PHYSICS
JEE-MAIN (April-Attempt) 10 April (Shift-1) Paper

SECTION - A

1. A ball is thrown upward with an initial velocity V_0 from the surface of the earth. The motion of the ball is affected by a drag force equal to $m\gamma\upsilon^2$ (where m is mass of the ball, υ is its instantaneous velocity and γ is a constant). Time taken by the ball to rise to its zenith is :

(1) $\frac{1}{\sqrt{2\gamma g}}\tan^{-1}\left(\sqrt{\frac{2\gamma}{g}}V_0\right)$

(2) $\frac{1}{\sqrt{\gamma g}}\ln\left(1+\sqrt{\frac{\gamma}{g}}V_0\right)$

(3) $\frac{1}{\sqrt{\gamma g}}\sin^{-1}\left(\sqrt{\frac{\gamma}{g}}V_0\right)$

(4) $\frac{1}{\sqrt{\gamma g}}\tan^{-1}\left(\sqrt{\frac{\gamma}{g}}V_0\right)$

Sol. **4**

$$\frac{mdu}{dt} = -(mg + m\gamma u^2)$$

$$\frac{du}{dt} = -(g + \gamma u^2)$$

$$\int_{v_0} \frac{du}{(g+\gamma u^2)} = \int_0^t -dt$$

$$\therefore t = \frac{1}{\sqrt{\gamma g}}\tan^{-1}\left(\sqrt{\frac{\gamma}{g}}v_0\right)$$

2. Two radioactive materials A and B have decay constants 10λ and λ, respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of A to that of B will be 1/e after a time :

(1) $\frac{11}{10\lambda}$ (2) $\frac{1}{10\lambda}$ (3) $\frac{1}{9\lambda}$ (4) $\frac{1}{11\lambda}$

Sol. **3**

Decay at t = 0

A	B
10λ	λ
N_0	N_0

$N_A = N_0\, e^{-10\lambda t}$

and

$N_B = N_0\, e^{-\lambda t}$

$$\frac{N_A}{N_B} = \frac{e^{-10\lambda t}}{e^{-\lambda t}}$$

$$\frac{N_A}{N_B} = e^{-9\lambda t} = \frac{1}{e}$$

$\Rightarrow 9\lambda t = 1$

$$\therefore t = \frac{1}{9\lambda}$$

3. A cylinder with fixed capacity of 67.2 lit contains helium gas at STP. The amount of heat needed to raise the temperature of the gas by 20°C is : [Given that R = 8.31 J mol^{-1} K^{-1}]

(1) 700 J (2) 350 J (3) 748 J (4) 374 J

Sol. **3**

$Q = nC_v\Delta T = \frac{67.2}{22.4}\left(\frac{3}{2}R\right)(20)$

$= 748$ J

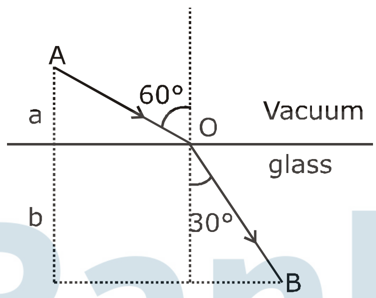
4. An npn transistor operates as a common emitter amplifier, with a power gain of 60 dB. The input circuit resistance is 100Ω and the output load resistance is 10 kΩ. The common emitter current gain β is :

(1) 10^4 (2) 10^2 (3) 6×10^2 (4) 60

Sol. **2**

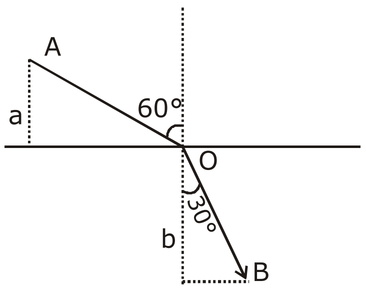
powe gain $= \beta^2 \frac{R_0}{R_L}$

5. A ray of light AO in vacuum is incident on a glass slab at angle 60° and refracted at angle 30° along OB as shown in the figure. The optical path length of light ray from A to B is :



(1) $2a + \frac{2b}{3}$ (2) $\frac{2\sqrt{3}}{a} + 2b$ (3) $2a + \frac{2b}{\sqrt{3}}$ (4) 2a + 2b

Sol. **4**



$AO = \frac{a}{\cos 60^\circ} = 2a$

$OB = \frac{b}{\cos 30^\circ} = \frac{2b}{\sqrt{3}}$

Optical path length

= AO + μOB

$= 2a + \sqrt{3}.\frac{2b}{\sqrt{3}}$

= 2 (a + b)

6. Two coaxial discs, having moments of inertia I_1 and $\frac{I_1}{2}$, are rotating with respective angular velocities ω_1 and $\frac{\omega_1}{2}$, about their common axis. They are brought in contact X with each other and thereafter they rotate with a common angular velocity. If E_f and E_i are the final and initial total energies, then $(E_f - E_i)$ is :

(1) $\frac{I_1\omega_1^2}{6}$ (2) $-\frac{I_1\omega_1^2}{24}$ (3) $\frac{3}{8}I_1\omega_1^2$ (4) $-\frac{I_1\omega_1^2}{12}$

Sol. **2**

$$\omega = \frac{I_1\omega_1 + \frac{I_1}{2}\cdot\frac{\omega_1}{2}}{I_1 + I_1/2} = \frac{\frac{5}{4}I_1\omega_1}{\frac{3}{2}I_1} = \frac{5}{6}\ \omega_1$$

Loss of energy = $E_f - E_i$

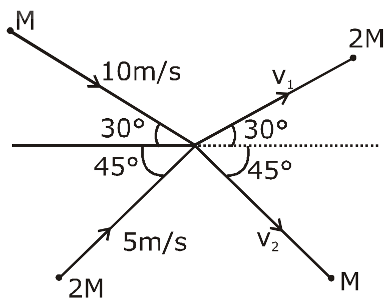
$$= \frac{1}{2}\ I_1 w_1^{\ 2} + \frac{1}{2}\left(\frac{I_1}{2}\frac{w_1^2}{4}\right) - \frac{1}{2}\left(\frac{3}{2}I_1\right)\left(\frac{5}{6}w_1^2\right)^2$$

$$= \frac{9}{16}\ I_1\omega_1^{\ 2} - \frac{75}{144}\ I_1\ \omega_1^{\ 2}$$

$$= \frac{81-75}{144}\ I_1\omega_1^{\ 2} = \frac{6I_1\omega_1^2}{144} = \frac{I_1\omega_1^2}{24}$$

$\Delta E = -I_1 w_1^{\ 2}/24$

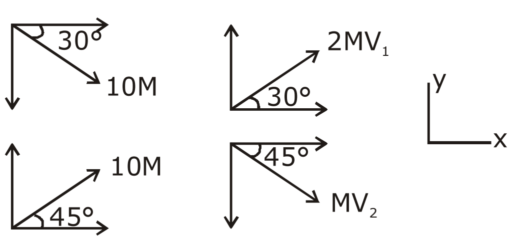
7. Two particles, of masses M and 2M, moving, as shown, with speeds of 10 m/s and 5 m/s, collide elastically at the origin. After the collision, they move along the indicated directions with speeds v_1 and v_2, respectively. They values of v_1 and v_2 are nearly:



(1) 6.5 m/s and 3.2 m/s (2) 3.2 m/s and 6.3 m/s
(3) 3.2 m/s and 12.6 m/s (4) 6.5 m/s and 6.3 m/s

Sol. **4**

From momentum conservation



Along : x 10 M cos 30° + 10 M cos 45° = 2 MV_1 cos 30° + MV_2 cos 45°
Along : y –10 M sin 30° + 10 M cos 45° = 2 MV_1 sin 30° – MV_2 cos 45°
Solving we get V_1 = 6.31 m/s
V_2 = 11.16 m/s

8. A current of 5A passes through a copper conductor (resistivity = 1.7×10^{-8} ΩM) of radius of cross-section 5 mm. Find the mobility of the charges if their drift velocity is 1.1×10^{-3} m/s.

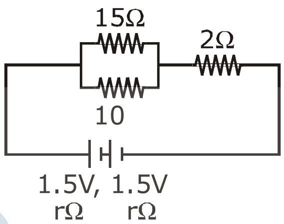
(1) 1.5 m^2/Vs (2) 1.3 m^2/Vs (3) 1.0 m^2/Vs (4) 1.8 m^2/Vs

Sol. **3**

$$V_d = \mu E = \mu \frac{V}{l} = \frac{\mu}{l} iR = \frac{\mu i}{l} \cdot \frac{\delta l}{A} = \frac{\mu i l}{A}$$

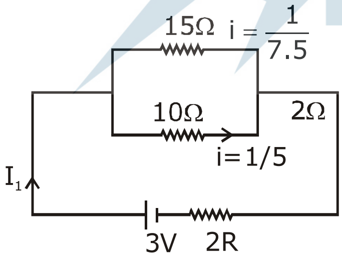
$$\therefore \mu = \frac{V_d A}{i\delta} = 1.57 \text{ m}^2/\text{vs}$$

9. In the given circuit, an ideal voltmeter connected across the 10Ω resistance reads 2V. The internal resistance r, of each cell is :



(1) 1Ω (2) 0.5Ω (3) 1.5Ω (4) 0Ω

Sol. **2**



$$I_1 = \frac{1}{7.5} + \frac{1}{5} = \frac{1+1.5}{7.5}$$

$$(8 + 2r)\frac{1}{3} = 3$$

$\therefore$ 8 + 2r = 9
r = 1/2 = 0.5 Ω

10. A particle of mass m is moving along a trajectory given by
$x = x_0 + a \cos\omega_1 t$
$y = y_0 + b \sin\omega_2 t$
The torque, acting on the particle about the origin, at t = 0 is :

(1) $+my_0 a\omega_1^2\hat{k}$ (2) $m(-x_0 b + y_0 a)\omega_1^2\hat{k}$

(3) Zero (4) $m\left(x_0 b\omega_2^2 - y_0 a\omega_1^2\hat{k}\right)\hat{k}$

Sol. **1**

at t = 0 $x = x_0 + a$

$y = y_0 = 0$

$$v = \frac{dx}{dt}\hat{i} + \frac{dy}{dt}\hat{j}$$

$$a = \frac{d^2x}{dt^2}\hat{i} + \frac{d^2y}{dt^2}\hat{j}$$

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$\vec{\tau} = m\,(\vec{r} \times \vec{a})$$

$$\vec{\tau} = m\left[(x_0 + a)\hat{i} + y_0\hat{j}\right] \times \left[\frac{d^2x}{dt^2}\hat{i} + \frac{d^2y}{dt^2}\hat{j}\right]$$

$$\vec{\tau} = my_0aw_1^2\,\hat{k}$$

11. Given below in the left column are different modes of communication using the kinds of waves given in the right column.

A. Optical Fibre Communication		P.	Ultrasound
B. Radar		Q.	Infrared Light
C. Sonar		R.	Microwaves
D. Mobile Phones		S.	Radio Waves

From the options given below, find the most appropriate match between entries in the left and the right column.

(1) A - Q, B - S, C - R, D - P
(2) A - R, B - P, C - S, D - Q
(3) A - Q, B - S, C - P, D - R
(4) A - S, B - Q, C - R, D - P

Sol. **3**

$A \rightarrow S$

$B \rightarrow R$

$C \rightarrow P$

$D \rightarrow Q$

12. n moles of an ideal gas with constant volume heat capacity C_v undergo an isobaric expansion by certain volume. The ratio of the work done in the process, to the heat supplied is :

(1) $\frac{4nR}{C_v + nR}$
(2) $\frac{nR}{C_v + nR}$
(3) $\frac{4nR}{C_V - nR}$
(4) $\frac{nR}{C_V - nR}$

Sol. **2**

$\Delta w = nR\Delta T$

$\Delta Q = \Delta w + \Delta U$

$$= nR\Delta T + n\left(\frac{C_V}{n}\right)\Delta T$$

$$= (nR + C_V)\,\Delta T$$

$$\therefore \frac{\Delta w}{\Delta Q} = \frac{nR\Delta T}{(nR + C_V)\Delta T} = \left(\frac{nR}{nR + C_V}\right)$$

13. A transformer consisting of 300 turns in the primary and 150 turns in the secondary gives output power of 2.2 kW. If the current in the secondary coil is 10 A, then the input voltage and current in the primary coil are :

(1) 220 V and 10 A
(2) 440 V and 20 A
(3) 220 V and 20 A
(4) 440 V and 5 A

Sol. **4**

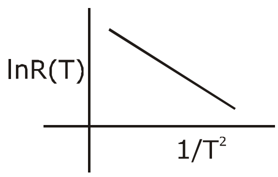
$n_P : n_S = 2 : 1$
$P_0 = 2.2$ kW
$i_0 = 10$ A

$V_0 = \frac{P_0}{i_0} = \frac{2.2 \times 10^3}{10} = 220$ V

$\therefore V_i - 2 \times 220$ V
$= 440$ V

and $i_i = \frac{P_i}{V_i} = \frac{2.2 \times 10^3}{440} = 5$ A

14. In an experiment, the resistance of a material is plotted as a function of temperature (in some range). As shown in the figure, it is a straight line.



One may conclude that :

(1) $R(T) = R_0 e^{-T^2/T_0^2}$
(2) $R(T) = \frac{R_0}{T^2}$
(3) $R(T) = R_0 e^{-T_0^2/T^2}$
(4) $R(T) = R_0 e^{T^2/T_0^2}$

Sol. **3**

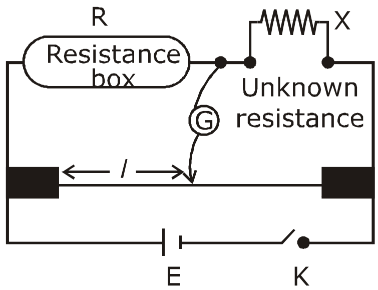
$y = mx + C$

$\ln R = -m \frac{1}{T^2} + C$

$R = e^{-m/T^2} (e^C)$

$R = R_0 e^{-m/T^2}$

15. In a meter bridge experiment, the circuit diagram and the corresponding observation table are shown in figure.



Sl. No.	R (Ω)	ℓ (cm)
1.	1000	60
2.	100	13
3.	10	1.5
4.	1	1.0

Which of the readings is inconsistent ?

(1) 2 (2) 3 (3) 4 (4) 1

Sol. **3**

$$\frac{x}{R} = \left(\frac{100 - l}{l}\right)$$

$$X = R\,\frac{(100 - l)}{l}$$

16. A message signal of frequency 100 MHz and peak voltage 100 V is used to execute amplitude modulation on a carrier wave of frequency 300 GHz and peak voltage 400 V. The modulation index and difference between the two side band frequencies are :

(1) 0.25 ; 1×10^8 Hz
(2) 0.25 ; 2×10^8 Hz
(3) 4 ; 1×10^8 Hz
(4) 4 ; 2×10^8 Hz

Sol. **2**

$$\begin{cases} f_m = 100\,\text{Hz}\,(\text{message}) \\ V_0 = 1000\,(\text{peak}) \end{cases}$$

$$\begin{cases} f_C = 300\text{GHz} \\ V_0 = 400\text{V}\,(\text{peak})\,\text{carrier} \end{cases}$$

Modulation index $= \dfrac{(V_0)_{message}}{(V_0)_C} = \dfrac{100}{400} = \dfrac{1}{4}$

$f_{max} - f_{min} = (f_c + f_m) - (f_c - f_m)$
$= 2f_m = 2 \times 10^8$ Hz

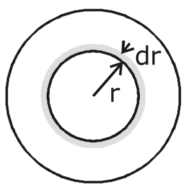
17. A thin disc of mass M and radius R has mass per unit area $\sigma(r) = kr^2$ where r is the distance from its centre. Its moment of inertia about an axis going thought its centre of mass and perpendicular to its plane is :

(1) $\dfrac{2MR^2}{3}$ (2) $\dfrac{MR^2}{3}$ (3) $\dfrac{MR^2}{6}$ (4) $\dfrac{MR^2}{2}$

Sol. **1**

dm = (dA) (σ)
dm = ($2\pi r dr$) (kr^2)
dI = dm – r^2 = $2\pi kr^3\,dr.r^2$
dI = $2\pi k\, r^5\, dr$

$$I = 2\pi k.\frac{r^6}{6}$$



and $m = 2\pi k \int_u^r r^3 dr = 2\pi k\,\dfrac{r^4}{4}$

$$\frac{I}{m} = \frac{2\pi k r^6}{6} \times \frac{4}{2\pi k r^4} = \frac{2r^2}{3}$$

$$I = \frac{2mr^2}{3}$$

18. The electric field of a plane electromagnetic wave is given by

$\vec{E} = E_0 \hat{i} \cos(kz)\cos(\omega t)$

The corresponding magnetic field $\vec{B}$ is then given by :

(1) $\vec{B} = \frac{E_0}{C}\hat{k}\sin(kz)\cos(\omega t)$ (2) $\vec{B} = \frac{E_0}{C}\hat{j}\cos(kz)\sin(\omega t)$

(3) $\vec{B} = \frac{E_0}{C}\hat{j}\sin(kz)\cos(\omega t)$ (4) $\vec{B} = \frac{E_0}{C}\hat{j}\sin(kz)\sin(\omega t)$

Sol. **4**

19. The value of acceleration due to gravity at Earth's surface is 9.8 ms^{-2}. The altitude above its surface at which the accelerate due to gravity decreases to 4.9 ms^{-2}, is close to : (Radius of earth = 6.4×10^6 m)

(1) 9.0×10^6 m (2) 1.6×10^6 m (3) 6.4×10^6 m (4) 2.6×10^6 m

Sol. **4**

$$g_n = g.\left(1+\frac{h}{R}\right)^{-2}$$

$$\frac{g}{2} = g\left(1+\frac{h}{R}\right)^{-2}$$

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

$h = (\sqrt{2} - 1)\,R$

$h = 2.6 \times 10^6$ m

20. The ratio of surface tensions of mercury and water is given to be 7.5 while the ratio of their densities is 13.6. Their contact angles, with glass, are close to 135° and 0°, respectively, It is observed that mercury gets depressed by an amount h in a capillary tube or radius r_1, while water rises by the same amount h in a capillary tube of radius r_2. The ratio, (r_1/r_2), is then close to :

(1) 3/5 (2) 2/5 (3) 4/5 (4) 2/3

Sol. **2**

$\frac{T_{Hg}}{T_w} = 7.5$ $\frac{\delta_{hg}}{\delta_{\omega}} = 13.6$

$\theta_{Hg} = 135°$ and $\theta_{glass} = 0°$

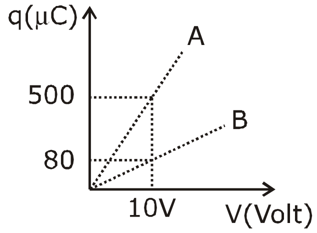
$$h = \frac{27\cos\theta}{r\delta g}$$

$$\frac{r_{Hg}}{r_{\omega}} = \frac{T_{Hg}}{T_{\omega}}.\frac{\cos\theta_{Hg}}{\cos\theta_w}.\frac{\delta_w}{\delta_{hg}}$$

$$= (7.5)\left(\frac{1/\sqrt{2}}{1}\right)\frac{1}{13.6}$$

$$= \frac{7.5}{(\sqrt{2})(13.6)} = 0.4 = \frac{2}{5}$$

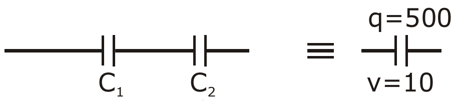
21. Figure shows charge (q) versus voltage (V) graph for series and parallel combination of two given capacitors, The capacitances are :



(1) 50 μF and 30μF
(2) 60 μF and 40μF
(3) 40 μF and 10μF
(4) 20 μF and 30μF

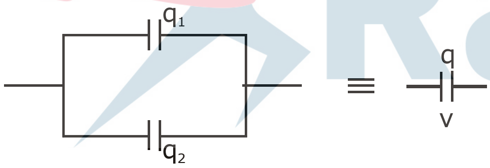
Sol. **3**

in series



$$\frac{C_1C_2}{C_1+C_2} = \frac{500}{10} = 50$$

In parallel



$$C_1 + C_2 = \frac{80}{10} = 8$$

$\therefore C_1\,C_2 = 400$

22. In a photoelectric effect experiment the threshold wavelength of light is 380 nm. If the wavelength of incident light is 260 nm, the maximum kinetic energy of emitted electrons will be :

Given E (in eV) $= \dfrac{1237}{\lambda(\text{in nm})}$

(1) 1.5 eV (2) 4.5 eV (3) 3.0 eV (4) 15.1 eV

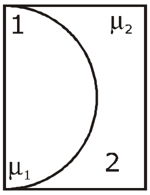
Sol. **1**

$$E_P = \frac{1237}{260}\text{ ev} = 4.75\text{ ev}$$

$$Q = \frac{1237}{300}\text{ ev} = 3.25\text{ ev}$$

$K_{max} = E - Q = 1.5$ ev

23. One plano-convex and one plano-concave lens of same radius of curvature 'R' but of different materials are joined side by side as shown in the figure. If the refractive index of the material of 1 is μ_1 and that of 2 is μ_2, then the focal length of the combination is :



(1) $\frac{R}{2(\mu_1-\mu_2)}$ (2) $\frac{R}{2-(\mu_1-\mu_2)}$ (3) $\frac{R}{\mu_1-\mu_2}$ (4) $\frac{2R}{\mu_1-\mu_2}$

Sol. **3**

$$\frac{1}{f_1} = (\mu_1 - 1)\left(\frac{1}{\infty}-\frac{1}{-R}\right) = \frac{\mu_1-1}{R}$$

$$\frac{1}{f_2} = (\mu_2 - 1)\left(\frac{1}{-R}-\frac{1}{\infty}\right) = \frac{\mu_2-1}{R}$$

$$\frac{1}{f_{eq}} = \left(\frac{\mu_1-1}{R}\right)+\left(\frac{\mu_2-1}{-R}\right)$$

$$f_{eq} = \frac{R}{(\mu_1-\mu_2)}$$

24. A 25×10^{-3} m^3 volume cylinder is filled with 1 mol of O_2 gas at room temperature (300K). The molecular diameter of O_2, and its root mean square speed, are found t be 0.3 nm and 200 m/s, respectively. What is the average collision rate (per second) for an O_2 molecule?
(1) $\sim10^{12}$ (2) $\sim10^{10}$ (3) $\sim10^{11}$ (4) $\sim10^{13}$

Sol. **1**

collision frequency = $\sqrt{\frac{8KT}{\pi m}}\ \frac{\sqrt{2}\pi d^2 N_A P}{RT}$

$= 2.9 \times 10^7\ s^{-1}$

25. The displacement of a damped harmonic oscillator is given by
$x(t) = e^{-0.1t}\cos(10\pi t+\phi)$. Here t is in seconds.
The time taken for its amplitude of vibration to drop to half of its initial value is close to :
(1) 27 s (2) 7 s (3) 13 s (4) 4 s

Sol. **2**

$x = e^{-0.1t}\cos(10\pi t + \phi)$

$A \xrightarrow[t]{} A/2$

$A = A_0\, e^{-bt}$ where b = 0.1

$$\frac{A_0}{2} = A_0 \cdot e^{-bt}$$

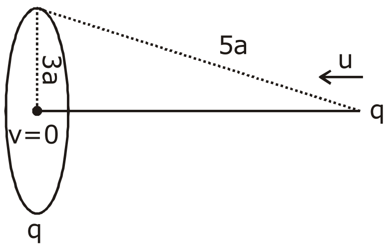
$$t = \frac{\ln 2}{b} = 10 \ln 2 = 6.93 \simeq 7s$$

26. A uniformly charged ring of radius 3a and total charge q is placed in xy-plane centred at origin. A point charge q is moving towards the ring along the z-axis and has speed v at z = 4a. The minimum value of v such that it crosses the origin is :

(1) $\sqrt{\frac{2}{m}}\left(\frac{4}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$ (2) $\sqrt{\frac{2}{m}}\left(\frac{2}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$

(3) $\sqrt{\frac{2}{m}}\left(\frac{1}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$ (4) $\sqrt{\frac{2}{m}}\left(\frac{1}{5}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$

Soll. **2**



z = 4a

$v = \frac{kq}{5a}$

$U_i = \frac{kq^2}{(5a)}$

$U_f = \frac{kq^2}{(3a)}$

$\frac{1}{2}mv^2 = \left(\frac{1}{3}-\frac{1}{5}\right)\frac{kq^2}{5a}$

$\frac{mv^2}{2} = \frac{2}{15}\frac{Kq^2}{5a}$

$v = \sqrt{\frac{4}{15}\frac{kq^2}{ma}}$

27. A proton, an electron, and a Helium nucleus, have the same energy. They are in circular orbits in a plane due to magnetic field perpendicular to the plane Let r_p, r_e and r_{He} be their respective radii, then,

(1) $r_e > r_p > r_{He}$ (2) $r_e < r_p < r_{He}$ (3) $r_e > r_p = r_{He}$ (4) $r_e < r_p = r_{He}$

Sol. **4** P e^- H_e^{++}

$r = \frac{mu}{q(B)}$

$r = \frac{\sqrt{2mK}}{qB}$ K → same

$r \propto \frac{\sqrt{m}}{q}$ B → same

$r_1 : r_2 : r_3 = \frac{\sqrt{m}}{e} : \frac{\sqrt{m/2000}}{e} : \frac{\sqrt{4m}}{2e}$

$\frac{\sqrt{m}}{e} : \frac{\sqrt{m}/e}{\sqrt{2000}} : \sqrt{\frac{m}{e}}$

$= 1 : \frac{1}{\sqrt{2000}} : 1$

i.e., $r_p = r_{He} > r_e$

28. A moving coil galvanometer allows a full scale current of 10^{-4} A. A series resistance of 2 MΩ is required to convert the above galvanometer into a voltmeter of range 0 - 5 V. Therefore the value of shunt resistance required to convert the above galvanometer into an ammeter of range 0-10 mA is :

(1) 10Ω (2) 500Ω (3) 100Ω (4) 200Ω

Sol. **Wrong**

29. A stationary source emits sound waves of frequency 500 Hz. Two observers moving along a linepassing through the source detect sound to be of frequencies 480 Hz and 530 Hz. Their respective speeds area, in ms^{-1}, (Given speed of sound = 300 m/s)

(1) 16, 14 (2) 12, 16 (3) 8, 18 (4) 12, 18

Sol. **4**

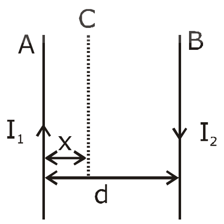
f = 500 Hz (u = 0)

$f_{5/1}$ = 480 Hz $f_{5/2}$ = 530

$f_{5/1} = \left(\frac{300 - V_1}{300}\right) 500 = 480$ & $\left(\frac{300 + V_B}{300}\right) 500 = 530$

V_1 = 12 m/s and V_2 = 18 m/s

30. Two wires A & B are carrying currents I_1 & I_2 as shown in the figure. The separation between them is d. A third wire C carrying a current I is to be kept parallel to them at a distance x from A such that the net force acting on it is zero. The possible values of x are :



(1) $x = \left(\frac{I_2}{I_1 + I_2}\right) d$ and $x = \left(\frac{I_2}{I_1 - I_2}\right) d$

(2) $x = \left(\frac{I_1}{I_1 + I_2}\right) d$ and $x = \frac{I_2}{(I_1 - I_2)} d$

(3) $x = \pm \frac{I_1 d}{(I_1 - I_2)}$

(4) $x = \left(\frac{I_1}{I_1 - I_2}\right) d$ and $x = \frac{I_2}{(I_1 + I_2)} d$

Sol. **3**