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IIT JEE PHYSICS PAPER SOLUTION

27 JUNE 2022

EVENING SHIFT

QUESTIONS BASED ON GRAVITATIONAL POTENTIAL ENERGY ,MEAN FREE PATH,ELECTRIC FORCE,MAGNETIC FIELD FORCE & TRANSISTOR ARE TRICKY

Q1: The SI unit of physical quantity is pascal-second. The dimensional formula of this quantity will be

(A) $[ML^{-1}T^{-1}]$ ✓

(B) $[ML^{-1}T^{-2}]$

(C) $[ML^{2}T^{-1}]$

(D) $[ML^{-1}T^{3}T^{0}]$

PASCAL SECOND

$= ML^{-1}T^{-2}T$

$= ML^{-1}T^{-1}$

$P = F/A$

$= \frac{MLT^{-2}}{L^2}$

$= ML^{-1}T^{-2}$

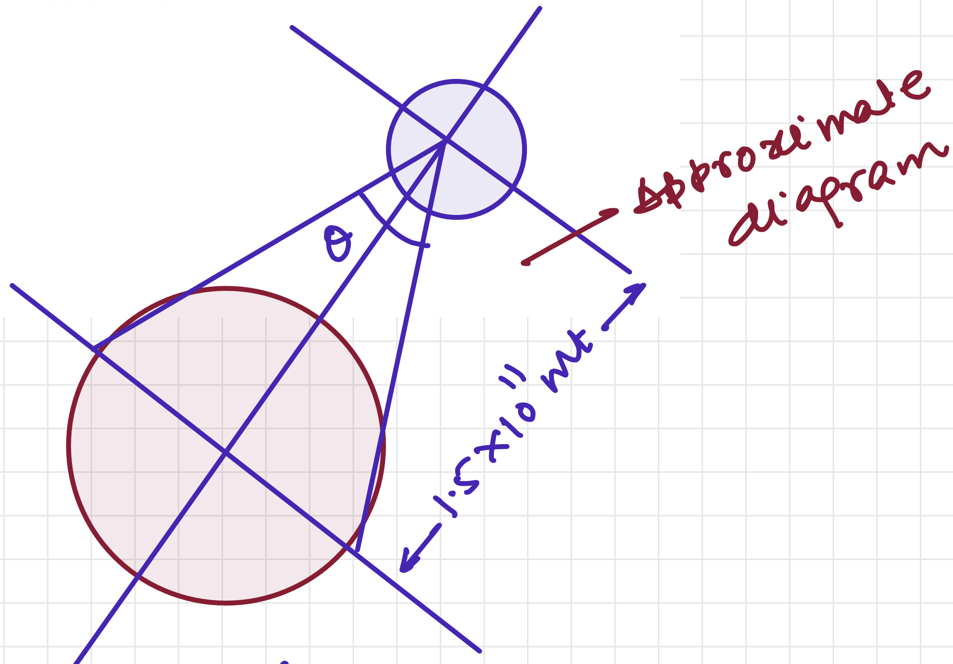
Q2: The distance of the Sun from earth 1.5×10^{11} m and its angular diameter is (2000)s when observed from the earth. The diameter of the Sun will be:

(A) 2.45×10^{10} m

(B) 1.45×10^{10} m

(C) 1.45×10^{9} m ✓

(D) 0.14×10^{9} m



$$\text{Angle} = \frac{\text{ARC}}{\text{Radius}}$$

$$\frac{2000\ \text{sec}}{60}\Big\}\text{min} \times \frac{1}{60}\Big\}\text{degree}\Big\} \times \frac{\pi}{180}$$

$$= \frac{20}{36} \times \frac{\pi}{180}\ \text{radian}$$

$$\frac{20}{36} \times \frac{\pi}{180} = \frac{D}{1.5 \times 10^{11}}$$

$$D = \frac{20}{36} \times \frac{3.14 \times 1.5 \times 10^{11}}{180}$$

$$= 0.0145 \times 10^{11}$$

$$= 1.45 \times 10^{9}\ \text{mt}$$

Q3: When a ball is dropped into a lake from a height 4.9 m above the water level. it hits the water with a velocity v and then sinks to the bottom with the constant velocity v. It reaches the bottom of the lake 4.0 a after it is dropped. The approximate depth of the lake is

(A) 19.6 m

(B) 29.4 m ✓

(C) 39.2 m

(D) 73.5 m

(motion between O & A)

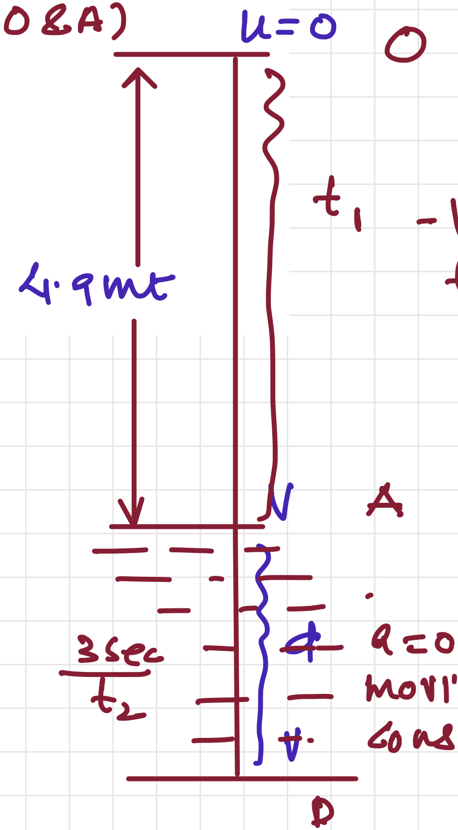
$$v^2 = u^2 + 2as$$

$$v^2 = (0)^2 + 2(-g)(-4.9)$$

$$v^2 = 2 \times 4.9 \times 2 \times 4.9$$

$$v = \sqrt{(4.9)(4.9)(2)(2)}$$

$$= 4.9 \times 2 = 9.8 \text{ mt/sec}$$



$$v = u + at$$

$$-v = 0 - 9.8 \times t_1$$

$$t_1 = \frac{9.8}{9.8} = 1\text{sec}$$

d = ?

MOTION BETWEEN A & D

$$v = \frac{d}{t}$$

$$d = (v)(t) = 9.8 \times 3$$

$$= 29.4 \text{ mt}$$

Q4: One end of a massless spring of spring constant k and natural length l_0 is fixed while the other end is connected to a small object of mass *m* lying on a frictionless table. The spring remains horizontal on the table. If the object is made to rotate at an angular velocity ω about an axis passing trough fixed end, then the elongation of the spring will be

(A) $\frac{k-m\omega^2 l_0}{m\omega^2}$

(B) $\frac{m\omega^2 l_0}{k+m\omega^2}$

(C) $\frac{m\omega^2 l_0}{k-m\omega^2}$ ✓

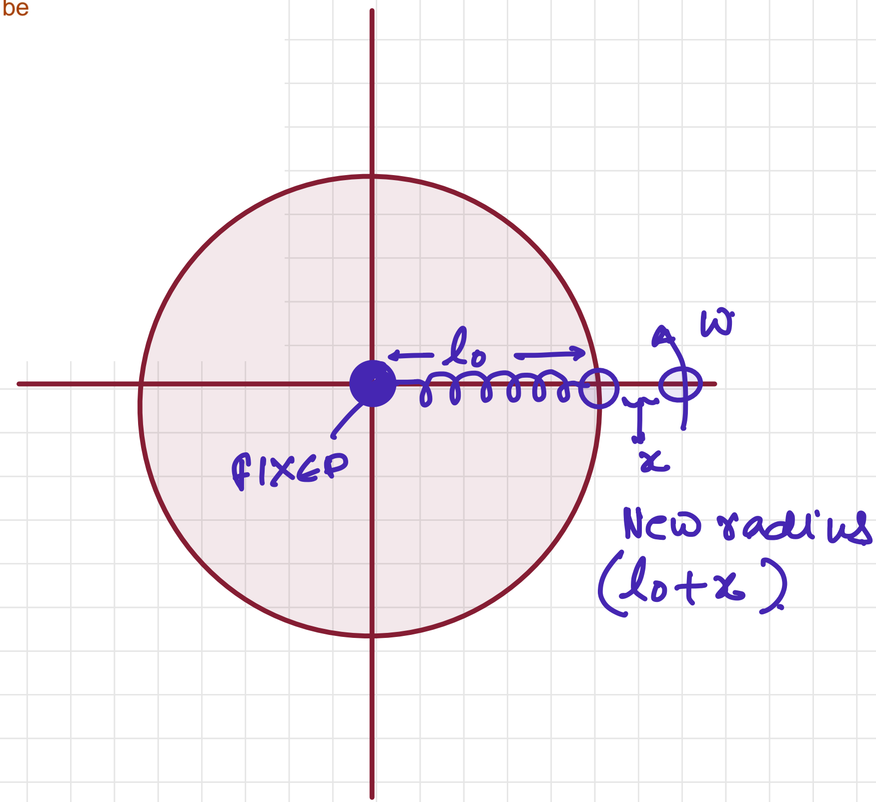
(D) $\frac{k+m\omega^2 l_0}{m\omega^2}$

$$kx = m\omega^2(l_0 + x)$$

$$kx = m\omega^2 l_0 + m\omega^2 x$$

$$x(k - m\omega^2) = m\omega^2 l_0$$

$$x = \frac{m\omega^2 l_0}{k - m\omega^2}$$



Q5: A stone tide to a string of length L is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position and has a speed u. The magnitude of change in its velocity. as it reaches a position where the string is horizontal, is $\sqrt{x\left(u^2-gL\right)}$.The value of x is

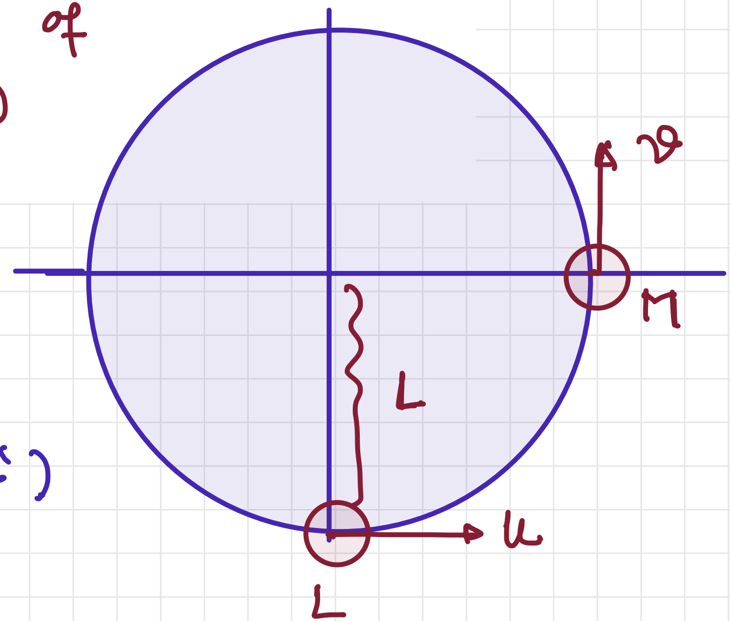
(A) 3

(B) 2 ✓

(C) 1

(D) 5

Apply conservation of energy between (L) and (M)



$$\frac{1}{2} m u^2 = m g L + \frac{1}{2} m \vartheta^2$$

$$u^2 = 2gL + \vartheta^2$$

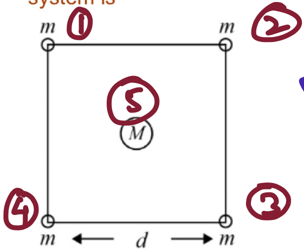
$$\vartheta_M = \vartheta = \left(\sqrt{u^2 - 2gl}\right)(\hat{j})$$

$$u_i = u\,\hat{i}$$

change in velocity $\vartheta_M - \vartheta_i = \left(\sqrt{u^2 - 2gl}\right)\hat{j} - u\,\hat{i}$

$$|\vartheta_M - \vartheta_i| = \sqrt{u^2 - 2gl + u^2} = \sqrt{2(u^2 - gl)}, \quad x = 2$$

Q6: Four sphere each of mass m form a square of side d (as shown in figure). A fifth sphere of mass M is situated at the centre of square. The total gravitational potential energy of the system is



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

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

(C) $-\frac{Gm}{d}\left[3m^2+4\sqrt{2}M\right]$

(D) $-\frac{Gm}{d}\left[6m^2+4\sqrt{2}M\right]$

$m_1 \quad m_2 \quad m_3 \quad m_4 \quad m_5$

FORMULAE

$$U=-G\left[\frac{m_1m_2}{r_{12}}+\frac{m_1m_3}{r_{13}}+\frac{m_1m_4}{r_{14}}+\frac{m_1m_5}{r_{15}}+\frac{m_2m_3}{r_{23}}+\frac{m_2m_4}{r_{24}}+\frac{m_2m_5}{r_5}+\frac{m_3m_4}{r_{34}}+\frac{m_3m_5}{r_{35}}+\frac{m_4m_5}{r_{45}}\right]$$

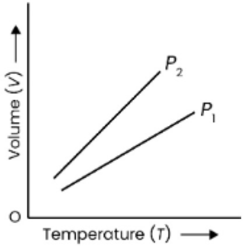
$$U=-G\left(\frac{m^2}{d}+\frac{m^2}{d\sqrt{2}}+\frac{m^2}{d}+\frac{mM}{d/\sqrt{2}}+\frac{m.m}{d}+\frac{mm}{d\sqrt{2}}+\frac{mM}{d/\sqrt{2}}+\frac{mm}{d}+\frac{mM}{d/\sqrt{2}}+\frac{mM}{d/\sqrt{2}}\right]$$

$$=-G\left[m^2\left(\frac{1}{d}+\frac{1}{d\sqrt{2}}+\frac{1}{d}+\frac{1}{d}+\frac{1}{d\sqrt{2}}+\frac{1}{d}\right]-GmM\left[\frac{\sqrt{2}}{d}+\frac{\sqrt{2}}{d}+\frac{\sqrt{2}}{d}+\frac{\sqrt{2}}{d}\right]$$

$$=-G\left[m^2\left(\frac{4}{d}+\frac{2}{d\sqrt{2}}\right)+mM\left(\frac{4\sqrt{2}}{d}\right)\right]$$

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

Q7: For a perfect gas, two pressure P_1 and P_2 are shown in figure. The graph shows:



(A) $P_1 > P_2$ ✓

(B) $P_1 < P_2$

(C) $P_1 = P_2$

(D) Insufficient data to draw any conclusion

$PV = RT$

$\frac{V}{T} = \frac{R}{P} \Rightarrow$ slope of the graph

$P \propto \frac{1}{\text{slope of the graph}}$

Hence $P_1 > P_2$

Q8: According to kinetic theory of gazes.

A. The motion of the gas molecules freezes at 0°C.

B. The mean free path of gas molecules decreases if the density of molecules is increased.

C. The mean free path of gas molecules increases if temperature is increased keeping pressure constant.

D. Average kinetic energy per molecule per degree of freedom is $\frac{3}{2}k_BT$ (for monoatomic gases). Choose the most appropriate answer from the options given below:

(A) A and C only

(B) B and C only ✓

(C) A and B only

(D) C and D only

MEAN FREE PATH $\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$

$n = \frac{N}{V}$

$\lambda = \frac{1}{\sqrt{2}\pi d^2 (N/V)}$

$PV = NkT$

$\frac{N}{V} = \frac{P}{kT}$

$\lambda = \frac{kT}{\sqrt{2}\pi d^2 P}$

$P = \frac{\rho RT}{M}$

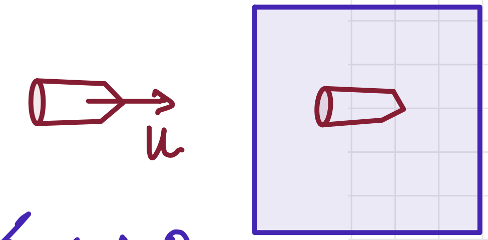
Q9: A lead bullet penetrates into a solid object and melts. Assuming that 40% of its kinetic energy is used to heat it, the initial speed of bullet is:
(Given initial temperature of the bullet = 127°C.
Melting point of the bullet = 327°C.
Latent heat of fusion of lead = 2.5×10^4 J kg^{-1}.
Specific heat capacity of lead = 125 J/kg K)

(A) 125 ms^{-1}

(B) ✓ 500 ms^{-1}

(C) 250 ms^{-1}

(D) 600 ms^{-1}



$$\frac{2}{5}\left(\frac{1}{2} m v^2\right) = m \cdot s \cdot \Delta\theta + mL$$

$$\frac{v^2}{5} = s\,\Delta\theta + L$$

$$\frac{v^2}{5} = (125)(327-127) + 2.5 \times 10^4$$

$$\frac{v^2}{5} = (125)(200) + 2.5 \times 10^4$$

$$= 250 \times 10^2 + 2.5 \times 10^4$$

$$= 2.5 \times 10^4 + 2.5 \times 10^4$$

$$= 5 \times 10^4$$

$$v^2 = 5 \times 5 \times 10^4$$

$$v = 500 \text{ mt/sec}$$

Q10: The equation of a particle executing simple harmonic motion is given by $x = \sin\pi\left(t + \frac{1}{3}\right) m$. At t = 1s, the speed of particle will be (Given: $\pi = 3.14$).

(A) 0 cm s^{-1}

(B) 157 cm s^{-1} ✓

(C) 272 cm s^{-1}

(D) 314 cm s^{-1}

$x = \sin\pi(t+1/3)$

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

$= \cos\pi(t+1/3)\,\frac{d}{dt}\pi(t+1/3)$

$= \pi\cos\pi(t+1/3)$

put t=1sec

$= \pi\cos\left(\frac{4}{3}\pi\right)$

$= \pi\cos(240^\circ)$

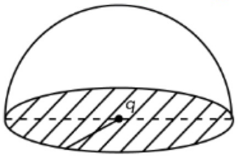
$= \pi\cos(180+60^\circ)$

$= (3.14)(-1/2)$ mt/sec

$= 1.57$ mt/sec

157 cm/sec

Q11: If a charge q is placed at the centre of a closed hemispherical non-conducing surface, the total flux passing through the flat surface would be:



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

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

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

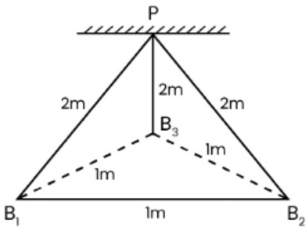
(D) $\frac{q}{2\pi\epsilon_0}$

$\phi = q/\epsilon_0$

1/2 of the flux will go up and 1/2 of the flux go down

hence $\phi_{\text{through flat surface}} = \frac{q}{2\epsilon_0}$

Q12: Three identical charged balls each of charge 2 C are suspended from a common point P by silk threads of 2 m each (as shown in figure). They form an equilateral triangle of side 1m. The ratio of net force on a charged ball to the force between any two charged balls will be:

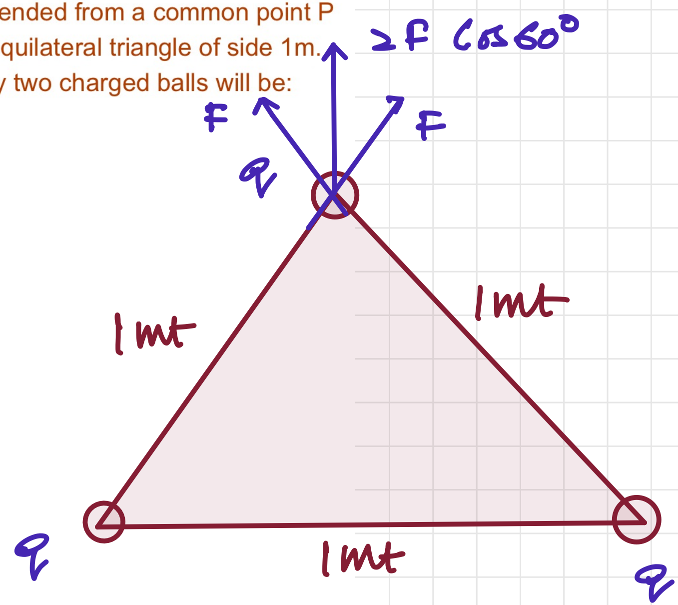


(A) 1 : 1

(B) 1 : 4

(C) $\sqrt{3} : 2$

(D) $\sqrt{3} : 1$

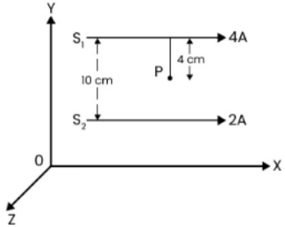


$$\frac{2F\cos 30^\circ}{F} = 2\left(\frac{\sqrt{3}}{2}\right) = \frac{\sqrt{3}}{1}$$

Q13: Two long parallel conduction S_1 and S_2 are separated by a distance 10cm and carrying currents of 4A and 2A respectively. The conductors are placed along x-axis in X-Y plane. There is a point P located between the conductors (as shown in figure).

A charge particle of 3πcoulomb is passing through the point P with velocity $\vec{v} = (2\hat{i} + 3\hat{j})\ m/s.$ where $\hat{i} \& \hat{j}$ represents unit vector along x and y axis respectively.

The force acting on the charge particle is $4\pi \times 10^{-5}\ (-x\hat{i} + 2\hat{j})\ N.$ The value of x is :

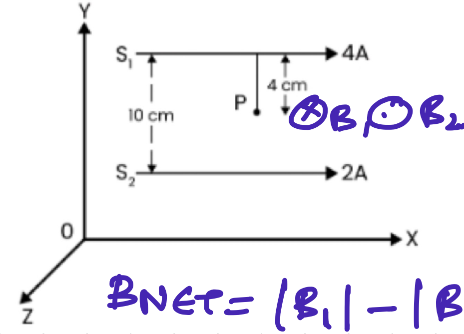


(A) 2

(B) 1

(C) 3

(D) -3



$B_{NET} = |B_1| - |B_2|$

$= \frac{\mu_0}{4\pi} \frac{2 \times 4}{4/100} - \frac{\mu_0}{4\pi} \frac{2 \times 2}{6/100}$

$= \frac{\mu_0}{4\pi} \times 100 \left[2 - \frac{2}{3}\right] = \frac{\mu_0}{4\pi} \times 100 \times \frac{4}{3}$

$= \frac{\mu_0}{3\pi} \times 100 (-\hat{k})$

$F = q(\vec{v} \times \vec{B})$

$= 3\pi (2\hat{i} + 3\hat{j}) \times \frac{100 \times \mu_0}{3\pi} (-\hat{k})$

$= 4\pi \times 10^{-5} (2\hat{j} - 3\hat{i})$

$x = 3$

Q14: If L.C and R are the self inductance, capacitance and resistance respectively. Which of the following does not have the dimension of time?

(A) RC

(B) $\frac{L}{R}$

(C) $\sqrt{LC}$

(D) ✓ $\frac{LC}{C}$

ANS-14

$\tau = RC = T$

$\tau = L/R = T$

$f = \frac{1}{2\pi\sqrt{LC}}$

$\sqrt{LC} = \frac{1}{f 2\pi} \Rightarrow T$

$\frac{LC}{C} \rightarrow$ does not have (T)

Q15: Given below are tun statements.

Statement I: A time varying electric field is a source of changing magnetic field and vice-versa. Thus a disturbance in electric or magnetic field creates EM waves.

TRUE

Statement II: In a material medium, the EM wave travels with speed $v = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$. In the light of the above statements, choose the correct answer from the options given below.

WRONG

$$v = \frac{1}{\sqrt{\mu_0 \mu_r \epsilon_0 \epsilon_r}}$$

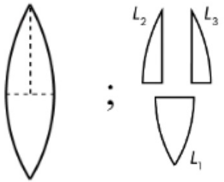
(A) Both statement I and statement II are true

(B) Both statement I and statement II are false

(C) ✓ Statement I is correct but statement II is false

(D) Statement I is incorrect but statement II is true

Q16: convex lens has power P. It is cut into two halves along its principal axis. Further one piece (out of the two halves) is cut into two halves perpendicular to the principal axis (as shown in figure). Choose the incorrect option for the reported pieces.

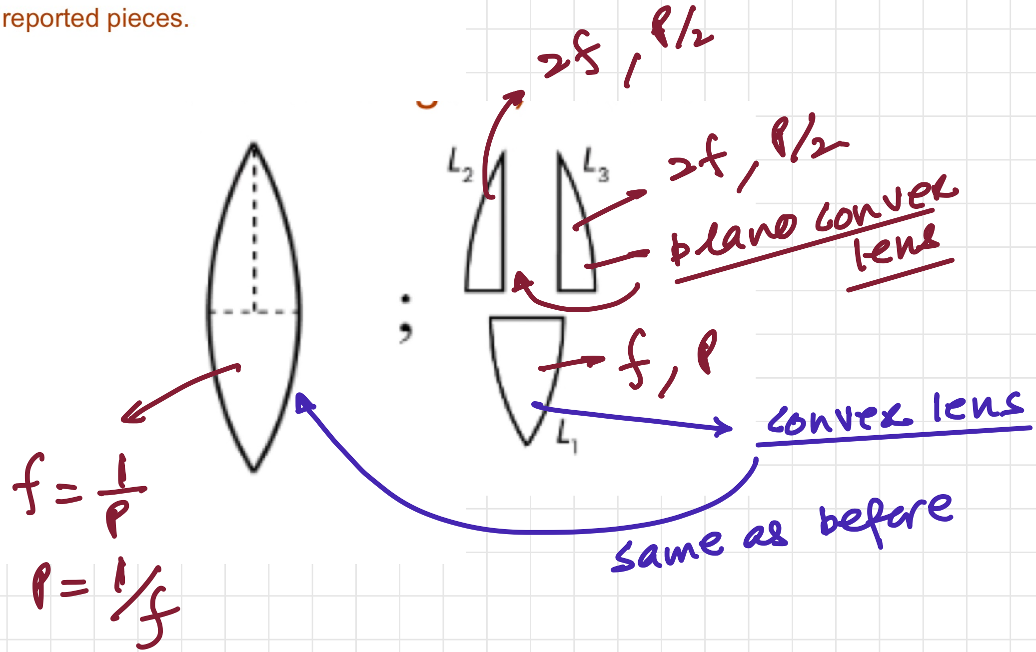


(A) Power of $L_1 = \frac{P}{2}$

(B) Power of $L_2 = \frac{P}{2}$

(C) Power of $L_3 = \frac{P}{2}$

(D) Power of $L_1 = P$



Q17: 1f a wave gets refracted into a denser medium, then which of the following is true?

(A) wavelength, speed and frequency decreases

(B) wavelength increases, speed decreases and frequency remains constant

(C) ✓ wavelength and speed decreases but frequency remains constant

(D) wavelength. speed and frequency increases

RARER | DENSER

f | f

c

λ

$\mu = \frac{c}{v} \Rightarrow v = \frac{c}{\mu}$ — Decreases

$\mu = \frac{f\lambda}{f\lambda'}$

$\lambda' = \frac{\lambda}{\mu}$ — Decreases

Q18: Given below are tun statement:

Statement I: In hydrogen atom, the frequency of radiation emitted when an electron jumps from lower energy orbit (E_1) to higher energy orbit (E_2). is given as $hf = E_1 - E_2$ → WRONG emitted only when high energy to low energy.

Statement II: The jumping of electron from higher energy orbit (E_2) to lower energy orbit (E_1) is associated with frequency of radiation given as $f = (E_2 - E_1)/h$

This condition is Bobr's frequency condition.

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

(A) A Both statement I and statement II are true

(B) Both summon I and statement II are false

(C) Statement I is correct but statement II is false

(D) ✓ Statement I is incorrect but statement II is true

$E_2 - E_1 = \frac{hc}{\lambda} = h\nu$

TRUE

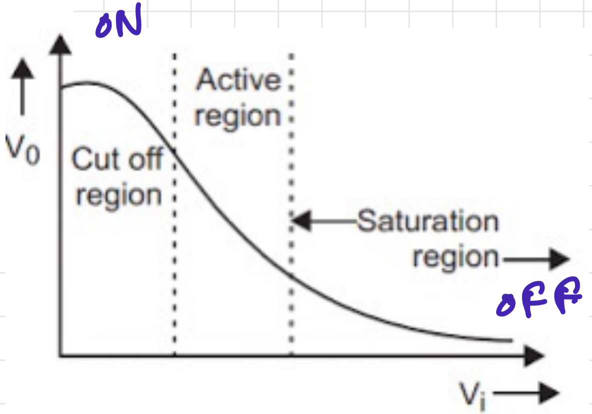
Q19: For a transistor to act as a switch, it much be operated in

(A) Active region

(B) Saturation state only

(C) Cut-off state only

(D) Saturation and cut-off state ✓



TRANSISTOR (SWITCH)

TRANSFER CHARCTERISTIC

Q20: We do not transmit low frequency signal to long distances because

(a) The size of the antenna should be comparable to signal wavelength which is unreal solution for a signal of longer wavelength.

(b) Effective power radiated by a long wavelength baseband signal would be high.

(c) We want to avoid mixing up signals transmitted by different transmitter simultaneously.

(d) Low frequency signal can be sent to long distances by superimposing with a high frequency wave as well.

Therefore the most suitable option will be

(A) All statements are true

(B) (a), (b) and (c) are true only

(C) (a), (c) and (d) are true only

(D) (b), (c) and (d) are true only

a) size of the antenna $= \lambda/4 \rightarrow$ will be very large practically not possible

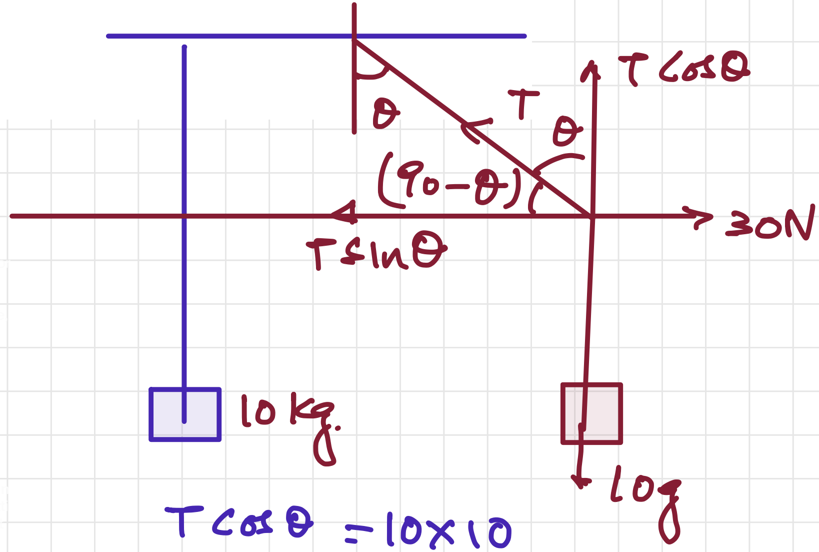
b) Radiation from a linear antenna $\propto 1/\lambda^2$

c) TRUE

d) $\rightarrow$ modulation.

Q21: A mass of 10kg is suspended vertically by a rope of length 5m from the roof. A force of 30 N is applied at the middle point of rope in horizontal direction. The angle made by upper half of the rope with vertical is $\theta = \tan^{-1}\left(x \times 10^{-1}\right)$. The value of x is ___3___. (Given, g = 10 m/s^2)

3



$T\cos\theta = 10 \times 10$

$T\sin\theta = 30$

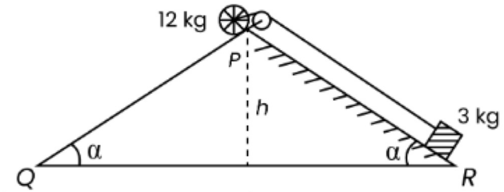
$\tan\theta = \frac{30}{100} = 3 \times 10^{-1}$

$\theta = \tan^{-1}(3 \times 10^{-1})$

$x = 3$

Q22: A rolling wheel of 12 kg is on an inclined plane at position P and connected to a mass of 3kg through a string of fixed length and pulley as shown in figure. Consider PR as friction free surface.

The velocity of centre of mass of the wheel when it reaches at the bottom Q of the inclined plane PQ will be $\frac{1}{2}\sqrt{xgh}\, m/s$. The value of x is $\underline{8/3}$



$8/3$

Change is PE = KE

$12g(h) - 3gh = \frac{1}{2}3v^2 + \frac{1}{2}(12)v^2 + \frac{1}{2}I\omega^2$

$9gh = \frac{3}{2}v^2 + 6v^2 + \frac{1}{2}mR^2\frac{v^2}{R^2}$

$= \frac{3}{2}v^2 + 6v^2 + 6v^2$

$= v^2\left(\frac{3}{2} + 12\right) = v^2\left(\frac{27}{2}\right)$

$9gh = v^2\left(\frac{27}{2}\right)_3$

$v = \sqrt{\frac{2}{3}gh}$

$v = \frac{1}{2}\sqrt{\frac{4 \times 2}{3}gh}$

$= \frac{1}{2}\sqrt{\frac{8}{3}gh}$

$x = 8/3$

Q23: A diatomic gas $(\gamma = 1.4)$ does 400 J of work when it is expanded isobarically. The heat given to the gas in the process is ___1400___ J.

1400

$W = 400\,J = P\Delta V = nR\Delta T$

$\Delta Q = ?$

$\Delta Q = nC_p\Delta T$

$\Delta Q = n\left(\frac{\gamma R}{\gamma - 1}\right)\Delta T$

$\Delta Q = (nR\Delta T)\left(\frac{\gamma}{\gamma - 1}\right)$

$= 400 \times \frac{1.4}{(1.4 - 1)}$

$= 400 \times \frac{1.4}{0.4}$

$= 100 \times 14 = 1400\,J$

Q24: A particle executes simple harmonic motion. Its amplitude is 8 cm and time period is 6 s. The time it will take to travel from its position of maximum displacement to the point corresponding to half of its amplitude. is ____________ s.

If particle travels from maximum displacement

If particle travels for zero displacement then equation is

$y = a\sin\omega t$

$y = a\cos\omega t$

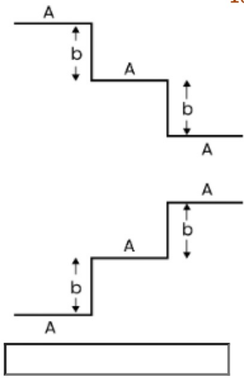
$\frac{a}{2} = a\cos\omega t$

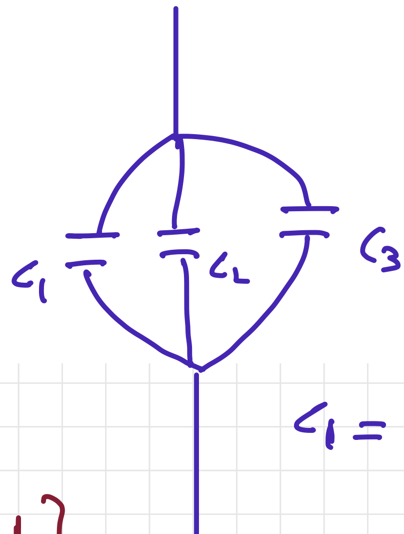
$\cos\pi/3 = \cos\omega t$

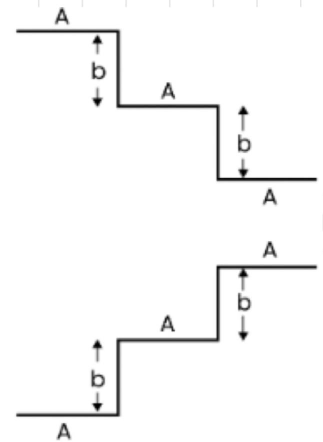
$\frac{\pi}{3} = \frac{2\pi}{T}\cdot t$

$t = T/12 = \frac{6}{6} = 1\,sec$

Q25: A parallel plate capacitor is made up of stair like structure with a plate area A of each stair and that is connected with a wire of length b, as shown in the figure. The capacitance of the arrangement is $\frac{x}{15}\frac{\epsilon_0 A}{b}$. The value of x is 23.







$C_1 = \frac{\epsilon_0 A}{5b}$, $C_2 = \frac{\epsilon_0 A}{3b}$

$C_3 = \frac{\epsilon_0 A}{b}$

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

$= \frac{\epsilon_0 A}{b}\left[\frac{1}{5} + \frac{1}{3} + 1\right]$

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

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