JEE Advanced (2022)

PAPER-II

Physics

SECTION 1

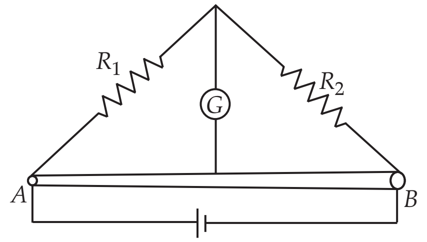
- This section contains **EIGHT (08)** questions.
- The answer to each question is a **SINGLE DIGIT INTEGER ranging from 0 to 9, BOTH INCLUSIVE.**
- For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated 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 $t = 0$, the particle's position $\vec{r} = \left(\frac{1}{\sqrt{2}}\hat{i} + \sqrt{2}\hat{j}\right)$ and its velocity $\vec{v} = \left(-\sqrt{2}\,\hat{i} + \sqrt{2}\,\hat{j} + \frac{2}{\pi}\hat{k}\right)$ ms^{-1} v_x and v_y denote the x and the y components of the particle's velocity, respectivey. **Ignore gravity.** When $z = 0.5$ m, the value of $(xv_y - yv_x)$ is .... m^{2}s^{-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 ....

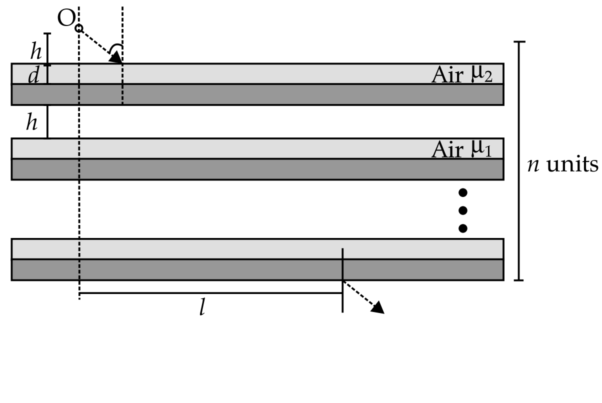
Q 3. Two resistances R_1 = X Ω and R_2 = 1 Ω are connected to a wire AB of uniform resistivity, as shown in the figure. The radius of the wire varies linearly along its axis from 0.2 mm at A to 1 mm at B. A galvanometer (G) connected to the centre of the wire, 50 cm from each end along its axis, shows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



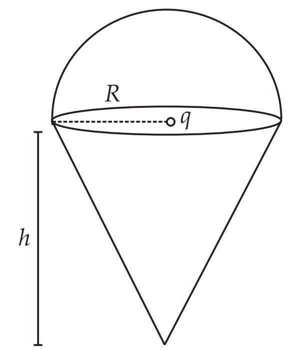
Q 4. In a particular system of units, a physical quantity can be expressed in terms of the electric charge e, electron mass m, Planck's constant h, and Coulomb's constant $k = \frac{1}{4\pi\varepsilon_0}$, where ε_0 is the permittivity of vacuum.

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, $d = \frac{\sqrt{3}-1}{2}$ cm, and refractive indices $\mu_1 = \sqrt{\frac{3}{2}}$ and $\mu_2 = \sqrt{3}$, 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 $\theta = 60°$ to the normal. For a specific value of n, the ray of light emerges from the bottom of the configuration at a distance $l = \frac{8}{\sqrt{3}}$ cm, as shown in the figure. The value of n is ....

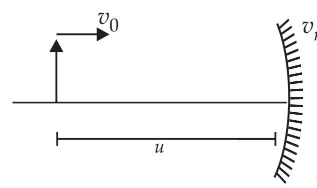


Q 6. A charge q is surrounded by a closed surface consisting of an inverted cone of height h and base radius R, and a hemisphere of radius R as shown in the figure. The electric flux through the conical surface is $\frac{nq}{6\varepsilon_0}$ (in SI units). The value of n is ....



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 $k_2 = 0.016$ 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 = ($n\pi$) s, then the integer cleses to 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 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}.

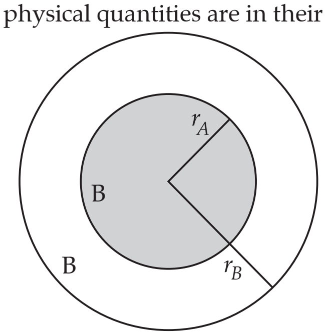


SECTION 2

- 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 $\frac{k}{\varepsilon_0}$.

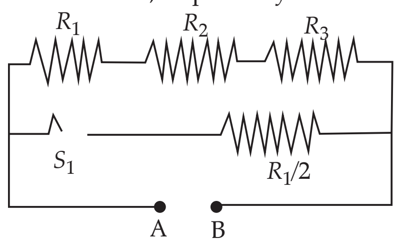
(C) If r_B = 2, then the total charge of the configuration is 15 πk.

(D) If $r_B = \frac{5}{2}$, then the magnitude of the electric field just outside B is $\frac{13\pi k}{\varepsilon_0}$.

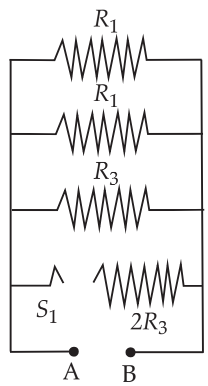
Q 10. In Circuit-1 and Circuit-2 shown in the figures, R_1 = 1 Ω, R_2 = 2 Ω and R_3 = 3 Ω.

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 isulator, 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 place on the xy plane with its center at the origin. The Coulomb potential along the z-axis is

$$V(z) = \frac{\sigma}{2\varepsilon_0}\left(\sqrt{R^2 + z^2} - z\right).$$

A particle of positive charge q is place 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 $\beta = \frac{2c\varepsilon_0}{q\sigma}$. Which of the following statement(s) is (are) correct?

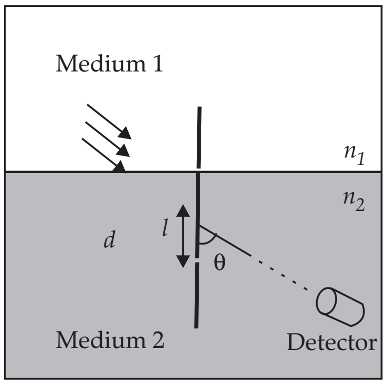
(A) For $\beta = \frac{1}{4}$ and $z_0 = \frac{25}{7}R$, the particle reaches the origin.

(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 $n_1 (\neq n_2)$. 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.

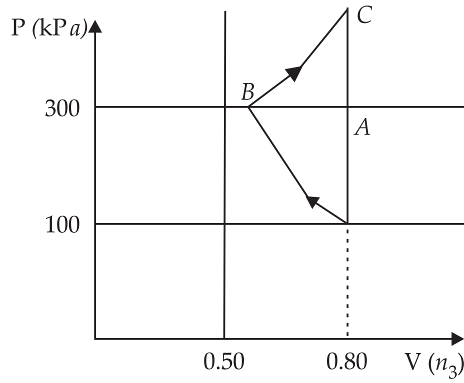
(B) The two rays interfere constructively at the detector.

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



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

(A) The magnitude of the total work done in the process $A \to B \to C$ is 144 kJ.

(B) The magnitude of the work done in the process $B \to C$ is 84 kJ.

(C) The magnitude of the work done in the process $A \to B$ is 60 kJ.

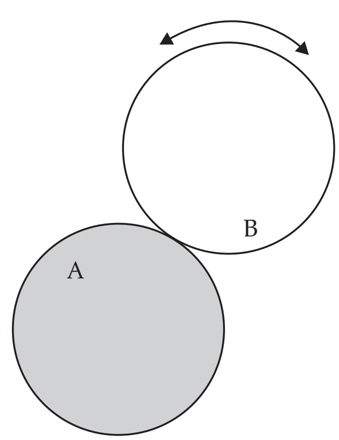
(D) The magnitude of the work done in the process $C \to A$ is zero.

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

(A) 1.72×10^{-7} m, 1.20 eV
(B) 1.72×10^{-7} m, 5.60 eV
(C) 3.78×10^{-7} m, 5.60 eV
(D) 3.78×10^{-7} m, 1.20 eV

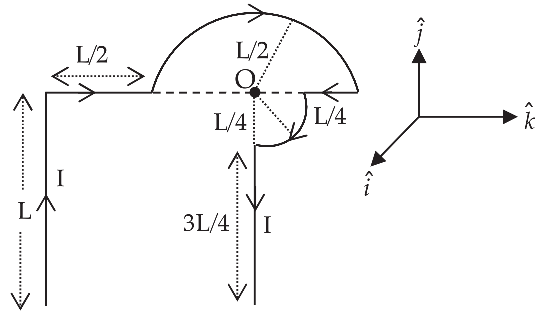
Q 17. Area of the cross-section of a wire is measured using a screw gauge. The pitch of the main scale is 0.5 mm. The circular scale has 100 divisions and for one full rotation of the circular scale, the main scale shifts by two divisions. The measured readings are listed below :

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 ± 0.02 mm, $\pi(1.23 \pm 0.02)$ mm^2
(B) 2.22 ± 0.01 mm, $\pi(1.23 \pm 0.01)$ mm^2
(C) 2.14 ± 0.02 mm, $\pi(1.14 \pm 0.02)$ mm^2
(D) 2.14 ± 0.01 mm, $\pi(1.14 \pm 0.01)$ mm^2

Q 18. Which one of the following options represents the magnietic 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

$$Fx = -kx = ma_x$$
$$= -x \qquad (k = 1)$$
$$a = \frac{d^2x}{d+2} = -x$$

As, $x = A_x \sin(\omega t + \phi\, x)$

$x = A_x \sin(t + \phi\, x) \qquad (\omega = 1\text{rad/j})$

$V_x = A_x \omega \cos(\omega t + \phi\, x)$

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

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

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

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

Again

$$F_y = -k_y = -y = ma_y$$
$$\frac{d^2y}{d+2} = -y$$
$$y = A_y \sin(\omega t + \phi_y)$$
$$v_y = A_y \omega\cos(\omega t + \phi_y)$$

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

$$({}_x v_y - {}_y v_x) = \sqrt{\frac{5}{2}}\sin(\omega t + \phi_x) \times 2\cos(\omega t + \phi_y)$$
$$-2\sin(\omega t + \phi_y) \times \sqrt{\frac{5}{2}}\cos(\omega t + \phi_x)$$
$$= \sqrt{10}\sin(\phi_x - \phi_y)$$
$$= \sqrt{10}(\sin\phi_x \cos\phi_y - \cos\phi_x \sin\phi_y)$$
$$= \sqrt{10}\left(\frac{1}{\sqrt{5}} \times \frac{1}{\sqrt{2}} - \left(-\frac{2}{\sqrt{5}} \times \frac{1}{\sqrt{2}}\right)\right)$$
$$= 3$$

2. Correct answer is [2]

Explanation: Let the number of α-particles be n_α

Let the number of β-particles be n_β

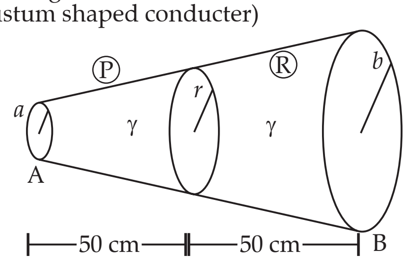
Hence, $4n_\alpha = 230 - 214$

$$n_\alpha = 4$$
$$n_\beta = 84 - (90 - 2n_\alpha)$$
$$= 84 - 90 + 2(4)$$
$$= 2$$

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

3. Correct answer is [5]

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



$$r = \frac{a+b}{2} = \frac{0.2+1}{2} = 0.6 \qquad \text{...(i)}$$

As $\quad R = \dfrac{\rho l}{A} \qquad$ ...(ii)

Hence, Resistence of left 50 cm wire

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

Resistence of Right 50 cm wire

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

For wheatstone balanced condition

$$\frac{R_1}{P} = \frac{R_2}{Q} \qquad (R_1 = X)$$
$$\frac{(X) \times \pi \times 0.2 \times 0.6}{\rho \times 0.5 \times 10^6} = \frac{(1\pi) \times 0.6 \times 1}{\rho \times 0.5 \times 10^6}$$
$$\frac{(X) \times \pi \times 0.12}{\rho \times 0.5 \times 10^6} = \frac{\pi \times 0.6 \times 1}{\rho \times 0.5 \times 10^6}$$
$$X = 5$$

4. Correct answer is [4]

Explanation: Given equation,

$$[B] = [e]^\alpha [M_e]^\beta [h]^\gamma [K]^\delta$$
$$[M'T^{-2}L^{-1}] = [IT]^\alpha [M]^\beta [ML^2T^{-1}]^\gamma [ML^3T^{-4}]^\delta$$

on compairing the order on both sides

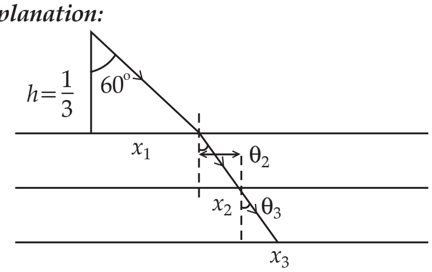
$$\beta + \gamma + \delta = 1$$
$$2\gamma + 3\delta = 0$$
$$\alpha - \gamma - 4\delta = -2$$
$$\alpha - 2\delta = -1$$

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

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

$$\theta_2 = 30^\circ$$

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

Also

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

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

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

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

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

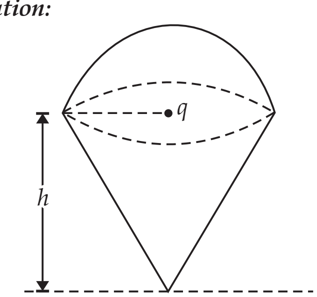
And, $\eta = \dfrac{l}{x_1+x_2+x_3}$

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

$$\eta = 4$$

6. Correct answer is [3]

Explanation:



So from symmetrical approah

Flux, $\phi = \dfrac{q_{in}}{\varepsilon_0}$

Flux through cone, $\phi = \dfrac{q}{2\varepsilon_0}$

On comparing it with given values, we get:

$$n = 3$$

7. Correct answer is [6]

Explanation: Time period of oscillation

$$= T_1 + T_2$$

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

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

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

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

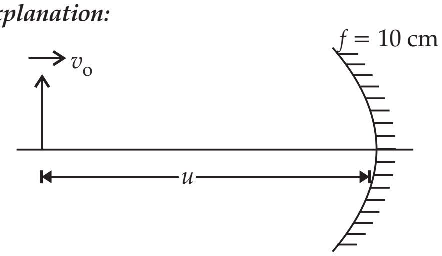
$$= \frac{70\pi}{12}$$

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

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

8. Correct answer is [3]

Explanation:



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

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

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

[where, v_n = speed of mirror]

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

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

$$v_0 = 5v_m$$

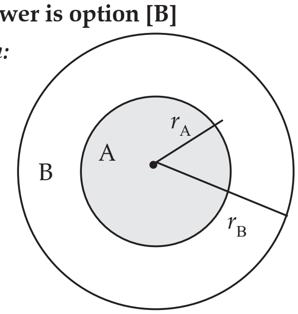
$$v_m = \frac{v_o}{5} = \frac{15}{5}$$

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

SECTION - 2

9. Correct answer is option [B]

Explanation:



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

$$= \left.\frac{4\pi r^4 k}{4}\right]_0^{r_A} + 8\pi k\left.\frac{r^2}{2}\right]_{r_A}^{r_B}$$

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

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

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

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

$$= 3\pi k$$

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

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

$$= 6\pi k$$

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{6\pi k}{r_B}\right) = \frac{k}{\varepsilon_0}$$

Hence, $V = \frac{k}{\varepsilon_0}$

(C) If $r_B = 2$

$Q_{total} = 13\pi K$

(D) If $r_B = 5/2$

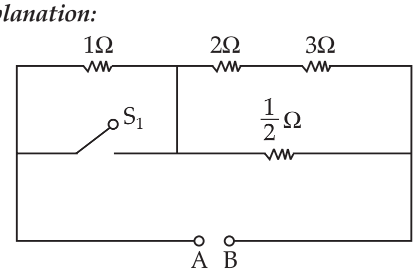
$Q_{total} = 22\pi k$

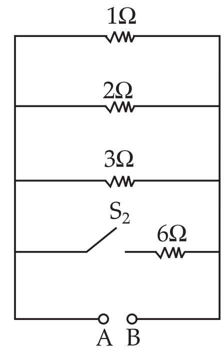
$$E = \frac{1}{4\pi\varepsilon_0}\frac{(22\pi k}{25} \times 4$$

$$E = \frac{22k}{25\varepsilon_0}$$

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

Explanation:





Case I: When both S_1 and S_2 open

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

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

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

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

$P_2 > P_1$

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

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

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

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

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

$P_1 > P_2$

For Q_1

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

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

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

$Q_1 > P_1$

11. Correct answer are option [C, D]

Explanation: For adiabatic process:

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^\gamma \Rightarrow P_1V_1{}^\gamma - P_2V_2{}^\gamma$$

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

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

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

Also, $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

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

At same temperature,

$$P_1V_1 = P_2V_2$$

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

$$\left(\frac{r_1}{r_2}\right)^3 = \frac{P_{a_2}+4S/r_2}{P_{a_1}+4S/r_1}$$

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

Explanation:

$$V(z) = \frac{\sigma}{2\varepsilon_0}\left(\sqrt{R^2+z^2}-z\right)$$

$$U(z)_{net} = \frac{\sigma q}{2\varepsilon_0}\left(\sqrt{R^2+z^2}-z\right)+cz$$

$$= c\left[\frac{\sigma q}{2c\varepsilon_0}\left(\sqrt{R^2+z^2}-z\right)+z\right]$$

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 $\beta = \frac{1}{4}$

$$U_{(z)net} = 2.887\text{ Rc}$$

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 β $\frac{1}{4}$ 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 mearly equal to 3Rc

Also, for option (C)

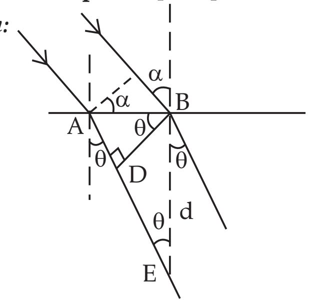
$U_{(z)net}$ at $Z = \frac{R}{\sqrt{3}} > U_{(z)net}$ at $z = \frac{3R}{\sqrt{7}}$

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

$\Delta x = n_1BC - n_2AD$

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

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

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

Explanation: For adiabatic process,

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

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

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

$$W_{AB} = \frac{P_AV_A - P_BV_B}{\left(\frac{5}{3}-1\right)} = \frac{80-300\times\frac{0.8}{3^{3/5}}}{2/3}$$

$W_{AB} = -60$ kJ

As volume is constant, So it is a Isochoric process ($C\to A$)

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

$$= 300\times\frac{0.8}{3^{3/5}}\ln\left[\frac{0.8}{0.8}\times3^{3/5}\right]$$

Hence, $W_{BC} = 79$ kJ

SECTION - 3

15. Correct answer is option [B].

Explanation: Angular momentum of B with respect to A

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

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

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

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

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

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:

$$KE = h\nu - \phi$$

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

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

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

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

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

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 subsituting 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,

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

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

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

Let x_1 be reading in Case I

$$x_1 = MSR + CSR - \text{zero error}$$
$$= 2 + 0.20 - 0.04$$
$$= 2.20 - 0.04$$
$$x_1 = 2.16 \text{ mm}$$

For Case II,

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

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

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

Let x_2 be reading in Case II

$$x_2 = MSR + CSR - \text{zero error}$$
$$= 2 + 0.16 - 0.04$$
$$= 2.16 - 0.04$$
$$= 2.12 \text{ mm}$$

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

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

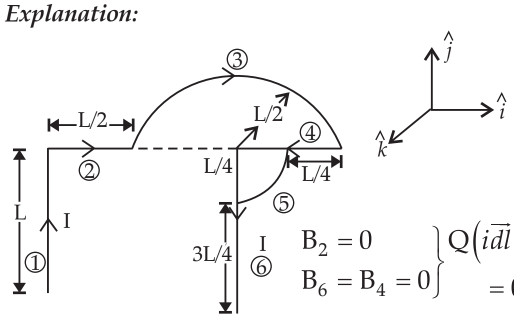
$$dA = \frac{2\pi d}{4}(\Delta d)$$

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

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

18. Correct answer is option [C]

Explanation:



$$B_2 = 0, \quad B_6 = B_4 = 0 \quad Q\left(i\vec{dl} \,\&\, \vec{r}\right) = 0$$

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

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

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

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