

JEE Advanced (2022)

PAPER-I

Physics

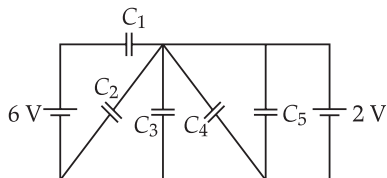
SECTION 1

- This section contains **EIGHT (08)** questions.
- The answer to each question is a **NUMERICAL VALUE**.
- For each question, enter the correct numerical value of the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer. If the numerical value has more than two decimal places, **truncate/round-off** the value to **TWO** decimal places.
- Answer to each question will be evaluated according to the following marking scheme:
 Full Marks : +3 ONLY if the correct numerical value is entered;
 Zero Marks : 0 In all other cases.

Q 1. Two spherical stars A and B have densities ρ_A and ρ_B , respectively. A and B have the same radius, and their masses M_A and M_B are related by $M_B = 2M_A$. Due to an interaction process, star A loses some of its mass, so that its radius is halved, while its spherical shape is retained, and its density remains ρ_A . The entire mass lost by A is deposited as a thick spherical shell on B with the density of the shell being ρ_A . If v_A and v_B are the escape velocities from A and B after the interaction process, the ratio $\frac{v_B}{v_A} = \sqrt{\frac{10n}{15^{1/3}}}$. The value of n is

Q 2. The minimum kinetic energy needed by an alpha particle to cause the nuclear reaction ${}^{16}_7\text{N} + {}^4_2\text{He} \rightarrow {}^1_1\text{H} + {}^{19}_8\text{O}$ in a laboratory frame is n (in MeV). Assume that ${}^{16}_7\text{N}$ is at rest in the laboratory frame. The masses of ${}^{16}_7\text{N}$, ${}^4_2\text{H}$, ${}^1_1\text{H}$ and ${}^{19}_8\text{O}$ can be taken to be $16.006 u$, $4.003 u$, $1.008 u$ and $19.003 u$, respectively, where $1 u = 930 \text{ MeV } c^{-2}$. The value of n is

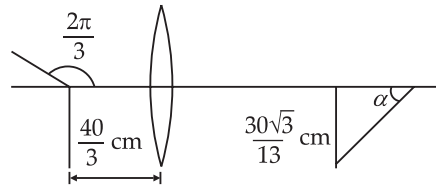
Q 3. In the following circuit $C_1 = 12 \mu\text{F}$, $C_2 = C_3 = 4 \mu\text{F}$ and $C_4 = C_5 = 2 \mu\text{F}$. The charge stored in C_3 is μC .



Q 4. A rod of length 2 cm makes an angle $\frac{2\pi}{3}$ rad with the principal axis of a thin convex lens. The lens has a focal length of 10 cm and is placed at a distance

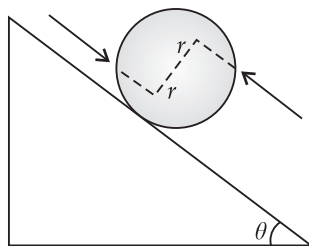
of $\frac{40}{3}$ cm from the object as shown in the figure.

The height of the image is $\frac{20\sqrt{3}}{13}$ cm and the angle made by it with respect of the principal axis is α rad. The value of α is $\frac{\pi}{n}$ rad, where n is



Q 5. At time $t = 0$, a disk of radius 1 m starts to roll without slipping on a horizontal plane with an angular acceleration of $\alpha = \frac{2}{3} \text{ rad } s^{-2}$. A small stone is stuck to the disk. At $t = 0$, it is at the contact point of the disk and the plane. Later, at time $t = \sqrt{\pi} \text{ s}$, the stone detaches itself and flies off tangentially from the disk. The maximum height (in m) reached by the stone measured from the plane is $\frac{1}{2} + \frac{x}{10}$. The value of x is [Take $g = 10 \text{ ms}^{-2}$.]

Q 6. A solid sphere of mass 1 kg and radius 1 m rolls without slipping on a fixed inclined plane with an angle of inclination $\theta = 30^\circ$ from the horizontal. Two forces of magnitude 1 N each, parallel to the incline, act on the sphere, both at distance $r = 0.5 \text{ m}$ from the centre of the sphere, as shown in the figure. The acceleration of the sphere down the plane is ms^{-2} . (Take $g = 10 \text{ ms}^{-2}$.)



- Q 7. Consider an LC circuit, with inductance $L = 0.1$ H and capacitance $C = 10^{-3}$ F, kept on a plane. The area of the circuit is 1 m^2 . It is placed in a constant magnetic field of strength B_0 which is

perpendicular to the plane of the circuit. At time $t = 0$, the magnetic field strength starts increasing linearly as $B = B_0 + \beta t$ with $\beta = 0.04 \text{ T s}^{-1}$. The maximum magnitude of the current in the circuit is mA.

- Q 8. A projectile is fired from horizontal ground with speed v and projection angle θ . When the acceleration due to gravity is g , the range of the projectile is d . If at the highest point in its trajectory, the projectile enters a different region where the effective acceleration due to gravity is $g' = \frac{g}{0.81}$, then the new range is $d' = nd$. the value of n is

SECTION 2

- This section contains **SIX (06)** questions.
- The question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is (are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks	:	+4	ONLY if (all) the correct option(s) is (are) chosen;
Partial Marks	:	+3	If all the four options are correct but ONLY three options are chosen;
Partial Marks	:	+2	If three or more options are correct but ONLY two options are chosen, both of which are correct;
Partial Marks	:	+1	If two or more options are correct but ONLY one option is chosen and it is a correct option;
Zero Marks	:	0	If none of the options is chosen (i.e., the question is unanswered);
Negative Marks	:	-2	In all other cases.

- Q 9. A medium having dielectric constant $K > 1$ fills the space between the plates of a parallel plate capacitor. The plates have large area, and the distance between them is d . The capacitor is connected to a battery of voltage V , as shown in Figure (a). Now, both the plates are moved by a distance of $\frac{d}{2}$ from their original positions, as shown in Figure (b).

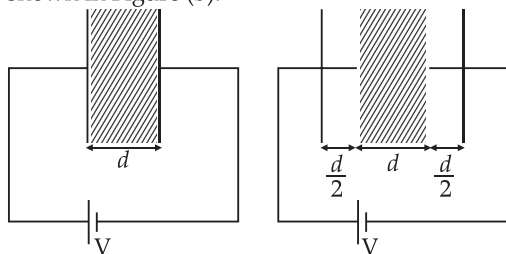


Figure (a)

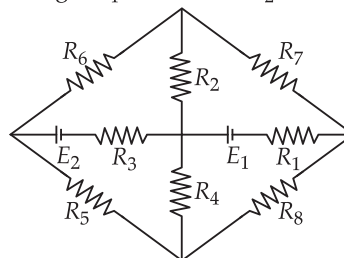
Figure (b)

In the process of going from the configuration depicted in Figure (a) to that in Figure (b), which of the following statement(s) is (are) correct ?

- (A) The electric field inside the dielectric material is reduced by a factor of $2K$.
- (B) The capacitance is decreased by a factor of $\frac{1}{K+1}$.

- (C) The voltage between the capacitor plates is increased by a factor of $(K+1)$.
- (D) The work done in the process **DOES NOT** depend on the presence of the dielectric material.

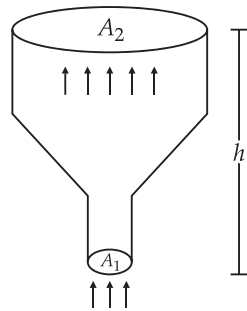
- Q 10. The figure shows a circuit having eight resistances of 1Ω each, labelled R_1 to R_8 , and two ideal batteries with voltages $E_1 = 12 \text{ V}$ and $E_2 = 6 \text{ V}$.



Which of the following statement(s) is (are) correct?

- (A) The magnitude of current flowing through R_1 is 7.2 A .
- (B) The magnitude of current flowing through R_2 is 1.2 A .
- (C) The magnitude of current flowing through R_3 is 4.8 A .
- (D) The magnitude of current flowing through R_5 is 4.8 A .

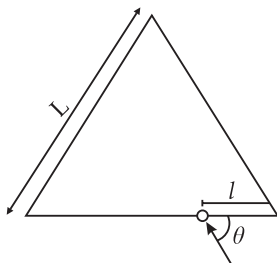
Q 11. An ideal gas of density $\rho = 0.2 \text{ kg m}^{-3}$ enters a chimney of height h at the rate of $\alpha = 0.8 \text{ kg s}^{-1}$ from its lower end, and escapes through the upper end as shown in the figure. The cross-sectional area of the lower end is $A_1 = 0.1 \text{ m}^2$ and the upper end is $A_2 = 0.4 \text{ m}^2$. The pressure and the temperature of the gas at the lower end are 600 Pa and 300 K, respectively, while its temperature at the upper end is 150 K. The chimney is heat insulated so that the gas undergoes adiabatic expansion. Take $g = 10 \text{ ms}^{-2}$ and the ratio of specific heats of the gas $\gamma = 2$. Ignore atmospheric pressure.



Which of the following statement(s) is (are) correct?

- (A) The pressure of the gas at the upper end of the chimney is 300 Pa.
- (B) The velocity of the gas at the lower end of the chimney is 40 ms^{-1} and at the upper end is 20 ms^{-1} .
- (C) The height of the chimney is 590 m.
- (D) The density of the gas at the upper end is 0.05 kg m^{-3} .

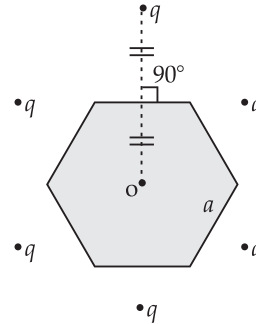
Q 12. Three plane mirrors form an equilateral triangle with each side of length L . There is a small hole at a distance $l > 0$ from one of the corners as shown in the figure. A ray of light is passed through the hole at an angle θ and can only come out through the same hole. The cross section of the mirror configuration and the ray of light lie on the same plane.



Which of the following statement(s) is (are) correct?

- (A) The ray of light will come out for $\theta = 30^\circ$, for $0 < l < L$.
- (B) There is an angle for $l = \frac{L}{2}$ at which the ray of light will come out after two reflections.
- (C) The ray of light will **NEVER** come out for $\theta = 60^\circ$, and $l = \frac{L}{3}$.
- (D) The ray of light will come out for $\theta = 60^\circ$, and $0 < l < \frac{L}{2}$ after six reflections.

Q 13. Six charges are placed around a regular hexagon of side length a as shown in the figure. Five of them have charge q , and the remaining one has charge x . The perpendicular from each charge to the nearest hexagon side passes through the centre O of the hexagon and is bisected by the side.



Which of the following statement(s) is (are) correct in SI units ?

- (A) When $x = q$, the magnitude of the electric field at O is zero
- (B) When $x = -q$, the magnitude of the electric field at O is $\frac{q}{6\pi\epsilon_0 a^2}$.
- (C) When $x = 2q$, the potential at O is $\frac{7q}{4\sqrt{3}\pi\epsilon_0 a}$.
- (D) When $x = 3q$, the potential at O is $-\frac{3q}{4\sqrt{3}\pi\epsilon_0 a}$.

Q 14. The binding energy of nucleons in a nucleus can be affected by the pair-wise Coulomb repulsion. Assume that all nucleons are uniformly distributed inside the nucleus. Let the binding energy of a proton be E_b^p and the binding energy of a neutron be E_b^n in the nucleus.

Which of the following statement(s) is (are) correct?

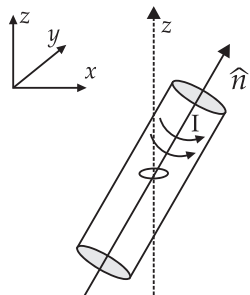
- (A) $E_b^p - E_b^n$ is proportional to $Z(Z - 1)$ where Z is the atomic number of the nucleus.
- (B) $E_b^p - E_b^n$ is proportional to $A^{-\frac{1}{3}}$ where A is the mass number of the nucleus.
- (C) $E_b^p - E_b^n$ is positive.
- (D) E_b^p increases if the nucleus undergoes a beta decay emitting a positron.

SECTION 3

- This section contains **FOUR (04)** Matching List Sets.
- Each set has **ONE** Multiple Choice Question.
- Each set has **TWO** list : **List-I** and **List-II**.
- **List-I** has **Four** entries (I), (III) and (IV) and **List-II** has **Five** entries (P), (Q), (R), (S) and (T).
- **FOUR** options are given in each Multiple Choice Question based on **List-I** and **List-II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme :
 Full Marks : +3 **ONLY** is the option corresponding to the correct combination is chosen;
 Zero Marks : 0 If none of the options is chosen (i.e., the question is unanswered);
 Negative Marks : -1 In all other cases.

- Q 15.** A small circular loop of area A and resistance R is fixed on a horizontal xy -plane with the centre of the loop always on the axis \hat{n} of a long solenoid. The solenoid has m turns per unit length and carries current I counter-clockwise as shown in the figure. The magnetic field due to the solenoid is in \hat{n} direction. List-I gives time dependences of \hat{n} in terms of a constant angular frequency ω . List-II gives the torques experienced by the circular loop at time

$$t = \frac{\pi}{6\omega}. \text{ Let } \alpha = \frac{A^2 \mu_0^2 m^2 I^2 \omega}{2R}.$$

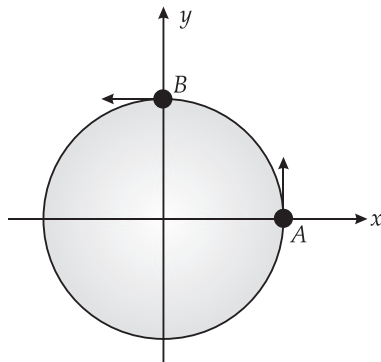


List-I	List-II
(I) $\frac{1}{\sqrt{2}} (\sin \omega t \hat{j} + \cos \omega t \hat{k})$	(P) 0
(II) $\frac{1}{\sqrt{2}} (\sin \omega t \hat{i} + \cos \omega t \hat{j})$	(Q) $-\frac{\alpha}{4} \hat{i}$
(III) $\frac{1}{\sqrt{2}} (\sin \omega t \hat{i} + \cos \omega t \hat{k})$	(R) $\frac{3\alpha}{4} \hat{i}$
(IV) $\frac{1}{\sqrt{2}} (\sin \omega t \hat{j} + \cos \omega t \hat{k})$	(S) $\frac{\alpha}{4} \hat{j}$
	(T) $-\frac{3\alpha}{4} \hat{i}$

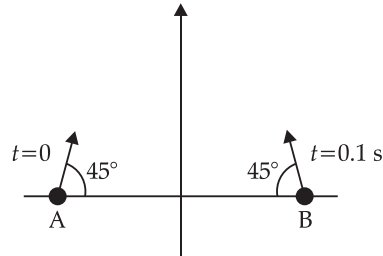
Which one of the following options is correct ?

- (A) I \rightarrow Q, II \rightarrow P, III \rightarrow S, IV \rightarrow T
 (B) I \rightarrow S, II \rightarrow T, III \rightarrow Q, IV \rightarrow P
 (C) I \rightarrow Q, II \rightarrow P, III \rightarrow S, IV \rightarrow R
 (D) I \rightarrow T, II \rightarrow Q, III \rightarrow P, IV \rightarrow R
- Q 16.** List-I describes four systems, each with two particles A and B in relative motion as shown in figures, List-II gives possible magnitudes of their relative velocities (in ms^{-1}) at time $t = \frac{\pi}{3}$ s.

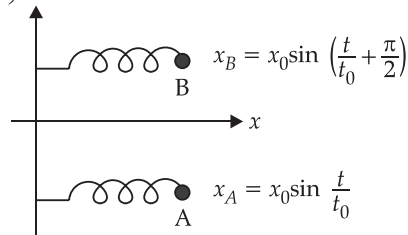
List-I	List-II
(I) A and B are moving on a horizontal circle of radius 1 m with uniform angular speed $\omega = 1 \text{ rad s}^{-1}$. The initial angular positions of A and B at time $t = 0$ are $\theta = 0$ and $\theta = \frac{\pi}{2}$, respectively.	(P) $\frac{\sqrt{3} + 1}{2}$



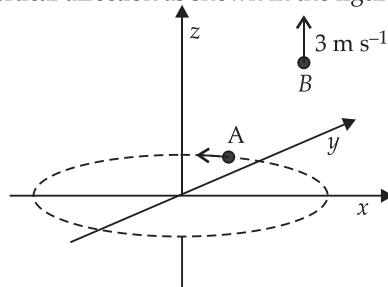
- (II) Projectiles A and B are fired (in the same vertical plane) at $t = 0$ and $t = 0.1$ s respectively, with the same speed $v = \frac{5\pi}{\sqrt{2}} \text{ ms}^{-1}$ and at 45° from the horizontal plane. The initial separation between A and B is large enough so that do not collide ($g = 10 \text{ ms}^{-2}$). (Q) $\frac{(\sqrt{3}-1)}{\sqrt{2}}$



- (III) Two harmonic oscillators A and B moving in the x direction according to $x_A = x_0 \sin \frac{t}{t_0}$ and $x_B = \sin \left(\frac{t}{t_0} + \frac{\pi}{2} \right)$ respectively, starting from $t = 0$. Take $x_0 = 1 \text{ m}$, $t_0 = 1 \text{ s}$. (R) $\sqrt{10}$



- (IV) Particle A is rotating in a horizontal circular path of radius 1 m on the xy -plane, with constant angular speed $\omega = 1 \text{ rad s}^{-1}$. Particle B is moving up at a constant speed 3 ms^{-1} in the vertical direction as shown in the figure. (Ignore gravity.) (S) $\sqrt{2}$



(T) $\sqrt{2r\pi^2 + 1}$

Which one of the following options is correct ?

- (A) I \rightarrow R, II \rightarrow T, III \rightarrow P, IV \rightarrow S
 (B) I \rightarrow S, II \rightarrow P, III \rightarrow Q, IV \rightarrow R
 (C) I \rightarrow S, II \rightarrow T, III \rightarrow P, IV \rightarrow R
 (D) I \rightarrow T, II \rightarrow P, III \rightarrow R, IV \rightarrow S

- Q 17. List-I describes thermodynamic processes in four different systems. List-II gives the magnitudes (either exactly or as a close approximation) of possible changes in the internal energy of the system due to the process.
- | | | | |
|--|--------------------------------------|---|--------------------------------------|
| <p>(I) 10^{-3} kg of water at 100°C is converted to steam at the same temperature, at a pressure of 10^5 Pa. The volume of the system changes from 10^{-6} m^3 to 10^{-3} in the process. Latent heat of water = 2250 kJ/kg.</p> | <p>(P) 2 kJ</p> | <p>(II) 0.2 moles of a rigid diatomic ideal gas with volume V at temperature 500 K undergoes an isobaric expansion to volume $3V$. Assume $R = 8.0 \text{ J mol}^{-1} \text{ K}^{-1}$.</p> | <p>(Q) 7 kJ</p> |
| <p>(III) One mole of a monatomic ideal gas is compressed adiabatically from volume $V = \frac{1}{3} \text{ m}^3$ and pressure 2 kPa to volume $\frac{V}{8}$.</p> | <p>(R) 4 kJ</p> | | |

- (IV) Three moles of a diatomic ideal gas whose molecules can vibrate, is given 9 kJ of heat and undergoes isobaric expansion.
- (S) 5 kJ
(T) 3 kJ

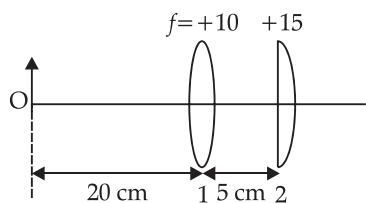
Which one of the following options is correct ?

- (A) I \rightarrow T, II \rightarrow R, III \rightarrow S, IV \rightarrow Q
(B) I \rightarrow S, II \rightarrow P, III \rightarrow T, IV \rightarrow P
(C) I \rightarrow P, II \rightarrow R, III \rightarrow T, IV \rightarrow Q
(D) I \rightarrow Q, II \rightarrow R, III \rightarrow S, IV \rightarrow T

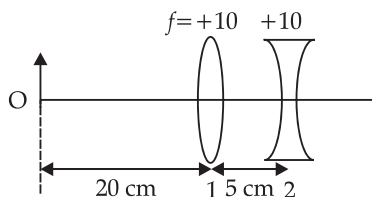
- Q 18. List-I contains four combinations of two lenses (1 and 2) whose focal length (in cm) are indicated in the figures. In all cases the object is placed 20 cm from the first lens on the left, and the distance between the two lenses is 5 cm. List-II contains the positions of the final images.

List-I

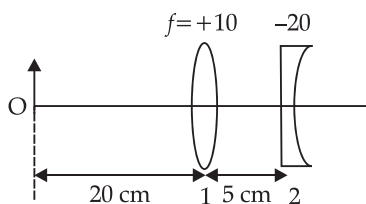
(I)



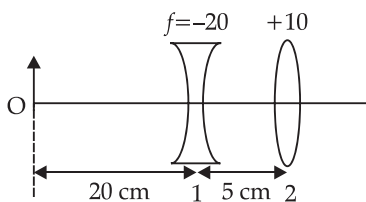
(II)



(III)



(IV)



List-II

- (P) Final image is formed at 7.5 cm on the right side of lens 2.
(Q) Final image is formed at 60.0 cm on the right side of lens 2.
(R) Final image is formed at 30.0 cm on the left side of lens 2.
(S) Final image is formed at 6.0 cm on the right side of lens 2.
(T) Final image is formed at 30.0 cm on the right side of lens 2.

Which one of the following options is correct ?

- (A) I \rightarrow P, II \rightarrow R, III \rightarrow Q, IV \rightarrow T
(B) I \rightarrow Q, II \rightarrow P, III \rightarrow T, IV \rightarrow S
(C) I \rightarrow P, II \rightarrow T, III \rightarrow R, IV \rightarrow Q
(D) I \rightarrow T, II \rightarrow S, III \rightarrow Q, IV \rightarrow R

□□

Q.No.	Answer key	Topic's name	Chapter's name
Section -I			
1	2.30	Escape Velocity	Gravitation
2	2.32	Nuclear Energy	Atoms and Nuclei
3	8	Capacitances combinations	Electrostatics
4	6	Rectilinear propagation of light	Optics
5	0.52	Rotational Motion	Rotational Motion
6	2.86	Rotational Motion	Rotational Motion
7	4	LC Circuits	Electromagnetic Induction and Alternating Currents
8	0.95	Kinematics in Two Dimensions	Kinematics
Section -II			
9	B	Capacitances	Electrostatics
10	A,B,C & D	Electric Resistance	Current Electricity
11	B	Degree of Freedom and Specific Heat Capacities of Gases	Kinetic Theory of Gases
12	A & B	Optics	Optics
13	A,B & C	Electrostatic Force, Electric Field and Electrostatic Potential	Electrostatics
14	A,B & D	Binding Energy	Atoms and Nuclei
Section -III			
15	C	Magnetic Effects of Current	Magnetic Effects of Current and Magnetism
16	C	Rotational Motion	Rotational Motion
17	C	Specific Heat Capacities of Gases	Kinetic Theory of Gases
18	A	Optics	Optics

Solutions

SECTION - 1

1. **Correct answer is [2.30]**

Explanation : Given,

$$R_A = R_B = R, \text{ and } M_B = 2M_A$$

For star A:

$$\text{Radius of star (remain)} = R'_A = R_{A/2}$$

$$\text{Mass of star (remain)} = M'_A = \rho A \frac{4\pi}{3} (R')^3 = \frac{M_A}{8}$$

By using law of energy conservation

$$\frac{-GM_A^1}{R_A^1} + \frac{1}{2}mv_A^2 = 0$$

$$\text{Hence, } v_A = \sqrt{\frac{2GM_{A'}}{R_{A'}}} = \sqrt{\frac{2GM_A(2)}{8R}} = \sqrt{\frac{-GM_A}{2R}}$$

For star B:

$$\text{Total mass over B} = \frac{7}{8}M_A$$

Now new radius of B will be r

$$\frac{4\pi}{3}(r^3 - R_B^3)\rho_A = \frac{7}{8}\rho_A \left(\frac{4}{3}\pi R_A^3\right)$$

$$\Rightarrow r^3 = \left(\frac{15}{8}\right)R_B^3$$

$$\text{Hence, } r = \frac{(15)^{1/3}}{2}R$$

$$\frac{v_B^2}{2} = \frac{23GM_A}{8 \times 15^{1/3} \cdot (R/2)}$$

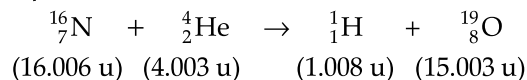
$$v_B = \sqrt{\frac{23GM_A}{2 \times 15^{1/3} \cdot R}}$$

$$\text{Now, } \frac{v_B}{v_A} = \sqrt{\frac{23}{15^{1/3}}} = \sqrt{\frac{10n}{15^{1/3}}}$$

$$\text{Hence, } n = 2.30$$

2. **Correct answer is [2.32]**

Explanation : Given,



From conservation of linear momentum,

$$P_{\text{final}} = P_{\text{initial}}$$

$$4v_0 = 1v' + 19v' = 20v'$$

$$v_0 = \frac{20v'}{4}$$

$$v' = \frac{4v_0}{20} = \frac{v_0}{5}$$

By using:

$$E = \Delta mc^2$$

$$= (1.008 + 19.003 - 16.006 - 4.003) \times 930$$

$$= 1.86$$

Now,

$$\frac{1}{2}m_1v_1^2 - \frac{1}{2}m_2v_2^2 = 1.86$$

$$\frac{1}{2}(4)(v_0^2) - \frac{1}{2}(20)\frac{v_0^2}{25} = 1.86$$

$$2v_0^2 - \frac{2}{5}v_0^2 = 1.86$$

$$\frac{8v_0^2}{5} = 1.86$$

$$v_0^2 = \frac{1.86 \times 5}{8}$$

Minimum energy needed (n)

$$n = \frac{1}{2}m_N v_N^2 + \frac{1}{2}M_{\text{He}} v_{\text{He}}^2$$

$$= \frac{1}{2}(4)(v_0^2)$$

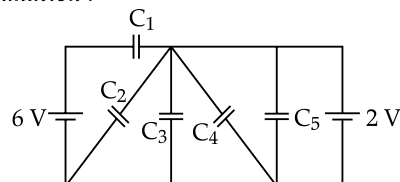
$$= 2v_0^2$$

$$= \frac{2 \times 1.86 \times 5}{8} = 2.32$$

Hence, $n = 2.32$

3. **Correct answer is [8]**

Explanation :



$$C_1 = 12 \mu\text{F}, C_2 = C_3 = 4 \mu\text{F}, C_4 = C_5 = 2 \mu\text{F}.$$

From the nodal analysis, potential across C_3 is $(2V - 0) = 2V$

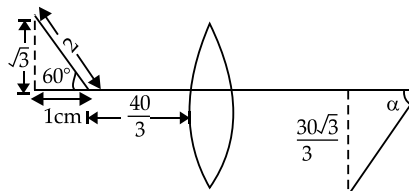
$$\text{Charge on } C_3 \text{ is} = C_3(2V)$$

$$= 4 \times 2$$

$$= 8 \mu\text{F}$$

4. **Correct answer is [6]**

Explanation :



$$m = \frac{h_i}{h_o} = \frac{v}{u} = \frac{-30\sqrt{3}}{\sqrt{3}} = -\frac{v}{43}$$

$$\frac{v}{43} = 6$$

$$\Rightarrow v_1 = \frac{430}{13} \text{ cm}$$

According to lens formula

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

$$\frac{1}{v} = \frac{1}{10} - \frac{3}{40}$$

$$v = 40 \text{ cm}$$

Separation (x) = $v - v_1$

$$40 - \frac{430}{13} = \frac{90}{13} \text{ cm}$$

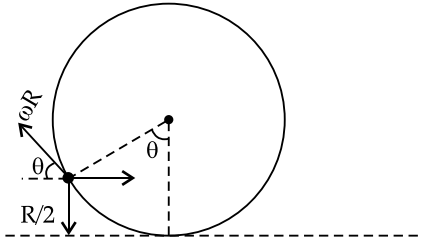
$$\tan \alpha = \frac{\frac{30\sqrt{3}}{13}}{\frac{90}{13}} = \frac{1}{\sqrt{3}}$$

$$\alpha = \frac{\pi}{6} = \frac{\pi}{n}$$

Hence, $n = 6$

5. **Correct answer is [0.52]**

Explanation : At, $t = 0, \omega = 0$



At, $t = \sqrt{\pi}, \omega = \alpha t$

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

$$v = r\omega$$

$$= \frac{2}{3} (\sqrt{\pi})(1)$$

$$\theta = \omega_0 t + \frac{1}{2} \alpha t^2$$

$$= 0 + \frac{1}{2} \alpha t^2$$

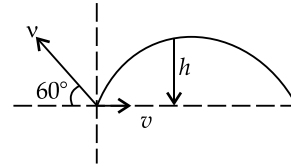
$$= \frac{1}{2} \left(\frac{2}{3} \times \pi \right) = \frac{\pi}{3} \text{ radian}$$

As, $v_y = v \sin \theta$

$$v_y = v \sin 60 = \frac{\sqrt{3}}{2} v$$

$$h = \frac{u_y^2}{2g} = \frac{\frac{3}{4} v^2}{2g}$$

[By using III equation of motion]



$$h = \frac{\frac{3}{4} \times \frac{4}{9} \pi}{2g}$$

$$h = \frac{3\pi}{9 \times 2g} = \frac{\pi}{6g}$$

Maximum height from plane will be given by

$$H = h + \frac{R}{2}$$

$$H = \frac{\pi}{6 \times 10} + \frac{1}{2}$$

$$= \frac{3.14}{60} + \frac{1}{2}$$

By comparing with given height we get,

$$x = \frac{3.14}{6} = 0.52$$

Hence, $h = 0.52 \text{ m}$

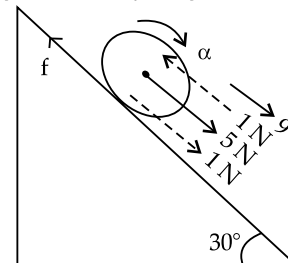
6. **Correct answer is [2.86]**

Explanation :

$$I_s = \frac{2}{5} Mr^2$$

Given, $M = 1 \text{ kg}, r = 0.5 \text{ m}$

According to free body diagram concept



$$5 - 1 + 1 - f = 1 \text{ (a)}$$

$$5 - f = a$$

....(i)

Now due to rotation:

Net torque = $I\alpha$ {About the centre of mass}

$$f \times -2(1 \times 0.5) = \frac{2}{5} Mr(\alpha) \quad (\because a = r\alpha)$$

$$f - 1 = \frac{2}{5} a$$

$$f - 1 = \frac{2}{5} a$$

$$f = 1 + \frac{2}{5} a \quad \dots(ii)$$

By using equation (i) & (ii)

$$5 - a = 1 + \frac{2}{5} a$$

$$4 = 1 + \frac{2}{5} a + a$$

$$a = \frac{20}{7} = 2.857$$

Hence, $a = 2.86 \text{ m/s}^2$

7. **Correct answer is [4]**

Explanation : Energy stored in capacitor and inductor are same and maximum.

$$\text{Hence, } \frac{q_0^2}{2C} = \frac{1}{2} LI_m^2$$

$$\frac{q_0^2}{CL} = I_m^2$$

$$I_m = \frac{q_0}{\sqrt{LC}} = \frac{CV}{\sqrt{LC}}$$

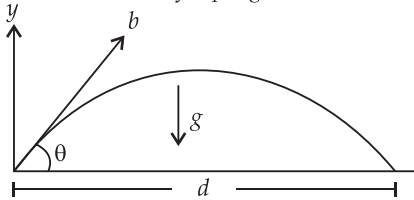
$$I_m = \sqrt{\frac{C}{L}} \times V = \sqrt{\frac{10^{-3}}{0.1}} \times 0.04$$

$$I_m = I_o = I_{\max} = 0.004$$

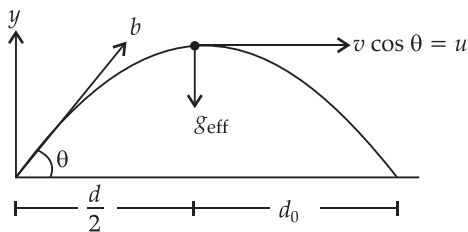
Hence, $I_m = 4 \text{ mA}$

8. **Correct answer is [0.95]**

Explanation : Initially, $a_1 = g$



$$\text{Finally, } a_2 = g' = \frac{g}{0.81}$$



$$\text{Range} = d = \frac{v^2 \sin 2\theta}{g}$$

$$H_{\max} = \frac{v^2 \sin^2 \theta}{2g}$$

$$\frac{1}{2} g_{\text{eff}} t^2 = H_{\max}$$

$$t = \sqrt{\frac{2H_{\max}}{g_{\text{eff}}}}$$

$$t = \sqrt{\frac{v^2 \sin 2\theta}{g^2}} \times 0.81$$

$$t = \left(\frac{0.9v \sin \theta}{g} \right)$$

$$\text{Now, } d' = \frac{d}{2} + d_0 \quad \dots(i)$$

$$d_0 = v \cos \theta \times t \quad \dots(ii)$$

$$= v \cos \theta \left(\frac{0.9v \sin \theta}{g} \right)$$

$$= \frac{0.9v^2 \sin \theta \cos \theta}{g}$$

Using (i) & (ii)

$$d' = \frac{v^2 \sin 2\theta}{2g} + \frac{0.9v^2 \sin \theta \cos \theta \times 2}{g \times 2}$$

$$= \frac{v^2 \sin 2\theta}{2g} (1 + 0.9)$$

$$= \frac{v^2 \sin 2\theta}{2g} (1.9) \quad (\text{As } d' = nd)$$

$$= d \left(\frac{1.9}{2} \right)$$

$$d' = 0.95d$$

$$\text{Hence, } n = 0.95$$

SECTION - 2

9. **Correct answer is option [B].**

Explanation :

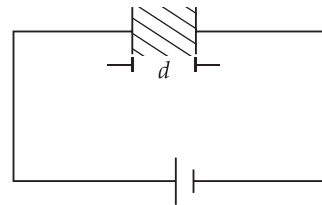


Figure (a)

$$\text{Here, } E_0 = \frac{V}{d} \text{ and } C_0 = \frac{\epsilon_0 AK}{d}$$

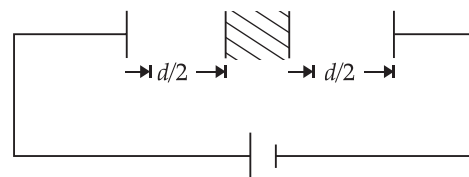


Figure (b)

Here,
$$C^1 = \frac{\epsilon_0 A}{d-t + \frac{t}{K}}$$

$$= \frac{\epsilon_0 A}{2d-d + \frac{d}{K}}$$

$$= \frac{\epsilon_0 A}{d + \frac{d}{K}}$$

$$C' = \frac{\epsilon_0 A}{d\left(1 + \frac{1}{K}\right)}$$

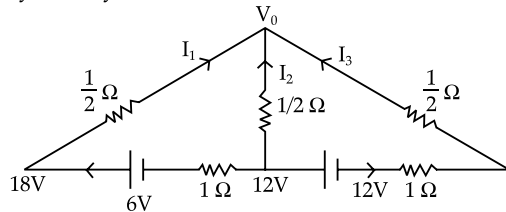
$$C' = \frac{\epsilon_0 AK}{d(K+1)}$$

$$C' = \frac{C_0}{K+1}$$

Hence, The capacitance is decreased by a factor of $\frac{1}{1+K}$.

10. Correct answer is options [A, B, C & D].

Explanation : By using the concept of folding symmetry, we have,



By using KCL

$$i_1 + i_2 + i_3 = 0$$

$$\frac{18 - V_0}{3/2} + \frac{12 - V_0}{1/2} + \frac{0 - V_0}{3/2} = 0$$

$$54 = 5V_0$$

$$V_0 = \frac{54}{5} \text{ volt}$$

And also

$$\frac{18 - V'}{1} + \frac{2\left(\frac{54}{5} - V'\right)}{1} = 0$$

$$3V' = 18 + \frac{108}{5}$$

$$V' = \frac{66}{5} \text{ V}$$

$$I_1 = \frac{36}{5} = 7.2 \text{ A}$$

$$I_2 = \frac{6}{5} = 1.2 \text{ A}$$

$$I_3 = \frac{24}{5} = 4.8 \text{ A}$$

$$I_5 = \frac{12}{5} = 2.4 \text{ A}$$

11. Correct answer is option [B]

Explanation : Given, $g = 10 \text{ m/s}^2$; $\gamma = 2$

As per Adiabatic condition

$$P_1^{1-\gamma} T_1^\gamma = P_2^{1-\gamma} T_2^\gamma = \text{Constant}$$

$$\frac{P_2}{P_1} = \left(\frac{T_1}{T_2}\right)^{\gamma/1-\gamma}$$

$$P_2 = \left(\frac{300}{150}\right)^{2-1} \times 600$$

$$P_2 = \frac{600}{4} = 150 \text{ Pa}$$

Now: $\frac{dm}{dt} = \rho \cdot A_1 v_1 = 0.8 \text{ kg/s}$

Hence, $v_1 = \frac{0.8}{0.2 \times 0.1} = 40 \text{ m/s}$

As we know

$$P = \frac{\rho RT}{M} \Rightarrow \rho \propto \frac{P}{T}$$

$$\frac{\rho_1}{\rho_2} = \frac{P_1}{P_2} \cdot \frac{T_2}{T_1} = \frac{1}{2}$$

$$\rho_2 = 2\rho_1$$

Work done on the gas = total energy

= $\Delta K + \Delta U + \text{internal energy}$

$$P_1 A_1 \Delta x_1 - P_2 A_2 \Delta x_2 = \frac{1}{2} \Delta m v_2^2 - \frac{1}{2} \Delta m v_1^2 + \Delta m g h + \frac{f}{2}$$

$$(P_2 \Delta V_2 - P_1 \Delta V_1) 2P_1 \frac{\Delta v_1}{\Delta m} - 2P_2 \frac{\Delta v_2}{\Delta m} = \frac{v_2^2 - v_1^2}{2} + g h$$

$$\frac{2 \times 600}{0.2} - \frac{2 \times 150}{0.1} = \frac{20^2 - 40^2}{2} + 10h$$

$$6000 - 3000 = \frac{400 - 1600}{2} + 10h$$

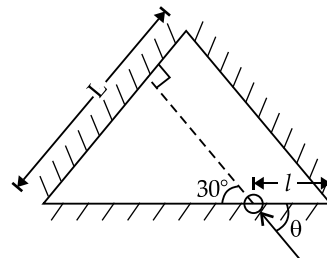
$$3000 = -600 + 10h$$

$$10h = 3000 + 600$$

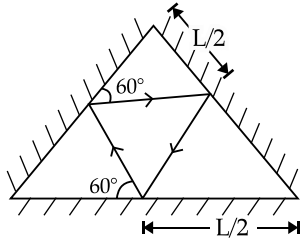
$$h = 360 \text{ m}$$

12. Correct answer is options [A & B].

Explanation :



Ray will come out after one reflection for $\theta = 30^\circ$ and $0 < l < L$

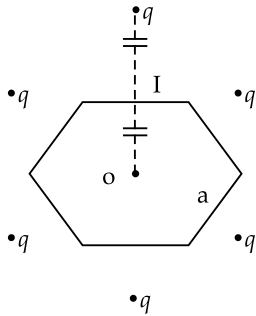


$$\text{If } \theta = 60^\circ : l = \frac{L}{2}$$

Ray will come out after two reflections.

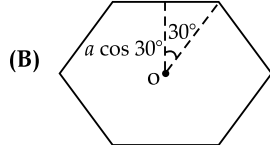
13. Correct answer is options [A, B & C].

Explanation :



(A) Diagonally opp. elements cancel out the electric field of each other because of symmetry of charges'

$$\therefore \vec{E}_0 = 0$$



$$E_{\text{net}} = \frac{2q \times 4}{4\pi\epsilon_0 \cdot 4.3a^2}$$

$$E_{\text{net}} = \frac{q}{6\pi\epsilon_0 a^2}$$

$$(C) \text{ As, } V = \frac{Kq}{r}$$

So here for the combination

$$V = \frac{7Kq}{2d} = \frac{7q}{4\pi\epsilon_0(\sqrt{3}a)}$$

$$V = \frac{7q}{4\sqrt{3}\pi\epsilon_0 a}$$

14. Correct answers is options [A, B & D].

Explanation : Electrostatic potential energy = $E_p - E_N$

$$\text{Required binding energy} = Z \times \frac{1}{4\pi\epsilon_0} \frac{(Z-1)e^2}{R}$$

$$\text{As: } R = R_0 A^{1/3}$$

$$= \frac{Z(Z-1)e^2}{4\pi\epsilon_0 R_0 A^{1/3}}$$

Conclusion, Binding energy of proton increases if the nucleus undergoes a beta decay emitting a positron.

SECTION - 3

15. Correct answer is option [C].

$$(I) \quad B = \frac{\mu_0 m I}{\sqrt{2}} (\sin \omega t \hat{j} + \cos \omega t \hat{k})$$

$$\phi = \vec{B} \cdot \vec{A}$$

$$= \frac{\mu_0 m R}{\sqrt{2}} \cos(\omega t) \cdot A$$

$$e = \frac{d\phi}{dt} = \frac{\mu_0 m I \omega A}{\sqrt{2}} \sin \omega t$$

$$i = \frac{e}{R} = \frac{\mu_0 m I \omega A^2}{\sqrt{2} R} \sin \omega t$$

$$\text{As, } \vec{M} = i \vec{A}$$

$$= i A (\hat{K}) = \frac{\mu_0 m I \omega A^2}{\sqrt{2} R} \sin(\omega t) \hat{k}$$

$$\vec{\tau} = \vec{M} \times \vec{B}$$

$$= \frac{\mu_0 m^2 I^2 \omega A^2}{\sqrt{2} R} \sin^2 \omega t (-\hat{i})$$

$$\vec{\tau} = -\frac{\alpha}{4} \hat{i}$$

$$(II) \quad \vec{B} = \frac{\mu_0 m I}{\sqrt{2}} (\sin \omega t \hat{i} + \cos \omega t \hat{j})$$

$$\phi = 0 ; e = 0 ; i = 0 ; t = 0$$

$$(III) \quad \vec{B} = \frac{\mu_0 m I}{\sqrt{2}} (\sin \omega t \hat{i} + \cos \omega t \hat{k})$$

$$\phi = \vec{B} \cdot \vec{A}$$

$$= \frac{\mu_0 m I}{\sqrt{2}} \cos \omega t \cdot A$$

$$e = -\frac{d\phi}{dt} = \frac{\mu_0 m I \omega A}{\sqrt{2}} \sin \omega t$$

$$i = \frac{e}{R} = \frac{\mu_0 m I \omega A}{\sqrt{2} R} \sin \omega t$$

$$\vec{M} = i \times \vec{A}$$

$$\vec{\tau} = \vec{M} \times \vec{B} = \frac{\mu_0 m^2 I^2 \omega A^2}{\sqrt{2} R} \sin^2 \omega t (\hat{j})$$

$$= \frac{\alpha}{4} \hat{j}$$

$$\begin{aligned}
 \text{(IV)} \quad \vec{\tau} &= \vec{M} \times \vec{B} \\
 &= i \vec{A} \times \vec{B} \\
 &= \frac{e}{R} (\vec{A} \times \vec{B}) \\
 &= -\frac{d\phi}{dt} \left(\frac{\vec{A} \times \vec{B}}{R} \right) \\
 &= \frac{1}{R} \left[A \hat{k} \times \frac{\mu_0 m F}{\sqrt{2}} (\cos \omega t \hat{j} + \sin \omega t \hat{k}) \right] \\
 &= \frac{3}{4} \alpha \hat{i}
 \end{aligned}$$

16. Correct answer is [C].

Explanation : (I) Resultant velocity

$$v_{AB}^2 = v_A^2 + v_B^2 - 2v_{AB} \cos \theta$$

$$\omega_A = \omega_B, \theta = 90^\circ$$

$$v_A = v_B = 1 \text{ m/s}$$

$$v_{BA} = v_{BA} = \sqrt{2} \text{ m/s}$$

(II)

$$\vec{v}_A = \frac{5\pi}{2} \hat{i} + \frac{5\pi}{2} \hat{j}$$

$$\vec{v}_A = \frac{5\pi}{2} \hat{i} + \left(\frac{5\pi}{2} - \frac{10\pi}{3} \right) \hat{j} \\ = \frac{5\pi}{2} \hat{i} - \frac{5\pi}{6} \hat{j}$$

$$\vec{v}_B = -\frac{5\pi}{2} \hat{i} + \frac{5\pi}{2} \hat{j}$$

$$= -\frac{5\pi}{2} \hat{i} - \left(\frac{5\pi}{2} + 1 \right) \hat{j}$$

$$v_{BA} = -5\pi \hat{i} - \hat{j}$$

$$v_{BA} = \sqrt{25\pi^2 + 1}$$

(III) If $x_A = \sin t$, then $v_A = \cos t = \frac{1}{2} \text{ m/s}$

$$\text{If } x_B = \cos t, \text{ then } v_B = -\sin t = -\frac{\sqrt{3}}{2} \text{ m/s}$$

$$v_{BA} = -\left(\frac{\sqrt{3} + 1}{2} \right) \text{ m/s}$$

$$v_{AB} = \frac{1}{2} - \left(-\frac{\sqrt{3}}{2} \right) = \frac{1 + \sqrt{3}}{2} \text{ m/s}$$

(IV) \vec{v}_A and \vec{v}_B are perpendicular

$$|\vec{v}_{BA}| = \sqrt{v_A^2 + v_B^2}$$

$$= \sqrt{10} \text{ m/s}$$

17. Correct answer is [C].

Explanation : (I) According to work-energy theorem

$$\Delta U = \Delta Q - \Delta W$$

$$= \left((10^{-3} \times 2250) - \frac{10^5 (10^{-3} - 10^{-6})}{10^3} \right) \text{ kJ}$$

$$\Delta U = 2.1501 \text{ kJ}$$

(II) $\Delta U = nC_v \Delta T$

$$= \frac{5}{2} n R \Delta T$$

$$= \frac{5}{2} (0.2)(8)(1500 - 500) \text{ J}$$

$$= 4 \text{ kJ}$$

(III) $P_1 V_1^\gamma = P_2 V_2^\gamma$

$$2 \left(\frac{1}{3} \right)^{5/3} = P_2 \left(\frac{1}{24} \right)^{5/3}$$

$$P_2 = 64 \text{ kPa}$$

$$\Delta U = nC_v \Delta T = \frac{3}{2} (P_2 V_2 - P_1 V_1)$$

$$= \frac{3}{2} \left(64 \times \frac{1}{24} - 2 \times \frac{1}{3} \right) \text{ kJ}$$

$$= 3 \text{ kJ}$$

(IV) $\Delta U = nC_v \Delta T$

$$= n \cdot \frac{7}{2} R \Delta T$$

$$= 7 \text{ kJ}$$

18. Correct answer is option [A].

Explanation :

$$\text{(I)} \quad v_1 = \frac{uf}{u+f} = \frac{-20(10)}{-20+10} = 20 \text{ cm}$$

$$u_2 = 15$$

$$v_2 = \frac{15 \times 15}{15 + 15} = 7.5 \text{ cm}$$

(II) $v_1 = 20; u_2 = 15$

$$v_2 = \frac{15(-10)}{15 + (-10)} = -30 \text{ cm}$$

(III) $v_1 = 20; u_2 = 15; v_2 = \frac{15(-20)}{15 + (-20)} = 60 \text{ cm}$

(IV) $v_1 = \frac{(-20)(-20)}{-20 + (-20)} = -10 \text{ cm}$

$$u_2 = -15 \text{ cm}$$

$$v_2 = \frac{-15 \times 10}{-15 + 10} = 30 \text{ cm}$$

JEE Advanced (2022)

PAPER-II

Physics

SECTION 1

- This section contains **EIGHT (08)** questions.
- The answer to each question is a **SINGLE DIGIT INTEGER ranging from 0 to 9, BOTH INCLUSIVE**.
- For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 If ONLY the correct integer is entered;

Zero Marks : 0 If the question is unanswered;

Negative Marks : -1 In all other cases.

Q 1. A particle of mass 1 kg is subjected to a force which depends on the position as $\vec{F} = -k(x\hat{i} + y\hat{j})$ kg ms⁻² with $k = 1$ kg s⁻². At time

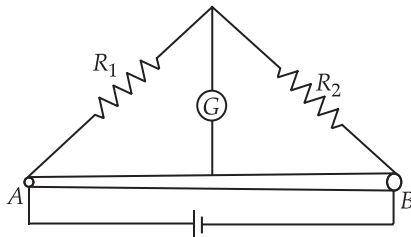
$$t = 0, \text{ the particle's position } \vec{r} = \left(\frac{1}{\sqrt{2}}\hat{i} + \sqrt{2}\hat{j} \right)$$

$$\text{and its velocity } \vec{v} = \left(-\sqrt{2}\hat{i} + \sqrt{2}\hat{j} + \frac{2}{\pi}\hat{k} \right) \text{ms}^{-1}$$

v_x and v_y denote the x and the y components of the particle's velocity, respectively. **Ignore gravity.** When $z = 0.5$ m, the value of $(xv_y - yv_x)$ is m²s⁻¹.

Q 2. In a radioactive decay chain reaction, ${}^{230}_{90}\text{Th}$ nucleus decays into ${}^{214}_{84}\text{Po}$ nucleus. The ratio of the number of α to number of β^- particles emitted in this process is

Q 3. Two resistances $R_1 = X \Omega$ and $R_2 = 1 \Omega$ are connected to a wire AB of uniform resistivity, as shown in the figure. The radius of the wire varies linearly along its axis from 0.2 mm at A to 1 mm at B. A galvanometer (G) connected to the centre of the wire, 50 cm from each end along its axis, shows deflection when A and B are connected to a battery. The value of X is



Q 4. In a particular system of units, a physical quantity can be expressed in terms of the electric charge e , electron mass m , Planck's constant h , and Coulomb's constant

$$k = \frac{1}{4\pi\epsilon_0}, \text{ where } \epsilon_0 \text{ is the permittivity of vacuum.}$$

In terms of these physical constants, the dimension of the magnetic field is $[B] = [e]^\alpha [m_e]^\beta [h]^\gamma [k]^\delta$. The value of $\alpha + \beta + \gamma + \delta$ is

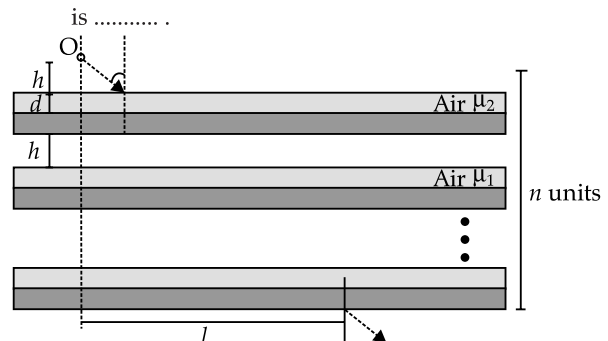
Q 5. Consider a configuration of n identical units, each consisting of three layers. The first layer is a column of air of height, $h = \frac{1}{3}$ cm, and the second and third layers are of equal thickness,

$$d = \frac{\sqrt{3}-1}{2} \text{ cm, and refractive indices}$$

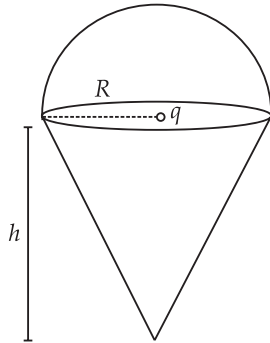
$$\mu_1 = \sqrt{\frac{3}{2}} \text{ and } \mu_2 = \sqrt{3}, \text{ respectively. A light}$$

source O is placed on the top of the first unit, as shown in the figure. A ray of light from O is incident on the second layer of the first unit at an angle of $\theta = 60^\circ$ to the normal. For a specific value of n , the ray of light emerges from the bottom of the configuration at a distance

$$l = \frac{8}{\sqrt{3}} \text{ cm, as shown in the figure. The value of } n$$



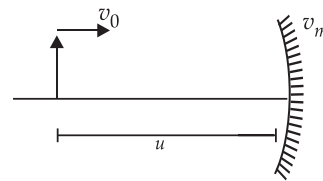
Q 6. A charge q is surrounded by a closed surface consisting of an inverted cone of height h and base radius R , and a hemisphere of radius R as shown in the figure. The electric flux through the conical surface is $\frac{nq}{6\epsilon_0}$ (in SI units). The value of n is



Q 7. On a frictionless horizontal plane, a bob of mass $m = 0.1$ kg is attached to a spring with natural length $l_0 = 0.1$ m. The spring constant is $k_1 = 0.009$

Nm^{-1} when the length of the spring $l > l_0$ and is $k_2 = 0.016 \text{ Nm}^{-1}$ when $l < l_0$. Initially the bob is released from $l = 0.15$ m. Assume that Hooke's law remains valid throughout the motion. If the time period of the full oscillation is $T = (n\pi) \text{ s}$, then the integer n is

Q 8. An object and a concave mirror of focal length $f = 10$ cm both move along the principal axis of the mirror with constant speeds. The object moves with speed $v_0 = 15 \text{ cm}^{-1}$ towards the mirror with respect to a laboratory frame. The distance between the object and the mirror at a given moment is denoted by u . When $u = 30$ cm, the speed of the mirror v_m is such that the image is instantaneously at rest with respect to the laboratory frame, and the object forms a real image. The magnitude of v_m is cm s^{-1} .

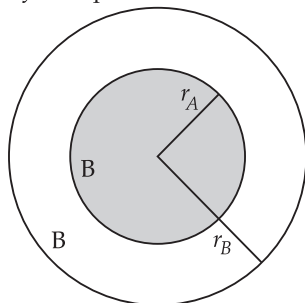


SECTION 2

- This section contains **NINE (09)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is (are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks	: +4	ONLY if (all) the correct option(s) is (are) chosen;
Patial Marks	: +3	If all the four options are correct but ONLY three options are chosen;
Partial Marks	: +2	If three or more optios are correct but ONLY two options are chosen, both of which are correct;
Partial Marks	: +1	If two or more options are correct but ONLY one option is chosen and it is a correct option;
Zero Marks	: 0	If unanswered;
Negative Marks	: -2	In all other cases.

Q 9. In the figure, the inner (shaded) region A represents a sphere of radius $r_A = 1$, within which the electrostatic charge density varies with the radial distance r from the center as $\rho_A = kr$, where k is positive. In the spherical shell B of outer radius r_B , the electrostatic charge density varies as $\rho_B = \frac{2k}{r}$. Assume that dimensions are taken care of. All physical quantities are in their SI units.



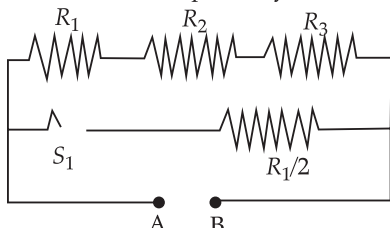
Which of the following statement(s) is (are) correct?

- (A) If $r_B = \sqrt{\frac{3}{2}}$, then the electric field is zero everywhere outside B.
- (B) If $r_B = \frac{3}{2}$, then the electric potential just outside B is $\frac{k}{\epsilon_0}$.
- (C) If $r_B = 2$, then the total charge of the configuration is $15\pi k$.
- (D) If $r_B = \frac{5}{2}$, then the magnitude of the electric field just outside B is $\frac{13\pi k}{\epsilon_0}$.

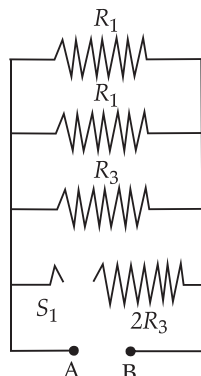
Q 10. In Circuit-1 and Circuit-2 shown in the figures, $R_1 = 1 \Omega$, $R_2 = 2 \Omega$ and $R_3 = 3 \Omega$.

P_1 and P_2 are the power dissipations in Circuit-1 and Circuit-2 when the switches S_1 and S_2 are in open conditions, respectively.

Q_1 and Q_2 are the power dissipations in Circuit-1 and Circuit-2 when the switches S_1 and S_2 are in closed conditions, respectively.



Circuit-1



Circuit-2

Which of the following statement(s) is (are) correct?

- (A) When a voltage source of 6 V is connected across A and B in both circuits, $P_1 < P_2$.
- (B) When a constant current source of 2 Amp is connected across A and B in both circuits, $P_1 > P_2$.
- (C) When a voltage source of 6 V is connected across A and B in Circuit-1, $Q_1 > P_1$.
- (D) When a constant current source of 2 Amp is connected across A and B in both circuits, $Q_2 < Q_1$.

Q 11. A bubble has surface tension S . The ideal gas inside the bubble has ratio of specific heats $\gamma = \frac{5}{3}$. The bubble is exposed to the atmosphere

and it always retains its spherical shape. When the atmospheric pressure is P_{a1} , the radius of the bubble is found to be r_1 and the temperature of the enclosed gas is T_1 . When the atmospheric pressure is P_{a2} , the radius of the bubble and the temperature of the enclosed gas are r_2 and T_2 , respectively. heat

Which of the following statement(s) is (are) correct?

(A) If the surface of the bubble is a perfect

insulator, then
$$\left(\frac{r_1}{r_2}\right)^5 = \frac{P_{a2} + \frac{2S}{r_2}}{P_{a1} + \frac{2S}{r_1}}$$

(B) If the surface of the bubble is a perfect heat insulator, then the total internal energy of the bubble including its surface energy does not change with the external atmospheric pressure.

(C) If the surface of the bubble is a perfect heat conductor and the change in atmospheric temperature is negligible, then

$$\left(\frac{r_1}{r_2}\right)^3 = \frac{P_{a2} + \frac{4S}{r_2}}{P_{a1} + \frac{4S}{r_1}}$$

(D) If the surface of the bubble is a perfect heat

insulator, then
$$\left(\frac{T_2}{T_1}\right)^{\frac{5}{2}} = \frac{P_{a2} + \frac{4S}{r_2}}{P_{a1} + \frac{4S}{r_1}}$$

Q 12. A disk of radius R with uniform positive charge density σ is placed on the xy plane with its center at the origin. The Coulomb potential along the z -axis is

$$V(z) = \frac{\sigma}{2\epsilon_0} \left(\sqrt{R^2 + z^2} - z \right).$$

A particle of positive charge q is placed initially at rest at a point on the z axis with $z = z_0$ and $z_0 > 0$. In addition to the Coulomb force, the particle

experiences a vertical force $\vec{F} = -c \hat{k}$, $c > 0$. Let $\beta = \frac{2c\epsilon_0}{q\sigma}$. Which of the following statement(s) is

(are) correct?

(A) For $\beta = \frac{1}{4}$ and $z_0 = \frac{25}{7}R$, the particle reaches the origin.

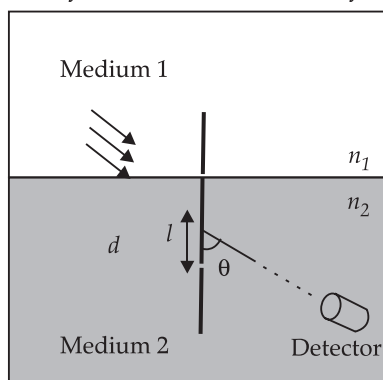
(B) For $\beta = \frac{1}{4}$ and $z_0 = \frac{3}{7}R$, the particle reaches the origin.

(C) For $\beta = \frac{1}{4}$ and $z_0 = \frac{R}{\sqrt{3}}$, the particle returns back to $z = z_0$.

(D) For $\beta > 1$ and $z_0 > 0$, the particle always reaches the origin.

Q 13. A double slit setup is shown in the figure. One of the slits is in medium 2 of refractive index n_2 . The other slit is at the interface of this medium with another medium 1 of refractive index n_1 ($n_1 \neq n_2$). The line joining the slits is perpendicular to the interface and the distance between the slits is d . The slit widths are much smaller than d . A monochromatic parallel beam of light is incident on the slits from

medium 1. A detector is placed in medium 2 at a large distance from the slits, and at an angle θ from the line joining them, so that θ equals the angle of refraction of the beam. Consider two approximately parallel rays from the slits received by the detector.



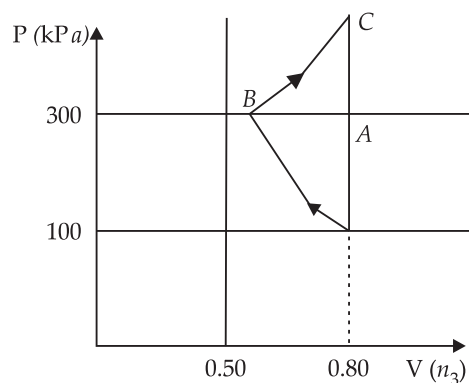
Which of the following statement(s) is (are) correct?

- (A) The phase difference between the two rays is independent of d .
- (B) The two rays interfere constructively at the detector.
- (C) The phase difference between the two rays depends on n_1 but is independent of n_2 .
- (D) The phase difference between the two rays vanishes only for certain values of d and the angle of incidence of the beam, with θ being the corresponding angle of refraction.

Q 14. In the given P-V diagram, a monoatomic gas

$\left(\gamma = \frac{5}{3}\right)$ is first compressed adiabatically from state A to state B. Then it expands isothermally from state B to state C.

[Given: $\left(\frac{1}{3}\right)^{0.6} \approx 0.5, \ln 2 \approx 0.7$]



Which of the following statement(s) is (are) correct?

- (A) The magnitude of the total work done in the process $A \rightarrow B \rightarrow C$ is 144 kJ.
- (B) The magnitude of the work done in the process $B \rightarrow C$ is 84 kJ.
- (C) The magnitude of the work done in the process $A \rightarrow B$ is 60 kJ.
- (D) The magnitude of the work done in the process $C \rightarrow A$ is zero.

SECTION 3

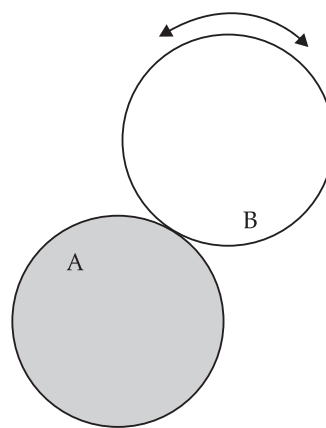
- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme :

Full Marks : +3 **ONLY** the correct option is chosen;

Zero Marks : 0 If none of the options is chosen (*i.e.*, the question is unanswered);

Negative Marks : -1 In all other cases.

Q 15. A flat surface of a thin uniform disk A of radius R is glued to a horizontal table. Another thin uniform disk B of mass M and with the same radius R rolls without slipping on the circumference of A, as shown in the figure. A flat surface of B also lies on the plane of the table. The center of mass of B has fixed angular speed ω about the vertical axis passing through the center of A. The angular momentum of B is $nM\omega R^2$ with respect to the center of A. Which of the following is the value of n ?



- (A) 2 (B) 5
 (C) $\frac{7}{2}$ (D) $\frac{9}{2}$

Q 16. When light of a given wavelength is incident on a metallic surface, the minimum potential needed to stop the emitted photoelectrons is 6.0 V. This potential drops to 0.6 V if another source with wavelength four times that of the first one and intensity half of the first one is used. What are the wavelength of the first source and the work function of the metal, respectively ?

[Take $\frac{hc}{e} = 1.24 \times 10^{-6} \text{ J m C}^{-1}$.]

- (A) $1.72 \times 10^{-7} \text{ m}$, 1.20 eV
 (B) $1.72 \times 10^{-7} \text{ m}$, 5.60 eV
 (C) $3.78 \times 10^{-7} \text{ m}$, 5.60 eV
 (D) $3.78 \times 10^{-7} \text{ m}$, 1.20 eV

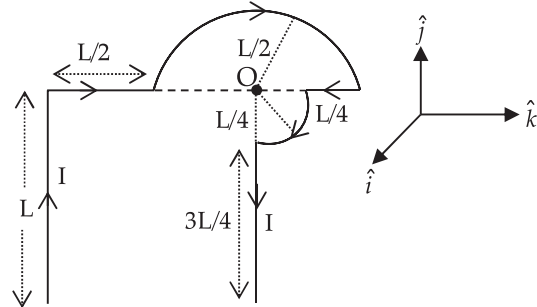
Q 17. Area of the cross-section of a wire is measured using a screw gauge. The pitch of the main scale is 0.5 mm. The circular scale has 100 divisions and for one full rotation of the circular scale, the main scale shifts by two divisions. The measured readings are listed below :

Measurement condition	Main scale reading	Circular scale reading
Two arms of gauge touching each other without wire	0 division	4 divisions
Attempt-1 : With wire	4 divisions	20 divisions
Attempt-2 : With wire	4 divisions	16 divisions

What are the diameter and cross-sectional area of the wire measured using the screw gauge?

- (A) $2.22 \pm 0.02 \text{ mm}$, $\pi(1.23 \pm 0.02) \text{ mm}^2$
 (B) $2.22 \pm 0.01 \text{ mm}$, $\pi(1.23 \pm 0.01) \text{ mm}^2$
 (C) $2.14 \pm 0.02 \text{ mm}$, $\pi(1.14 \pm 0.02) \text{ mm}^2$
 (D) $2.14 \pm 0.01 \text{ mm}$, $\pi(1.14 \pm 0.01) \text{ mm}^2$

Q 18. Which one of the following options represents the magnetic field \vec{B} at O due to the current flowing in the given wire segments lying on the xy plane?



- (A) $\vec{B} = \frac{-\mu_0 I}{L} \left(\frac{3}{2} + \frac{1}{4\sqrt{2}\pi} \right) \hat{k}$
 (B) $\vec{B} = -\frac{\mu_0 I}{L} \left(\frac{3}{2} + \frac{1}{2\sqrt{2}\pi} \right) \hat{k}$
 (C) $\vec{B} = \frac{-\mu_0 I}{L} \left(1 + \frac{1}{4\sqrt{2}\pi} \right) \hat{k}$
 (D) $\vec{B} = \frac{-\mu_0 I}{L} \left(1 + \frac{1}{4\pi} \right) \hat{k}$

□□

Q.No.	Answer key	Topic's name	Chapter's name
Section -I			
1	3	SHM	Electronic Devices
2	2	Decay	Atoms and Nuclei
3	5	Wheatstone bridge	Current Electricity
4	4	Dimensions	Physics and Measurement
5	4	Snell's Law	Optics
6	3	Electric flux	Electrostatics
7	6	SHM	Oscillations and Waves
8	3	Optics	Optics
Section -II			
9	B	Electrostatic Potential	Electrostatics
10	A,B & C	Current Electricity	Current Electricity
11	C & D	Properties of Liquids	Properties of Solids and Liquids
12	A, C & D	Electrostatic Potential	Electrostatics
13	A & B	Optics	Optics
14	C & D	Heat, Work and Internal Energy	Thermodynamics
Section -III			
15	B	Angular Momentum	Rotational Motion
16	A	Work Function	Dual Nature of Matter and Radiation
17	D	Least Count Error	Physics and Measurement
18	C	Magnetic Field	Magnetic Effects of Current and Magnetism

Answers

SECTION - 1

1. Correct answer is [3]

Explanation: As the restoring force acts, so

$$F_x = -kx = ma_x \\ = -x \quad (k = 1)$$

$$a = \frac{d^2x}{dt^2} = -x$$

As,

$$x = A_x \sin(\omega t + \phi_x) \\ x = A_x \sin(t + \phi_x) \quad (\omega = 1 \text{ rad/s})$$

$$V_x = A_x \omega \cos(\omega t + \phi_x)$$

At, $t = 0$; $x = \frac{1}{\sqrt{2}}$ and $v_x = -\sqrt{2} \text{ m/s}$

$$\frac{1}{\sqrt{2}} = A_x \sin(\phi_x)$$

and $-\sqrt{2} = A_x \cos(\phi_x)$

$$\tan \phi_x = \frac{-1}{2} \quad \text{So } A_x = \sqrt{\frac{5}{2}} \text{ m}$$

Again

$$F_y = -ky = -y = ma_y \\ \frac{d^2y}{dt^2} = -y$$

$$y = A_y \sin(\omega t + \phi_y) \\ v_y = A_y \omega \cos(\omega t + \phi_y)$$

At $t = 0$: $y = \sqrt{2} \text{ m}$ and $v_y = \sqrt{2} \text{ m/s}$

$$\sqrt{2} = A_y \sin \phi_y$$

$$\sqrt{2} = A_y \cos \phi_y$$

$$\tan \phi = 1 \text{ and } \phi = \frac{\pi}{4}$$

Hence, $A_y = 2$

Now

$$(xv_y - yv_x) = \sqrt{\frac{5}{2}} \sin(\omega t + \phi_x) \times 2 \cos(\omega t + \phi_y)$$

$$-2 \sin(\omega t + \phi_y) \times \sqrt{\frac{5}{2}} \cos(\omega t + \phi_x)$$

$$= \sqrt{10} \sin(\phi_x - \phi_y)$$

$$= \sqrt{10} (\sin \phi_x \cos \phi_y - \cos \phi_x \sin \phi_y)$$

$$= \sqrt{10} \left(\frac{1}{\sqrt{5}} \times \frac{1}{\sqrt{2}} - \left(-\frac{2}{\sqrt{5}} \times \frac{1}{\sqrt{2}} \right) \right)$$

$$= 3$$

2. Correct answer is [2]

Explanation: Let the number of α -particles be n_α

Let the number of β -particles be n_β

Hence, $4n_\alpha = 230 - 214$

$$n_\alpha = 4$$

$$n_\beta = 84 - (90 - 2n_\alpha)$$

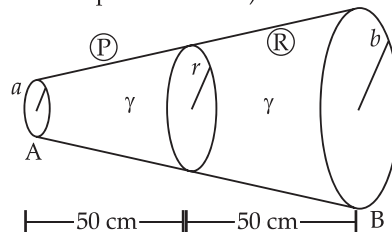
$$= 84 - 90 + 2(4)$$

$$= 2$$

So, $\frac{n_\alpha}{n_\beta} = \frac{4}{2} = 2 : 1$

3. Correct answer is [5]

Explanation: According to the given condition wire is having different cross-section at two junction. (Frustum shaped conductor)



$$r = \frac{a+b}{2} = \frac{0.2+1}{2} = 0.6 \quad \dots(i)$$

As $R = \frac{\rho l}{A} \quad \dots(ii)$

Hence, Resistance of left 50 cm wire

$$= \frac{\rho \times 0.5 \times 10^6}{\pi \times 0.2 \times 0.6}$$

Resistance of Right 50 cm wire

$$= \frac{\rho \times 0.5 \times 10^6}{\pi \times 0.6 \times 1}$$

For wheatstone balanced condition

$$\frac{R_1}{P} = \frac{R_2}{Q} \quad (R_1 = X)$$

$$\frac{(X) \times \pi \times 0.2 \times 0.6}{\rho \times 0.5 \times 10^6} = \frac{(1\pi) \times 0.6 \times 1}{\rho \times 0.5 \times 10^6}$$

$$\frac{(X) \times \pi \times 0.12}{\rho \times 0.5 \times 10^6} = \frac{\pi \times 0.6 \times 1}{\rho \times 0.5 \times 10^6}$$

$$X = 5$$

4. Correct answer is [4]

Explanation: Given equation,

$$[B] = [e]^\alpha [M_e]^\beta [h]^\gamma [K]^\delta$$

$$[M^1 T^{-2} L^{-1}] = [IT]^\alpha [M]^\beta [ML^2 T^{-1}]^\gamma [ML^3 T^{-4}]^\delta$$

on comparing the order on both sides

$$\beta + \gamma + \delta = 1$$

$$2\gamma + 3\delta = 0$$

$$\alpha - \gamma - 4\delta = -2$$

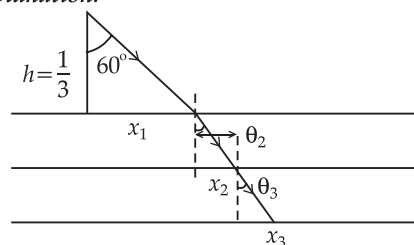
$$\alpha - 2\delta = -1$$

On solving above equations

$$\alpha + \beta + \gamma + \delta = 4$$

5. Correct answer is [4]

Explanation:



$$x_1 = \frac{1}{3} \times \tan 60$$

$$= \frac{1}{\sqrt{3}} \text{ cm}$$

By Snell's law

$$1 \times \sin 60 = \frac{\sqrt{3}}{\sqrt{2}} \sin \theta_2$$

$$\theta_2 = 45^\circ$$

$$x_2 = d$$

Again, by applying Snell's law

$$\sqrt{\frac{3}{2}} \times \frac{1}{\sqrt{2}} = \sqrt{3} \times \sin \theta_3$$

$$\theta_3 = 30^\circ$$

$$x_3 = \frac{d}{\sqrt{3}}$$

Also

$$x_1 + x_2 + x_3 = \frac{1}{\sqrt{3}} + d + \frac{d}{\sqrt{3}}$$

$$= \frac{1}{\sqrt{3}} + \left(\frac{\sqrt{3}-1}{2} \right) + \frac{\sqrt{3}-1}{2\sqrt{3}}$$

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

$$= \frac{4}{2\sqrt{3}}$$

$$x_1 + x_2 + x_3 = \frac{2}{\sqrt{3}} \text{ cm}$$

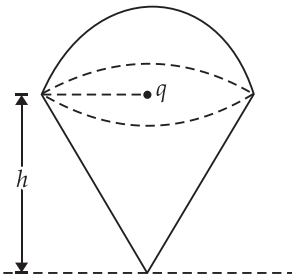
And, $\eta = \frac{l}{x_1 + x_2 + x_3}$

$$\eta = \frac{8/\sqrt{3}}{2/\sqrt{3}} = 4$$

$$\eta = 4$$

6. Correct answer is [3]

Explanation:



So from symmetrical approach

Flux, $\phi = \frac{q_{in}}{\epsilon_0}$

Flux through cone, $\phi = \frac{q}{2\epsilon_0}$

On comparing it with given values, we get:

$$n = 3$$

7. Correct answer is [6]

Explanation: Time period of oscillation

$$= T_1 + T_2$$

$$= \pi \sqrt{\frac{m}{K_1}} + \pi \sqrt{\frac{m}{K_2}}$$

$$= \pi \sqrt{\frac{0.1}{0.009}} + \pi \sqrt{\frac{0.1}{0.016}}$$

$$= \frac{\pi}{0.3} + \frac{\pi}{0.4}$$

$$= \frac{\pi(0.4+0.3)}{0.12}$$

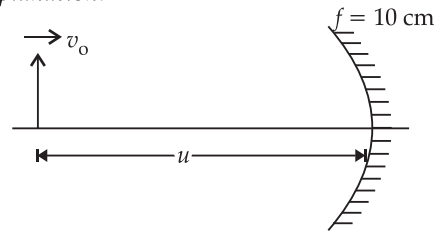
$$= \frac{70\pi}{12}$$

$$= 5.83\pi \text{ seconds}$$

$$\approx 6\pi \text{ seconds}$$

8. Correct answer is [3]

Explanation:



Magnification, $m = \frac{f}{u-f}$

$$= \frac{10}{30-10} = \frac{1}{2}$$

Also $m^2 = \frac{v_m}{v_0 - v_m}$

[where, v_m = speed of mirror]

$$m^2(v_0 - v_m) = v_m$$

$$(v_0 - v_m) \times \frac{1}{4} = v_m$$

$$v_0 = 5v_m$$

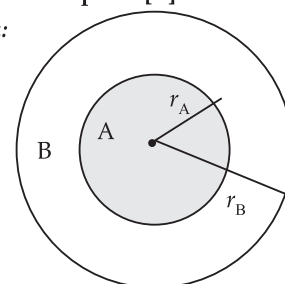
$$v_m = \frac{v_0}{5} = \frac{15}{5}$$

$$v_m = 3 \text{ cm/s}$$

SECTION - 2

9. Correct answer is option [B]

Explanation:



$$Q_{\text{total}} = \int_0^{r_A} kr(4\pi r^2)dr + \int_r^{r_A} \frac{2k}{r}(4\pi r^2)dr$$

$$= \frac{4\pi r^4 k}{4} \Big|_0^{r_A} + 8\pi k \frac{r^2}{2} \Big|_r^{r_A}$$

$$= \pi r_A^4 k + 4\pi k (r_B^2 - r_A^2)$$

(A) If $r_B = \sqrt{\frac{3}{2}}$ & $r_A = 1$

$$Q_{\text{total}} = \pi k r_A^4 + 4\pi k \left(\frac{3}{2} - r_A^2 \right)$$

$$= \pi k + 4\pi k \left(\frac{3}{2} - 1 \right)$$

$$= 3\pi k$$

(B) If $r_B = \frac{3}{2}$ & $r_A = 1$

$$Q_{\text{total}} = \pi k r_A^4 + 4\pi k \left(\frac{9}{4} - 1 \right)$$

$$= 6\pi k$$

$$V = \frac{1}{4\pi\epsilon_0} \left(\frac{6\pi k}{r_B} \right) = \frac{k}{\epsilon_0}$$

Hence, $V = \frac{k}{\epsilon_0}$

(C) If $r_B = 2$

$$Q_{\text{total}} = 13\pi k$$

(D) If $r_B = 5/2$

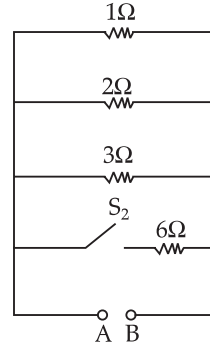
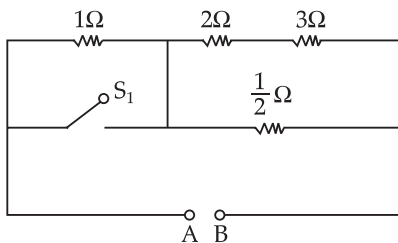
$$Q_{\text{total}} = 22\pi k$$

$$E = \frac{1}{4\pi\epsilon_0} \frac{(22\pi k)}{25} \times 4$$

$$E = \frac{22k}{25\epsilon_0}$$

10. Correct answer is option [A, B & C].

Explanation:



Case I: When both S_1 and S_2 open

$$R_{\text{eq}(1)} = 1 + \frac{5 \times \frac{1}{2}}{5 + \frac{1}{2}} = 1 + \frac{5}{\pi} = \frac{16}{11} \Omega$$

$$P_{(1)} = \frac{V^2}{R_{\text{eq}(1)}} = \frac{(6)^2}{16} \times 11 = \frac{36 \times 11}{16} = \frac{99}{4} \text{ Watt}$$

$$R_{\text{eq}(2)} = \frac{6}{11} \Omega$$

$$P_{(2)} = \frac{v^2}{R_{\text{eq}(2)}} = \frac{36 \times 11}{6} = 66 \text{ Watt}$$

$$P_2 > P_1$$

If $I = 2A$ is used in both circuits, then

$$P_1 = i^2(R_{\text{eq}(1)})$$

$$= 4 \times \frac{16}{11} = \frac{64}{11} \text{ Watt}$$

$$P_2 = i^2(R_{\text{eq}(2)})$$

$$= 4 \times \frac{6}{11} = \frac{24}{11}$$

$$P_1 > P_2$$

For Q_1

$$R_{\text{eq}} = \frac{5}{11} \Omega$$

$$Q_1 = \frac{V^2}{R_{\text{eq}}} = \frac{(6)^2}{5/11} = \frac{36 \times 11}{5} \text{ Watt}$$

$$P_1 = 24.75 \text{ W} = \frac{64}{11} \text{ Watt}$$

$$Q_1 > P_1$$

11. Correct answer are option [C, D]

Explanation: For adiabatic process:

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1} \right)^\gamma \Rightarrow P_1 V_1^\gamma = P_2 V_2^\gamma$$

$$\left(P_{a1} + \frac{4S}{\gamma_1} \right) \left(\frac{4}{3} \pi r_1^3 \right)^{5/3}$$

$$= \left(P_{a2} + \frac{4S}{r_2} \right) \left(\frac{4}{3} \pi r_2^3 \right)^{5/3}$$

$$\left(\frac{r_1}{r_2}\right)^5 = \frac{P_{a2} + 4S/r_2}{P_{a1} + 4S/r_1}$$

Also, $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

$$\frac{T_2}{T_1} = \frac{(P_{a2} + 4S/r_2)^{2/5}}{\left(P_{a2} + \frac{4S}{r_1}\right)^{2/5}}$$

At same temperature,

$$P_1 V_1 = P_2 V_2$$

$$\left(P_{a1} + \frac{4S}{r_1}\right) \left(\frac{4}{3} \pi r_1^3\right) = \left(P_{a2} + \frac{4S}{r_2}\right) \left(\frac{4}{3} \pi r_2^3\right)$$

$$\left(\frac{r_1}{r_2}\right)^3 = \frac{P_{a2} + 4S/r_2}{P_{a1} + 4S/r_1}$$

12. Correct answer are option [A, C, D].

Explanation:

$$V(z) = \frac{\sigma}{2\epsilon_0} (\sqrt{R^2 + z^2} - z)$$

$$U(z)_{net} = \frac{\sigma q}{2\epsilon_0} (\sqrt{R^2 + z^2} - z) + cz$$

$$= c \left[\frac{\sigma q}{2c\epsilon_0} (\sqrt{R^2 + z^2} - z) + z \right]$$

When, $z = 0$ and $\beta = 1/4$

$$U(z)_{net} = c(4R) = 4Rc$$

When, $z = z_0 = \frac{25}{7}R$ and; $B = \frac{1}{4}$

$$U(z)_{net} = C \left[4 \times \frac{26R}{7} - 3 \times \frac{25R}{7} \right] = \frac{29Rc}{7}$$

When, $z = z_0 = \frac{3R}{7}$ and $\beta = \frac{1}{4}$

$$U(z)_{net} = 3Rc$$

When, $Z = \frac{R}{\sqrt{3}}$ and $\beta = \frac{1}{4}$

$$U(z)_{net} = 2.887 Rc$$

As per option (A), particle reaches at origin with the KE

$$\frac{d(U)_z}{dz} = 0 \text{ at } z = \frac{3R}{\sqrt{7}}$$

So, at $\beta = \frac{1}{4}$ and $z = \frac{3R}{\sqrt{7}}$

$$U(z)_{net} = \sqrt{7}Rc = 2.645 Rc$$

Similarly, for option (B),

$U(z)_{net}$ at $z = \frac{R}{\sqrt{3}}$ the kinetic energy at origin will

become negative and nearly equal to $3Rc$

Also, for option (C)

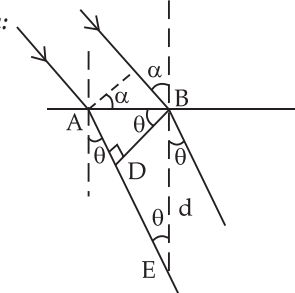
$$U(z)_{net} \text{ at } Z = \frac{R}{\sqrt{3}} > U(z)_{net} \text{ at } z = \frac{3R}{\sqrt{7}}$$

Particle will return to z_0

As per option D ($\beta > 1$ & $z_0 > 0$) $U(z)_{net}$ increases continuously with Z . So, particle reaches the origin.

13. Correct answer is options [A, B].

Explanation:



$$\tan \theta = \frac{AB}{d}$$

And, $AB = d \tan \theta$... (i)

$$BC = AB \sin \alpha = d \tan \theta \sin \alpha$$

$$AD = AB \sin \theta$$

Path difference in vacuum

$$\Delta x = n_1 BC - n_2 AD$$

$$\Delta x = n_1 (AB) \sin \alpha - n_2 (AB \sin \theta)$$

Hence, $AB (n_1 \sin \alpha - n_2 \sin \theta) = 0$

14. Correct answer is option [C, D].

Explanation: For adiabatic process,

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

$$= 100(0.8)^{5/3} = 300(V)^{5/3}$$

$$V = V_B = \frac{0.8}{3^{3/5}}$$

$$W_{AB} = \frac{P_A V_A - P_B V_B}{\left(\frac{5}{3} - 1\right)} = \frac{80 - 300 \times \frac{0.8}{3^{3/5}}}{2/3}$$

$$W_{AB} = -60 \text{ kJ}$$

As volume is constant, So it is a Isochoric process (C → A)

$$\text{Also, } W_{BC} = nRT \ln \frac{V_2}{V_1} = PV \ln \left(\frac{V_2}{V_1} \right)$$

$$= 300 \times \frac{0.8}{3^{3/5}} \ln \left[\frac{0.8}{0.8} \times 3^{3/5} \right]$$

Hence, $W_{BC} = 79 \text{ kJ}$

SECTION - 3

15. Correct answer is option [B].

Explanation: Angular momentum of B with respect to A

$$\vec{L} = \vec{L}_{CM} + \vec{L}_{Body}$$

$$= M(2R)^2 \omega_{\hat{k}} + \frac{MR^2}{2} (\omega_{\text{body}})_{\hat{k}}$$

$$= \left(2MR^2 \omega + \frac{MR^2 \omega_{(z)}}{2} \right)_{\hat{k}}$$

$$= \left(\frac{4MR^2 \omega + 2MR^2 \omega}{2} \right)_{\hat{k}}$$

$$\vec{L} = 5MR^2 \omega \hat{k}$$

Hence, by comparing it with angular momentum, we get $n = 5$

16. **Correct answer is option [A]**

Explanation: By Einstein's photoelectric equation, we have:

$$\text{KE} = h\nu - \phi$$

$$h\nu - \phi = 6 \text{ eV}$$

$$\frac{hc}{\lambda} - \phi = 6 \text{ eV} \quad \dots(i)$$

$$\frac{hc}{4\lambda} - \phi = 0.6 \text{ eV}$$

$$\frac{3hc}{4\lambda} = 5.4 \text{ eV} : \lambda = \frac{3hc}{5.4 \text{ eV} \times 4}$$

$$\lambda = \frac{3 \times 1.24 \times 10^{-6}}{4 \times 5.4} = 1.72 \times 10^{-7} \text{ m} \quad \dots(ii)$$

From equation (i) & (ii), we conclude

$$\frac{hc}{1.72 \times 10^{-7}} \times \frac{1}{1.6 \times 10^{-19}} - \phi = 6 \text{ eV}$$

on substituting all the values we get

$$\phi = (7.27 - 6)$$

$$\phi = 1.27 \text{ eV}$$

$$\phi = 1.20 \text{ eV}$$

17. **Correct answer option is (D).**

Explanation: For Case I,

$$\text{MSR} = 4 \times 0.5 = 2 \text{ mm}$$

$$\text{CSR} = \frac{1}{100} \times 20 = 0.20 \text{ mm}$$

$$\text{Zero error} = \frac{1}{100} \times 4 = 0.04 \text{ mm}$$

Let x_1 be reading in Case I

$$x_1 = \text{MSR} + \text{CSR} - \text{zero error}$$

$$= 2 + 0.20 - 0.04$$

$$= 2.20 - 0.04$$

$$x_1 = 2.16 \text{ mm}$$

For Case II,

$$\text{MSR} = 4 \times 0.5 = 2 \text{ mm}$$

$$\text{CSR} = \frac{1}{100} \times 16 = 0.16 \text{ mm}$$

$$\text{zero error} = \frac{1}{100} \times 4 = 0.04 \text{ mm}$$

Let x_2 be reading in Case II

$$x_2 = \text{MSR} + \text{CSR} - \text{zero error}$$

$$= 2 + 0.16 - 0.04$$

$$= 2.16 - 0.04$$

$$= 2.12 \text{ mm}$$

$$\text{Average reading} = \frac{x_1 + x_2}{2} = 2.14 \text{ mm}$$

$$\text{Area} = \pi r^2 = \frac{\pi d^2}{4}$$

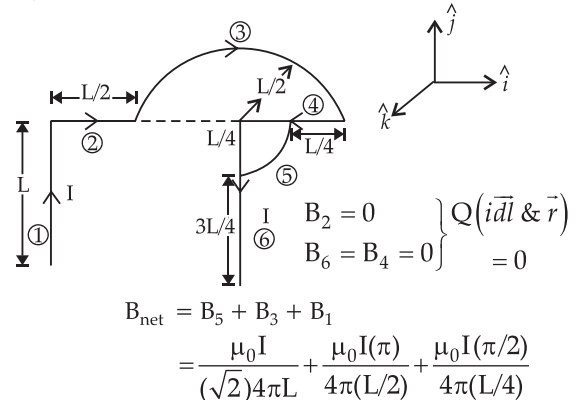
$$dA = \frac{2\pi d}{4} (\Delta d)$$

$$\text{error} = \frac{1}{100} = 0.01 \text{ mm}$$

Hence, $A = \pi [1.14 + 0.01] \text{ mm}^2$

18. **Correct answer is option [C]**

Explanation:



$$B_{\text{net}} = B_5 + B_3 + B_1$$

$$= \frac{\mu_0 I}{(\sqrt{2})4\pi L} + \frac{\mu_0 I(\pi)}{4\pi(L/2)} + \frac{\mu_0 I(\pi/2)}{4\pi(L/4)}$$

$$B_0 = B_{\text{net}} = -\frac{\mu_0 I}{L} \left(1 + \frac{1}{4\sqrt{2}\pi} \right) (\hat{k})$$

□□□