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E 281 BASEMENT M BLOCK MAIN ROAD GREATER KAILASH 2 NEW DELHI

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IIT JEE PHYSICS PAPER SOLUTION

25 JUNE 2022

MORNING SHIFT

QUESTIONS BASED ON VECTORS,
EMW,
OPTICAL FIBRE,
ORGAN PIPE ,
, PHOTO DIODE,
MAGNETIC FIELD DUE TO STRAIGHT,
CYLINDRICAL WIRE

Q1: If $Z = \frac{A^2 B^3}{C^4}$, then the relative error in Z will be:

(A) $\frac{\Delta A}{A} + \frac{\Delta B}{B} + \frac{\Delta C}{C}$

(B) $\frac{2\Delta A}{A} + \frac{3\Delta B}{B} - \frac{4\Delta C}{C}$

(C) $\frac{2\Delta A}{A} + \frac{3\Delta B}{B} + \frac{4\Delta C}{C}$ ✓

(D) $\frac{\Delta A}{A} + \frac{\Delta B}{B} - \frac{\Delta C}{C}$

ANS-1

$$Z = \frac{A^2 B^3}{C^4}$$

$$\frac{\Delta Z}{Z} = 2\frac{\Delta A}{A} + 3\frac{\Delta B}{B} + 4\frac{\Delta C}{C}$$

Remember it can never be positive

Q2: $\vec{A}$ is a vector quantity such that $|\vec{A}|$ =non zero constant. Which of the following expression is true for $\vec{A}$?

ANS-2

(A) $\vec{A}.\vec{A}=0$

(B) $\vec{A}\times\vec{A}<0$

✓ (C) $\vec{A}\times\vec{A}=0$

(D) $\vec{A}\times\vec{A}>0$

$\bar{A}.\bar{A} = |A||A|\cos 0 = |A|^2$

$\bar{A}\times\bar{A} = |A||A|\sin 0^\circ \hat{n} = 0$

└ possible

Q3: Which of the following relations is true for two unit vector $\hat{A}$ and $\hat{B}$ making an angle θ to each other?

(A) $|\hat{A}+\hat{B}| = |\hat{A}-\hat{B}| \tan\frac{\theta}{2}$

(B) $|\hat{A}-\hat{B}| = |\hat{A}+\hat{B}| \tan\frac{\theta}{2}$

(C) $|\hat{A}+\hat{B}| = |\hat{A}-\hat{B}| \cos\frac{\theta}{2}$

(D) $|\hat{A}-\hat{B}| = |\hat{A}+\hat{B}| \cos\frac{\theta}{2}$

ANS- B

$$|\hat{A}+\hat{B}| = \sqrt{(1)^2+(1)^2+2(1)(1)\cos\theta}$$
$$= \sqrt{2(1+\cos\theta)}$$
$$= \sqrt{2\{1+2\cos^2\theta/2-1\}}$$
$$= 2\cos\theta/2$$

$$|\hat{A}-\hat{B}| = \sqrt{1^2+1^2-2(1)(1)\cos\theta}$$
$$= \sqrt{2(1-\cos\theta)} = \sqrt{2(2\sin^2\theta/2)}$$
$$= 2\sin\theta/2$$

NOW. $$\frac{|\hat{A}-\hat{B}|}{|\hat{A}+\hat{B}|} = \frac{2\sin\theta/2}{2\cos\theta/2}$$
$$= \tan\theta/2$$

$$|\hat{A}-\hat{B}| = \{\tan\theta/2\}\,|\hat{A}+\hat{B}|$$

Q4: If force $\overrightarrow{F} = 3\hat{i} + 4\hat{j} - 2\hat{k}$ acts on a particle having position vector $2\hat{i} + \hat{j} + 2\hat{k}$ then, the torque about the origin will be:

(A) $3\hat{i} + 4\hat{j} - 2\hat{k}$

(B) $-10\hat{i} + 10\hat{j} + 5\hat{k}$

(C) $10\hat{i} + 5\hat{j} - 10\hat{k}$

(D) $10\hat{i} + \hat{j} - 5\hat{k}$

ANS-4

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$= (2\hat{i} + \hat{j} + 2\hat{k}) \times (3\hat{i} + 4\hat{j} - 2\hat{k})$$

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 1 & 2 \\ 3 & 4 & -2 \end{vmatrix}$$

$$= \hat{i}(-2-8) + \hat{j}(6+4) + \hat{k}(8-3)$$

$$= 10\hat{i} + 10\hat{j} + 5\hat{k}$$

Q5: The height of any point P above the surface of earth is equal to diameter of earth. The value of acceleration due to gravity at point P will be : (Given g = acceleration due to gravity at the surface of earth)

(A) $\frac{g}{2}$

(B) $\frac{g}{4}$

(C) $\frac{g}{3}$

(D) $\frac{g}{9}$

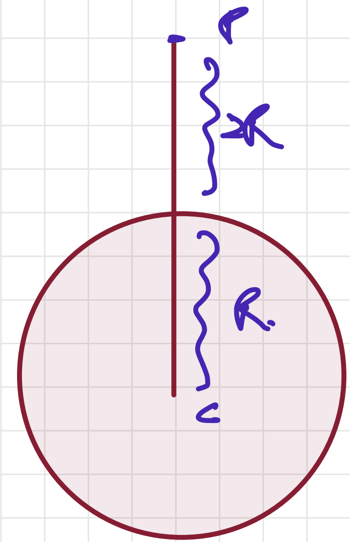
ANS-5

$$g_c = g = \frac{GM}{R^2}$$

$$g_P = \frac{GM}{(R+2R)^2}$$

$$\frac{g}{g_P} = \frac{GM}{R^2} \cdot \frac{9R^2}{GM}$$

$$g_P = g/9$$



Q6: The terminal velocity (v_t) of the spherical rain drop depends on the radius r of the spherical rain drop as :

(A) $r^{\frac{1}{2}}$

(B) r

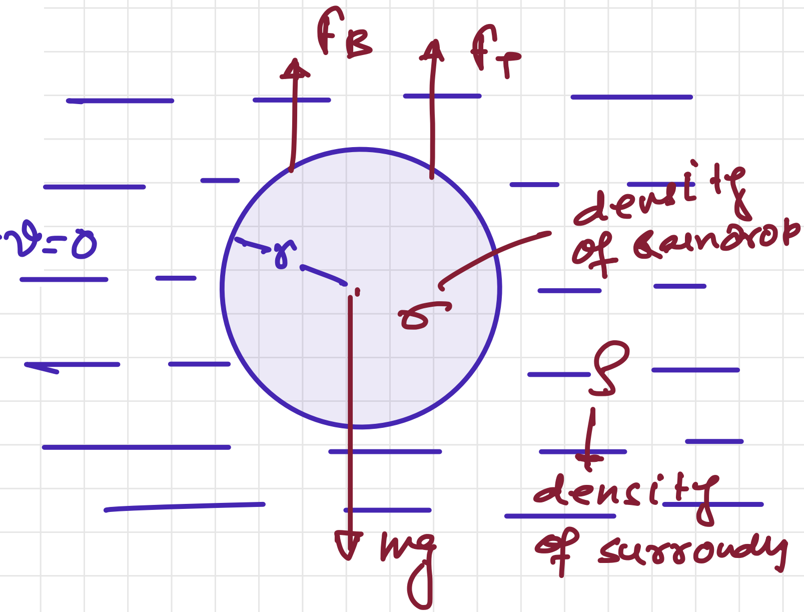
(C) r^2 ✓

(D) r^3

ANS-C

$$mg - F_B - F_T = 0$$

$$\frac{4}{3}\pi r^3 \sigma g - \frac{4}{3}\pi r^3 \rho g - 6\pi\eta r v = 0$$



$$\frac{4}{3}\pi r^3 g(\sigma - \rho) = 6\pi\eta r v$$

$$v = \frac{\frac{4}{3}\pi r^3 g(\sigma - \rho)}{6\pi\eta r}$$

$$= \frac{2}{9}\frac{(\sigma - \rho) g r^2}{\eta}$$

$$v \propto r^2$$

Q7: The relation between root mean square speed (v_{rms}) and most probable speed (v_p) for the molar mass M of oxygen gas molecule at the temperature of $300\ \mathrm{K}$ will be:

(A) $v_{\mathrm{rms}}=\sqrt{\frac{2}{3}} v_{\mathrm{p}}$

✓ (B) $v_{\mathrm{rms}}=\sqrt{\frac{3}{2}} v_{\mathrm{p}}$

(C) $v_{rms}=v_p$

(D) $v_{rms}=\sqrt{\frac{1}{3}} v_p$

ANS-7

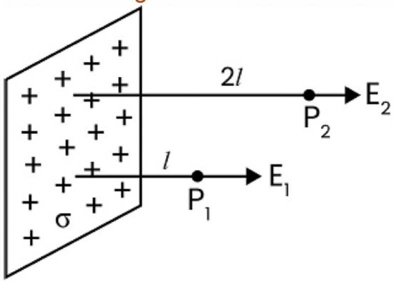
$v_{rms}=\sqrt{\frac{3RT}{M}}$

$v_{mp}=\sqrt{\frac{2RT}{M}}$

$\frac{v_{rms}}{v_{mp}}=\sqrt{\frac{3}{2}}$

$v_{rms}=\sqrt{\frac{3}{2}}\ v_{mp}$

Q8: In the figure, a very large plane sheet of positive charge is shown. P_1 and P_2 are two points at distance ℓ and 2ℓ from the charge distribution. If σ is the surface charge density, then the magnitude of electric fields E_1 and E_2 at P_1 and P_2 respectively are:



(A) $E_1 = \frac{\sigma}{\varepsilon_0}, E_2 = \frac{\sigma}{2\varepsilon_0}$

(B) $E_1 = \frac{2\sigma}{\varepsilon_0}, E_2 = \frac{\sigma}{\varepsilon_0}$

(C) $E_1 = E_2 = \frac{\sigma}{2\varepsilon_0}$

(D) $E_1 = E_2 = \frac{\sigma}{\varepsilon_0}$

ANS-8

Electric field due to large conducting sheet does not depend on distance from the sheet

$$E = \frac{\sigma}{2\epsilon_0} = E_1 = E_2$$

Q9: Match list – 1 with list – II

List – I	List – II
(A) AC generator	(I) Detects the presence of current in the circuit
(B) Galvanometer	(II) Converts mechanical energy into electrical energy
(C) Transformer	(III) Works on the principle of resonance in AC circuit
(D) Metal detector	(IV) Changes an alternating voltage for smaller or greater value

Chose the correct answer from the options given below:

(A) $A \to II, B \to I, C \to IV, D \to III$

(B) $A \to II, B \to I, C \to III, D \to IV$

(C) $A \to III, B \to IV, C \to II, D \to I$

(D) $A \to III, B \to I, C \to II, D \to IV$

AC. GENERATOR

Converts mechanical energy to electrical.

GALVANOMETER

sense the current in the circuit

TRANSFORMER

works for AC only step up or step down.

METAL DETECTOR

Resonance circuit is installed in metal detector

Q10: A long straight wire with a circular cross-section having radius R, is carrying a steady current I. The current I is uniformly distributed across this cross-section. Then the variation of magnetic field due to current I with distance r $(r < R)$ from its centre will be :

(A) $B \propto r^2$

(B) $B \propto r$ ✓

(C) $B \propto \frac{1}{r^2}$

(D) $B \propto \frac{1}{r}$

FULL DERIVATION JUST GO THROUGH IT.

$B \propto r$

case I: $r = a < R$; $r = R$; $r = b > R$

Case-I

$r = a < R$, $\oint \vec{B} \cdot d\vec{l} = \mu_0 I$

current enclosed is equal to I'

$B \cdot 2\pi a = \mu_0 I'$

$B = \frac{\mu_0}{2\pi} \frac{I'}{a}$

Since current density is constant hence $\frac{I}{\pi R^2} = \frac{I'}{\pi a^2}$

$I' = \frac{I a^2}{R^2}$

$B = \frac{\mu_0}{2\pi} \frac{I a^2}{R^2 \cdot a}$

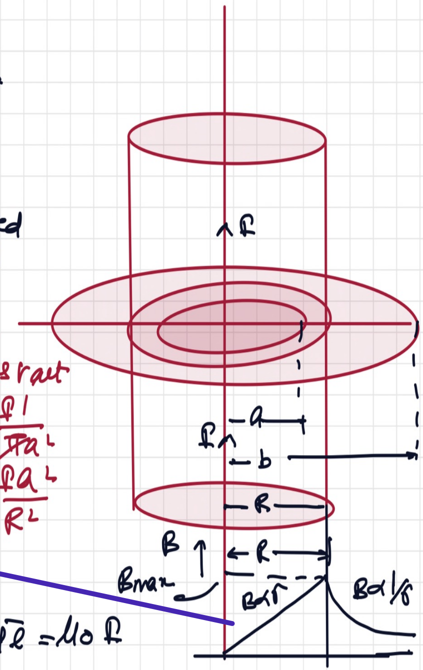
$B = \left(\frac{\mu_0}{2\pi} \frac{I}{R^2}\right)(a)$ — constant

$B \propto a \propto r$

Case-2 → $r = R$ apply A.C.L $\oint \vec{B} \cdot d\vec{l} = \mu_0 I$

current enclosed $= I$

$B \, 2\pi R = \mu_0 I \Rightarrow B = \frac{\mu_0}{2\pi} \frac{I}{R} = B_{max}$



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Q11: If wattless current flows in the AC circuit, then the circuit is :

(A) Purely Resistive circuit

(B) Purely Inductive circuit ✓

(C) LCR series circuit

(D) RC series circuit only

$P_{avg} = V_{rms} I_{rms} \cos\phi$

For Inductor & capacitor

$\phi = 90^\circ$

$P_{avg} = V_{rms} I_{rms} \cos 90$

$= \text{zero}$

hence wattless current flows in Inductor or capacitor

Q12: The electric field in an electromagnetic wave is given by $E = 56.5 \sin \omega(t - \frac{x}{c}) NC^{-1}$. Find the intensity of the wave if it is propagating along x-axis in the free space. (Given)

(A) $5.65 Wm^{-2}$

(B) $4.24 Wm^{-2}$ ✓

(C) $1.9 \times 10^{-7} Wm^{-2}$

(D) $56.5 Wm^{-2}$

AHS-12

AVERAGE ELECTRICAL ENERGY DENSITY

$= \frac{1}{2} \epsilon_0 E_{rms}^2 = \frac{1}{4} \epsilon_0 E_0^2$

Energy / Volume

$\frac{dE}{A\,dx} = \frac{1}{2} \epsilon_0 E_0^2$ — (1)

$I = \frac{dE}{A\,dt}$ — (2)

EQUATION (1) / EQUATION (2)

$\frac{dE\,A\,dt}{A\,dx\,dE} = \frac{\frac{1}{2} \epsilon_0 E_0^2}{I}$

$\frac{dt}{dx} = \frac{\frac{1}{2} \epsilon_0 E_0^2}{I}$

$\frac{dx}{dt} = \frac{I}{\frac{1}{2} \epsilon_0 E_0^2} = c$

$\frac{dx}{dt} = c$ = velocity of EMW

$I = \frac{1}{2} \epsilon_0 E_0^2 (c)$

$= \frac{1}{2} (8.85 \times 10^{-12}) (56.5)^2 \times (3 \times 10^8)$

$= 4.24$ watt/mt^2

Q13: The two light beams having intensities I and 9I interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\frac{\pi}{2}$ at point P and π at point Q. Then the difference between the resultant intensities at P and Q will be:

(A) 2I

(B) 6I ✓

(C) 5I

(D) 7I

ANS-13

$I_P = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\pi/2$

$I_Q = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\pi$

$I_P = 9I + I = 10I$ —— (1)

$I_Q = 9I + I + 2\sqrt{I(9I)}(-1)$

$= 9I + I - 6I = 4I$ — (2)

$I_P - I_Q = 10I - 4I = 6I$

Q14: A light wave travelling linearly in a medium of dielectric constant 4 , incidents on the horizontal interface separating medium with air. The angle of incidence for which the total intensity of incident wave will be reflected back into the same medium will be:
(Given: Relative permeability of medium $\mu_r = 1$)

(A) 10°

(B) 20°

(C) 30°

(D) 60° ✓

ANS-14

Reflected back only when incident angle > critical angle

$i > c$

$\sin i > \sin c$

$\sin i > 1/\mu$

$\sin i > 1/2$

$\theta > 30^\circ$

which means 60° — As per option

$\mu = \frac{c}{v}$

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

$\mu = \sqrt{\mu_r \epsilon_r}$

$= \sqrt{(4)(1)}$

$= 2$

Q15: Given below are two statements:
Statement I: Davisson-Germer experiment establishes the wave nature of electrons.
Statement II: If electrons have wave nature, they can interfere and show diffraction.
In the light of the above statements choose the correct answer from the option given below:
(A) Both Statement I and Statement II are true
(B) Both Statement I and Statement II are false
(C) Statement I is true but Statement II is false
(D) Statement I is false but Statement II is true

ANS-15

↓

wave nature of electron is observed by this experiment.

since high speed electron are incident on Ni crystal and they get diffracted just like wave. so wave nature of electron was observed in the experiment

Q16: The ratio for the speed of the electron in the 3rd orbit of He^+ to the speed of the electron in the 3^{rd} orbit of hydrogen atom will be :

(A) 1: 1

(B) 1: 2

(C) 4: 1

✓ (D) 2: 1

ANS-16

mug up this formula.

$$v = (2.19 \times 10^6)\left(\frac{Z}{n}\right) \frac{mt}{sec}$$

$$v \propto \frac{Z}{n}$$

$$v_1 \propto 2/3 \qquad v_2 \propto 1/3$$

$$\frac{v_1}{v_2} = \frac{2}{1}$$

Q17: The photodiode is used to detect the optical signals. These diodes are preferably operated in reverse biased mode because:

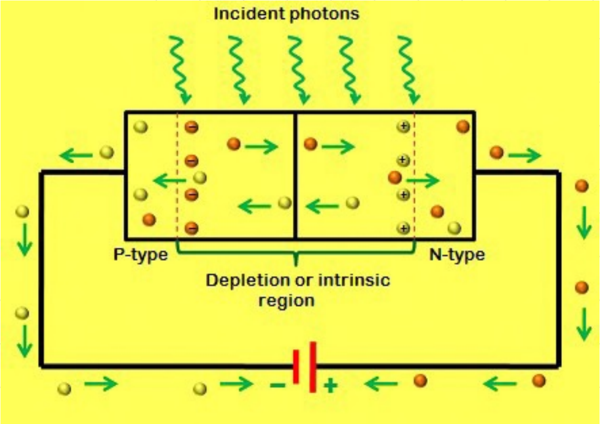
ANS-17

(A) Fractional change in majority carriers produce higher forward bias current

(B) Fractional change in majority carriers produce higher reverse bias current

(C) Fractional change in minority carriers produce higher forward bias current

(D) ✓ Fractional change in minority carriers produce higher reverse bias current



The current in the forward bias is primarily due to major carriers but in reverse bias it is **due to minor carriers**. As the fractional change in the reverse current due to the photo-effects is more easily measurable than in the forward bias current. So photodiodes are operated in the reverse bias.

Q18: A signal of 100THz frequency can be transmitted with maximum efficiency by

(A) Coaxial cable

✓ (B) Optical fibre

(C) Twisted pair of copper wires

(D) Water

ANS-10

↓ VERY LAGEE FREQUENCY ONLY THROUGH OPTICAL FIBRE.

Q19: The difference of speed of light in the two media A and B $(v_A - v_B)$ is 2.6×10^7 m/s. If the refractive index of medium B is 1.47, then the ratio of refractive index of medium B to medium A is : (Given: speed of light in vacuum $c = 3 \times 10^8$ ms^{-1})

(A) 1.303

(B) 1.318

(C) 1.13 ✓

(D) 0.12

ANS-19

$\mu_A = \frac{c}{v_A}$, $\mu_B = \frac{c}{v_B}$

$v_A = \frac{c}{\mu_A}$, $v_B = \frac{c}{\mu_B}$

$v_A - v_B = c\left(\frac{1}{\mu_A} - \frac{1}{\mu_B}\right)$

$(2.6 \times 10^7) = (3 \times 10^8)\left(\frac{1}{1.47} - \frac{1}{n_B}\right)$

$n_B = 1.67$

$\frac{n_B}{n_A} = \frac{1.67}{1.47} = 1.13$

Q20: A teacher in his physics laboratory allotted an experiment to determine the resistance (G) a galvanometer. Students took the observations for $\frac{1}{3}$deflection in the galvanometer. Which of the below is true for measuring value of G?

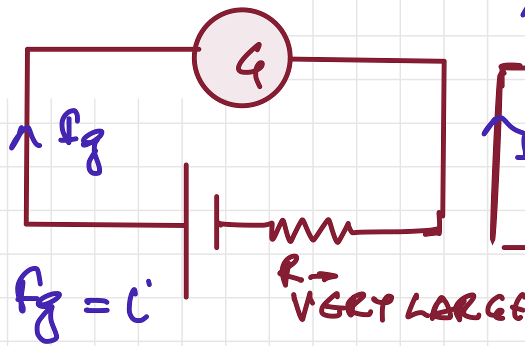
(A) $\frac{1}{3}$deflection method cannot be used for determining the resistance of the galvanometer.

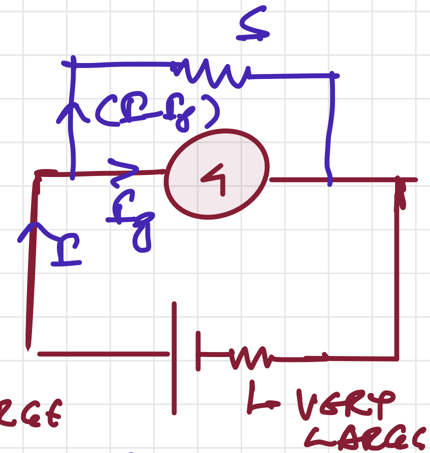
(B) $\frac{1}{3}$deflection method can be used and in this case the G equals to twice the value of shunt resistance(s)

(C) 1/3rd deflection method can be used and in this case, the G equals to three times the value of shunt resistance(s)

(D) $\frac{1}{3}$ deflection method can be used and in this case the G value equals to the shunt resistance(s)

ANS-20





$$I_g(R_g) = (I - I_g)S$$

$$I_g = \left(\frac{S}{R_g+S}\right) i$$

$$I_g\Big|_2 = \frac{1}{3} I_g$$

$$\left(\frac{S}{R_g+S}\right) i = \frac{i}{3}$$

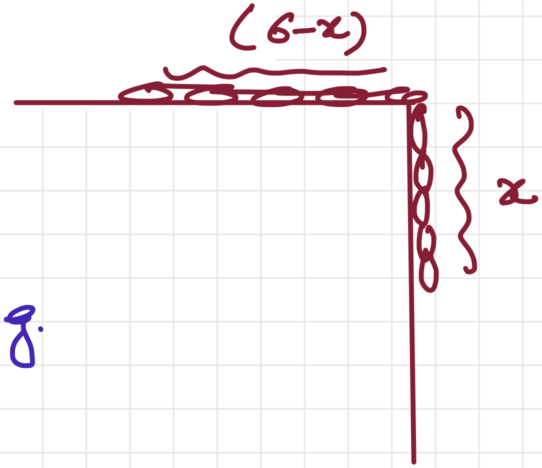
$$R_g = 2S$$

Q21: A uniform chain of 6m length is placed on a table such that a part of its length is hanging over the edge of the table. The system is at rest. The co-efficient of static friction between the chain and the surface of the table is 0.5, the maximum length of the chain hanging from the a table is ________ m.

2 mt

Let Net mass M

Mass per unit length = M/ℓ



To prevent sliding

$T = \frac{M}{\ell} x g$

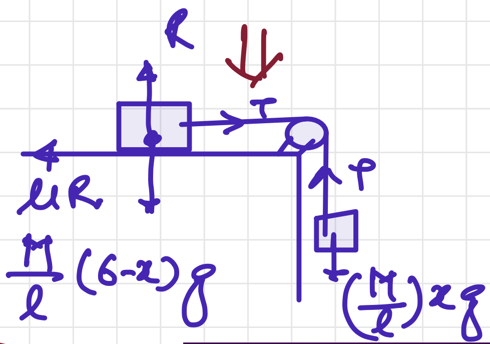
$\mu\left(\frac{M}{\ell}\right)(6-x)g > T > \frac{M}{\ell} x g$

$\mu\left(\frac{M}{\ell}\right)(6-x)g > \frac{M}{\ell} x g$

$0.5(6-x) = x$

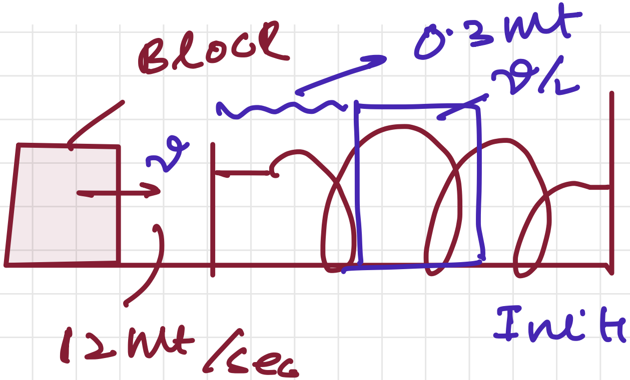
$3 - 0.5x = x$

$3 = 1.5x \Rightarrow x = 3/1.5 = 2\,mt$



Q22: A 0.5 kg block moving at a speed of $12\ \mathrm{ms}^{-1}$ compresses a spring through a distance 30 cm when its speed is halved. The spring constant of the spring will be 600 Nm^{-1}

600



Initial energy = Final energy

$$\frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{v}{2}\right)^2 + \frac{1}{2}k(0.3)^2$$

$$\frac{1}{2}m\left(v^2 - \frac{v^2}{4}\right) = \frac{1}{2}k(0.3)^2$$

$$\frac{1}{2}m\left(\frac{3v^2}{4}\right) = \frac{1}{2}k(0.3)^2$$

$$k = \frac{0.5 \times 3 \times (12)^2}{4 \times 0.3 \times 0.3}$$

$= 600\ \mathrm{N/m}$

Q23: The velocity of upper layer of water in a river is $36\,\mathrm{kmh^{-1}}$. Shearing stress between horizontal layers of water is $10^{-3}\,\mathrm{Nm^{-2}}$. Depth of the river is m. (Co-efficient of viscosity of water is $10^{-2}\,Pa.s$)

100 mt

ANS-23

$F_v = \eta A \frac{dv}{dx}$

Sheer stress

$= F/A = \eta \frac{dv}{dx}$

$10^{-3} = (10^{-2})\left(\frac{10-0}{h}\right)$

$h = 100$ mt

Q24: A steam engine intakes 50 g of steam at $100^\circ C$ per minute and cools it down to $20^\circ C$. If latent heat of vaporization of steam is $540\ \text{calg}^{-1}$, then the heat rejected by the steam engine per minute is _______ $\times 10^3\ \text{cal}$
(Given: specific heat capacity of water: $1\text{cal}g^{-1}{}^\circ C^{-1}$

ANS-24

→ During condensation heat rejected

(1) $= (100\ \text{grm}) \times \left(540 \frac{\text{cal}}{\text{grm}}\right) = 5.4 \times 10^{4}$ cal

(2) Rejected during cooling of water

$= (100\ \text{grm}) \left(\frac{1\ \text{cal}}{\text{grm}\ {}^\circ C}\right) (100-20)({}^\circ C)$

$= 8000$ cal

ADD (1) & (2)

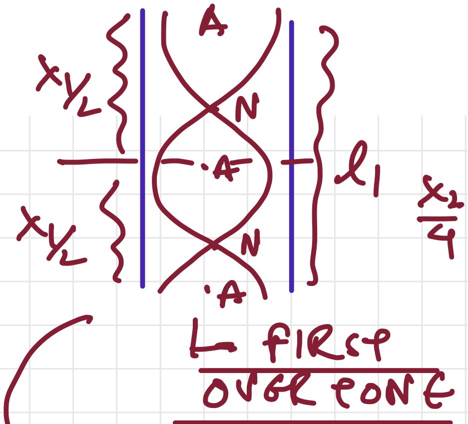
Total heat rejected per minute by engine

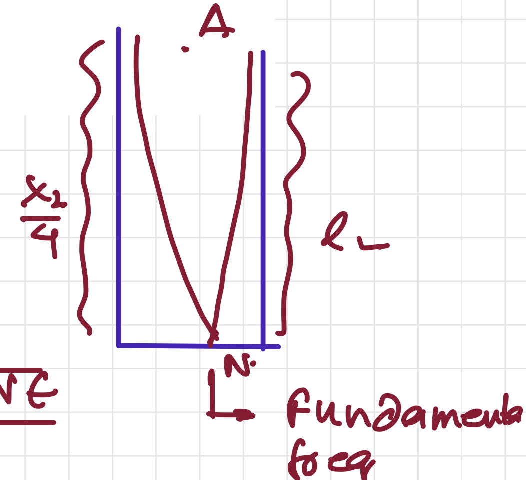
$= 5.4 \times 10^4\ \text{cal} + 0.8 \times 10^4\ \text{cal}$

$= 6.2 \times 10^4$ cal

Q25: The first overtone frequency of an open organ pipe is equal to the fundamental frequency of a closed organ pipe. If the length of the closed organ pipe is 20 cm. The length of the open organ pipe is ___80___ cm.

80 cm





$$l_1 = \frac{\lambda_1}{2} + \frac{\lambda_1}{2} = \lambda_1$$

$$v = f_1 \lambda_1$$

$$f_1 = \frac{v}{\lambda_1} = \frac{v}{l_1}$$

$$l_2 = \lambda_2/4 \Rightarrow \lambda_2 = 4l_2$$

$$v = f_2 \lambda_2$$

$$f_2 = \frac{v}{\lambda_2} = \frac{v}{4l_2}$$

$$f_1 = f_2$$

$$\frac{v}{l_1} = \frac{v}{4l_2} \Rightarrow l_1 = 4 \times 20$$

$$= 80 \text{cm}$$

-
-
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-
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