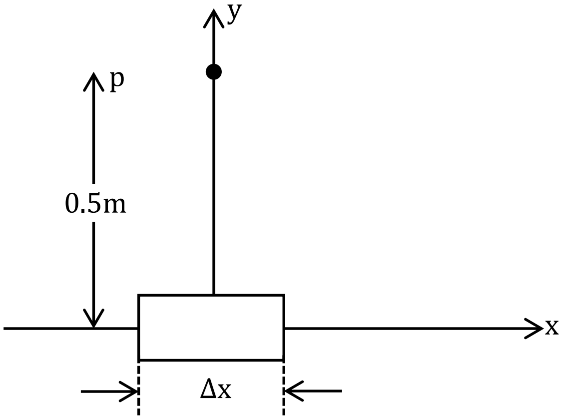
JEE MAIN 2024 SESSION-2
Paper with Solution

PHYSICS | 06th April 2024 _ Shift-1

SECTION – A

31. An element $\Delta l = \Delta x\hat{i}$ is placed at the origin and carries a large current I = 10 A. The magnetic field on the y-axis at a distance of 0.5m from the elements Δx of 1cm length is :



(1) 8×10^{-8}T (2) 10×10^{-8}T (3) 4×10^{-8}T (4) 12×10^{-8}T

Sol. **3**

by biot-savart law

small magnetic field, $dB = \frac{\mu_0}{4\pi}\cdot\frac{i(\vec{dl}\times\vec{r})}{r^3} = \frac{\mu_0}{4\pi}\frac{i\cdot dl\sin\theta}{r^2}$

since element is very small, dl = 1 cm, r = 50 cm, i = 10 A, sin θ = 1

magnetic field = $\frac{(10^{-7})\times(10)(10^{-2})}{(0.5)^2}$ = 4×10^{-8} T

32. Given below are two statements :

Statement I : In an LCR series circuit, current is maximum at resonance.

Statement II : Current in a purely resistive circuit can never be less than that in a series LCR circuit when connected to same voltage source.

In the light of the above statements, choose the correct from the options given below :

(1) Statement I is true but Statement II is false

(2) Statement I is false but Statement II is true

(3) Both Statement I and Statement II are false

(4) Both Statement I and Statement II are true

Sol. **4**

in LCR circuit, $i = \frac{V}{Z}$

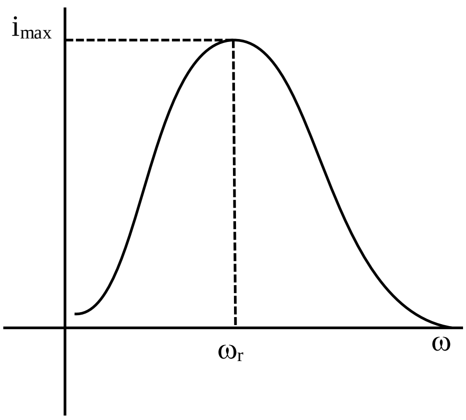
$Z = \sqrt{(x_c - x_L)^2 + R^2}$

Z_{min} = R at resonance ($X_C = X_L$)

therefore, $i_{max} = \frac{V}{Z_{min}} = \frac{V}{R}$ at resoname

also, current in LCR circuit $i \le \frac{V}{R}$

here $\frac{V}{R}$ is the curent in purely resistive circuit.



33. Match L is I with List II

LIST-I		LIST-II	
A.	Torque	I.	$[M^1L^1T^{-2}A^{-2}]$
B.	Magnetic field	II.	$[L^2A^1]$
C.	Magnetic moment	III.	$[M^1T^{-2}A^{-1}]$
D.	Permeability of free space	IV.	$[M^1L^2T^{-2}]$

Choose the correct answer from the options given below :

(1) A-III, B-I, C-II, D-IV
(2) A-IV, B-II, C-III, D-I
(3) A-IV, B-III, C-II, D-I
(4) A-I, B-III, C-II, D-IV

Sol. **3**

(A) Torque $(\vec{r}) = \vec{r} \times \vec{F}$ $[M^1L^2T^{-2}]$

(B) Magnetic field $\left(F = ilB \text{ or } B = \frac{F}{il}\right)$ $[M^1T^{-2}A^{-1}]$

(C) magnetic moment (M = iNA) $[M^0L^2T^0A^1]$ $[L^2A^1]$

(D) Permeability of free space (μ_0) $\Rightarrow$ $B = \frac{\mu_0 i}{2\pi l}$ $[M^1L^1T^{-2}A^{-2}]$

34. A small ball of mass m and density ρ is dropped in a viscous liquid of density ρ_0. After sometime, the ball falls with constant velocity. The viscous force on the ball is :

(1) $mg\left(\frac{\rho_0}{\rho} - 1\right)$
(2) $mg(1 - \rho\rho_0)$
(3) $mg\left(1 + \frac{\rho}{\rho_0}\right)$
(4) $mg\left(1 - \frac{\rho_0}{\rho}\right)$

Sol. **4**

at constant velocity

$F_B + F_V = mg$

$F_V = mg - F_B$

$= mg\left(1 - \frac{\rho_0}{\rho}\right)$

$F_B = \rho_0 \cdot \left(\frac{m}{\rho}\right) \cdot g$

35. A bullet of mass 50g is fired with a speed 100 m/s on a plywood and emerges with 40 m/s. The percentage loss of kinetic energy is :

(1) 44%
(2) 32%
(3) 84%
(4) 16%

Sol. **3**

$$\% \text{ loss of K.E} = \frac{k_f - k_i}{k_i} \times 100\%$$

$$= \frac{\frac{1}{2}m(40)^2 - \frac{1}{2}m(100)^2}{\frac{1}{2}m(100)^2} \times 100\%$$

$$= -\frac{(140)(60)}{100 \times 100} \times 100 = -84\%$$

[84% in magnitude]

36. The ratio of the shortest wavelength of Balmer series to the shortest wavelength of Lyman series for hydrogen atom is :

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

Sol. **4**

for Balmer series limit, $\frac{1}{\lambda_B} = R\left[\frac{1}{(2)^2} - \frac{1}{\infty^2}\right] = \frac{R}{4}$

for Lyman series limit, $\frac{1}{\lambda_\ell} = k\left[\frac{1}{(1)^2} - \frac{1}{\infty^2}\right] = R$

$\left(\frac{\lambda_B}{\lambda_\ell} = 4\right)$

37. A sample contains mixture of helium and oxygen gas. The ratio of root mean square speed of helium and oxygen in the sample, is :

(1) $\frac{1}{32}$ (2) $\frac{1}{2\sqrt{2}}$ (3) $\frac{1}{4}$ (4) $\frac{2\sqrt{2}}{1}$

Sol. **4**

$V_{rms} = \sqrt{\frac{3RT}{M}}$

$\frac{V_{He}}{V_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{He}}} = \sqrt{\frac{32}{4}} = \sqrt{8} = 2\sqrt{2}$

38. σ is the uniform surface charge density of a thin spherical shell of radius R. The electric field at any point on the surface of the spherical shell is :

(1) $\sigma/\in_0 R$ (2) $\sigma/\in_0$ (3) $\sigma/2\in_0$ (4) $\sigma/4\in_0$

Sol. **2**

electric field at surface due to thin shell

$= \frac{KQ}{R^2} = \frac{1}{4\pi\in_0}\cdot\frac{\sigma\times 4\pi R^2}{R^2} = \frac{\sigma}{\in_0}$

here, $Q = \sigma \times 4\pi R^2$

$k = \frac{1}{4\pi\varepsilon_0}$

39. While measuring diameter of wire using screw gauge the following readings were noted. Main scale reading is 1 mm and circular scale reading is equal to 42 divisions. Pitch of screw gauge is 1 mm and it has 100 divisions on circular scalar. The diameter of the wire is $\frac{x}{50}$ mm . The value of x is :

(1) 142 (2) 21 (3) 42 (4) 71

Sol. **4**

reading by screw gauge = main scale reading + least count × circular scale reading

$= 1\text{mm} + \frac{1\text{mm}}{100}\times 42$

= 1.42 mm = 71/50 mm

40. Electromagnetic waves travel in a medium with speed of $1.5\times10^{8}\,ms^{-1}$. The relative permeability of the medium is 2.0. The relative permittivity will be :

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

Sol. **1**

Speed of light in vaccum = $\dfrac{1}{\sqrt{\mu_0 \in_0}} = 3\times10^{8}$

Speed of light in medium = $\dfrac{1}{\sqrt{\mu_0 \in_0}\cdot\sqrt{\mu_r \in_r}} = \dfrac{3}{2}\times10^{8}$

Also, given, $\in_r = 2$, therefore, $\mu_r = 2$.

41. In photoelectric experiment energy of 2.48 eV irradiates a photo sensitive material. The stopping potential was measured to be 0.5 V. Work function of the photo sensitive material is :

(1) 2.48 eV (2) 0.5 eV (3) 1.98 eV (4) 1.68 eV

Sol. **3**

$eV_S = h\nu - \phi$

$0.5eV = 2.48\text{ eV} - \phi$

$\phi = (2.48 - 0.5)\text{ eV} = 1.98\text{ eV}$

42. To project a body of mass m from earth's surface to infinity, the required kinetic energy is (assume, the radius of earth is R_E, g = acceleration due to gravity on the surface of earth) :

(1) mgR_E (2) $1/2mgR_E$ (3) $4mgR_E$ (4) $2mgR_E$

Sol. **1**

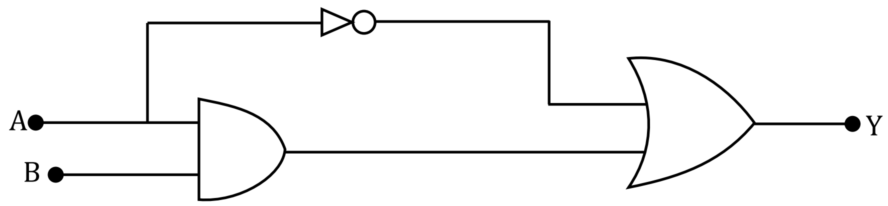
escape speed (u) = $\sqrt{\dfrac{2GM}{R}}$

escape kinetic energy = $\dfrac{1}{2}mu^2$

$= \dfrac{GMm}{R} = mgR$

Also, $g = \dfrac{GM}{R^2}$

43. The correct truth table for the following logic circuit is :



(1)

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	0

(2)

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	1

(3)

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

(4)

A	B	Y
0	0	0
0	1	1
1	0	0
1	1	1

Sol. **2**

By Boolean expression

y = $\bar{A} + A \cdot B$

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	1

44. The specific heat at constant pressure of a real gas obeying $PV^2 = RT$ equations is :

(1) $\frac{R}{3} + C_V$ (2) R (3) $C_V + R$ (4) $C_V + \frac{R}{2V}$

Sol. **4**

dQ = du + dw

ncdT = nc_vdT + dw

we need to find dw

we have pv^2 = RT, P = constant

differentiating, (P) (2v.dv) = RdT

$$P.dv = \frac{R.dT}{2v}$$

$$\text{Also, } dw = P.dv = \frac{R.dT}{2v}$$

for one mole of gas,

$$C.dT = C_v dT + \frac{R.dT}{2v}$$

$$C = C_v + \frac{R}{2v}$$

45. To find the spring constant (k) of a spring experimentally, a student commits 2% positive error in the measurement of time and 1% negative error in measurement of mass. The percentage error in determining value of k is:

(1) 3% (2) 4% (3) 5% (4) 1%

Sol. **3**

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$k = 4\pi^2 . \frac{m}{T^2}$$

$$\frac{\Delta k}{k} = \frac{\Delta m}{m} - 2.\frac{\Delta T}{T}$$

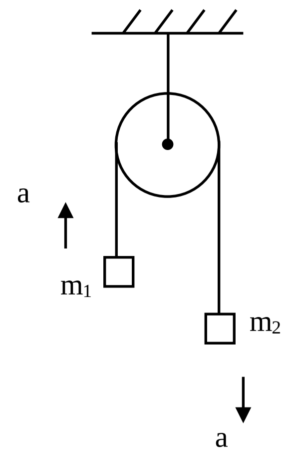
= – 1% – 2(2%)

= – 5%

46. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (where $m_2 > m_1$). If the acceleration of the system is $\frac{g}{\sqrt{2}}$, then the ratio of the masses $\frac{m_1}{m_2}$ is :

(1) $\frac{\sqrt{3}+1}{\sqrt{2}-1}$ (2) $\frac{1+\sqrt{5}}{\sqrt{2}-1}$ (3) $\frac{1+\sqrt{5}}{\sqrt{5}-1}$ (4) $\frac{\sqrt{2}-1}{\sqrt{2}+1}$

Sol. **4**



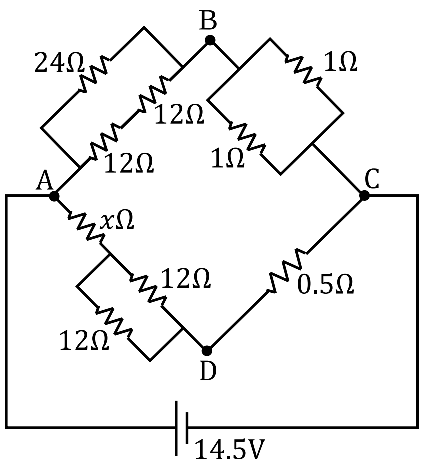
$$a = \frac{(m_2 - m_1)g}{m_1 + m_2}$$

$$a = \frac{g}{\sqrt{2}} = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)g$$

$$\left(1+\sqrt{2}\right)m_1 = \left(\sqrt{2}-1\right)m_2$$

$$\frac{m_1}{m_2} = \frac{\sqrt{2}-1}{\sqrt{2}+1}$$

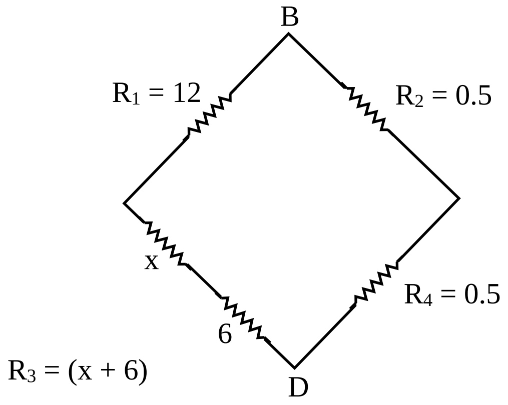
47. The value of unknown resistance (x) for which the potential between B and D will be zero in the arrangement shown, is :



(1) 6Ω (2) 9Ω (3) 42Ω (4) 3Ω

Sol. **1**

Potential difference between B & D will be zero in a balanced Wheatstone bridge ($R_1R_4 = R_2R_3$)



$(12)(0.5) = (0.5)(x + 6)$

$\boxed{x = 6}$

48. Four particles A, B, C, D of mass $\frac{m}{2}, m, 2m, 4m$ have same momentum, respectively. The particle with maximum kinetic energy is :

(1) A (2) D (3) B (4) C

Sol. **1**

Kinetic energy = $\frac{P^2}{2m}$

P $\Rightarrow$ momentum (same for all)

$KE \propto \frac{1}{mass}$

particle A is of least mass, have maximum kinetic energy

49. Which of the following phenomena does not explain by wave nature of light.

A. reflection

B. diffraction

C. photoelectric effect

D. interference

E. polarization

Choose the most appropriate answer from the options given below :

(1) E only (2) A, C only (3) B, D only (4) C only

Sol. **4**

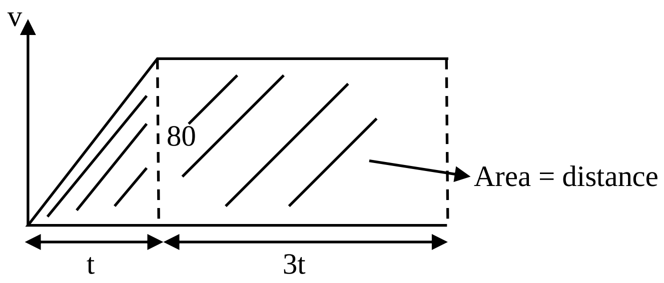
Photoelectric effect can not be explained by wave nature of light.

Reflection, diffraction, interference, & polarization are shown by wave nature of light.

50. A train starting from rest first accelerates uniformly up to a speed of 80 km/h for time t, then it moves with a constant speed for time 3t. the average speed of the train for this duration of journey will be (in km/h) :

(1) 30 (2) 80 (3) 40 (4) 70

Sol. **4**



average speed = $\dfrac{\text{distance}}{\text{time}}$

$= \dfrac{\frac{1}{2}(t)(80)+80\times 3t}{4t}$

$= \dfrac{40t+240t}{4t}$

$= \dfrac{280}{4} = 70\text{km / hr}$

SECTION – B

51. For three vectors $\vec{A}=\left(-x\hat{i}-6\hat{j}-2\hat{k}\right),\vec{B}=\left(-\hat{i}+4\hat{j}+3\hat{k}\right)$ and $\vec{C}=\left(-8\hat{i}-\hat{j}+3\hat{k}\right)$, if $\vec{A}.\left(\vec{B}\times\vec{C}\right)=0$ then value of x is ________ .

Sol. **4**

$\vec{B}=-\hat{i}+4\hat{j}+3\hat{k}$

$\vec{C}=-8\hat{i}-\hat{j}+3\hat{k}$

$$\vec{B}\times\vec{C}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ -1 & 4 & 3\\ -8 & -1 & 3\end{vmatrix}=\begin{matrix}(\hat{i})[12-(-3)]\\ -\hat{j}(-3-(-24))\\ \hat{k}(1-(-32))\end{matrix}$$

$\vec{A}=-x\hat{i}-6\hat{j}-2\hat{k},\ \ \vec{B}\times\vec{C}=15\hat{i}-21\hat{j}+33\hat{k}$

$\vec{A}.\left(\vec{B}\times\vec{C}\right)=0$

$-15x + 126 - 66 = 0$

$x = 4$

52. If the radius of earth is reduced to three-fourth of its present value without change in its mass then value of duration of the day of earth will be _______ hours 30 minutes.

Sol. **13**

By angular momentum conservation

$I_1\omega_1 = I_2\omega_2$

$\dfrac{2}{5}mr^2\cdot\omega=\dfrac{2}{5}m\left(\dfrac{3}{4}r\right)^2\cdot\omega'$

$\omega'=\dfrac{16}{9}\omega$

$$\frac{2\pi}{T'} = \frac{16}{9} \times \frac{2\pi}{T}$$

$$T' = \frac{9T}{16} = \frac{9}{16} \times 24 \text{ hours}$$

$$= \frac{9 \times 3}{2} \text{ hours}$$

$$= 13.5 \text{ hours}$$

= 13 hours, 30 minutes

53. The refractive index of prism is $\mu = \sqrt{3}$ and the ratio of the angle of minimum deviation to the angle of prism is one. The value of angle of prism is __________°.

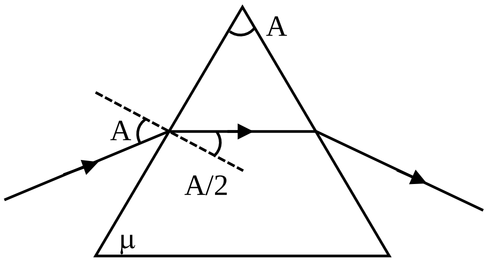
Sol. **60**

$\delta = i + e - A$ and $\frac{\delta}{A} = 1$; $\delta = A$

$A = i + e - A$

$i + e = 2A$ and for δ_{min}, $i = e$

So, $i = e = A$



by snell's law at 1st surface of prism.

$1. \sin A = \sqrt{3}.\sin\left(\frac{A}{2}\right)$

$A = 60°$

54. A wire of resistance R and radius r is stretched till is radius became r/2. If new resistance of the stretched of the stretched wire is x R, then value of x is _________.

Sol. **16**

Resistance, $R = \frac{\rho l}{\pi r^2}$; $\pi r^2 l$ = constant

$$l \propto \frac{1}{r^2}$$

surface, $R \propto \frac{1}{r^4}$

if radius becomes half, then resistance becomes 16 times.

55. A big drop is formed by coalescing 1000 small droplets of water. The ratio of surface energy of 1000 droplets to that of energy of big drop is $\frac{10}{x}$. The value of x is _________.

Sol. **1**

If radius of a small drop is 'r'

then radius of a bigger drop is R and it is given by –

$\frac{4}{3}\pi r^3 \times 1000 = \frac{4}{3}\pi R^3$

(R = 10r)

surface energy of 1000 drops = 1000 × T × $4\pi r^2$

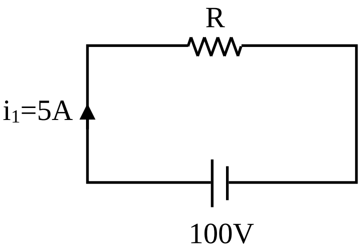
surface energy of bigger drop = T × $4\pi R^2$

required ratio = $= \frac{1000 \times T \times 4\pi r^2}{T \times 4\pi R^2}$

$= \frac{1000 r^2}{R^2} = 10$

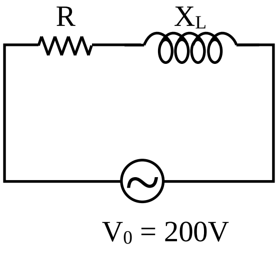
56. When a dc voltage of 100V is applied to an inductor, a dc current of 5A flows through it. When an ac voltage of 200V peak value is connected to inductor, its inductive reactance is found to be $20\sqrt{3}\Omega$. The power dissipated in the circuit is _______ W.

Sol. **250**



$R = \frac{V}{i} = \frac{100}{5} = 20\Omega$

DC supply



$X_L = 20\sqrt{3}\Omega$

Eav = $\frac{X_L}{R}$ = $\sqrt{3}$

($\phi = 60°$)

$z = \sqrt{X_L^2 + R^2}$

$= \sqrt{(20\sqrt{3})^2 + (20)^2}$ = 40 Ω power dissipated

$p = i_{rms}.v_{rms}.\cos\phi$

$$= \frac{v_{rms}^2}{z}\cdot\cos\phi$$

$$= \frac{\left(\frac{200}{\sqrt{2}}\right)^2}{40}\times\frac{1}{2} = \frac{2\times 10000}{40}\times\frac{1}{2}$$

= 250 W

57. Radius of a certain orbit of hydrogen atom is $8.48\,\overset{o}{A}$. If energy of electron in this orbit is E/x, then x = ______.

(Given $a_0 = 0.529\,\overset{o}{A}, E =$ energy of electron in ground state).

Sol. **16**

$r = r_0.\ \frac{n^2}{z}$, for hydrogen, z = 1

$8.48 = 0.529.\ n^2;\ n^2 = 16;\ n = 4$

energy of electron in n^{th} orbit $(E)' = \frac{E}{n^2} = \frac{E}{16}$

58. A particle is doing simple harmonic motion of amplitude 0.06 m and time period 3.14 s. The maximum velocity of the particle is _______ cm/s.

Sol. **12**

A = 0.06

$$T = \frac{2\pi}{\omega} = 3.14 \Rightarrow \omega = 2$$

$$V_{max} = \omega A = 2\times\frac{6}{100} = 12\,cm/s$$

59. A circular coil having 200 turns, $2.5\times10^{-4}\,m^2$ area and carrying $100\mu A$ current is placed in a uniform magnetic field of IT. Initially the magnetic dipole moment $(\vec{M})$ was directed along $\vec{B}$. Amount of work, required to rotate the coil through 90° from its initial orientation such that $\vec{M}$ becomes perpendicular to $\vec{B}$, is ________ μJ.

Sol. **5**

work done by external = $\Delta U = U_f - U_i = M.B$

initially, $U_i = -MB\cos\theta$

$= -MB$

finally, $U_f = -Mb\cos 90 = 0$

M(magnetic moment of coil) = i.N.A

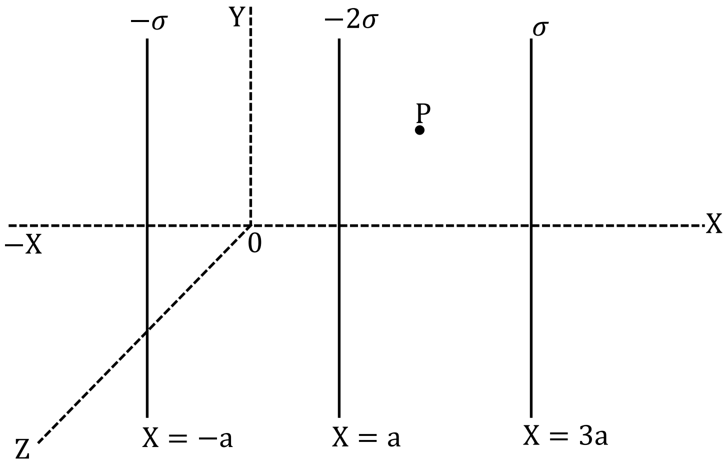
$$= (100\times10^{-6})\cdot(200)\cdot(2.5\times10^{-4})$$

$= 5\times10^{-6}$

work = $\Delta U = MB = (5\times10^{-6})(1)$

$= 5\,\mu J$

60. Three infinitely long charged thin sheets are placed as shown in figure. The magnitude of electric field at the point P is $\frac{x\sigma}{\epsilon_0}$. The value of x is _______ (all quantities are measured in SI units).



Sol. **2**

$$\vec{E} = \overrightarrow{E_1} + \overrightarrow{E_2} + \overrightarrow{E_3}$$

$$= \frac{\sigma}{2\varepsilon_0}(-\hat{i}) + \frac{-2\sigma}{2\varepsilon_0}(\hat{i}) + \frac{-\sigma}{2\varepsilon_0}(\hat{i})$$

$$= -\frac{4\sigma}{2\varepsilon_0}\hat{i} = \frac{2\sigma}{\varepsilon_0}(-\hat{i})$$

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