FINAL JEE–MAIN EXAMINATION – APRIL, 2024

(Held On Saturday 06th April, 2024) **TIME : 3 : 00 PM to 6 : 00 PM**

PHYSICS — TEST PAPER WITH SOLUTION

SECTION-A

31. The longest wavelength associated with Paschen series is : (Given $R_H = 1.097 \times 10^7$ SI unit)

(1) 1.094×10^{-6}m (2) 2.973×10^{-6}m

(3) 3.646×10^{-6}m (4) 1.876×10^{-6}m

Ans. (4)

Sol. For longest wavelength in Paschen's series:

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

For longest $n_1 = 3$

$n_2 = 4$

$$\frac{1}{\lambda} = R\left[\frac{1}{(3)^2} - \frac{1}{(4)^2}\right]$$

$$\frac{1}{\lambda} = R\left[\frac{1}{9} - \frac{1}{16}\right]$$

$$\frac{1}{\lambda} = R\left[\frac{16-9}{16\times 9}\right]$$

$$\Rightarrow \lambda = \frac{16\times 9}{7R} = \frac{16\times 9}{7\times 1.097\times 10^7}$$

$\lambda = 1.876 \times 10^{-6}$ m

32. A total of 48 J heat is given to one mole of helium kept in a cylinder. The temperature of helium increases by 2°C. The work done by the gas is : (Given, $R = 8.3$ J $K^{-1}mol^{-1}$.)

(1) 72.9 J (2) 24.9 J

(3) 48 J (4) 23.1 J

Ans. (4)

Sol. 1st law of thermodynamics

$\Delta Q = \Delta U + W$

$\Rightarrow +48 = nC_v\Delta T + W$

$$\Rightarrow 48 = (1)\left(\frac{3R}{2}\right)(2) + W$$

$\Rightarrow W = 48 - 3 \times R$

$\Rightarrow W = 48 - 3 \times (8.3)$

$\Rightarrow \boxed{W = 23.1 \text{ Joule}}$

33. In finding out refractive index of glass slab the following observations were made through travelling microscope 50 vernier scale division = 49 MSD; 20 divisions on main scale in each cm

For mark on paper

MSR = 8.45 cm, VC = 26

For mark on paper seen through slab

MSR = 7.12 cm, VC = 41

For powder particle on the top surface of the glass slab

MSR = 4.05 cm, VC = 1

(MSR = Main Scale Reading, VC = Vernier Coincidence)

Refractive index of the glass slab is:

(1) 1.42 (2) 1.52

(3) 1.24 (4) 1.35

Ans. (1)

Sol. $1 \text{ MSD} = \frac{1\text{cm}}{20} = 0.05$ cm

$$1 \text{ VSD} = \frac{49}{50}\text{ MSD} = \frac{49}{50}\times 0.05 \text{ cm} = 0.049 \text{ cm}$$

LC = 1MSD – 1VSD = 0.001 cm

For mark on paper, L_1 = 8.45 cm + 26 × 0.001 cm = 84.76 mm

For mark on paper through slab, L2 = 7.12 cm + 41× 0.001 cm = 71.61 mm

For powder particle on top surface, ZE = 4.05 cm + 1 × 0.001 cm = 40.51 mm

∴ actual L_1 = 84.76 – 40.51 = 44.25 mm

actual L2 = 71.61 – 40.51 = 31.10 mm

$$L_2 = \frac{L_1}{\mu}$$

$$\Rightarrow \mu = \frac{L_1}{L_2} = \frac{44.25}{31.10} = 1.42$$

34. In the given electromagnetic wave $E_y = 600 \sin(\omega t - kx)\ Vm^{-1}$, intensity of the associated light beam is (in W/m^2); (Given $\epsilon_0 = 9\times10^{-12}C^2N^{-1}m^{-2}$)

(1) 486 (2) 243

(3) 729 (4) 972

Ans. **(1)**

Sol. Intensity $= \frac{1}{2}\varepsilon_0 E_0^2 c$

$$= \frac{1}{2} \times 9 \times 10^{-12} \times (600)^2 \times 3 \times 10^8$$

$$= \frac{9}{2} \times 36 \times 3 = 486\ w/m^2$$

35. Assuming the earth to be a sphere of uniform mass density, a body weighed 300 N on the surface of earth. How much it would weigh at R/4 depth under surface of earth ?

(1) 75 N (2) 375 N

(3) 300 N (4) 225 N

Ans. **(4)**

Sol. At surface: mg = 300 N

$$m = \frac{300}{g_s}$$

At Depth $\frac{R}{4}$: $g_d = g_s\left[1-\frac{d}{R}\right]$

$$g_d = g_s\left[1-\frac{R}{4R}\right]$$

$$g_d = \frac{3g_s}{4}$$

weight at depth $= m \times g_d$

$$= m \times \frac{3g_s}{4}$$

$$= \frac{3}{4} \times 300$$

$$= 225\ N$$

36. The acceptor level of a p-type semiconductor is 6eV. The maximum wavelength of light which can create a hole would be : Given hc = 1242 eV nm.

(1) 407 nm (2) 414 nm

(3) 207 nm (4) 103.5 nm

Ans. **(3)**

Sol. Energy $= \frac{hc}{\lambda}$;

$$E = \frac{1240}{\lambda(nm)} eV$$

$$6 = \frac{1240}{\lambda(nm)}$$

$$\lambda = \frac{1240}{6} = 207nm$$

37. A car of 800 kg is taking turn on a banked road of radius 300 m and angle of banking 30°. If coefficient of static friction is 0.2 then the maximum speed with which car can negotiate the turn safely : ($g = 10\ m/s^2$, $\sqrt{3} = 1.73$)

(1) 70.4 m/s (2) 51.4 m/s

(3) 264 m/s (4) 102.8 m/s

Ans. **(2)**

Sol. m = 800 kg

r = 300 m

$\theta = 30°$

$\mu_s = 0.2$

$$V_{max} = \sqrt{Rg\left[\frac{\tan\theta + \mu}{1-\mu\tan\theta}\right]}$$

$$= \sqrt{300 \times g \times \left[\frac{\tan 30° + 0.2}{1-0.2\times\tan 30°}\right]}$$

$$= \sqrt{300 \times 10 \times \left[\frac{0.57 + 0.2}{1-0.2\times0.57}\right]}$$

$V_{max} = 51.4\ m/s$

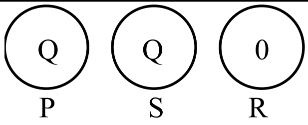
38. Two identical conducting spheres P and S with charge Q on each, repel each other with a force 16N. A third identical uncharged conducting sphere R is successively brought in contact with the two spheres. The new force of repulsion between P and S is :

(1) 4 N (2) 6 N

(3) 1 N (4) 12 N

Ans. **(2)**

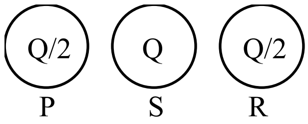
Sol.



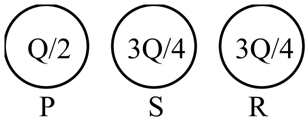
$F_{PS} \propto Q^2$

$F_{PS} = 16$ N

Now If P & R are brought in contact then



Now If S & R are brought in contact then



New force between P & S is :

$F_{PS} \propto \frac{Q}{2} \times \frac{3Q}{4}$

$F_{PS} \propto \frac{3Q^2}{8} = \frac{3}{8} \times 16 = 6N$

39. In a coil, the current changes form –2 A to +2A in 0.2 s and induces an emf of 0.1 V. The self-inductance of the coil is :

(1) 5 mH (2) 1 mH

(3) 2.5 mH (4) 4 mH

Ans. (1)

Sol. $(\text{Emf})_{\text{induced}} = -L\frac{di}{dt}$

In magnitude form,

$|\text{Emf}_{\text{ind}}| = \left|(-)L\frac{di}{dt}\right|$

$\Rightarrow 0.1 = \frac{(L)[+2-(-2)]}{0.2}$

$\Rightarrow \boxed{L = \frac{0.1 \times 0.2}{4} = 5\text{mH}}$

40. For the thin convex lens, the radii of curvature are at 15 cm and 30 cm respectively. The focal length the lens is 20 cm. The refractive index of the material is :

(1) 1.2 (2) 1.4

(3) 1.5 (4) 1.8

Ans. (3)

Sol. $\frac{1}{f} = \left(\frac{\mu_{\text{lens}}}{\mu_{\text{air}}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\Rightarrow \frac{1}{+20} = \left(\frac{\mu}{1} - 1\right)\left(\frac{1}{+15} - \frac{1}{(-30)}\right)$

$\Rightarrow \frac{1}{20} = (\mu - 1)\left(\frac{3}{30}\right)$

$\Rightarrow \mu - 1 = \frac{1}{2}$

$\Rightarrow \boxed{\mu = 1 + \frac{1}{2} = \frac{3}{2} = 1 \cdot 5}$

41. Energy of 10 non rigid diatomic molecules at temperature T is :

(1) $\frac{7}{2}$RT (2) 70 K_BT

(3) 35 RT (4) 35 K_BT

Ans. (4)

Sol. Degree of freedom(f) = 5 + 2(3N – 5)

f = 5 + 2(3 × 2 –1) = 7

energy of one molecule = $\frac{f}{2}K_BT$

energy of 10 molecules

$= 10\left(\frac{f}{2}K_BT\right) = 10\left(\frac{7}{2}K_BT\right) = 35\ K_BT$

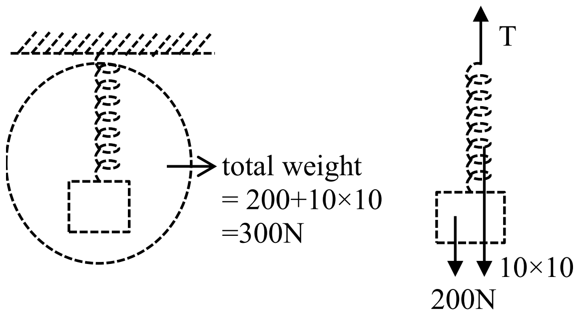
42. A body of weight 200 N is suspended form a tree branch thought a chain of mass 10 kg. The branch pulls the chain by a force equal to (if g = 10 m/s^2):

(1) 150 N (2) 300 N

(3) 200 N (4) 100 N

Ans. (2)

Sol.



Chain block system is in equilibrium so

T = 200 + 100 = 300 N.

43. When UV light of wavelength 300 nm is incident on the metal surface having work function 2.13 eV, electron emission takes place. The stopping potential is : (Given hc = 1240 eV nm)
(1) 4 V (2) 4.1 V (3) 2 V (4) 1.5 V

Ans. (3)

Sol. $\frac{hc}{\lambda} - \phi = e.V_s$

$\Rightarrow \frac{1240}{300} eV - 2.13\ eV = eVs$

$\Rightarrow$ 4.13 eV – 2.13 eV = eVs.

$\Rightarrow$ So, $\boxed{V_s = 2volt}$

44. The number of electrons flowing per second in the filament of a 110 W bulb operating at 220 V is : (Given e = 1.6×10^{-19} C)
(1) 31.25×10^{17} (2) 6.25×10^{18}
(3) 6.25×10^{17} (4) 1.25×10^{19}

Ans. (1)

Sol. Power (P) = V.I

$\Rightarrow 110 = (220)\ (I)$

$\Rightarrow I = 0.5$ A

Now, $I = \frac{n \cdot e}{t}$

$\Rightarrow 0.5 = \left(\frac{n}{t}\right)(1.6 \times 10^{-19})$

$\Rightarrow \frac{n}{t} = \frac{0.5}{1.6 \times 10^{-19}}$

$\Rightarrow \boxed{\frac{n}{t} = 31.25 \times 10^{17}}$

45. When kinetic energy of a body becomes 36 times of its original value, the percentage increase in the momentum of the body will be :
(1) 500% (2) 600%
(3) 6% (4) 60%

Ans. (1)

Sol. Kinetic energy (K) = $\frac{P^2}{2m}$

$\Rightarrow P = \sqrt{2mK}$

If $K_f = 36\ K_i$

So, $P_f = 6\ P_i$

% increase in momentum = $\frac{P_f - P_i}{P_i} \times 100\%$

$= \frac{6P_i - P_i}{P_i} \times 100\%$

= 500%

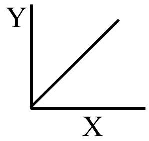
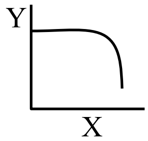
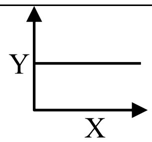
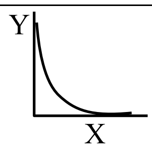
46. Pressure inside a soap bubble is greater than the pressure outside by an amount :
(given : R = Radius of bubble, S = Surface tension of bubble)
(1) $\frac{4S}{R}$ (2) $\frac{4R}{S}$
(3) $\frac{S}{R}$ (4) $\frac{2S}{R}$

Ans. (1)

Sol. There are two liquid-air surfaces in bubble so

$\Delta P = 2\left(\frac{2S}{R}\right) = \frac{4S}{R}$

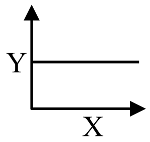
47. Match List-I with List-II

List-I (Y vs X)		List-II (Shape of Graph)	
(A)	Y = magnetic susceptibility X = magnetising field	(I)	
(B)	Y = magnetic field X = distance from centre of a current carrying wire for x < a (where a=radius of wire)	(II)	
(C)	Y = magnetic field X = distance from centre of a current carrying wire for x > a (where a = radius of wire)	(III)	
(D)	Y= magnetic field inside solenoid X = distance from center	(IV)	

Choose the correct answer from the options given below :
(1) (A)-(III), (B)-(I), (C)-(IV), (D)-(II)
(2) (A)-(I), (B)-(III), (C)-(II), (D)-(IV)
(3) (A)-(IV), (B)-(I), (C)-(III), (D)-(II)
(4) (A)-(III), (B)-(IV), (C)-(I), (D)-(II)

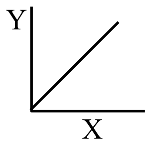
Ans. (4)

Sol. (A) Graph between Magnetic susceptibility and magnetising field is :



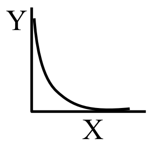
(B) magnetic field due to a current carrying wire for x < a :

$$B = \frac{\mu_0 \, i \, r}{2\pi a^2}$$

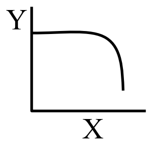


(C) magnetic field due to a current carrying wire for x > a :

$$B = \frac{\mu_0 \, i}{2\pi a}$$



(D) magnetic field inside solenoid varies as:



48. In a vernier calliper, when both jaws touch each other, zero of the vernier scale shifts towards left and its 4th division coincides exactly with a certain division on main scale. If 50 vernier scale divisions equal to 49 main scale divisions and zero error in the instrument is 0.04 mm then how many main scale divisions are there in 1 cm ?

(1) 40 (2) 5

(3) 20 (4) 10

NTA Ans. (3)

Allen Ans. (Bonus)

Sol. 4th division coincides with 3rd division then

0.004 cm = 4VSD – 3MSD

49MSD = 50 VSD

$$1\text{MSD} = \frac{1}{N}\text{ cm}$$

$$0.004 = 4\left\{\frac{49}{50}\text{MSD}\right\} - 3\text{MSD}$$

$$0.004 = \left(\frac{196}{50} - 3\right)\left(\frac{1}{N}\right)$$

$$N = \frac{46}{50} \times \frac{1000}{4} = \frac{46 \times 1000}{200} = 230$$

49. Given below are two statements :

Statement (I) : Dimensions of specific heat is $[L^2T^{-2}K^{-1}]$

Statement (II) : Dimensions of gas constant is $[M\,L^2T^{-1}K^{-1}]$

(1) Statement (I) is incorrect but statement (II) is correct

(2) Both statement (I) and statement (II) are incorrect

(3) Statement (I) is correct but statement (II) is incorrect

(4) Both statement (I) and statement (II) are correct

Ans. (3)

Sol. $\Delta Q = mS\Delta T$

$$\mathbf{s} = \frac{\Delta Q}{m\Delta T}$$

$$[\mathbf{s}] = \left[\frac{ML^2T^{-2}}{MK}\right]$$

$$[\mathbf{s}] = [L^2\,T^{-2}\,K^{-1}]$$

Statement-(I) is correct

$$PV = nRT \quad \Rightarrow R = \frac{PV}{nT}$$

$$[R] = \frac{[ML^{-1}T^{-2}][L^3]}{[mol][K]}$$

$$[R] = [ML^2T^{-2}\,mol^{-1}K^{-1}]$$

Statement-II is incorrect

50. A body projected vertically upwards with a certain speed from the top of a tower reaches the ground in t_1. If it is projected vertically downwards from the same point with the same speed, it reaches the ground in t_2. Time required to reach the ground, if it is dropped from the top of the tower, is :

(1) $\sqrt{t_1 t_2}$ (2) $\sqrt{t_1 - t_2}$

(3) $\sqrt{\frac{t_1}{t_2}}$ (4) $\sqrt{t_1 + t_2}$

Ans. (1)

Sol. $t_1 = \dfrac{u+\sqrt{u^2+2gh}}{g}$

$t_2 = \dfrac{-u+\sqrt{u^2+2gh}}{g}$

$t = \dfrac{\sqrt{2gh}}{g}$

$t_1 t_2 = \dfrac{(u^2+2gh)-u^2}{g^2} = \dfrac{2gh}{g^2} = t^2$

$\Rightarrow t = \sqrt{t_1 t_2}$

SECTION-B

51. In Franck-Hertz experiment, the first dip in the current-voltage graph for hydrogen is observed at 10.2 V. The wavelength of light emitted by hydrogen atom when excited to the first excitation level is ______ nm.

(Given hc = 1245 eV nm, e = 1.6×10^{-19}C).

Ans. **(122)**

Sol. $10.2 \text{ eV} = \dfrac{hc}{\lambda}$

$\lambda = \dfrac{1245 \text{ eV} - \text{nm}}{10.2\text{eV}} = 122.06 \text{ nm}$

52. For a given series LCR circuit it is found that maximum current is drawn when value of variable capacitance is 2.5 nF. If resistance of 200Ω and 100 mH inductor is being used in the given circuit. The frequency of ac source is _____ × 10^3 Hz. (given $\pi^2 = 10$)

Ans. **(10)**

Sol. for maximum current, circuit must be in resonance.

$f_0 = \dfrac{1}{2\pi\sqrt{L \times C}}$

$f_0 = \dfrac{1}{2\pi\sqrt{100 \times 10^{-3} \times 2.5 \times 10^{-9}}}$

$= \dfrac{1}{2\pi\sqrt{25 \times 10^{-11}}}$

$= \dfrac{1}{2\pi \times 5} \times 10^5 \times \sqrt{10} \text{ Hz}$

$= \dfrac{100}{10} \times 10^3 \text{ Hz}$

$f_0 = 10 \times 10^3$ Hz

53. A particle moves in a straight line so that its displacement x at any time t is given by $x^2 = 1 + t^2$. Its acceleration at any time t is x^{-n} where n = _____.

Ans. **(3)**

Sol. $x^2 = 1 + t^2$

$2x\dfrac{dx}{dt} = 2t$

$xv = t$

$x\dfrac{dv}{dt} + v\dfrac{dx}{dt} = 1$

$x.a + v^2 = 1$

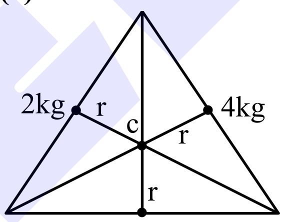
$a = \dfrac{1-v^2}{x} = \dfrac{1-t^2/x^2}{x}$

$a = \dfrac{1}{x^3} = x^{-3}$

54. Three balls of masses 2kg, 4kg and 6kg respectively are arranged at centre of the edges of an equilateral triangle of side 2 m. The moment of inertia of the system about an axis through the centroid and perpendicular to the plane of triangle, will be ______ kg m^2.

Ans. **(4)**

Sol.



$r = \dfrac{1}{\sqrt{3}}$

Moment of inertia about C and perpendicular to the plane is :

$I = r^2 [2 + 4 + 6]$

$= \dfrac{1}{3} \times 12$

$I = 4 \text{ kg-m}^2$

55. A coil having 100 turns, area of $5 \times 10^{-3} m^2$, carrying current of 1 mA is placed in uniform magnetic field of 0.20 T such a way that plane of coil is perpendicular to the magnetic field. The work done in turning the coil through 90° is _____ μJ.

Ans. **(100)**

Sol. $W = \Delta U = U_f - U_i$

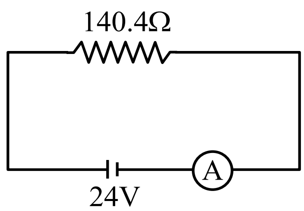
$W = (-\vec{\mu}.\vec{B})_f - (-\vec{\mu}.\vec{B})_i$

$= 0 + (\vec{\mu}.\vec{B})_i$

$= (100 \times 5 \times 10^{-3} \times 1 \times 10^{-3}) \times 0.2$ J

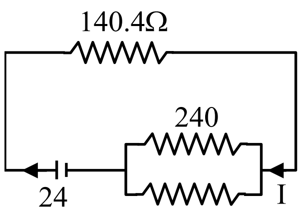
$= 1 \times 10^{-4}$ J = 100 μJ

56. In the given figure an ammeter A consists of a 240Ω coil connected in parallel to a 10 Ω shunt. The reading of the ammeter is ______ mA.



Ans. (160)

Sol.



Req

$= 140.4 + \frac{240 \times 10}{240 + 10}$

$Req = 140.4 + \frac{2400}{250}$

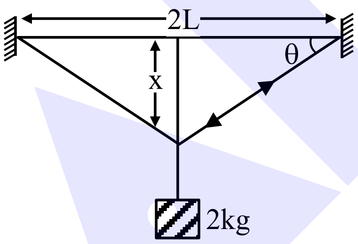
$Req. = 150\Omega$

$\therefore$ Current in ammeter $= \frac{24}{150}$

$= 160$ mA

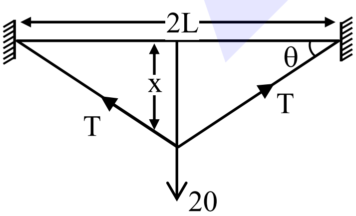
57. A wire of cross sectional area A, modulus of elasticity 2×10^{11} Nm^{-2} and length 2 m is stretched between two vertical rigid supports. When a mass of 2 kg is suspended at the middle it sags lower from its original position making angle $\theta = \frac{1}{100}$ radian on the points of support. The value of A is _____ $\times 10^{-4}$ m^2 (consider x<<L).

(given : g=10 m/s^2)



Ans. (1)

Sol.



In vertical derection

$2T \sin\theta = 20$

using small angle approximation $\sin\theta = \theta$

$\theta = \frac{1}{100}$

$\therefore$ $T = \frac{10}{\theta}$

$T = 1000N$

Change in length $\Delta L = 2\sqrt{x^2 + L^2} - 2L$

$= 2L\left[1 + \frac{x^2}{2L^2} - 1\right]$

$\Delta L = \frac{x^2}{L}$

$\therefore$ Modulus of elasticity $= \frac{\text{stress}}{\text{strain}}$

$2 \times 10^{11} = \frac{10^3}{A \times \frac{x^2}{L}} \times 2L$

$\therefore$ $A = 1 \times 10^{-4}$ m^2

58. Two coherent monochromatic light beams of intensities I and 4I are superimposed. The difference between maximum and minimum possible intensities in the resulting beam is x I. The value of x is______.

Ans. **(8)**

Sol. $I_{max} = \left(\sqrt{I} + \sqrt{4I}\right)^2 = 9I$

$I_{min} = \left(\sqrt{4I} - \sqrt{I}\right)^2 = I$

$\therefore I_{max} - I_{min} = 8I$

59. Two open organ pipes of length 60 cm and 90 cm resonate at 6^{th} and 5^{th} harmonics respectively. The difference of frequencies for the given modes is _____ Hz.

(Velocity of sound in air = 333 m/s)

Ans. **(740)**

Sol. The difference in frequency in open organ pipe =

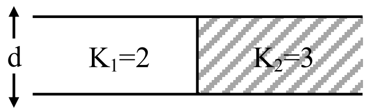
$f = \frac{nv}{2L}$

$\Delta f = \frac{6v}{2 \times 0.6} - \frac{5v}{2 \times 0.9}$

$v = 333$ m/s

$\Delta f = 740$ Hz

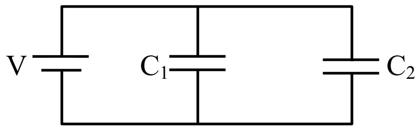
60. A capacitor of 10 μF capacitance whose plates are separated by 10 mm through air and each plate has area 4 cm^2 is now filled equally with two dielectric media of $K_1 = 2$, $K_2 = 3$ respectively as shown in figure. If new force between the plates is 8 N. The supply voltage is _____ V.



NTA Ans. (80)

Allen Ans. (Bonus)

Sol.



$C_{eq} = C_1 + C_2$

$$C_1 = \frac{2 \in_0 A}{2 \times d} = 10\mu F$$

$$C_2 = \frac{3 \in_0 A}{2d} = 15\mu F$$

$C_{eq} = 25\ \mu F$

Now the charge on $C_1 = 10V\ \mu c$

$C_2 = 1.5\ V\ \mu C.$

Now force between the plates $\left[F = \frac{Q^2}{2A \in_0}\right]$

$$\frac{100V^2 \times 10^{-12}}{2 \times 2 \times 10^{-4} \in_0} + \frac{225V^2 \times 10^{-12}}{2 \times 2 \times 10^{-4} \times \in_0} = 8$$

$325\ V^2 = 8 \times 4 \times 10^{-4} \times 8.85$

$$V^2 = \frac{32 \times 8.85 \times 10^{-4}}{325}$$

$$\therefore\ V = \sqrt{\frac{283.2 \times 10^{-4}}{325}}$$

$$\boxed{V = 0.93 \times 10^{-2}}$$