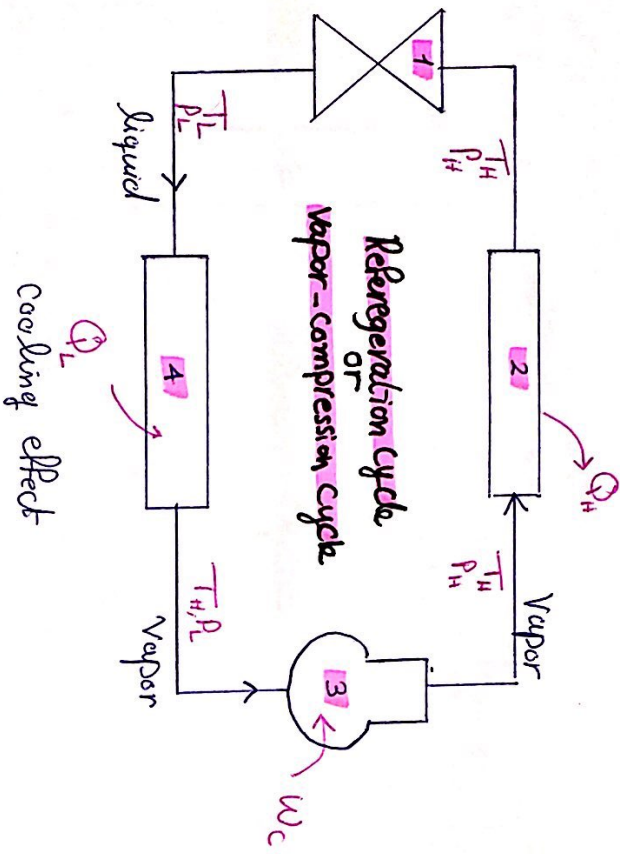


(Heat pump)

Refrigeration Cycle

obj:- obtaining cooling effects

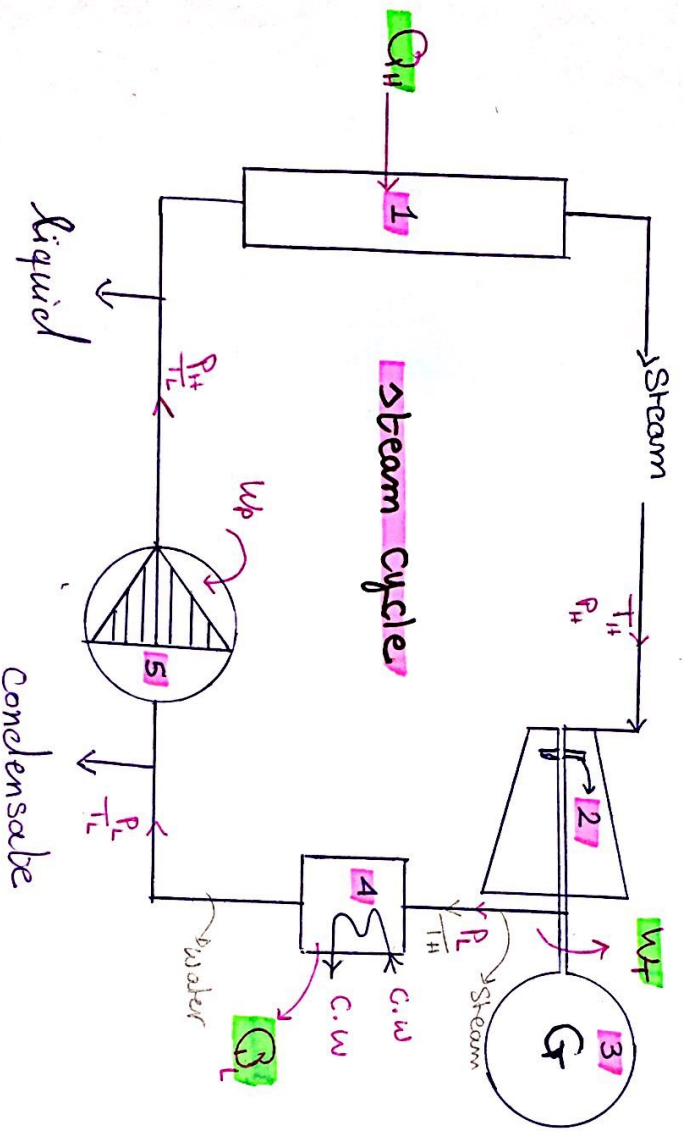


- 1: Expansion valve
- 2: Condenser
- 3: Compressor
- 4: Evaporator

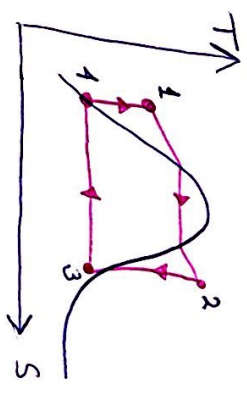
(Heat engine)

Steam power plants

obj: obtaining Electrical energy



- 1-2: Boiler
- 2-3: Turbine
- 3-4: Condenser
- 4-1: Pump



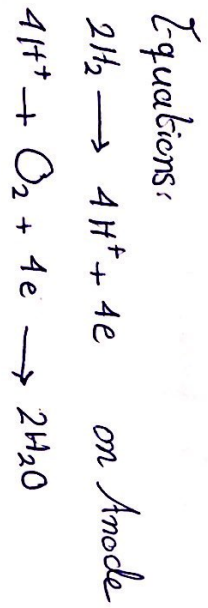
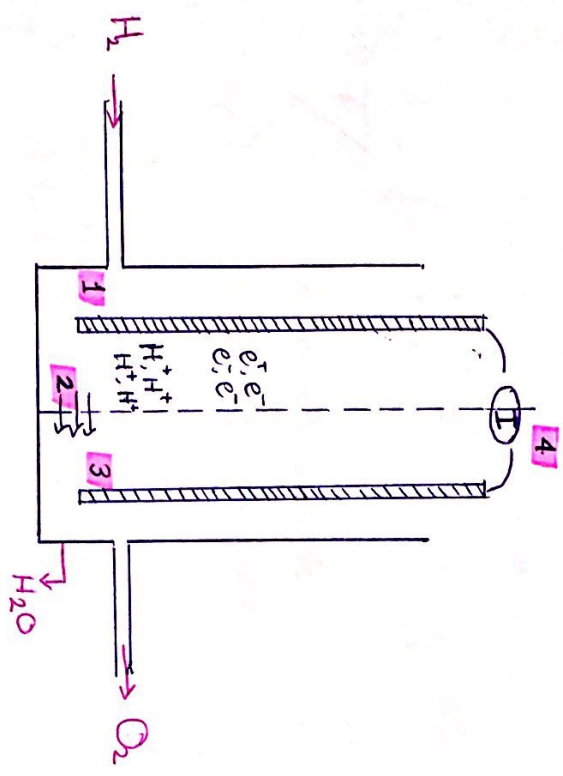
- 1: Steam Generator
fuel used to generate heat that turns water to steam (chemical energy)
- 2: Steam Turbine
It has blades to generate work to use after
- 3: Electrical Generator
It generates electricity using work

4: Condenser
It changes steam to water using cold water

5: Pump : to pump the condensed water to the steam generated. Pump has the highest temperature.

Fuel Cells

obj: Electricity Generation



1: Anode

2: membrane

3: Cathode

4: Electrical current

Chapter 2: Properties of pure substances

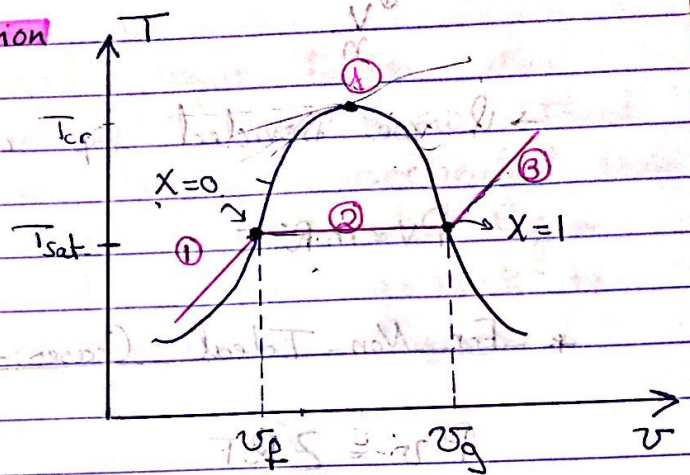
- Water is a pure substance (since its chemical properties are not variable)

1- **Compressed liquid Region**
(sub-cooled liquid)
 $T < T_{sat}$, $P > P_{sat}$

2- **Saturation Region**
(mix of vap & liq)

$$T = T_{sat}$$

$$P = P_{sat}$$



3- **Superheated Region**

$$T > T_{sat}$$

$$P < P_{sat}$$

$$X = \text{Quality} = \frac{m_{vap}}{m_{liq} + m_{vap}}$$

4- **Critical point**

$$T = T_{cr} \quad P = P_{cr} \quad v = v_{cr}$$

if $T < T_{cr}$: compressed liquid $P > P_{cr}$

if $T > T_{cr}$: superheated vapor

⇒ How to find X:

$$v = v_{fp} + X \cdot v_{fg}$$

* For Ideal Gases: (Nitrogen & Argon)

Equation of states at low pressure

$$P \bar{V} = \bar{R} T$$

$$\bar{R} : \text{constant} = 8.3145 \text{ kJ kmole}^{-1} \text{K}^{-1}$$

$$\downarrow \bar{V}$$

$$: n$$

→ If we divided Eq with Mwt

$$PV = mRT$$

$$R = \frac{\bar{R}}{M}$$

* For Non-Ideal Gases:-

$$P \bar{V} = Z \bar{R} T$$

$$Z = 1 \text{ for Ideal Gases}$$

Z: Compressibility factor

Methods of plotting the properties of a substance:-

- 1- Tables
- 2- Assuming Ideal Gas
- 3- finding Z

* When to use Method 1:

→ If the material is included in the Tables and two properties are Given.

• If T, P are Given:

We check Superheated Vapor Tables. Now:
If $T > T_{sat}$ at that P , we know that this material is in the superheated state.
If $T < T_{sat}$ then it's in saturated region or compressed liquid so we go back to tables of saturated & compressible regions.

• If T, v are Given or P, v :

We check for the value of v_g at T_{Given} / P_{Given}
If $v_{Given} > v_g$ → Superheated and use line Eq
If $v_{Given} < v_g$ → Saturated and Take T, P of the Table

• If x is Given and it's $0 < x < 1$ then it's in the Saturated Region

* When to use Method 2:-

→ If the material is not included in the tables Assume it's an ideal gas.

Ideal Gas law

$$PV = m R T$$

↑ R : look for it A.5

⇒ Assuming $Z=1$

* when to use Method 3:

→ If T or P are Given we can find T_r, P_r
By finding T_r, P_r from A.2

→ Then after finding T_r / P_r , Go to Table D.3
and find values of Z_f, Z_g (If the mat is the saturated Region)
and use: $Z = Z_f + Z_{fg} \times X$

→ If it's not in the saturated Region
Go to Figure D.1 and find Z .

Linear Equation :-

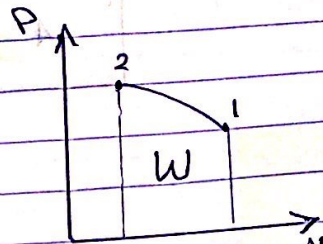
$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

usually x or y are Given. and x_2, y_2, y_1, x_1
are obtained from Tables

Work and heat

Work = $F \times x$ depends on path (inexact differential)

• Area under curve equals work



Note:
Volume and all properties are exact (depends on initial and final pos)

$$\text{Work} = W_{12} = \int_{V_1}^{V_2} P \, dV$$

W $\left\{ \begin{array}{l} + \text{ Done by system} \\ - \text{ Done on system} \end{array} \right.$

P has three cases:

□ P constant: $W_{12} = P(V_2 - V_1) = P_m(V_2 - V_1)$

□ P is not constant: \rightarrow Graphical solution (Area under P-V curve)

\rightarrow find a relationship between P and V.

For ideal gases: $PV = nRT$

constant if the

system is closed and

Iso Thermal

and so $PV = \text{constant} = C$

$$W = \int_{V_1}^{V_2} \frac{C}{V} \, dV = P_1 V_1 \ln |V_2 - V_1|$$

• In Mixing Processes: W_{20}



specific Work

$$W = \frac{\text{Work}}{m}$$

$$= \frac{\text{kJ}}{\text{kg}}$$

Heat: Temperature difference due to Energy transfer

Heat transfer modes:

- 1- conduction
- 2- convection
- 3- Radiation

Heat $\rightarrow +$: Heat transferred to system.

Heat $\leftarrow -$: Heat transferred from system.

* First law of Thermodynamics for a control mass system:

$$Q_{12} = (E_2 - E_1) + W_{12}$$

$$= m(u_2 - u_1) + \int_{v_1}^{v_2} P dv$$

Polytropic process:

$$PV^n = \text{constant}$$

where n is an integer

$$P_1 V_1^n = P_2 V_2^n = \text{constant}$$

$$\text{So } P = \frac{C}{V^n}$$

$$\text{Now } W_{12} = \int P dv = \int_{V_1}^{V_2} \frac{C}{V^n} dv$$

And here there are two cases:

$n \neq 1$

$$W_{12} = \frac{P_2 V_2 - P_1 V_1}{1-n}$$

$n = 1$

$$W_{12} = P_1 V_1 \ln \left| \frac{V_2}{V_1} \right|$$

If the Gas is ideal:

$$W_{12} = \frac{mR(T_2 - T_1)}{1-n}$$

(Non isothermal system)

Enthalpy H :

$$Q_{12} = H_2 - H_1$$

$$H = U + PV$$

Enthalpy $[kJ]$ ← Internal Energy

$$h = u + Pv$$

Enthalpy $[kJ/kg]$

$h < h_f$: compressed liquid
 $h > h_g$: superheated vapor
 $h_f < h < h_g$: saturated mixture of vapor and liquid
 $P = P_{sat}$, $T = T_{sat}$, x

Specific heat: amount of heat required per unit mass to raise the temperature of the substance by one degree. C_v, C_p

1- Constant volume: $\Rightarrow W_2 = 0$ C_v

$$C_v = \left(\frac{\partial u}{\partial T} \right)_v$$

2- Constant pressure $\Rightarrow C_p$

$$C_p = \left(\frac{\partial h}{\partial T} \right)_p$$

$C_{v0} - C_{p0}$ for ideal gases:

$$u_2 - u_1 = C_{v0} (T_2 - T_1)$$

constant

$$h_2 - h_1 = C_{p0} (T_2 - T_1)$$

assumed constant

$$C_{p0} - C_{v0} = R \quad \text{for ideal Gases}$$

• 1st law of Thermodynamics as a rate :-

$$\dot{Q}_{12} = \frac{dE}{dt} + \dot{W}_{G.M.12}$$

↳ U + K.E + P.E

Note: **Springs**

Equation of pressure:

$$PA = P_0A + m_p g + k \Delta x$$