PAPER SOLUTION
WINTER 2023

Subject code : 3110006
Subject Name : Basic Mechanical Engineering

Q-1 : (a) What do you mean by 'boiler mountings' and 'boiler accessories? Write three Examples of them.

Ans : Boiler mounting are essential fitting that are mounted on the boiler to ensure it's safe operation and facilitate its functioning. They are integral parts of the boiler and are directly mounted on the boiler shell.

→ Boiler accessories are optional components that are installed to improve the efficiency and performance of the boiler or to enhance its operational convenience.

→ Example of boiler mountings
1. Safety valves
2. water level indicators
3. pressure gauges

→ Example of boiler accessories
1. Economizers
2. Superheaters
3. feed water pumps

(b) Explain advantages and disadvantages of wind energy.

Ans : Wind energy has several advantages and disadvantages

- Advantages:

1. Renewable : wind energy is a renewable resource meaning it will never run out as long as the sun continuous to shine and the wind bloues .
2. Environmentally friendly : wind energy production generates no air or water pollution and does not produce greenhouse gas emissions helping to mitigate climate change.
3. Low operating costs : once a wind turbine is installed, the operational cause are relatively low compared to Fassil fuel based power plants, as wind is free and turbines require minimal maintenance.
4. Land multipurpose use : wine turbines can be installed on land that can still be used for agriculture or other purposes, allowing for dual land use and minimizing land footprint.

- Disadvantages :

1. Visual impact : wind turbines can be considered visually intrusive especially in scenic or natural areas , leading to aesthetic concerns and opposition from some communities.
2. Nice pollution : wind turbines can produce noise during operation , which may disturb nearby residence although modern turbines design into minimizes this issue .
3. Bird and bat collisions : wind turbines can pose a risk two birds and bats , particularly during migration routes although effects efforts are made to mitigate this impact through careful sitting and technological advancements
4. Initial costs and infrastructure requirements : the initial investment in wind energy infrastructure including turbines manufacturing and installation can be significant , requiring upfront capital and suitable infrastructure such as transmission line to connect to the grid.

(c) (i) Fill in the blanks: 1 bar = _____ Pa = _____ kPa = _____ MPa

1 atm = _____ bar

(ii) Write the equation of 1st law of thermodynamics for a stationary closed system.

(iii) Determine the power required to accelerate a 900-kg car from rest to a velocity of 80 km/h in 20 sec on a horizontal road. (Neglect friction, rolling resistance, air drag, etc.)

Ans:- (i) 1 bar = 10^5 Pa = 10^2 kPa = 0.1 MPa

1 atm = 1.01325 bar

(ii) equation of the first law of thermodynamics for a stationary closed system is ,

$$\Delta U = Q - w$$

Where , ΔU = is change in internal energy of the system

Q = Is the heat added to the system

w = Is the work done by the system

(iii) mass (m) = 900 kg

Initial velocity (u) = 0 m/s

Final velocity (v) = 80 km/j = 22.22 m/s

t = 20 sec

$\rightarrow$ using the equation of motion

$$v = u + at$$

Where v = final velocity

u = initial velocity

a = acceleration

t = time taken

$$a = \frac{v-u}{t}$$

$$= \frac{22.22-0}{20}$$

$$a = 1.11\ m/s^2$$

$$\rightarrow F = mg$$

$$= 900 * 1.11\ m/s^2$$

$$= 999$$

$\rightarrow$ P = F • V

$= 999 \bullet 22.22$

$= 22{,}200\ w$

Q-2 : (a) State the function of the following in boilers:

Economizer, air preheater, Superheaters.

Ans:

1) Economizers : an economizer is a heat exchange installed in the boiler exhaust stake to recover heat from the flue gases before they are expelled into the atmosphere. Its function is to preheat boiler feedwater using the waste heat from the flue gases.

2) Air Preheater : an air preheater is another type of heat exchanger in a boiler system. It's function is to Preheated the combustion air before it enters the boiler. Combustion chamber by recovering heat from the flue gases and transferring it to the incoming combustion air , the air preheater helps increased thermal efficiency of the boiler by reducing the amount of fuel needed to achieve the desired combustion temperature.
3) Superheaters : a Superheaters is a component in a boiler system that is used to increase the temperature of the stream produced by the boiler to a level higher than its saturation temperature its function is to superheat the steam by adding more heat energy to it after it has already been generated in the boiler.

(b) Provide meaning of the following statements regarding cast iron material:

1. **It is brittle and has low ductility.**
2. **It has high compressive strength but low tensile strength.**
3. **It has excellent castability.**
4. **It has poor formability.**

Ans :

1) This statement means that cast iron tends to fracture or brake easily under tension or bending forces and has limited ability to deform plastic curly without fracturing . In other words it is not very flexible and cannot be easily stretched or shaped without breaking.
2) this statement indicates that cast iron can with stand a significant amount of force when compressed , meaning it can resist being squashed aur compacted. However, it, has relatively poor resistance to being pulled apart or stretched, which is known as tonsil strength.
3) the statement means that cast iron is well – suited for casting processes , such as sand casting or investment casting, where molten metal is poured into a mold and allowed to solidify into the desired shape.
4) this statement suggest that cast iron is difficult to deform or shape using mechanical processes like bending, rolling or forging . Unlike materials with higher ductility, such as steel cast iron does not readily yield or flow when subjected to these forming operations.

(c) A gas whose pressure, volume, and temperature are 2.75 bar, 0.09 m^3, and 185°C respectively has the state changed at constant pressure until its Temperature becomes 15oC. Calculate (i) the heat transferred, and (ii) the Work done. Take R = 0.29 kJ/kg K and cp = 1.005 kJ/kg K.

Ans :

Given :

$$P = 2.75\ bar$$
$$V = 0.09\ m^3$$
$$T = 185℃ = 185 + 273.15 = 458.15\ K$$
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$
$$\therefore V_2 = \frac{288.15 \times 0.09}{458.15}$$
$$\therefore V_2 = 0.0566\ m^3$$

$$\rightarrow PV = MRT$$
$$\therefore m = \frac{PV}{RT} = \frac{(2.75 \times 10^5)(0.09)}{0.29 \times (458.15)}$$
$$\therefore m = 185.8780\ kg$$

$$\rightarrow \Delta T = T_f - T_i = 15℃ - 185℃ = -170℃$$

1. Heat Transferred

$$Q = mC_p\Delta T$$
$$= 185.878 \times 1.005 \times (-170)$$
$$Q = -31757.2563\ KJ$$

2. $W = P\Delta V$

$$= (2.75 \times 10^5) \times (0.172 - 0.0566)$$
$$= 3.173 \times 10^4\ J$$

(c) The gauge pressure of an automobile tire is measured to be 210 kPa before a trip and 220 kPa after the trip at a location where the atmospheric pressure is 95 kPa. Assuming the volume of the tire remains constant and the air temperature before the trip is 25°C, determine air temperature in the tire after the trip. Convert this change in temperature into percentage change.

Ans :

→ Volume remaing constant

$P_1T_1 = P_2T_2$

Given,

$$P_1 = 210\ KPa = 210 + 95 = 305\ KPa$$
$$P_2 = 220\ KPa = 220 + 95 = 315\ KPa$$
$$T_1 = 25℃ = 25 + 273.15 = 298.15\ K$$

$$T_2 = \frac{P_1T_1}{P_2}$$

$$= \frac{305 \times 10^3 \times 298.15}{315 \times 10^3}$$

$$T_2 = 288.49\ K$$

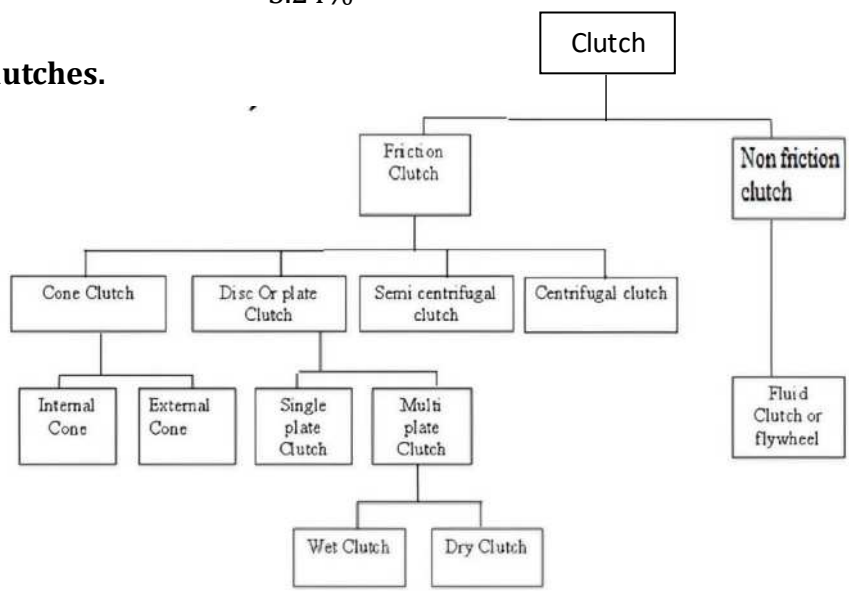
→ Percentage Change $= \frac{T_2 - T_1}{T_1} \times 100$

$$= \frac{288.49\ K - 298.15\ K}{298.15\ K} \times 100\%$$

$$= -3.24\%$$

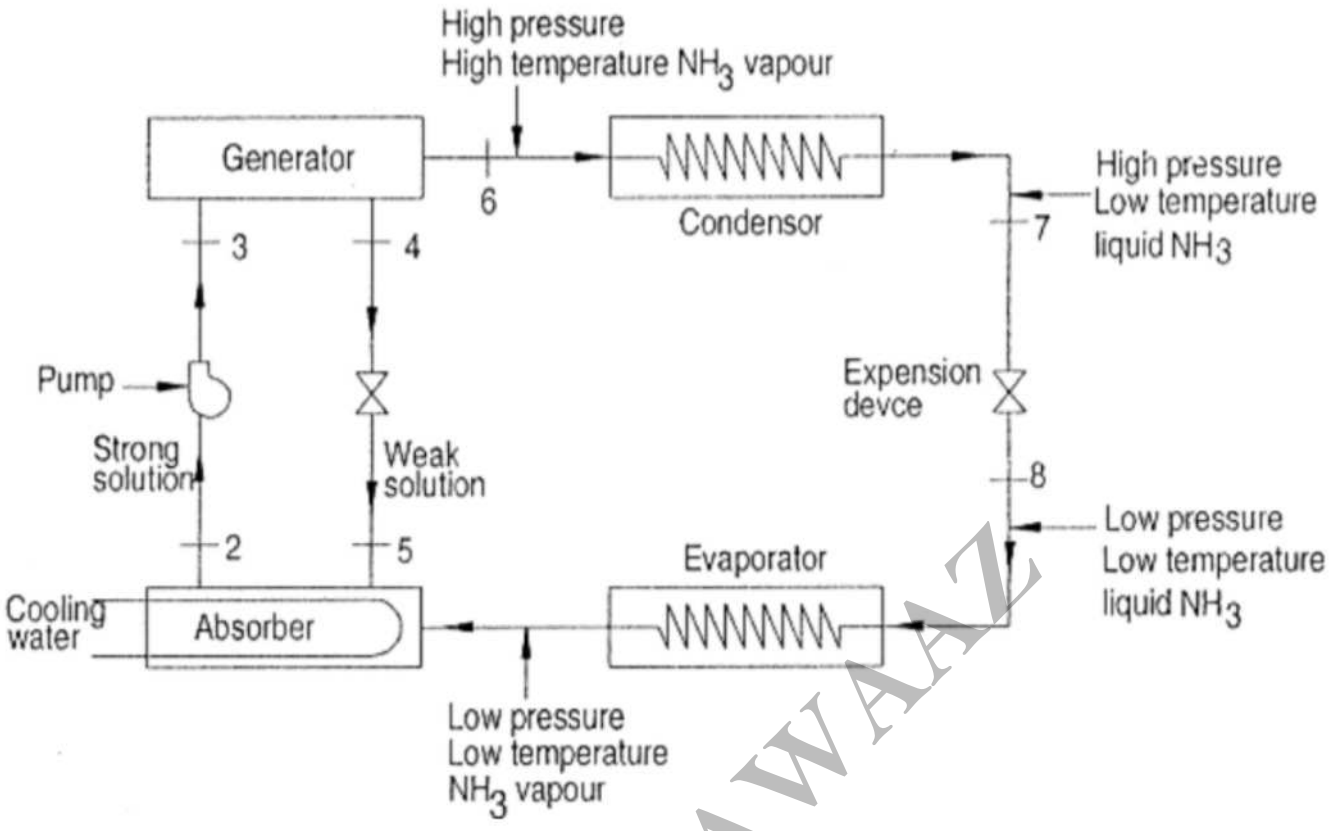
Q-3 : (a) Classify clutches.

Ans :



(b) Draw a schematic diagram of the vapor absorption refrigeration system.

Ans :



(c) Determine the missing properties and the phase descriptions in the following table for water. Use steam tables and write necessary explanations.

	$T, °C$	P, kPa	$h, kJ/kg$	x	*Phase description*
(i)		200		0.6	
(ii)	124		1835.2		

Ans :

(i) The dryness factor is given as 0.6 which means that the phase of water at the given pressure has both liquid and vapour phases , Therefore the phase description is liquid vapour phase .

→ Refer to saturation properties of saturated water to obtain the temperature as 120.21°C at $P = 200kPa$

→ The energy is

$h = h_f + xh_g$ ---------- ①

→ Substitution the values in eq 1

$h = 504.5 + 0.6(2529.1) = 2021.96\ kJ/kg$

(ii) Refer to the saturation properties of saturated water and use interpolation as

$$P = \frac{(T - T_1)(P_2 - P_1)}{T_2 - T_1}$$

→ Substitute the values from saturated water table

$$P = \frac{(125 - 120)(270.28 - 198.67)}{130 - 120}$$

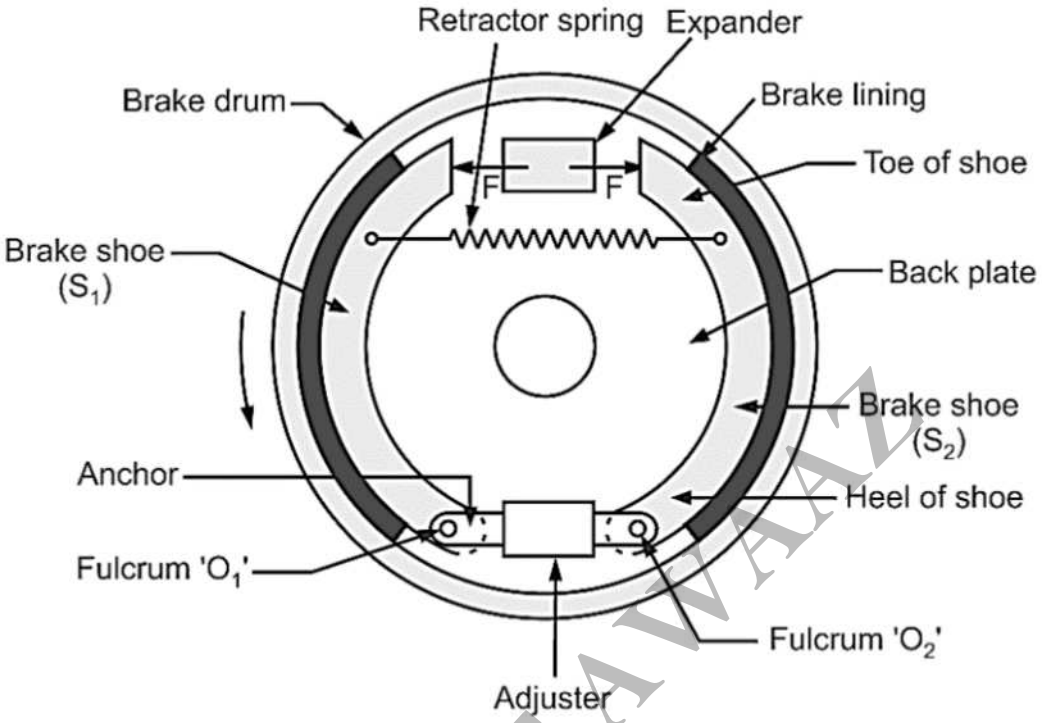
$$= 35.805\ KPa$$

→ From table $h_f = 524.83 \frac{KJ}{Kg}$, $h_g = 2534.3\ KJ/Kg$

→ Dryness factor, $x = \frac{h-h_f}{h_g-h_f} = \frac{1600-524.83}{2534.3-524.83} = 0.53$

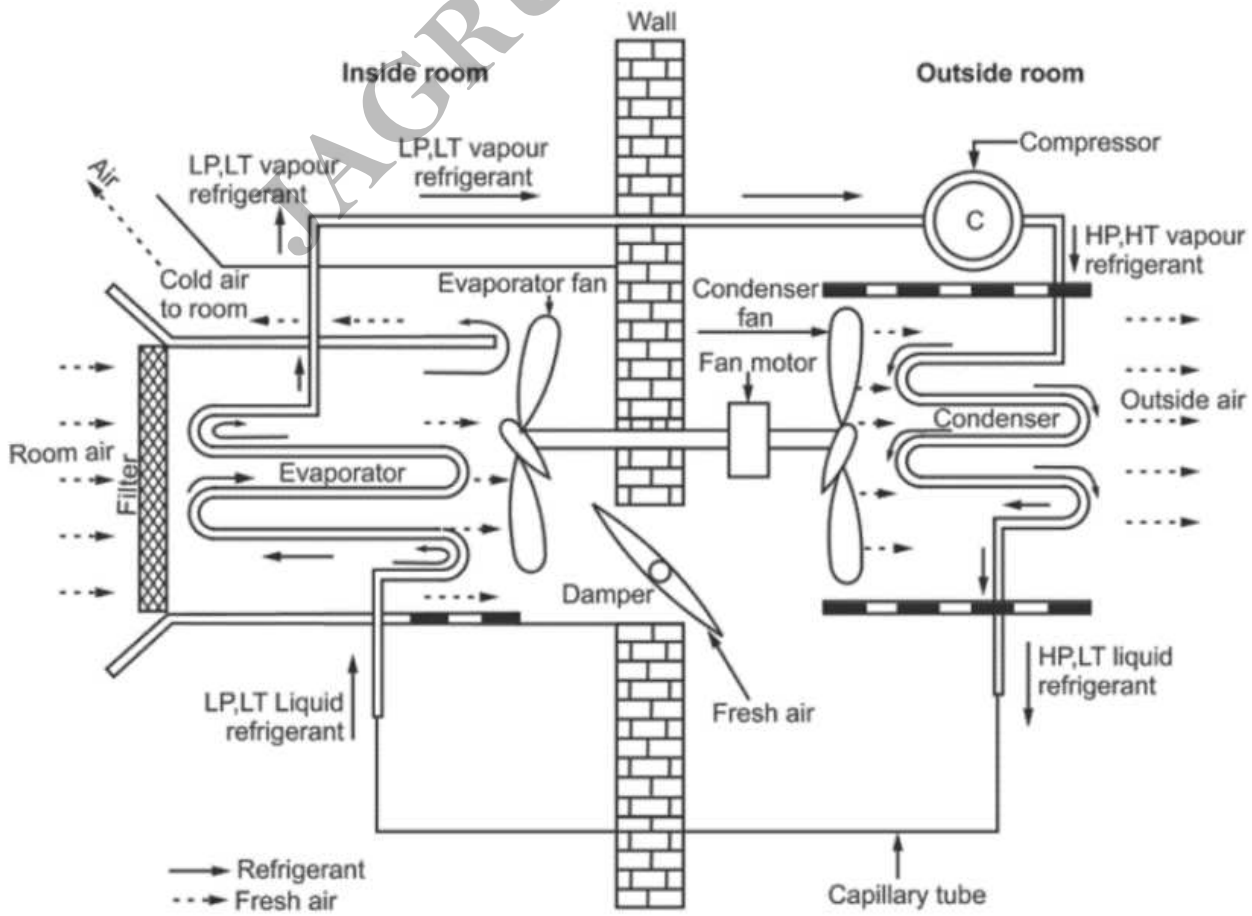
Q-3 : (a) Draw a labeled diagram of a shoe brake used in automobiles.

Ans :



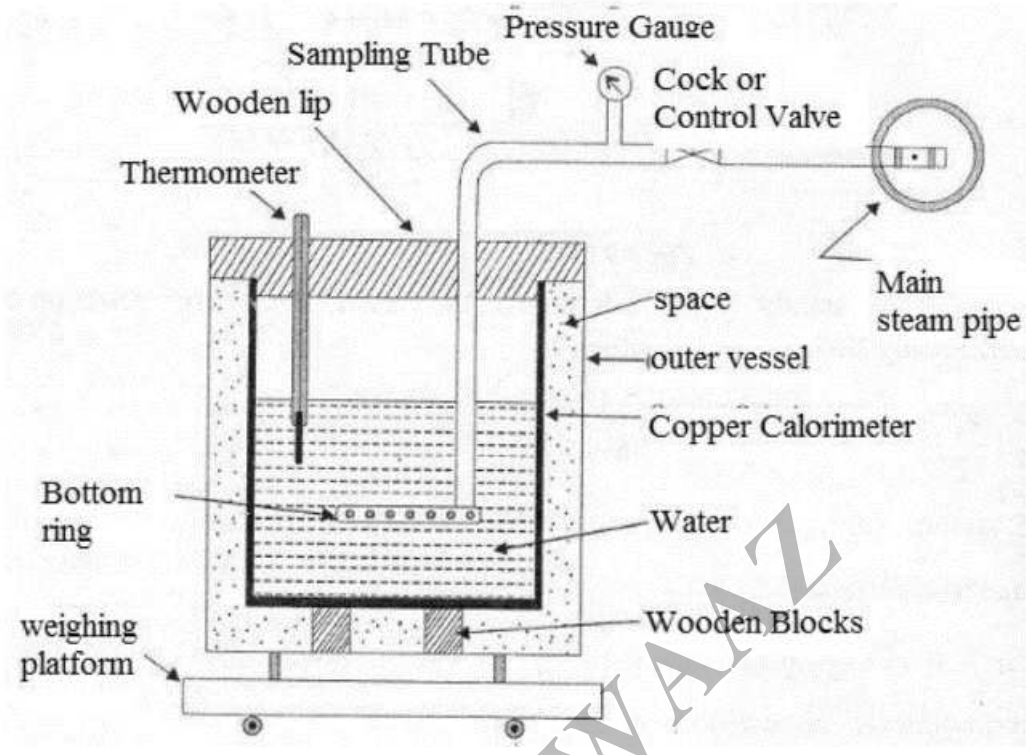
(b) Draw a self-explanatory diagram of window room air-conditioner

Ans :



(c) Draw a neat, labeled diagram of barrel calorimeter. Write the equation used for this calorimeter for finding dryness fraction and state what each term in it Indicates.

Ans :



Q-4 : (a) Match the following:

Rigid flange coupling	**Axis of shafts are parallel but not in alignment**
Pin type flexible coupling	**Where angular misalignment is more**
Universal coupling	**Requires proper alignment of shaft axes**
Oldham's coupling	**For small angular misalignment**

Ans :

1. Rigid flange coupling : Requires proper alignment of shaft axes
2. Pin type flexible coupling : Where angular misalignment is more
3. Universal coupling : Axis of shafts are parallel but not in alignment
4. Oldham's coupling : For small angular misalignment

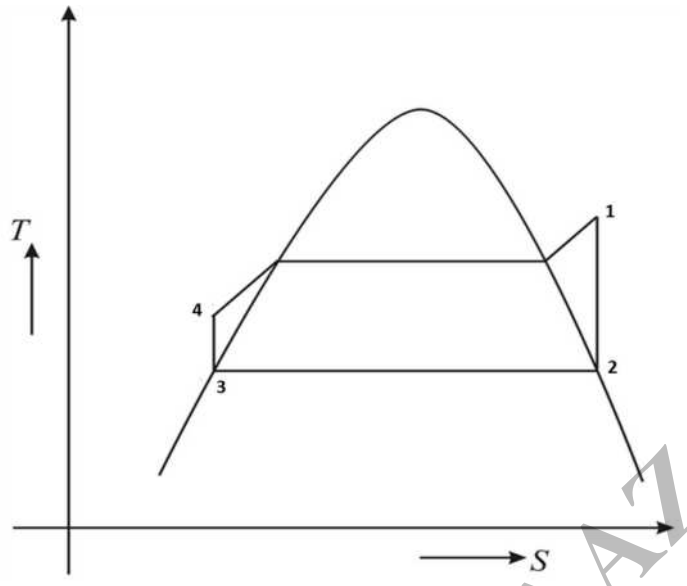
(b) Compare centrifugal pumps v/s reciprocation pumps.

Ans :

No.	Centrifugal pump	Reciprocating pump
1.	Suitable for large discharge and smaller heads.	Suitable for less discharge and higher heads.
2.	Required less floor space and simple foundation.	Required more floor space and heavy foundation
3.	Maintenance cost is less.	Maintenance cost is high.
4.	Can handle dirty water.	Can not handle dirty water.
5.	Can run at high speed.	Can not run at high speed.
6.	Its delivery is continuous	Its delivery is pulsating

(c) Consider a steam power plant operating on the simple ideal Rankine cycle. Steam enters the turbine at 3 MPa and 350°C and is condensed in the condenser at a pressure of 74 kPa. Draw the T-s diagram and determine the thermal efficiency of this cycle. (Do not neglect the pump work.)

Ans :



→ Calculating dryness fraction at point 2.

$$S_1 = S_2$$

$$\because \quad 6.7428 = S_f + K_2 f_{f_g}$$

$$= 1.213 + X_2 \times 6.2434$$

$$x_2 = \frac{6.7428 - 1.213}{6.2434}$$

$$= 0.8857$$

→ Calculating enthalpy at point 2

$$h_2 = h_f + X h_{f_g}$$

$$= 384.39 + 0.8857 \times 2278.6$$

$$= 2402.546\ KJ/Kg$$

Given $h_1 = 3115.3 KJ/Kg$

→ $h_4 = h_3 + vdp$

$= 384.39 + 0.0010037 \times [3000 - 74]$

$= 387.123\ KJ/Kg$

→ Pump work = vdp

$= 0.001037 \times [3000 - 74]$

$= 3.033\ KJ/Kg$

→ $W_{net} = W_T - W_P = (h_1 - h_2) - 3.033$

$= (3115.3 - 2400 - 2.546) - 3.035$

$= 709.721\ KJ/Kg$

→ Heat input $= h_1 - h_4$
$= 3115.3 - 387.423$
$= 2727.877\ KJ/Kg$

→ Efficiency of cycle $= \frac{Work\ delivered}{Heat\ input}$

$= \frac{709.721}{2727.877}$

$= 0.2601 = 26.01\% = Ans.$

Q-4 : (a) Give the similarities and differences between a clutch and a brake.

Ans :

→ **Similarities**

Features	Clutch	Brake
Control Motion	Yes	Yes
Apply Force	Yes	Yes
Dissipate Energy	Yes	Yes
Require maintenance	Yes	Yes

→ **Differences**

Features	Clutch	Brake
Function	connects / disconnects shafts	slows / stops motion
Engagement	progressive	Quick and full
Complexity	More complex	Simpler
Operating principle	Friction.	Friction.

(b) Explain any one type of rotary pumps with figure.

Ans:

→ One type of rotary pump is the gear pump gear pumps are positive displacement pumps that operate by trapping fluid between the teeth of rotating gears and the pumps casing hosing if to move from the inlet to the outlet of the pumps here's how its works

1. **Internal gear pump** : This type of gear pump consists of an external gear and an internal gear meshing together inside a casing. The gears rotate in opposite direction and the fluid is the trapped between the teeth of the gear and the casting as the rotate as the gear rotate the fluid is a carried from the inlet side to the outlet side of the pump.

2. **External gear pump :** In this design to gears mess externally with one gear being driven by the prime mover and other being driven by the missing action fluid is a trapped between the teeth of the gears and the pump casing and the is carried from the inlet to the outlet as the gear rotate.

→ Components :-

- Inlet: Where fluid enter the pump
- Outlet: Where fluid exist the pump
- Gears: One or more gears that rotate the create the pumping action
- Casing: Encloses the gears and provides a sealed chamber for fluid movement.

- Seals: Prevent leakage of fluid from the pump.

→ Advantages :-

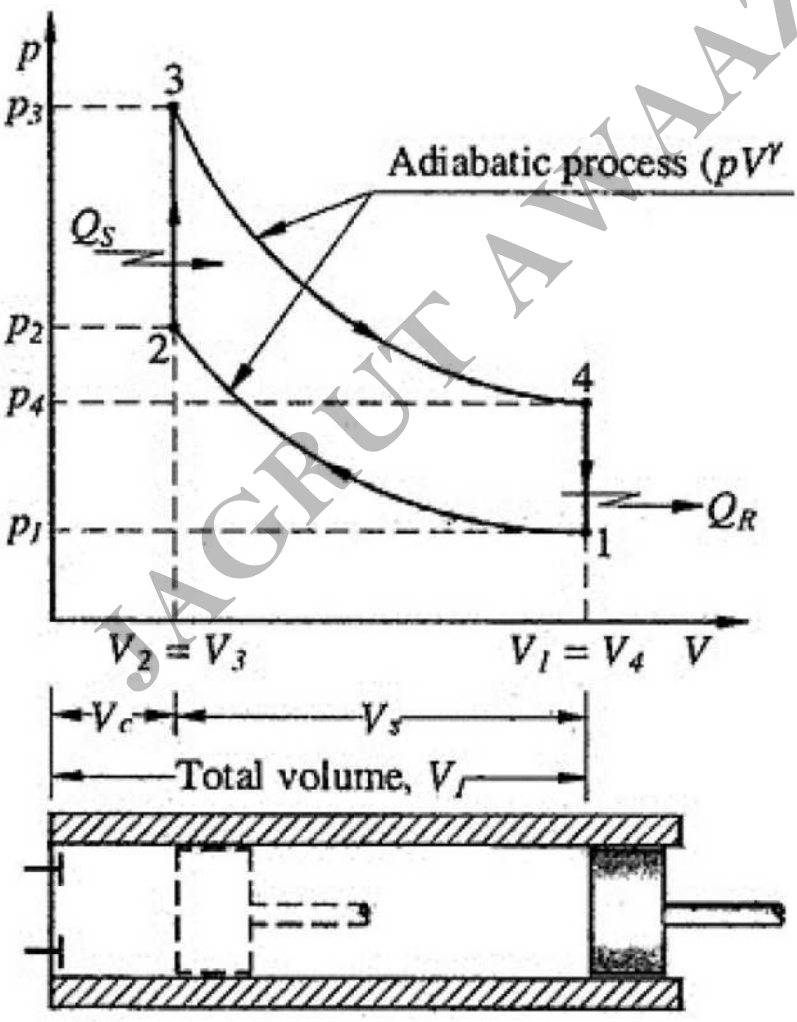
- Simple designs
- Compact size
- Capable of generating high pressure
- Suitable for the wide range of fluids including viscous fluid

→ disadvantages

- Can be noisy
- Required precious alignment of gears for optimal performance
- Limited ability to handle abrasive or corrosive fluids
-

(c) Derive, using P-v diagram, the equation to find air standard efficiency of Otto Cycle. Use the formula you derived to find which gas from the following will Give maximum efficiency for the same compression ratio: exhaust gas (γ=1.3), Air, and monatomic gas (γ=1.67)

Ans :



→ Consider a unit mass of air undergoing a cyclic change.

→ Heat supplied during the process 2 – 3,

$$q_1 = C_V(T_3 - T_2)$$

→ Heat rejected during process 4 – 1,

$$q_2 = C_V(T_4 - T_1)$$

→ Work done,

$$\therefore W = q_1 - q_2$$
$$\therefore W = C_V(T_3 - T_2) - C_V(T_4 - T_1)$$

→ Thermal efficiency,

$$\eta = \frac{Work\ done}{Heat\ supplied} = \frac{W}{q_1}$$

*-

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

$$= 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)} \quad \text{---------- ①}$$

→ For Adiabatic compression process (1 – 2),

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = r^{\gamma-1}$$

$$\therefore T_2 = T_1 r^{\gamma-1} \quad \text{---------- ②}$$

→ For Isentropic expansion process (3 – 4),

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$\therefore T_3 = T_4\left(\frac{V_4}{V_3}\right)^{\gamma-1}$$

$$\therefore T_3 = T_4\left(\frac{V_1}{V_2}\right)^{\gamma-1} \qquad (\because V_1 = V_4, V_2 = V_3)$$

$$\therefore T_3 = T_4(r)^{\gamma-1} \quad \text{---------- ③}$$

→ From equation 1,2,3 we get,

$$\eta_{otto} = 1 - \frac{T_4 - T_1}{T_4 r^{\gamma-1} - T_1 r^{\gamma-1}}$$

$$\eta_{otto} = \frac{(T_4 - T_1)}{r^{\gamma-1}(T_4 - T_1)}$$

$$\therefore \eta_{otto} = 1 - \frac{1}{r^{\gamma-1}} \quad \text{---------- ④}$$

→ Expression 4 is known as the air standard efficiency of the Otto cycle.

1. Exhaust gas ($\gamma = 1.3$)

$$\eta_{exhaust} = 1 - \frac{1}{r^{1.3-1}} = 1 - \frac{1}{r^{0.3}}$$

2. Air ($\gamma = 1.4$)

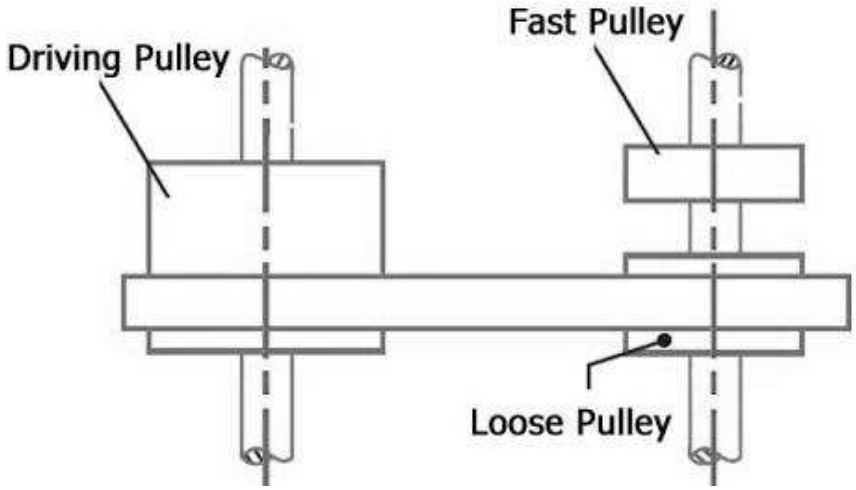
$$\eta_{air} = 1 - \frac{1}{r^{1.4-1}} = 1 - \frac{1}{r^{0.4}}$$

3. Monoatomic gas (γ=1.07)

$$\eta_{monoatomic} = 1 - \frac{1}{r^{1.07-1}} = 1 - \frac{1}{r^{0.67}}$$

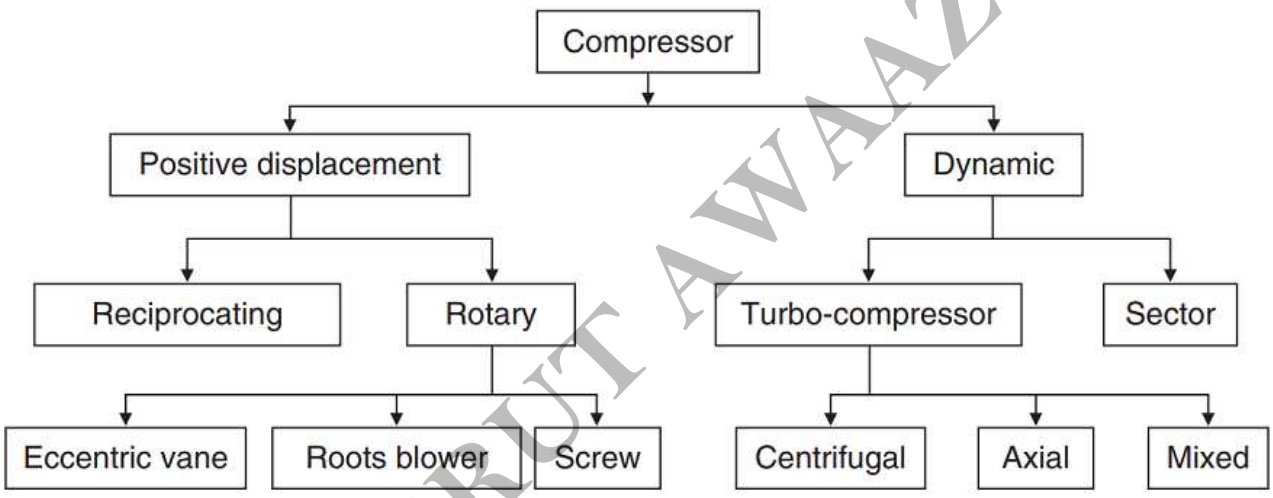
Q-5 : (a) Draw a schematic diagram of the fast and loose pulley drive.

Ans :



(b) Give classification of air compressors.

Ans :



(c) A 4-stroke 6-cylinder IC engine has a stroke volume of 1.75 liters and is operating at a mean effective pressure of 6 bar. At what crankshaft rpm will the engine develop 35 hp? (Take 1 hp = 736 watts)

What is the function of a carburetor and a fuel injector in an IC engine?

Ans :

→ Volume of stroke = 1.75L

→ Mean effective pressure(MEP) = 6 bar $= 6 \times 10^5$

→ $P = 35hp = 25.760\ Kw$

→ Cylinder = 6

→ Total volume swept $(V_s) = 1.75\ l = 1.75 \times 10^{-3} m^3$

$$P_{total} = \frac{n \times MEP \times V_S}{2} = \frac{6 \times 6 \times 1.75}{2} = 31.5 \times 10^5 \frac{N}{m^2} l$$

$$P_{total} = \frac{2\pi NT}{60}$$

$$N = \frac{(P_{total} \times 60)}{2\pi T} \qquad \text{---------- ①}$$

→ $P_{hp} = 2\pi \times N \times T$

$$T = \frac{P_{hp}}{2\pi \times N}$$

$$T = \frac{25760W}{2\pi \times N}$$

→ Substitute in eq 1

$$N = \frac{31.5 \times 10^5 \times 60N}{2\pi \times \left(\frac{25760W}{2\pi \times N}\right)}$$

$$\because N \times \frac{25760}{N} = 1890\ N$$

$$N = 13.65\ rpm$$

1. Carburetor:
   → A carburetor is a device that a mix air and fuel in the correct ratio for combustion in the engine.
   → In a carburetor, air flows through a narrow passage called the Venturi which creates are low pressure area causing fuel to be bro one from a jet and mix with the incoming air
   → The mixture of air and fuel then enter the engine cylinder for combustion
2. Fuel injector:
   → A fuel injector is a device that directly inject fuel into the combustion chamber of the engine cylinder
   → It operates by electronic control valves that open and close the precisely control the amount of the fuel inject into the cylinder
   → Fuel injectors can deliver fuel more preciously and efficiently then carburetor landing the better fuel economy lower emission and improve engine performance.

Q-5 : (a) Draw a schematic diagram of the fast and loose pulley drive.

Ans :

Sr.	Gear drive	Belt drive
1.	Require less space compared to belt drive	Required more space compared to gear drive
2.	Much greater life expectancy than belt drivers	Lower life expectancy than gear drivers.
3.	Requires regular lubrication	Require relatively less or no lubrication
4.	Noisier in operation	Very quiet in operation

(b) Define with regard to compressors: double-acting compressor, multistage compressor, displacement (swept) volume, pressure ratio.

Ans :

1. Double-acting Compressor :-
   → A double acting compressor is a type of compressor where compression occurs on both sides of the piston or within which stage of the compressor.
   → In a double acting compressor board the upward and downward strokes of the piston or stages of the compressor are utilized for compression.

2. Multistage Compressor :-
   → A multi stage compressor is a compressor that consists of multiple stages of compression
   → Which stage of compression consists of a set of compression components such as piston rotor or impellers that further compressed the gas before it enters the next stage.

3. Deplacement volume
   → Deplacement volume also known as swept volume , is the volume of gas swept to by the compression components of the compressor during one complete cycle.
   → It represents the physical volume that the piston rotor or impeller display as it moves through its stroke or rotation.

4. Pressure ratio
   → Pressure ratio is the ratio of the discharge pressure to the suction pressure in a compressor.
   → It indicates the degree of compression achieved by the compressor

(C) A petrol engine has a compression ratio of 6 and develops 15 kW. Its brake thermal efficiency is half of its air standard efficiency. Find the fuel consumption. Take calorific value of petrol as 41500 kJ/kg.
Why are more two-wheeler automobiles made with a 4-stroke engine instead of a 2-stroke engine? Give three technical reasons for this.

Ans :

$r = 6$

$P_{Output} = 15\ KW$

$C.V = 41500\ \frac{KJ}{Kg}$

1. Calculate air standard efficiency

$$\eta_{air} = 1 - \frac{1}{r^{\gamma-1}}$$

$$= 1 - \frac{1}{(6)^{\gamma-1}}$$

$$= 1 - \frac{1}{6^{1.4-1}}$$

$$= 1 - \frac{1}{6^{0.4}}$$

$$= 1 - \frac{1}{2.449}$$

$$\eta_{air} \approx 0.591$$

2. The brake thermal efficiency

$$\eta_{brake} = \frac{\eta_{air}}{2}$$

$$= \frac{0591}{2}$$

$$= 0.2955$$

3. Calculate the fuel consumption :

$$\eta_{brake} = \frac{P_{output}}{F.C \times C.V}$$

$$\because F.C = \frac{P_{output}}{\eta_{brake} \times C.V}$$

$$= \frac{15\ KW}{0.2955 \times 41500\ KJ/Kg}$$

$$= \frac{15 \times 10^3}{0.2955 \times 41500 \times 10^3\ J/Kg}$$

$$= \frac{15}{0.2955 \times 41500}$$

$$F.C = 1.22 \times 10^{-3}\ Kg/s$$

→ There are several technical reasons

1. Better fuel efficiency :-
   → 4 stroke engines typical have better fuel efficiency compared to 2 stroke engines.
   → In a 4 Rock engine each talk of piston perform a specific function landing to more efficient ambition and better utilization of fuel.

2. Lower Emissions :-
   → 4 stroke engines generally produce lower emissions compared to 2 stroke engines.
   → With increasing environmental regulation manufacturers prefer 4 stroke engine for their lower ambition profile.

3. Improve durability and reliability
   → 4 stroke engines are typically more durable and reliable compared to 2 stock engines
   → The designs of four stroke engine allows for better lubrication of engine components landing to reduce water and longer and engine life.

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