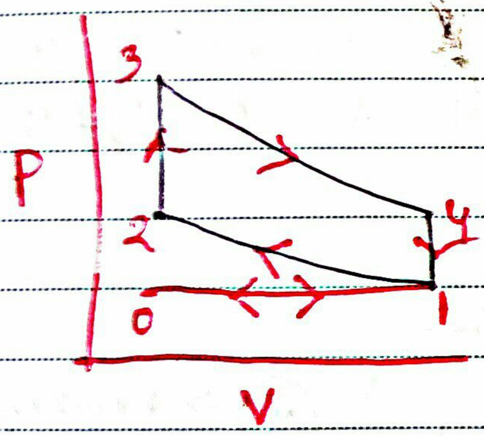
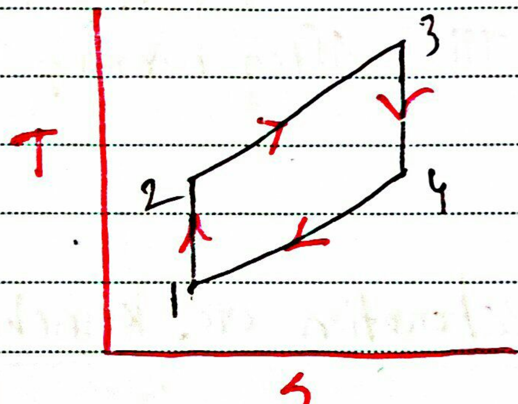
Petrol Engine

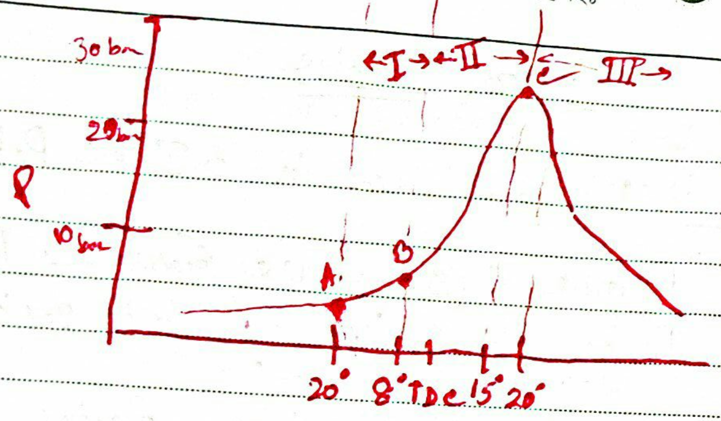
Fuel :- The fuel used in S.I or Petrol Engine is also called Gasoline. The boiling Temp. of Gasoline is about 200°c.

Cycle :- The cycle Petrol Engine uses is called constant volume cycle or Otto cycle.





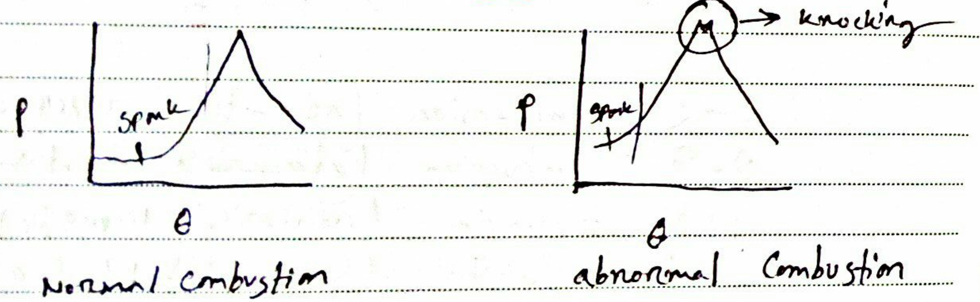
1-2 Compression (adiabatic & reversible)
2-3 Combustion (~~adiabatic~~ & constant Vol)
3-4 Expansion (adiabatic & reversible)
4-1-0 Exhaust (4-1 constant Vol, 1-0, &
0-1 Intake 0-1 constant pressure)



I = Ignition Lag
II = Flame Propagation
III = After burning

A = Spark
B = Start of flame Propagation
C = End of fuel burn.

Detonation or knocking :-



The abnormal Combustion called 'detonation or knocking', the end charge auto-ignites before the flame front reaches it.

To avoid detonation, A high auto-ignition temp. and a long ignition delay are desirable qualities for SI engine fuels.

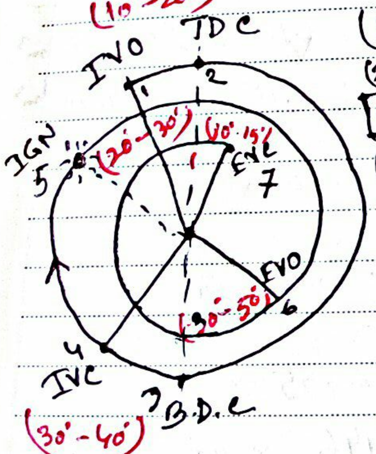
Effect of Detonation :-

1. Noise & Roughness
2. Mechanical Damage
3. Carbon deposite
4. Increase of heat
5. Decrease of Power & efficiency.
6. Pre ignition.

Reason

1) High compression Ratio
2) High inlet air Temp
3) High wall Temp of cylinder wall.
4) coolant Temp

Value Timing



(10-20°)
(20°-30°)
(20-30°)
(30°-50°)
(10°-15°)

Intet value opens (1-2) 10-20° before TDC

Inlet value Closes (3-4) (30-40°) after BDC

∴ 1-4 Suction continues.

4-5 Compression starts (30°-40°) after BDC & ends (20-30°) before TDC

5 → ignition before (20-30°) TDC

(5-6) Exansion, starts (20°-30°) before TDC, ends (30°-50°) before BDC

(6-7) Exhaust, starts (30°-50°) before BDC, ends (10°-15) after TDC

Firing Order

for four cylinder 1-2-4-3 or 1-3-4-2

Efficiency :-

$\eta = 1 - \frac{1}{r^{\gamma - 1}}$ [$\gamma = 1.3 \sim 1.4$]

$= 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}$ [r = Compression ratio]

Example :

1. Motorcycle
2. Private Car
3. Sports Car (super car: Bugatti Varon)

or any lightweight vehicle

Prob: The dia and stroke length of a single cylinder two stroke gas engine working on the constant volume cycle are 2oomm & 3oomm respectively with clearance volm 2.78 ltr. Find the standard efficiency.

Sol: Given, $d = .2m$, $L = .3m$, $V_c = \frac{2.78}{1000} m^3 = 2.78 \times 10^{-3} m^3$

Stroke volm $V_s = \frac{\pi}{4} d^2 L = \frac{\pi}{4} \times (.2)^2 \times .3 = 9.42 \times 10^{-3} m^3$

Compression ratio $r = \frac{V_c + V_s}{V_c} = 4.38$

$\therefore \eta = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{4.38^{1.4-1}}$

$= 1 - .5538$

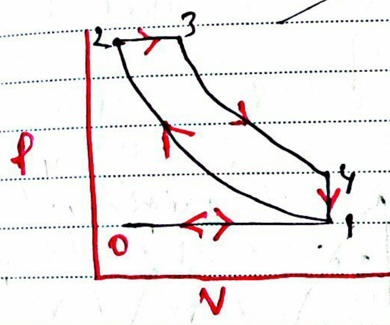
$= .446 \times 100$

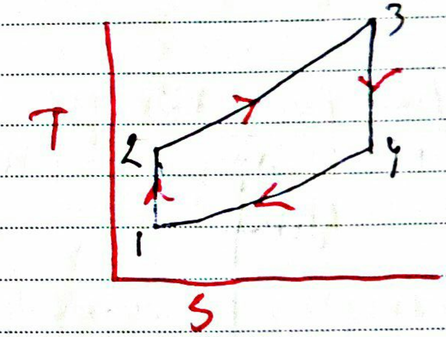
$= 44.6\%$ Ans

Diesel Engine

Fuel:- The fuel used in Diesel engine is called Diesel. It's Boiling range is about 200 to 370°C. It's mainly used in compression ignition (CI) engines.

Cycle:- The cycle diesel engine follows is also called Diesel cycle / Constant pressure cycle





1-2 Compression (isentropic)
2-3 Injection (isobaric)
3-4 Expansion (isentropic)
4-1 Exhaust (Constant vol & ~~isentro~~pic)
1-0 Exhaust
0-1 Intake

Efficiency :-

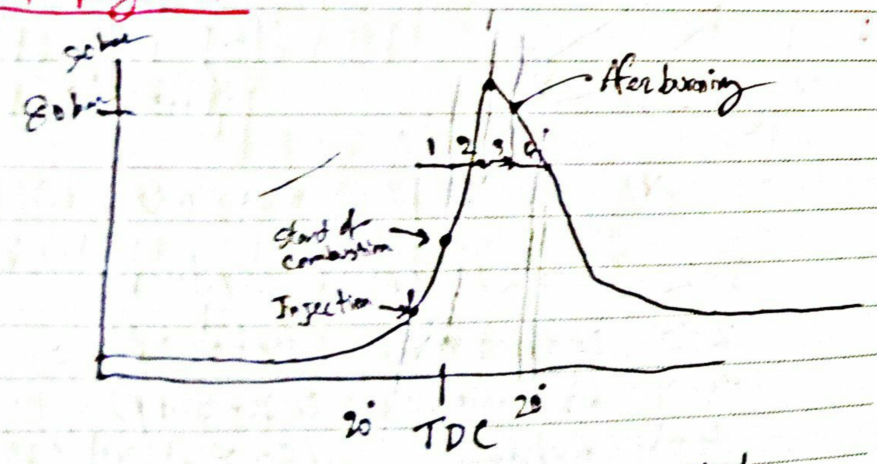
$$\eta = 1 - \frac{1}{\gamma}\left(\frac{T_4 - T_1}{T_3 - T_2}\right)$$

$$= 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}\right]$$

Example :-

1) Bus
2) Truck
3) Ship
4) Powerplant
5) Any heavy weight vehicle.

Flame Propagation



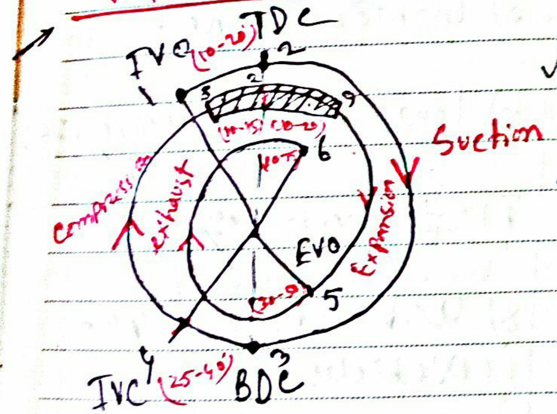
1 → First Stage → ignition delay period.
2 → 2nd stage → Uncontrolled Combustion

3 → 3rd stage → Controlled Combustion.
4 → 4th Stage → After burning.

Diesel oil has Cetane Number (40-60)
Octane Number (30)

Petrol oil has octane number (80-90)
Cetane Number (18)

Valve Timing :-



1-2 inlet valve opens 10°-20° before TDC
3-4 inlet valve closes 25°-40° after BDC

5-3 Exhaust valve opens 30°-50° before BDC
2-6 Exhaust valve closes 10-15° after TDC

8-2 fuel injection starts 10-15° before TDC
2-9 fuel injection stops 10-20° after TDC

Comparison of SI & CI Engine

Diesel Engine	Petrol Engine
1) Cycle:- Diesel cycle	1) Cycle: Otto cycle
2) One isobaric process	2) No isobaric process.
3) Consists Nozzle/injector	3) Consists spark plug.
4) Higher Compression Ratio (15-25)	4) Lower Compression Ratio. (6-10)
5) Heavier Engine	5) Lighter engine.
6) Thermal Efficiency high (40%)	6) Low Thermal efficiency (26%)
7) Starting Difficult	7) Starting easy.
8) Used for low speed vehicles.	8) Used for high speed Vehicles.
9) Running cost low	9) Running cost high.
10) Initial cost high	10) Initial cost low
11) Maintenance & cost high	11) Maintenance cost low.

Octane No:- The percentage by volume of iso-octane in a mixture of iso-octane & Normal-heptane which shows the same tendency to knock as the given fuel, under same test engine & specified conditions, known as Octane Number of that fuel.

% by volume of iso-octane in a mixture of iso-octane + Normal-heptane which shows the same tendency to knock as the given fuel, under same test engine & condition, is known as octane number.

Cetane No:- The percentage by volume of cetane in a mixture of cetane & α-Methyl-Napthalene which has the same ignition delay as the given fuel, under same test engine and condition is known as cetane No.

% by volume of cetane in a mixture of cetane + α-Methyl-napthalene has same ignition delay as the given fuel, under same test engine & condition is called cetane No.

Octane : iso octane + Normal-heptane

Cetane : cetane + α Methyl Napthalen

Tests for I.C Engine

1. Indicated Mean effective Pressure :-

$$P_m = \frac{\text{Area of Indicator Card} \times \text{Scale of indicator spring}}{\text{Length of indicator card}}$$

it is measured by
Ex Planimeter

2. Indicated Power :-

$$I.P = \frac{100 \, k \, P_m \, L A n}{60}$$

k = cylinder No.
P_m = mean effective pressure in bar
L = Length of stroke, m
A = Piston area, m^2
n = RPM.

3. Brake Power :-

$$B.P = \frac{2\pi N T}{60}$$

T = Torque = W × l

4. Efficiency

i) Mechanical $\eta_{mech} = \frac{B.P}{I.P}$

(ii) Overall $\eta_{overall} = \frac{BP \times 3600}{m_f \times C}$

m_f → mass of fuel; C → calorific value of fuel

Automobile Related Terms

- ABS → Anti lock Breaking System.
- VVT → Variable Value timing
- VVTI → Variable Value timing with Intelligence
- VTEC → Variable timing & Lift Electronic Control
- EFI → Electronic fuel Injection.
- MPFI → Multi Point Fuel Injection.
- TPFC → Transient Power Fuel Control System.
- SAE → Society of Automotive Engineers.
- DTSI → Digital Twin Spark Ignition.
- SOHC / DOHC → Single/Double overhead Cam shaft
- HCCI → Homogeneous Charge Compression Ignition.
- EEC → Electronic Engine Control.

Mathmatical Problems

Q:1:- The engine of the Fiat car has four cylinders of 68 mm bore & 75 mm stroke. The compression ratio is 8. Determine cubic capacity of the engine & the clearance volume of each cylinder.

Ans:-

Swept volume of single cylinder

$$V_s = \frac{\pi d^2}{4} \times l = \frac{\pi}{4} \times (6.8)^2 \times (7.5)$$

$$= 272.37 \text{ cm}^3 \text{ or cc}$$

Total cubic capacity of four cylinder's

$$= 4 \times 272.37 = 1089.48 \text{ cc}$$

We know

Compression ratio $r = 8 = \frac{V}{V_c}$

$$8 = \frac{V_c + V_s}{V_c} = \frac{V_s}{V_c} + 1$$

$$\therefore \frac{V_s}{V_c} = 7 \quad \therefore V_c = \frac{272.37}{7} = 38.91 \text{ cc}$$

Ans

Q.2: A four stroke petrol engine delivers 35 kW with a mechanical efficiency of 80%. The fuel consumption of the engine is 0.4 kg/kW·hr & the air-fuel ratio is 14:1. The heating value of fuel is 43000 kJ/kg.

Find a) The indicated power.
b) The friction power.
c) The brake thermal efficiency.
d) The fuel consumption/hr.
e) The Air consumption/hr.

Ans: We know

$$\eta_{mech} = \frac{B.P}{I.P}$$

$$\therefore .8 = \frac{35 \text{ kW}}{I.P} \quad \therefore I.P = 43.75 \text{ kW}$$

$\therefore$ a) $I.P = 43.75$ kW

b) $F.P = I.P - B.P = 43.75 - 35$
$= 8.75$ kW

c) $$\eta_{b.thermal} = \frac{B.P \times hr}{m_{f/hr} \times c_v}$$

$$= \frac{35 \times 3600}{(35 \times .4) \times 43000}$$

$$= 20.9\%$$ Ans

d) Fuel consumption/hr $m_f = .4 \times 35$

$= 14$ kg/hr

e) Air consumption/hr $m_a = A/F \times m_f$

$= 14/1 \times 14$

$= 196$ kg/hr

Ans

Prob: Find highest possible theoretical efficiency of heat engine operating between hot reservoir 2100°C & sink of about 15°C, following carnot cycle.

Ans

Given $T_1 = 2100°C = 2373$ K

$T_2 = 15°C = 288$ K

We know for Ideal engine (operates in carnot cycle)

$$\eta = \frac{T_1 - T_2}{T_1} = \frac{2373 - 288}{2373}$$

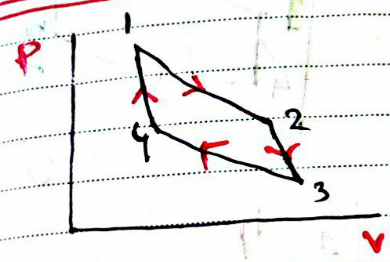
$$= \frac{2085}{2373}$$

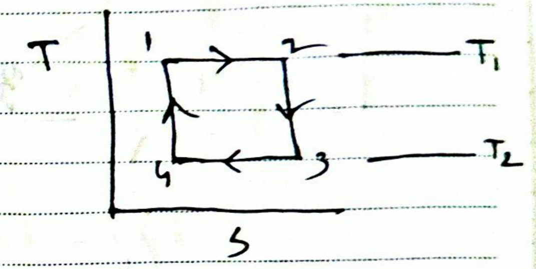
$$= 87.86\%$$

Ans: 87.86%

Thermodynamic cycles

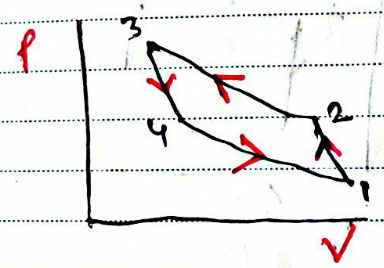
1) Carnot cycle :- (for Heat engine)

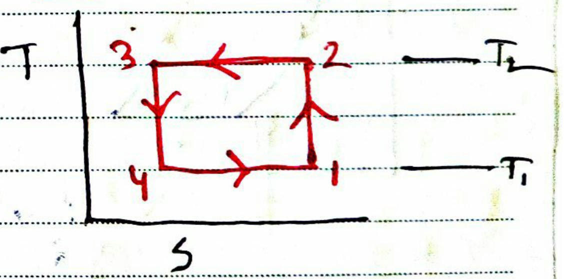




$$\therefore \eta_{th} = 1 - \frac{T_2}{T_1}$$

2) Reverse Carnot cycle :- (for Refrigeration)

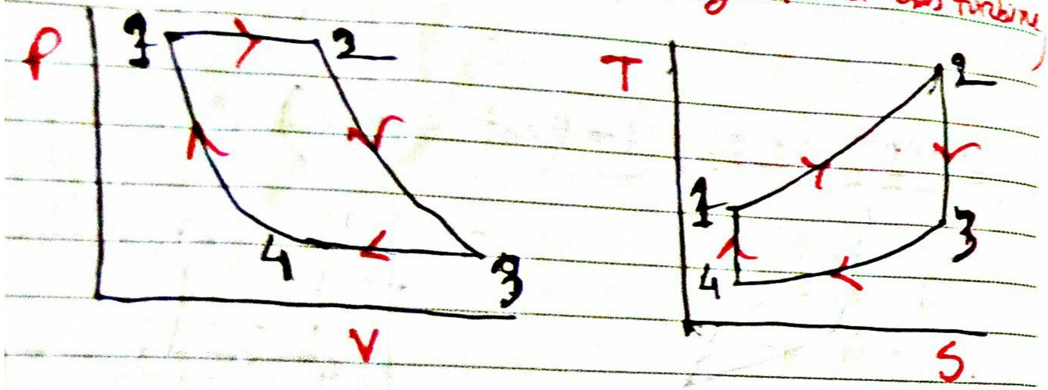




$$COP = \frac{T_1}{T_2 - T_1}$$

$$\eta_{th} = \frac{1}{COP} = \frac{T_2 - T_1}{T_1} = \frac{T_2}{T_1} - 1$$

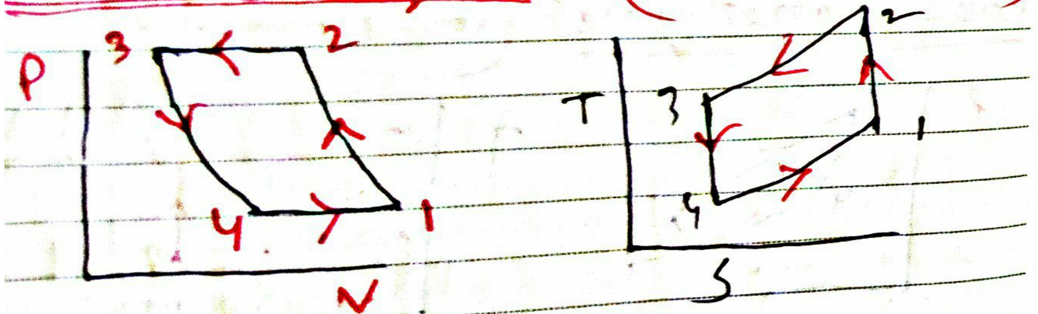
Joule cycle:- (for ~~Air Refrigeration &~~ Gas turbine)



$$\eta_{th} = 1 - \frac{T_3 - T_4}{T_2 - T_1}$$

$$\eta = 1 - \frac{T_3}{T_2} = 1 - \frac{T_4}{T_1} = 1 - \frac{1}{r^{\gamma-1}}$$

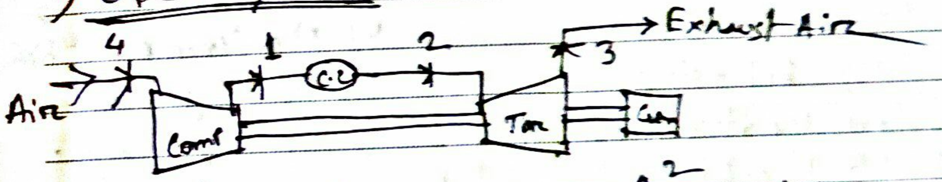
Reversed Joule cycle:- (for Air Refrigeration)

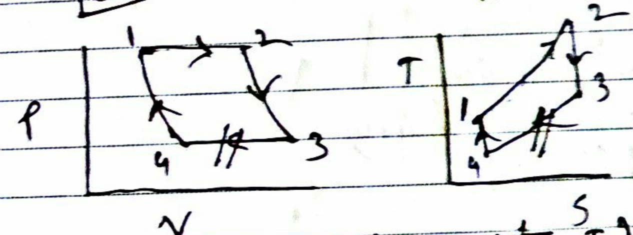


Gas Turbine

Types:- 1) Open cycle
2) Close cycle

1) Open cycle



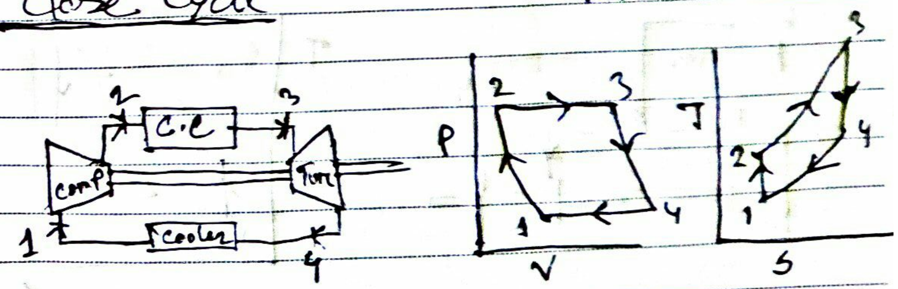


1-4 → Compression
1-2 → Combustion
2-3 → Expansion

$$\eta = \frac{c_p(T_2 - T_3) - c_p(T_1 - T_4)}{c_p(T_2 - T_1)}$$

$$\eta = \frac{\text{net work}}{\text{net heat addition}}$$

2) Close Cycle

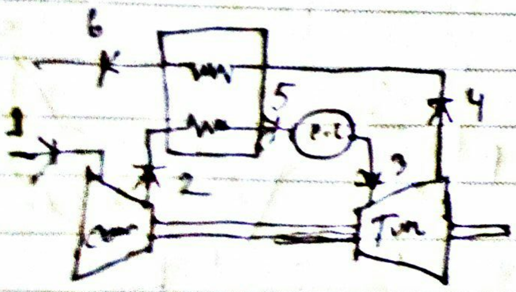


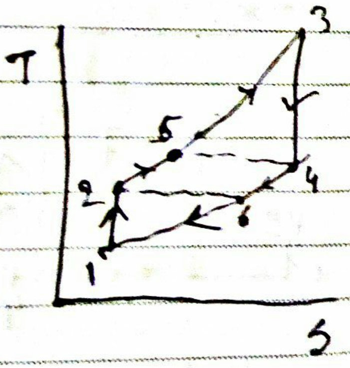
1-4 Compression
2-3 Combustion
3-4 Expansion
4-1 Cooling

Gas turbine Vs IC engine

Gas Turbine	I.C Engine
1) Simple Mechanism	1) Not simple
2) Higher Speed	2) Low speed
3) Compact & low weight	3) Not easy balancing
4) Small foundation	4) Maintenance cost high
5) Easy balancing	5) Knocking happens
6) Low Maintenance cost	6) Starting easy.
7) No knocking	
8) Low Thermal efficiency.	
9) Poor part load efficiency.	
10) Starting difficult	

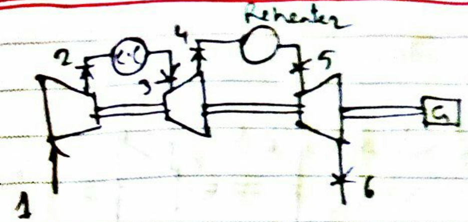
Gas turbine with heat Exchanger :-

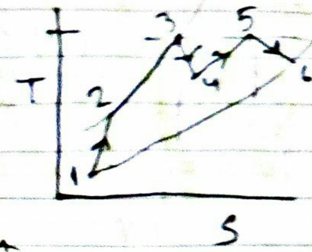




$\eta_{thermal}$ = Increases

Gas Turbine with Reheating

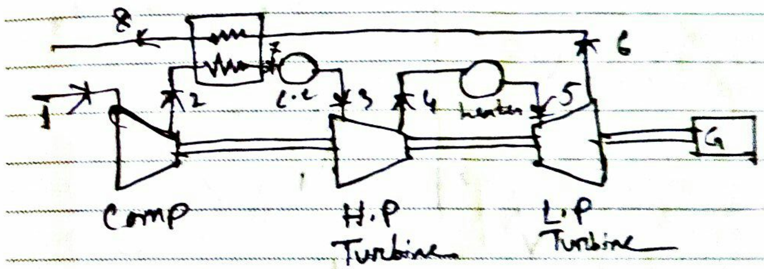


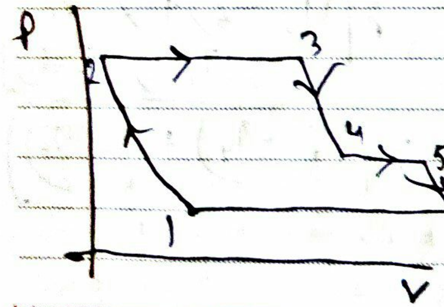


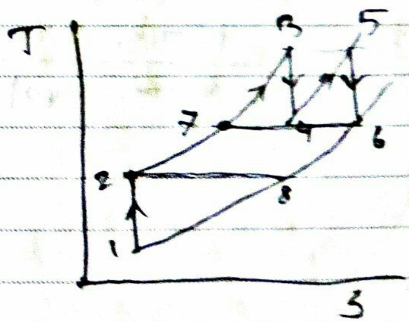
η_{th} = decreases

network output = Increases.

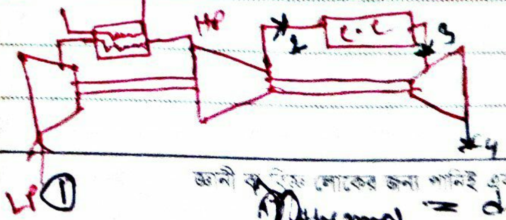
Gas Turbine with Reheating & Regeneration

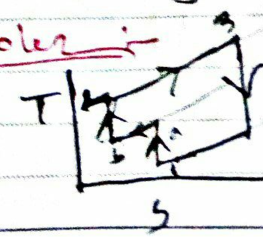






Gas Turbine with Inter Cooler :-

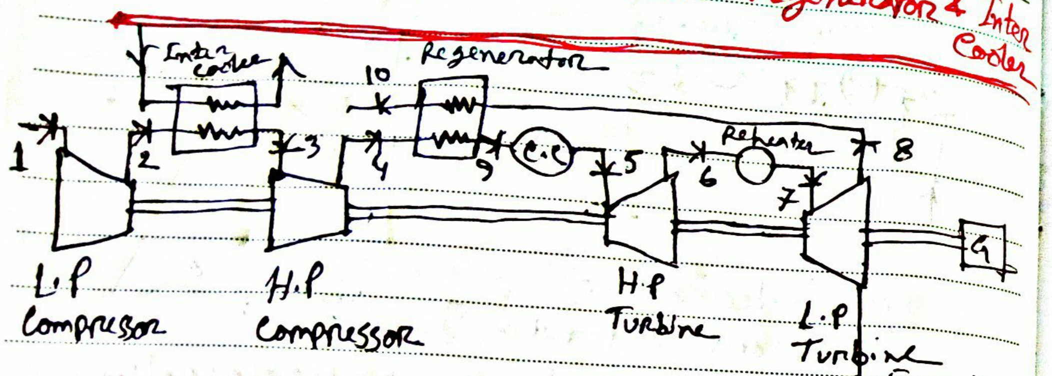


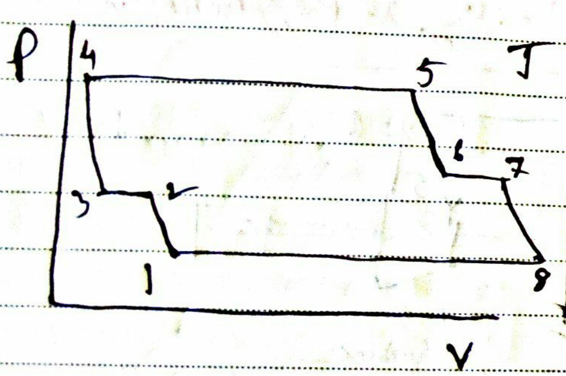


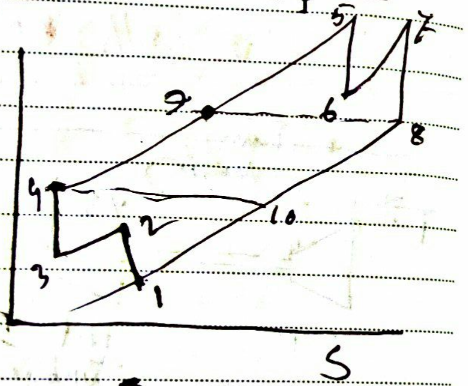
$\eta_{thermal}$ = decreases

Net workoutput = Increases

Gas Turbine with Reheater & Regenerator & Inter Cooler







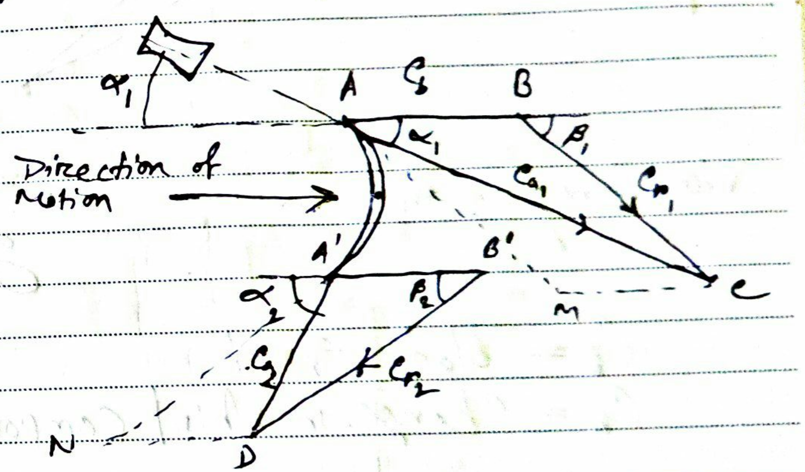
$$\eta = \frac{\text{Work output}}{\text{Heat input}} = \frac{C_p\left[(T_5 - T_6) + (T_7 - T_8) - (T_4 - T_3) - (T_2 - T_1)\right]}{C_p\left[(T_5 - T_4) + (T_7 - T_6)\right]}$$

Steam Turbine

Types:- 1) Impulse Turbine 2) Reaction Turbine

Impulse Turbine:

Velocity Triangles



$\alpha_1 \rightarrow$ Nozzle Angle

$\beta_1 \rightarrow$ inlet angle to moving blade

$C_{a_1} \rightarrow$ Steam absolute velocity

$C_{r_1} \rightarrow$ Steam relative velocity

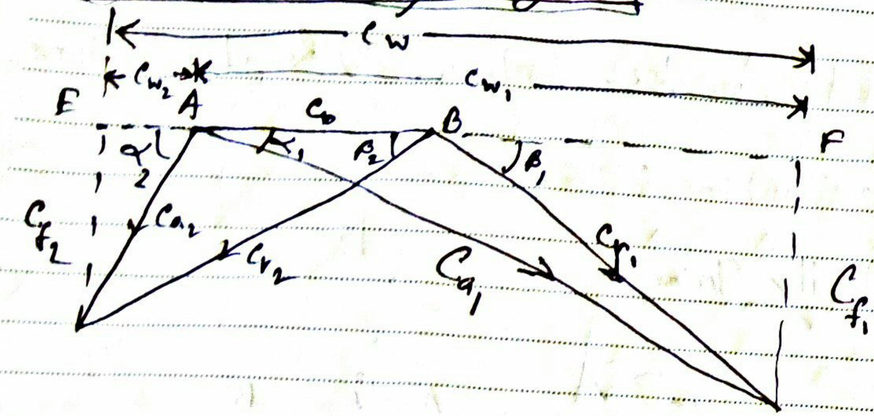
$C_b \rightarrow$ Blade speed

$C_{r_2} \rightarrow$ Steam relative velocity at outlet

$C_{a_2} \rightarrow$ " absolute velocity at outlet

$\beta_2 \rightarrow$ outlet angle of moving blade

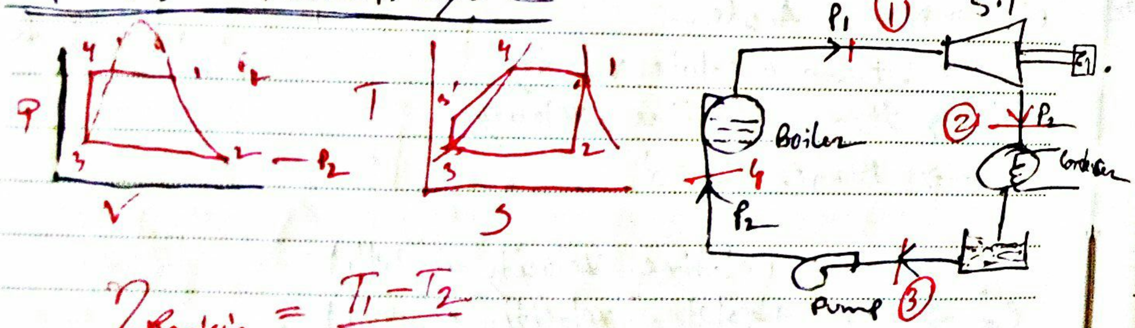
Combined Velocity diagram :-



Work done/kg of Steam $= \frac{C_b \times C_w}{g}$

C_b = blade speed
C_w = Change in whirl component

Operates on Rankin cycle



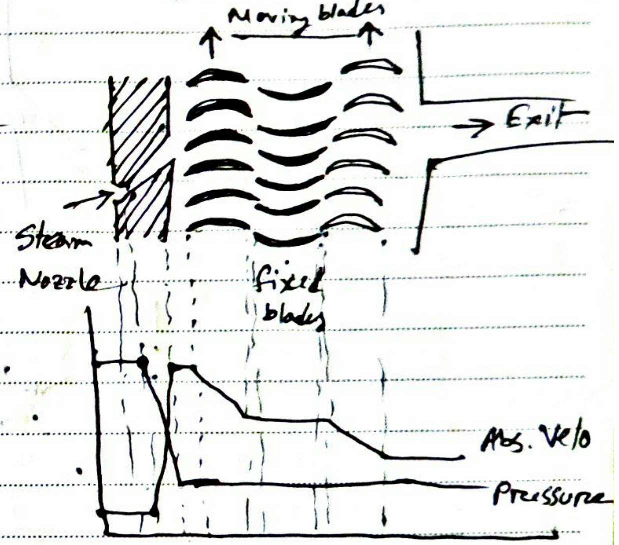
$\eta_{Rankin} = \frac{T_1 - T_2}{T_1}$

$= W_{output} / Q_{heat\ input} = \frac{Q_1 - Q_2}{Q_1}$

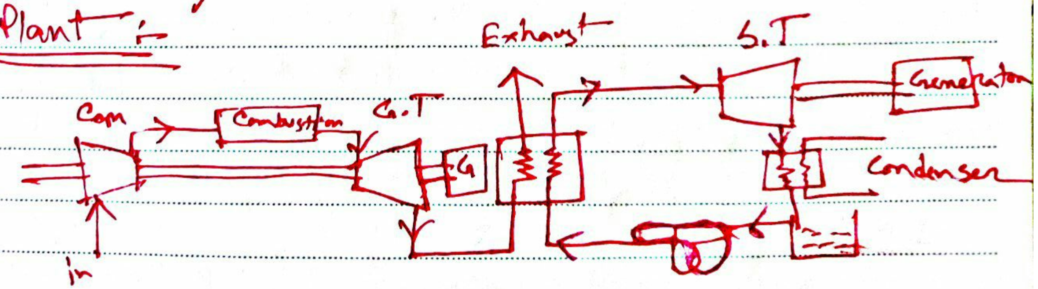
Steam turbine Staging :-

Velocity Compounding :- Converting the total enthalpy fall into kinetic energy in one stage but dividing the conversion of kinetic energy of steam into mechanical energy of the wheel in portion's.

Ex :- Curtis Turbine



Combined cycle power Plant :-

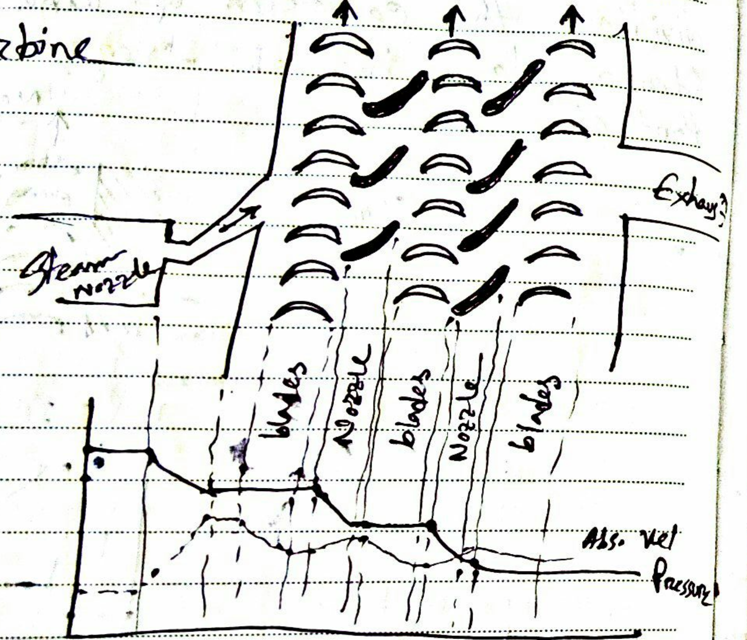


Gas Turbine + Steam Turbine

Pressure Compounding:-

~~Diving~~ Dividing the fall of total pressure drop in Portions. Several sets of Nozzle separated from each other by a turbine wheel.

Ex:- Rateau Turbine



Reaction Turbine:-

The total energy at the ~~inlt~~ inlet of a turbine is kinetic energy as well as pressure energy.

Ex:- Parson's Turbine

Difference betⁿ Impulse & Reaction

Impulse	Reaction
1) fluid expansion completes at nozzle.	1) Fluid expansion completes on rotor blades.
2) Relative velocity of steam reduce or constant.	2) Relative velocity of steam increase.
3) Blades are ~~symmetri~~ symmetrical	3) Blades are Asymmetrical and has ~~an~~ Aero foil section.
4) Less stages canbe used.	4) More stages can be used for same power.
5) Blade speed high	5) Blade speed low.

Boiler

Definition :- The equipment for producing steam is called boiler.

Application :-

i) Power generation
ii) Heating
iii) Chemical industries
iv) Sugar mills
v) Textile industries etc

Type :-

a) Fire tube	b) Water tube
i) flue gas pass through tube.	i) water passes through tube.
ii) slow process to get steam.	ii) faster than fire tube.
iii) More reliable, low initial cost.	iii) less reliable, Maintenance cost high.
iv) Difficult to access.	iv) Easy to access, inspect, & repair.
v) Transport is very difficult.	v) Transport is easy.
Ex :- locomotive fire box Scotch marine horizontal/verticle boiler	Ex :- Babcock & wilcox boiler Stirling boiler.

a) Internally fired
Ex Lancashire
Locomotive
Scotch boiler

b) Externally fired
Ex Babcock & wilcox boiler.

High Pressure Boiler's

i) Lamont Boiler
ii) Benson Boiler
iii) Loeffler Boiler

Steam Accumulator :-

It's function is to support the boiler and process load and permits the boiler operation at constant load.

Boiler Mountings

Definition:- The equipment's necessary to ensure safety and complete control of the boiler are called Boiler Mountings.

1) Safety Valve
2) Pressure gauge
3) Steam stop valve
4) Blow-off cock
5) Water level indicator
6) Fusible plug
7) Feed check valve

Boiler Accessories

Definition:- The equipment's required to increase efficiency of the boiler & proper working of the boiler are called Boiler Accessories.

1) Air Preheater
2) Economiser
3) Superheater
4) Feed pump
5) Injector.

Boiler Performance

$$\text{Boiler Efficiency} = \frac{m_s (H_s - h_w)}{m_f \times C_v}$$

H_s = Sp. Enthalpy of steam
h_w = Sensible heat of feed water
m_s = mass of steam produced
m_f = mass of fuel
C_v = Calorific value

Some Major Power plant's Name & Capacity

1. Ghorasal Thermal Power Plant → 950 MW
2. Ashuganj Power plant → 724 MW
3. Barapukuria Coal power plant → 250 MW
4. Kaptai Hydro Power Plant → 230 MW
   ↳ (Kaplan Turbine) → (Low head)
5. Siddhirganj Thermal Power plant → 260 MW
6. Meghnaghat Gas Turbine → 450 MW
7. Haripur Gas Turbine → 360 MW
8. Raozan Gas engine → 240 MW

Heat Transfer

Modes of heat Transfer :- There are Three Modes of heat Transfer
a) Conduction
b) Convection
c) Radiation

1) Conduction :- In this method heat flows through a solid body without the movement of any particle's in that body. Heat is conducted from one place to another through the vibration of molecule's.

$$Q = kA \frac{dt}{dx}$$

It follows the fourier law of heat. which implies that the heat transfer is proportional to the cross-section area & temp difference between two point.

$$LMTD = \frac{\Delta T_A - \Delta T_B}{\ln\left(\frac{T_A}{T_B}\right)}$$

ΔT_A = Difference of temp of two fluid at (A) end.
ΔT_B = Difference of temp of two fluid at (B) end.

2) Convection :- In this method heat flow's from one place to another through the movement of particle's of liquid or gas.

Newton-Rikhman law

$$Q = hA\,dT$$

The law of convection heat Transfer states that the Amount of heat to be transfered is proportional to the crosssection area & the temp. difference between two point's.

3) Radiation :- In this method, no medium is required. The heat flow's as electro magnetic waves.

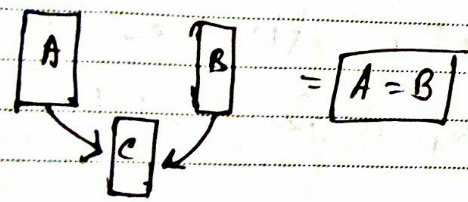
Nusselt No :- $Nu = \frac{hL}{K}$, convection / conduction

It signifies the rate of Convective heat transfer is high or Conductive heat Transfer is high.
Nu high mean's convective h.T is high
Nu Low conductive h.T is h

Refreegeration & A.C

Laws of Thermodynamics:-

1) **Zeroth Law:-** If two bodies are at thermal equilibrium with a third body then 1st two bodies are also in thermal equilibrium with each other.



2) **1st Law:-** The heat and work are mutually convertible: or heat is proportional to work

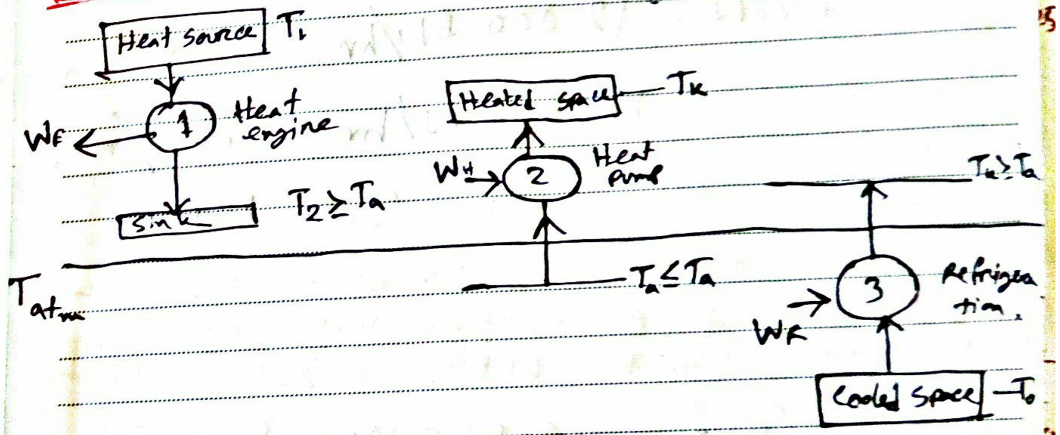
$Q \propto W$

3) **2nd Law:-** It is impossible to transfer heat from a lower temp. body to higher temp. body without any third agent.

Type of Refrigeration:-

1) Vapour Compression. → Reverse Carnot
2) Vapour absorption.
3) Gas Compression. → Reverse Joule

Comparison of Heat engine, heat pump & Refrigeration.



1. heat engine → Work's above T_{atm} (50°–500°C)
2. Heat pump → Work's to keep space heated (0 – 36°C)
3. Refrigeration → Work's to keep space cooled (0 – -25°C)

Ton of Refrigeration :-

The heat absorbed by 1000 kg of ice to melt from 0°C to 0°C water in 24 hour's, is called ~~one~~ 1 Ton of Refrigeration.

$1 \text{ TON} = 12,000 \text{ Btu/hr} = 200 \text{ Btu/min}$

$= 12,660 \text{ kJ/hr} = 211 \text{ kJ/min}$

$= 3.5 \text{ kW}$

Prob: A vapour compression refrigeration having a cooling capacity to 2 Ton. Find the power req. in kW to run the compression when the COP is 3.52.

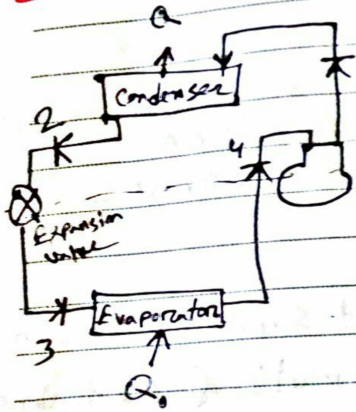
Ans: Given, ~~COP~~ $= 2 \text{ Ton} = 2 \times 3.5 = 7 \text{ kW}$

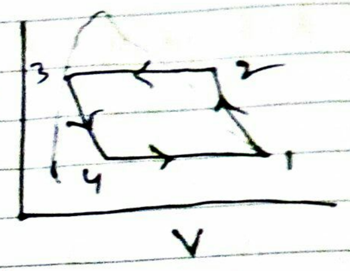
$COP = \frac{\text{Cooling effect}}{\text{Power}}$

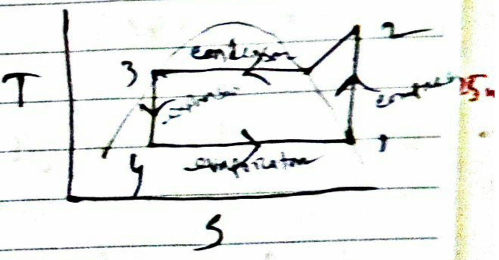
$3.52 = \frac{7 \text{ kW}}{P}$

$\therefore P = 1.98 \simeq 2 \text{ kW}$ Ans

Vapor Compression :

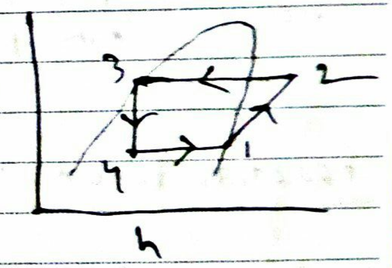






Refrigerating effect

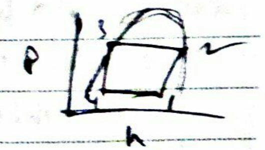
$q_0 = (h_1 - h_4)\dot{m}$ [$\dot{m}$ = mass of vapour]

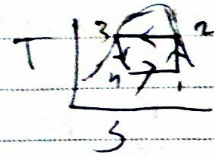


Compression work

$w = \dot{m}(h_2 - h_1)$

$COP = \frac{q_0}{w}$





Four Factor's for Comfort A.C

1) Temp. of air.
2) Humidity of air.
3) Purity of air.
4) Motion of air.

HVAC → Heating, Ventilation & Air Conditioning

Hydraulic Machines :-

* Hydraulic Turbines :-

Types : 1) Impulse Turbine
2) Reaction Turbine

Impulse Turbine :-

It is the most simplest turbine, in which water impinges on free buckets of the turbine and causes the buckets as well as the shaft to rotate.

Ex :- Pelton wheel is only impulse turbine which is currently available.

Reaction Turbine :-

In this type of turbine, water enter's at high pressure then the part of it convert's into kinetic energy and other part remain's as pressure energy which later gradually change's through runner from pressure energy to kinetic energy.

Ex :- Francis , Kaplan

Type's according To their operating head :-

1) High head Turbine :- Pelton wheel (251m-1770m)
2) Medium head Turbine :- Franci's Turbine (60m-250m)
3) Low head Turbine :- Kaplan Turbine (60m)

Hydraulic Pumps :-

Types :- 1) Reciprocating Pump
2) Centrifugal Pump

Reciprocating Pump :- (Positive displacement pump)

Discharge :- $Q = \frac{ALN}{60}$

Power :- $P = \frac{wQ(H_s + H_d)}{\eta}$

Slip :- The difference between theoretical & actual discharge is called slip.

if the actual discharge is more than theoretical discharge then it is called negative slip.

Reason's :- (i) Long suction pipe (2) low delivery head (3) running speed high

Centrifugal Pump :-

NPSH :- The net positive suction head is difference between the net inlet head & the head corresponding to the vapour pressure of the liquid.

Priming :- Priming is the operation in which the suction pipe, casing of the pump & the portion of the delivery pipe upto the delivery valve are completely filled with the liquid which is to be pumped. So that the air from this portion of the pump is driven out & no air pocket is left.

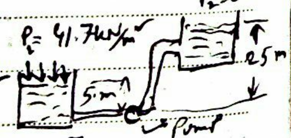
The necessity of priming a centrifugal pump is due to the fact that the pressure generated in a centrifugal pump impeller is directly proportional to the density of the fluid that is in contact with it.

Parameter's :-

$Q = \pi D b V_f$ → Impeller dia, Impeller width, flow velocity

$P = \frac{wQH_m}{\eta}$

Prob :- A 15kw pump with 80% efficiency is discharge oil of sp. gr. 0.85 to the over head Tank in fig 1. If losses in the whole system 1.75m of fluid, find discharge.



Solve We know, $\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + H_m = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$ $P_1 = 41.7 kN/m^2$

$\frac{41.7\times10^3}{.85\times9.81\times10^3} + 5 + H_m = 25 + 1.75$ $[V_1, V_2 \text{ neg}]$

$H_m = 16.75 \text{ m}$ $(P_2 = 0, \text{ atmospher})$

We know $P = \frac{\gamma Q H_m}{\eta}$ ⇒ $15\times10^3\times.8 = .85\times9810\times16.75\times Q$

$Q = 0.086 \text{ m}^3/\text{s}$

If the suction pressure falls below the vapour pressure of the liquid, cavitation will happen.

Compressor's :-

Compressor is a m/c used to compress the air & raise its pressure.

Types :- 1) Reciprocating 2) Rotary

Compression Ratio :- It is the ratio of discharge pressure to the inlet pressure.

Volumetric efficiency :- It is the ratio of actual free air delivered to the displacement of the compressor.

Rotary Compressor :-

a) Positive displacement — The air is squeezed by trapping in two parts.
1) Roots blower
2) Vane blower
3) Screw compressor

b) Non-Positive displacement — Rise of air pressure due to dynamic effect.
1) Radial or centrifugal compressor.
2) Axial flow

Fluid

Viscosity:- It is the property of a fluid by virtue of which it offers resistance to the movement of one layer of fluid over an adjacent layer.

Newton's law of Viscosity

The shear stress is proportional to the force applied & inversely proportional to the area in contact.

$$\tau = F/A = \mu \frac{V}{Y} = \mu \frac{du}{dy}$$

or shear stress is proportional to the velocity gradiant of the fluid.

μ = Coefficient of viscosity.

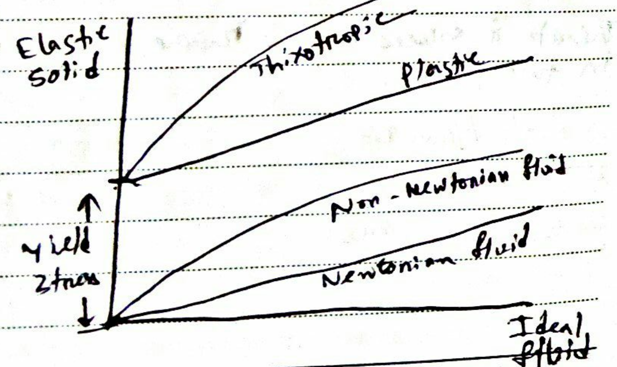
$\nu = \mu/\rho$ = kinematic viscosity.

Unit of viscosity

$\mu = N s/m^2$ OR $= kg/m.s$ } SI

$= kg(f) sec/m^2$

$= (gram/cm\text{-}sec)$ → Poise



Newtonian fluid → Their viscosity is not dependent on the rate of angular deformation.

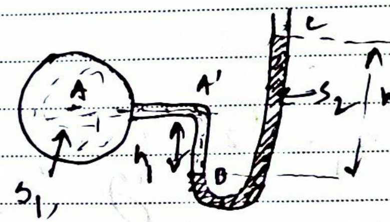
kinematic viscosity $\nu = \mu/\rho$
unit $= m^2/s$, or (cm^2/sec) → stoke

Fluid pressure & Measurement:-

1) Manometer
   a) Simple Manometer
   b) Differential Manometer
2) Mechanical Gages

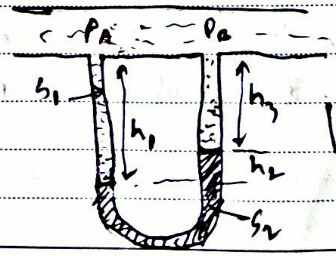
i) Piezometer:- Simplest of Manometers. (for moderate pressure) $[P = \rho g h]$

(ii) U-tube manometer: (for higher pressures)



A' point, B point, (C point)

$$\frac{P_A}{\rho g S_1} + h_1 - h_2\left(\frac{S_2}{S_1}\right) = 0$$



$$\frac{P_A}{\rho g S_1} + h_1 - h_2\left(\frac{S_2}{S_1}\right) - \frac{P_B}{\rho g S_1} - h_3 = 0$$

$$(\because h_1 - h_3 = h_2)\left(\frac{P_A - P_B}{\rho g S_1}\right) + h_2 - h_2\left(\frac{S_2}{S_1}\right) = 0$$

$$\Rightarrow \frac{P_A - P_B}{\rho g S_1} = h_2\left\{\left(\frac{S_2}{S_1}\right) - 1\right\}$$

$$\frac{P_A - P_B}{\rho g} = h_2 (S_2 - S_1)$$

Buoyancy :- The tendency for an immersed body to be lifted up in the fluid, due to opposite force or the action of gravity, is known as Buoyancy.

Archimedes' Law :- It states that when a body is immersed in a fluid either wholly or partially it is lifted up by a force which is equal to the weight of the fluid displaced by the body.

Continuity equation :-

$\rho A_1 V_1 = \rho A_2 V_2$ (V → velocity, A → Area)

$m_1 = m_2$ ($\frac{m}{V} = \rho$, $m = \rho V$, ρ → density, V → Volume)

$Q_1 = Q_2$

Bernoulli's equation

$$\frac{P_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + z_2 + h_L$$

(h_L → head loss)

Venturi Meter :- A venturimeter is a device which is used for measuring the rate of flow of fluid through a pipe.

Euler No :- $E_u = \frac{V}{\sqrt{P/\rho}}$, Inertia / Pressure force

Orifice Meter :- It is another simple device used for measuring the discharge through pipe.

Pitot Tube :- A pitot tube is a simple device used for measuring the velocity of flow.

$\Delta P = \rho g h$ $V = \sqrt{2gh}$

Laminar flow :- $R_e = \frac{\rho V L}{\mu}$ or $\frac{\rho V D}{\mu}$ (L → length, D → Dia)

$Re < 2000$, is called laminar flow in pipes.

$Re < 3 \times 10^5$, is called laminar flow in plate.

Turbulent flow

$Re > 4000$, is called Turbulent flow in pipes

$Re > 6 \times 10^5$ is called Turbulent flow in plate.

Notch :- Notch may be defined as an opening provided in the side of a tank such that the liquid surface in the tank is below the top edge of the opening.

Reynold No :- Inertia / Viscous force

Large value means Inertia force is high

Small " " Viscous force is high

Most economical section's :-

a) for Rectangular section :- $y = B/2$ [y = height, B = width]

or $R = y/2$ [R = hydraulic radius]

b) for Trapizoidal section :- $R = y/2$

c) for Triangular section :- $R = \frac{y}{2\sqrt{2}}$

Compressible fluid

Math

A test plane is described as having attained a flight speed of Ma = 2 at an altitude of 16 km where the temp. is approximately −56.5°C, assuming k = 1.4, R = 287 J/kg K, determine the speed of the airplane.

Given, $T = -56.5°C = 216.5 K$

$k = 1.4$

$R = 287$ J/kgK.

$k = \gamma = 1.4$

$\therefore C = \sqrt{kRT}$ [where, sound speed C]

$= \sqrt{1.4 \times 287 \times 216.5}$

$= 294.9 \approx 295$ m/s

Now as given, Ma = 2, we know

$V/C = Ma$

$V/295 = 2$

$\therefore V = 590$ m/s ≈ 2124 km/hr

Strength of Materials

Stress :- The internal force per unit area at any section of the body (i.e undergo the pressure), is called Stress.

$\sigma = P/A$ Pa or N/m²

Two Types :- i) Compressive 2) Tensile

Strain :- The deformation per unit length is known as strain.

$\epsilon = \delta l / l$

Two Types :- i) Compressive 2) Tensile.

Young's Modulus of Elasticity :-

According to hook's law, with in elastic limit the stress is directly proportional to the strain.

$\sigma \propto \epsilon$

$\sigma = E\epsilon$

$\therefore \frac{P}{A} = E\frac{\delta l}{l}$

$\therefore E = \frac{Pl}{A\delta l}$

$\therefore \delta l = \frac{Pl}{AE}$

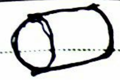
Bulk Modulus

$K = \frac{m \cdot E}{3(m-2)}$, $m = \frac{1}{\text{Poison Ratio}}$

Mod of Rigidity

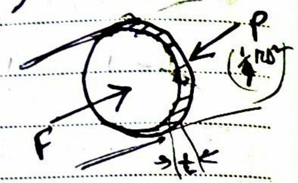
$C = \frac{m \cdot E}{2(m+1)}$

$E = \frac{9K \times C}{3K + C}$



Stress inside Pipes :-

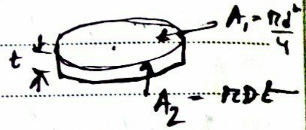
Longitudinal Stress (~~Normal~~ to the direction of flow)



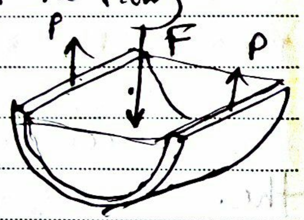
$\therefore F = P$

$P_1 \frac{1}{4}\pi D^2 = \sigma_L \times \pi D t$

$\therefore \boxed{\frac{P_1 D}{4t} = \sigma_L}$



Tangential Stress (Normal to the direction of the flow)

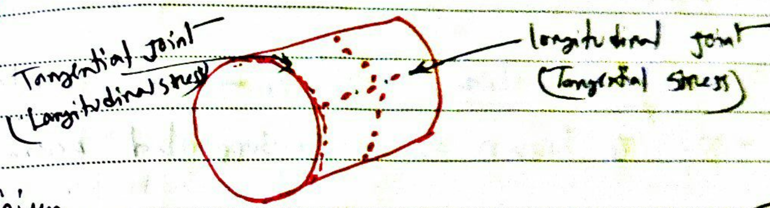


$F = 2P$

$P_1 \times DL = 2 \times Lt\sigma$

$\therefore \boxed{\sigma_t = \frac{P_1 D}{2t_1}}$

Problem :- The strength of Longitudinal joint in Fig-1 is 33 kips/ft, whereas for tangential joint is 16 kips/ft. Calculate the max diameter of the cylinder tank if the internal pressure is 150 PSI



Given

Ans :- Internal pressure $P = 150 \frac{lb}{in^2} \times \left(\frac{12\ in}{ft}\right)^2 = 21600\ lb/ft^2$

Longitudinal stress = 16000 lb/ft²

Tangential stress = 33000 lb/ft²

Now

For Longitudinal stress we know,

$\sigma_L = \frac{PD}{4t}$

$\therefore \frac{16000\ lb/ft}{t} = \frac{21600\ lb/ft^2 \times D}{4 \times t}$ [Let, t=1]

$D = 2.96\ ft = 35.55\ in$

For Tangential Stress we know

$\sigma_t = \frac{PD}{2t}$

$\frac{33000}{t} = \frac{21600 \times D}{2 \times t}$

$\Rightarrow D = 3.05\ ft = 36.67\ in$ Ans

So, Smallest dia = 35.55 in

Ans

Types of Beams

1) Cantilever Beam :- A beam fixed at one end and free at the other end is known as a cantilever beam.

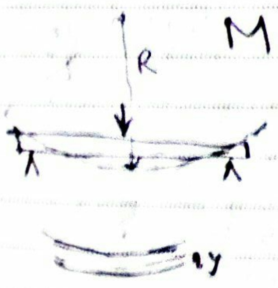
2) Simply Supported Beam: A beam supported at its both ends is known as simply supported beam.

3) Over hanging beam: A beam having its end portion extended beyond the support, is known as overhanging beam.

4) Fixed beam: Both ends fixed is called fixed beam.

5) Continuous beam: A beam having support more than two is called continuous beam.

Bending Equation for Beams :-



$M = \frac{\sigma I}{y}$ or $M = \frac{EI}{R}$

$\sigma = \frac{My}{I}$

Bending Moment = M
Young's Modulus = E
Moment of inertia = I
Radius of curvature = R
Distance of extreme fibre from neutral axis = y

Deflection of Beams :-

$M = EI \frac{d^2y}{dx^2}$

Euler equation for axial load at Beam or Column :-

critical load $P = \frac{\pi^2 EI}{l^2}$

both end hinged	$l = L$
one end fixed other free	$l = 2L$
Both ends fixed	$l = \frac{L}{2}$
one end fixed other end hinged	$l = \frac{L}{\sqrt{2}}$

Problem: Consider a rectangular steel bar 40mm×50mm in cross section, pinned at each end & subjected to axial compression. The bar is 2m long & E = 200 GPa. Determine Buckling load & axial stress using Euler's formula.

Sol

Given

$E = 200\times10^9$ Pa

b = 50mm
h = 40mm

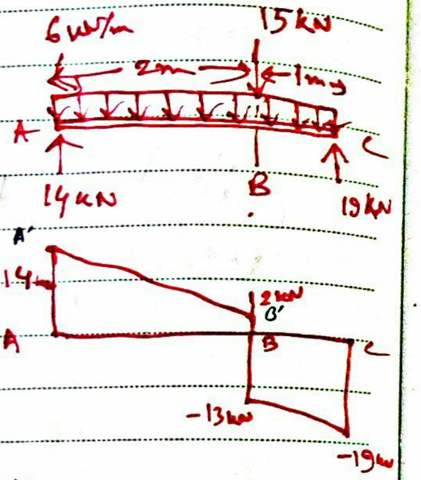
$I = \frac{1}{12}bh^3 = \frac{1}{12}\times\frac{50}{1000}\times\left(\frac{40}{1000}\right)^3$
$= 2.67\times10^{-7}\ m^4$

$\therefore P_{cr} = \pi^2 EI/l^2$ [both end hinged $l = L$]

$= \frac{\pi^2\times200\times10^9\times2.67\times10^{-7}}{2^2} = 131.76\times10^3$ N
$= 131.76$ kN

$\therefore$ Stress $\sigma = P/A = 131.76/2\times10^{-3} = 65,880$ kN
$= 65.8$ MPa

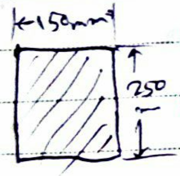
Prob: A beam 150 mm wide by 250 mm deep supports the loads shown in fig-1, Determine max^m flexural stress.



M_{at} point B (area of ABB'A')

$\frac{1}{2} \times 2 \times 12 + 2 \times 2 = 16$ kN.m

M = 16 kN.m



we know

$$\sigma = \frac{My}{I}$$

$y = 125$ mm $= .125$ m

$I = \frac{1}{12} \times \left(\frac{150}{1000}\right) \times \left(\frac{250}{1000}\right)^3 = 1.95 \times 10^{-4}$ m^4

$= \frac{16 \times .125}{1.95 \times 10^{-4}}$

$= 10256.4$ kN/m^2

$= 10.25$ MPa

Ans

⊞ Given Temperature of air $= 30°C$, Pressure $= 766$ mm of Hg then findout the density of air.

Given, $T = 30°C = 303$ K,

$P = \frac{766}{760} = \frac{766}{760} \times 101.325 \times 10^3$ Pa $= 102.125$ kPa

we know, $P = \rho RT = \rho \times 287 \times 303$

$\therefore \rho = \frac{102.125 \times 10^3 \text{ Pa}}{287 \times 303} = 1.17$ $\frac{N/m^2}{J/kg \cdot K \times K}$

kg/m^3

$\frac{N/m^2}{Nm/kg} = \frac{N}{m^2} \times \frac{kg}{Nm}$ kg/m^3

⊞ Given, Discharge of Pump $Q = 20$ m^3/hr, Head $H = 30$ m motor efficiency $\eta = 90\%$, find Required Power.

$$P = \frac{\gamma QH}{\eta} = \frac{9810 \times .0055 \times 30}{.9}$$

$= 1798.5$ W

$= 1.79$ kW

$= 1.8$ kW

Ans

⊞ Find highest possible Theoritical efficiency of heat engine, Given, Temp of reservoir is 2100°C, cooling water 15°C

we know for carnot cycle $\eta = \frac{T_1 - T_2}{T_1}$

$T_1 = 2100 + 273 = 2373$ K

$T_2 = 288$ K

$= \frac{2373 - 288}{2373}$

$= 87.86\%$

Ans

⊞ A compressor air Tank Vol^m 0.84 m^3, filled with air gause pressure of 50 kPa, Find the density & weight of air. Assume the Temp of air 30°C & atmospheric pressure 101 kPa.

Abs. Press :- $P = P_a + P_g = (101 + 50) = 151$ kPa $= 151 \times 10^3$ Pa

air Temp $T_1 = 30°C + 273 = 303$ K

Vol $V = .84$ m^3

$P = \rho RT$

$\therefore \rho = \frac{151 \times 10^3}{287 \times 303} = 1.23$ kg/m^3

$m = \rho V = 1.73 \times .84 = 1.45$ kg

$W = mg = 14.22$ N

COP $= \frac{T_1}{T_1 - T_2} = \frac{308}{..} = 7.7$

A tube filled with fluid of sp. gravity .9, depth 120cm, find the pressure at that depth in KN/m^2

$Sp.\ gravity = \frac{W_{oil}}{W_{water}}$

$\therefore .9 = \frac{W_{oil}}{1000\times 92.81}$

$\therefore W_{oil} = .9 \times 9810 = 8829\ \frac{kg}{m^2} \times ms^{-2} = kg/m^2s^2$

$\therefore$ we know, $P = wh$

$= 8829 \times 1.2 = 10594.8\ Pa$

$= 10.59\ kPa$ Ans

A 250×150 mm of rectangular beam has its bending moment 30 KN-m, what is the flexural stress?

Given, $b\times h = 250\times 150 = .25 \times .15$

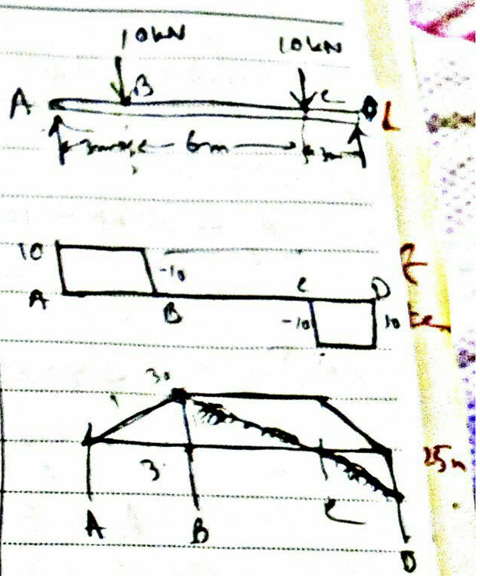
$I = \frac{bh^3}{12} =$ ~~.00019~~ m^4 $.000070$

flexural stress is $\sigma = \frac{Mc}{I} = \frac{30\times10^3 \times h/2}{bh^3/12} = \frac{30\times10^3\times 6}{bh^2}$

$= \frac{30\times10^3\times0.075}{.000070}$ $= \frac{30\times10^3\times6}{.250\times(.15)^2}$

$=$ $= 32\times10^6\ Pa$

Draw shear force Diagram & Bending moment diagram.



$\uparrow \Sigma F_y = 0$

$R_1 + R_2 - 10k - 10kN = 0$

$\therefore R_1 + R_2 = 20kN$

Again, $\Sigma M_A \circlearrowright + = 0$

$-10\times3 - 9\times10 + R_2\times12 = 0$

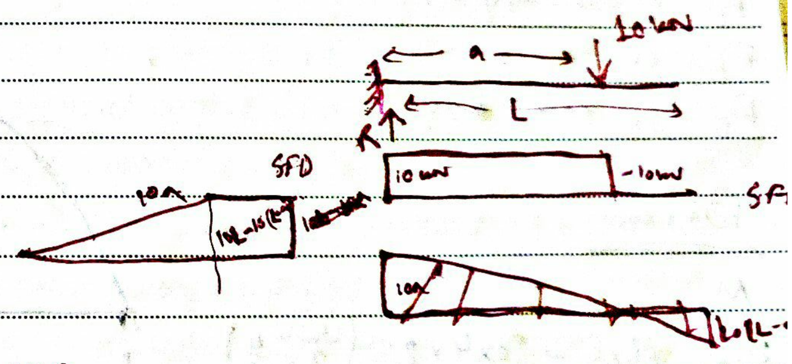
$\Rightarrow R_2 = \frac{120}{12} = 10kN$

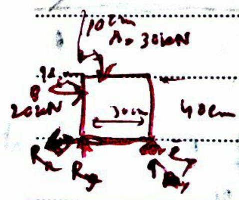
$R_1 = 10kN$

$M_C = 10\times90 - 10\times6$

$= 90 - 60 = 30$

$M_D = 10\times12 - 10\times90 - 10\times3$





$\Sigma F_y \uparrow + = 0$

$C_y + R_y = 30kN$

$C_y = 30kN - R_y$

$\Sigma F_x \rightarrow + = 0$

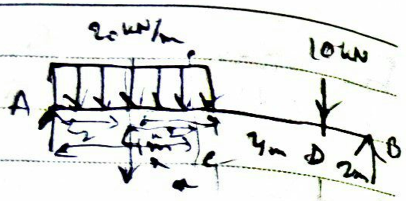
$-R_x + 20 = 0$

$R_x = 20kN$

$\Sigma M_R = 0$

$C_y\times30 - 10\times30 - 20\times30 = 0$

$C_y = 30$



Shear force Values

$\uparrow + \sum F_y = 0$

$A_y - 80\,kN - 10\,kN + B_y = 0$

$\therefore A_y + B_y = 90\,kN$

$\sum M_A \curvearrowleft + = 0 \quad -80\times2 - 8\times10 + 10B_y = 0$

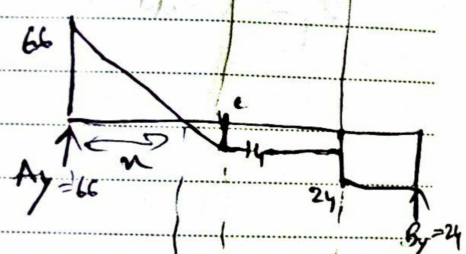
$\therefore B_y = \frac{240}{10} = 24\,kN$

$\therefore A_y = 90 - 24 = 66\,kN$

$\therefore A_y = 66$

$B_y = 24$

SFD



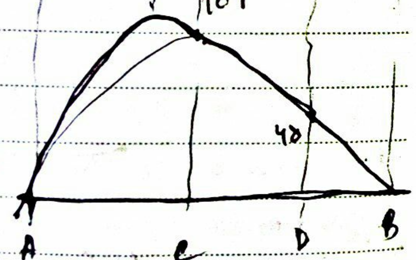
$F_A = 66$

$F_C = 66 - 80 = -14$

$F_D = 66 - 80 - 10 = -24$

$F_B = 66 - 80 - 10 + 24 = 0$

BMD



$M_A = 0$

$M_C = 66\times4 - 20\times4\times2$ (where $2 = \frac{4}{2}$ center of gravity for the load)

$= 104$

$M_D = $ [illegible]

$= 66\times8 - 20\times4\times6 = 48$

$M_B = 66\cdot10 - 20\times4\times8 - 20 = 0$

To find Max Moment Point x,

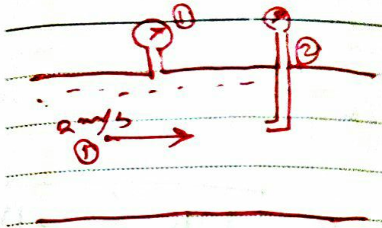
$\sum M_x = 0$

$66x - (20x)\frac{x}{2} = 0$

$66x - 10x^2 = 0$ [illegible]

$5x^2 - 33x = 0$ $10x^2 - 66x = 0$

$x(5x - 33) = 0$



$P_1 = 100\,kPa$

$V = 2\,m/s$

What will be the pressure at the Pitot tube ?

we know,

$V = \sqrt{2gh}$

$2 = \sqrt{2gh}$

$h = .204\,m$

$\therefore \Delta P = \gamma h = 9810\times.204$

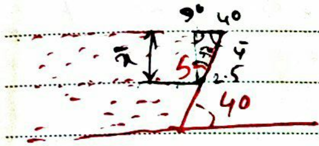
$= 2001.24\,Pa$

$= 2\,kPa$

$\therefore P_2 = P_1 + \Delta P$

$= 100\,kPa + 2\,kPa$

$= 102\,kPa$ Ans



here, width of the plate 3m

What will be the resultant force on the plate.

$\bar{x} = 2.5 \sin 40°$

$= 1.607\,m$

$\therefore P = 9810 \times (5\times3) \times 1.607$

$= 236470.05\,Pa$

$= 236.47\,kPa$ Ans

$66x - 40x^2 = 0$

$\Rightarrow 40x^2 - 66x = 0$

$\Rightarrow x(40x - 66) = 0$

$x = 0, \; 1.65\,m$

$66x - (20x)(x-2) = 0$

$66x - 20x^2 + 40x = 0$

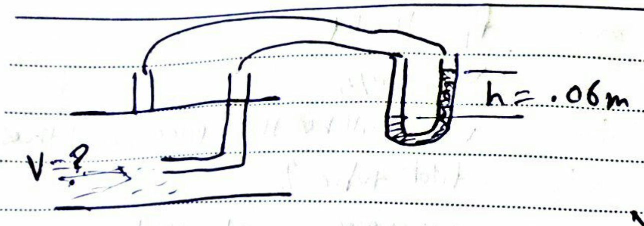
$16x - 20x^2 = 0$

$20x^2 - 16x = 0$

$5x^2 - 4x = 0$

$x(5x - 4) = 0$

$x = 4/5 = .8\,m$



$$V = \sqrt{2gh\left(\frac{S_m}{S} - 1\right)}$$

Sp. Gravity S_m = Oil or fluid in Manometer

Sp. Gravity S = flowing fluid

S_m = .91

S_{air} = .0012

$\therefore V = 29.85 \text{ m/s}$

for sphere

$$\frac{\theta}{\theta_i} = e^{-Bi\,Fo} = e^{-\frac{h_c r}{k} \times \frac{\alpha t}{r^2}} = e^{-\frac{ht}{\rho c r}}$$

$\because \alpha = k/\rho c$

for sphere

$Bi = \frac{h_c r}{k}$

$F_o = \frac{\alpha t}{r^2} = \frac{k \times t}{\rho c r^2}$

35th BCS Written Exam

Mechanical Problems Solution

3(b) A steel ball [c = .46 kJ/kg-k, k = 35 W/m k] 5.0 cm in diameter & initially at a uniform temp. of 450°c is suddenly placed in a controlled environment in which the temp is maintained at 100°c. The convective heat transfer coefficient is 10 W/m²k. Calculate the time required for the ball to attain a temp. of 150°c.

Ans:- Given,

D = 5 cm = .05m

c = .46 kJ/kgk

k = 35 W/m k

h = 10 W/m²k

T_1 = 450°c = 723 k

T_∞ = 100°c = 373 k

T_2 = 150°c = 423 k

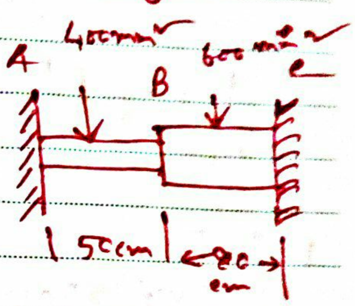
we know, ρ_{steel} = 7800 kg/m³

We know, Transient heat conduction

$$\frac{T_2 - T_\infty}{T_1 - T_\infty} = \frac{423 - 373}{723 - 373} = e^{-\frac{10 \times t}{7800 \times .46 \times 105}}$$

6(b) A steel rod ABC is firmly held between two rigid support A & C As shown in Fig 1.:

Find the stress developed in the two portions of the rod where it is heated through 15K. Take $\alpha = 12\times10^{-6}/K$ & $E = 200\ GPa$.



Given,

$T = 15K, \quad \alpha = 12\times10^{-6}/K$

$E = 200\ GPa$

$A_1 = 400mm^2 = 4\times10^{-4}m^2$

$A_2 = 600mm^2 = 6\times10^{-4}m^2$

$l_1 = 50cm = .5m$

$l_2 = 80cm = .8m$

~~Thermal stress $P/A = \sigma_{th} = \alpha T E = 12\times10^{-6}\times15\times200\times10^{9}$~~

~~$= 36\times10^{6}$ Pa~~

$\delta l_{th_1} = l_1 \times \alpha T$

$= .5\times12\times10^{-6}\times15$

$= 9\times10^{-5}m$

$\delta l_{th_2} = l_2\times\alpha T$

$= .8\times12\times10^{-6}\times15$

$= 1.44\times10^{-4}m$

$\delta l_1 + \delta l_2 = \delta l_{m_1} + \delta l_{m_2}$

$\frac{PL_1}{A_1E} + \frac{PL_2}{A_2E} = .9\times10^{-5} + .144\times10^{-4}$

$P\left(\frac{.5}{4\times10^{-4}\times200\times10^{9}} + \frac{.8}{6\times10^{-4}\times200\times10^{9}}\right) = 2.34\times10^{-4}$

$P\left(1.292\times10^{-8}\right) = 2.34\times10^{-4}$

$P = 18111.4$ Pa

$= 18.11$ kPa

$\sigma_{AB} = \frac{P}{A_1} = \frac{18\times10^{3}}{4\times10^{-4}} = 45$ GPa

$\sigma_{BC} = \frac{P}{A_2} = \frac{18\times10^{3}}{6\times10^{-4}} = 30$ GPa

Ans:- 45 GPa, 30 GPa

7) (d) An engine works between the temp. limits of 1000°C & 0°C. What can be the max thermal efficiency of the engine.

Given $T_1 = 1000°C = 1273\,K$

$T_2 = 0°C = 273\,K$

max efficiency $\eta_{carnot} = 1 - \frac{T_2}{T_1}$

$= 1 - \frac{273}{1273}$

$= 78.55\%$

Ans:

(e) 0.1m³ of air at a pressure of 1.5 bar is expanded isothermally to 0.5m³. Calculate the final pressure & heat supplied during the process.

Given $V_1 = 0.1\,m^3$ $P_1 = 1.5 = 151.2\,kPa$

$V_2 = 0.5\,m^3$ $P_2 = ?$

$P_1V_1 = P_2V_2$

$\therefore P_2 = \frac{P_1V_1}{V_2} = \frac{151.2\times10^{3}\times0.1}{0.5} = 30.24\,kPa$

$P_1V_1 = P_2V_2 = 15120\,J = 15.12\,kJ$

$Q = W = 2.3 P_1 V_1 \log\left(\frac{V_2}{V_1}\right)$

$= 24307$ J

$= 24.30$ kJ

Ans

(8) (c) Find the power transmitted by a belt over a pulley of 60cm diameter at 200 rpm the coefficient of friction between the belt & pulley is 0.25, angle of lap 160° & max tension in the belt is 2500 N.

Given, Pulley dia $D = 60$ cm $= .6$ m

rpm $N = 200$ rpm

$f = .25$

$\theta = 160°$

$2500\ N = T_1$

~~$T = (F - \mu F) \times \frac{d}{2}$~~

~~$= 562.5$ N·m~~

~~$P = \frac{2\pi N T}{60}$~~

~~$= \frac{2 \times 3.1416 \times 200 \times 562.5}{60}$~~

~~$= 11.78$ kW~~

We know

$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\theta$

$= .25 \times \frac{160 \times \pi}{180}$

$= 0.698$

$\therefore \ln\left(\frac{T_1}{T_2}\right) = 0.698$

$\therefore \frac{T_1}{T_2} = e^{0.698} = 2.01$

$\therefore T_1 = 2.01 \times T_2$

$\therefore T_2 = T_1 / 2.01 = 1243.8$ N

Velocity $V = \frac{\pi d N}{60}$

$= \frac{3.1416 \times .6 \times 200}{60}$

$= 6.28$ m/s

Power $P = (T_1 - T_2) \times 6.28$

$= 7888.9 \approx 7889$ W

$\simeq 7.8$ kW Ans

Date

11(e) A 4-stroke diesel engine has a cylinder bore of 150mm & a stroke of 250 mm. The crank shaft speed is 300rpm & the fuel consumption is 1.2 kg/hr. having a calorific value of 39900 kJ/kg. The Indicated mean effective pressure is 5.5 bar. If the comp ratio is 15 & cut off is 1.8, calculate the $\eta_{ind\ thermal}$ & air standard efficiency.

Given,

$d = 150mm = .15m$, $l = 250mm = .25m$

$n = 300rpm$, $f = 1.2kg/hr$

$CV = 39,900\ kJ/kg$

$P_m = 5.5 bar$
$= 557.3 \times 10^3 Pa$

$r = 15$

$\rho = 1.8$

$A = \frac{\pi d^2}{4}$
$= 0.01767$

We know, Indicated power

$$I.P = \frac{100\ k P_m LAN}{60} \qquad k = 1$$

$$= \frac{100 \times 1 \times 557.3 \times 10^3 \times .25 \times 0.01767 \times}{60}$$

$$= 1230.93\ kW$$

Let, $\gamma = 1.4$

$$\eta_{i_{th}} = \frac{I.P}{m \times C.V} = \frac{1230.93 \times 10^3}{\frac{1.2}{3600} \times 39900 \times 10^3}$$

$$\eta_{air} = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^\gamma - 1}{\gamma(\rho-1)}\right] = 92.55\ \%$$

Date

air standard efficiency

$$\eta_{air} = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right]$$

$$= 1 - \frac{1}{15^{.4}}\left[\frac{1.8^{1.4}-1}{1.4(1.8-1)}\right]$$

$$= 1 - \frac{1}{15^{0.4}}\left(\frac{1.277}{1.12}\right)$$

$$= 1 - \frac{1.14}{15^{0.4}} = 0.614$$

$$= 61.4\ \%\ \text{Ans}$$

Ans: ~~92.53 %~~

61.4 %

Date

12 (b) A large vertical plate 4.0 m high is maintained at 60°C & exposed to atmospheric air at 10°C. Calculate the heat transfer if the plate is 10m wide.

Given, $H = 4m$ $\quad T_1 = 60°C = 333k$

$W = 10m$ $\quad T_0 = 10°C = 283k$

$\therefore A = 40m^2$

Let h = convective heat transfer coefficient = 5

$= 5\ w/m^2k$

$\therefore$ We knows

$Q = hA\,dT$

$= 5 \times 40 \times 50$

$= 10000\ w$

$= 10\ kw$

Ans: 10kw

ব্যাকরণ

শুদ্ধ বানান

- ~~অক~~ অকস্মাৎ
- অগ্ন্যাশয়
- অগ্ন্যুৎপাত
- অত্যধিক
- অনিন্দ্য
- অনূর্ধ্ব
- অন্তঃসত্ত্বা
- অন্তর্জ্বালা
- অন্ত্যেষ্টিক্রিয়া
- অপাংক্তেয়
- অশ্বত্থ
- অন্বেষণ
- অনসূয়া
- অদ্যাপি
- অভ্যন্তরীণ
- অন্তর্ভুক্ত
- অদ্ভুত
- আকাঙ্ক্ষা
- আর্দ্র
- আদ্যক্ষর

- আনুষঙ্গিক
- আবিষ্কার
- আভিধানিক
- আহ্নিক
- ইন্দ্রিয়
- ইতোমধ্যে
- ইন্দ্রজালিক
- উচ্ছ্বাস
- উজ্জ্বল
- উদ্যুক্ত
- উপর্যুক্ত
- উদ্গিরণ
- ঊর্ধ্বলোক
- ঊর্ধ্ব
- এতদ্ব্যতীত
- ঐন্দ্রজালিক
- ঐশ্বর্য
- ঔজ্জ্বল্য
- কনিষ্ঠ
- কাঙ্ক্ষিত
- কৃত্তিবাস
- কঙ্কণ
- কনীনিকা
- সুসম্পাদিত
- সন্নিহিত

- গৃহিণী
- গণনা
- গীতাঞ্জলি
- জলোচ্ছ্বাস
- জাজ্বল্যমান
- জীবাশ্ম
- জ্যৈষ্ঠ
- জ্যেষ্ঠ
- জ্যোৎস্না
- তত্ত্ব
- তাত্ত্বিক
- তিতিক্ষা
- ত্বরণ
- দধীচি
- দাতব্য
- দারিদ্র্য/দরিদ্রতা
- দীনতা
- দুর্নিরীক্ষ্য
- দ্বন্দ্ব
- দ্বিধা
- দ্বৈত
- দূষণ
- দুর্দশাগ্রস্ত
- ধ্বন্যাত্মক
- নঞর্থক
- নিক্কণ
- নিশীথ
- নিরীক্ষণ
- নিরীহ
- নৈঋত

- ন্যূনতম
- ~~নিশীথী~~ নিশীথিনী
- ন্যূনাধিক
- নিপীড়িত
- পঙ্ক্তি
- প্রতিদ্বন্দ্বিতা
- প্রতিদ্বন্দ্বী
- প্রত্যূষ
- প্রসারিণী
- পৈতৃক
- পিপীলিকা
- পাষাণ
- পুরস্কার
- প্রতিযোগিতা
- প্রণয়ন
- পুঙ্খানুপুঙ্খ
- প্রাণিবিদ্যা
- বয়োজ্যেষ্ঠ
- বাল্মীকি
- বিবাদী
- বিভীষিকা
- বুদ্ধিজীবী
- বৈশিষ্ট্য
- ব্যক্তিস্বাতন্ত্র্য
- ব্যঞ্জনা
- ব্যতিক্রম
- ব্যতীত
- ব্যবচ্ছেদ
- ব্যবস্থা
- বৃহস্পতি
- ব্যূহ
- ক্রন্দন
- ব্রাহ্মণ
- ভাগীরথী
- ভৌগোলিক
- ভ্রাতৃত্ব
- ভ্রাতুষ্পুত্র
- ভ্রাম্যমাণ
- ভবিষ্যৎ

- মন্বন্তর
- মরীচিকা
- মাহাত্ম্য
- মুহুর্মুহু
- মুমূর্ষু
- মুহূর্ত
- মৃণালিনী
- মনোহারিণী
- মনীষী
- যদ্যপি
- রূপায়ণ
- লক্ষণ
- শারীরিক
- শাশ্বত
- শ্মশ্রু
- শ্রদ্ধাঞ্জলি
- শুশ্রূষা
- শুচিস্মিতা
- ষাণ্মাসিক
- সত্ত্বেও
- সমীচীন
- সমভিব্যাহারে
- ষাণ্মাসিক

- Abrogate → রদ করা
- Abscender → ~~ফেরারী~~ ফেরারি
- Affiliation → সমষ্টীকরণ
- Allegation → অভিযোগ
- Amalgamation → সংমিশ্রণ
- Ambiguous → অস্পষ্ট
- Anthropology → নৃতত্ত্ব
- Apartheid → বর্ণবৈষম্য
- Assessment → নির্ধারণ
- Amendment → সংশোধনী
- Banquet → ভোজসভা
- Barter - বিনিময়
- Biennial → দ্বিবার্ষিক
- Bona fide → প্রকৃত, বিশ্বস্ত
- Census → আদমশুমারি
- Charter - সনদ
- Context → প্রসঙ্গ
- Deed → দলিল
- Dialect → উপভাষা
- Disarmament → নিরস্ত্রীকরণ
- Dyarchy → দ্বৈত শাসন
- Divulge → প্রকাশ করা
- Monetary Policy → মুদ্রানীতি
- Mortgage → বন্ধক
- Nomads → যাযাবর
- Ombudsman → ন্যায়পাল
- Osteology → অস্থিবিজ্ঞান
- Pamphlet → পুস্তিকা
- Ordnance → সমরাস্ত্র
- Ordinance → অধ্যাদেশ

বঙ্গানুবাদ

- Etiquette → শিষ্টাচার
- Manifesto → ইশতেহার
- Meteorology → আবহাওয়া বিদ্যা
- Knave → প্রতারক
- Monarchy → রাজতন্ত্র
- Phonology → ভাষার ধ্বনি বিজ্ঞান
- Pleadings → আরজি ও লিখিত জবাব
- Philology → ভাষাতত্ত্ব
- Protocol → দলিলের খসড়া
- Referendum → গণভোট
- Subsidiary → সহায়ক
- Provoke → উস্কানি দেয়া
- Epicurism → ভোগবাদ

সমার্থক শব্দ

অগ্নি → আগুন, অনল, হুতাশন, সর্বভুক, শিখা, পাবক, দহন, বহ্নি, বৈশ্বানর, সর্বশুচি।

অন্ধকার → আঁধার, তিমির, তমসা, তম, আঁধি, আন্ধার; তমিস্র

অশ্ব → ঘোড়া, ঘোটক, বাজী, তুরগ, তুরঙ্গ, হয়, তুরঙ্গম।

আকাশ → গগন, নভঃ, আসমান, অন্তরীক্ষ, দ্যুলোক, ব্যোম, শূন্যলোক, খ, অম্বর, দ্যু, ছায়ালোক, নভোমণ্ডল।

মেঘ:— বারিদ, জলদ, জলধর, নীরদ, অম্বুদ, জীমূত, পয়োধর।

জল → অম্বু, জীবন, নীর, পানি, সলিল, বারি, অপ্, পানীয়, অপ, তোয়, উদক।

সমুদ্র → সাগর, বারিশ, জলধি, বারিধি, অর্ণব, পাথার, দরিয়া, নীলাম্বু, বারীন্দ্র, সিন্ধু,

নদী → গাঙ, তটিনী, স্রোতস্বিনী, স্রোতস্বতী, প্রবাহিনী, কল্লোলিনী, সরিৎ,

পৃথিবী → ধরণী, দুনিয়া, জগৎ, ক্ষিতি, অবনী, বসুন্ধরা, বসুমতি, ভুবন, ~~ভূলোক~~ ভূলোক, মহী, মেদিনী, পৃথ্বী, বসুধা, ভূ, অখিল, মর্ত্য, ব্রহ্মাণ্ড, ধরিত্রী।

চাঁদ → চন্দ্র, বিধু, শশাঙ্ক, শশধর, নিশাকর, সুধাংশু, হিমাংশু, ইন্দু, শশী, সোম, মৃগাঙ্ক, সিতাংশু, কলাধর, নিশানাথ,

সূর্য → আদিত্য, তপন, দিবাকর, রবি, মিহির, ভাস্কর, মার্তণ্ড, সবিতা, আফতাব, অর্ক, ভানু, প্রভাকর, দিনমণি, দিনপতি।

বন — অরণ্য, কানন, কুঞ্জ, অটবী, জঙ্গল,

বাতাস — বায়ু, পবন, হাওয়া, সমীরণ, সমীর, অনিল, মরুৎ, মারুত, প্রভঞ্জন, গন্ধবহ।

বিটপী — গাছ, তরু, উদ্ভিদ, মহীরুহ, বৃক্ষ, অটবী, দ্রুম, শাখী, পর্ণী, শিখরী,

Tungsten inert-gas (TIG) arc welding: In TIG welding, the heat is produced from an arc between the non-consumable tungsten electrode and the work piece. The welding zone is shielded by an atmosphere of inert gas supplied from a suitable source. The direct current with straight polarity is used for welding copper alloys and stainless steel, whereas the reversed polarity is used for magnesium. The alternating current is more versatile in welding for steel, cast iron, aluminium and magnesium.

21. Define Reynolds number, Nusselt number, Froude number, Prandtl number and Mach number with their significance.

Answer:

Types of force present in moving fluid:

(a) **Inertia Force:** product of mass and acceleration of the flowing fluid.

(b) **Viscous Force:** Product of shear stress due to viscosity and cross sectional area of flow.

(c) **Gravity Force:** Product of mass and acceleration due to gravity of fluid.

(d) **Surface Tension force:** Product of surface tension per unit length and length of the surface of flowing liquid.

(e) **Pressure Force:** Product of intensity of pressure and area of flowing fluid.

(f) **Elastic Force:** Product of elastic stress and area of the flowing liquid.

(g) **Head:** Head is a concept that relates the energy in an incompressible fluid height of an equivalent static column of that fluid.

Some Dimensionless Number

Reynolds Number: It is defined as the ratio of the inertia force to the viscous force. i.e.,

Re = Inertia Force/Viscous Force= $\rho VD/\mu = VD/\vartheta$

Significance:

- Reynolds number signifies the relative predominance of the inertia to the viscous forces occurring in the flow systems.
- Higher the Reynolds number the greater will be the relative contribution of inertia effect. Smaller the value of Re, the greater will be the relative magnitude of the viscous stresses.
- Reynolds number is taken as an important criterion of kinematic and dynamic similarities in forced convection heat transfer.
- It indicates that the flow is laminar or turbulent. For pipe flow if Re <2000, the flow is laminar, if Re>4000, the flow is turbulent.
  If 2000 >Re<4000 it is transition. For flat plate in case of laminar flow Re< 50,000 and in case of turbulent, Re is between 50,000 to 100,000.

Prandtl Number (Pr): It is the ratio of kinematic viscosity (ϑ) to the thermal diffusivity (α). i.e.,

$$Pr = \vartheta / \alpha$$

Kinematic viscosity indicates the impulse transport through molecular friction whereas thermal diffusivity indicates the heat energy transport by conduction process.

Significance:

- Prandtl number provides a measure of the relative effectiveness of the momentum and energy transport by diffusion.
- Prandtl number is a connecting link between velocity field and temperature field.

Nusselt Number (Nu): It is the ratio of heat flow rate by convection process under a unit temperature gradient to the heat flow rate by conduction process under a unit temperature gradient through a stationary thickness of L meters. i.e.

Nu= hL/K

Significance:

- The Nusselt number represents the enhancement of heat transfer through a fluid layer as a result of convection relative to conduction across the same fluid layer.
- The larger the Nusselt number, the more effective the convection.
- A Nusselt number of Nu = 1 for a fluid layer represents heat transfer across the layer by pure conduction.

Stantan Number: It is the ratio of heat transfer coefficient to the flow of heat per unit temperature residue of the velocity of fluid.

It also defined as-

St= Nu/(Re.Pr)

So, it is the ratio of Nusselt number and the product of Reynolds number and Prandtl number.

Peclet Number: It is the ratio of mass heat flow rate by convection to the flow rate by conduction under a unit temperature gradient and through a thickness L.

It also defined as – Pe = Re.Pr

Graetz Number: It is defined as the ratio of heat capacity of fluid flowing through the pipe per unit length of the pipe to the conductivity of pipe. i.e.

G= mCp/ LK

Grasshaff Number: Gr = (Inertia Force ×Buoyancy Force)/ (Viscous Force)^2

Froude Number: The Froude number is a dimensionless number defined as the ratio of a characteristic velocity to a gravitational wave velocity. It may equivalently be defined as the ratio of a body's inertia to gravitational forces. In fluid mechanics, the Froude number is used to determine the resistance of an object moving through water, and permits the comparison of objects of different sizes. Named after William Froude, the Froude number is based on the speed/length ratio as defined by him.

The Froude number is defined as:

$$Fr = \frac{V}{C}$$

where, V is a characteristic velocity , and c is a characteristic water wave propagation velocity. The Froude number is thus analogous to the Mach number. The greater the Froude number, the greater the resistance.

Weber Number= Inertia Force/ Surface Tension Force

Euler's Number= Inertia Force/Pressure Force

Mach's Number (M) = $\sqrt{\left(\frac{\text{Inertia Force}}{\text{Elastic Froce}}\right)}$ = Velocity of fluid or body moving in fluid / Velocity of sound in the fluid = V/C

Significance: (a) When M<1 then, Flow is called sub-sonic.

(b) When M=1 then, Flow is called sonic.

(c) When 6>M>1 then, Flow is called super-sonic.

(d) When M>6 then, Flow is called hypersonic.

Synchronous Motor (S.M)	Induction Motor (I.M)
1. Operating speed is constant.	1. Operating speed is variable.
2. Synchronous motors are not self starting.	2. Induction motors (3phase) are self starting.
3. S.M operates with load having lagging, leading & unity power factor.	3. I.M operates with load having only lagging power factor.
4. An additional dc excitation is required.	4. No dc excitation is required.

D.C. Motor	A.C motor / I.M.
1. DC motors are direct current motors.	1. AC motors are alternating current motors.
2. DC motor receives power by conduction.	2. AC motor receives power by induction.
3. Here armature is rotating part and field system is stationary.	3. Here armature is stationary and field system is rotating.
4. Dc motors are self-starting.	4. Ac motor requires effective starting equipment.
5. It requires brush and commutator.	5. It requires no brush and commutator. (I.M)

DC generator	AC generator / Alternator
1. Generates constant E.M.F. at its terminals.	1. Generates alternating E.M.F. at its terminals.
2. In dc generators, the armature rotates and the field system is stationary.	2. In alternators, the armature is stationary and the field system is rotating.
3. DC generator uses all the energy that is produced.	3. Alternators conserve energy by using only the energy that is needed.

38. Draw the P-V and T-S diagram of Steam Turbine. Types of Draft tubes and pipe fittings.

Answer:

Rankine cycle:

Consider the idealized four-steady-state-process cycle in which state 1 is saturated liquid and state 3 is either saturated vapor or superheated vapor. This system is termed the Rankine cycle and is the model for the simple steam power plant. It is convenient to show the states and processes on a T–S diagram.

Principle components of Rankine cycle:

The four basic components of Rankine cycle are shown in figure 1 each component in the cycle is regarded as control volume, operating at steady state.

Pump: The liquid condensate leaving the condenser at the state 1 is pumped to the operating pressure of the boiler. The pump operation is considered isentropic.

Boiler: The heat is supplied in the working fluid (feed water) in the boiler and thus vapour is generated. The vapour leaving the boiler is either at saturated at the state 3 or superheated at the state 3, depending upon the amount of heat supplied in the boiler.

Turbine: The vapour leaving the boiler enters the turbine, where it expands isentropically to the condenser pressure at the state 4. The work produced by the turbine is rotary (shaft) work and is used to drive an electric generator or machine.

Condenser: The condenser is attached at the exit of the turbine. The vapour leaving the turbine is wet vapour and it is condensed completely in the condenser to the state 1, by giving its latent heat to some other cooling fluid like water.

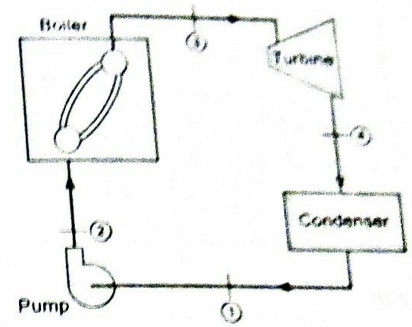


Figure 1: Simple steam power plant that operates on the Rankine cycle

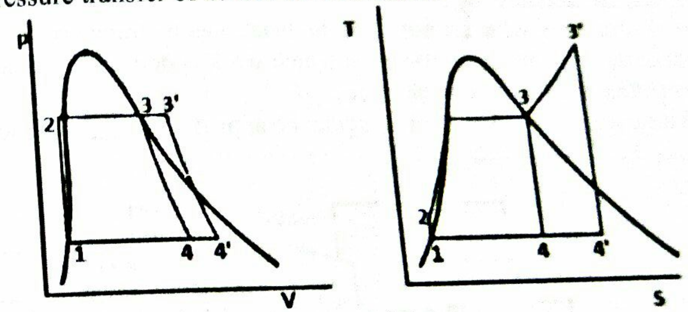
The various processes in simple Rankine cycle are:

1–2: Reversible adiabatic pumping process in the pump,

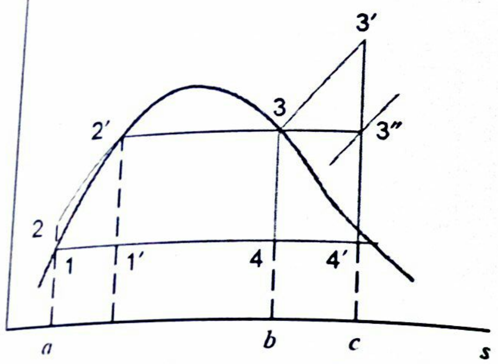
2–3: Constant-pressure transfer of heat in the boiler,

3–4: Reversible adiabatic expansion in the turbine (or other prime mover such as a steam engine),

4–1: Constant-pressure transfer of heat in the condenser.



The Rankine cycle is chosen as ideal cycle even though thermal efficiency is less than Carnot cycle (1-2-3-4-1). This is due to mainly two reasons:



1. The first reason concerns the pumping process. State 1^{l} is a mixture of liquid and vapor. Great difficulties are encountered in building a pump that will handle the mixture of liquid and vapor at 1^{l} and deliver saturated liquid at 2^{l}. It is much easier to condense the vapor completely and handle only liquid in the pump: The Rankine cycle is based on this fact.
2. The second reason concerns superheating the vapor. In the Rankine cycle the vapor is superheated at constant pressure, process $3–3^{l}$. In the Carnot cycle all the heat transfer is at constant temperature, and therefore the vapor is superheated in process $3–3^{ll}$. Note, however, that during this process the pressure is dropping, which means that the heat must be transferred to the vapor as it undergoes an expansion process in which work is done. This heat transfer is also very difficult to achieve in practice.

hus, the Rankine cycle is the ideal cycle that can be approximated in practice.

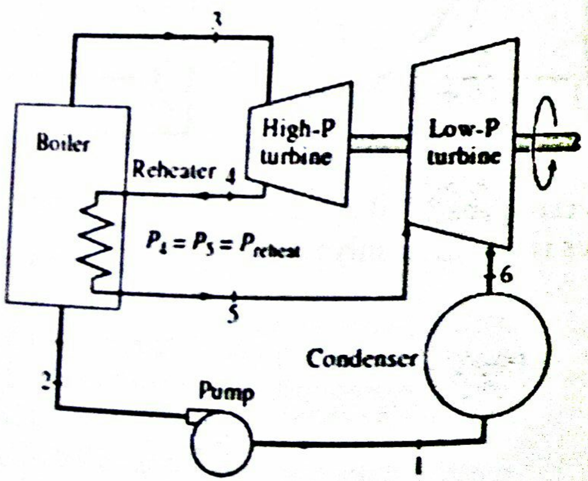


fig- re-heat cycle

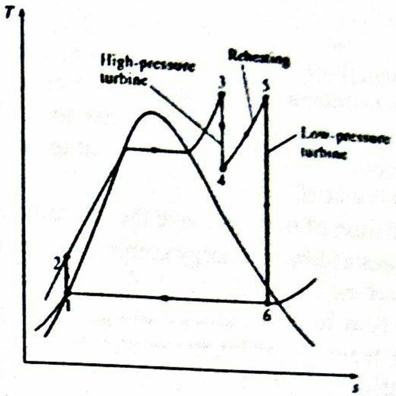


fig- re-heat cycle

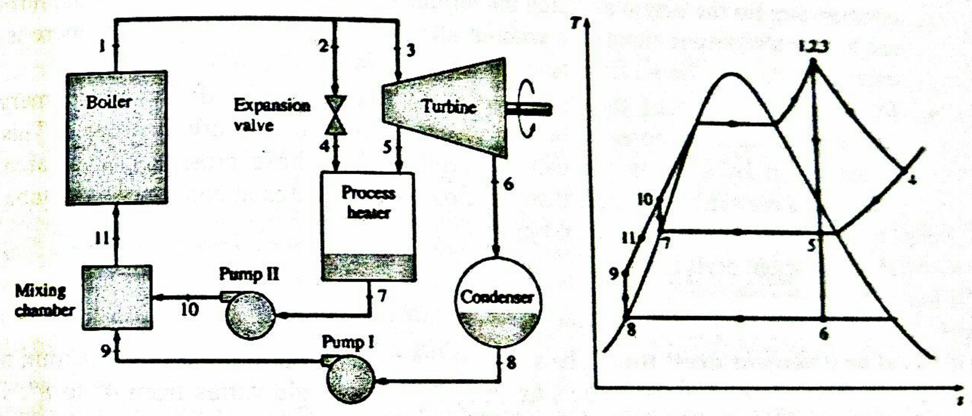


Fig.: Schematic of Co-generation

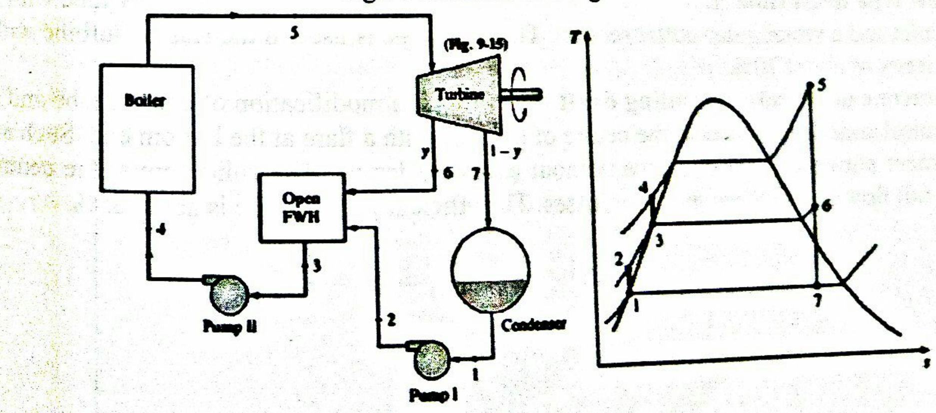
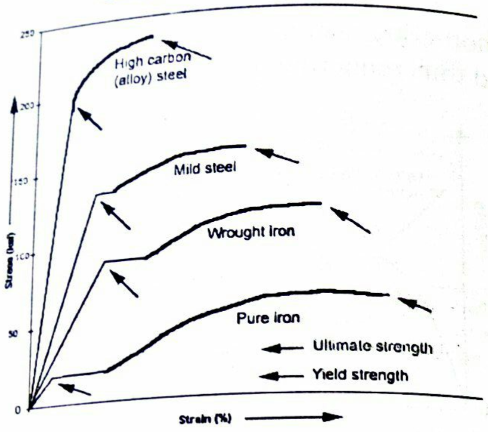


Fig. Rankine Cycle with Regeneration

Comparative Stress/Strain Diagram



40. Define real fluid, ideal fluid, Newtonian fluid and Non-Newtonian fluid.

Answer:

Real Fluid: A fluid which possesses viscosity is known as real fluid. All fluids, in practice, are real fluid.

Ideal Fluid: A fluid, which is incompressible and is having no viscosity, is known as fluid. Ideal fluid is only an imaginary fluid.

Newtonian Fluid: A real fluid in which the shear stress is directly proportional to the shear strain (velocity gradient) is known as a Newtonian fluid.

Non-Newtonian Fluid: A real fluid in which the shear stress is not proportional to the shear strain is known as Non-Newtonian Fluid.

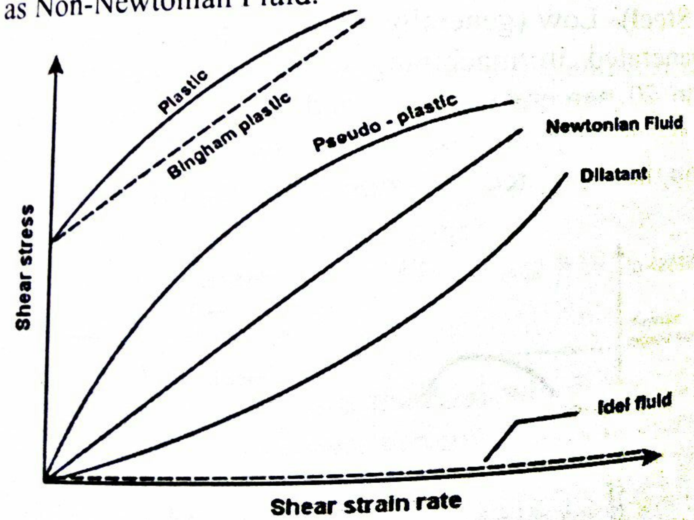
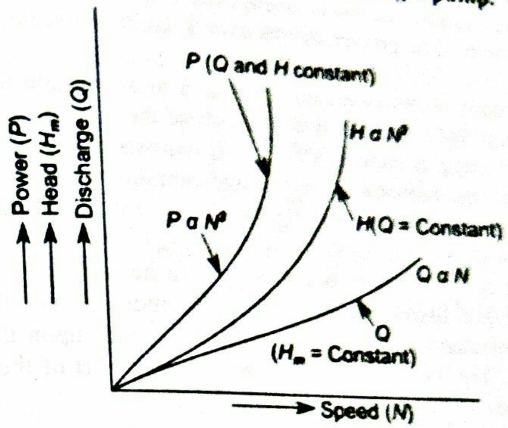


Fig. : Variation of shear stress with rate of deformation

41. Draw characteristics curve and performance of centrifugal pump.

Answer:



Main characteristics curves of a pump.

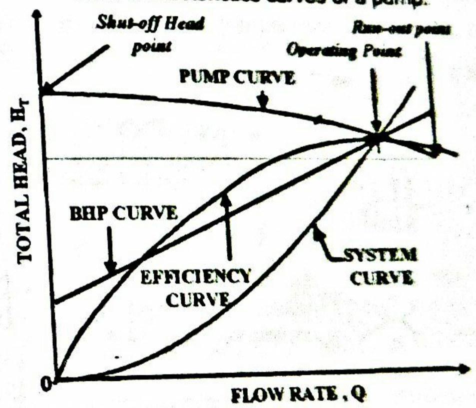


Fig.: Performance curve of a centrifugal pump

42. Write a short note on- pressure gauge, fuel pump, spark plug, carburetor, fuel pump, Injector or Atomizer, dual fuel and condenser.

Answer:

Pressure Gauge:

A pressure gauge is used to measure the pressure the pressure of the stream inside the steam boiler. It is fixed in front of the Stream boiler. The pressure gauge generally used for Bourdon type.

A Bourdon pressure gauge, in its simplest form, consists of an elliptical elastic tube ABC bent into an arc of a circle. This bent up tube is called bourdon's tube.

One end of the tube gauge is fixed and connected to the steam space in the boiler. The other end connected to a sector through a link. The stream, under pressure, flows into the tube. As a result of this increased pressure, the Bourdon's tube tends to straight itself. Since the tube

Fuses: A fuse is a short piece of wire or thin strip which melts when excessive current flows through it for sufficient time. It is inserted in series with the circuit to be protected. Under normal operating conditions, the fuse element it at a temperature below its melting point. Therefore, it carries the normal load current without overheating. However, when a short circuit or overload occurs, the current through the fuse element increases beyond its rated capacity. This raises the temperature and the fuse element melts (or blows out), disconnecting the circuit protected by it. In this way, a fuse protects the machines and equipment from damage due to excessive currents. It is worthwhile to note that a fuse performs both detection and interruption functions.

S. No.	Particular	Fuse	Circuit breaker
1.	*Function*	It performs both detection and interruption functions.	It performs interruption function only. The detection of fault is made by relay system.
2.	*Operation*	Inherently completely automatic.	Requires elaborate equipment (*i.e.* relays) for automatic action.
3.	*Breaking capacity*	Small	Very large
4.	*Operating time*	Very small (0·002 sec or so)	Comparatively large (0·1 to 0·2 sec)
5.	*Replacement*	Requires replacement after every operation.	No replacement after operation.

Strain Gage Measurement:

A fundamental parameter of the strain gage is its sensitivity to strain, expressed quantitatively as the gage factor (GF). Gage factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain):

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

In practice, strain measurements rarely involve quantities larger than a few millistrain (e x 10-3). Therefore, to measure the strain requires accurate measurement of very small changes in resistance. For example, suppose a test specimen undergoes a strain of 500 me. A strain gage with a gage factor of 2 will exhibit a change in electrical resistance of only 2 (500 x 10-6) = 0.1%. For a 120 Ω gage, this is a change of only 0.12 Ω.

To measure such small changes in resistance, strain gages are almost always used in a bridge configuration with a voltage excitation source. The general Wheatstone bridge, illustrated in Figure 3, consists of four resistive arms with an excitation voltage, VEX, that is applied across the bridge.

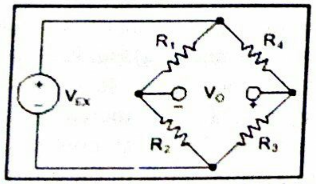


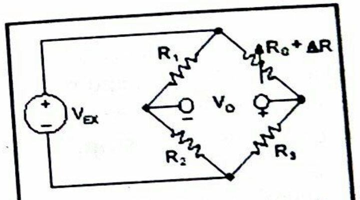
Figure 3. Wheatstone Bridge

The output voltage of the bridge, VO, is equal to:

$$V_O = \left[\frac{R_3}{R_3 + R_4} - \frac{R_2}{R_1 + R_2}\right] \bullet V_{EX}$$

From this equation, it is apparent that when R1/R2 = R4/R3, the voltage output VO is zero. Under these conditions, the bridge is said to be balanced. Any change in resistance in any arm of the bridge results in a nonzero output voltage.

Therefore, if you replace R4 in Figure 3 with an active strain gage, any changes in the strain gage resistance will unbalance the bridge and produce a nonzero output voltage. If the nominal resistance of the strain gage is designated as RG, then the strain-induced change in resistance, DR, can be expressed as DR = RG·GF·e, from the previously defined Gage Factor equation. Assuming that R1 = R2 and R3 = RG, the bridge equation above can be rewritten to express VO/VEX as a function of strain (see Figure 4). Note the presence of the 1/(1+GF·e/2) term that indicates the nonlinearity of the quarter-bridge output with respect to strain.



$$\frac{V_O}{V_{EX}} = -\frac{GF \bullet \varepsilon}{4}\left(\frac{1}{1 + GF \bullet \frac{\varepsilon}{2}}\right)$$

Figure 4. Quarter-Bridge Circuit

Ideally, you would like the resistance of the strain gage to change only in response to applied strain. However, strain gage material, as well as the specimen material to which the gage is applied, also responds to changes in temperature. Strain gage manufacturers attempt to minimize sensitivity to temperature by processing the gage material to compensate for the thermal expansion of the specimen material for which the gage is intended. While compensated gages reduce the thermal sensitivity, they do not totally remove it.

Generator: Generator is a machine which converts the mechanical energy to electrical energy.

51. Explain the abbreviations. Write the factors should be taken in consideration while choosing the location of a nuclear power plant. Draw a stud bolt & specify them.

Answer:

DOHC (Double overhead camshaft):
A typical DOHC engine has two camshafts and 4 valves per cylinder. One camshaft operates intake valves that are installed on one side, while another camshaft controls exhaust valves on the opposite side. Most modern cars have DOHC engines.

SOHC (Single overhead camshaft):
The camshaft is installed in the cylinder head and valves are operated either by the rocker arms or directly through the lifters.

HCCI (Homogeneous charge compression ignition):
Homogeneous charge compression ignition (HCCI) is a form of internal combustion in which well-mixed fuel and oxidizer (typically air) are compressed to the point of auto-ignition.

ABS (Anti-lock braking system):
(ABS) is an automobile safety system that allows the wheels on a motor vehicle to maintain tractive contact with the road surface according to driver inputs while braking, preventing the wheels from locking up (ceasing rotation) and avoiding uncontrolled skidding.

VTEC (Variable valve timing and lift electronic control):
VTEC is a system developed by Honda to improve the volumetric efficiency of a four-stroke internal combustion engine. The VTEC system uses two camshaft profiles and hydraulically selects between profiles.

VVT-I (Variable valve timing with intelligence):
VVT-I is an automobile variable valve timing technology developed by Toyota. It varies the timing of the intake valves by adjusting the relationship between the camshaft drive (belt or chain) and intake camshaft.

ACT (Air charge temperature): An air charge temperature sensor is a device inside the engine that monitors the temperature of the air going into the engine.

MFI: A mechanical fuel injection system from Hilborn includes the manifold, nozzles, barrel valve, and hoses. The main jet, housed in the primary bypass valve, is also included along with 2 additional jets, *or pills*. To complete the system, you will need ram tubes, fuel pump, fuel filter, fuel shutoff valve and, possibly, a hi-speed bypass valve. If Hilborn cannot supply a fuel pump drive, you will need to fashion a drive for the pump to run at 1/2 crankshaft speed.

There are 4 main parts to a mechanical system:

1. Fuel Pump
2. Fuel Nozzles
3. Main Jet (*or pill*)
4. Barrel Valve

CFI (Continuous fuel injection): In a continuous injection system, fuel flows at all times from the fuel injectors, but at a variable flow rate. This is in contrast to most fuel injection systems, which provide fuel during short pulses of varying duration, with a constant rate of flow during each pulse. Continuous injection systems can be multi-point or single-point, but not direct.

DGI (Direct gasoline injection): In a direct injection engine, fuel is injected into the combustion chamber as opposed to injection before the intake valve (petrol engine) or a separate pre-combustion chamber (diesel engine).

PFI (Port fuel injection): Port Fuel Injection (PFI) is the world's most widely used system for internal combustion engines and offers many advantages for engines with a low pressure output.

ECM (Electronic Control module): Electronic control module is the computer responsible for providing fuel to the engine and controlling the quality of engine's emissions. The ECM uses a microprocessor and software to analyze and respond to the input values from an array of sensors.

EEC (Electronic engine control): An Electronic Engine Control System regulates the functions of the injection system in such a way that the engine provides the demanded engine torque. The injection parameters are constantly matched to the engine and the flight situation. Engines with an electronically controlled diesel or gasoline system with minimum fuel consumption and emissions.

EFI (Electronic fuel injection): The Electronic Fuel Injection system fitted to most modern vehicles combines sophisticated computer controls with a high pressure fuel delivery system to provide optimum power and fuel efficiency.

EMI (Electromagnetic interference): Electromagnetic interference (EMI), also called radio-frequency interference (RFI) when in the radio frequency spectrum, is a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction.

HCM (Heater control module): It is a computer that controls and automates the operation of the heating, ventilation, and air conditioning systems (HVAC)

GPS (Global positioning system): The Global Positioning System is a global navigation satellite system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

VECI (Vehicle emission control information): Each vehicle has a VECI decal containing emission control information that applies specifically to the vehicle and engine. Manufacturers must use a standardized system for identifying their individual engine families.

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers): Founded in 1894, it is a global society advancing human well-being through sustainable technology for the built environment.

ASTM (American Society for Testing and Materials): It is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services.

SAPTA (South Asian Preferential Trade Agreement)

Mathematical Problems

1. **In a boiler, feed water supplied per hour is 205 kg while coal fired per hour is 23 kg. The net enthalpy rise per kg of water is 145KJ. If the calorific value of the coal is 2050 KJ/kg, then calculate the boiler efficiency.**

Solution:

Here, $m_s = 205kg$; $m_f = 23kg$; $(h-h_f) = 145KJ$ and $C = 2050KJ/kg$

We know, Boiler efficiency, $\eta = \frac{m_s(h-h_{f1})}{m_f \times C}$

$= \frac{205 \times 145}{23 \times 2050}$

$= 0.63 = 63\%$ (Ans.)

Summary of Processes for Perfect Gas (Unit mass)

Process	Index n	Heat added	$\int_1^2 pdv$	p, v, T relations	Specific heat, c
Constant pressure	$n = 0$	$c_p(T_2 - T_1)$	$p(v_2 - v_1)$	$\frac{T_2}{T_1} = \frac{v_2}{v_1}$	c_p
Constant volume	$n = \infty$	$c_v(T_2 - T_1)$	0	$\frac{T_1}{T_2} = \frac{p_1}{p_2}$	c_v
Constant temperature	$n = 1$	$2.3 p_1 v_1 \log_e \frac{v_2}{v_1}$	$2.3 p_1 v_1 \log_e \frac{v_2}{v_1}$	$p_1 v_1 = p_2 v_2$	∞
Reversible adiabatic	$n = \gamma$	0	$\frac{p_1 v_1 - p_2 v_2}{\gamma - 1}$	$p_1 v_1^\gamma = p_2 v_2^\gamma$ $\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma - 1} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma - 1}{\gamma}}$	0
Polytropic	$n = n$	$c_n(T_2 - T_1)$ $= c_v\left(\frac{\gamma - n}{1 - n}\right) \times (T_2 - T_1)$ $= \frac{\gamma - n}{\gamma - 1} \times$ work done (non-flow)	$\frac{p_1 v_1 - p_2 v_2}{n - 1}$	$p_1 v_1^n = p_2 v_2^n$ $\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{n - 1} = \left(\frac{p_2}{p_1}\right)^{\frac{n - 1}{n}}$	$c_n = c_v\left(\frac{\gamma - n}{1 - n}\right)$

2. **Air at 1.02 bar, 22°C, initially occupying a cylinder volume of 0.015 m³, is compressed reversibly and adiabatically by a piston to a pressure of 6.8 bar. Calculate : (i)The final temperature ; (ii)The final volume ; (iii)The work done.**

Solution:

Given, Initial pressure, $P_1 = 1.02$ bar $= 1.02 \times 10^5$ Pa

Initial temperature, $T_1 = 22 + 273 = 295$ K; Initial volume, $V_1 = 0.015\ m^3$

Final pressure, $P_2 = 6.8$ bar

(i)Final temperature:

Using the relation, $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$

or, $\frac{T_2}{295} = \left(\frac{6.8}{1.02}\right)^{\frac{1.4-1}{1.4}}$

or, $T_2 = 295 \times \left(\frac{6.8}{1.02}\right)^{\frac{1.4-1}{1.4}}$

= 507.24K = 234.24°C. (Ans.)

101. A solid steel shaft 5 m long is stressed at 80 MPa when twisted through 4°. Using G =83 GPa, compute the shaft diameter. What power can be transmitted by the shaft at 20Hz?

Solution:

$$\theta = \frac{TL}{JG}$$

$$4^\circ\left(\frac{\pi}{180^\circ}\right) = \frac{T(5)(1000)}{\frac{1}{32}\pi d^4(83000)}$$

$$T = 0.1138d^4$$

$$\tau_{max} = \frac{16T}{\pi d^3}$$

$$80 = \frac{16(0.1138d^4)}{\pi d^3}$$

$$d = 138\ \text{mm}$$

$$T = \frac{P}{2\pi f}$$

$$0.1138d^4 = \frac{P}{2\pi(20)}$$

$$p = 14.3d^4 = 14.3(138^4)$$

$$p = 5\,186\,237\,285\ \text{N·mm/sec}$$

$$p = 5\,186\,237.28\ \text{W}$$

$$p = 5.19\ \text{MW}$$

102. A steel propeller shaft is to transmit 4.5 MW at 3 Hz without exceeding a shearing stress of 50 MPa or twisting through more than 1° in a length of 26 diameters. Compute the proper diameter if G = 83 GPa.

Solution:

$$T = \frac{P}{2\pi f} = \frac{4.5(1000000)}{2\pi(3)}$$

$$T = 238\,732.41\ \text{N·m}$$

Based on maximum allowable shearing stress:

$$\tau_{max} = \frac{16T}{\pi d^3}$$

$$50 = \frac{16(238732.41)(1000)}{\pi d^3}$$

$$d = 289.71\ \text{mm}$$

Based on maximum allowable angle of twist:

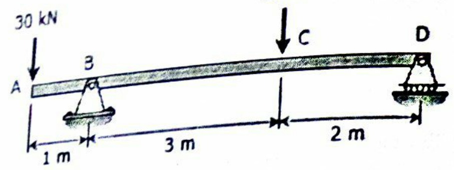
$$\theta = \frac{TL}{JG}$$

$$1^\circ\left(\frac{\pi}{180^\circ}\right) = \frac{238732.41(26d)(1000)}{\frac{1}{32}\pi d^4(83000)}$$

$$d = 352.08\ \text{mm}$$

Use the bigger diameter, d =352mm (Ans.)

...m loaded as shown in Fig.



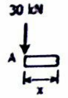
...tion:

From the load diagram:

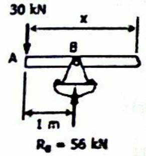
$\sum M_B = 0$
$5R_D + 1(30) = 3(50)$
$R_D = 24$ kN

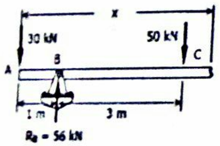
$\sum M_D = 0$
$5R_B = 2(50) + 6(30)$
$R_B = 56$ kN

Segment AB:
$V_{AB} = -30$ kN
$M_{AB} = -30x$ kN·m

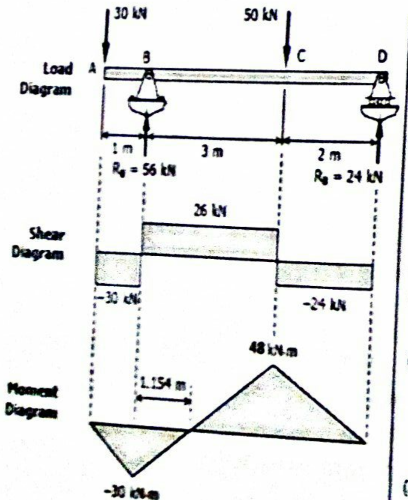


Segment BC:
$V_{BC} = -30 + 56$
$= 26$ kN
$M_{BC} = -30x + 56(x - 1)$
$= 26x - 56$ kN·m





Segment CD:
$V_{CD} = -30 + 56 - 50$
$= -24$ kN
$M_{CD} = -30x + 56(x - 1) - 50(x - 4)$
$= -30x + 56x - 56 - 50x + 200$
$= -24x + 144$



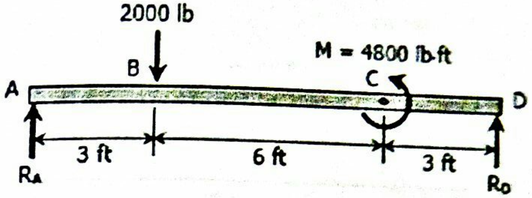
To draw the Shear Diagram:

(1) In segment AB, the shear is uniformly distributed over the segment at a magnitude of −30 kN.
(2) In segment BC, the shear is uniformly distributed at a magnitude of 26 kN.
(3) In segment CD, the shear is uniformly distributed at a magnitude of −24 kN.

To draw the Moment Diagram:

(1) The equation $M_{AB} = -30x$ is linear, at $x = 0$, $M_{AB} = 0$ and at $x = 1$ m, $M_{AB} = -30$ kN·m.
(2) $M_{BC} = 26x - 56$ is also linear. At $x = 1$ m, $M_{BC} = -30$ kN·m; at $x = 4$ m, $M_{BC} = 48$ kN·m. When $M_{BC} = 0$, $x = 2.154$ m, thus the moment is zero at 1.154 m from B.
(3) $M_{CD} = -24x + 144$ is again linear. At $x = 4$ m, $M_{CD} = 48$ kN·m; at $x = 6$ m, $M_{CD} = 0$.

104. Beam loaded as shown in Fig

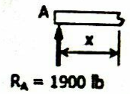


Solution:

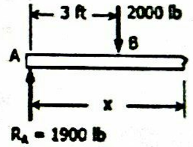
$\sum M_A = 0$
$12R_D + 4800 = 3(2000)$
$R_D = 100$ lb

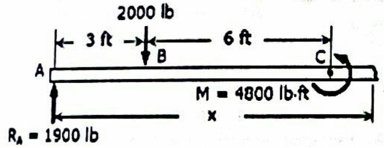
$\sum M_D = 0$
$12R_A = 9(2000) + 4800$
$R_A = 1900$ lb

Segment AB:
$V_{AB} = 1900$ lb
$M_{AB} = 1900x$ lb·ft

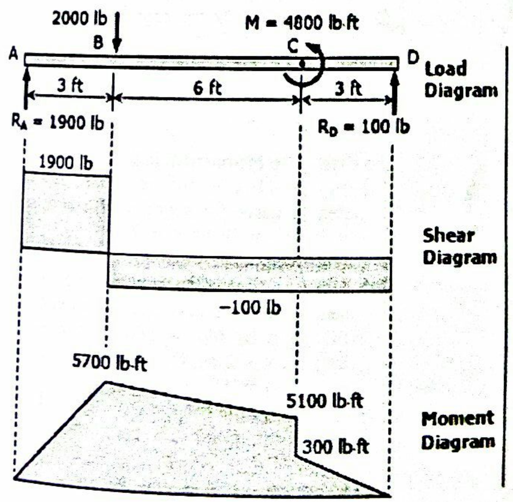


Segment BC:
$V_{BC} = 1900 - 2000$
$= -100$ lb
$M_{BC} = 1900x - 2000(x - 3)$
$= 1900x - 2000x + 6000$
$= -100x + 6000$





Segment CD:
$V_{CD} = 1900 - 2000$
$= -100$ lb
$M_{CD} = 1900x - 2000(x - 3) - 4800$
$= 1900x - 2000x + 6000 - 4800$
$= -100x + 1200$



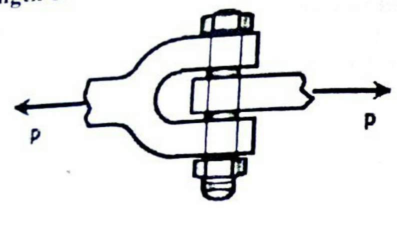
To draw the Shear Diagram:

(1) At segment AB, the shear is uniformly distributed at 1900 lb.
(2) A shear of −100 lb is uniformly distributed over segments BC and CD.

To draw the Moment Diagram:

(1) $M_{AB} = 1900x$ is linear; at $x = 0$, $M_{AB} = 0$; at $x = 3$ ft, $M_{AB} = 5700$ lb·ft.
(2) For segment BC, $M_{BC} = -100x + 6000$ is linear; at $x = 3$ ft, $M_{BC} = 5700$ lb·ft; at $x = 9$ ft, $M_{BC} = 5100$ lb·ft.
(3) $M_{CD} = -100x + 1200$ is again linear; at $x = 9$ ft, $M_{CD} = 300$ lb·ft; at $x = 12$ ft, $M_{CD} = 0$.

118. Find the smallest diameter bolt that can be used in the clevis shown in Fig. if P = 400 kN. The shearing strength of the bolt is 300 MPa.



Solution:

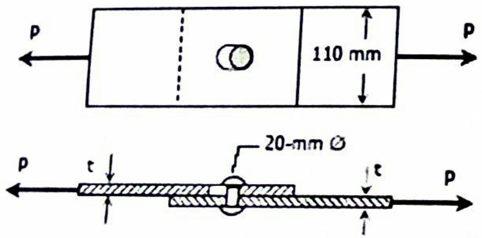
The bolt is subjected to double shear

$$V = \tau A$$

$$\Rightarrow 400 \times (1000) = 300 \times \left[2\left(\frac{1}{4}\pi d^2\right)\right]$$

$$= 29.13 \text{ mm}$$

119. In Fig., assume that a 20-mm-diameter rivet joins the plates that are each 110 mm wide. The allowable stresses are 120 MPa for bearing in the plate material and 60 MPa for shearing of rivet. Determine (a) the minimum thickness of each plate; and (b) the largest average tensile stress in the plates.



Solution:

(a) From shearing of rivet:

$P = \tau A_{rivets}$

$= 60[\frac{1}{4}\pi(20^2)]$

$= 6000\pi$ N

From bearing of plate material:

$P = \sigma_b A_b$

$6000\pi = 120(20t)$

$t = 7.85$ mm

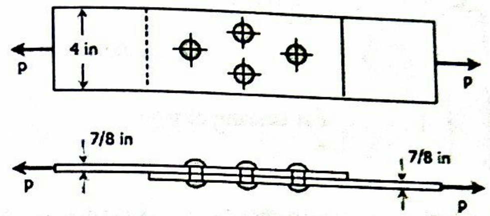
(b) Largest average tensile stress in the plate:

$P = \sigma A$

$6000\pi = \sigma[7.85(110 - 20)]$

$\sigma = 26.67$ MPa

120. The lap joint shown in Fig. is fastened by four ¾-in diameter rivets. Calculate the maximum safe load P that can be applied if the shearing stress in the rivets is limited to 14 ksi and the bearing stress in the plates is limited to 18 ksi. Assume the applied load is uniformly distributed among the four rivets.



Solution:

Based on shearing of rivets:

$P = \tau A$

$P = 14[4(\frac{1}{4}\pi)(\frac{3}{4})^2]$

$P = 24.74$ kips

Based on bearing of plates:

$P = \sigma_b A_b$

$P = 18[4(\frac{3}{4})(\frac{7}{8})]$

$P = 47.25$ kips

Safe load $P = 24.74$ kips

121. In the clevis shown in Fig., find the minimum bolt diameter and the minimum thickness of each yoke that will support a load P = 14 kips without exceeding a shearing stress of 12 ksi and a bearing stress of 20 ksi.