JEE–MAIN EXAMINATION – APRIL 2025

(HELD ON WEDNESDAY 2nd APRIL 2025) **TIME : 9:00 AM TO 12:00 NOON**

PHYSICS — TEST PAPER WITH SOLUTION

SECTION-A

26. A light wave is propagating with plane wave fronts of the type x + y + z = constant. The angle made by the direction of wave propagation with the x-axis is :

(1) $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (2) $\cos^{-1}\left(\frac{2}{3}\right)$

(3) $\cos^{-1}\left(\frac{1}{3}\right)$ (4) $\cos^{-1}\left(\sqrt{\frac{2}{3}}\right)$

Ans. (1)

Sol. The direction of propagation of light is perpendicular to the wave front and is symmetric about x, y and z axis.

∴ Angle made by the light with x, y & z axis is same.

∴ $\cos\alpha = \cos\beta = \cos\gamma$ (α, β & γ are angle made by light with x, y & z axis respectively)

Also $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$ [Sum of direction cosines]

$\therefore \ \alpha = \cos^{-1}\frac{1}{\sqrt{3}}$

27. The equation for real gas is given by $\left(P+\frac{a}{V^2}\right)(V-b)=RT$, where P,V,T and R are the pressure, volume, temperature and gas constant, respectively. The dimension of ab^{-2} is equivalent to that of :

(1) Planck's constant (2) Compressibility

(3) Strain (4) Energy density

Ans. (4)

Sol. $\left[P+\frac{a}{V^2}\right](V-b)=RT$

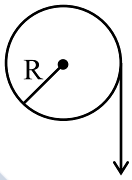
$\therefore [a] = [P]\,[V^2] = ML^{-1}T^{-2}L^6 = ML^5T^{-2}$

$[b] = [V] = L^3$

$[ab^{-2}] = ML^5T^{-2}L^{-6} = ML^{-1}T^{-2}$

Dimension of energy density.

28. A cord of negligible mass is wound around the rim of a wheel supported by spokes with negligible mass. The mass of wheel is 10 kg and radius is 10 cm and it can freely rotate without any friction. Initially the wheel is at rest. If a steady pull of 20 N is applied on the cord, the angular velocity of the wheel, after the cord is unwound by 1 m, would be :



(1) 20 rad/s (2) 30 rad/s

(3) 10 rad/s (4) 0 rad/s

Ans. (1)

Sol. $W_F = 20 \times 1 = 20$ J

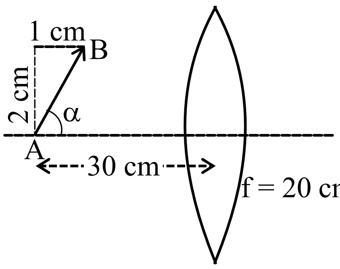
$\therefore \ \Delta KE = 20\text{ J} = \frac{1}{2}I\omega^2$

$I = MR^2 = 10 \times 0.1^2 = 0.1$ kg m^2

$\therefore \ 20 = \frac{1}{2}\times 0.1\times\omega^2$

$\Rightarrow \omega = 20$ rad/sec

29. A slanted object AB is placed on one side of convex lens as shown in the diagram. The image is formed on the opposite side. Angle made by the image with principal axis is :

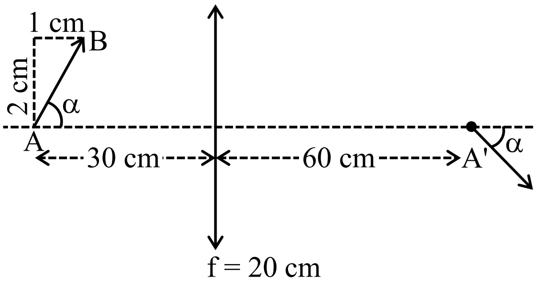


(1) $-\frac{\alpha}{2}$ (2) –45°

(3) +45° (4) –α

Ans. (2)

Sol.



Location of image of A :-

$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{v}-\frac{1}{-30}=\frac{1}{20}\Rightarrow\frac{1}{v}=\frac{1}{60}\Rightarrow v=60cm$

$\therefore m = 2$

Since size of object is small wrt the location

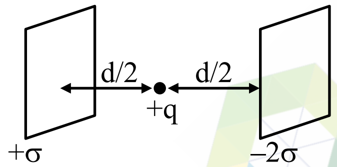
hence

$dv = m^2du \Rightarrow dv = 4 \times 1 = 4$ cm

$h_i = mh_0 \Rightarrow h_i(dy) = 2 \times 2 = 4$ cm

$\therefore$ Angle made with principle axis = –45°

30. Consider two infinitely large plane parallel conducting plates as shown below. The plates are uniformly charged with a surface charge density +σ and –2σ. The force experienced by a point charge +q placed at the mid point between two plates will be :

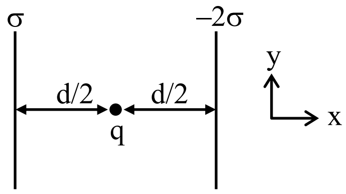


(1) $\frac{\sigma q}{4\epsilon_0}$ (2) $\frac{3\sigma q}{2\epsilon_0}$

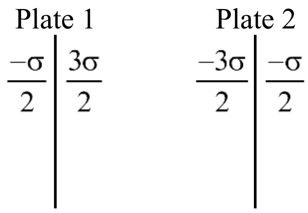
(3) $\frac{3\sigma q}{4\epsilon_0}$ (4) $\frac{\sigma q}{2\epsilon_0}$

Ans. (2)

Sol.



Final charge distribution will be



$\therefore F_{net} = \frac{3\sigma}{2\epsilon_0}q$

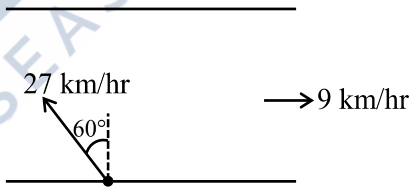
31. A river is flowing from west to east direction with speed of 9 km h^{-1}. If a boat capable of moving at a maximum speed of 27 km h^{-1} in still water, crosses the river in half a minute, while moving with maximum speed at an angle of 150° to direction of river flow, then the width of the river is :

(1) 300 m (2) 112.5 m

(3) 75 m (4) $112.5 \times \sqrt{3}$ m

Ans. (2)

Sol.



$\therefore V_{\perp}$ = river flow = $27 \times \cos 60° = \frac{27}{2}$ km / hr.

Time taken = 30 sec.

$\therefore S = Vt = \frac{27}{2}\times\frac{5}{18}\times 30m = 112.5m$

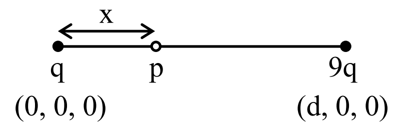
32. A point charge +q is placed at the origin. A second point charge +9q is placed at (d, 0, 0) in Cartesian coordinate system. The point in between them where the electric field vanishes is :

(1) (4d/3, 0, 0) (2) (d/4, 0, 0)

(3) (3d/4, 0, 0) (4) (d/3, 0, 0)

Ans. (2)

Sol.



Let $E_P = 0$

$$\therefore \frac{kq}{x^2} = \frac{k9q}{(d-x)^2}$$

$$\Rightarrow \frac{d-x}{x} = 3 \Rightarrow x = \frac{d}{4}$$

$\therefore$ co-ordinate of P is $\left(\frac{d}{4}, 0, 0\right)$

33. The battery of a mobile phone is rated as 4.2 V, 5800 mAh. How much energy is stored in it when fully charged ?

(1) 43.8 kJ (2) 48.7 kJ

(3) 87.7 kJ (4) 24.4 kJ

Ans. (3)

Sol. Given V = 4.2 volt

$\therefore$ Energy supplied by battery

$= vq = 4.2 \times 5800 \times 3600 \times 10^{-3}$ J = 87.696 kJ

$\therefore$ Energy stored in the battery when fully charged

= 87.696 kJ ≈ 87.7 kJ

34. A particle is subjected two simple harmonic motions as :

$x_1 = \sqrt{7}\sin 5t$ cm

and $x_2 = 2\sqrt{7}\sin\left(5t + \frac{\pi}{3}\right)$ cm

where x is displacement and *t* is time in seconds. The maximum acceleration of the particle is $x \times 10^{-2}$ ms^{-2}. The value of x is :

(1) 175 (2) $25\sqrt{7}$

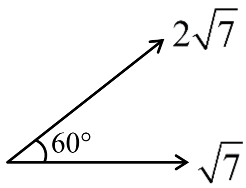
(3) $5\sqrt{7}$ (4) 125

Ans. (1)

Sol. $x_1 = \sqrt{7}\sin 5t$

$x_2 = 2\sqrt{7}\sin\left(5t + \frac{\pi}{3}\right)$

From phasor,



$\therefore$ Amplitude of resultant SHM = 7

$$\phi = \tan^{-1}\frac{2\sqrt{7}\times\sqrt{3}/2}{\sqrt{7} + 2\sqrt{7}\times\frac{1}{2}} = \tan^{-1}\frac{\sqrt{21}}{2\sqrt{7}} = \tan^{-1}\frac{\sqrt{3}}{2}$$

$\therefore X_R = 7\sin(5t + \phi)$

$a_R = -7 \times 25\sin(5t + \phi)$

$\therefore a_{max} = 175$ cm/sec $= 175 \times 10^{-2}$ m/sec

35. The relationship between the magnetic susceptibility (χ) and the magnetic permeability (μ) is given by :

(μ_0 is the permeability of free space and μ_r is relative permeability)

(1) $\chi = \frac{\mu}{\mu_0} - 1$ (2) $\chi = \frac{\mu_r}{\mu_0} + 1$

(3) $\chi = \mu_r + 1$ (4) $\chi = 1 - \frac{\mu}{\mu_0}$

Ans. (1)

Sol. We have

$\mu_r = (1 + \chi) \Rightarrow \chi = (\mu_r - 1)$

$\mu = \mu_0\mu_r \Rightarrow \mu_r = \frac{\mu}{\mu_0}$

$$\therefore \chi = \left(\frac{\mu}{\mu_0} - 1\right)$$

36. A zener diode with 5V zener voltage is used to regulate an unregulated dc voltage input of 25 V. For a 400 Ω resistor connected in series, the zener current is found to be 4 times load current. The load current (I_L) and load resistance (R_L) are :

(1) $I_L = 20$ mA; $R_L = 250\ \Omega$

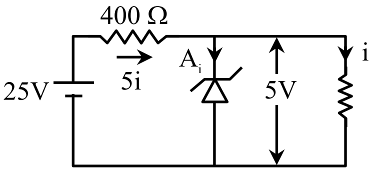
(2) $I_L = 10$ A; $R_L = 0.5\ \Omega$

(3) $I_L = 0.02$ mA; $R_L = 250\ \Omega$

(4) $I_L = 10$ mA; $R_L = 500\ \Omega$

Ans. **(4)**

Sol.



From the circuit diagram,

$$5i = \frac{20}{400} = \frac{1}{20}\text{A}$$

$$\therefore\ i = \frac{1}{100}\text{A} = 10\text{ mA} = \text{Load current}$$

Also, $V_L = 5$ V

$$\therefore\ R_L = \frac{5}{10\times10^{-3}}\Omega = 500\ \Omega$$

37. In an adiabatic process, which of the following statements is true ?

(1) The molar heat capacity is infinite

(2) Work done by the gas equals the increase in internal energy

(3) The molar heat capacity is zero

(4) The internal energy of the gas decreases as the temperature increases

Ans. **(3)**

Sol. For adiabatic process, dQ = 0

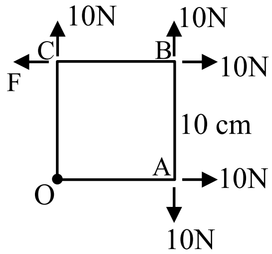
$\therefore$ Molar heat capacity = 0

$\because\ dQ = 0 \Rightarrow dU = -dW$

Also $dU = \frac{f}{2}nRdT$

$\therefore$ Only option (3) is correct.

38. A square Lamina OABC of length 10 cm is pivoted at 'O'. Forces act at Lamina as shown in figure. If Lamina remains stationary, then the magnitude of F is :

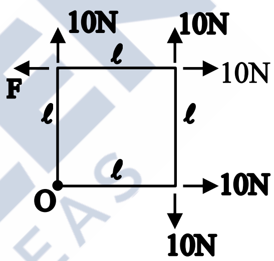


(1) 20 N
(2) 0 (zero)
(3) 10 N
(4) $10\sqrt{2}$ N

Ans. **(3)**

Sol. Since the lamina is equilibrium.

$\therefore\ F_{net} = 0\ \&\ \tau_{net} = 0$



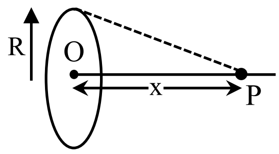
$T_O = 10\ell - F\ell \Rightarrow F = 10$ N

39. Let B_1 be the magnitude of magnetic field at center of a circular coil of radius R carrying current I. Let B_2 be the magnitude of magnetic field at an axial distance 'x' from the center. For x : R = 3 : 4, $\frac{B_2}{B_1}$ is :

(1) 4 : 5
(2) 16 : 25
(3) 64 : 125
(4) 25 : 16

Ans. **(3)**

Sol.



$B_1 = \frac{\mu_0 i}{2R}$ $\qquad$ $B_2 = B_1\sin^3\theta$

$$\therefore\ \frac{B_2}{B_1} = \sin^3\theta = \left(\frac{4}{5}\right)^3 = \frac{64}{125}$$

40. Considering Bohr's atomic model for hydrogen atom :

(A) the energy of H atom in ground state is same as energy of He^+ ion in its first excited state.

(B) the energy of H atom in ground state is same as that for Li^{++} ion in its second excited state.

(C) the energy of H atom in its ground state is same as that of He^+ ion for its ground state.

(D) the energy of He^+ ion in its first excited state is same as that for Li^{++} ion in its ground state

Choose the **correct** answer from the options given below :

(1) (B), (D) only (2) (A), (B) only

(3) (A), (D) only (4) (A), (C) only

Ans. (2)

Sol. $E \propto \frac{Z}{n^2}$

$Z_H = 1$ $\quad Z_{He^+} = 2$ $\quad Z_{Li^{+2}} = 3$

1^{st} excited state $\Rightarrow n = 2$

2^{nd} excited state $\Rightarrow n = 3$

From the given statements only A & B are correct.

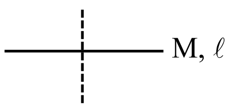
41. Moment of inertia of a rod of mass 'M' and length 'L' about an axis passing through its center and normal to its length is 'α'. Now the rod is cut into two equal parts and these parts are joined symmetrically to form a cross shape. Moment of inertia of cross about an axis passing through its center and normal to plane containing cross is :

(1) α (2) α/4

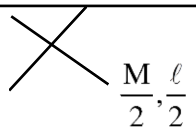
(3) α/8 (4) α/2

Ans. (2)

Sol.



$$\alpha = \frac{M\ell^2}{12} \quad \ldots \text{(i)}$$

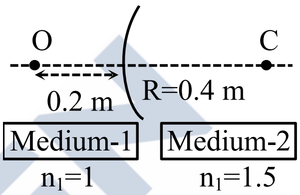


$$\alpha' = 2\left[\frac{\frac{M}{2}\left(\frac{\ell}{2}\right)^2}{12}\right]$$

$$\alpha' = \frac{M\ell^2}{48} = \frac{\alpha}{4}$$

Correct option is (2)

42.



A spherical surface separates two media of refractive indices 1 and 1.5 as shown in figure. Distance of the image of an object 'O', is :

(C is the center of curvature of the spherical surface and R is the radius of curvature)

(1) 0.24 m right to the spherical surface

(2) 0.4 m left to the spherical surface

(3) 0.24 m left to the spherical surface

(4) 0.4 m right to the spherical surface

Ans. (2)

Sol. $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

$$\frac{1.5}{v} - \frac{1}{(-0.2)} = \frac{1.5-1}{0.4}$$

$$\frac{1.5}{v} = \frac{0.5}{0.4} - \frac{1}{0.2}$$

$$\frac{1.5}{v} = -\frac{1.5}{0.4}$$

$v = -0.4$ m

43. Match **List–I** with **List–II**.

List–I	List–II
(A) Coefficient of viscosity	(I) $[ML^0T^{-3}]$
(B) Intensity of wave	(II) $[ML^{-2}T^{-2}]$
(C) Pressure gradient	(III) $[M^{-1}LT^2]$
(D) Compressibility	(IV) $[ML^{-1}T^{-1}]$

Choose the **correct** answer from the options given below :

(1) (A)–(I), (B)–(IV), (C)–(III), (D)–(II)

(2) (A)–(IV), (B)–(I), (C)–(II), (D)–(III)

(3) (A)–(IV), (B)–(II), (C)–(I), (D)–(III)

(4) (A)–(II), (B)–(III), (C)–(IV), (D)–(I)

Ans. (2)

Sol. (A) Coefficient of viscosity

$[\eta] = [M^1L^{-1}T^{-1}]$

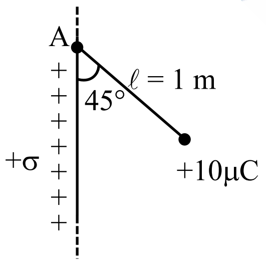
(B) Intensity $[I] = [M^1L^0T^{-3}]$

(C) Pressure gradient $= [ML^{-2}T^{-2}]$

(D) Compressibility $[K] = [M^{-1}L^1T^2]$

44. A small bob of mass 100 mg and charge +10 μC is connected to an insulating string of length 1 m. It is brought near to an infinitely long non–conducting sheet of charge density 'σ' as shown in figure. If string subtends an angle of 45° with the sheet at equilibrium the charge density of sheet will be :

(Given, $\varepsilon_0 = 8.85 \times 10^{-12}\ \frac{F}{m}$ and acceleration due to gravity, $g = 10\ m/s^2$)

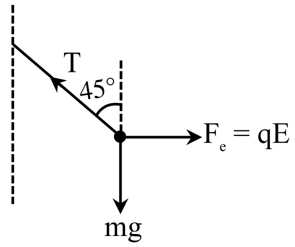


(1) 0.885 nC/m^2 (2) 17.7 nC/m^2

(3) 885 nC/m^2 (4) 1.77 nC/m^2

Ans. (4)

Sol.



$qE = mg$

$$q\left[\frac{\sigma}{2\varepsilon_0}\right] = mg$$

$$\sigma = \frac{2\varepsilon_0 mg}{q}$$

$$\sigma = \frac{2 \times 8.85 \times 10^{-12} \times 100 \times 10^{-6} \times 10}{10 \times 10^{-6}}$$

$\sigma = 17.7 \times 10^{-10}\ C/m^2$

$\sigma = 1.77\ nC/m^2$

45. A monochromatic light is incident on a metallic plate having work function ϕ. An electron, emitted normally to the plate from a point A with maximum kinetic energy, enters a constant magnetic field, perpendicular to the initial velocity of electron. The electron passes through a curve and hits back the plate at a point B. The distance between A and B is :

(Given : The magnitude of charge of an electron is e and mass is m, h is Planck's constant and c is velocity of light. Take the magnetic field exists throughout the path of electron)

(1) $\sqrt{2m\left(\frac{hc}{\lambda}-\phi\right)}/eB$ (2) $\sqrt{m\left(\frac{hc}{\lambda}-\phi\right)}/eB$

(3) $\sqrt{8m\left(\frac{hc}{\lambda}-\phi\right)}/eB$ (4) $2\sqrt{m\left(\frac{hc}{\lambda}-\phi\right)}/eB$

Ans. (3)

Sol. $KE_{max} = \frac{hc}{\lambda} - \phi$

$p = \sqrt{2mK_{max}}$

$p = \sqrt{2m\left(\frac{hc}{\lambda} - \phi\right)}$

$d_{A-B} = 2R$

$= 2\left[\frac{p}{qB}\right]$

$d_{AB} = \frac{2\sqrt{2m\left(\frac{hc}{\lambda} - \phi\right)}}{eB} = \frac{\sqrt{8m\left(\frac{hc}{\lambda} - \phi\right)}}{eB}$

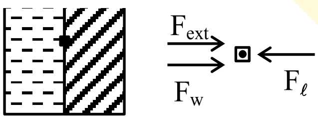
SECTION-B

46. A vessel with square cross–section and height of 6 m is vertically partitioned. A small window of 100 cm^2 with hinged door is fitted at a depth of 3 m in the partition wall. One part of the vessel is filled completely with water and the other side is filled with the liquid having density 1.5×10^3 kg/m^3. What force one needs to apply on the hinged door so that it does not get opened ?

(Acceleration due to gravity = 10 m/s^2)

Ans. **(150)**

Sol.



in equilibrium

$F_{ext} + F_w = F_\ell$

$\Rightarrow F_{ext} = F_\ell - F_w$

$= (P_0 + \rho_\ell gh)A - (P_0 + \rho_w gh)A$

$= (\rho_\ell - \rho_w)ghA$

$= (1500 - 1000) \times 10 \times 3 \times (100 \times 10^{-4})$

= 150 m

47. A steel wire of length 2 m and Young's modulus 2.0×10^{11} Nm^{-2} is stretched by a force. If Poisson ratio and transverse strain for the wire are 0.2 and 10^{-3} respectively, then the elastic potential energy density of the wire is ____ $\times 10^5$ (in SI units)

Ans. **(25)**

Sol. $\ell = 2m$; $Y = 2 \times 10^{11}\ \frac{N}{m^2}$

$\mu = -\frac{\left(\frac{\Delta r}{r}\right)}{\left(\frac{\Delta \ell}{\ell}\right)} \Rightarrow \frac{\Delta \ell}{\ell} = \frac{1}{\mu} \times \left(\frac{\Delta r}{r}\right)$

$= \frac{1}{0.2} \times (10^{-3})$

$\Rightarrow \frac{\Delta \ell}{\ell} = 5 \times 10^{-3}$

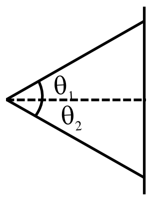
$u = \frac{1}{2} y\varepsilon_\ell^2 = \frac{1}{2} \times 2 \times 10^{11} \times [5 \times 10^{-3}]^2$

$= 25$

48. If the measured angular separation between the second minimum to the left of the central maximum and the third minimum to the right of the central maximum is 30° in a single slit diffraction pattern recorded using 628 nm light, then the width of the slit is ____ μm.

Ans. **(6)**

Sol.



$\theta_1 = \sin^{-1}\left(\frac{2\lambda}{a}\right)$

$\theta_2 = \sin^{-1}\left(\frac{3\lambda}{a}\right)$

$\because\ \theta_1 + \theta_2 = 30°$

$$\Rightarrow \sin^{-1}\left(\frac{2\lambda}{a}\right)+\sin^{-1}\left(\frac{3\lambda}{a}\right)=\frac{\pi}{6}$$

$$\Rightarrow \frac{2\lambda}{a}\sqrt{1-\left(\frac{3\lambda}{a}\right)^2}+\frac{3\lambda}{a}\sqrt{1+\left(\frac{2\lambda}{a}\right)^2}=\sin\frac{\pi}{6}$$

Here λ = 628 nm

After solving

A = 6.07 μm

Approximate Method :

$\theta = \theta_1 + \theta_2$

$$\Rightarrow \frac{\pi}{6}=\frac{2\lambda}{a}+\frac{3\lambda}{a}$$

$$\Rightarrow \frac{\pi}{6}=\frac{5}{a}(628\text{nm})$$

$\Rightarrow a = 6\ \mu m$

49. γ_A is the specific heat ratio of monoatomic gas A having 3 translational degrees of freedom. γ_B is the specific heat ratio of polyatomic gas B having 3 translational, 3 rotational degrees of freedom and 1 vibrational mode. If $\frac{\gamma_A}{\gamma_B}=\left(1+\frac{1}{n}\right)$, then the value of n is ______.

Ans. (3)

Sol. $$\frac{\gamma_A}{\gamma_B}=\frac{f_A+2}{f_A}\times\frac{f_B}{f_B+2}$$

$$=\frac{3+2}{3}\times\frac{(6+2)}{(6+2)+2}$$

$$=\frac{5}{3}\times\frac{8}{10}=\frac{40}{30}$$

$$\because \frac{40}{30}=1+\frac{1}{n}$$

$$\Rightarrow \frac{40}{30}-1=\frac{1}{n}$$

$\Rightarrow n = 3$

50. A person travelling on a straight line moves with a uniform velocity v_1 for a distance x and with a uniform velocity v_2 for the next $\frac{3}{2}x$ distance. The average velocity in this motion is $\frac{50}{7}m/s$. If v_1 is 5 m/s then v_2 = ______ m/s.

Ans. (10)

Sol. $$v_{avg}=\frac{x_1+x_2}{t_1+t_2}$$

$$\Rightarrow \frac{50}{7}=\frac{x+\frac{3x}{2}}{\frac{x}{5}+\frac{3x}{2v_2}}$$

$$\Rightarrow \frac{50}{7}=\frac{5/2}{\frac{1}{5}+\frac{3}{2v_2}}$$

$$\Rightarrow \frac{1}{5}+\frac{3}{2v_2}=\frac{7}{20}$$

$$\Rightarrow \frac{3}{2v_2}=\frac{7}{20}-\frac{1}{5}=\frac{7-4}{20}$$

$$\Rightarrow \frac{3}{2v_2}=\frac{3}{20}$$

$\Rightarrow v_2 = 10$ m/s