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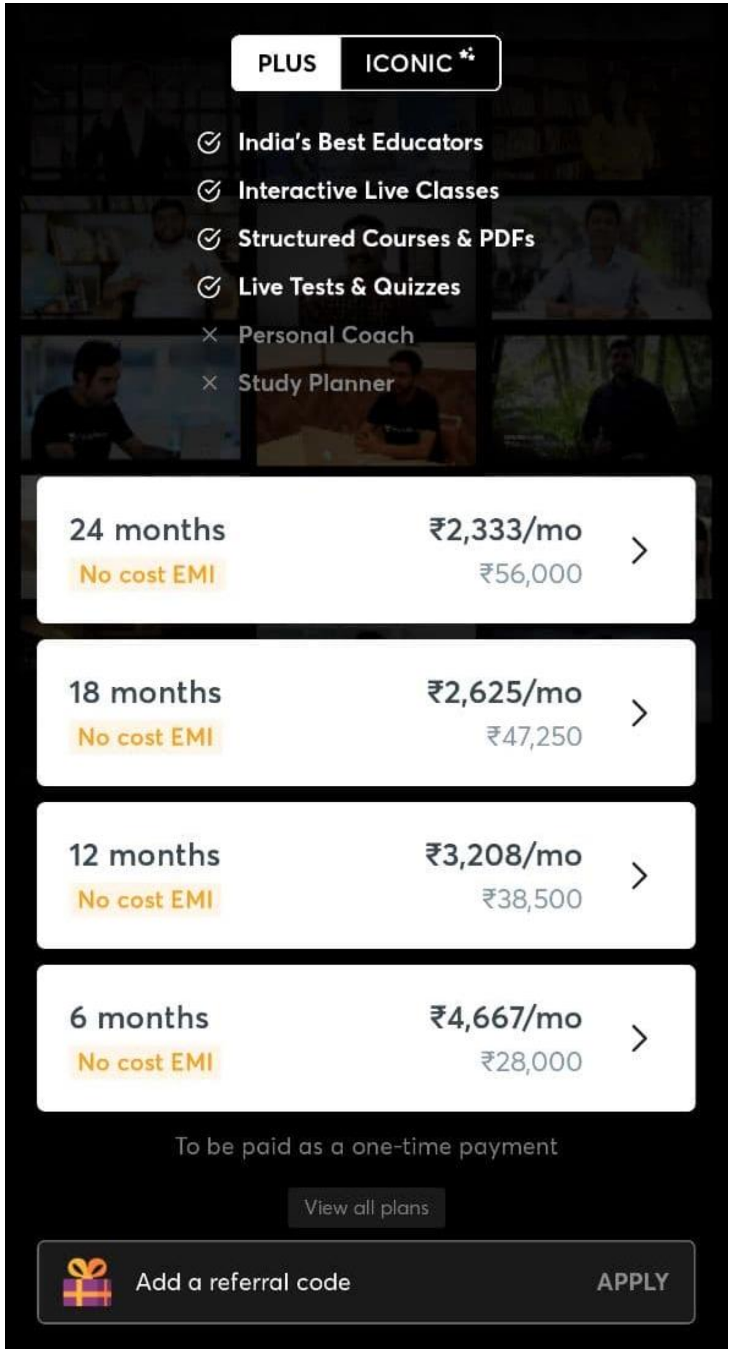

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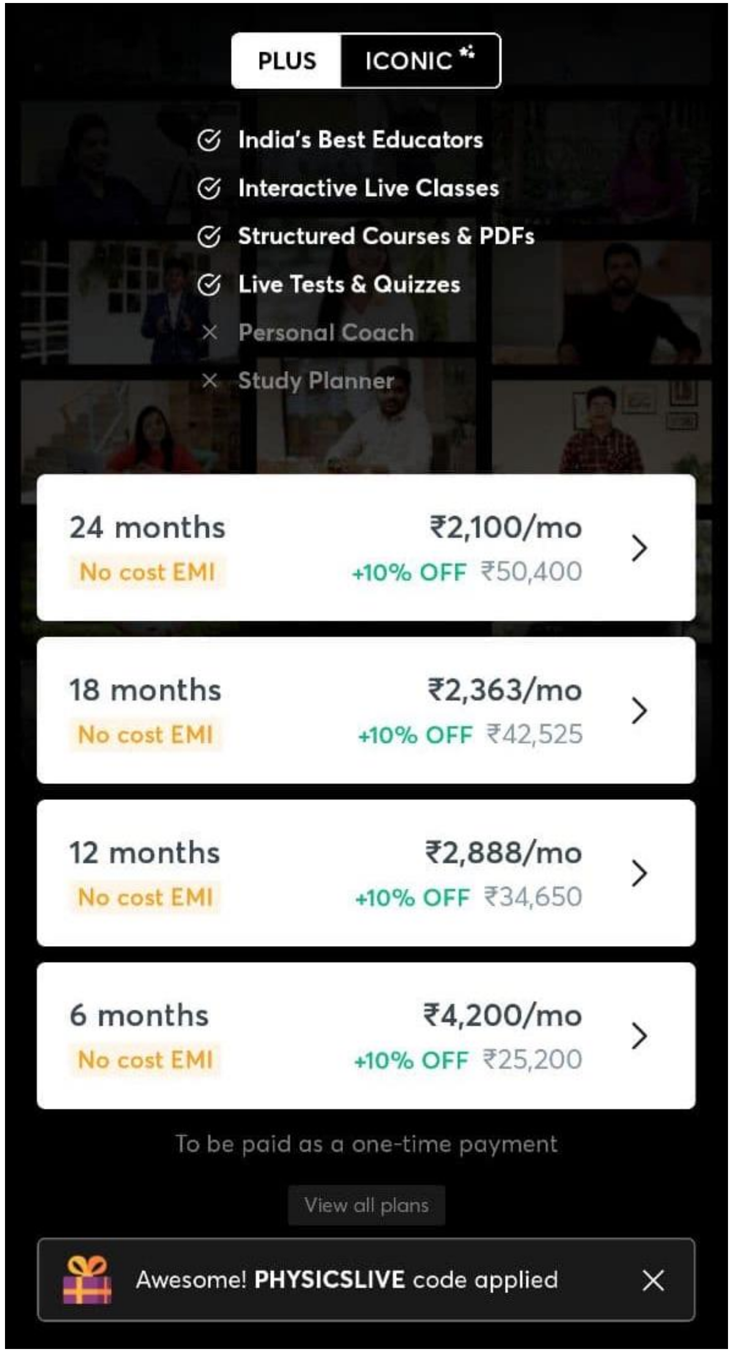
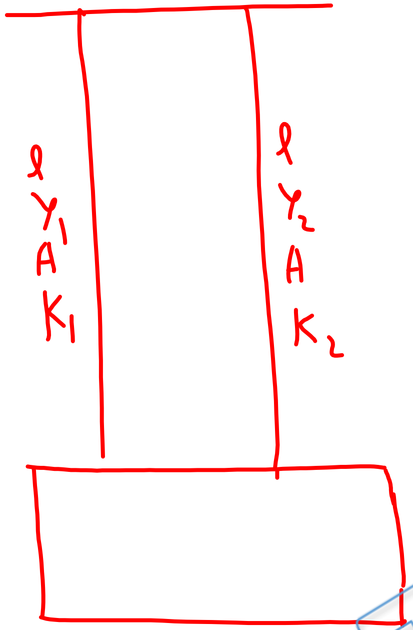


Solution
Exercise: 1 (L-1)

Thermo-1 (Elasticity, Calorimetry, Thermal Expansion, Heat Transfer)

By Physicsaholics Team

1)



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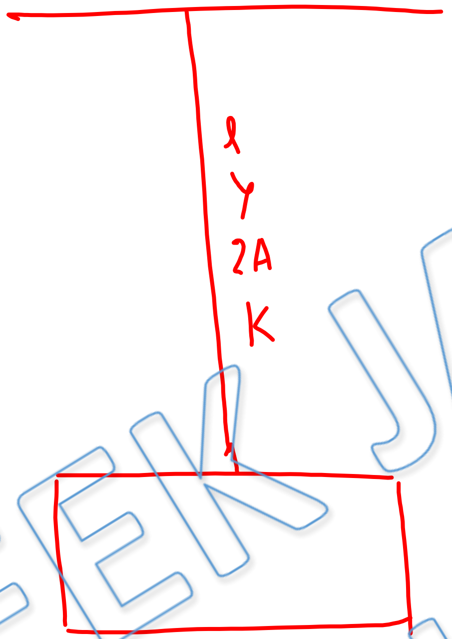


K_1 & K_2 are stiffness

equivalent $K = K_1 + K_2$

$$\Rightarrow \quad \frac{2YA}{l} = \frac{Y_1 A}{l} + \frac{Y_2 A}{l}$$

$$\Rightarrow \quad Y = \frac{Y_1 + Y_2}{2}$$

Ans (b)

2)

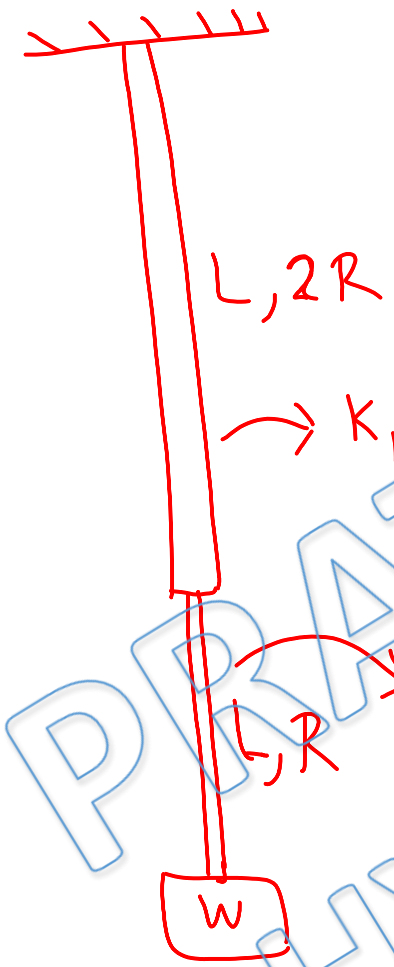
for a material breaking stress is constant

$\Rightarrow$ breaking force = breaking stress × Area of cross section

$\Rightarrow$ breaking force does not depend on length of wire

Ans (d)

3)



$$K_1 = \frac{Y(4\pi R^2)}{L}$$

$$K_2 = \frac{Y\pi R^2}{L}$$

If effective stiffness is K

$$\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} = \frac{L}{4\pi R^2 Y} + \frac{L}{\pi R^2 Y} = \frac{5L}{4\pi R^2 Y}$$

$$K = \frac{4\pi R^2 Y}{5L}$$

$$U = \frac{F^2}{2K} = \frac{W^2 \times 5L}{2 \times 4\pi R^2 Y}$$

$$= \frac{5}{8}\frac{W^2 L}{\pi R^2 Y}$$

Ans(c)

4)

On increasing T, intermolecular force decreases

$\Rightarrow \gamma$ decreases

Ans (d)

4)

On increasing T, intermolecular force decreases

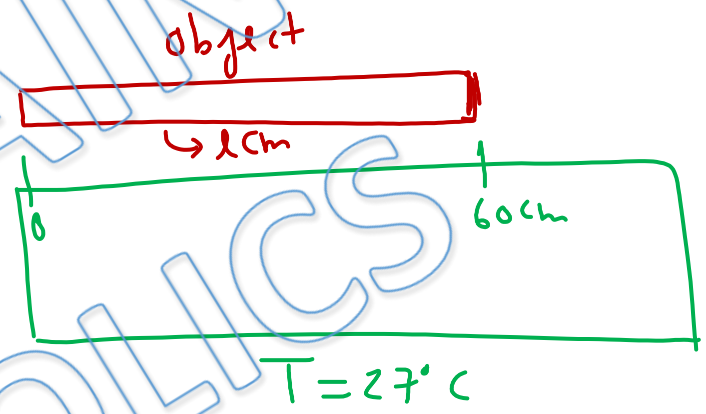
$\Rightarrow \gamma$ decreases

Ans (d)

5)

Reading = 60 cm

actual length of object = l cm



$$l = 60\left(1 + 1.2\times10^{-5}\times(27-15)\right)$$

$$l = 60 + 60\times1.2\times12\times10^{-5}$$

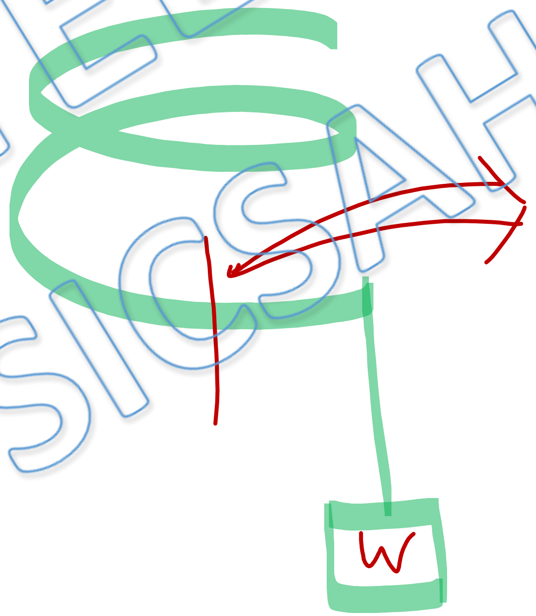
$$= 60 + 864\times10^{-5}$$

$$= 60.00864 \text{ cm}$$

Error = .00864 cm

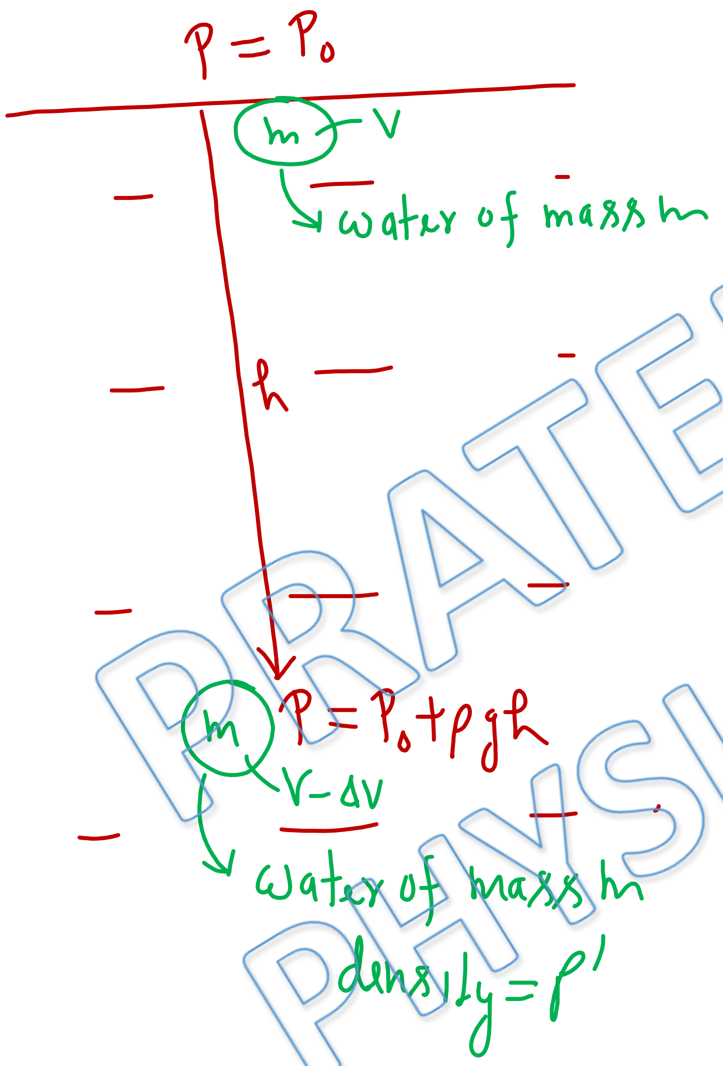
6)

On hanging load, length of spring wire increases $\Rightarrow$ longitudinal strain



Shear stress

7)



$$\rho = \frac{m}{V}$$

$$\frac{d\rho}{\rho} = -\frac{dV}{V}$$

$$B = -\frac{\Delta P}{\Delta V / V} = -\frac{\Delta P \rho}{\Delta \rho}$$

$$B = \frac{\rho g h \rho}{\Delta \rho}$$

$$\Delta \rho = \frac{\rho^2 g h}{B}$$

Ans (c)

8)

$$l = \frac{V}{\pi R^2} \Rightarrow \frac{\Delta l}{l} = \frac{\Delta V}{V} - 2\frac{\Delta R}{R} = \frac{2}{100} - \frac{2 \times 002}{100}$$

$$= \frac{.196}{100} = 1.96 \times 10^{-3}$$

Longitudinal stress $= Y\frac{\Delta l}{l} = 2 \times 10^{11} \times 1.96 \times 10^{-3}$

$$= 3.92 \times 10^{8} \ N/m^2$$

Ans (d)

9)

Increment in volume of liqud = increment in capacity of vessel

$$\Rightarrow \quad V \gamma \Delta T = V(3\alpha)\Delta T$$

$$\Rightarrow \gamma = 3\alpha$$

Ans(d)

10) for sphere $V = \frac{4}{3}\pi R^3 \Rightarrow \frac{\Delta V}{V} = \frac{3\Delta R}{R}$ (for small change)

Change in pressure $= \frac{mg}{A}$

Bulk Modulus $K = -\frac{\Delta P}{\Delta V/V} = \frac{mg}{A \times \frac{3\Delta R}{R}}$

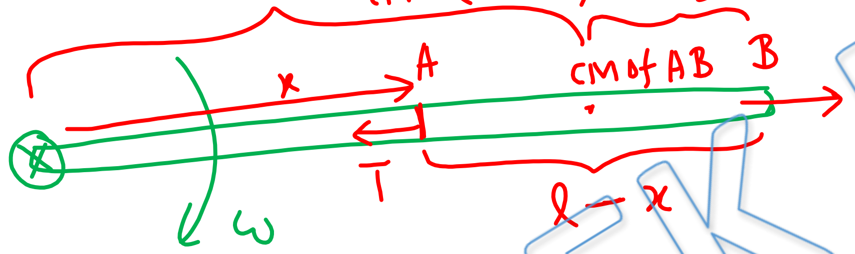
$\Rightarrow \frac{\Delta R}{R} = \frac{mg}{3AK}$

Ans (b)

11)

length of Rod = l

$r_{CM} = \left(l - \frac{l-x}{2}\right)$



mass of AB $= \frac{m}{l}(l-x)$

$r_{CM} = l - \frac{l-x}{2} = \frac{l+x}{2}$

at $x = x$

T = Centrifugal force on AB

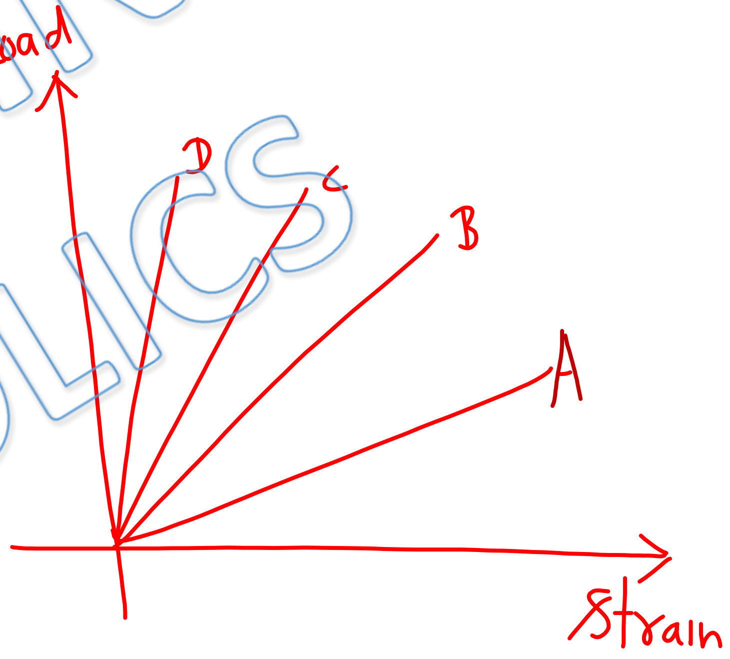
$$T = \underbrace{m_{AB} r_{CM} \omega^2}_{\text{formula}} = \left[\frac{m}{l}(l-x)\right]\left(\frac{l+x}{2}\right)\omega^2 = \frac{m(l^2-x^2)\omega^2}{2l}$$

$$\Rightarrow \text{stress} = \frac{T}{A} = \frac{m\omega^2}{2Al}(l^2-x^2) \rightarrow$$ Parabolically decreasing on increasing x

Ans (a)

12)

$$Y = \frac{\text{stress}}{\text{strain}} \Rightarrow Y = \frac{\text{Load}}{A \times \text{strain}}$$



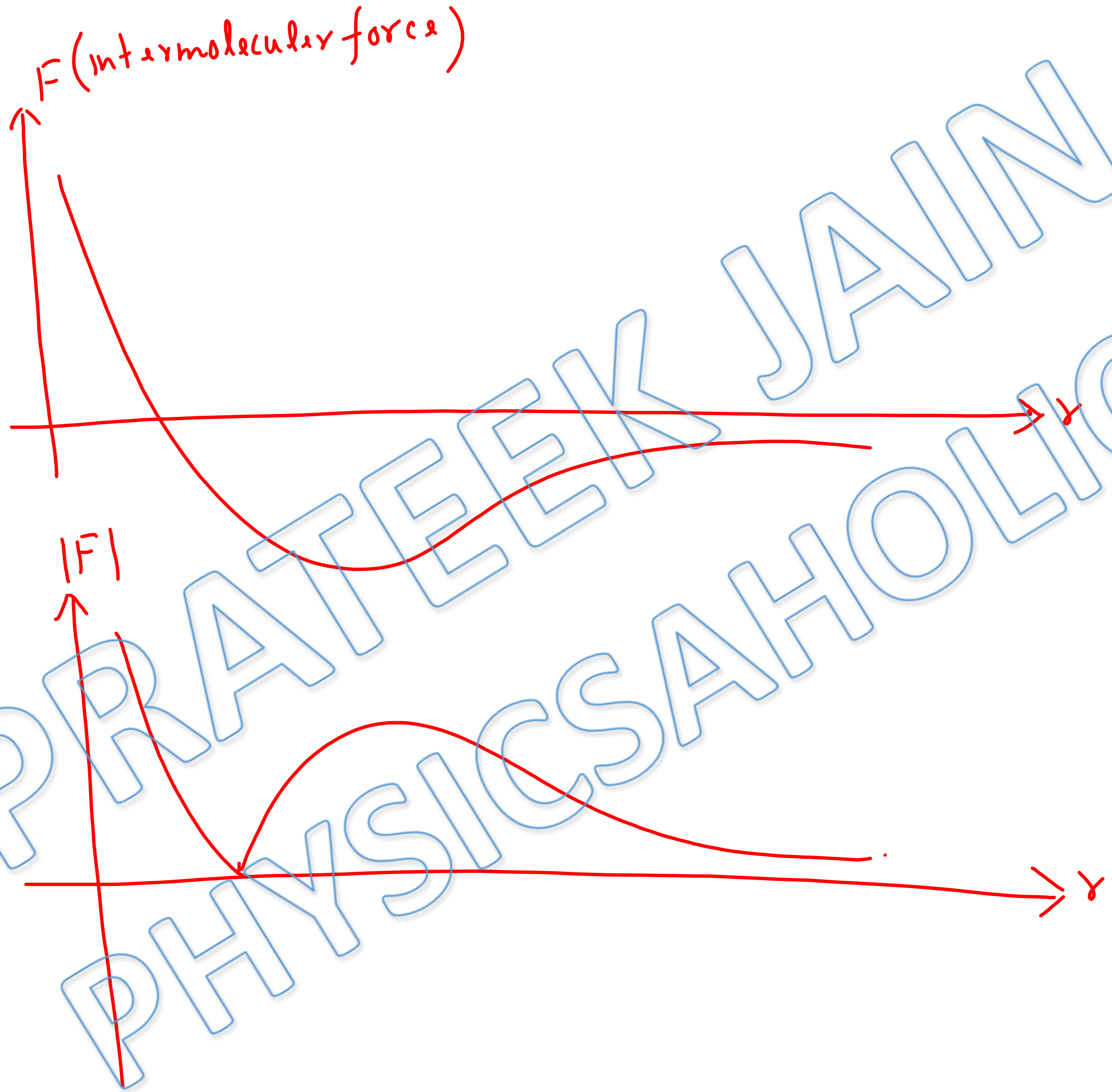
$$\text{Slope} = \frac{\text{Load}}{\text{strain}} = YA$$

$$\Rightarrow \quad A \propto \text{slope}$$

$\Rightarrow$ OD is thickest

ANS(c)

13)



Ans (c)

14)

$$\Delta Q = \underbrace{m_1 s_1 \Delta T_1}_{\text{water}} = \underbrace{m_2 s_2 \Delta T_2}_{\text{alcohol}}$$

$$\Rightarrow \quad m s \times 25 = m \frac{s}{2} \Delta T_2$$

$$\Delta T_2 = 50^\circ C$$

Ans (c)

15)

Heat supplied by block = Heat absorbed by ice

$\Rightarrow$ $2500 \times .1 \times [500 - 0^\circ] = m \times 80$

$\Rightarrow$ $m = \frac{2500 \times 5\cancel{0}}{8\cancel{0}}$

$= 1562.5\ Kg$

$\simeq 1.5\ Kg$

Ans (b)

16)

Heat supplied to ice $= mL_f + ms\Delta T + mL_v$

$= 10 \times 80 + 10 \times 1 \times 100 + 10 \times 540$

$= 7200$

Heat supplied to calorimeter $= 10 \times 1 \times 100$

$= 1000$ Cal

Total heat supplied $= 8200$ Cal

Ans(d)

17)

Heat supplied to water per second $= \frac{200\cancel{0} \times 8\cancel{0}}{1\cancel{00}} = 1600\ J$

mass Rate of flow $= 100\ g/sec$ (for water $1cc \equiv 1gram$)

$$\frac{\Delta Q}{\Delta t} = \frac{\Delta m}{\Delta t} S\, \Delta T$$

$$16\cancel{00} = 1\cancel{00} \times 4.2\ \Delta T$$

$$\Delta T = \frac{16}{4.2}\ ^\circ C \simeq 3.8^\circ C$$

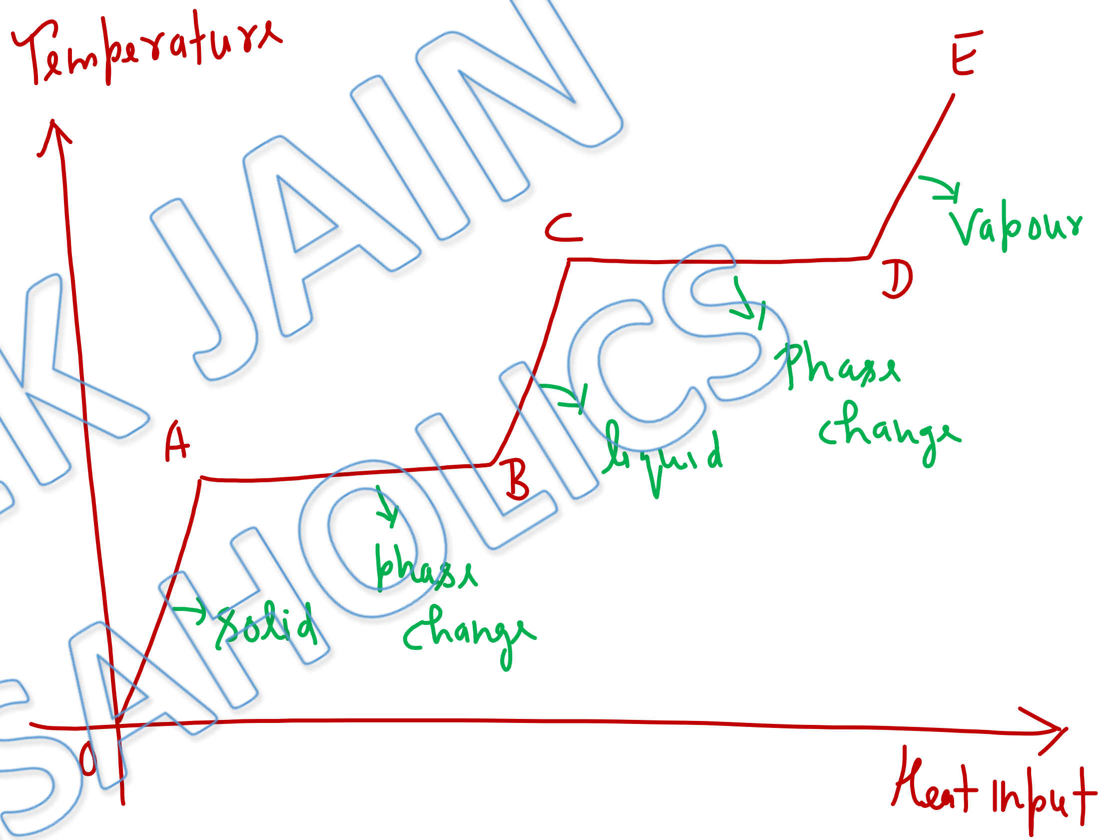
Outlet temperature $= 10 + \Delta T = 13.8^\circ C$

18)

Slope of DE

$$= \frac{dT}{dQ} = \frac{dT}{C\,dT}$$

$$= \frac{1}{\text{Heat Capacity of Vapour}}$$



Ans(d)

19) Initial PE = Latent heat

$$mgh = \frac{m}{5} L$$

$$\Rightarrow \quad h = \frac{L}{5g}$$

Ans (A)

20)

$$s = aT^3$$

$$dQ = ms\,dT$$

$$\Rightarrow \int dQ = \int_1^2 aT^3\,dT$$

$$\Rightarrow Q = \frac{a}{4}\left[T^4\right]_1^2$$

$$= \frac{15a}{4}$$

Ans (b)

21)

Heat supplied for vapourisation = Rate × time = $42 \frac{KJ}{min} \times 10 \, min$

$= 420 \, KJ$

$\Delta Q = mL$

$\Rightarrow 420 \, KJ = 5 \, L$

$\Rightarrow L = 84 \, KJ/kg$

Ans (c)

22)

$$C = m_1 s_1 = m_2 s_2$$

$$\Rightarrow V_1 \rho_1 s_1 = V_2 \rho_2 s_2$$

$$\Rightarrow \overset{2}{\cancel{8}} \times 15\cancel{00} \times s_A = \overset{3}{\cancel{12}} \times 20\cancel{00} \times s_B$$

$$\Rightarrow \frac{s_A}{s_B} = \frac{\cancel{3} \times 20}{2 \times \underset{5}{\cancel{15}}}$$

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

V → Volume

ρ = density

Ans (d)

23)

Heat supplied by steam = Heat gained by (water + Calorimeter)

$\Rightarrow \quad m \times 540 + m \times 1 \times 20 = 1100 \times 1 (80^\circ - 15^\circ) + 20 \times 1 (80^\circ - 15^\circ)$

$\Rightarrow \quad 560m = 71500 + 1300$

$m = \dfrac{72800}{560} = 130 \text{ gram}$

$= .130 \text{ Kg}$

Ans (a)

24)

$$-\frac{\Delta T}{\Delta t} = bA(T - T_0)$$

$$\Rightarrow \quad \frac{10^\circ C}{4\,min} = bA\left(\frac{60+50}{2} - T_0\right)$$

$$\& \quad \frac{10^\circ C}{8\,min} = bA\left(\frac{40+30}{2} - T_0\right)$$

$$\Rightarrow \quad 2 = \frac{55 - T_0}{35 - T_0} \Rightarrow 55 - T_0 = 70 - 2T_0$$

$$\Rightarrow \quad T_0 = 15^\circ C$$

Ans(b)

25) Temperature is Constant at 50 c

$\Rightarrow$ Rate of heat supplied by heater = Rate of radiation at 50 c

$$\Rightarrow \quad 10 = e\sigma A\left[(323)^4 - (293)^4\right]$$

at 35°c

Heat loss by radiation = loss in internal energy

$$\Rightarrow 60 \times e\sigma A\left[(308)^4 - (293)^4\right] = C \times (35.1 - 34.9)$$

$$\Rightarrow 600 \times \frac{(308)^4 - (293)^4}{(323)^4 - (293)^4} = C \times .2$$

$$\Rightarrow C = 3000 \times \frac{(308)^4 - (293)^4}{(323)^4 - (293)^4}$$

$$= 1500 /°c$$

26)

$$\Delta V = V_0 \gamma \Delta T$$

$$= \frac{4}{3}\pi R^3 \times 3\alpha \Delta T$$

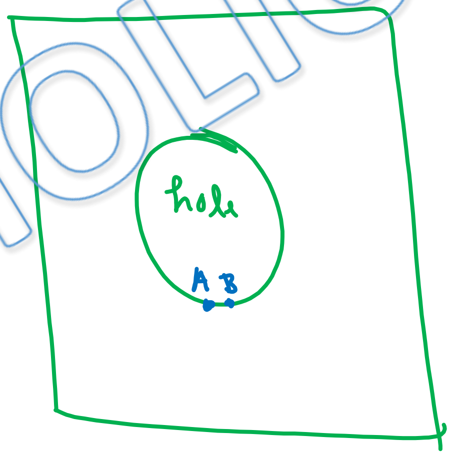
$$= 4\pi \alpha R^3 \Delta T$$

Ans (c)

27) On increasing temperature, distance b/w adjescent particles always increases.

$\Rightarrow$ distance b/w A & B increases

$\Rightarrow$ Radius of hole increases



Ans(b)

28) On increasing temperature, natural length of rod increases

$\Rightarrow$ Since rod is in it's new natural length, deformation is zero

$\Rightarrow$ longitudinal strain $= 0$

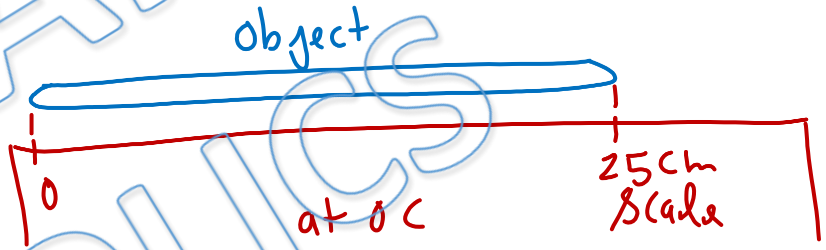
ANS (c)

29)

length of object

= actual distance b/w 0 & 25cm mark

< 25cm (Since scale is calibrated to work at 20°C)



ANS (B)

30)

$$\text{Thermal stress} = \underset{\uparrow}{B}\,\underset{\nearrow}{\gamma}\,\Delta T$$

Bulk Modulus

Coefficient of volume expansion

$$= 1.4 \times 10^{11} \times 3 \times 17 \times 10^{-5} \times 10$$

$$= 7.14 \times 10^{7}\ Pa$$

Ans (b)

31)

$$\frac{\Delta l}{l} = \alpha \Delta T = 1\%$$

$$\frac{\Delta A}{A} = \beta \Delta T = 2\alpha \Delta T = 2\%$$

Ans (b)

32)

Natural length after increasing temp $= l(1+\alpha t)$

length " " " $= l$

$\Rightarrow$ strain $= \dfrac{l\alpha t}{l(1+\alpha t)} = \dfrac{\alpha t}{1+\alpha t}$

$\Rightarrow$ stress $= E\,(\text{strain}) = \dfrac{E\alpha t}{1+\alpha t}$

$\Rightarrow$ force $= \dfrac{EA\alpha t}{1+\alpha t}$

Ans (b)

33)

$$\alpha_x = 1 \times 10^{-5} /°C$$
$$\alpha_y = 2 \times 10^{-5} /°C$$
$$\alpha_z = 3 \times 10^{-5} /°C$$

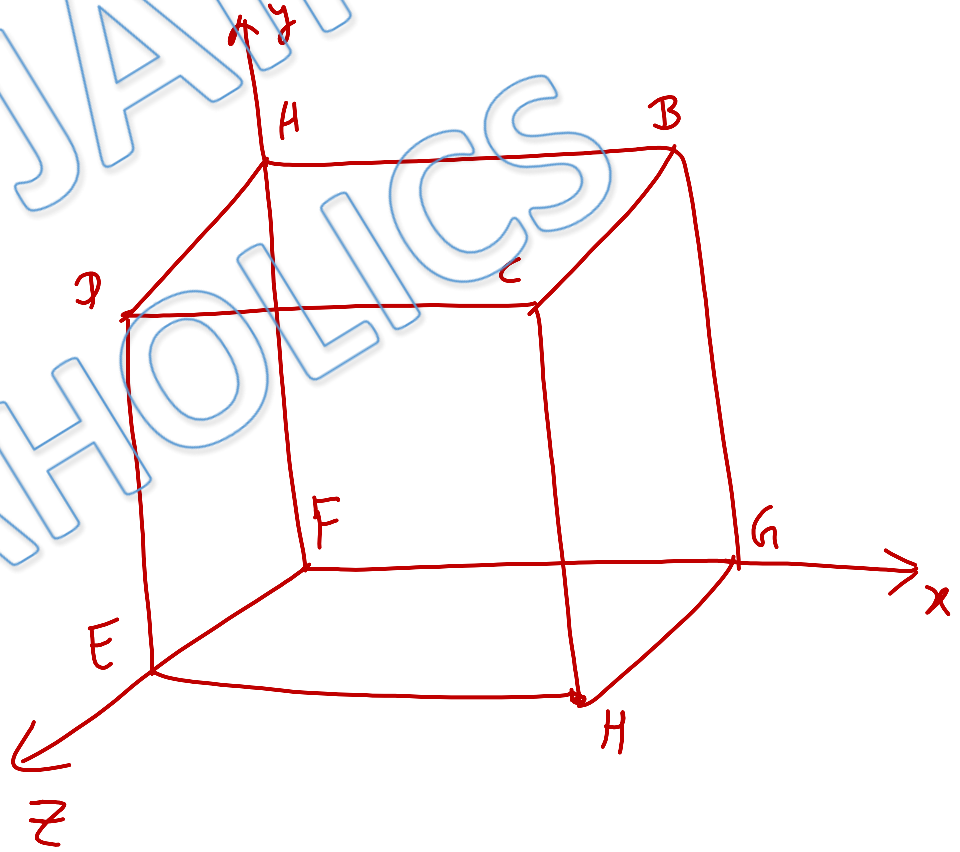
$$\beta = \alpha_1 + \alpha_2$$

$$\beta_{ABCD} = \alpha_x + \alpha_z = 4 \times 10^{-5} /°C$$

$$\beta_{BCGH} = \alpha_y + \alpha_z = 5 \times 10^{-5} /°C$$

$$\beta_{CDEH} = \alpha_x + \alpha_y = 3 \times 10^{-5} /°C$$

$$\beta_{EFGH} = \alpha_x + \alpha_z = 4 \times 10^{-5} /°C$$



Ans (c)

34) Apparent Coefficient of volume expansion $= \gamma_l - \gamma_s$

$$\Rightarrow \quad C = \gamma_l - \gamma_c$$

$$S = \gamma_l - \gamma_s$$

$$C - S = \gamma_s - \gamma_c$$

$$\gamma_s = C - S + \gamma_c$$

$$\alpha_s = \frac{\gamma_s}{3} = \frac{C - S + \gamma_c}{3}$$

Ans (c)

35) Pressure at bottom of each Column must be same

$$\Rightarrow \quad \rho_1 g l_1 = \rho_2 g l_2$$

$$\Rightarrow \quad \frac{\rho_0 l_1}{1+\gamma t_1} = \frac{\rho_0 l_2}{1+\gamma t_2}$$

$$\Rightarrow \quad l_1 + l_1 \gamma t_2 = l_2 + l_2 \gamma t_1$$

$$\Rightarrow \quad l_1 - l_2 = \gamma (l_2 t_1 - l_1 t_2)$$

$$\Rightarrow \quad \gamma = \frac{l_1 - l_2}{l_2 t_1 - l_1 t_2}$$

36)

$$P = \frac{m}{A}$$

$m \rightarrow$ mass of liquid

$A \rightarrow$ base Area of vessel

% change in P = % change in m − % change in A

$$= 0 - \frac{\Delta A}{A} \times 100$$

$$= -\frac{\cancel{A}\beta\Delta T}{\cancel{A}} \times 100$$

$$= -2\alpha\Delta T \times 100 = -2 \times 10^{-3} \times 10 \times 100$$

$$= -2$$

$\Rightarrow$ Pressure decreases by 2%

ANS (C)

37) On heating Capacity of vessel increases

$\Rightarrow$ It can contain more volume of oil

Since $\gamma_g = \gamma_l$

$\Rightarrow$ Capacity & volume of oil increases by same amount

$\Rightarrow$ same mass of oil will still fill the vessel

Ans(d)

38)

by <u>using definition</u>

a → Conduction

b → Convection

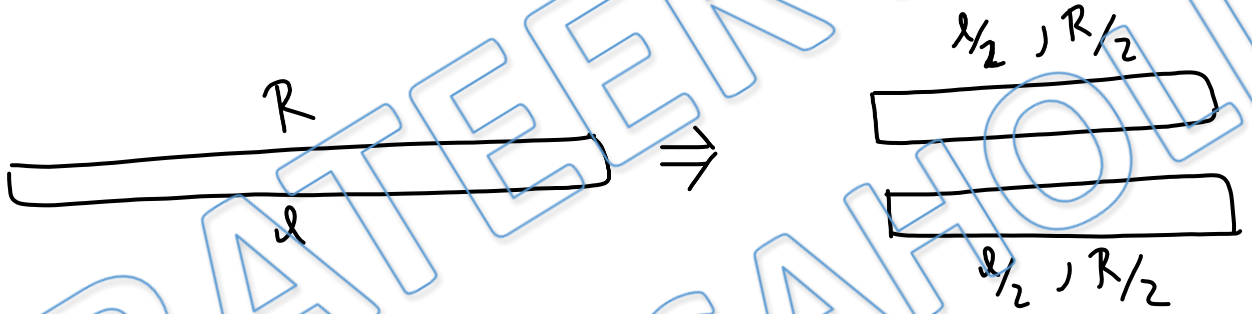
c → radiation

Ans(a)

39)

$$\frac{\Delta Q}{\Delta t} = \frac{\Delta T}{R} \Rightarrow \Delta t = \frac{\Delta Q \, R}{\Delta T}$$

Thermal Resistance



Rods are in parallel

Effective Resistance $= R/4$

Since $\Delta t \propto R$.

new time is one fourth of previous one

Ans(b)

40)

$$\frac{\Delta Q}{\Delta t} = \frac{KA\,\Delta T}{l}$$

$$\Rightarrow \frac{L\,\Delta m}{\Delta t} = \frac{KA\,\Delta T}{l}$$

$$\Rightarrow \frac{\Delta m}{\Delta t} = \frac{KA\,\Delta T}{lL} = \frac{235 \times \pi (2\times10^{-2})^2 \times 20}{2.35 \times \frac{10}{3} \times 10^5}$$

$$= \frac{2000\pi \times 4 \times 10^{-4} \times 3}{10^6}$$

$$= 24\pi \times 10^{-6}\ \mathrm{Kg/Sec}$$

41)

Thermal Current $I = \frac{-KA\,\Delta T}{\Delta x}$

Slope of graph $= \frac{\Delta T}{\Delta x} = -\frac{I}{KA}$

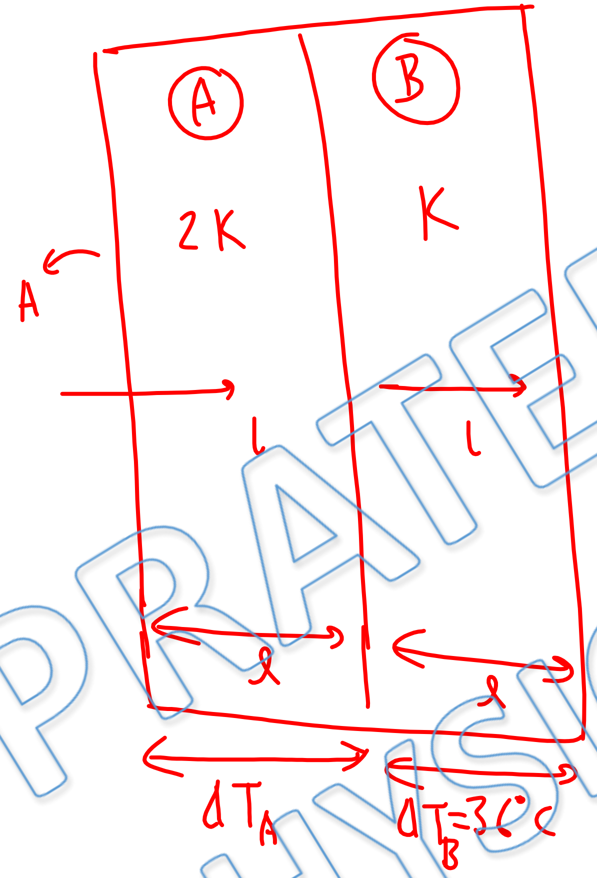
$\Rightarrow |\text{Slope}| = \frac{I}{KA}$

Since K is lower for air

|Slope| should be high in air

Ans(d)

42)

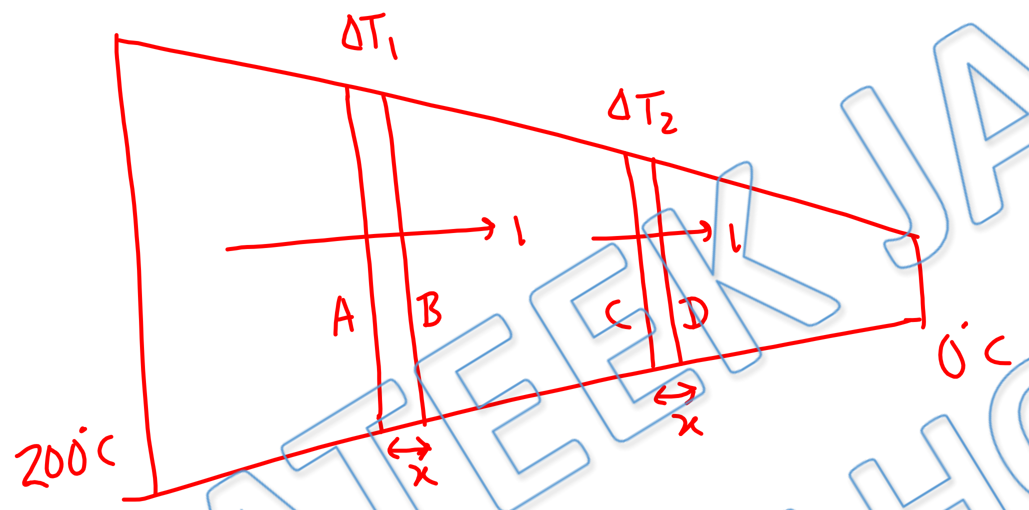


$$I = \frac{2KA\,\Delta T_A}{l} = \frac{KA\,\Delta T_B}{l}$$

$$\Rightarrow \Delta T_A = \frac{\Delta T_B}{2} = \frac{36^\circ}{2} = 18^\circ C$$

ANS(c)

43)



$$I = \frac{K A_1 \Delta T_1}{x} = \frac{K A_2 \Delta T_2}{x}$$

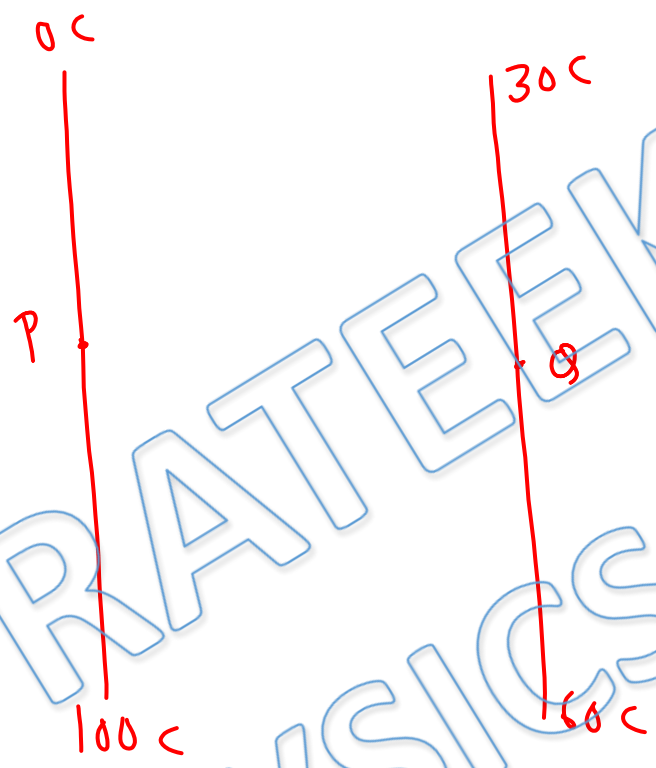
$$\Rightarrow A_1 \Delta T_1 = A_2 \Delta T_2$$

Since $A_1 > A_2$

$$\Rightarrow \Delta T_1 < \Delta T_2$$

Ans (c)

44)



If there is no rod b/w P & Q.

$$T_p = \frac{0+100^\circ}{2} = 50^\circ c$$

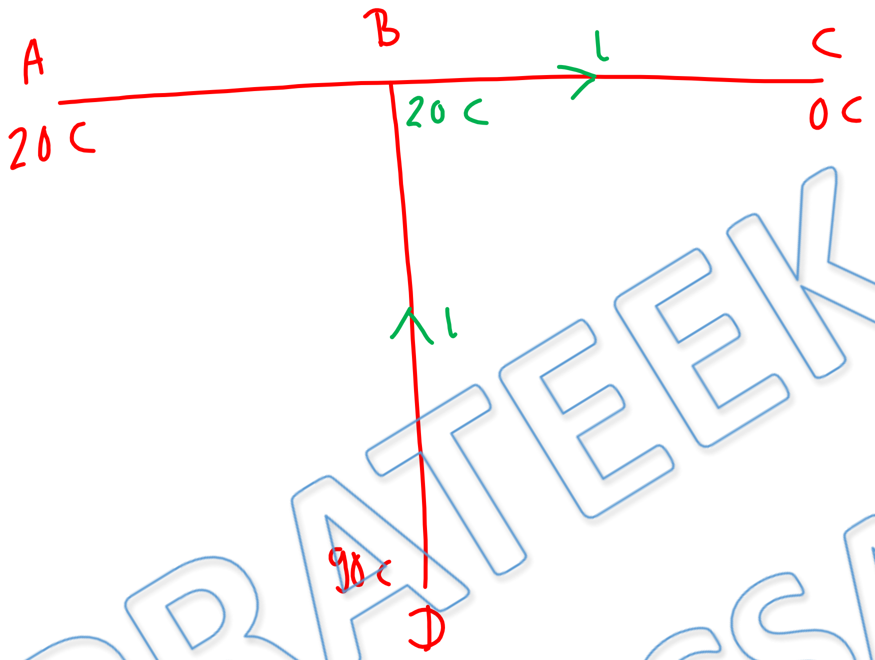
$$T_Q = \frac{30+60^\circ}{2} = 45^\circ c$$

If there is a rod b/w P & Q,

Heat will flow from P to Q

Ans(a)

45)



no thermal Current in AB

$\Rightarrow T_B = 20\,C$

$$l = \frac{KA(90-20)}{(BD)} = \frac{KA(20-0)}{(BC)}$$

$$\Rightarrow \frac{70}{BD} = \frac{20}{BC}$$

$$\Rightarrow \frac{BD}{BC} = 7/2$$

ANS(b)

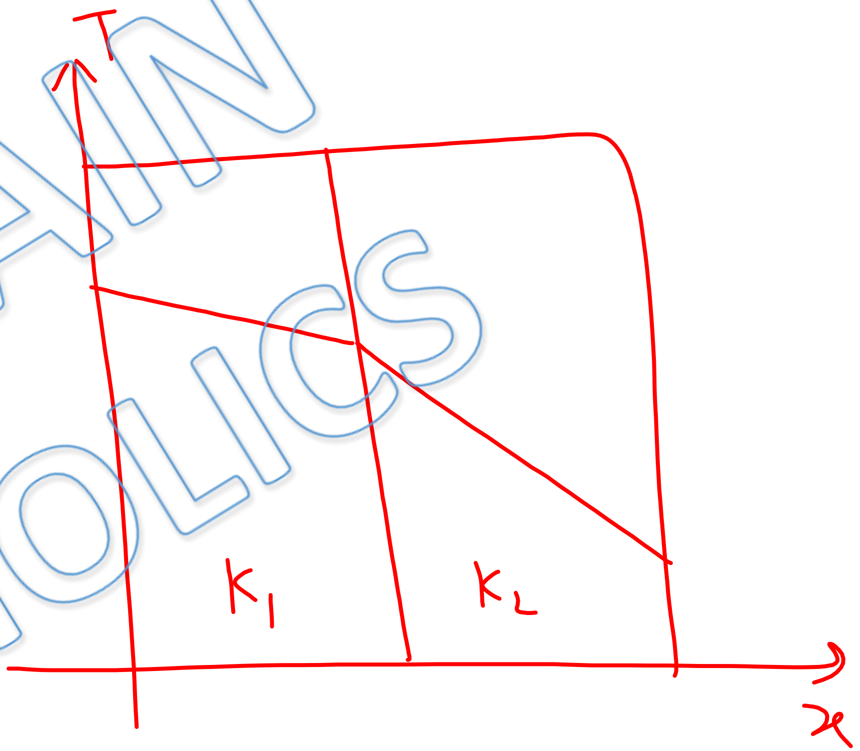
46)

$$I = \frac{-KA\,dT}{dx}$$

$$\Rightarrow \quad |\text{Slope}| = \left|-\frac{dT}{dx}\right| = \frac{I\,dx}{KA}$$

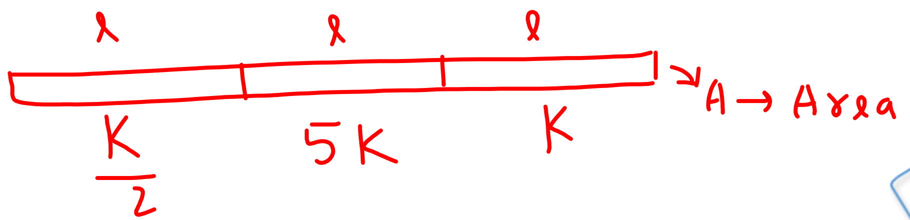
|Slope| is higher for Second slab

$\Rightarrow$ K is higher for first Slab



Ans (a)

47)



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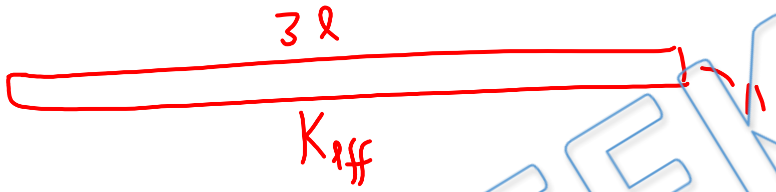


$$R = R_1 + R_2 + R_3$$

$$\Rightarrow \frac{3l}{K_{eff}A} = \frac{2l}{KA} + \frac{l}{5KA} + \frac{l}{KA} = \frac{10l + l + 5l}{5KA}$$

$$\Rightarrow \frac{3\cancel{l}}{K_{eff}\cancel{A}} = \frac{16\cancel{l}}{5K\cancel{A}} \Rightarrow K_{eff} = \frac{15K}{16}$$

Ans (a)

48)

Power radiated by sphere $= e\sigma\, 4\pi R^2 T^4$

Intensity at foil $= \dfrac{e\sigma\, 4\pi R^2 T^4}{4\pi d^2}$

Power received by foil $= \dfrac{e\sigma R^2 T^4}{d^2} A$ ($\perp$ Area of foil)

$P \propto \dfrac{T^4}{d^2}$

On increasing both T & d to 2 times

Power increases to 4 times

ANS (b)

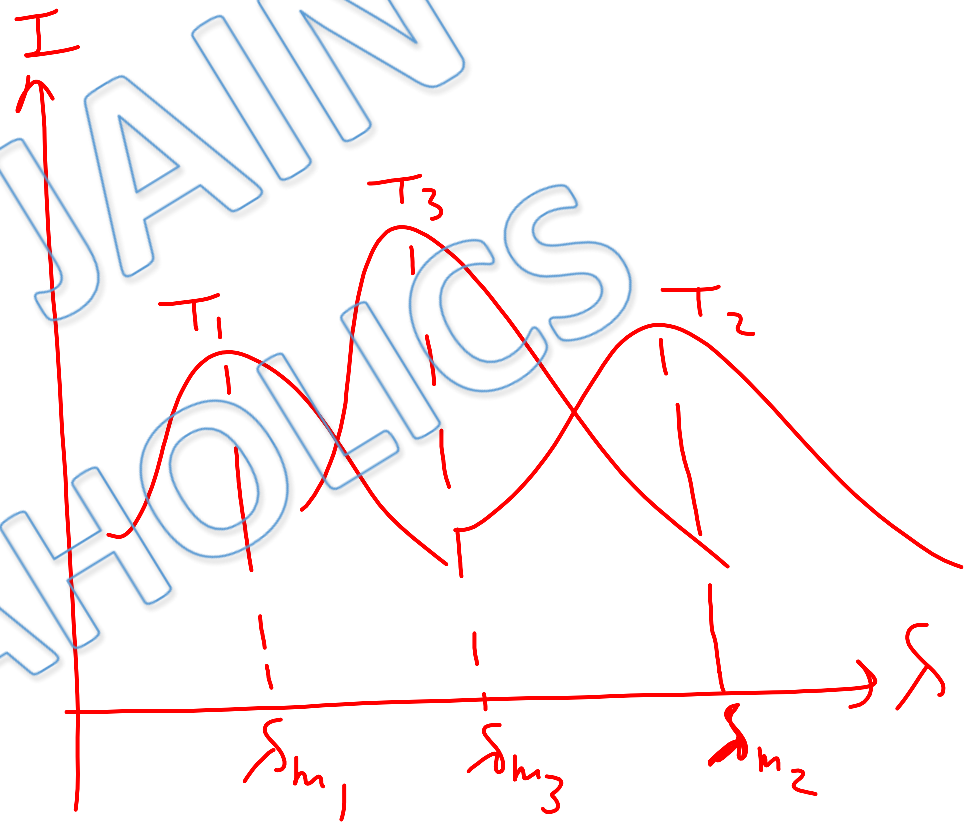
49)

$\lambda_m T = \text{Constant}$

$\lambda_{m_1} < \lambda_{m_3} < \lambda_{m_2}$

$\Rightarrow \quad T_1 > T_3 > T_2$

ANS (b)



50)

$T_1 = 273^\circ C = 546\ K$

$T_2 = 0\ C = 273\ K$

$T_2 = T_1/2$

$E \propto T^4$

Since temperature is reduced to half

E reduces to $E/16$

Ans (a)

51)

$$\lambda_m T = \text{Constant}$$

$$\Rightarrow \quad \lambda_0 T_0 = \frac{3\lambda_0}{4} T_1$$

$$\Rightarrow \quad T_1 = \frac{4T_0}{3}$$

now $\quad U = e\sigma A T^4$

$\Rightarrow$ U increases to $\left(\frac{4}{3}\right)^4$ times

$\Rightarrow$ " " " $\frac{256}{81}$ times

ANS(d)

52) $$-\frac{\Delta T}{\Delta t} = KA\left(T - T_0\right)$$

$$\Rightarrow \frac{50-40}{5} = KA\left(\frac{50+40}{2} - 20\right) \Rightarrow 2 = KA \times 25 \Rightarrow KA = \frac{2}{25}$$

Let temperature after 5 min is T

$$\Rightarrow \frac{40-T}{5} = KA\left(\frac{40+T}{2} - 20\right)$$

$$\Rightarrow \frac{40-T}{5} = \frac{2}{25}\left(\frac{T}{2}\right)$$

$$\Rightarrow 200 - 5T = T \Rightarrow 6T = 200$$

$$\Rightarrow T = \frac{100}{3}\,^{\circ}C$$

ANS(b)

53)

$$-\frac{dQ}{dt} = e\sigma A\left(T^4 - T_0^4\right)$$

$$\Rightarrow -ms\frac{dT}{dt} = e\sigma 4\pi R^2\left(T^4 - T_0^4\right)$$

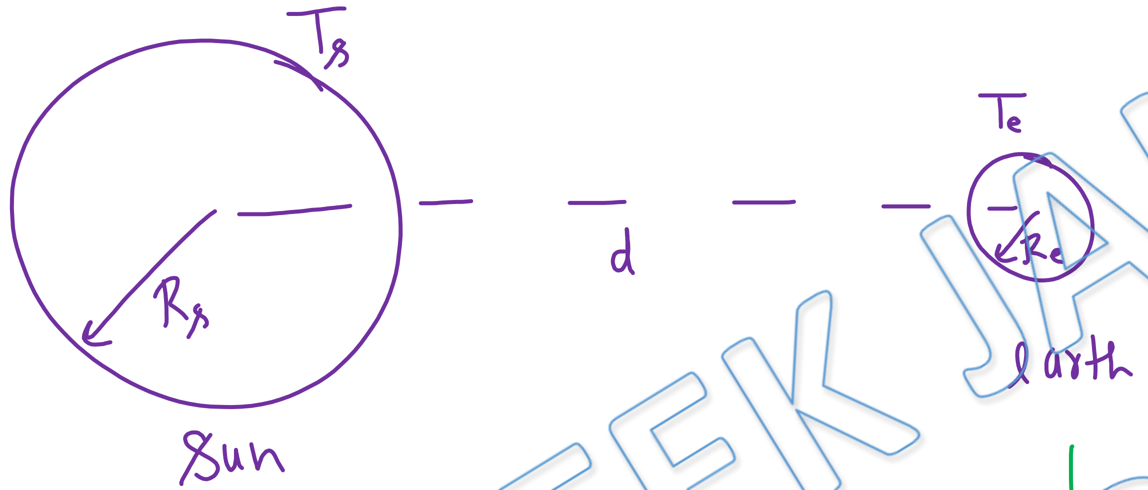
$$\Rightarrow -\frac{dT}{dt} = \frac{e\sigma 4\pi R^2}{\rho \times s \times \frac{4}{3}\pi R^3}\left(T^4 - T_0^4\right)$$

density

$$\Rightarrow -\frac{dT}{dt} \propto \frac{1}{R}$$

ANS(c)

54)



Power emitted by sun $= \sigma 4\pi R_s^2 T_s^4$

Intensity at earth surface $= \dfrac{\sigma 4\pi R_s^2 T_s^4}{4\pi d^2}$

Power incident on earth $= \dfrac{\sigma R_s^2 T_s^4}{d^2} \times \pi R_e^2$

" Radiated by earth $= \sigma 4\pi R_e^2 T_e^4$

$$\frac{\sigma R_s^2 T_s^4 \pi R_e^2}{d^2} = \sigma 4\pi R_e^2 T_e^4$$

$$T_e^4 = \frac{R_s^2 T_s^4}{4 d^2}$$

$$T_e = T_s \sqrt{\frac{R_s}{2d}}$$

$$= 6000 \sqrt{\frac{7\times10^8}{2\times1.5\times10^{11}}}$$

$$= 290K$$

ANS(a)

55)

$$P = e\sigma A T^4$$

$$\Rightarrow 100 = 7 \times 5.67 \times 10^{-8} \times 2\pi \times 4 \times 10^{-5} \times 6\, T^4$$

$$\Rightarrow T^4 = \frac{100}{.7 \times 5.67 \times 2\pi \times 4 \times 6 \times 10^{-13}}$$

$$\Rightarrow T^4 = \frac{10^{15}}{60} = \frac{10^{16}}{600}$$

$$\Rightarrow T = 2018\, K$$

56)

Air is bad Conductor of heat

Air b/w thin blankets reduces heat transfer

Ans(c)

57)

$$P = e\sigma A T^4 = 4\pi e\sigma R^2 T^4$$

$$\frac{P_1}{P_2} = \left(\frac{e_1}{e_2}\right)\left(\frac{R_1}{R_2}\right)^2\left(\frac{T_1}{T_2}\right)^4$$

$$= \left(\frac{.6}{.8}\right)\left(\frac{2}{4}\right)^2\left(\frac{300}{400}\right)^4$$

$$= \frac{\cancel{6}^{\,3}}{\cancel{8}_{\,4}} \times \frac{1}{4} \times \frac{81}{256}$$

$$= \frac{243}{4096}$$

$$= .059$$

Ans (a)

58)

If $T_{object} = T_{body}$

$\Rightarrow$ There will be no heat transfer b/w body & object whatever be conductivity of object

Ans (a)

59)

All Cases have equal effective resistance

$\Rightarrow$,, ,, ,, ,, Thermal Current

Temperature difference across a

$= I R_A$

$=$ same in all Cases

Ans(b)

Chalo Niklo