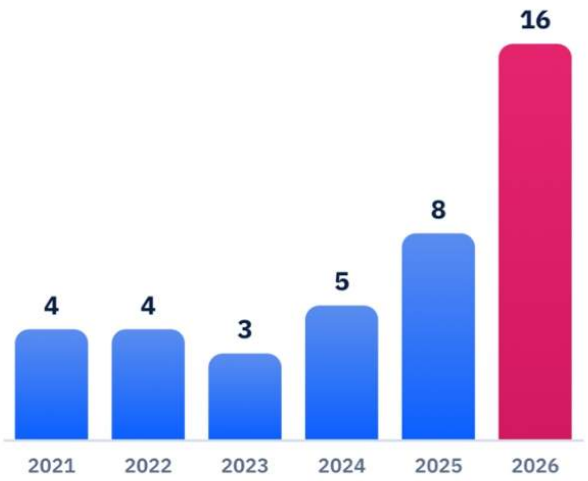
40
JEE Advanced selections in 6 years

AIR 168
best rank — Saksham Bishnoi, 2026

16 of 35
students selected, JEE Advanced 2026

14 of 35
above 98 percentile, JEE Main 2026

JEE ADVANCED SELECTIONS PER YEAR



BEST RANK EACH YEAR

YEAR	JEE ADVANCED	JEE MAIN
2026	**Saksham Bishnoi** AIR 168 · 4 Years Classroom	**Saksham Bishnoi** AIR 811 · 99.95 %ile
2025	**Chakshu** AIR 4,233 · 2 Years Classroom	**Chakshu** AIR 8,538 · 99.44 %ile
2024	**Harshit** AIR 777 · 2 Years Classroom	**Harshit** AIR 1,473 · 99.91 %ile
2023	**Aditya Jain** AIR 2,373 · 2 Years Classroom	**Aditya Jain** AIR 2,503 · 99.79 %ile
2022	**Rachit Sharma** AIR 698 · 1 Year Classroom	**Rachit Sharma** AIR 1,016 · 99.90 %ile
2021	**Sparsh Mittal** AIR 2,237 · 1 Year Classroom	**Sparsh Mittal** AIR 1,562

JEE ADVANCED 2026 — THIRTEEN NAMED SELECTIONS



Saksham Bishnoi
AIR 168
4 Years Classroom



Sulokya Bibhuty
AIR 1,315
3 Years Classroom



Aarush
AIR 2,699
1 Year Classroom



Manishka
AIR 2,869
4 Years Classroom



Oojit Kumar
AIR 5,765
4 Years Classroom



Harshit Goyal
AIR 6,407
4 Years Classroom



Pranab Sharma
AIR 6,750
3 Years Classroom



Aditya Dhar
AIR 15,183
3 Years Classroom



Arpit Anshuman
AIR 19,308
4 Years Classroom



Lokesh
AIR 22,857
3 Years Classroom



Arjun
AIR 24,674
3 Years Classroom



Sanyam Gulyani
AIR 25,123
1 Year Classroom



Saket
AIR 27,628
3 Years Classroom

Sixteen students of the 2026 batch were selected in JEE Advanced; the thirteen above are named with their All India Rank.

JEE MAIN 2026 — TOP SIX, WITH PERCENTILE



Saksham Bishnoi
AIR 811
99.95 %ile
4 Years Classroom



Sulokya Bibhuty
AIR 1,095
99.94 %ile
3 Years Classroom



Harshit Goyal
AIR 2,662
99.83 %ile
4 Years Classroom



Manishka
AIR 4,817
99.70 %ile
4 Years Classroom



Oojit Kumar
AIR 5,040
99.69 %ile
4 Years Classroom



Aarush
AIR 5,276
99.67 %ile
1 Year Classroom

14 of the 35 students in the 2026 batch scored above the 98th percentile in JEE Main.

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