

# FINAL JEE-MAIN EXAMINATION – JANUARY, 2024

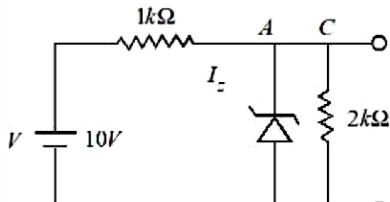
(Held On Monday 29<sup>th</sup> January, 2024)

TIME : 9 : 00 AM to 12 : 00 NOON

## PHYSICS

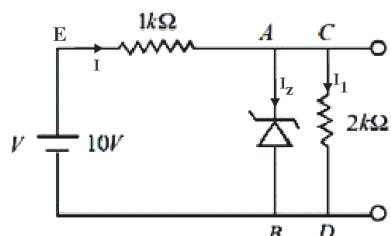
### SECTION-A

31. In the given circuit, the breakdown voltage of the Zener diode is 3.0 V. What is the value of  $I_z$ ?



- (1) 3.3 mA                          (2) 5.5 mA  
(3) 10 mA                            (4) 7 mA

Ans. (2)



Sol.

$$V_z = 3V$$

Let potential at B = 0 V

Potential at E( $V_E$ ) = 10 V

$$V_C = V_A = 3 V$$

$$I_z + I_1 = I$$

$$I = \frac{10 - 3}{1000} = \frac{7}{1000} A$$

$$I_1 = \frac{3}{2000} A$$

$$\text{Therefore } I_z = \frac{7 - 1.5}{1000} = 5.5 \text{ mA}$$

32. The electric current through a wire varies with time as  $I = I_0 + \beta t$ , where  $I_0 = 20 \text{ A}$  and  $\beta = 3 \text{ A/s}$ . The amount of electric charge crossed through a section of the wire in 20 s is :

- (1) 80 C                              (2) 1000 C  
(3) 800 C                            (4) 1600 C

Ans. (2)

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Sol. Given that

$$\text{Current } I = I_0 + \beta t$$

$$I_0 = 20 \text{ A}$$

$$\beta = 3 \text{ A/s}$$

$$I = 20 + 3t$$

$$\frac{dq}{dt} = 20 + 3t$$

$$\int_0^{20} dq = \int_0^{20} (20 + 3t) dt$$

$$q = \int_0^{20} 20 dt + \int_0^{20} 3t dt$$

$$q = \left[ 20t + \frac{3t^2}{2} \right]_0^{20} = 1000 \text{ C}$$

33. Given below are two statements:

**Statement I :** If a capillary tube is immersed first in cold water and then in hot water, the height of capillary rise will be smaller in hot water.

**Statement II :** If a capillary tube is immersed first in cold water and then in hot water, the height of capillary rise will be smaller in cold water.

In the light of the above statements, choose the **most appropriate** from the options given below

- (1) Both **Statement I** and **Statement II** are true  
(2) Both **Statement I** and **Statement II** are false  
(3) **Statement I** is true but **Statement II** is false  
(4) **Statement I** is false but **Statement II** is true

Ans. (3)

Sol. Surface tension will be less as temperature increases

$$h = \frac{2T \cos \theta}{\rho g r}$$

Height of capillary rise will be smaller in hot water and larger in cold water.

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38. The resistance  $R = \frac{V}{I}$  where  $V = (200 \pm 5)$  V and  $I = (20 \pm 0.2)$  A, the percentage error in the measurement of R is :
- 3.5%
  - 7%
  - 3%
  - 5.5%

**Ans. (1)**

**Sol.**  $R = \frac{V}{I}$

According to error analysis

$$\frac{dR}{R} = \frac{dV}{V} + \frac{dI}{I}$$

$$\frac{dR}{R} = \frac{5}{200} + \frac{0.2}{20}$$

$$\frac{dR}{R} = \frac{7}{200}$$

$$\% \text{ error } \frac{dR}{R} \times 100 = \frac{7}{200} \times 100 = 3.5\%$$

39. A block of mass 100 kg slides over a distance of 10 m on a horizontal surface. If the co-efficient of friction between the surfaces is 0.4, then the work done against friction (in J) is :

- 4200
- 3900
- 4000
- 4500

**Ans. (3)**

**Sol.** Given  $m = 100$  kg

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

$$\mu = 0.4$$

$$\text{As } f = \mu mg = 0.4 \times 100 \times 10 = 400 \text{ N}$$

$$\text{Now } W = f.s = 400 \times 10 = 4000 \text{ J}$$

40. Match List I with List II

	List I		List II
A.	$\oint \vec{B} \cdot d\vec{l} = \mu_0 i_c + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$	I.	Gauss' law for electricity
B.	$\oint \vec{E} \cdot d\vec{l} = \frac{d\phi_B}{dt}$	II.	Gauss' law for magnetism
C.	$\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$	III.	Faraday law
D.	$\oint \vec{B} \cdot d\vec{A} = 0$	IV.	Ampere – Maxwell law

Chose the correct answer from the options given below

- A-IV, B-I, C-III, D-II
- A-II, B-III, C-I, D-IV
- A-IV, B-III, C-I, D-II
- A-I, B-II, C-III, D-IV

**Ans. (3)**

**Sol.** Ampere – Maxwell law

$$\rightarrow \oint \vec{B} \cdot d\vec{l} = \mu_0 i_c + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$$

$$\text{Faraday law} \rightarrow \oint \vec{E} \cdot d\vec{l} = \frac{d\phi_B}{dt}$$

$$\text{Gauss' law for electricity} \rightarrow \oint \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$$

$$\text{Gauss' law for magnetism} \rightarrow \oint \vec{B} \cdot d\vec{A} = 0$$

41. If the radius of curvature of the path of two particles of same mass are in the ratio 3:4, then in order to have constant centripetal force, their velocities will be in the ratio of:

- $\sqrt{3} : 2$
- $1 : \sqrt{3}$
- $\sqrt{3} : 1$
- $2 : \sqrt{3}$

**Ans. (1)**



**Sol.** Given  $m_1 = m_2$

$$\text{and } \frac{r_1}{r_2} = \frac{3}{4}$$

$$\text{As centripetal force } F = \frac{mv^2}{r}$$

In order to have constant (same in this question) centripetal force

$$F_1 = F_2$$

$$\frac{m_1 v_1^2}{r_1} = \frac{m_2 v_2^2}{r_2}$$

$$\Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{r_1}{r_2}} = \frac{\sqrt{3}}{2}$$

- 42.** A galvanometer having coil resistance  $10\Omega$  shows a full scale deflection for a current of  $3\text{mA}$ . For it to measure a current of  $8\text{A}$ , the value of the shunt should be:

- (1)  $3 \times 10^{-3}\Omega$       (2)  $4.85 \times 10^{-3}\Omega$   
(3)  $3.75 \times 10^{-3}\Omega$       (4)  $2.75 \times 10^{-3}\Omega$

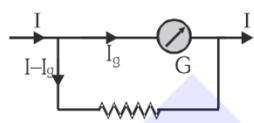
**Ans. (3)**

**Sol.** Given  $G = 10\Omega$

$$I_g = 3\text{mA}$$

$$I = 8\text{A}$$

In case of conversion of galvanometer into ammeter.



$$\text{We have } I_g G = (I - I_g)S$$

$$S = \frac{I_g G}{I - I_g}$$

$$S = \frac{(3 \times 10^{-3})10}{8 - 0.003} = 3.75 \times 10^{-3}\Omega$$

- 43.** The de-Broglie wavelength of an electron is the same as that of a photon. If velocity of electron is  $25\%$  of the velocity of light, then the ratio of K.E. of electron and K.E. of photon will be:

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

**Ans. (2)**

**Sol.** For photon

$$E_p = \frac{hc}{\lambda_p} \Rightarrow \lambda_p = \frac{hc}{E_p}$$

For electron

$$\lambda_e = \frac{h}{m_e v_e} = \frac{hv_e}{2K_e}$$

$$\text{Given } v_e = 0.25 c$$

$$\lambda_e = \frac{h \times 0.25c}{2K_e} = \frac{hc}{8K_e}$$

$$\text{Also } \lambda_p = \lambda_e$$

$$\frac{hc}{E_p} = \frac{hc}{8K_e}$$

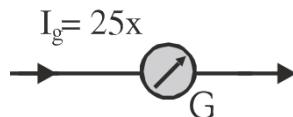
$$\frac{K_e}{E_p} = \frac{1}{8}$$

- 44.** The deflection in moving coil galvanometer falls from 25 divisions to 5 division when a shunt of  $24\Omega$  is applied. The resistance of galvanometer coil will be :

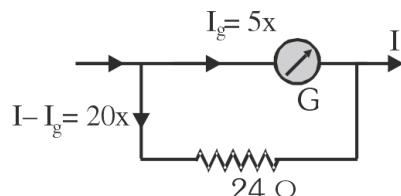
- (1)  $12\Omega$       (2)  $96\Omega$   
(3)  $48\Omega$       (4)  $100\Omega$

**Ans. (2)**

**Sol.** Let  $x$  = current/division



After applying shunt



$$\text{Now } 5x \times G = 20x \times 24$$

$$G = 4 \times 24$$

$$G = 96\Omega$$



45. A biconvex lens of refractive index 1.5 has a focal length of 20 cm in air. Its focal length when immersed in a liquid of refractive index 1.6 will be:
- 16 cm
  - 160 cm
  - + 160 cm
  - + 16 cm

**Ans.** (2)

**Sol.**  $\mu_l = 1.5$

$$\mu_m = 1.6$$

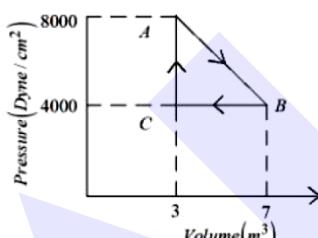
$$f_a = 20 \text{ cm}$$

$$\text{As } \frac{f_m}{f_a} = \frac{(\mu_l - 1)\mu_m}{(\mu_l - \mu_m)}$$

$$\frac{f_m}{20} = \frac{(1.5 - 1)1.6}{(1.5 - 1.6)}$$

$$f_m = -160 \text{ cm}$$

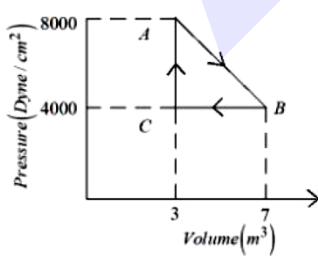
46. A thermodynamic system is taken from an original state A to an intermediate state B by a linear process as shown in the figure. Its volume is then reduced to the original value from B to C by an isobaric process. The total work done by the gas from A to B and B to C would be :



- 33800 J
- 2200 J
- 600 J
- 1200 J

**Ans. (BONUS)**

**Sol.**



$$\text{Work done AB} = \frac{1}{2} (8000 + 6000) \text{ Dyne/cm}^2 \times$$

$$4\text{m}^3 = (6000 \text{ Dyne/cm}^2) \times 4\text{m}^3$$

$$\text{Work done BC} = -(4000 \text{ Dyne/cm}^2) \times 4\text{m}^3$$

$$\text{Total work done} = 2000 \text{ Dyne/cm}^2 \times 4\text{m}^3$$

$$= 2 \times 10^3 \times \frac{1}{10^5} \frac{\text{N}}{\text{cm}^2} \times 4\text{m}^3$$

$$= 2 \times 10^{-2} \times \frac{\text{N}}{10^{-4} \text{ m}^2} \times 4\text{m}^3$$

$$= 2 \times 10^2 \times 4 \text{ Nm} = 800 \text{ J}$$

47. At what distance above and below the surface of the earth a body will have same weight, (take radius of earth as R).

$$(1) \sqrt{5}R - R$$

$$(2) \frac{\sqrt{3}R - R}{2}$$

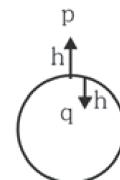
$$(3) \frac{R}{2}$$

$$(4) \frac{\sqrt{5}R - R}{2}$$

**Ans. (4)**

$$\text{Sol. } g_p = \frac{gR^2}{(R+h)^2}$$

$$g_q = g \left(1 - \frac{h}{R}\right)$$



$$g_p = g_q$$

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

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

$$\text{Take } \frac{h}{R} = x$$

So

$$x^3 - x + x^2 = 0$$

$$x = \frac{\sqrt{5} - 1}{2}$$

$$h = \frac{R}{2} (\sqrt{5} - 1)$$



48. A capacitor of capacitance  $100 \mu\text{F}$  is charged to a potential of  $12 \text{ V}$  and connected to a  $6.4 \text{ mH}$  inductor to produce oscillations. The maximum current in the circuit would be :
- (1)  $3.2 \text{ A}$       (2)  $1.5 \text{ A}$   
(3)  $2.0 \text{ A}$       (4)  $1.2 \text{ A}$

**Ans.** (2)

**Sol.** By energy conservation

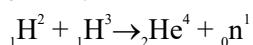
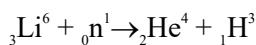
$$\frac{1}{2}CV^2 = \frac{1}{2}LI_{\max}^2$$

$$I_{\max} = \sqrt{\frac{C}{L}} V$$

$$= \sqrt{\frac{100 \times 10^{-6}}{6.4 \times 10^{-3}}} \times 12$$

$$= \frac{12}{8} = \frac{3}{2} = 1.5 \text{ A}$$

49. The explosive in a Hydrogen bomb is a mixture of  ${}_1\text{H}^2$ ,  ${}_1\text{H}^3$  and  ${}_3\text{Li}^6$  in some condensed form. The chain reaction is given by

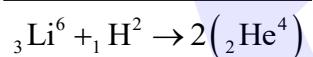
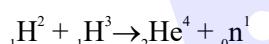
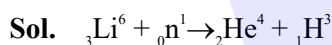


During the explosion the energy released is approximately

[Given :  $M(\text{Li}) = 6.01690 \text{ amu}$ .  $M({}_1\text{H}^2) = 2.01471 \text{ amu}$ .  $M({}_2\text{He}^4) = 4.00388 \text{ amu}$ , and  $1 \text{ amu} = 931.5 \text{ MeV}$ ]

- (1)  $28.12 \text{ MeV}$       (2)  $12.64 \text{ MeV}$   
(3)  $16.48 \text{ MeV}$       (4)  $22.22 \text{ MeV}$

**Ans.** (4)



Energy released in process

$$Q = \Delta mc^2$$

$$Q = [M(\text{Li}) + M({}_1\text{H}^2) - 2 \times M({}_2\text{He}^4)] \times 931.5 \text{ MeV}$$

$$Q = [6.01690 + 2.01471 - 2 \times 4.00388] \times 931.5 \text{ MeV}$$

$$Q = 22.216 \text{ MeV}$$

$$Q = 22.22 \text{ MeV}$$

50. Two vessels A and B are of the same size and are at same temperature. A contains  $1\text{g}$  of hydrogen and B contains  $1\text{g}$  of oxygen.  $P_A$  and  $P_B$  are the pressures of the gases in A and B respectively, then

$$\frac{P_A}{P_B} \text{ is :}$$

- (1) 16      (2) 8      (3) 4      (4) 32

**Ans.** (1)

$$\frac{P_A V_A}{P_B V_B} = \frac{n_A R T_A}{n_B R T_B}$$

$$\text{Given } V_A = V_B$$

$$\text{And } T_A = T_B$$

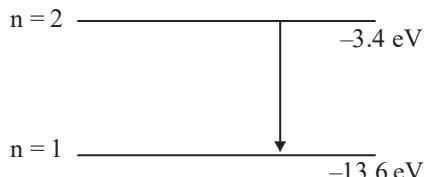
$$\frac{P_A}{P_B} = \frac{n_A}{n_B}$$

$$\frac{P_A}{P_B} = \frac{1/2}{1/32} = 16$$

## SECTION-B

51. When a hydrogen atom going from  $n = 2$  to  $n = 1$  emits a photon, its recoil speed is  $\frac{x}{5} \text{ m/s}$ . Where  $x = \text{_____}$ . (Use : mass of hydrogen atom  $= 1.6 \times 10^{-27} \text{ kg}$ )

**Ans.** (17)



**Sol.**

$$\Delta E = 10.2 \text{ eV}$$

$$\text{Recoil speed}(v) = \frac{\Delta E}{mc}$$

$$= \frac{10.2 \text{ eV}}{1.6 \times 10^{-27} \times 3 \times 10^8}$$

$$= \frac{10.2 \times 1.6 \times 10^{-19}}{1.6 \times 10^{-27} \times 3 \times 10^8}$$

$$v = 3.4 \text{ m/s} = \frac{17}{5} \text{ m/s}$$

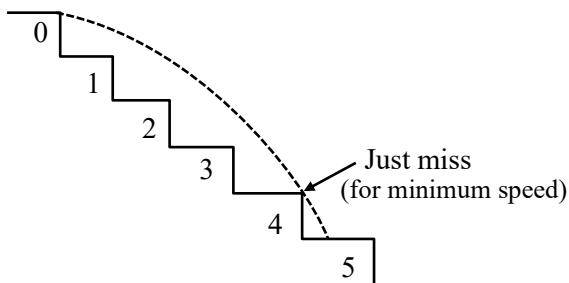
Therefore,  $x = 17$



52. A ball rolls off the top of a stairway with horizontal velocity  $u$ . The steps are 0.1 m high and 0.1 m wide. The minimum velocity  $u$  with which that ball just hits the step 5 of the stairway will be  $\sqrt{x} \text{ ms}^{-1}$  where  $x = \underline{\hspace{2cm}}$  [use  $g = 10 \text{ m/s}^2$ ].

**Ans. (2)**

**Sol.**



The ball needs to just cross 4 steps to just hit 5<sup>th</sup> step

Therefore, horizontal range ( $R$ ) = 0.4 m

$$R = u.t$$

Similarly, in vertical direction

$$h = \frac{1}{2}gt^2$$

$$0.4 = \frac{1}{2}gt^2$$

$$0.4 = \frac{1}{2}g\left(\frac{0.4}{u}\right)^2$$

$$u^2 = 2$$

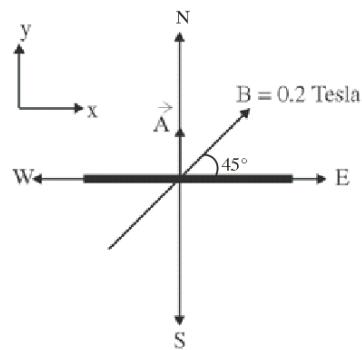
$$u = \sqrt{2} \text{ m/s}$$

$$\text{Therefore, } x = 2$$

53. A square loop of side 10 cm and resistance  $0.7\Omega$  is placed vertically in east-west plane. A uniform magnetic field of 0.20 T is set up across the plane in north east direction. The magnetic field is decreased to zero in 1 s at a steady rate. Then, magnitude of induced emf is  $\sqrt{x} \times 10^{-3}\text{V}$ . The value of  $x$  is  $\underline{\hspace{2cm}}$ .

**Ans. (2)**

**Sol.**



$$\vec{A} = (0.1)^2 \hat{j}$$

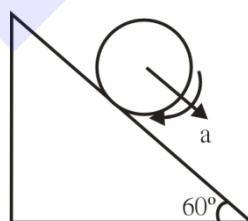
$$\vec{B} = \frac{0.2}{\sqrt{2}} \hat{i} + \frac{0.2}{\sqrt{2}} \hat{j}$$

**Magnitude of induced emf**

$$e = \frac{\Delta\phi}{\Delta t} = \frac{\vec{B} \cdot \vec{A} - 0}{1} = \sqrt{2} \times 10^{-3} \text{ V}$$

54. A cylinder is rolling down on an inclined plane of inclination  $60^\circ$ . Its acceleration during rolling down will be  $\frac{x}{\sqrt{3}} \text{ m/s}^2$ , where  $x = \underline{\hspace{2cm}}$ . (use  $g = 10 \text{ m/s}^2$ ).

**Ans. (10)**



**Sol.**

$$\text{For rolling motion, } a = \frac{g \sin \theta}{1 + \frac{I_{cm}}{MR^2}}$$

$$a = \frac{g \sin \theta}{1 + \frac{1}{2}}$$

$$= \frac{2 \times 10 \times \frac{\sqrt{3}}{2}}{3}$$

$$= \frac{10}{\sqrt{3}}$$

$$\text{Therefore } x = 10$$



55. The magnetic potential due to a magnetic dipole at a point on its axis situated at a distance of 20 cm from its center is  $1.5 \times 10^{-5}$  Tm. The magnetic moment of the dipole is \_\_\_\_\_ Am<sup>2</sup>.

$$\text{Given: } \frac{\mu_0}{4\pi} = 10^{-7} \text{ TmA}^{-1}$$

**Ans. (6)**

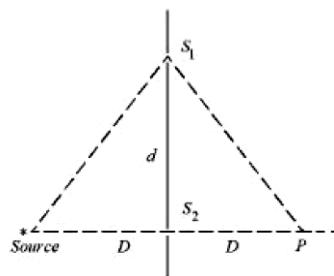
$$\text{Sol. } V = \frac{\mu_0}{4\pi} \frac{M}{r^2}$$

$$\Rightarrow 1.5 \times 10^{-5} = 10^{-7} \times \frac{M}{(20 \times 10^{-2})^2}$$

$$\Rightarrow M = \frac{1.5 \times 10^{-5} \times 20 \times 20 \times 10^{-4}}{10^{-7}}$$

$$M = 1.5 \times 4 = 6$$

56. In a double slit experiment shown in figure, when light of wavelength 400 nm is used, dark fringe is observed at P. If D = 0.2 m. the minimum distance between the slits S<sub>1</sub> and S<sub>2</sub> is \_\_\_\_\_ mm.



**Ans. (0.20)**

**Sol.** Path difference for minima at P

$$2\sqrt{D^2 + d^2} - 2D = \frac{\lambda}{2}$$

$$\therefore \sqrt{D^2 + d^2} - D = \frac{\lambda}{4}$$

$$\therefore \sqrt{D^2 + d^2} = \frac{\lambda}{4} + D$$

$$\Rightarrow D^2 + d^2 = D^2 + \frac{\lambda^2}{16} + \frac{D\lambda}{2}$$

$$\Rightarrow d^2 = \frac{D\lambda}{2} + \frac{\lambda^2}{16}$$

$$\Rightarrow d^2 = \frac{0.2 \times 400 \times 10^{-9}}{2} + \frac{4 \times 10^{-14}}{4}$$

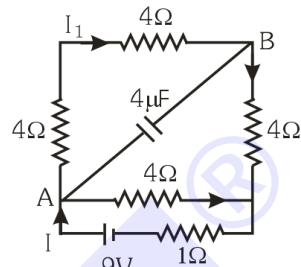
$$\Rightarrow d^2 \approx 400 \times 10^{-10}$$

$$\therefore d = 20 \times 10^{-5}$$

$$\Rightarrow d = 0.20 \text{ mm}$$

57. A 16Ω wire is bent to form a square loop. A 9V battery with internal resistance 1Ω is connected across one of its sides. If a 4μF capacitor is connected across one of its diagonals, the energy stored by the capacitor will be  $\frac{x}{2}$  μJ. where  $x = \underline{\hspace{2cm}}$ .

**Ans. (81)**



**Sol.**

$$I = \frac{V}{R_{eq}} \quad I = \frac{V}{R_{eq}} = \frac{9}{1 + \frac{12 \times 4}{12 + 4}} = \frac{9}{4}$$

$$I_1 = \frac{9}{4} \times \frac{4}{16} = \frac{9}{16}$$

$$V_A - V_B = I_1 \times 8 = \frac{9}{16} \times 8 = \frac{9}{2} \text{ V}$$

$$\therefore U = \frac{1}{2} \times 4 \times \frac{81}{4} \mu\text{J}$$

$$\therefore U = \frac{81}{2} \mu\text{J}$$

$$\therefore x = 81$$

58. When the displacement of a simple harmonic oscillator is one third of its amplitude, the ratio of total energy to the kinetic energy is  $\frac{x}{8}$ , where  $x = \underline{\hspace{2cm}}$ .

**Ans. (9)**

**Sol.** Let total energy = E =  $\frac{1}{2} KA^2$

$$U = \frac{1}{2} K \left( \frac{A}{3} \right)^2 = \frac{KA^2}{2 \times 9} = \frac{E}{9}$$

$$KE = E - \frac{E}{9} = \frac{8E}{9}$$

$$\text{Ratio } \frac{\text{Total}}{\text{KE}} = \frac{E}{\frac{8E}{9}} = \frac{9}{8}$$

$$x = 9$$



59. An electron is moving under the influence of the electric field of a uniformly charged infinite plane sheet S having surface charge density  $+\sigma$ . The electron at  $t = 0$  is at a distance of 1 m from S and has a speed of 1 m/s. The maximum value of  $\sigma$  if the electron strikes S at  $t = 1$  s is  $\alpha \left[ \frac{m \epsilon_0}{e} \right] \frac{C}{m^2}$   
the value of  $\alpha$  is

**Ans. (8)**

$$\text{Sol. } u = 1 \text{ m/s; } a = -\frac{\sigma e}{2\epsilon_0 m}$$

$$t = 1 \text{ s}$$

$$S = -1 \text{ m}$$

$$\text{Using } S = ut + \frac{1}{2}at^2$$

$$-1 = 1 \times 1 - \frac{1}{2} \times \frac{\sigma e}{2\epsilon_0 m} \times (1)^2$$

$$\therefore \sigma = 8 \frac{\epsilon_0 m}{e}$$

$$\therefore \alpha = 8$$

60. In a test experiment on a model aeroplane in wind tunnel, the flow speeds on the upper and lower surfaces of the wings are  $70 \text{ ms}^{-1}$  and  $65 \text{ ms}^{-1}$  respectively. If the wing area is  $2 \text{ m}^2$  the lift of the wing is \_\_\_\_\_ N.  
(Given density of air =  $1.2 \text{ kg m}^{-3}$ )

**Ans. (810)**

$$\text{Sol. } F = \frac{1}{2} \rho (v_1^2 - v_2^2) A$$

$$F = \frac{1}{2} \times 1.2 \times (70^2 - 65^2) \times 2$$

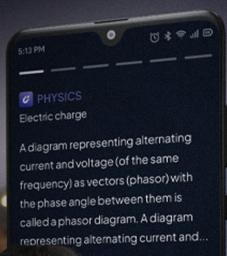
$$= 810 \text{ N}$$

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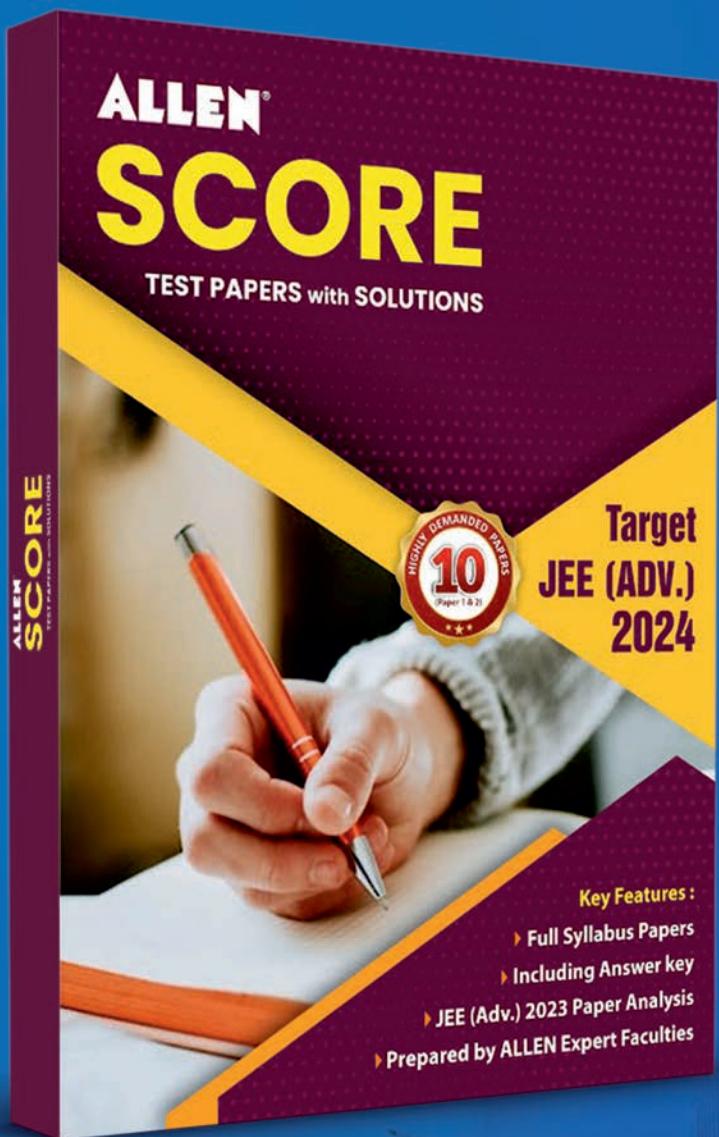


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