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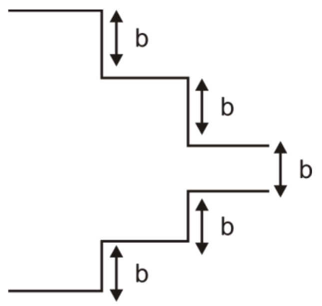
JEE Mains Paper-2022

PHYSICS

1.

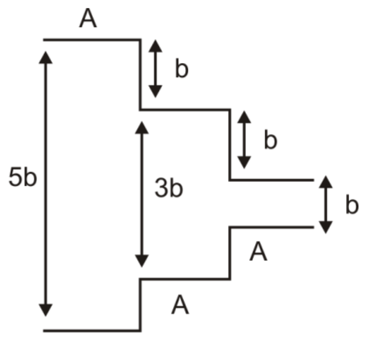


6 Capacitor plates are arranged as shown. The area of each of the plates is A. The capacitance of the arrangement is___

(1) $\frac{15}{28}\frac{\epsilon_0 A}{d}$ (2) $\frac{23}{15}\frac{\epsilon_0 A}{b}$

(3) $\frac{15}{22}\frac{\epsilon_0 A}{d}$ (4) $\frac{17}{23}\frac{\epsilon_0 A}{d}$

Sol. Answer (2)



In this case capacitors will be in parallel combination

$C_{eq} = C_1 + C_2 + C_3$

$$= \frac{\epsilon_0 A}{5b} + \frac{\epsilon_0 A}{3b} + \frac{\epsilon_0 A}{b}$$

$$= \frac{\epsilon_0 A}{b}\left(\frac{3+5+15}{15}\right) = \frac{23 \epsilon_0 A}{15b}$$

2. Deuteron and proton enter a magnetic field perpendicularly having equal kinetic energy.

Find $\frac{r_d}{r_p}$ radius of circular trajectories.

(1) $\sqrt{2}$ (2) $\frac{1}{\sqrt{2}}$

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

Sol. Answer (1)

Radius of path (r) = $\frac{\sqrt{2mk}}{qB}$

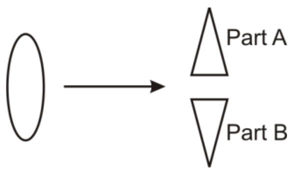
Both particle have same kinetic energy (k) and enter in the same magnetic field.

So, $r \propto \sqrt{m}$

$$\frac{r_d}{r_p} = \frac{\sqrt{m_d}}{\sqrt{m_p}} \qquad \left\{\begin{matrix} \text{since } m_d = 2m_p \\ q_d = q_p \end{matrix}\right\}$$

$$\Rightarrow \frac{r_d}{r_p} = \sqrt{2}$$

3. A thin lens of focal length f (in metres) is cut into two parts symmetrically as shown:



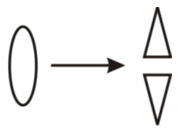
Then the power of part A is :

(1) $\frac{1}{f}$ (2) $\frac{1}{2f}$

(3) $\frac{2}{f}$ (4) $\frac{1}{3f}$

Sol. Answer (1)

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

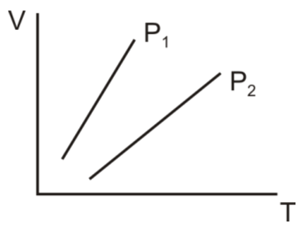


Due to cutting of lens there is no effect on radius of curvature.

Hence focal length will remain same

$P = \frac{1}{f}$

4.



For the V-T graph we can say that

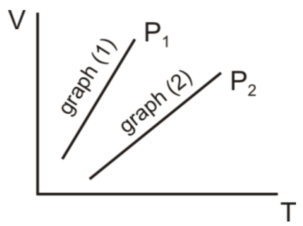
(1) $P_1 < P_2$

(2) $P_1 > P_2$

(3) $P_1 = P_2$

(4) No relationship can be obtained

Sol. Answer (1)



Using; PV = nRT

$\Rightarrow \frac{V}{T} = \frac{nR}{P}$

$\frac{V}{T} \propto \frac{1}{P}$

$\left(\frac{V}{T}\right)_1 > \left(\frac{V}{T}\right)_2$

Hence $P_1 < P_2$

5. An ideal diatomic gas is expanded isobarically and work done in the process is 400 J. Find the heat given to the gas in this process

(1) 160 J (2) 700 J

(3) 320 J (4) 1400 J

Sol. Answer (4)

for Isobaric process $\Rightarrow W = nR\Delta T$

$400 = nR\Delta T$

Heat supplied $Q = nC_P\Delta T$

$Q = \frac{n7R}{2}\Delta T$ $\left\{\text{for diatomic } C_P = \frac{7R}{2}\right\}$

$= \frac{7}{2}(nR\Delta T) = \frac{7}{2} \times 400$

Q = 1400 J

6. A wave propagates from one medium to another medium. Out of the parameters: wavelength, frequency and speed of the wave, the parameters that change are

(1) Wavelength and frequency

(2) Frequency and speed

(3) Wavelength and speed

(4) All the three

Sol. Answer (3)

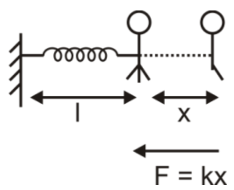
Whenever wave goes from one medium to another, its speed and wavelength change and frequency remains unchanged.

7. A spring with spring constant k and length l was attached to mass m and rotated about its axis at other end with w find elongation.

(1) $\frac{k - mw_0^2 l}{mw^2}$ (2) $\frac{k + mw_0^2 l^2}{mw^2}$

(3) $\frac{mw_0^2 l}{k - mw_0^2}$ (4) $\frac{mw_0^2 l}{k + mw_0^2}$

Sol. Answer (3)



Spring force will provide centripetal acceleration

$F = mw_0^2(l + x)$

$kx = mw_0^2 l + mw_0^2 x$

$x(k - mw_0^2) = mw_0^2 l$

$x = \frac{mw_0^2 l}{k - mw_0^2}$

8. For a Non conducting hemisphere with a charge q at centre, flux through curved surface is

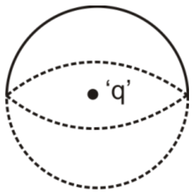
(1) $\frac{q}{\epsilon_0}$

(2) $\frac{q}{2\epsilon_0}$

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

(4) $\frac{\pi q}{4\epsilon_0}$

Sol. Answer (2)



Flux through complete sphere = $\frac{q}{\epsilon_0}$

So, for hemisphere $(\phi) = \frac{1}{2}\left(\frac{q}{\epsilon_0}\right) = \frac{q}{2\epsilon_0}$

9. When does a transistor act as a switch?

(1) Saturation only

(2) Cut off

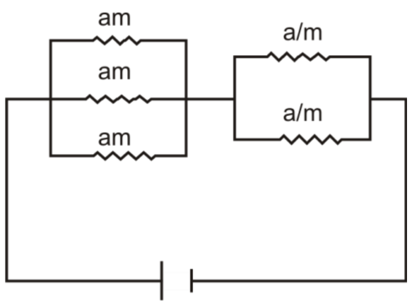
(3) Active

(4) Cut off + Saturation

Sol. Answer (4)

Transistor acts as a switch in cut off and saturation region.

10. A network of resistors is shown:



Find the value of m for minimum resistance of the network.

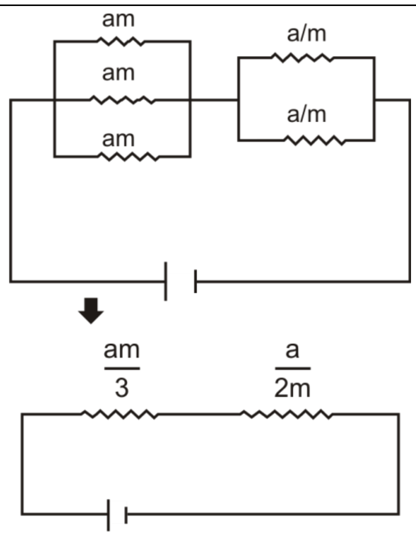
(1) $\sqrt{3/2}$

(2) $\sqrt{2/3}$

(3) $\sqrt{5/4}$

(4) $\sqrt{4/5}$

Sol. Answer (1)



$$R_{eq.} = \frac{am}{3} + \frac{a}{2m} = \frac{(am)(2m)+(a)(3)}{6m}$$

$$\Rightarrow R_{eq.} = \frac{2am^2 + 3a}{6m}$$

For Req. to be minium;

$$\frac{d}{dm}\left(\frac{2am^2+3a}{6m}\right) = 0$$

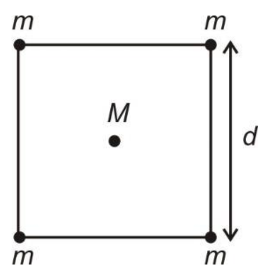
$$\Rightarrow \frac{(6m)(4am)-(2am^2+3a)(6)}{(6m)^2} = 0$$

$$\Rightarrow 24am^2 - 12am^2 - 18a = 0$$

$$\Rightarrow 12am^2 = 18a$$

$$\Rightarrow m = \sqrt{\frac{18}{12}} = \sqrt{\frac{3}{2}}$$

11. Four point masses each of mass *m* are placed at the corners of square of side d and a mass M is placed at the centre. The gravitational potential energy of system is



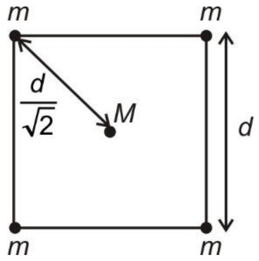
(1) $-\frac{Gm}{d}[4\sqrt{2}M + (4+\sqrt{2})m]$

(2) $-\frac{Gm}{d}[4\sqrt{2}m + (4+\sqrt{2})M]$

(3) $-\frac{GM}{d}[4\sqrt{2}m + (4+\sqrt{2})m]$

(4) $-\dfrac{GM}{d}[4\sqrt{2}M+(4+\sqrt{2})M]$

Sol. Answer (1)



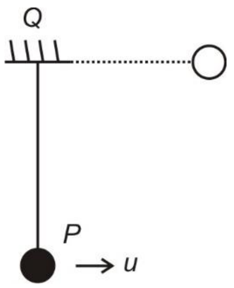
Total gravitational potential energy of system is sum of potential energy of all the two particle system of configuration

$$U=4\left(\frac{-GMm}{\frac{d}{\sqrt{2}}}\right)+4\left(\frac{-Gm^2}{d}\right)+2\left(\frac{-Gm^2}{\sqrt{2}d}\right)$$

$$=\frac{-Gm}{d}\left(4\sqrt{2}M+4m+\sqrt{2}m\right)$$

$$=\frac{-Gm}{d}\left(4\sqrt{2}M+\left(4+\sqrt{2}\right)m\right)$$

12. A bob P is suspended by the means of a thread from point Q, length of thread is l. Bob is given a velocity u as shown. The change in velocity of bob till thread becomes horizontal



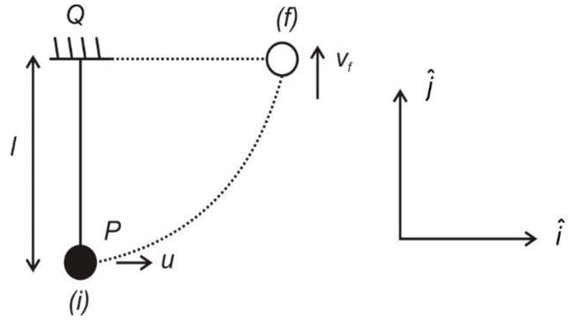
(1) $\sqrt{u^2+gl}$

(2) $\sqrt{2u^2-2gl}$

(3) $\sqrt{u^2-gl}$

(4) $\sqrt{u^2-2gl}$

Sol. Answer (2)



Using work energy theorem between initial and final position;

$$\frac{1}{2}mv_f^2-\frac{1}{2}mu^2=W_{gravity}+W_{Tension}$$

$$\Rightarrow\frac{1}{2}mv_f^2-\frac{1}{2}mu^2=-mgl+0$$

$$\Rightarrow v_f=\sqrt{u^2-2gl}$$

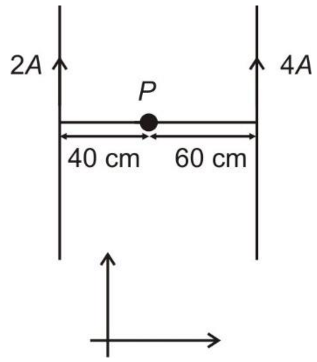
$$\vec{v_i}=u\hat{i},\vec{v_f}=\sqrt{u^2-2gl}\,\hat{j}$$

$$\Delta\vec{v}=\vec{v_f}-\vec{v_i}=\sqrt{u^2-2gl}\,\hat{j}-u\hat{i}$$

$$\left|\Delta\vec{v}\right|=\sqrt{(\sqrt{u^2-2gl})^2+(u)^2}$$

$$=\sqrt{2u^2-2gl}$$

13. A point charge q = 2C is projected with the velocity of $\vec{v}=2\hat{i}+3\hat{j}$ from point P. The magnetic force acting on the charge at this moment is



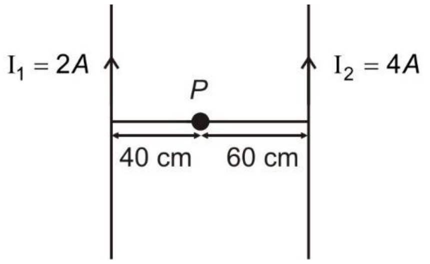
(1) 2.4×10^{-6} N

(2) 3.2×10^{-6} N

(3) 4.2×10^{-6} N

(4) 3.6×10^{-6} N

Sol. Answer (1)



Given, $q = 2C$

$\vec{v} = 2\hat{i} + 3\hat{j}$

$|\vec{v}| = \sqrt{4+9} = \sqrt{13}$ m/s

$\vec{B_1} = \dfrac{\mu_0 I_1}{2\pi d_1}(-\hat{k})$

$\vec{B_2} = \dfrac{\mu_0 I_2}{2\pi d_2}(\hat{k})$

$\overrightarrow{B_{net}} = \vec{B_1} + \vec{B_2} = \dfrac{\mu_0}{2\pi}\left(\dfrac{4}{0.6} - \dfrac{2}{0.4}\right)\hat{k}$

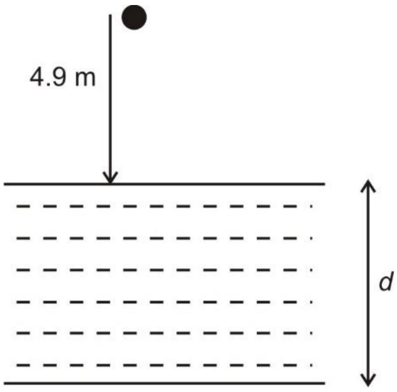
$\overrightarrow{B_{net}} = 2 \times 10^{-7} \times \dfrac{5}{3}\hat{k} = \dfrac{10}{3} \times 10^{-7}\hat{k}$

Since net magnetic field is perpendicular to $\vec{v}$

$F_m = qvB = 2 \times \sqrt{13} \times \dfrac{10}{3} \times 10^{-7}$

$= 2.4 \times 10^{-6}$ N

14. A particle is released from a height of 4.9 m above the surface of water as shown. The particle enters the water and moves with constant velocity and reaches bottom of tank in 4 sec after the release the value of d is (g = 9.8 m/s^2)



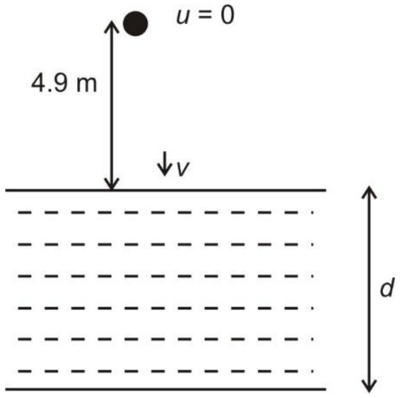
(1) 34.3 m

(2) 19.8 m

(3) 38.2 m

(4) 29.4 m

Sol. Answer (4)



Velocity at the time of reaching surface of water

$v^2 - u^2 = 2as$

$\Rightarrow v^2 - (0) = (2)(9.8)(4.9)$

$\Rightarrow v = 9.8$ m/s

Also;

$4.9 = 0.\,t + \dfrac{1}{2}(9.8)t^2$

$\Rightarrow t = 1\,$s

So, remaining time to travel in the water

$= 4 - 1 = 3$ sec

$d = vt = 9.8 \times 3 = 29.4$ m

15. **Statement 1** : An electron jumps from lower energy state E_1 to higher energy state E_2 then the photon absorbed is given as $h\nu = E_1 - E_2$

Statement 2 : An electron jumps from higher energy state E_2 to lower energy state E_1 then the photon released is given by $h\nu = E_2 - E_1$

(1) Both are true

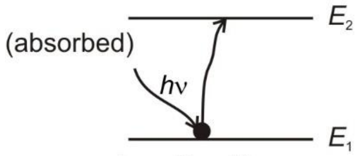
(2) Statement 1 is true, Statement 2 is false

(3) Statement 1 is false, Statement 2 is true

(4) Both are false

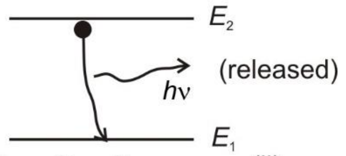
Sol. Answer (3)

Statement-1



$h\nu = E_2 - E_1$ .... (i)

Statement-2



$h\nu = E_2 - E_1$ .... (ii)

In statement 1 given $h\nu = E_1 - E_2$, hence it is false and statement 2 correct.

16. For a particle, position is given by

$$x = 1\sin\left[\pi\left(t + \frac{1}{3}\right)\right]$$

Then find the velocity of the particle at t = 1

(1) $\frac{1}{2}$units

(2) $-\frac{1}{2}$units

(3) $\frac{\pi}{2}$units

(4) $-\frac{\pi}{2}$units

Sol. Answer (4)

Position $(x) = 1\sin\left(\pi\left(t + \frac{1}{3}\right)\right)$

$$v = \frac{dx}{dt} = \frac{d}{dt}\left(1\sin\left(\pi t + \frac{\pi}{3}\right)\right)$$

$$= 1.\cos\left(\pi t + \frac{\pi}{3}\right)(\pi)$$

$$v = \pi\cos\left(\pi t + \frac{\pi}{3}\right)$$

$$v|_{t=1} = \pi\cos\left(\pi(1) + \frac{\pi}{3}\right)$$

$$= \pi\cos\left(\pi + \frac{\pi}{3}\right)$$

$$= \pi\left(\frac{-1}{2}\right) = \frac{-\pi}{2} \text{ unit}$$

17. Time period of oscillation is t = 6 sec when the amplitude A = x, the time period, when $A = \frac{x}{2}$ is

(1) $\sqrt{6}$ sec

(2) 3 sec

(3) 6 sec

(4) 9 sec

Sol. Answer (3)

Time period of oscillation will be independent on the amplitude. Hence for $A = \frac{x}{2}$ time period same i.e. 6 sec.

18. Which of the following expressions dues not have the dimension [M°L°T¹]?

(1) $\frac{L}{C}$ (2) $\sqrt{LC}$

(3) RC (4) $\frac{L}{R}$

Sol. Answer (1)

RC and $\frac{L}{R}$ is the time constant of R-C and L–R circuit respectively. So, they have dimension of time.

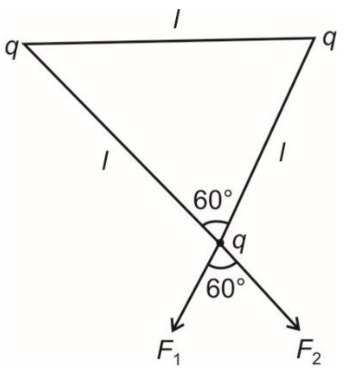
$\sqrt{LC}$ also have dimension formula of time.

19. Three charged particles having charge 'q' each are suspended by the means of thread from a common point. In equilibrium they make an equilateral triangle of edge l. The electrostatic force on one of the charge is

(1) $\frac{2\sqrt{3}q^2}{4\pi\varepsilon_0 l^2}$ (2) $\frac{2q^2}{4\pi\varepsilon_0 l^2}$

(3) $\frac{q^2}{8\pi\varepsilon_0 l^2}$ (4) $\frac{\sqrt{3}\,q^2}{4\pi\varepsilon_0 l^2}$

Sol. Answer (4)



$$F_1 = F_2 = \frac{kq^2}{l^2}$$

$$F_{nel} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2(\cos 60°)}$$

$$= \sqrt{F_1^2 + F_1^2 + F_1^2}$$

$\sqrt{3}F_1$

$= \frac{\sqrt{3}q^2}{4\pi\varepsilon_0 l^2}$

20. Which of the following statements is true about kinetic theory of gases?

(1) Mean free path increases with increase in density

(2) Mean free path decreases with decrease in temperature, keeping volume constant

(3) Average kinetic energy per degree of freedom = $\frac{3}{2}k_bT$

(4) Average kinetic energy per degree of freedom = $\frac{1}{2}k_bT$

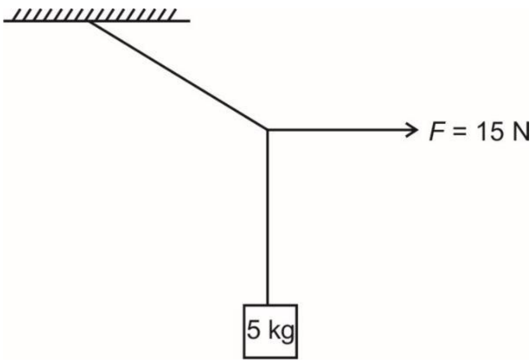
Sol. Answer (4)

(1) Mean free path $(\lambda) = \frac{1}{\sqrt{2}\pi n d^2}$

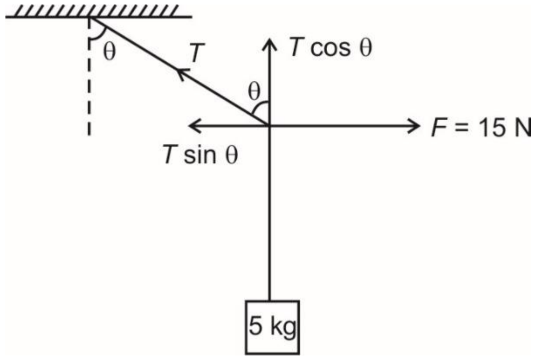
If n increase then λ decrease.

From law of equipartition of energy, average kinetic energy per degree of freedom of one molecule is $= \frac{1}{2}k_bT$

21. A block of mass 5 kg is hanging vertically with the help of a rope. A force 15 N is applied at the centre of the rope horizontally as shown. The angle made by the upper portion of the rope with the vertical in equilibrium is given by $\tan^{-1}\left(\frac{x}{10}\right)$. The value of x is ______



Sol. Answer (3)



Since it is in equilibrium

$T\sin\theta = 15$ …(1)

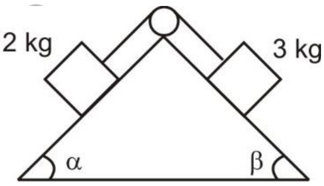
$T\cos\theta = 50$ …(2)

Div. (1) by (2)

$\tan\theta = \frac{3}{10} \Rightarrow \theta = \tan^{-1}\left(\frac{3}{10}\right)$

$x = 3$

22. Acceleration of 12 kg as shown in figure is



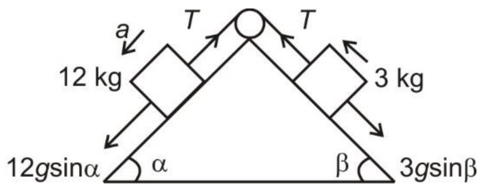
(1) $\frac{g}{2}(4\sin\alpha - \sin\beta)$

(2) $\frac{g}{5}(4\sin\alpha - \sin\beta)$

(3) $\frac{g}{2}(4\sin\alpha + \sin\beta)$

(4) $\frac{g}{5}(4\sin\alpha + \sin\beta)$

Sol. Answer (2)



$12g\sin\alpha - T = 12a$ ......(1)

$T - 3g\sin\beta = 3a$ ......(2)

From equation (1) and (2)

$a = \frac{(4g\sin\alpha - g\sin\beta)3}{15}$

$a = \frac{g}{5}(4\sin\alpha - \sin\beta)$

23. A wire of length 20 cm is in N-S direction it is moving with 20 m/s in east. Horizontal component of earth's magnetic field is $B_H = 4 \times 10^{-4}$ T and angle of dip is $\phi = 45^\circ$. Find induced emf in wire

(1) 1.6×10^{-4} V

(2) 16×10^{-4} V

(3) 18×10^{-4} V

(4) 1.8×10^{-4} V

Sol. Answer (2)

Vertical component of earth's magnetic field is perpendicular to length of the wire so induced emf in wire e = $B_v \times V \times l$

angle of dip $\phi = 45^\circ$

so $B_v = B_H$

e = $B_v \times V \times l = 4 \times 10^{-4} \times 0.2 \times 20$

= 16×10^{-4} volt

24. Low frequency signal cannot be transmitted to large distance. Identify incorrect statement

(1) It can be transmitted by modulating high frequency signal with it.

(2) Antenna size required is very large to directly transmit it.

(3) Power of low-frequency signal gets attenuated.

(4) Low frequency signal can be used under space communication.

Sol. Answer (4)

Under space communication, low frequency signal can be used due to its high energy.