DETAILS EXPLANATIONS

1. (A) Modulus of Resilience

$$U = \frac{\sigma^2}{2E}$$

$$E = \frac{fL}{\Delta l}$$

$$\therefore \quad U = \frac{f\Delta l}{2L} = \frac{200 \times 2.2}{2 \times 1.2 \times 10^3} = 0.18 \text{ units}$$

(B) Equivalent bending moment

$$= \frac{M + \sqrt{M^2 + T^2}}{2}$$

Equivalent-Torsion = $\sqrt{M^2 + T^2}$

(C) Slenderness Ratio, $\lambda = \frac{l}{r}$

where r = Radius of Gyration = $\sqrt{\frac{I}{A}} = \frac{d}{4}$

$$\Rightarrow \quad \frac{l}{d} = \frac{150}{4} = 37.5$$

(D) Bulk modulus $K = \frac{P}{\left(\frac{\Delta V}{V}\right)}$

$$\Delta V = \frac{1280 \times 7800}{1.33 \times 10^6} = 7.50 \text{ CC}$$

2. Let the diameter of solid shaft be d_s. Let the external and internal diameter of the hollow shaft be d_o and d_i respectively.

It is given that both the shafts are made of same material, have same weight and length and are subjected to equal torsional force.

$\therefore$ Weight of solid shaft = Weight of hollow shaft.

$$\Rightarrow \quad \gamma \frac{\pi}{4} d_s^2 L = \gamma \frac{\pi}{4}(d_0^2 - d_i^2)L$$

$$d_s^2 = d_o^2 - d_i^2$$

Now, we know that torsional stiffness is given as

$$K = \frac{T}{\theta}$$

$$K = \frac{GI_P}{L}$$

For same value of G and L

$$K = \frac{T}{\theta} \alpha I_P$$

$$\frac{K_{hollow}}{K_{solid}} = \frac{K_h}{K_s} = \frac{\frac{\pi}{32}(d_0^4 - d_i^4)}{\frac{\pi}{32}(d_s^4)}$$

$$\Rightarrow \qquad \frac{K_h}{K_s} = \frac{(d_0^2 + d_i^2)(d_o^2 - d_i^2)}{(d_o^2 - d_i^2)(d_o^2 - d_i^2)}$$

$$\Rightarrow \qquad \frac{K_h}{K_s} = \frac{d_o^2 + d_i^2}{d_o^2 - d_i^2}$$

Now, the quantity $\frac{d_o^2 + d_i^2}{d_o^2 - d_i^2}$ is always greater than '1'.

$\therefore \qquad K_h > K_S$

So, Torsional stiffness of hollow shaft will be more than solid shaft of equal weight and material.

3. ***(A) Air Pollution :*** If desire limit of constituent in air exceed their limit in air then we called air is polluted 'so' that affect the life of the biosphere.

Pollutants of Air are classified into:

(i) Primary Air Pollutants

(ii) Secondary Air Pollutants

Air Pollutant

→ Primary

→ Secondary

- SO_2, SO_3
- H_2SO_4

- CO, CO_2
- NO, NO_2
- Pb
- Hydrocarbons
- O_3
- Formaldehyde
- Peroxy Acetyl Nitrate(PAN)
- It is form with combination of primary air pollutant
- H_2S, H_2F, Ethyl and Methyl, Mercaptan

Effects of Air Pollution

(i) Particulates can reduces visibility and create smog.

(ii) Smog reduces the amount of sunlight.

(iii) Oxides such as Nitrogen dioxide (NO_2) and sulphur oxide create acids that lead to acid rain.

(iv) Excessive amount of lead can cause lead poisoning.

(v) Disease from Air pollutants are rising every year.

(vi) Effect respiratory system of human being.

(B) Main causes of water pollution

(i) By household waste

(ii) By industrial waste

(iii) By pesticide

(iv) By intensive farming

(v) By animal dung

(vi) By oil spill

(viii) By oil pollutor

(ix) By nuclear waste

(x) Volcanic actvities (ie sulphur, cold lava)

By sewage and liquid waste of households, agricultural land and factories are discharged into lakes and rivers and dumping of solid waste are main cause of water pollution.

Water pollution can be controlled by

1. Treatment of waste water is essential before being discharged.

2. Parameters like total solid, BOD, COD, nitrates & phosphates, oil and grease, toxic metals etc. to be considered for reduction in water.

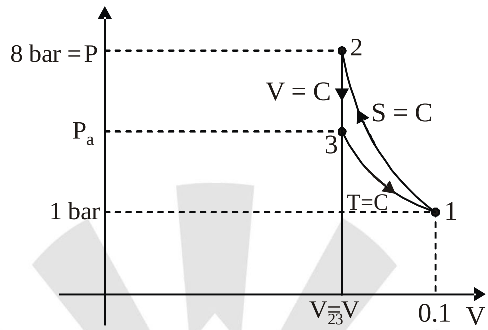
3. Waste water should be properly treated by primary and secondary treatments to reduce the BOD and COD levels.

4. Don't throw paints and oils in water channels

5. Take great care not to overuse pesticides and fertilizers.

4.

$$V_1 = 0.1\ m^3\ ,\ C_p = 14.3$$
$$T_1 = 300\ K\ ,\ C_v = 10.2$$
$$P_1 = 1\ bar$$
$$P_2 = 8\ bar$$



(i) $$\gamma = \frac{C_p}{C_v} = \frac{14.3}{10.2} = 1.4$$

$$R = C_p - C_v = 14.3 - 10.2 = 4.1$$

For process 1 - 2

$$T_2 = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \cdot T_1 = (8)^{\frac{0.4}{1.1}} \times 300$$

$$T_2 = 543.43\ K$$

For process 2 - 3, $$\frac{P_3}{P_2} = \frac{T_3}{T_2}$$

$$P_3 = 8 \times \frac{300}{543.43} = 4.416\ bar$$

(ii) For process 2 - 3

$$dU = mc_v\ dT$$

For calculating mass of gas

$$P_1V_1 = m\ R\ T_1$$

$$m = \frac{1.01325 \times 10^5 \times 0.1}{4.1 \times 10^3 \times 300} = 0.00823\ kg$$

Now $$\int_2^3 dU = m.C\int_2^3 dT$$

$$U_3 - U_2 = 0.00823 \times 10.2[T_3 - T_2]$$
$$= 0.084025\ [300 - 543.43]$$
$$U_3 - U_2 = -20.454 \text{ kJ}$$

(iii) $$\Sigma W = W_{1\text{-}2} + W_{2\text{-}3} + W_{3\text{-}1}$$
$$W_{1\text{-}2} = Q_{1\text{-}2} - (U_2 - U_1)$$

∵ Process 1 - 2 is isentropic

So, $Q_{1\text{-}2} = 0$

∴ $$W_{1\text{-}2} = -(U_2 - U_1) = -m\,C_v(T_2 - T_1)$$
$$= -0.00823 \times 10.2(543.43 - 300)$$
$$W_{1\text{-}2} = -\ 20.454 \text{ kJ}$$

Process 2 - 3

$$W_{2\text{-}3} = 0 \qquad \{\because dV = 0\}$$

Process 3 - 1

$$W_{3\text{-}1} = P_1V_1 \times \log\left(\frac{P_3}{P_1}\right) = 101.325 \times 0.1 \times \log\left(\frac{4.416}{1}\right) = 15.05 \text{ kJ}$$

So $$\Sigma W = -20.454 + 0 + 15.05$$
$$W_{net} = -5.4048 \text{ kJ}$$

And $$\Sigma Q = Q_{1\text{-}2} + Q_{2\text{-}3} + Q_{3\text{-}1}$$

For process 1 - 2,

$$Q_{2\text{-}3} = (U_3 - U_2) = -20.454$$

Process 3 - 1

$$Q_{3\text{-}1} = W_{3\text{-}1} = 15.05 \text{ kJ}$$

So $$\Sigma Q = 0 - 20.454 + 15.05$$
$$Q_{net} = -5.404 \text{ kJ}$$

Alternative

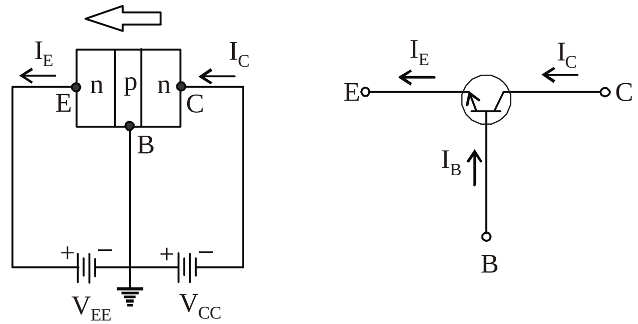
From Ist law of thermodynamics

$$\Sigma Q = \Sigma W$$

So $$Q_{net} = -5.404 \text{ kJ}$$

5. (i) Common-Base Configuration

Base is common to both the input and output sides of the configuration. To describe the behavior of a three-terminal device such as the common-base amplifiers of Fig. requires two sets of characteristics-one for the driving point or input parameters and the other for the output side.



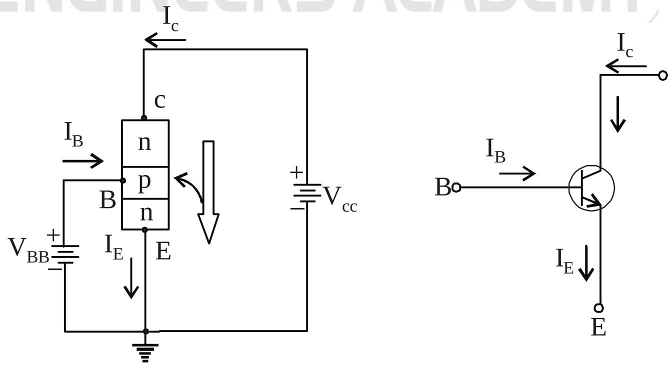
The input set for the common-base amplifier as shown in Fig. relates an input current (I_E) to an input voltage (V_{BE}) for various levels of output voltage (V_{CB}).

Alpha (α) : In the dc mode the levels of I_C and I_E due to the majority carriers are related by a quantity called alpha and defined by the following equation :

$$\alpha_{dc} = \frac{I_C}{I_E}$$

(ii) Common Emitter Configuration

The most frequently encountered transistor configuration appears in Fig. for the pnp and npn transistors. It is called the common emitter configuration because the emitter is common or reference to both the input and output terminals (in this case common to both the base and collector terminals). Two sets of characteristics are again necessary to describe fully the behavior of the common-emitter configuration: one for the input or base-emitter circuit and one for the output or collector emitter circuit.



Beta (β) : In the dc mode the levels of I_C and I_B are related by a quantity called beta and defined by the following equation :

$$\beta_{dc} = \frac{I_C}{I_B}$$

Relation between α and β

$$I_E = I_C + I_B$$

We have $$\frac{I_C}{\alpha} = I_C + \frac{I_C}{\beta}$$

and dividing both sides of the equation by I_C results in

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

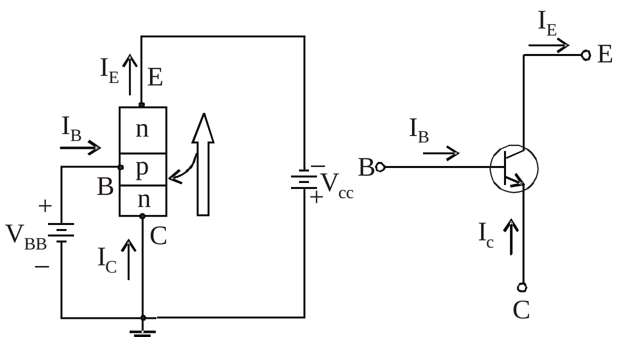
or $$\beta = \alpha\beta + \alpha = (\beta + 1)\alpha$$

So that $$\alpha = \frac{\beta}{\beta + 1}$$

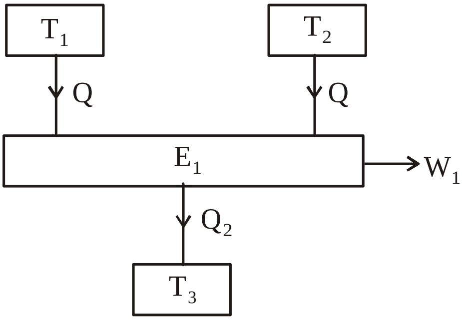
Or $$\beta = \frac{\alpha}{1 - \alpha}$$

(iii) Common-Collector Configuration

The common-collector configuration is shown in Fig. with the proper current directions and voltage notation. The common-collector configuration is used primarily for impedance matching purposes since it has a high input impedance and low output impedance, opposite to that of the common-base and common- emitter configuration.



6. ***Case 1 :***



$$\eta = 1 - \frac{Q_2}{2Q}$$

For reversible cycle,

$$\oint \frac{dQ}{T} = 0$$

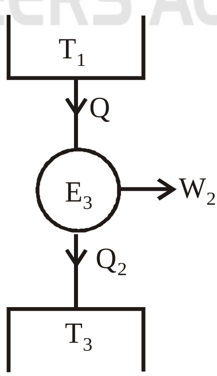
$$-\frac{Q}{T_1} - \frac{Q}{T_2} + \frac{Q_2}{T_3} = 0$$

$$Q\left[\frac{1}{T_1} + \frac{1}{T_2}\right] = \frac{Q_2}{T_3}$$

$$\frac{Q_2}{Q} = T_3\left[\frac{1}{T_1} + \frac{1}{T_2}\right] = \frac{T_3(T_1 + T_2)}{T_1 T_2}$$

$\therefore$ $$\eta_1 = 1 - \frac{T_3(T_1 + T_2)}{2T_1T_2}$$

Case 2 : $$\eta_{11} = 1 - \frac{Q_2}{Q} = 1 - \frac{T_3}{T_1}$$



Given that $\eta_1 = K\eta_{11}$

$$1-\frac{1}{2}\left(\frac{T_3(T_1+T_2)}{T_1T_2}\right) = K\left(1-\frac{T_3}{T_1}\right)$$

$$\frac{(2T_1T_2 - T_2T_3 - T_1T_3)}{2T_1T_2} = K\left(1-\frac{T_3}{T_1}\right)$$

$$K = \frac{(2T_1T_2 - T_2T_3 - T_1T_3)}{2T_2(T_1 - T_3)}$$

$$= \frac{\left(\frac{2T_1T_2}{T_2} - \frac{T_3T_2}{T_2} - \frac{T_3T_1}{T_2}\right)}{2(T_1 - T_3)} = \frac{\left(2T_1 - T_3 - \frac{T_1T_3}{T_2}\right)}{2(T_1 - T_3)}$$

$$K = \frac{1}{2(T_1 - T_3)} \times \frac{(2T_1T_2 - T_2T_3 - T_1T_3)}{T_2}$$

$$K = \frac{1}{2(T_1 - T_3)} \times \frac{T_1}{T_1T_2} \times [T_1T_2 + T_1T_2 - T_2T_3 - T_1T_3]$$

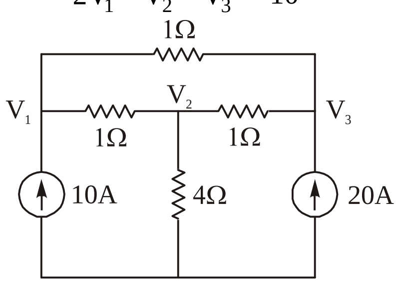
$$K = \frac{\frac{1T_1}{2T_2} \times [(T_2 - T_3)T_1 - (T_1 - T_3)T_2]}{T_1(T_1 - T_3)}$$

$$K = \frac{1}{2}\left[\left(\frac{T_2 - T_3}{T_1 - T_3}\right) + \left(\frac{T_2}{T_1}\right)\right] \times \frac{T_1}{T_2}$$

7. **(A)** KCL at node 1

$$\frac{V_1 - V_2}{1} + \frac{V_1 - V_3}{1} = 10$$

$$2V_1 - V_2 - V_3 = 10 \quad \text{...(1)}$$



KCL at node 2

$$\frac{V_2 - V_1}{1} + \frac{V_2 - V_3}{1} + \frac{V_2}{4} = 0$$

$$4V_2 - 4V_1 + 4V_2 - 4V_3 + V_2 = 0$$

$$-4V_1 + 9V_2 - 4V_3 = 0 \quad ...(2)$$

KCL at node 3

$$\frac{V_3 - V_1}{1} + \frac{V_3 - V_2}{1} = 20$$

$$-V_1 - V_2 + 2V_3 = 20 \quad ...(3)$$

From equation (1), (2) and (3)

$$V_1 = \frac{400}{3} = 133.33 \text{ V}$$

$$V_2 = 120 \text{ V}$$

$$V_3 = \frac{410}{3} = 136.66 \text{ V}$$

Voltage across 10 A source

$$V_1 = 133.33 \text{ V}$$

Voltage across 20 A source

$$V_3 = 136.66 \text{ V}$$

(B)

$$K = \frac{400}{500} = 0.8$$

$$\text{Rated output} = \frac{\text{Rating at a two-winding transformer}}{1 - K}$$

$$= \frac{2}{1 - 0.8} = 10 \text{ kVA}$$

Percentage impedance

= Percentage impedance of two-winding transformer × (1 – K)

= 5 × (1 – 0.8)% = 1%

8. ***Froude Model Law :*** Froude model law is the law in which the models are based on Froude number which means for dynamic similarity between the model and prototype, the Froude number for both of them should be equal. Froude model law is applicable when the gravity force is only predominant force which controls the flow in addition to the force of inertia. Froude model law is applied in the following fluid flow problems

1. Free surface flows such as flow over spillways, weirs, sluices, channels etc.
2. Flow of jet from an orifice or nozzle.
3. Where waves are likely to be formed on surface.
4. Where fluids of different densities flow over one another.

Let V_m= velocity of fluid in model

L_m= linear dimension or length of model

g_m= acceleration due to gravity at a place where model is tested and V_P, L_P and g_P are the corresponding values of the velocity, length and acceleration due to gravity for the prototype. Then according to Froude model law,

$$(Fe)\ \text{model} = (Fe)\ \text{prototype}$$

or
$$\frac{V_m}{\sqrt{g_m L_m}} = \frac{V_P}{\sqrt{g_P L_P}} \quad ....(i)$$

If the tests on the model are performed on the same place where prototype is to operate, then $g_m = g_P$ and equation (i) becomes as

$$\frac{V_m}{\sqrt{L_m}} = \frac{V_P}{\sqrt{L_P}} \quad ....(ii)$$

or
$$\frac{V_m}{V_P} \times \frac{1}{\sqrt{\frac{L_m}{L_P}}} = 1$$

$$\frac{V_P}{V_m} = \sqrt{\frac{L_P}{L_m}} = \sqrt{L_r} \quad \left[\because \frac{L_P}{L_m} = L_r\right]$$

Where, L_r = scale ratio for length

$$\frac{V_P}{V_m} = V_r = \text{scale ratio for velocity}$$

$$\frac{V_P}{V_m} = V_r = \sqrt{L_r} \quad ....(iii)$$

Scale ratio for various physical quantities based on Froude model law are

(i) Scale ratio for time

$$\text{Time} = \frac{\text{Length}}{\text{Velocity}}$$

Then ratio of time for prototype and model is

$$T_r = \frac{T_P}{T_m} = \frac{\left(\frac{L}{V}\right)_P}{\left(\frac{L}{V}\right)_m} = \frac{\frac{L_P}{V_P}}{\frac{L_m}{V_m}} = \frac{L_P}{L_m} \times \frac{V_m}{V_P}$$

$$= \left(\frac{L_P}{L_m}\right) \times \left(\frac{1}{\frac{V_P}{V_m}}\right) = L_r \times \frac{1}{\sqrt{L_r}}$$

$$\left[\because \frac{V_P}{V_m} = \sqrt{L_r}\right]$$

$$= \sqrt{L_r} \qquad \text{....(iv)}$$

(ii) Scale ratio for acceleration :

$$\text{Acceleration} = \frac{V}{T}$$

$$\therefore \quad a_1 = \frac{a_P}{a_m} = \frac{\left(\frac{V}{T}\right)_P}{\left(\frac{V}{T}\right)_m} = \frac{V_P}{T_P} \times \frac{T_m}{V_m} = \frac{V_P}{V_m} \times \frac{T_m}{T_P}$$

$$= \sqrt{L_r} \times \frac{1}{\sqrt{L_r}} \qquad \left[\because \frac{V_P}{V_m} = \sqrt{L_r}, = \frac{T_P}{T_m} = \sqrt{L_r}\right] \quad \text{...(v)}$$

$$= 1$$

(iii) Scale ratio for discharge

$$Q = A \times V = L^2 \times \frac{L}{T} = \frac{L^3}{T}$$

$$\therefore \quad Q_r = \frac{Q_P}{Q_m} = \frac{\left(\frac{L^3}{T}\right)_P}{\left(\frac{L^3}{T}\right)_m} = \left(\frac{L_P}{L_P}\right)^3 \times \left(\frac{T_m}{T_P}\right)$$

$$= L_r^3 \times \frac{1}{\sqrt{L_r}} = L_r^{2.5} \qquad \text{....(vi)}$$

(iv) Scale ratio for force

As Force = Mass × Acceleration

$$= pL^3 \times \frac{V}{T} = pL^2 . \frac{L}{T} . V = pL^2 V^2$$

∴ Ratio for force,

$$F_r = \frac{F_P}{F_m} = \frac{\rho_P L_P^2 V_P^2}{\rho_m L_m^2 V_m^2} = \frac{\rho_P}{\rho_m} \times \left(\frac{L_P}{L_m}\right)^2 \times \left(\frac{V_P}{V_m}\right)^2$$

If the fluid used in model and prototype is same, then

$$\frac{\rho_P}{\rho_m} = 1 \text{ or } p_P = p_m$$

and hence

$$F_r = \left(\frac{L_P}{L_m}\right)^2 \times \left(\frac{V_P}{V_m}\right)^2 = L_r^2 \times \left(\sqrt{L_r}\right)^2 = L_r^2 L_r = L_r^3 \qquad ...(vii)$$

(v) Scale ratio for pressure intensity

As $$P = \frac{\text{Force}}{\text{Area}} = \frac{\rho L^2 V^2}{L^2} = \rho L^2$$

∴ Pressure ratio,

$$P_r = \frac{P_P}{P_m} = \frac{\rho_p V_P^2}{\rho_m V_m^2}$$

If fluid is same, then

$$\rho_p = \rho_m$$

$$\therefore \quad P_r = \frac{V_P^2}{V_m^2} = \left(\frac{V_P}{V_m}\right)^2 = L_r \qquad ...(viii)$$

(vi) Scale ratio for work, energy, torque, moment etc.

Torque = Force × Distance = F × L

$$\therefore \quad \text{Torque ratio, } T_r^* = \frac{T_p^*}{T_m^*} = \frac{(F \times L)_P}{(F \times L)_m}$$

$$= F_r \times L_r = L_r^3 \times L_r = L_r^4 \qquad ...(ix)$$

(vii) Scale ratio for Power

As Power = Work per unit time

$$P = \frac{F \times L}{T}$$

$$\therefore \text{ Power ratio, } \quad P_r = \frac{P_P}{P_m} = \frac{\dfrac{F_P \times L_P}{T_P}}{\dfrac{F_m \times L_m}{T_m}} = \frac{F_P}{F_m} \times \frac{L_P}{L_m} \times \frac{1}{\dfrac{T_P}{T_m}} \qquad \text{...(x)}$$

$$= F_r L_r \frac{1}{T_r} = L_r^3 Lr \frac{1}{\sqrt{L_r}} = L_r^{3.5}$$

9. Fire resisting property of stone :

In case of fire, disintegration of stone structure takes place due to the following reasons-

- Unequal co-efficient of thermal expansion of minerals forming the stone.
- Poor conductivity of heat : When fire breaks out the minerals near the face expand. Similarly, when the fire is extinguished, rapid cooling of minerals near the face takes place. Hence, the face disintegrates.
- At high temperature, sand and splinters expand. Limestone splits into calcium oxide (CaO) and CO_2. Hence, disintegration takes place.
- Sandstone resists fire better. Argillaceous materials, though poor in strength, are good at resisting fire.

Fire resisting property of bricks :

First class bricks moulded from good clay can stand exposure to fire for a considerable length of time. The properties of bricks which render them fire resistant are the size of bricks, the method of construction and the component of fire resistance material in brick i.e. clay. It has been well established that brick masonry construction is most suitable for safeguarding the structure against fire hazards.

Fire resisting property of timber :

Wood is burnt to ash if its thickness is less than 12 mm. Very thick and heavy timber sections resists fire well, as combustion helps forms charcoal in the outer layers and prevents fire from spreading to internal layers. If care is taken during construction to provide fire-stops for upward movements of hot air, structure made from timber can be easily saved from fires.

By applying fire retardant paints, fire resistance of wood can be further increased. Fire resistant paint consist of sodium or calcium sulphates, zinc chloride. Timber can not be made completely fireproof, it can be made fire resistant. Timber takes much longer to fail, giving us time to save it from fire hazard.

Fire resisting property of steel :

Steel although incombustile has a very low fire resistance value with the increase in temperature the co-efficient of elasticity of the metal falls appreciably rendering the structural members soft and free to expand. It has been noticed that unprotected steel when subjected to fire, causes the collapse of the structure. Hence in a fire resistant construction, structural steel members must be suitably protected by covering them with materials like brick, concrete etc.

10. **(A)** ***Working From Whole to Part :***

It is very essential to establish first a system control points and to fix them with higher precision. Minor control points can be establish by less precise methods and the details can be located using these minor control points. By using this method prevention of accumulation of errors can be done.

(B) ***Hypotenusal allowance***

$= 100 (\sec \theta - 1)$

$= 100 (\sec 10^{o} - 1)$

$= 1.54$ links

1 link $= 20$ cm $= 0.20$ m

$\therefore$ Hypotenusal allowance

$= 0.20 \times 1.54 = 0.3080$

$= 0.31$ m

(C) If the vertical circle verniers do not read zero when line of sight is horizontal, the vertical angles measured will be incorrect. The error is known as the Index-error and can be eliminated either by applying index-correction or by taking both face observations.

(D) With the right eye in postion at the eye-piece, sight the prism-mirror with the left eye. Swing the mirror untill the bubble appears to be evenly situated to the centreline.