
HAPPY
DIWALI

Semester: I/II						
ELEMENTS OF MECHANICAL ENGINEERING **Category: Professional Core Course** **Stream: ME (ME, IM, CH, AS)** **(Theory)**						
Course Code	:	ME112TA		**CIE**	:	**100 Marks**
Credits: L:T:P	:	2:1:0		**SEE**	:	**100 Marks**
Total Hours	:	30L + 30T + 30EL		**SEE**	:	**3 Hours**

Unit-I	06 Hrs

Engineering Materials: Introduction and Classification of Engineering materials, Thermoset and Thermoplastics polymers, Ceramics, Classification of Fiber Reinforced Polymers (FRP) and their applications.

Properties of materials: Mechanical, Thermal, Chemical, Physical, Magnetic, Optical, Electrical and Electronics, Stress-Strain Diagram for mild steel & Cast Iron. materials and its desirable properties for Aerospace, Automotive, Electronic and Biomedical applications.

Unit – II	06 Hrs

Manufacturing Systems: Overview of manufacturing systems such as casting, forming & machining.

Metal Joining Processes: Introduction to metal joining processes, Welding & Soldering and its differences, Principle of Arc Welding, Gas Welding and soldering. Materials for Welding and soldering. Safety devices.

Emphasis on **modern** and emerging technologies: CNC machining. **Introduction to smart manufacturing**: automation & its types and features, IIoT. **Applications:** electronics, aerospace, biomedical, and sustainable manufacturing.

Unit – III	06 Hrs

Steam and its properties: property charts, Enthalpy, Numerical on steam.
Steam turbines: hydraulic turbines & its types- Pelton, Francis and Kaplan turbines (working principles).
Refrigeration: Refrigeration effect, working principle of Vapour Compression refrigeration systems, ton of refrigeration, COP, refrigerants and their properties.

Unit – IV	06 Hrs

IC Engines: Classification of IC Engines, Working of 4-Stroke petrol and diesel Engines and Comparison. Efficiency of Engines, FHP, BHP and IHP and numerical on IC Engines.
Elements of Power transmission system: Basics of power transmission- gear: types: spur, helical, bevel, Worm gear & rack and pinion, classifications, gear trains- simple & compound & simple Numericals.

Unit – V	06 Hrs

Hybrid Drives: Classification of hybrid electric vehicles – series, parallel & series-parallel, regenerative braking concepts. Introduction to hybrid vehicles, Configurations, EV/ICEV comparison, components, Traction Motor, mechanical & electrical characteristics, batteries & battery management systems, control module etc.
Mechatronics & Robotics: phases of mechatronics**,** basics of sensors, actuators, control system, applications-ABS, EMS.

Robotic system: basics of robotics, elements & Anatomy of robot, and configuration, and industrial applications of robots.

Course Outcomes	
CO1	Understand the fundamental principles of engineering materials, manufacturing methods, energy systems, mechanical drives, and smart technologies such as mechatronics, robotics, and artificial intelligence..
CO2	Explain the working principles and applications of conventional and modern manufacturing systems, thermal and mechanical systems, and intelligent automation in various engineering fields.
CO3	Apply basic engineering knowledge to interpret the behaviour of materials, select manufacturing processes, assess energy performance, and understand drive systems and intelligent control devices.
CO4	Identify and describe the role of integrated systems involving materials, energy, mechanical elements, production technologies, and smart automation for solving elementary engineering problems.

Index

UNIT-3

1) Turbines

Definition:- A turbine is a rotatory mechanical device that extracts energy from a fluid flow and converts it into useful work.

There are 3 types of turbines which are as follows:-

(i) Hydraulic turbine

(ii) Steam turbine

(iii) Gas turbine

2) Hydraulic Turbine

Hydraulic energy means the energy possessed by water in the form of potential energy, kinetic energy and intermolecular energy.

The power transmitted by a rotating shaft is usually known as mechanical energy.

The hydraulic machines are energy conversion devices in which hydraulic energy is either converted into mechanical energy is either converted into mechanical energy or vice versa.

The hydraulic machines which convert hydraulic energy is either converted into mechanical energy or vice versa.

Def:-
The hydraulic machines which convert hydraulic energy (potential energy, kinetic energy, intermolecular energy) into mechanical energy by setting the rotor in motion through dynamic action of water are known as hydraulic turbines

The hydraulic machine which convert mechanical energy into hydraulic energy are known as pumps.

3) Classification

Hydraulic turbines are classified into 3 types which are as follows:-

(i) According to the type of energy available in the inlet

→ **Impulse turbine:-** At the inlet of the rotor of the turbine, the energy available is only in the form of kinetic energy of water.

Example:- Pelton wheel, Banki turbine and Jonval turbine.

→ **Reaction turbine:-** At the inlet of the rotor of the turbine, the energy is available in the form of kinetic energy as well as pressure energy of water.

Example:- Francis turbine, propeller and Kaplan turbines

(ii) Based on the head under which the turbine works.

Head definition:- It is the vertical height difference between the water source and the turbine. It represents the potential energy of the water available to generate power.

→ **High End, impulse turbine:-**
$H > 250m$ E.g., Pelton wheel

→ **Medium head, reaction turbine:-**
$60 < H < 250m$ E.g., Francis wheel.

→ **low head, reaction turbine:-**
$H < 60m$ E.g. Kaplan turbine, Propeller turbine.

(iii) According to the direction of flow through the rotor or runner.

→ Tangential flow :- Water flows in a direction tangential to the path of rotation of rotor, i.e., normal to both axial and radial directions E.g. Pelton wheel.

→ Radial inward flow :- Water flows in a radial direction from larger diameter to smaller diameter of runner. E.g. Old Francis turbine.

→ Radial outward flow :- Water flows in a radial direction from smaller diameter to larger diameter of runner. E.g. Fourneyron turbine

→ Axial flow :- Water flows parallel to the axis of the turbine rotor. E.g. Kaplan turbine.

→ Mixed flow :- Water enters the rotor radially at outer periphery and leaves axially. E.g. Modern Francis turbine.

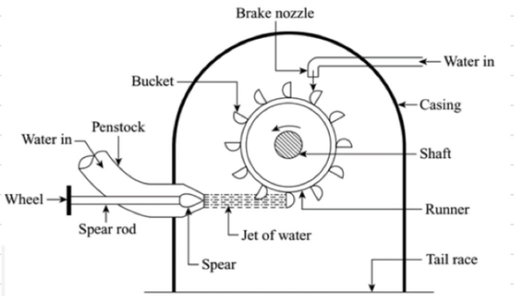
Pelton wheel

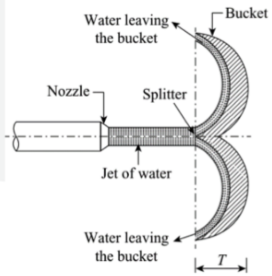
Named after L.A Pelton an American engineer. It is a high head, low flow rate, tangential flow, impulse hydraulic turbine.

The main parts of the pelton wheel are

→ Penstock :- A large sized pipe through which water flows from the reservoir to the turbine.

→ for regulating the flow from the reservoir to the turbine, the penstokes are fitted with control valves





→ Spear and nozzle arrangement :- The nozzle fitted at the end of the penstock is provided with a spear which controls the quantity of water striking the buckets of runner.

→ When the spear moves in forward direction, the flow area decreases and thus, the amount of water striking the runner is reduced and vice-versa.

→ Runner with Buckets :- Runner consists of a large disc in which a number of buckets (≥15) are evenly spaced round its periphery.

→ The Buckets take a shape of double Hemispherical cup or bowl.

→ Each bucket is divided into 2 symmetrical parts by a sharp edged riged called a splitter.

→ The jet of water strikes on the splitter which divides the jet into two equal parts, each of which after flowing round the inner smooth bucket surface leaves as its outer edge.

→ The buckets are so shaped that the jet of water gets deflected through 160° to 170°.

→ Casing :- In Pelton turbine, the casing does not perform any hydraulic function.

→ It is provided only to prevent splashing of water and to guide it to the tail race.

→ It also acts as a safeguard against accidents.

→ Braking jet :- In order to shutdown the turbine, the nozzle is completely closed by moving the spear in the forward direction.

→ However the runner still goes on revolving for a long time due to inertia.

→ To stop the runner in a short time, a small brake nozzle is provided which directs the jet of water on the back of the buckets.

Francis Turbine

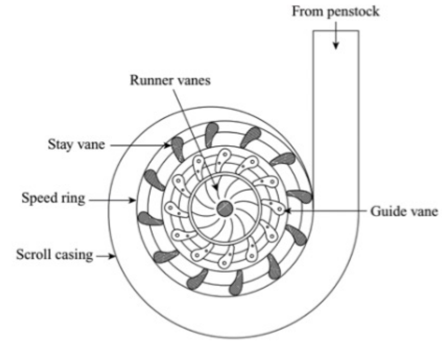
Name in the honor of J.B. Francis, an American engineer. It is a medium head, medium flow rate, mixed flow, reaction hydraulic turbine.

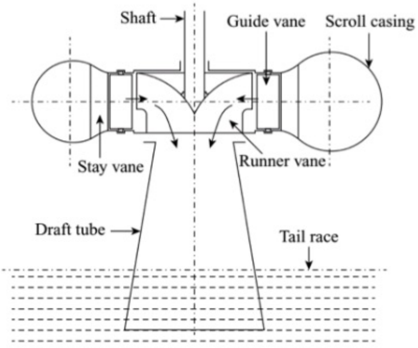
The main parts of a Francis turbine are
(i) penstoke
(ii) scroll casing
(iii) guide mechanism
(iv) runner
(v) draft tube

Penstock :- It is a large sized conduit which conveys water from reservoir to the runner.

Trash racks are commonly provided at the inlet of penstock to obstruct the entry of debris and other foreign matter into the turbine.

In Francis turbines, large size penstokes are required due to large volume of water flow.





Scroll casing :- The water from the penstoke enters the scroll casing which is of spiral shape of the turbine and maintains the even distribution of water around the circumference of the runner.

Guide mechanism :- Water from the casing flow through a stay ring having fixed stay vanes which direct the water to the guide vanes. Genrally, the no. of stay vanes is taken as half of the number of guide vanes.

The guide vanes are adjustable and are known as wicket gates. The guide vanes are airfoil shaped so that the flow remains smooth without any separation. The guide vanes behave like nozzles.

Runner :- It is also known as rotor.

Runner is circular wheel in which a series of radial curved vanes are evenly fixed. Usually, the no. of vanes varies between 16 to 24.

The radial curved vanes are so shaped that water enters the runner radially at the outer periphery and leaves axially at the inner periphery without shock.

Draft tube : A draft tube is a pipe of gradually increasing cross-sectional area.

One end of the draft tube is connected to the runner exit, while the other end is submerged deep into the tail race.

Kaplan Turbine

Named after an Austrian engineer, Victor Kaplan. It is an axial type, low head (2.5 m to 50 m), high specific speed, reaction turbine which handles large volume flow rate of water.

The main parts of a kaplan turbine are as follows :-

(i) Scroll casing

(ii) Guide vanes

(iii) Whirl chamber

(iv) Propeller-shaped

(v) Draft tube

(vi) Governor mechanism.

Scroll casing :- Its function is very similar to scroll casin in fransis turbine. It reduces the eddies formation an hence minimizes the eddy loss.

Guide vanes :- The function is similar to francis turbine.

Whirl Chamber :- Space between the guide-vane outlet

Runner :- The runner in a kaplan turbine is a set of specially designed blade that give the appearance of a ship's propeller.

The blades are connected to the drive shaft at the hub.

The number of blades varies from 3 to 8 and the blades are adjustable.

Draft tube :- The hydraulic aspects relating to draft-tube installation are same as described in connection with Francis turbines.

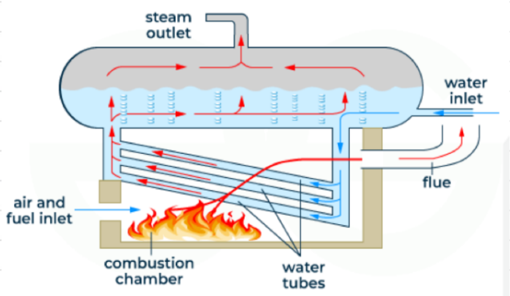
Governor Mechanism:- The governor is an essential, integrated component of the Kaplan turbine. It does 2 functions:-

(a) Controls the guide-vane openings and thereby regulates the discharge into the turbine.

(b) Regulates through servo control mechanism, the disposition of the blades to the flow and achives high efficiencies at part loads.

II Steam And it's properties

Introduction to steam



When the water is heated in a boiler or steam generator at constant pressure, its heat constant called enthalpy increases and its physical state changes.

With the addition of heat, the temperature of water rises and vaporization takes place.

The vapour so formed is called steam.

Steam does not obey laws of perfect gases

In a highly superheated state, its behavior approaches that of a perfect gas.

Evaporation:- It is the process of the conversion of water to water vapour.

Condensation:- It is the process where vapour turns into water.

Sensible heat:- The sensible heat of water is the heat added to or removed from water that cause a change in its temperature, but not its physical state (phase).

Specific heat:- It is the quantity of heat required to raise the temperature of 1 Kilogram of water by one degree.

Note:-

specific heat of ice = 2.09 KJ/Kg-k

specific heat of water = 4.1868 KJ/Kg-k

specific heat of superheated steam = 2.1 KJ/Kg-k

Latent heat of Vaporization:- It is the energy that is absorbed by the water during the phase transition from liquid water to the vapour at the saturation temperature.

Latent heat of Vaporization of water = 2256.9 KJ/Kg at 1 bar.

Latent heat of fusion:- It is the energy that is absorbed by the ice during the phase transition from ice to the water at the saturation temperature.

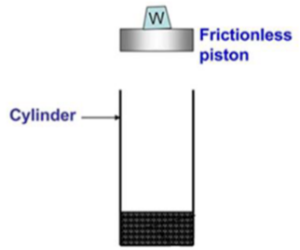
Latent heat of fusion = 335.9 KJ/Kg at 1 bar.

Boiling Point:- It is the temperature at which water converts into a vapour.

Freezing Point:- It is the temperature at which water converts to ice.

Formation of steam at constant Pressure.

Consider 1kg of water at 0°C in a cylinder fitted with a freely moving frictionless piston of negligible weight.



1 kg of water at 0°C

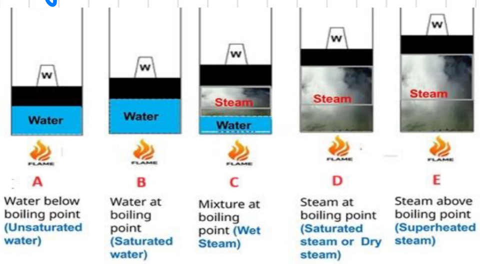
A kg of water in piston cylinder arrangement

The weight W is present on the piston. The pressure applied on the water due to weight W is

Pressure, $P = \frac{\text{weight applied on piston}}{\text{cross sectional area of piston}}$

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

Water at 0°C will be heated till it converts to superheated steam using a source of heat in the above mentioned arrangement as shown in next slide.



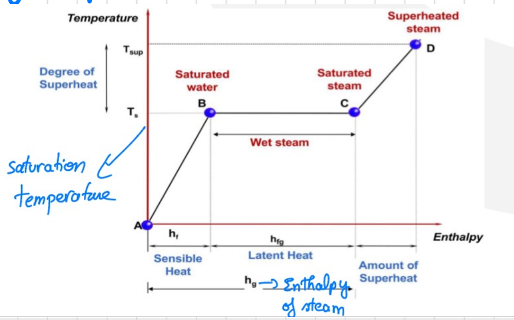
Formation of Steam at constant pressure

Temperature enthalpy plot

Steam to water conversion as depicted in the previous slide is represented using temperature enthalphy (T-h) plot here.

Enthalpy is a measure of total heat energy in the water or steam.

The total heat or enthalpy of steam is the sum of sensible heat, internal latent heat and the external work of evaporation.



Sensible Heat (h_f in J/kg):- Amount of heat required to raise the temperature of 1Kg of water from 0°C to saturation temperature T_{sat} °C at a given constant pressure.

Line AB on T-h plot represents sensible heating. Also called enthalpy of satured water.

Latent Heat (h_{fg} in J/kg):- Amount of heat required to convert 1kg of saturated water to 1kg of saturated steam at a saturation temperature T_{sat} °C for the given constant pressure.

Line BC on the T-h plot represents latent heating. Also called enthalpy of evaporation or vaporisation.

Amount of superheat (J/Kg):- It is the amount of heat required to raise the temperature of 1kg of dry steam at Saturation temperature to the desired higher temperature at a given constant pressure.

Line CD on the T-h plot represents superheating.

Degree of superheat :- The difference between the super-heated temperature and the saturation temperature $(T_{sup} - T_s)$.

Wet Steam :- It is a 2 phase mixture of water and vapour in thermal equilibrium at the Saturation temperature corresponding to the given stated pressure.

Dry Steam :- When all the water present in wet steam converts to vapour at the saturation temperature, it is called dry steam. It is a single-phase vapour.

Superheated Steam :- When the dry steam at Saturation temp is further heated, its temperature increases and the steam is called super-heated steam.

Superheated steam comes with the advantage of higher energy content and lesser changes of corroding the turbine or engine parts.

Dryness Fraction :- The wet steam is a mixture of dry steam & saturated water. The vapour fraction in the wet steam is called dryness fraction (x).

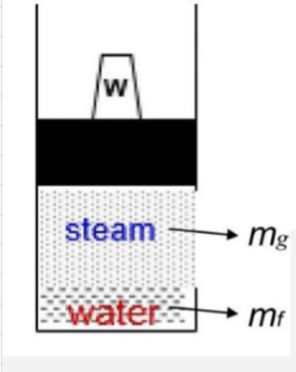
$$X = \frac{\text{mass of dry steam in the mixture}}{\text{total mass of wet steam}}$$

$$\Rightarrow \frac{m_g}{m_f + m_g}$$

For dry steam, $X = 1$

For saturated steam, $X = 0$

For Wet steam $0 < X < 1$



Enthalpy Equations

Enthalpy of unsaturated water (h_w):-

$$h_w = C_p(T_w - 0) \text{ KJ/Kg}$$

Enthalpy of saturated water (h_f):-

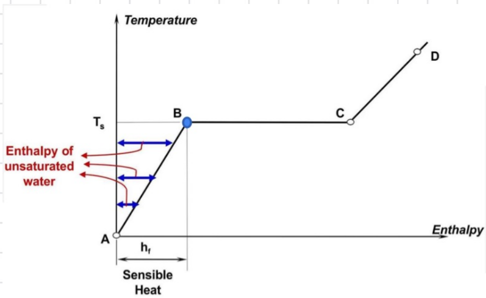
$$h_f = C_p(T_s - 0) \text{ KJ/Kg} \quad \text{where,}$$

C_p = Specific heat in KJ/Kg K

T_w = Temp of water in °C.

T_s = Temp of of water in °C $(T_w < T_s)$

h_f is also known as sensible heat.



Enthalpy of dry saturated steam (h_g):-

$$h_g = h_f + h_{fg} \text{ KJ/Kg}$$

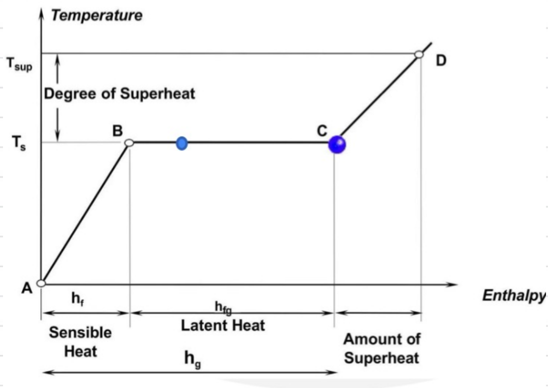
Enthalpy of wet steam (h):-

$h = h_f + x h_{fg}$ KJ/Kg where,

h_f = sensible heat in KJ/kgK

h_{fg} = latent heat in KJ/kg K

x = dryness fraction.



Enthalpy of superheated steam (h_{sup}):-

$$h_{sup} = \underbrace{h_f + h_{fg}}_{h_g} + C_{sup}(T_{sup} - T_s) \text{ KJ/Kg}$$

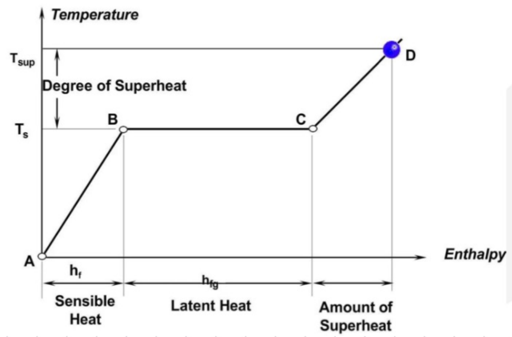
Amount or enthalpy of super-heat :-

$AOS = C_{sup}(T_{sup} - T_s)$ KJ/Kg where,

C_{sup} = specific heat of super heated steam in KJ/Kg K.

T_{sup} = Superheated Temperature in °C.

T_s = Saturation temperature in °C.



Steam Table

The working fluid in any system has 6 basic thermodynamic properties which are needed to define the state of the working medium completely.

These properties may not be independent and may be specific at specific conditions and are tabulated in the steam table at different pressure and Saturation temperature conditions.

These properties are pressure (P), temperature (T), volume (v), internal energy (u), enthalpy (h) and entropy (s).

Sample steam table is as below:-

Absolute pressure (P bar)	Saturation temperature (t°C)	Specific enthalpy (kJ/kg)			Specific entropy			Specific volume (m^3/kg)	
		h_f	h_{fg}	h_g	s_f	s_{fg}	s_g	v_f	v_g
1.0	99.7	417.51	2257.9	2675.4	1.3027	6.050	7.359	0.001043	1.725
5.0	151.1	640.12	210.7	274.7	1.86	4.588	6.819	0.001092	0.382
20.0	211.4	908.99	1888.6	2797.2	2.4469	3.779	6.3567	0.001175	0.1015

steam volume (v) :- Specific volume of dry and saturated steam (V_g) and saturated water (V_f) is diretly obtained from steam table corresponding to that pressure or saturation temperature.

For wet steam, the dryness fraction 'x' has to be used to estimate the specific volume.

Volume of 1 Kg wet steam
= volume of dry steam + volume of water

$$V = xV_g + (1-x)V_f$$

$$\Rightarrow V = xV_g \quad (\text{since } V_f \ll V_g)$$

The specific volume of superheated steam can be estimated with the help of gas laws since steam at these temperatures behaves like an ideal gas.

$$\frac{PV_{sup}}{T_{sup}} = \frac{PV_g}{T_s} \Rightarrow V_{sup} = \frac{T_{sup}V_g}{T_s}$$

If the specific volume of any steam is v then its density (ρ) will be $\frac{1}{v}$.

Entropy (s):- Entropy is a measure of randomness associated with the system and mathematically the change in entropy between initial and final state is defined as

$$S_2 - S_1 = \int_i^f \frac{dQ}{T} \quad \text{where,}$$

$dQ \rightarrow$ is the heat transfer in KJ and T is the temperature in Kelvin (K).

The unit used to measure entropy is KJ/Kg K.

Entropy of water:- Consider heating of unit mass of water from a temp of T_1°C to T_2°C at constant pressure.

Amount of heat addition for infinitesimal process is given by

$$dQ = C_p dT$$

Then change in entropy for the process is defined as

$$S_2 - S_1 = \int_{T_1}^{T_2} \frac{dQ}{T} = \int_{T_1}^{T_2} \frac{C_p dT}{T} = C_p \ln\left(\frac{T_2}{T_1}\right)$$

Entropy of wet steam :-

In case the steam remains wet during heat transfer of evaporating water and its dryness fraction is x, then

$$S = S_f + xS_{fg} \text{ KJ/Kg K}$$

If steam becomes dry and saturated then $x = 1$

$$S_g = S_f + S_{fg} \text{ KJ/Kg K}$$

Entropy of superheated steam :- Let the unit mass of dry saturated steam at temperature. If specific heat C_{psup} is considered constant, then

$$S_{sup} = S_g + C_{psup} \ln\left(\frac{T_{sup}}{T_s}\right) \text{ KJ/Kg K}$$

External work done during Evaporation:- The volume of saturated water (V_f) is very small in comparison to dry saturated steam (V_g).

Since this process takes place at constant pressure and as volume increases external work is done by the piston cylinder arrangement on the surroundings.

The energy required for this external work comes from absorbing energy from the total heat of the steam which is called as external work done during evaporation.

external work of evaporation $= P(V_g - V_f)$ KJ/Kg

since $V_f \ll V_g$ it can be neglected.

External work $= PV_g$ for dry saturated
$= xPV_g$ for wet steam

Internal Energy (u):- The energy stored in steam is called internal energy.

The work of evaporation is not stored in the steam since it is used in carrying out the external work done.

Therefore the internal energy of steam can be defined as

$h = u + P(V_g - V_f)$

$u = h - P(V_g - V_f)$ where,

$u \rightarrow$ internal energy of 1Kg of steam at presure P.

since $V_f << V_g$, it can be neglected

$u = h - PV_g$ for dry saturated steam

$u = h - xPV_g$ for wet steam

In case of superheated steam,

$h_{sup} = h_f + h_{fg} + C_{ps}(T_{sup} - T_s)$ KJ/kg

$\Rightarrow u = h_{sup} - PV_{sup}$

Find the enthalpy of 1kg of steam at 12 bar when
(a) stream is dry saturated
(b) steam is 22% wet
(c) superheated to 250°C
use the steam table assume the specific heat of the superheated steam as 2.25 kJ/kgk

ans) given :- $P = 12$ bar, wetness $= 22\%$, $T_{sup} = 250°C$
$C_{ps} = 2.25$ kJ/kg K

h_f, $h_{fg} \rightarrow 1984.3$ kJ/kg, $T_s = 188°C$
$h_f \rightarrow 798.43$ kJ/kg

solution:-

$h_g = h_f + h_{fg}$

$\Rightarrow h_g = 798.43 + 1984.3$

$\Rightarrow 2782$ kJ/kg

$h = h_f + h_{fg}$

$\Rightarrow 798.4 + (0.78 \times 1984.3)$

$\Rightarrow h = 2346.15$ kJ/kg

(iii) $h_{sup} = h_g + C_{ps}(T_{sup} - T_{sd})$

$\Rightarrow h_{sup} = 2782.7 + 2.25(250 - 188)$

$\Rightarrow h_{sup} = 2922.23$ kJ/kg

Q2) Steam at 10bar and dryness 0.98 revives 140 kJ per kg at the same pressure. What is the final state of the steam?

ans)

given :- $P = 10\,bar$
$x = 0.98$

To find :- Enthalpy of wet steam
final state of the steam

Solution :-

$$h = h_f + h_{fg}$$

$$\Rightarrow h = 762.6 + 0.98 \times 2013.6$$

$$\Rightarrow h = 2777.18\ kJ/kg$$

If 140 kJ/kg heat added to enthalpy of

$$h = 2735.92 + 140$$

$$\Rightarrow h = 2875.92 \text{ ——— } ①$$

Enthalpy of dry steam

$$h_g = h_f + h_g$$

$$\Rightarrow h_g = 7626 + 2013.6$$

$$\Rightarrow h_g = 2776.2\ kJ/kg \text{ ——— } ②$$

comparing ① and ②, we get value of h_g less than h, hence the given state of steam is superheated steam.

enthalpy of superheated steam

$$h_{sup} = h_g + C_{ps}(T_{sup} - T_{sat})$$

$$\Rightarrow 2875.92 = 2776.2 + 2.24(T_{sup} - 179.91)$$

$$\Rightarrow 224.4\ °C$$

Q3) The enthalpy of 1 Kg of steam at 70 Bar is 2680 kJ. What is the condition of the steam?

ans)

given :- $P = 70\,Bar$
$X = 0.94$

To find :- the condition of the steam

Solution :-

$$h = h_f + h_{fg}$$

$$\Rightarrow 1267.4 + 0.94 \times 1506$$

$$\Rightarrow 2773.5$$

comparing to the given value we get that the steam is wet steam

$$\Rightarrow h = h_f + x h_{fg}$$

$$\Rightarrow 2680 = 1267.4 + x(1506)$$

$$\Rightarrow x = 0.94$$

Q4) 6 kg of wet steam contains 0.6 kg of water particle into what is dryness factor of it?

ans)

Q5) 5 Kg of wet steam of dryness 0.8 passes from a boiler to a superheater at a constant pressure of 1 megapascal. In a superheater temperature increases to 350 °C. determine the ammount of heat supplied to the super heater. The specific heat of the steam (Cps) 2.25 kJ/kg K⁻¹ and

given :- mass of wet steam, $m = 5kg$
initial dryness fraction, $x_1 = 0.8$
constant pressure, $P = 1MPa = 1 bar$
final superheated temp = 350 °C
$C_{ps} = 2.25 \, kJ/kg \, k^{-1}$

Solution:- $h_1 = h_f + h_{fg} \times x_1$

$\Rightarrow 762.6 + (0.8 \times 2014.6)$

$\Rightarrow 2374.28 \, KJ/Kg$

$h_2 = h_f + C_{ps}(T_2 - T_1)$

$\Rightarrow 2777.1 + 2.25(350 - 179.88)$

$\Rightarrow 3159.87 \, kJ/kg$

now $Q = m(h_2 - h_1)$

$\Rightarrow 5(3159.87 - 2374.28)$

$\Rightarrow 3927.95 \, KJ/kg$

Q6) 1 Kg of superheated steam at 1.5 mpa contains 300 kJ of heat energy find the super heated temp if the 300 kJ of heat energy is removed. what is the condition of the steam. The specific heat of superheated steam is 2.25 kJ k⁻¹

ans)

Given Data

- **Mass of steam (m):** 1 kg
- **Pressure (P):** $1.5 \text{ MPa} = 15 \text{ bar}$
- **Initial Enthalpy (H_1):** 3000 kJ
- **Heat Removed (Q_{out}):** 300 kJ
- **Specific heat of superheated steam (C_p):** 2.25 kJ/kg K

Step 1: Find Properties from Steam Tables

First, we need to find the properties of saturated steam at the given pressure of 1.5 MPa. From the steam tables:

- **Saturation Temperature (T_{sat}):** $198.3°C$
- **Specific enthalpy of saturated liquid (h_f):** 844.7 kJ/kg
- **Specific enthalpy of saturated vapor (h_g):** 2792.2 kJ/kg

Part 1: Calculate the Initial Superheated Temperature

The initial specific enthalpy (h_1) is the total enthalpy divided by mass:

$$h_1 = \frac{H_1}{m} = \frac{3000 \text{ kJ}}{1 \text{ kg}} = 3000 \text{ kJ/kg}$$

Since $h_1 (3000 \text{ kJ/kg}) > h_g (2792.2 \text{ kJ/kg})$, the steam is indeed superheated.

We can find the superheated temperature (T_{sup}) using the following formula:

$$h_1 = h_g + c_p(T_{sup} - T_{sat})$$

Rearranging to solve for T_{sup}:

$$T_{sup} = T_{sat} + \frac{h_1 - h_g}{c_p}$$

$$T_{sup} = 198.3 + \frac{3000 - 2792.2}{2.25}$$

$$T_{sup} = 198.3 + \frac{207.8}{2.25}$$

$$T_{sup} = 198.3 + 92.36$$

$$T_{sup} \approx 290.66°C$$

The initial superheated temperature is approximately 290.66°C.

Part 2: Determine the Final Condition of the Steam

When heat is removed at constant pressure, the heat loss is equal to the change in enthalpy. We first find the final enthalpy (H_2):

$$H_2 = H_1 - Q_{out}$$

$$H_2 = 3000 \text{ kJ} - 300 \text{ kJ} = 2700 \text{ kJ}$$

The final specific enthalpy (h_2) is:

$$h_2 = \frac{H_2}{m} = \frac{2700 \text{ kJ}}{1 \text{ kg}} = 2700 \text{ kJ/kg}$$

Now, we compare h_2 to the saturation values at 1.5 MPa:

- $h_f = 844.7 \text{ kJ/kg}$
- $h_g = 2792.2 \text{ kJ/kg}$

Since $h_f < h_2 < h_g$ $(844.7 < 2700 < 2792.2)$, the steam is now a **saturated liqui**
vapor mixture (wet steam).

To fully describe its condition, we calculate the dryness fraction (or quality), x:

$$h_2 = h_f + x \cdot (h_g - h_f)$$

Rearranging to solve for x:

$$x = \frac{h_2 - h_f}{h_g - h_f}$$

$$x = \frac{2700 - 844.7}{2792.2 - 844.7}$$

$$x = \frac{1855.3}{1947.5}$$

$$x \approx 0.953$$

The final condition of the steam is a wet steam mixture with a dryness fraction of 0.953 (or 95.3% dry).

Q7) A mixture of Saturated water & steam at a temp of 250°C is contained in a closed vessal of 0.1 m³ capacity. If the mass of the saturated water is 2kg find the mass of the steam in the vessal. Also find the pressure specific volume, dryness fraction & enthalpy of the mixture?

ans)

given :- $T_s = 250°C$

Volume of the Vessel = 0.1 m³

$m_f = 2$ kg

at the saturation temp T_s 250°c the values are

Given Data

- **Temperature (T):** $250^{\circ}C$
- **Total Volume (V):** 0.1 m^3
- **Mass of Saturated Water (m_f):** 2 kg

Step 1: Find Properties from Steam Tables

For a saturated mixture at a temperature of **250°C**, we can find the following properties from a standard steam table:

- **Pressure (P_{sat}):** 3.9776 MPa
- **Specific volume of saturated liquid (v_f):** $0.001251 \text{ m}^3/\text{kg}$
- **Specific volume of saturated vapor (v_g):** $0.05009 \text{ m}^3/\text{kg}$
- **Specific enthalpy of saturated liquid (h_f):** 1085.8 kJ/kg
- **Specific enthalpy of saturated vapor (h_g):** 2800.9 kJ/kg

Step 2: Calculations

1. Pressure of the Mixture (P)

For a saturated mixture, the pressure is the saturation pressure corresponding to the temperature.

$$P = P_{sat} \text{ at } 250^{\circ}C$$

The pressure of the mixture is 3.9776 MPa.

2. Mass of the Steam (m_g)

The total volume is the sum of the volume of the water and the volume of the steam.

$$V = V_f + V_g$$

First, find the volume of the saturated water (V_f):

$$V_f = m_f \times v_f = 2 \text{ kg} \times 0.001251 \text{ m}^3/\text{kg} = 0.002502 \text{ m}^3$$

Now, find the volume of the steam (V_g):

$$V_g = V - V_f = 0.1 \text{ m}^3 - 0.002502 \text{ m}^3 = 0.097498 \text{ m}^3$$

Finally, calculate the mass of the steam (m_g):

$$m_g = \frac{V_g}{v_g} = \frac{0.097498 \text{ m}^3}{0.05009 \text{ m}^3/\text{kg}} \approx 1.946 \text{ kg}$$

The mass of the steam is 1.946 kg.

3. Dryness Fraction (x)

First, find the total mass (m):

$$m = m_f + m_g = 2 \text{ kg} + 1.946 \text{ kg} = 3.946 \text{ kg}$$

The dryness fraction (x) is the ratio of the mass of steam to the total mass:

$$x = \frac{m_g}{m} = \frac{1.946 \text{ kg}}{3.946 \text{ kg}} \approx 0.493$$

The dryness fraction is 0.493 (or 49.3%).

4. Specific Volume of the Mixture (v)

The specific volume (v) is the total volume divided by the total mass:

$$v = \frac{V}{m} = \frac{0.1 \text{ m}^3}{3.946 \text{ kg}} \approx 0.02534 \text{ m}^3/\text{kg}$$

The specific volume of the mixture is 0.02534 m³/kg.

5. Enthalpy of the Mixture (H)

First, we find the specific enthalpy (h) of the mixture using the dryness fraction:

$$h = h_f + x \cdot (h_g - h_f)$$

$$h = 1085.8 + 0.493 \cdot (2800.9 - 1085.8)$$

$$h = 1085.8 + 0.493 \cdot (1715.1)$$

$$h = 1085.8 + 845.54 = 1931.34 \text{ kJ/kg}$$

Now, calculate the total enthalpy (H) of the mixture:

$$H = m \times h = 3.946 \text{ kg} \times 1931.34 \text{ kJ/kg} \approx 7621.17 \text{ kJ}$$

The total enthalpy of the mixture is 7621.17 kJ.

mass of mixture = 2 + 1.96
=> 3.96 kg

The specific volume of the mixture is equal to volume of the vessal by total mass of the mixture

$$V_s = \frac{0.1}{0.25}$$

enthalpy of wet steam

$$h = h_f + x h_{fg} \quad kJ/kg$$

$$h = 1925.95 \quad kJ/kg$$

$$h = 3860$$

$$V_s = \frac{0.1}{3.96}$$

$$\Rightarrow V_s = 0.025 \ m^3/kg$$

IV Steam turbines

A steam turbine is a power producing turbomachine in which energy of high pressure, high temperature steam applied from a steam generator is converted continuously into shaft work and the lower pressure, lower temperature steam at its outlet is discharged.

It is a prime mover working on Rankine cycle and its variants.

It is an assemblage of nozzle & ring of moving blades mounted on a rotor shaft.

The high pressure, high temperature steam first expands in a nozzle and comes out as high velocity jet because of the static pressure drop in the nozzle.

The high velocity stream exiting the nozzle impinges on the rotor blades

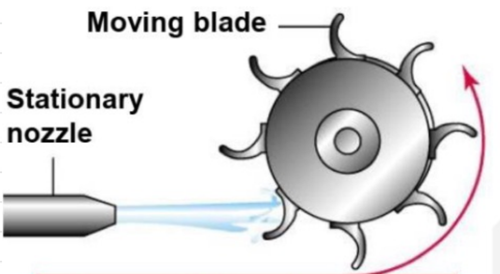
The rate of change of momentum of a high velocity jet striking on a curved blade which is free to rotate determines the motive power of a steam turbine.

Impulse And Reaction steam turbine

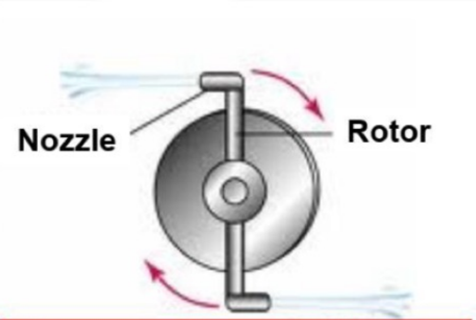
The conversion of energy of the steam in the blades to the driving thrust takes place by impulse, reaction or impulse reaction principle.

Steam turbines are classified into
(i) Impulse turbine :- Ex:- De Laval
Curtis turbine

(ii) Reaction turbine :- Ex :- Parson turbine



Concept of impulse turbine



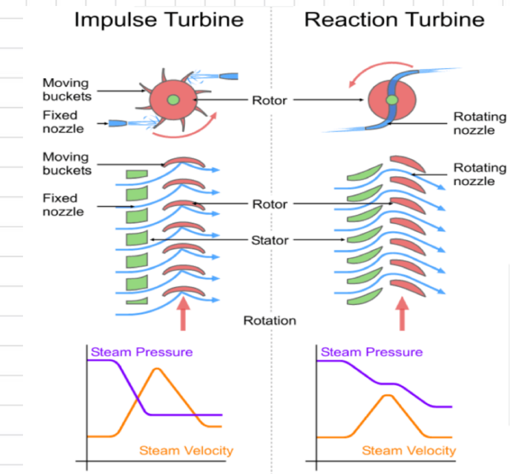
Concept of reaction turbine

In an impulse turbine, all the pressure drop occurs across nozzles (or stationary blades) and there will be no pressure drop across the rotor blades (neglecting frictional loss).

In a reaction turbine, there will be pressure drop across both stationary and moving blades.

The difference between impulse and reaction turbine are as follows:-

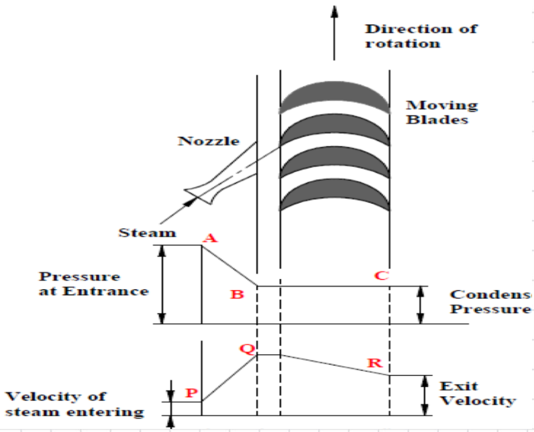
Impulse Steam turbine	Reaction Steam Turbine
Steam expands completely in nozzles. Pressure remains constant across rotor blades	Fixed blades act as nozzle. Steam expands partially in rotor and partially in stator blades
Driving thrust in case of impulse turbine is obtained due to *change of momentum because of change in the direction of steam velocity* (Impulse action) while flowing across the blade from inlet to outlet.	Driving thrust in reaction turbine consists of *reactive force and force corresponding to change of momentum because of the change in direction of steam velocity (Combined Impulse and reaction)*
Blade passage is of constant cross sectional area from inlet to outlet of rotor as P = const. across rotor blades	Blade passage is of variable cross sectional area (converging type) from inlet to outlet of rotor as pressure drops across rotor blades
Rotor blades are of symmetric profile and hence easier to manufacture.	Rotor blades are of airfoil shape and non-symmetric and are difficult to manufacture
It has got high rotational speed as it includes large pressure drop in nozzle, hence compounding is needed to reduce speed	It has got low rotational speed as it involves smaller pressure drops across stator. Hence no compounding is needed
Occupies less space per unit power.	Occupies more space per unit power
Suitable for lower power generation	Suitable for medium and larger power generation
E.g. De Laval, Curtis, Moore Turbine	E.g., Parson, Ljungstrom Turbine



De Lavel Turbine

Single stage of an impulse turbine.

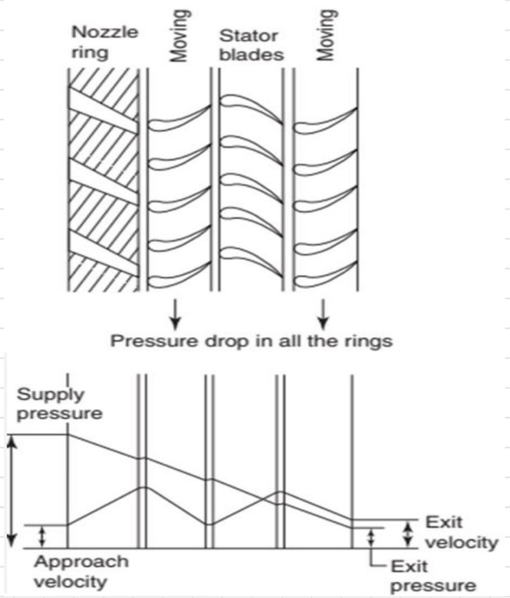
Since the expansion of the steam takes place in the nozzle is represented by the curve AB, the corresponding rise in velocity in the nozzle is represented by the curve PQ.



As there is no change in the pressure of steam that is passing over the blade, this flow is represented by the horizontal line BC.

As the blades absorb the kinetic energy of the steam as it flows over it, the velocity decreases. This is represented by the curve QR.

Parsons Turbine



Pressure compounded reaction turbine.

In Parsons staging, pressure drop not only happens in stationary blades but also in moving blades.

The cross-sectional area of the passages between the rotor blades is such that the passages act as nozzles, with expansion of steam occurring in the rotor blades also.

These stages are repeated one after the other, each stage comprising one set of stator blades followed by one set of rotor blades.

IV Refrigeration

American society of refrigerating engineers defines refrigeration as "the science of providing and maintaining temp of the system below that of the surrounding atmosphere.

The melting of ice or snow was one of the earliest methods of refrigeration & is still employed.

Another medium of refrigeration is solid carbon dioxide or dry ice. At atmospheric pressure, CO_2 cannot exist in a liquid state, and consequently, when solid CO_2 is exposed to atmosphere it sublimates, by absorbing the latent heat of sublimation from the surroundings.

In the above example, it is observed that the refrigeration effect has been accomplished by non-cyclic processes.

In closed cycle or cyclic process, the refrigerant flows inside tubes while refrigerating the space and does not get contaminated.

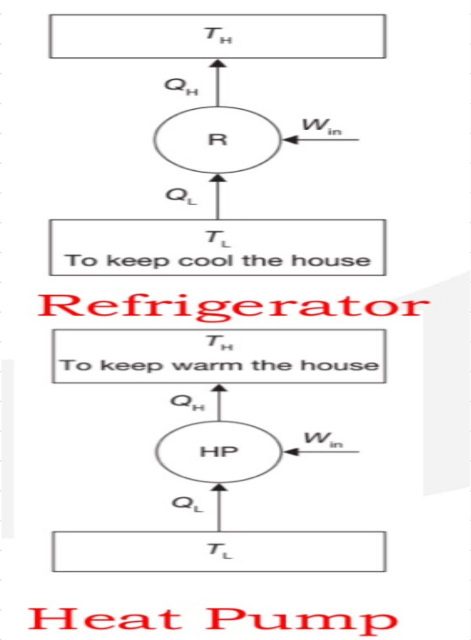
Refrigeration And Heat Pump

Clausius statement of the second law of thermodynamics says "it's impossible to construct a device that operating in a cycle, has no effect other than the transfer of heat from a cooler to a hotter body.

It means that heat will not flow from cold to hot regions without the assistance of outside agents

The devices that provide this assistance are called refrigerators and heat pumps.

The refrigeration unit transfers heat from cold to hot regions for the purpose of cooling while the heat pump does the same thing with the intent of heating the region.



The performance of the refrigerators and the heat pump is expressed in terms of the quantity known as Coefficient of performance (COP).

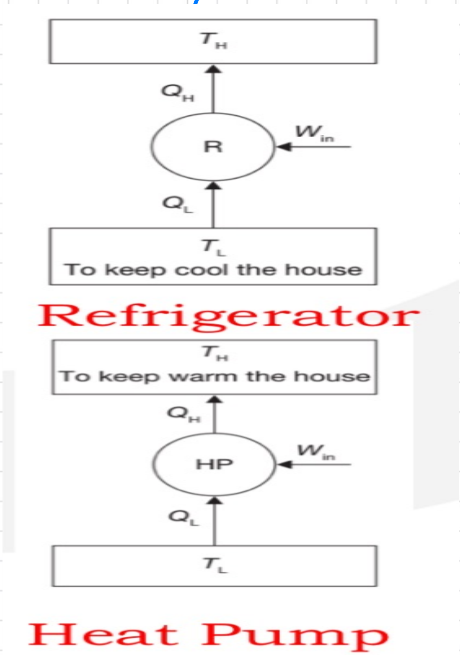
Coefficient of performance (COP):-

$$COP_R = \frac{\text{Desired Output}}{\text{Required input}}$$

$$\Rightarrow \frac{\text{Refrigeration effect}}{\text{work input}} \Rightarrow \frac{Q_L}{W_m}$$

$$COP_{HP} = \frac{\text{Desired Output}}{\text{Required input}}$$

$$\Rightarrow \frac{\text{Heating effect}}{\text{work input}} \Rightarrow \frac{Q_H}{W_m}$$



Unit of refrigeration

Refrigeration effect is the amount of heat extracted from the refrigerated space per unit mass flow of the refrigerant.

The higher the capacity of refregerator means higher shall be the refrigeration effect. Refrigeration effect is defined by the unit of refrigeration called Ton of refrigeration.

One Ton of refrigeration can be defined by the amount of heat being removed from 1 ton of water at 0°C to form 1 ton of ice at 0°C within 24 hours.

Latent heat of solidification from water to ice at 0°C = 334.5 kJ/kg

1 Ton refrigeration = $\frac{(m_{water} \times \text{latent heat of fusion of water})}{24 \text{ hrs}}$

$$\Rightarrow \frac{(100 \times 334.5)}{(24 \times 3600)}$$

$$\Rightarrow 3.87 \text{ kJ/s}$$

$$\Rightarrow 3.87 \text{ kW}$$

One ton or ton or tonne of refrigeration is SI units is often taken approximately equivalent to the heat removal rate of 3.5 kW or 210 kJ/min or 12600 kJ/h

Components Of Refrigeration System.

There are four basic components of a refrigeration system:-

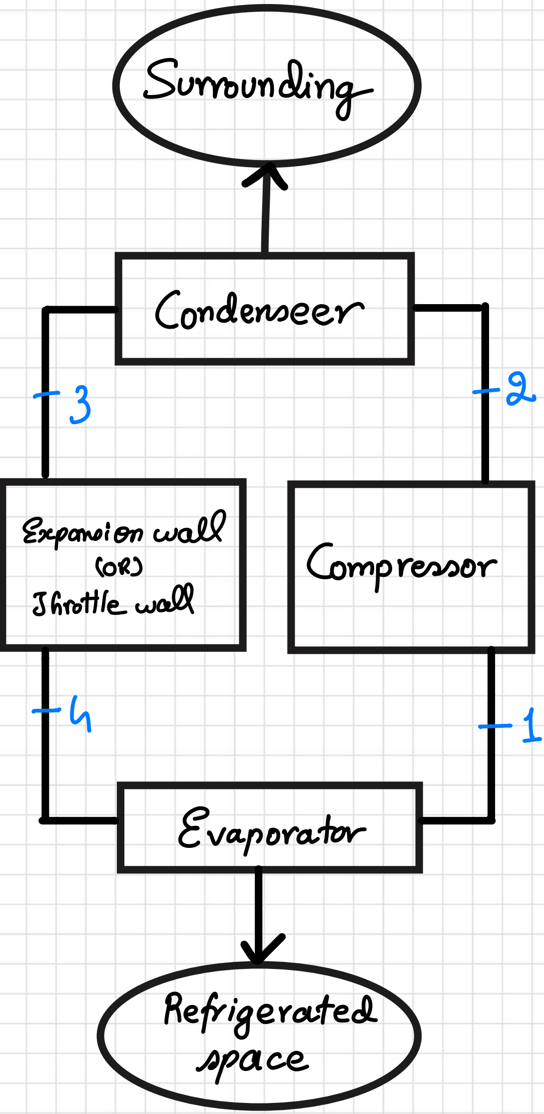
(i) Compressor

(ii) Condensor

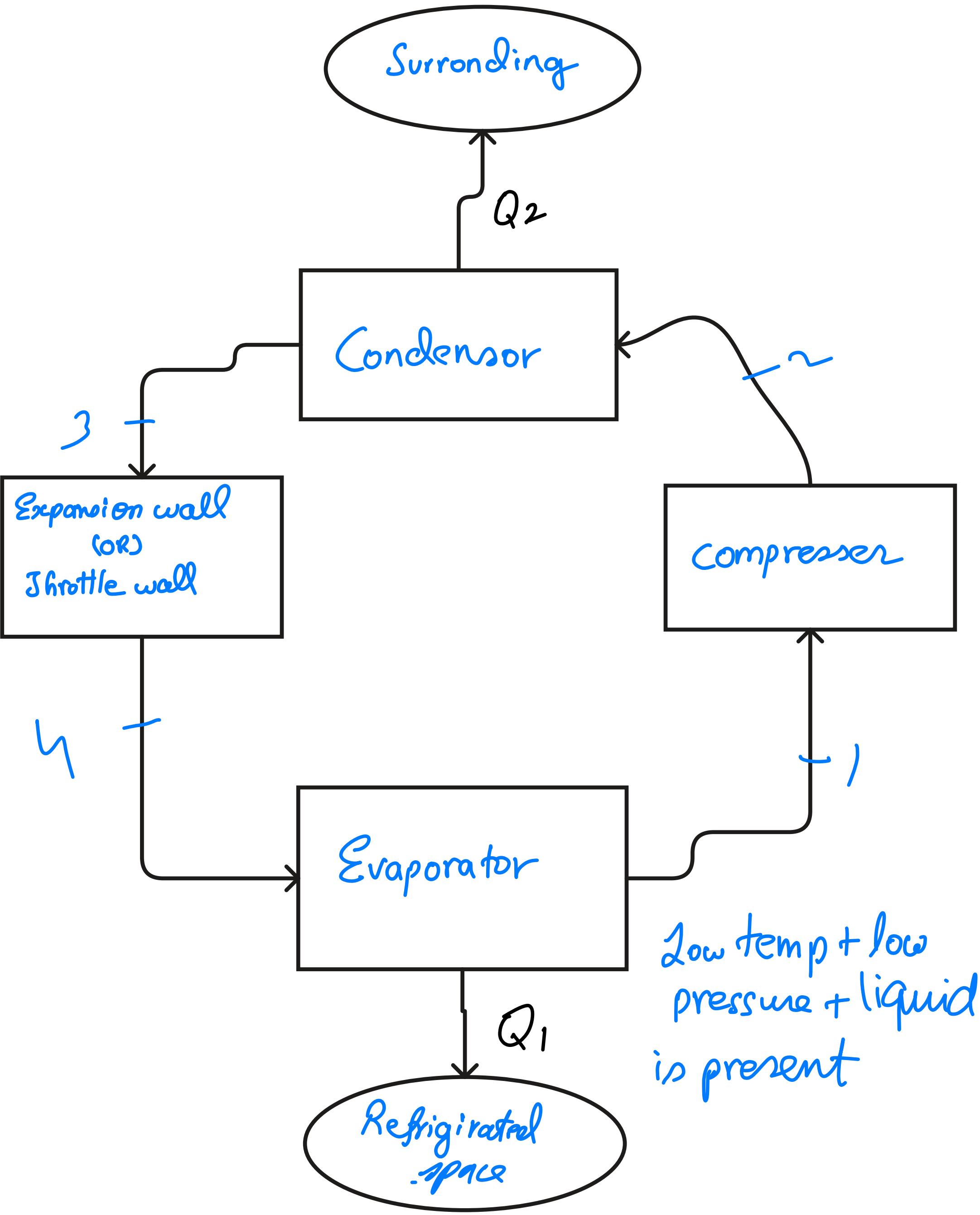
(iii) Expansion value

(iv) capillary tube

(v) Evaporator



Low temp + low pressure + liquid is present



Surronding
Q2
Condensor
2
3
Expansion wall
(OR)
Throttle wall
compresser
4
1
Evaporator
Q1
Low temp + low pressure + liquid is present
Refrigirated space

Imp

VCR, properties of refregeration

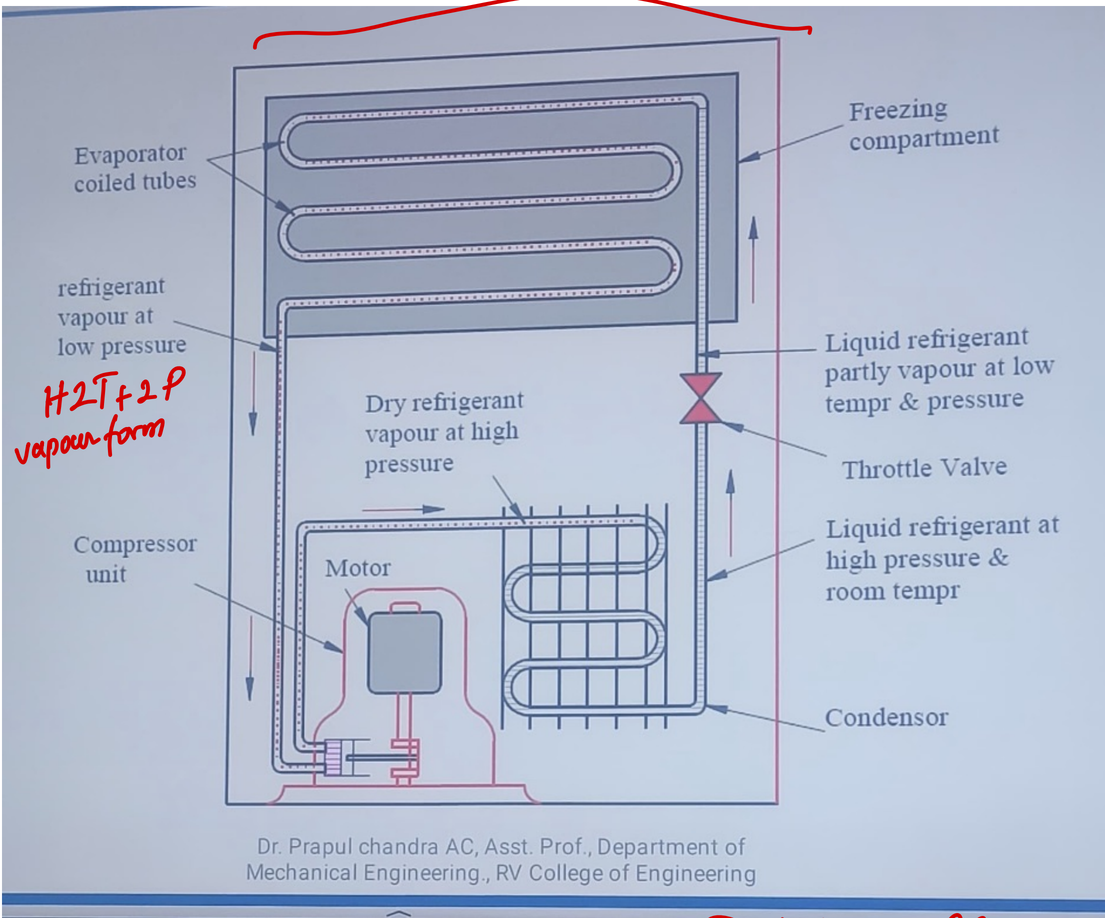
Types of refrigeration

(i) Vapour Compression refrigeration

(ii) Vapour absorption refrigeration

Properties of refrigeration

5 marks or 6 marks for CIE



Evaporator → 1, condensor → 1, Trottle wall → 2
copavator → 1

The properties of good refrigerant are as follows:-

Properties of good refrigerant

Thermodynamic properties
1. Boiling Point
2. Freezing point
3. Evaporator & condenser pressure

Physical properties
1. specific volume
2. specific heat
3. Viscosity

Safe working properties
1. Toxicity
2. Flammability
3. Corrosiveness
4. Chemical stability

other properties
1. COP
2. Odur
3. Leak
4. Action with Lubrication

The unit of refrigiration is tons of refrigeration.

In SI System

$$1 \text{ ton of refrigeration} = 210 \text{ kJ/min}$$
$$= 3.5 \text{ kW}$$