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PAPER-1 (B.E./B. TECH.)

JEE (Main) 2020

COMPUTER BASED TEST (CBT)

Questions & Solutions

Date: 05 September, 2020 (SHIFT-1) | TIME : (9.00 a.m. to 12.00 p.m)

Duration: 3 Hours | Max. Marks: 300

SUBJECT : PHYSICS

Resonance Eduventures Ltd.

Reg. Office & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) - 324005

Ph. No.: +91-744-2777777, 2777700 | **FAX No. :** +91-022-39167222

To Know more : sms **RESO** at **56677** | **Website :** www.resonance.ac.in | **E-mail :** contact@resonance.ac.in | **CIN : U80302RJ2007PLC024029**

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PART : PHYSICS

Single Choice Type (एकल विकल्पीय प्रकार)

This section contains **20 Single choice questions.** Each question has 4 choices (1), (2), (3) and (4) for its answer, out of which **Only One** is correct.

इस खण्ड में **20 एकल विकल्पी प्रश्न** हैं। प्रत्येक प्रश्न के 4 विकल्प (1), (2), (3) तथा (4) हैं, जिनमें से **सिर्फ एक सही** है।

1. A bullet of mass 5 g, travelling with a speed of 210 m/s, strikes a fixed wooden target. One half of its kinetic energy is converted into heat in the wood. The rise of temperature of the bullet if the specific heat of its material is 0.030 cal (g –ºC) (1 cal = 4.2 × 10^7 ergs) close to :

(1) 38.4ºC (2) 83.3ºC (3) 87.5ºC (4) 119.2ºC

Ans. **(3)**

Sol. As per given condition

$$\frac{1}{2}\times\frac{1}{2}mv^2 = (ms\Delta T)_{bullet}$$

$$\Delta t = \frac{V^2}{4s}$$

$$= \frac{210\times 210}{4\times 4.2\times 0.3\times 1000} = 87.5^\circ C$$

2. A galvanometer of resistance G is converted into a voltameter of range 0 – 1V by connecting a resistance R_1 in series with it. The additional resistance that should be connected in series with R_1 to increase the range of the voltmeter to 0 – 2V will be :

(1) $R_1 + G$ (2) R_1 (3) $R_1 – G$ (4) G

Ans. **(1)**

Sol. $i_g(R_1 + G) = 1$

$i_g(R_1 + G + R_2) = 2$

$$\frac{1}{R_1+G}(R_1 + G + R_2) = 2$$

$R_1 + G + R_2 = 2R_1 + 2G$

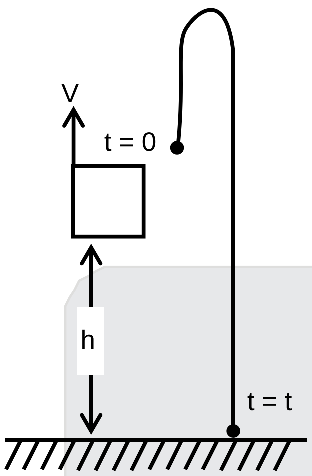
$R_2 = R_1 + G.$

3. A helicopter rises from rest on the ground vertically upwards with a constant acceleration g. A food packed is dropped from the helicopter when it is at a height h. The time taken by the packet to reach the ground is close to [g is the acceleration due to gravity] :

(1) $t = \frac{2}{3}\sqrt{\left(\frac{h}{g}\right)}$ (2) $t = \sqrt{\left(\frac{2h}{3g}\right)}$ (3) $t = 3.4\sqrt{\left(\frac{h}{g}\right)}$ (4) $t = 1.8\sqrt{\left(\frac{h}{g}\right)}$

Ans. **(3)**

Sol.



⇒For upward motion of helicopter

$v^2 = u^2 + 2as$

$v^2 = 0 + 2gh$

$v = \sqrt{2gh}$

⇒ Now particle will start moving under gravity.

$s = ut + \frac{1}{2}at^2$

$-h = \sqrt{2gh}\,t - \frac{1}{2}gt^2$

$\frac{1}{2}gt^2 - \sqrt{2gh}\,t - h = 0$

than $t = \dfrac{\sqrt{2gh} \pm \sqrt{2gh + 4 \times \frac{g}{2} \times h}}{2 \times \frac{g}{2}}$

$t = \sqrt{\frac{2gh}{g}}\left(1+\sqrt{2}\right)$; $t = \sqrt{\frac{2h}{g}}\left(1+\sqrt{2}\right)$

4. An electrical power line, having a total resistance of 2Ω, delivers 1 kW at 220 V. The efficiency of the transmission line is approximately :

(1) 85% (2) 91% (3) 96% (4) 72%

Ans. **(3)**

Sol. $i = \frac{P}{V} = \frac{1000}{220}$

$P_R = (i^2)R$

$\eta = \frac{1000 \times 100}{1000 + 41.32} = 96\%$.

5. A square loop of side 2a, and carrying current I, is kept in XZ plane with its centre at origin. A long wire carrying the same current I is placed parallel to the z-axis and passing through the point (0, b, 0), (b > > a). The magnitude of the torque on the loop about z-axis is given by:

(1) $\frac{2\mu_0 I^2 a^2}{\pi b}$ (2) $\frac{\mu_0 I^2 a^2}{2\pi b}$ (3) $\frac{2\mu_0 I^2 a^3}{\pi b^2}$ (4) $\frac{\mu_0 I^2 a^3}{2\pi b^2}$

Ans. **(1)**

Sol. $B = \frac{\mu_0 I}{2\pi d}$

torque = τ = MBsinθ

$= [I_1(2a)^2]\left(\frac{\mu_0 I_2}{2\pi d}\right)\sin 90^\circ = \frac{2\mu_0 I_1 I_2}{\pi d} \times a^2$

$= \frac{2\mu_0 i^2 a^2}{\pi d}$.

6. The value of the acceleration due to gravity is g_1 at a height $h = \frac{R}{2}$ (R = radius of the earth) from the surface of the earth. It is again equal to g_1 at a depth d below the surface the earth. The ratio $\left(\frac{d}{R}\right)$ equals:

(1) $\frac{4}{9}$ (2) $\frac{1}{3}$ (3) $\frac{5}{9}$ (4) $\frac{7}{9}$

Ans. **(3)**

Sol. Given that

$g_n = g_d$

$\frac{GM}{(R+h)^2} = \frac{GM}{R^3}(R-d)$

$\frac{GM}{(R+R/2)^2} = \frac{GM}{R^3}(R-d)$

$\frac{4GM}{9R^2} = \frac{GM}{R^2}\left(1-\frac{d}{R}\right)$

$\frac{4}{9} = 1-\frac{d}{R}$

$\frac{4}{9} = 1-\frac{d}{R}$

$\frac{d}{R} = 1-\frac{4}{9} = \frac{5}{9}$

$d = \frac{5}{9}R$,

7. Assume that the displacement (s) of air is proportional to the pressure difference (Δp) created by a sound wave. Displacement (s) further depends on the speed of sound (ν), density of air (ρ) and the frequency (f). If $\Delta p \sim 10$Pa, n~300 m/s, p~1 kg/m^3 and f~1000 Hz, then s will be of the order of (take the multiplicative constant to be 1)

(1) 1 mm (2) $\frac{3}{100}$ mm (3) 10 mm (4) $\frac{1}{10}$ mm

Ans. **(2)**

Sol. $S = \frac{P_0}{BK}$

$= \frac{P_0}{PV^2 \frac{\omega}{V}}$

$= \frac{P_0}{PV\omega}$

$= \frac{10}{1 \times 1000 \times 300}$ m

$\simeq \frac{3}{100}$ mm .

8. A wheel is rotating freely with an angular speed ω on a shaft. The moment of inertia of the wheel is I and the moment of inertia of the shaft is negligible. Another wheel of moment of inertia 3I initially at rest is suddenly coupled to the same shaft. The resultant fractional loss in the kinetic energy of the system is:

(1) $\frac{3}{4}$ (2) $\frac{1}{4}$ (3) 0 (4) $\frac{5}{6}$

Ans. **(1)**

Sol. From angular momentum conservation

$I\omega + 0 = I\omega_C + 3\,I\omega_C$

$\omega_C = \frac{\omega}{4}$

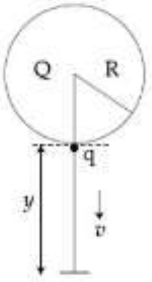
Loss of kinetic energy $= \frac{1}{2}I\omega^2 - \frac{1}{2}(I+3I)\left(\frac{\omega}{4}\right)^2$

$= \frac{1}{2}I\omega^2 - \frac{1}{2}I\frac{\omega^2}{4}$

$= \frac{3}{8}I\omega^2$

Fractional loss $= \frac{3}{4}$.

9. A solid sphere of radius R carries a charge Q + q distributed uniformly over its volume. A very small point like piece of it of mass m gets detached from the bottom of the sphere and falls down vertically under gravity. This piece carries charge q. If it acquires a speed ν when it has fallen through a vertical height y (see figure), then (assume the remaining portion to be spherical)



(1) $\nu^2 = 2y\left[\frac{QqR}{4\pi\varepsilon_0(R+y)^3 m} + g\right]$

(2) $\nu^2 = y\left[\frac{qQ}{4\pi\varepsilon_0 R^2 ym} + g\right]$

(3) $\nu^2 = y\left[\frac{qQ}{4\pi\varepsilon_0 R(R+y)m} + g\right]$

(4) $\nu^2 = 2y\left[\frac{qQ}{4\pi\varepsilon_0 R(R+y)m} + g\right]$

Ans. **(4)**

Sol. By using total energy conservation

$\Delta KE + (\Delta PE)_{Electo} + (\Delta PE)_{gravitationl} = 0$

$\frac{1}{2}mV^2 + \left(k\frac{Qq}{R+y} - k\frac{Qq}{R}\right) + (-mgy) = 0$

$\frac{1}{2}mV^2 = mgy + kQq\left(\frac{1}{R} - \frac{1}{R+y}\right)$; $V^2 = 2gy + \frac{2kQq}{m}\frac{y}{R(R+y)}$

$V^2 = 2y\left[\frac{qQ}{4\pi\varepsilon_0 R(R+y)m} + g\right]$

10. A physical quantity z depends on four observables a, b, c and d, as $z = \frac{a^2 b^{2/3}}{\sqrt{c}d^3}$. The percentage of error in the measurement of a,b,c and d are 2%, 1.5%, 4% and 2.5% respectively. The percentage of error in z is :

(1) 13.5% (2) 16.5% (3) 14.5% (4) 12.25%

Ans. **(3)**

Sol. $\frac{\Delta t}{t} = \frac{2\Delta a}{a} + \frac{2}{3}\frac{\Delta b}{b} + \frac{1}{2}\frac{\Delta c}{c} + 3\frac{\Delta d}{d}$

$= 2 \times 2 + \frac{2}{3} \times 1.5 + \frac{1}{2} \times 4 + 3 \times 2.5$

$= 4 + 1 + 2 + 7.5$

$= 14.5\%$.

11. Number of molecules in a volume of 4 cm^3 of a perfect monoatomic gas at some temperature T and at a pressure of 2 cm of mercury is close to ? (Given, mean kinetic energy of a molecule (at T) is 4×10^{-14} erg, g = 980 cm/^{2}, density of mercury = 13.6 g/cm^3).

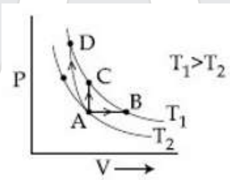
(1) 5.8×10^{16} (2) 4.0×10^{16} (3) 4.0×10^{18} (4) 5.8×10^{18}

Ans. **(3)**

Sol. $N = \frac{PV}{KT}$

$U = \frac{3}{2} KT \quad \therefore \quad N = \frac{3PV}{2U} = 3.99 \times 10^{18}$.

12. Three different processes that can occur in an ideal monoatomic gas are shown in the P vs V diagram. The paths are labelled as $A \rightarrow B$, $A \rightarrow C$ and $A \rightarrow D$. The change in internal energies during these process are taken as E_{AB}, E_{AC} and E_{AD} and the work done as W_{AB}, W_{AC} and W_{AD}. The correct relation between these parameters are:



(1) $E_{AB} > E_{AC} > E_{AD}$, $W_{AB} < W_{AC} < W_{AD}$ (2) $E_{AB} = E_{AC} = E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} > 0$

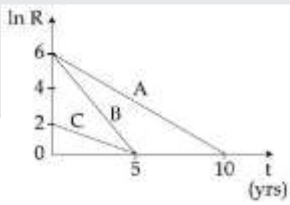
(3) $E_{AB} < E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} > W_{AD}$ (4) $E_{AB} = E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} < 0$

Ans. **(2)**

Sol. ΔT is same for $E_{AB} = E_{AC} = E_{AD}$

Note : In second option $W_{AD} < 0$ but it is correct option is NTA.

13. Activities of three radioactive substances A, B and C are represented by the curves A, B and C, in the figure. Then their half-lives $T_{\frac{1}{2}}(A) : T_{\frac{1}{2}}(B) : T_{\frac{1}{2}}(C)$ are in the ratio :



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

Ans. **(1)**

Sol. $R = R_0 e^{-\lambda t}$

$\ell nR = -\lambda \ell nt + \ell nR_0$

$\text{Slope} = \frac{\ell n2}{t_{1/2}} = \lambda$

$T_{\frac{1}{2}}(A) : T_{\frac{1}{2}}(B) : T_{\frac{1}{2}}(C) = 2 : 1 : 3$.

14. In a resonance tube experiment when the tube is filled with water up to a height of 17.0 cm from bottom, it resonates with a given tuning fork. When the water level is raised the next resonance with the same tuning fork occurs at a height of 24.5 cm. If the velocity of sound in air is 330 m/s, the running fork frequency is :

(1) 2200 Hz (2) 1100 Hz (3) 3300 Hz (4) 550 Hz

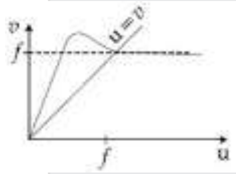
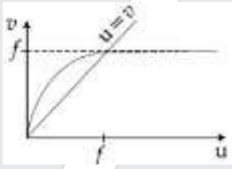
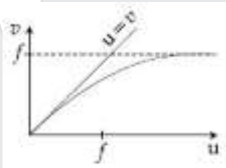
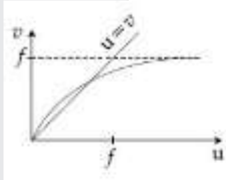
Ans. **(1)**

Sol. $\frac{\lambda}{2} = 24.5 - 17 = 7.5$ cm

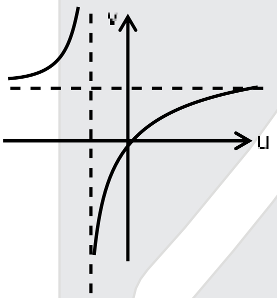
$f = \frac{V}{\lambda}$

$= \frac{330 \times 100}{15} = 2200$ Hz.

15. For a concave lens of focal length f, the relation between object and image distance μ and ν, respectively, from its pole can best the represented by ($\upsilon = \nu$ is the reference line) :

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

Ans. **(3)**

Sol.


16. With increasing biasing voltage of a photodiode, the photocurrent magnitude :

(1) remains constant

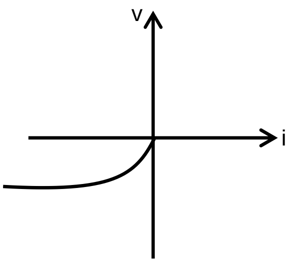
(2) increases initially and saturates finally

(2) increases linearly

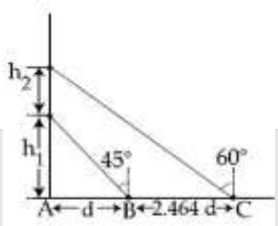
(4) increases initially and after attaining certain value, it decreases

Ans. **(2)**

Sol. Theory based



17. A balloon is moving up in are vertically above a point A on the ground. When it is a height h_1, a girl standing at a distance d (point B) from A (see figure) sees it at an angle 45º with respect to the vertical. When the balloon climbs up a further height h_2, it is seen at an angle 60º with respect to the vertical if the girl moves further by a distance 2.464 d (point C). Then the height h_2 is (given tan30º = 0.5774):



(1) 0.732 d (2) 0.464 d (3) 1.464 d (4) d

Ans. **(4)**

Sol. $t_{45} = \frac{h_1}{d}$

$h_1 = d$ ....(i)

$\frac{h_1 + h_2}{d + 2.464d} = \tan 30^\circ = \frac{1}{\sqrt{3}} = 0.5774$

$h_1 + h_2 = (3.464)d \times 0.5774$

$h_1 + h_2 = 2d$ ....(ii)

$\therefore$ $h_2 = d$.

18. A hollow spherical shell at outer radius R floats just submerged under the water surface. The inner radius of the shell is r. If the specific gravity of the shell material is $\frac{27}{8}$ with respect to water, the value of r is :

(1) $\frac{1}{3}$ R (2) $\frac{4}{9}$ R (3) $\frac{2}{3}$ R (4) $\frac{8}{9}$ R

Ans. **(4)**

Sol. In equilibrium

$mg = F_B$

$\frac{4}{3}\pi(R^3 - r^3)\rho_0 g = \frac{4}{3}\pi R^3 \rho_w g$

$\left[1 - \left(\frac{r}{R}\right)^3\right]\frac{27}{8}\rho_w = \rho_w$

$1 - \frac{r^3}{R^3} = \frac{9}{27}$

$1 - \frac{1}{3} = \frac{r^3}{R^3}$

$\frac{2}{3} = \frac{r^3}{R^3}$

$\frac{r}{R} = \left(\frac{2}{3}\right)^{1/3}$

$1 - \frac{r^3}{R^3} = \frac{8}{27}$

$\frac{r^3}{R^3} = 1 - \frac{8}{27} = \frac{19}{27}$

r = 0.89 .

19. An electron is constrained to move along the y-axis with a speed of 0.1c (c is the speed of light) in the presence of electromagnetic wave, whose electric field is $\vec{E} = 30\hat{j}\sin(1.5 \times 10^7 t - 5 \times 10^{-2}x)$ V/m. The maximum magnetic force experience by the electron will be:
(given c = 3 × 10^8 ms^{-1} and electron charge = 1.6 × 10^{-19}C)

(1) 2.4 × 10^{-18} N (2) 1.6 × 10^{-19} N (3) 4.8 × 10^{-19} N (4) 3.2 × 10^{-18} N

Ans. **(3)**

Sol. In electromagnetic wave is $\frac{E_0}{B_0} = C$

so maximum value of magnetic field is

$B_0 = \frac{E_0}{C}$

$F_{max.} = qVB_{max.}\sin 90^o$

$= \frac{qV_0E_0}{C}$

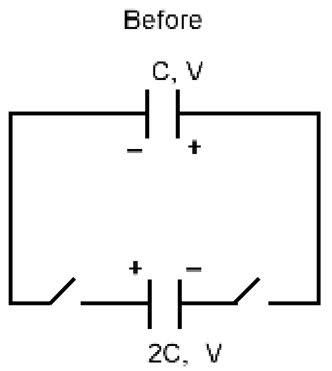
$\frac{1.6\times10^{-19}\times0.1\times3\times10^8\times30}{3\times10^8}$ = 4.8 × 10^{-19} N.

20. Two capacitors of capacitances C and 2C are charged to potential differences V and 2V, respectively. These are then connected in parallel in such a manner that the positive terminal of one is connected to the negative terminal of the other. The final energy of this configuration is :

(1) $\frac{25}{6}$ CV^2 (2) $\frac{9}{2}$ CV^2 (3) zero (4) $\frac{3}{2}$ CV^2

Ans. **(4)**

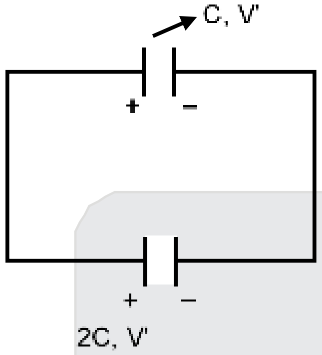
Sol.



Charge on C = CV

Charge on 2C = (2C) 2V)

After connecting



From charge conservation, $2C(2V) – CV = (C + 2C) V'$

Common potential V' = V

$U_f = \left(\frac{1}{2}CV^2 + \frac{1}{2}\times 2CV^2\right) = \frac{3}{2}CV^2$

$\Delta U = 3CV^2$

Numerical Value Type (संख्यात्मक प्रकार)

This section contains **5 Numerical value type questions.**

इस खण्ड में **5 सख्यात्मक प्रकार के प्रश्न** हैं।

21. A force $\vec{F} = (\hat{i} + 2\hat{j} + 3\hat{k})N$ acts at a point $(4\hat{i} + 3\hat{j} - \hat{k})m$. Then the magnitude of torque about the point $(\hat{i} + 2\hat{j} + \hat{k})$ m will be $\sqrt{x}$ N-m. The value of x is.........

Ans. **195**

Sol. $\vec{r} = (4-1)\,\hat{i} + (3\text{-}2)\,\hat{j} + (\text{-}1\text{-}1)\hat{k}$

$= 3\,\hat{i} + \hat{j} - 2\hat{k}$

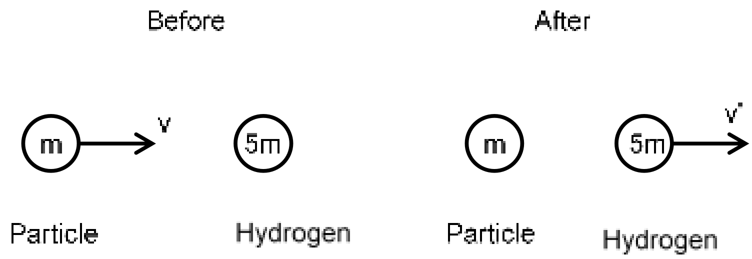
$$\tau = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 1 & -2 \\ 1 & 2 & 3 \end{vmatrix}$$

$= \hat{i}(7) - \hat{j}(11) + \hat{k}(5) = 7\hat{i} - 11\hat{j} + 5\hat{k} = \sqrt{49+121+25} = \sqrt{195}$.

22. A particle of mass 200 MeV/c² collides with a hydrogen atom at rest. Soon after the collision the particle comes to rest, and the atom recoils and goes to its first excited state. The initial kinetic energy of the particle (in eV) is $\frac{N}{4}$. The value of N is: (Given the mass of the hydrogen atom to be 1 GeV/c²)........

Ans. **51**

Sol.



For linear momentum conservation

$$mV + 0 = 0 + 5mV'$$

$$V' = \frac{v}{5}$$

$$\text{loss of KE} = \frac{1}{2}mv^2 - \frac{1}{2}(5m)\left(\frac{v}{5}\right)^2 = \frac{1}{2}mv^2\left(1 - \frac{1}{5}\right)$$

$$= \frac{4}{5}\left(\frac{mv^2}{2}\right) = \frac{4}{5}k = 10.2 \text{ eV}$$

$$k = 12.75 \text{ eV} = \frac{N}{4}$$

N = 51.

23. Two concentric circular coils, C_1 and C_2, are placed in the XY plane. C_1 has 500 turns, and a radius of 1 cm. C_2 has 200 turns and radius of 20 cm. C_2 carries a time dependent current $I(t) = (5t^2 - 2t + 3)$ A where t is in s. The emf induced in C_1 (in mV), at the instant t 1s is $\frac{4}{x}$. The value of x is …….

Ans. 5

Sol. $I = (5t^2 + 2t + C)$

$$\frac{di}{dt} = (10t + 2)$$

$$\phi_{small} = BA = \left(\frac{\mu_0 I N_2}{2R}\right)(\pi r^2)$$

induced emf in small coil

$$e = \frac{d\phi}{dt} = \left(\frac{\mu_0 N_2}{2r}\right)\pi r^2 N_1 \frac{di}{dt} = \left(\frac{\mu_0 N_1 N_2 \pi r^2}{2R}\right)(10t - 2)$$

at t = 1

$$e = \left(\frac{\mu_0 N_1 N_2 \pi r^2}{2R}\right)8 = 4\frac{\mu_0 N_1 N_2 \pi r^2}{R} = \frac{4(4\pi)10^{-7} \times 200}{20} \times 500 \times \frac{10^{-4}}{10^{-2}}\pi$$

$$= 80 \times \pi^2 \times 10^{-7} \times 10 \times 10^2 \times 10^{-2} = 8 \times 10^{-4} \text{ volt} = 0.8 \text{ mV} = \frac{4}{x}$$

x = 5.

24. A beam of electrons of energy E scatters from a target having atomic spacing of 1Å. The first maximum intensity occurs at θ = 60º. Then E (in eV) is……..

(Plank constant h = 6.64×10^{-34} Js, 1 eV = 1.6×10^{-19} J, electron mass m = 9.1×10^{-31} kg).

Ans. **50**

Sol. $2d\sin\theta = n\lambda$

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

d = 1Å

$$\lambda = \sqrt{3}\ \text{Å}$$

$$\sqrt{3} = \sqrt{\frac{150}{v}}$$

V = 50 volt

E = 50 eV.

25. A compound microscope consists of an objective lens of focal length 1 cm and an eye piece of focal length 5 cm with a separation of 10 cm. The distance between an object and the objective lens, at which the strain on the eye is minimum is $\frac{n}{40}$ cm. The value of n is…………

Ans. **50**

Sol. L = 10

$v_e = \infty$

$u_e = f_e = 5$

$v_0 = 10 - 5 = 5$

$$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

$$\frac{1}{5} - \frac{1}{u_0} = \frac{1}{1}$$

$$u_0 = -\frac{5}{4}\text{cm}$$

$$\frac{5}{4} = \frac{n}{40}$$

n = 50.