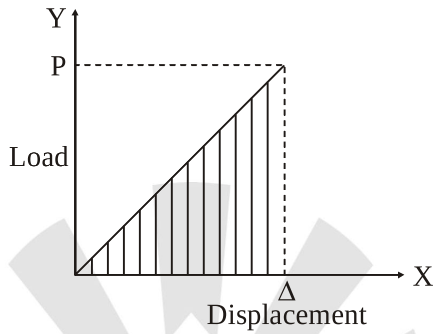
DETAILS EXPLANATIONS

1. **(a) Strain Energy :** It is the energy absorbed by any material of any shape/size, when the material is strained.

*** For gradually applied load**



Strain Energy

$$U = \text{Area under the curve}$$

$$U = \frac{1}{2} \times P \times \Delta$$

By Hooke's law,

$$\Delta = \frac{P \cdot l}{A \cdot E}$$

$$U = \frac{1}{2} \cdot P \cdot \frac{Pl}{AE}$$

$$U = \frac{P^2 l}{2AE}$$

(b) (i) Maximum principal stress theory (Rankine's Theory)

(ii) Maximum principal strain theory (St. Venant Theory)

(iii) Maximum shear stress-theory (Guest and Tresca Theory)

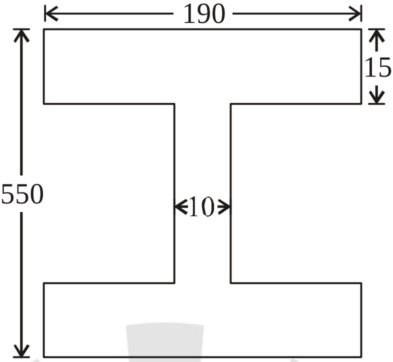
(iv) Maximum strain energy theory (Haigh's Theory)

(v) Maximum shear strain energy/distortion energy theory (Mises henky theory)

→ Above all these theories most safe results are produced by Maximum shear strain energy theory.

→ For uni-axial loading all theories will give same results.

(c) (i) For the given beam



(all dimensions in mm)

Since the section is symmetric about both axes, So the Neutral-axis will pass through geometrical-center.

Moment of Inertia of the section.

$$I_{xx} = \frac{190\times 550^3}{12} - \frac{(190-10)\times 520^3}{12}$$

I_{xx} = 525150833.3 mm^4

Bending stress

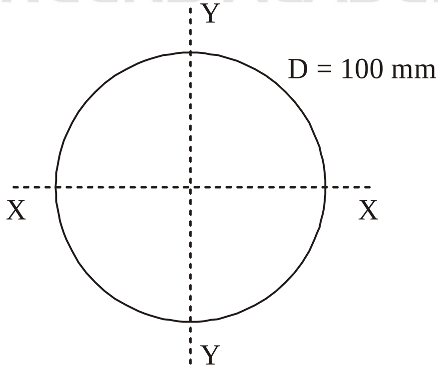
$$f = \frac{M}{I}\cdot y$$

So, $$M = \frac{f\cdot I}{y}$$

So, moment of Resistance of the Beam is

$$M = \frac{100\times 525150833.3\times 10^{-6}}{\left(\frac{550}{2}\right)} = 190.96 \text{ kN-m}$$

(ii)



Moment of Inertia $I_{xx} = \frac{\pi}{64} D^4$

$$I_{xx} = \frac{\pi}{64} \times (100)^4 = 4908738.52 \text{ mm}^4$$

Since bending stress

$$f = \frac{M}{I} \cdot y$$

So, moment of resistance

$$M = \frac{f \cdot I}{y} = \frac{100 \times 4908738.52}{\left(\frac{100}{2}\right)}$$

Given maximum stress

$$f = 100 \text{ N/mm}^2$$
$$M = 9.81 \text{ kN-m}$$

2. (a) Sir Abel's Process

This process is for fire-resistance of timbers. In this process, timber surface is cleaned and it is coated with a dilute solution of sodium silicate. A creme-like paste of slaked fat lime is then applied and finally, a concretrated solution of silicate of soda is applied on the timber surface.

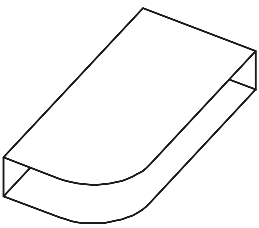
(b) Characterstics of Hollow Bricks

These are also known as cellular or cavity bricks. Such bricks have wall thickness of about 20 to 25 mm. They are prepared from special homogeneous clay. They are light in weight about one third the weight of the ordinary bricks of the same size. The use of such bricks leads to speedy construction. They also reduce the transmission of heat, sound and damp.

(c) Shape of Bricks :

1. Bullnose Brick:

A brick moulded with a rounded edge is termed as a bullnose. It is used for a rounded quoin.



Bullnose-Brick

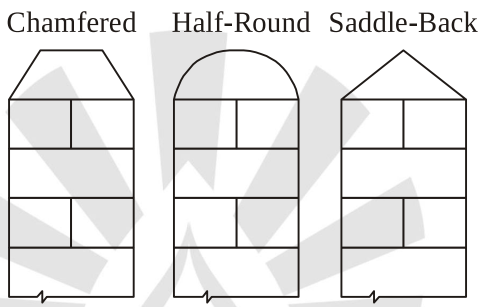
A connection which is formed when a wall takes a turn in known as quoin.

2. Channel Bricks

The bricks are moulded to the shape of a gutter or a channel and they are very often glazed. The bricks are used to function as drain.

3. Coping-Bricks

These bricks are made for suitable thickness of walls on which coping is to be provided.



Such bricks take various forms such as chamfered half-round or saddle back.

4. Cownose Bricks

A brick moulded with a double bullnose on end is known as cow-nose.

5. Curved Sector Bricks

These Bricks are in the form of curved sector and they are used in the construction of circular brick masonary pillars, brick chimneys.

The perforation may be circular, square, rectangular or any other regular shape in cross-section.

The water absorption after immersion for 24 hours in water should not exceed 15% by weight.

6. Hollow Bricks :

These are also known as cellular or cavity bricks. Such bricks have wall thickness of about 20-25 mm. They are prepared from special homogeneous clay. They are light in weight about one-third the weight of the ordinary bricks of the same-size.

7. Paving-Bricks : These Bricks are prepared from clay containing a higher percentage of iron. Such bricks resist better the abrasive action of traffic.

8. Perforated Bricks :

Perforated Bricks are used in the construction of brick panels for light weight structures and multi-storeyed framed structures.

3. (a) $\text{BOD} = (\text{BOD})_u[1-10^{-K_D \cdot t}]$

For 5 day $t = 5$ day

$$(\text{BOD})_5 = 0.68(\text{BOD})_u$$
$$(\text{BOD})_5 = 0.68 \times 250$$
$$(\text{BOD})_5 = 170 \text{ ppm}$$

(b) Assume 30% of BOD load removed in primary sedimentation i.e. $= 210 \times 0.30 = 63$ mg/lt

So, Remaining BOD = (210 – 63) = 147 mg/lt

Percent of BOD removal required

$$= (147 - 30) \times \frac{100}{147} = 80\%$$

BOD load applied to the filter

$$= \text{flow} \times \text{concent of sewage (kg/day)}$$

$$= 6 \times 106 \times \frac{147}{10^6}$$

$$= 882 \text{ kg/day}$$

To find out filter volume, using NRC equation.

$$E_2 = \frac{100}{1+0.44\sqrt{\left(\frac{F_{1BOD}}{V_1 \cdot R_{F_1}}\right)}}$$

$$80 = \frac{100}{1+0.44\sqrt{\left(\frac{882}{V_1}\right)}}$$

$$V_1 = 2704 \text{ m}^3$$

Depth of filter = 1.5 m,

$$\text{Filter Area} = \frac{2704}{1.5} = 1802.66 \text{ m}^2$$

Diameter = 48m < 60 m

Hydraulic loading Rate

$$= \frac{6\times10^6}{10^3} \times \frac{1}{1802.66} = 3.33 \frac{m^3}{day.m^2} < 4$$

Organic-loading rate

$$= 882\times\frac{1000}{2704} = 326.18 \frac{gm}{dm^3} \simeq 320 \text{ g/d/m}^3$$

4.

line	F.B.	B.B.	$\lvert B.B. - F.B. \rvert$
AB	74°	254°	$=180°$
BC	91°	271°	$=180°$
CD	166°	343°	$\neq 180°$
DE	177°	0°0'	$\neq 180°$
EA	189°	9°	$=180°$

So, points A, B, C and E are free from local attraction because the lines containing points A, B, C and E have the difference of fore and back bearing is equal to 180°.

And points D is affacted from local attraction to find corrected bearings.

Line	Bearing	Correction	Corrected Bearing
AB	74°0'	0° at A	74°0'
BA	254°0'	0° at B	254°0'
BC	91°0'	0° at B	91°0'
CB	271°0'	0° at C	271°0'
CD	166°0'	0° at C	166°0'
DC	343°0'	+3° at D	346°0'
DE	177°0'	+3° at D	180°0'
ED	0°0'	0° at E	0°0'
EA	189°0'	0° at E	189°0'
AE	9°0'	0° at A	9°0'

The correction at points A, B, C and E are 0° because these are free from local attraction.

5. Specific gravity of lubricating oil = 0.85

Dynamic-Viscosity = 0.01 × 9.81 N/m^2 = 0.0981

d = 3 cm

Pressure Drop in pipe = 14715 N/m^2

$$\Rightarrow \quad \frac{\Delta P}{\Delta L} = \frac{32\mu V}{D^2} = \frac{32 \times 0.0981 \times V}{9 \times 10^{-4}}$$

$$\Rightarrow \quad V = \frac{14715 \times 9 \times 10^{-4}}{32 \times 0.0981}$$

$$\Rightarrow \quad V = 4.2187 \text{ m/s}$$

Mass flow rate = ρaV

= 850 × 0.785 × 3^2 × 10^{-4} × 4.2187

= 2.5334 kg/sec

$$\text{Reynold's Number} = \frac{\rho V_d}{\mu} = \frac{850 \times 4.2187 \times 3 \times 10^{-2}}{0.01 \times 9.81} = 1097$$

Power-required to maintain flow

$$= (\Delta P) = PQgh_f$$

$$\text{Head loss } (h_f) = \frac{\Delta P}{\rho g} = \frac{40 \times 0.15 \times 9.81 \times 10^4}{850 \times 9.81} = 70.56$$

$$\text{Power Required} = \rho_a V_g h_f$$

$$= 2.5334 \times 9.81 \times 70.56 = 1753.60 \text{ Watt}$$

6. We determine the transform impedance and admittance representations for each of the elements and initial condtion sources.

Resistance : For resistance, the voltage and current are related in the time domain by ohm's law.

$$V_R(t) = R\ i_R(t)$$

or

$$i_R(t) = GV_R(t)$$

$$G = \frac{1}{R} \qquad ...(1)$$

The corresponding transform equation are

$$V_R(s) = RI_R(s)$$

$$I_R(s) = GV_R(s) \qquad ...(2)$$

The ratio of transform voltage $V_R(s)$ to the transform current $I_R(s)$ is defined as the transform impedance of the resistor, expressed as

$$Z_R(s) = \frac{V_R(s)}{I_R(s)} = R \qquad ...(3)$$

Similarly, the reciprocal of this ratio is the transform admittance for the resistor, expressed as

$$Y_R(s) = \frac{I_R(s)}{V_R(s)} = G \qquad ...(4)$$

From the above results, we can say that the resistor is frequency insensitive to the complex frequency.

Figure (a) shows a network representing resistor R current $i_R(t)$ and Voltage $V_R(t)$ in time domain.

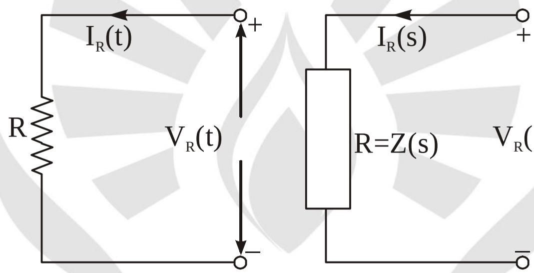


Figure (a) *Figure (b)*

Figure (b) gives the network representation of the same resistor and also transforms current $I_R(s)$ and voltage $V_R(s)$.

Inductance :

The time domain relation between the current in inductance $i_L(t)$ and the voltage $V_L(t)$ across it is expressed as

$$V_L(t) = L\frac{di_L(t)}{dt}$$

and $$i_L(t) = \frac{1}{L}\int_{-\infty}^{t} V_L(t)\,dt \qquad ...(5)$$

The equivalent transform equation for the voltage expression is

$$V_L(s) = L[sI_L(s) - i_L(0^+)] \qquad ...(6)$$

$$\Rightarrow \quad LsI_L(s) = V_L(s) + Li_L(0^+) \qquad ...(7)$$

In the equation (5) and (6) $V_L(s)$ is the transform of the applied voltage $V_L(t)$ and $i_L(0^+)$ is the transform voltage caused by the initial current $i_L(0^+)$ present in the inductor at time $t = 0^+$.

Considering the sum of the transform voltage and the initial current voltage as $V_L(s)$ we have the transform impedance for the inductor.

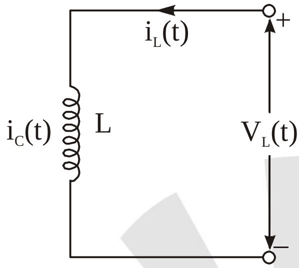


Figure (a)

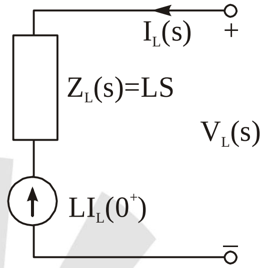


Figure (b)

$$Z_L = \frac{V_1(s)}{I_L(s)} = SL \qquad ...(8)$$

Figure (b) gives the transform representation of same inductor in terms of impedance using equation (6). The transform equation for the current expression of equation (7) is

$$I_L(s) = \left[\frac{V_L(s)}{s} + \frac{\int_{-\infty}^{0^+} V_L(t)\,dt}{s}\right]\frac{1}{L} \qquad ...(9)$$

$$\text{But } \int_{-\infty}^{t} V_L(t)\,dt = Li_L(0^+) \qquad ...(10)$$

Hence equation (9) be comes

$$I_L(s) = \frac{1}{L}.\frac{V_L(s)}{s} + \frac{i_L(0^+)}{s} \qquad ...(11)$$

$$\text{or } \frac{1}{Ls}.V_L(s) = I_L(s) - \frac{i_L(0^+)}{s} \qquad ...(12)$$

in the above equation $\frac{i_L(0^+)}{s}$ is the transform caused by the initial current $i_L(0^+)$ in the inductor.

$$\text{Let,} \quad I_1(s) = I_L(s) - \frac{i_L(0^+)}{s} \qquad ...(13)$$

then the equation (12) becomes

$$\frac{1}{Ls}V_L(s) = I_1(s) \qquad ...(14)$$

Where $I_1(s)$ is the total transform current through the indictor L. The transform impedance becomes

$$Y_L(s) = \frac{I_1(s)}{V_L(s)} = \frac{1}{Ls} \qquad ...(15)$$

Figure (a) shows the time domain representation of inductor L with inital current $I_L(0^+)$ figure (b) shows equivalent transfor circuit theus contains an admittance of value $\frac{1}{Ls}$ and equivalent transform current source.

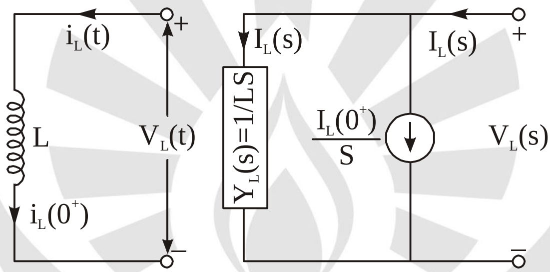


Figure (a) *Figure (b)*

Capacitance :

The time domain relation between voltage and current expressed as

$$i_c(t) =- C\frac{dV_c(t)}{dt} \qquad ...(16)$$

The equivalent transform equation for the voltage expression is

$$V_C(s) = \frac{1}{C}\left[\frac{I_c(s)}{s} + \frac{Q(0^+)}{s}\right] \qquad ...(17)$$

where $\frac{Q(0^+)}{s} = V_c(0^+)$ is the initial voltage across the capacitor. The above equation becomes

$$\frac{1}{Cs}I_C(s) = V_C(s) - \frac{V_C(0^+)}{s} \qquad ...(18)$$

By considering the initial charge on the capacitor zero. The equation becomes

$$\frac{1}{C(s)} I(s) = V(s)$$

The transform impedance of the capacitor is the ratio of transform voltage V(s) to the transform current I(s) and is

$$Z(s) = \frac{V(s)}{I(s)} = \frac{1}{CS}$$

the transform admittance of the capacitor is the ratio of transform current I(s) of transform voltage V(s) is

$$Y(s) = \frac{I(s)}{V(s)} = CS$$

7.

Here, $W_1 : W_2 : W_3 = 3 : 2 : 1$

Efficiency of engine, HE_1,

$$\frac{W_1}{Q_1} = \left(1 - \frac{T_2}{1100}\right) \Rightarrow Q_1 = \frac{1100 W_1}{(1100 - T_2)}$$

for HE_2 engine,

$$\frac{W_2}{Q_2} = \left(1 - \frac{T_3}{T_2}\right)$$

for HE_3 engine,

$$\frac{W_3}{Q_3} = \left(1 - \frac{300}{T_3}\right)$$

From energy balance on engine, HE_1

$$Q_1 = W_1 + Q_2 \Rightarrow Q_2 = Q_1 - W_1$$

Above gives,

$$Q_2 = \left\{\frac{1100 W_1}{(1100 - T_2)} - W_1\right\} = W_1 \left\{\frac{T_2}{1100 - T_2}\right\}$$

Substituting Q_2 in efficiency of HE_2

$$\frac{W_2}{W_1\left(\frac{T_2}{1100 - T_2}\right)} = \left(1 - \frac{T_3}{T_2}\right)$$

or

$$\frac{W_2}{W_1} = \left(\frac{T_2}{1100 - T_2}\right)\left(\frac{T_2 - T_3}{T_2}\right) = \left(\frac{T_2 - T_3}{1100 - T_2}\right)$$

or

$$\left\{\frac{2}{3} = \left(\frac{T_2 - T_3}{1100 - T_2}\right)\right\}$$

or $\quad 2200 - 2T_2 = 3T_2 - 3T_3$

$$\boxed{5T_2 - 3T_3 = 2200}$$

Energy balance on engine HE_2 gives,

$$Q_2 = W_2 + Q_3$$

Substituting in efficiency of HE_2,

$$\frac{W_2}{(W_2 + Q_3)} = \left(\frac{T_2 - T_3}{T_2}\right)$$

or $$W_2 . T_2 = (W_2 + Q_3)(T_2 - T_3)$$

or $$Q_3 = \frac{W_2 \ T_3}{(T_2 - T_3)}$$

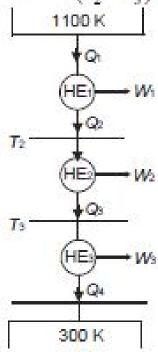


Fig. 4.25

Substituting Q_3 in efficiency of HE_3,

$$\frac{W_3}{\left(\frac{W_2 T_3}{T_2 - T_3}\right)} = \frac{T_3 - 300}{T_3}$$

$$\frac{W_3}{W_2} = \left(\frac{T_3}{T_2 - T_3}\right)\left(\frac{T_3 - 300}{T_3}\right)$$

$$\frac{1}{2} = \frac{T_3 - 300}{T_2 - T_3}$$

$$3T_3 - T_2 = 600$$

Solving, equations of T_2 and T_3, $T_3 = 433.33$ K

$$T_2 = 700 \text{ K}$$

Intermediate temperatures: **700 K** and **433.33 K Ans.**

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