THERMAL

$F \propto ma$

$F = \frac{ma}{g_c}$

$\frac{1}{g_c}$ = proportionality constn

g_c = universal constant

$F = 1\ kgf$

$m = 1\ kg$.

$a = 9.81\ m/s^2$

$1\ kgf = \frac{1\ kg \times 9.81\ m/s^2}{g_c}$

$g_c = 9.81\ \frac{kg.m}{kgf\ sec^2}$ - m.k.s.

$1\ kgf = 9.81\ N$.

$g_c = \frac{9.81}{9.81}\ \frac{kg\ m}{N\ sec^2}$

$= 1\ \frac{kg\ m}{N\ sec^2}$ (SI)

weight of body

$w = \frac{ma}{g_c}$

$g_c = 9.81$ or $g_c = 1$

SI M.K.S M.K.S S.I

weight of body vary place to place

mass of body does not vary place to place.

Specific volume: It is defined as volume per unit mass.

$S.V_{(v)} = \frac{volume}{mass}\ \left(\frac{m^3}{kg}\right)$

Density $(\rho) = \frac{mass}{volume}\ \left(\frac{kg}{m^3}\right)$

$\boxed{\rho\, v = 1}$

Density is reciprocal of specific volume and specific volume reciprocal of density

Relative density or specific gravity

It is defined as ratio of density of substance to density of water.

$\rho_{water} = 1\ gm/c.c$

$= 1000\ kg/m^3$.

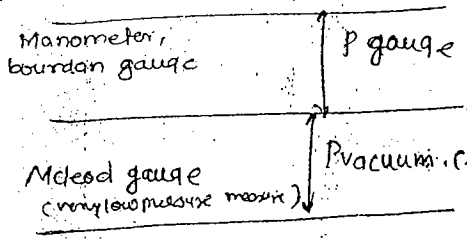
pressure: It is defined as force per unit area.

$P = \frac{Force}{Area}\ \left(\frac{N}{m^2}\right)$ or pascal.

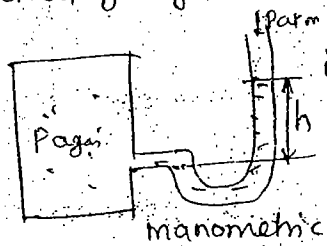
pascal is very small unit of pressure hence we using kpa and Mpa higher units of pressure.

$P_{abs} = P_{atm} + P_{gauge}$

$P_{abs} = P_{atm} - P_{vacuum}$.



Mcleod gauge based on boyles law.



if $P_{gas} > P_{atm}$ liquid rise in open limb if $P_{gas} < P_{atm}$ the liquid rise in closed limb. A height of rise of a manometric liquid gives an indication of the pressure

$P_{abs} = P_{atm} + P_g$. $\quad P_{abs} = P_{atm} - P_{vacuum}$.

$= P_{atm} + \frac{\rho g h}{g_c}$ $\quad = P_{atm} - \frac{\rho g h}{g_c}$.

1 Patm = 101.325 kPa = 760mm of Hg column

= 76 cm of Hg column.

= 10.33 of m of H_2O column.

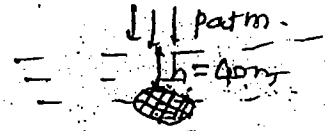
1 torr = 1mm of Hg column.

= 133.33 Pa

= 0.13333 kPa.

1 bar = 10^5 Pa. = 100 kPa. = 752.6 mm of Hg column

A Rock is submerged in sea water at a depth of 40m what is the pressure acting on the top of the rock



⇒ $P = \rho g h$:

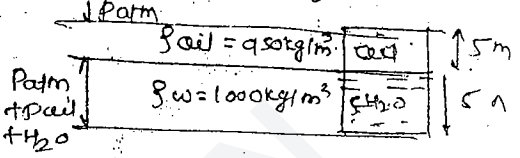
ρ sea water = 1100 kg/m³

$P_{abs} = P_{atm} + P_{gauge}$

$= P_{atm} + \frac{\rho g h}{1000 g_c}$

$= 101.325 + \frac{1100 \times 9.8 \times 40}{1000 \times 1} = 532.64$ kPa.

water is poured at a height 5m in cylindrical vessel above that oil of S.G 0.95 is poured for another 5m. what is difference in pressure acting on the bottom and top of vessel



⇒

pressure in difference

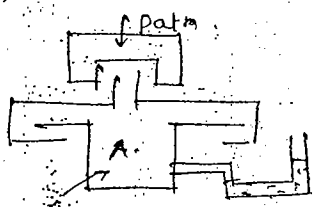
$\Delta P = p_{oil} + p_{water}$

$= \frac{\rho_o g h_o}{1000 g_c} + \frac{\rho_w . g h_w}{1000 g_c} = \frac{950 \times 9.81 \times 5}{1000 \times 1} + \frac{1000 \times 9.81 \times 5}{1000 \times 1}$

$= 95.64$ kPa.

A pressure cooker is designed for a pressure of 1 bar gauge the opening available in the head of cooker is 4 mm^2. what should be weight that should be kept above with nor withstand the pressure

⇒



$P_{inside} = P_{external}$

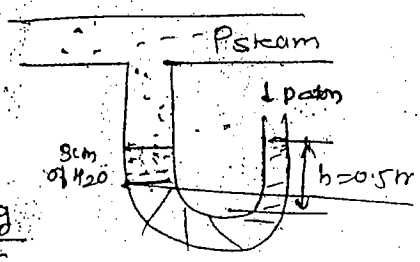
$P_{atm} + \frac{\rho g h}{conv g_c} P_{gauge} = P_{atm} + \frac{mg}{A}$

$P_{atm} + P_{gauge} = P_{atm} + \frac{mg}{A}$

$105 = \frac{m \times 9.81}{4 \times 10^{-6}}$

$\boxed{m = 40.7 gm}$

Steam is flowing in the main pipeline a manometer is connected with mercury as the manometric liquid which has a density of 13600 kg/m^3, what is the pressure of steam in the mains.



⇒ For balance

$P_{steam} + P_{H_2O} = P_{atm} + P_{Hg}$

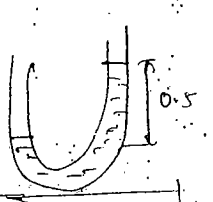
$P_{steam} + \frac{\rho_w . g . h_w}{1000 g_c} = P_{atm} + \frac{\rho_{Hg} . g . h_{Hg}}{1000 g_c}$

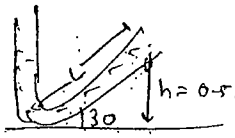
$P_{steam} + \frac{1000 \times 9.81 \times 3 \times 10^{-2}}{1000 \times 1} = \frac{101.325 + 13600 \times 9.81 \times 0.5}{1000 \times 1}$

$P_{steam} = 167.168$ kPa

The height of rise of mercury in u tube manometer it is replaced with inclined manometer which an angle of 30° up to what length the Hg should flow on inclined plane to measure the same pressure.

Ans (1)





$\frac{h}{L} = \sin\theta$

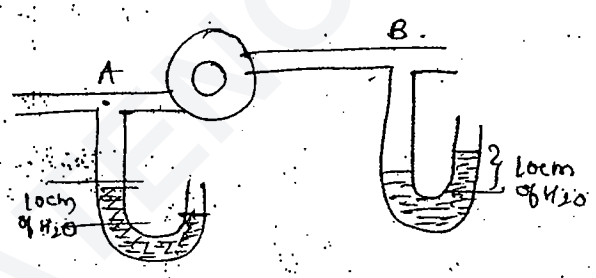
$L = \frac{h}{\sin\theta} = \frac{0.5}{\sin 30} = 1$

when a fluid of density of 2gm/cc the height of rise is 0.2m if it replaced with fluid of density 10gm/cc what is height of rise.

$\Rightarrow h \propto 1/\rho \quad \rho h = \text{constant} \quad \rho_1 h_1 = \rho_2 h_2$

$\Rightarrow 2 \times 10 = 2 \times 0.2 = 10 \times h_2 \quad \boxed{h_2 = 0.04m}$

Across a flow two manometer are connected as shown in the figure calculate difference in pressure in B and A in kPa.



$\Rightarrow$

$P_B - P_A = 10 - (-10)$

$= 20$ cm of H_2O

$= 0.2$ m of H_2O

$= \frac{0.2}{10.23} \times 101.325$

$= 1.98$ kPa

In thermodynamics we will be taking of system

Open system: It in this energy transaction interaction as well as mass interaction

eg: water flow through pipe line:

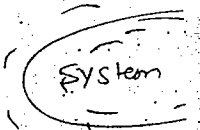
When water is flow in pipe the mass crosses the System boundary as well as energy crosses the system boundary.

Closed sys
only en
eg. sun

Isolated sy
energy into
eg: coffee

Identify
① A founta
② A candle
③ A biogas
④ A T.V. su
⑤ transfar
⑥ A.C rai
⑦ A moon

A system
Separated
the envel



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If system
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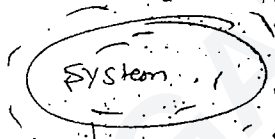
Closed system : Closed system is a system in which there is only energy interaction but no mass interaction
eg: sun.

Isolated system : Isolated system system in which there is neither energy interaction nor mass interaction
eg: coffee in a thermoflask

Identify to which category if following system belong.
① A fountain pen while writing – open system.
② A candle flame while burning – open system.
③ A biogan digestor – open system.
④ A TV switched ON – closed system.
⑤ transformer while working – closed system.
⑥ A.C railway coach – open system.
⑦ A moon in its orbit – closed system.

A system is defined as demarked volume which has been separated for the purpose of analysis observation and inferance the envelope of system is called as boundary. and volume bounded is called as surrounding. If system volume expand the work is said to be done by the system and system work is +ve, when system volume contract the work is said to be done on the system. the and workdone is given in –ve sign



If external agent does work on system the workdone is said to be -ve.

$\therefore$ $W_{system} + W_{surrounding} = 0$

If System does +ve work the surrounding will do negative work and vicaversa.

If heat is supplied to a system it is given +ve sign.
If heat is withdrawn from a system it is given a -ve sign

A system will not have heat & work will only energy in different forms. when energy system crosses boundary it may become heat or it may become work; heat and work are path function they depend upon the path followed. heat & work are inexact differential. heat & work are transient in nature. heat and work are boundary phenomenon.

$z = f(x,y)$

$dz = \left(\frac{dz}{dx}\right)_y dx + \left(\frac{\partial z}{\partial y}\right)_x dy$

$\left(\frac{\partial z}{\partial x}\right)_y = M \; ; \left(\frac{\partial z}{\partial y}\right)_x = N$

$\partial z = M dx + N dy$

$\frac{\partial M}{\partial y} = \frac{\partial}{\partial y}\left(\frac{\partial z}{\partial x}\right) = \frac{\partial^2 z}{\partial y \cdot \partial x}$

$\frac{\partial N}{\partial x} = \frac{\partial}{\partial x}\left(\frac{\partial z}{\partial x}\right) = \frac{\partial^2 z}{\partial x \cdot \partial y}$

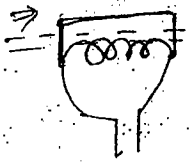
$\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$ → exact differential

$\frac{\partial M}{\partial y} \neq \frac{\partial N}{\partial x}$ → Inexact differential

exact differentials are point function they depend on the end state but do not depend upon path followed. whereas inexact differentials are path functions and depend upon the path followed.

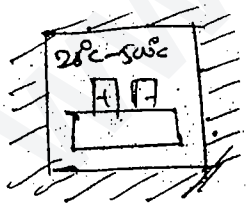
* Identify the signs of heat & work interaction in the following cases.

① A heater coil is kept in flowing water and it is connected external mean. what are the sign of heat and work and cold water enters the system leaves as hot water



work done is -ve
heat transfer +ve

② In a insulated rigid cylinder a battery is kept across the terminals of battery a resistor is connected and temp of air is increases from 25°C to 50°C. What are the signs of heat & work interaction.



$Q = 0$

$W = 0$

tions are
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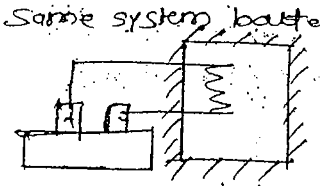
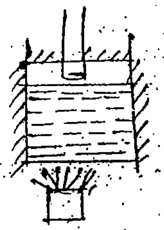
Same system battery placed outside what are signs of W & Q

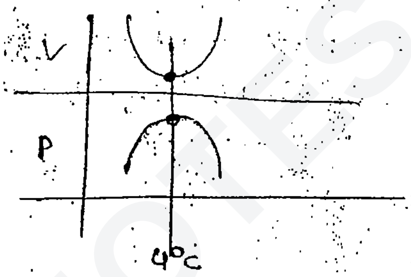


⇒ $Q = 0$
$W = +ve$

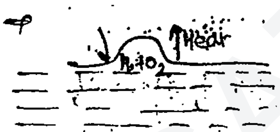
A piston cylinder mechanics water & ice are kept it is insulated all sides except the bottom it is heated by means of flame and emission allows to move such that the pressure remain constant till the ice completely melts what are the sign of W and Q



Q is +ve
W is 0

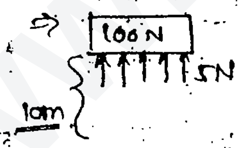


~~hydraulic~~ hydrogen and ~~nitrogen~~ in form of bubble to large lake ignited by minute spark: hydrogen and oxygen combined to form water. what are sign of W & Q



Q is -ve
W ~~zero~~ (-ve)

A 100N mass falls freely in atmosphere overcoming atmospheric drag ~~resistance~~ of 5N by a distance of 10 m. what is the workdone



⇒ Workdone = resistance force × distance travelled
= 5×10 = 50

A 1 kg mass falls freely in vacuum by a distance of 1 m what is the workdone

⇒ W = 0

State :

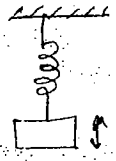
State of system is specified by certain specific thermodynamics coordinate minimum no. quadrant required are two and they should be independent nature like a pressure and volume. volume & temp , temp and pressure.

Change of state: If any one of the thermodynamic coordinates are both change then system is said an undergone change of state

Processes: locus of series of change of state gives a process

Types of processes:

Reversible process: It is process which can be made to exactly retraced its path without suffering any variations or losses. Any process without friction or losses can be called as reversible process. eg:



Electroplating: If anode is made cathode and cathode is made anode whatever material deposited can be redeposited back so this closed to reversible

If water 100°c is heated to steam at 100° by a flame of 150°c it is internally reversible and externally irreversible

If water at 100°c is converted to steam at 100°c by using a flame of 100.01°c then it is internally reversible as well as externally reversible.

Irreversible: Any process that cannot made to exactly retraced its path is called an irreversible process.

eg: combustion, water falling from top of a dam.
suns energy,

Any process with friction irreversible process.

Extensive property:

Any property that is depend on mass is called an extensive property

eg volume, enthalpy, internal energy, entropy, K.E, P.E etc.

Intensive

Any prop
intensive p

eg: speed p
Specific
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② very fe
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③ They can
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④ They can
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property,
are same

Diatherm

diatherm
heat to
called a

eg steel, s

Intensive property:

Any property that is independent of mass is called an intensive property.

eg: speed pressure, temp, velocity, acct^n, viscosity and any specific extensive property. is an intensive property. Specific volume, specific internal energy, specific enthalpy, specific entropy, specific K.E, specific P.E.

density is an intensive property.

Macroscopic & Microscopic approach

Macroscopic	Microscopic
① No assumption are made regarding structure of matter	① In this matter is composed of molecule.
② very few parameter are required to specify the state of system like pressure, volume volume temp, temp & pres.	② Many parameters required to specified to state of system. i.e. $6 \times 6.023 \times 10^{23}$ coordinate are required.
③ they can easily be measured	③ they cannot be easily measured
④ They can be sensed by sense per substance	④ They can not be sensed by sensed per substance.

Rate of change of molecule per of momentum per unit area is called pressure and pressure is microscopic property. microscopic property is leading to a macroscopic property, hence the approaches are different but conclusion are same.

Diathermic substance:

diathermic substances are those substance which allows heat to pass through them. any good conductor of heat is called a diathermic substance.

eg steel, silver, copper etc.

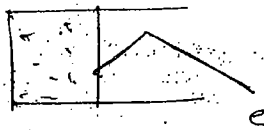
Adiabatic substance :

are those substances which do not allows heat to pass to them

eg Abseetos, glasswool, coal, everabmite

when two separate system are in contact each other through a diathermic wall there is interaction between two system. and two system achieved common thermodynamic coordinates. which is called as state of thermal equilibrium. if two separate system are in contact each other to a due adiabatic wall. there is no interaction beth two system and system remains as they are

Thermodynamic equilibrium :



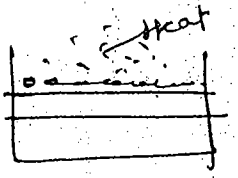
If there no internal forces or external forces acting on system then the system is said to be mechanical equilibrium. If temp across every section is same then the system is said to be an thermal equilibrium. the chemical constitution are such that they are no exothermic reaction or endothermic reaction then the system is said to be a ~~ex~~ ex end chemical equilibrium.

if system is in mechanical thermal, chemical equilibrium is called thermodynamic equilibrium

Quasistatic process (ideal process)

It is an ideal process is very very slow process

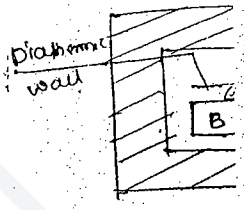
If a system is made to undergoes a series of change of state such that it is in thermodynamic equilibrium at each and every state then the locus of all the state is called as quasistatic process. quasistatic process is ideal process which can never exist in reality



Sand grains allows to fall one after another on piston cylinder arrangement then moment of such a piston is called as quasistatic process.

A series of

Zeroth



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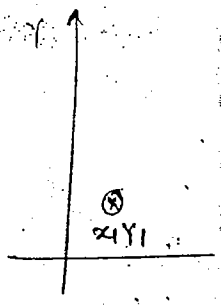

If we fi
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The refer
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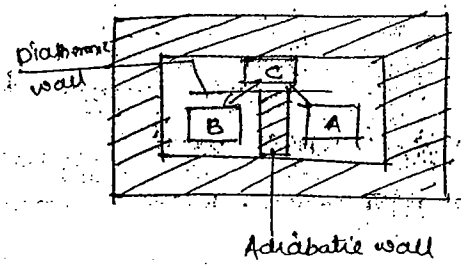
① Liquid

Hg is u
Alcohol i

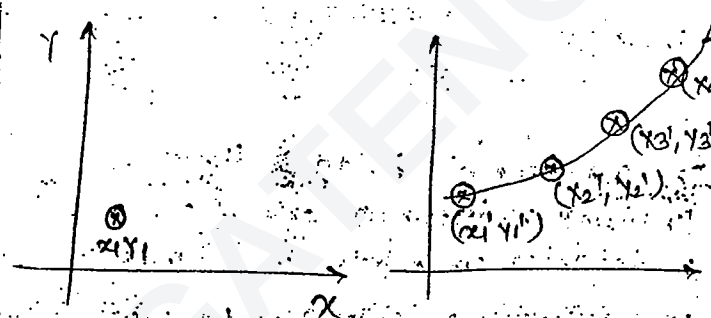
A series of process consitute a thermodynamics cycle. the minimum no. of process required are 2!

Zeroth's Law of thermodynamics:



When two separate system are individually in thermal equilibrium with the third system then the two systems are in thermal equilibrium with one & another. which is called as zeroth law of thermodynamics.

Significance of zeroth law is it's gives us concept of temp and defines an Isotherm



If we find a series of state on a system which are in thermal equilibrium with one state of another system then locus of all this state is called isotherm

The reference point for the measurement of temp is triple point of water. at that triple point of water we assumed that it is (273.16K, 0.01°c)

The instrument used to measure the temp is called a thermometer. thermometer are of different type

① Liquid in glass thermometer

- Mercury thermometer
- Alcohol thermometer

Hg is used for high temp measurement

Alcohol is used for low temp measurement

② Gas thermometer

- constant volume type
- constant pressure type

In Cv type $p \propto T$ $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

In $p = c$ $V \propto T$ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

③ Resistance thermometer

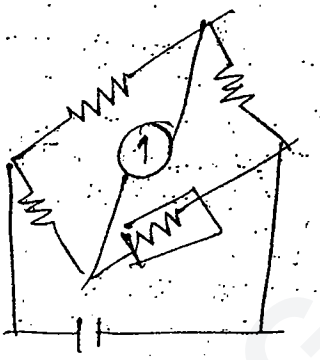
function on principle of change in resistance with temp as temp increases resistance increases. and here

$$R_t = R_0 (1 + At + Bt^2)$$

R_t = Resistance at temp t

R_0 = Resistance at temp 0°C

A, B = constants.

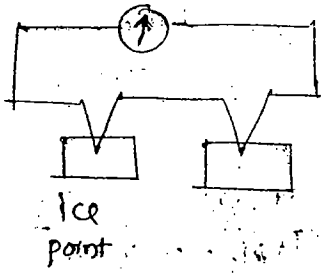


In wheatstone's bridges three known resistance and one resistance unknown resistance resistance is kept in place where temp measured

$$R_t = R_0 (1 + At + Bt^2)$$

Thermocouple :

A thermocouple is formed by joining two dissimilar metal of thermal electrical ~~resistance~~ series. one higher order element and another is lower order element if the two junction are kept at at ice point and other at steam point. due to the difference in temp an emf is generated. and this emf is used to measure the temp.



emf = $e = at + bt^2$
a, b = constant
t = temp

Magnetic thermometer

It's function on the principle adiabatic demagnetisation i.e. magnetisation & dimagnetisation related to temp highely sensitive thermometer and used to measure very low temp of the order of -275°C.

Pyrometer the function on principle of radiation the (are used to measure temp from distance.

Work and Heat

Work
- Non flow work
- flow work

Non flow work
- control mass

flow work
- control volume

on a fixed mass of gas if some operation are performed it is called control mass and it is a non flow process and here mass is focus of attention

In a fixed control volume 'mass' enters from one side and leaves from other side on a continuous basis here volume is focus of attention. hence it is control volume called flow process.

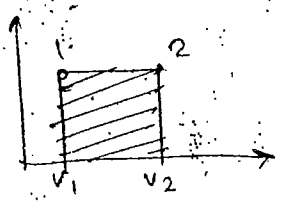
Non flow process (reversible)

$$_1W_2 = \int_{v_1}^{v_2} p\,dv$$

p: intensive property
dv: change in extensive property

on p-v diagram the area under curves gives the amount of heat & workdone

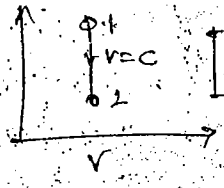
Isobaric process
Isopiestic process
constant pressure



$p = c$
$dp = 0$
$\boxed{{}_1W_2 = p(V_2 - V_1)}$

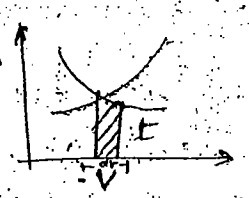
Isochoric process
Isometric process
constant volume process

$V = c$
$dv = 0$



$\boxed{{}_1W_2 = 0}$

Isothermal process
constant temp process



$T = C$
$dT = 0$

Any process that is very slow is called isothermal process.

$p_1V_1 = p_2V_2 = c$

engine running at 10rpm, a tortoise walking, snail is walking are examples of constant temp / isothermal process.

$$ {}_1W_2 = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2} \frac{c}{V}\,dV = c \ln \frac{V_2}{V_1} $$

$$ = p_1V_1 \ln \frac{V_2}{V_1} = p_2V_2 \ln \frac{V_2}{V_1} $$

$$ = mRT_1 \ln \frac{p_1}{p_2} = mRT_2 \ln \frac{p_1}{p_2} $$

Adiabatic process:

It is superfast process i.e. very very fast process burst in a balaon, burst in a car tyre, bursting of a bomb, engine running at 3000 rpm

$dQ = 0$ heat transfer is zero because there is no time to heat transfer takes place

$$ \boxed{pV^\gamma = c} $$

$$ TV^{\gamma-1} = c $$

$$ Tp^{\frac{1-\gamma}{\gamma}} $$

$$ pV^\gamma = c $$

$$ p_1V_1^\gamma = p_2V_2^\gamma $$

$$ {}_1W_2 = \int_{V_1}^{V_2} p\,dV $$

$$ = \frac{c\,V_2^{-\gamma+1}}{-\gamma} $$

polytropic

$$ pV^n $$

$$ TV^{n-1} $$

$$ Tp^{\frac{1-n}{n}} $$

$$ {}_1W_2 = $$

genera
all val
when n
when r
work is
$n = 1$

8-4te

$Tp^{\frac{1-\gamma}{\gamma}} = C$ $\gamma = \frac{C_p}{C_v}$ = ratio of specific heat

$\gamma = 1.4$ for air → diatomic gases, O_2, N_2

$\gamma = 1.6$ for monoatomic gases (helium, ar...

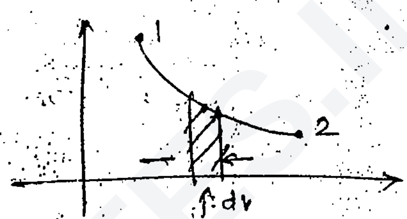
$\gamma = 1.33$ for triatomic gases (superheated...

$= p(V_2 - V_1)$

$W_2 = 0$

$pV^{\gamma} = C$

$p_1 V_1^{\gamma} = p_2 V_2^{\gamma} = C$



$${}_1W_2 = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2} \frac{C}{V^{\gamma}}\,dV = C \cdot \frac{V^{-\gamma+1}}{-\gamma+1}\Bigg|_{V_1}^{V_2}$$

$$= \frac{C V_2^{-\gamma+1} - C V_1^{-\gamma+1}}{-\gamma+1} = \frac{p_2 V_2^{\gamma} \cdot V_2^{-\gamma+1} - p_1 V_1^{\gamma} \cdot V_1^{-\gamma+1}}{}$$

$$= \frac{p_1 V_1 - p_2 V_2}{\gamma - 1} = \frac{mR(T_1 - T_2)}{(\gamma - 1)}$$

$$= mC_v(T_1 - T_2)$$ $C_v = \frac{R}{\gamma - 1}$

...n temp pres.

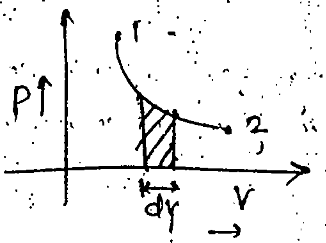
small is
mal press.

polytropic process

$pV^n = C$ n can take any value from 0 to ∞

$TV^{n-1} = C$

$Tp^{\frac{1-n}{n}} = C$



...rocess

...ing of a

these is

$${}_1W_2 = \frac{p_1 V_1 - p_2 V_2}{n-1} = \frac{mR(T_1 - T_2)}{n-1}$$

general expression for workdone. this valid for all values of 'n' except n=1

when n=1 it is isothermal process

when n=1 polytropic work is infinite but isothermal work is finite hence hence it is not valid for n=1

$pv^n = c$ put $n = 0$ $p = c$ — constant pressure process.

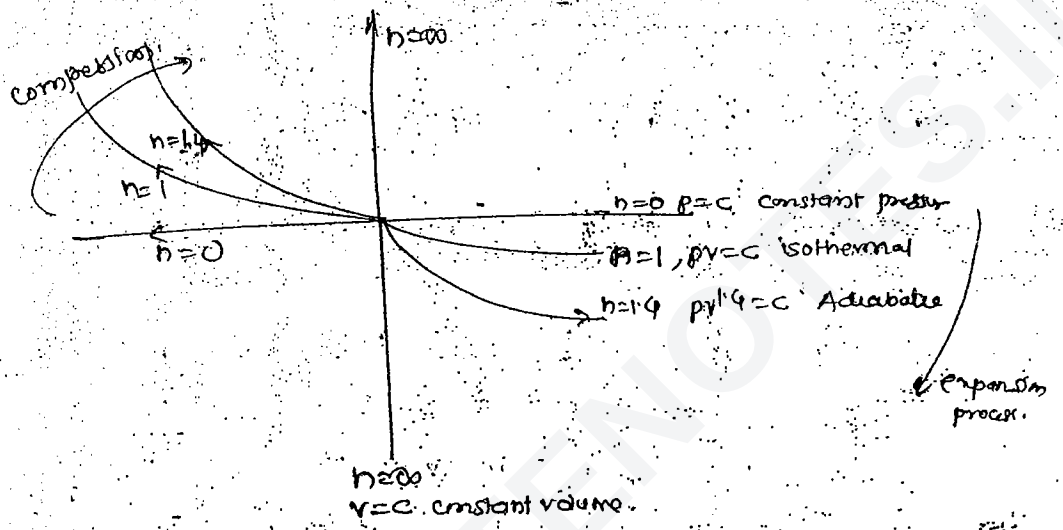
$pv^n = c$ put $n = 1$ $pv = c$ Isothermal

$pv^n = c$ $n = 1.4$ $pv^{1.4} = c$ Adiabatic process.

$(pv^n)^{1/n} = c^{1/n} = c_1$

$p^{1/n} v = c_1$

$n = \infty$ $v = c$ constant volume process.

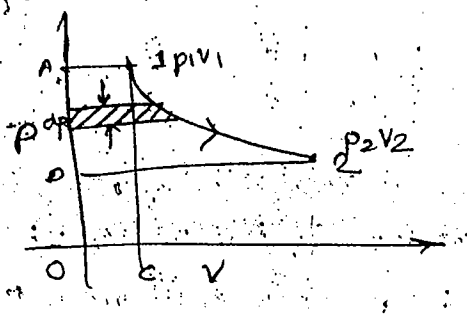


In expansion process as the value of n is increases from 0 to ∞ the work of expansion goes on decreasing.

As value increasing for 0 to ∞, in compression process the work of compression goes on increasing.

Flow work (irreversible)

$$1W_2 = -\int_{v_1}^{v_2} v\,dp$$



Area to the left is workdone

$$\int v\,dp = \text{Area } OA1C + \text{Area } 12B - \text{Area } OD2B$$

Isometric

$v = c$

$\int v\,dp =$

$=$

constant p

$p = c$

$dp = 0$

Isothermal

$T = c$

$dT = 0$

$p_1 v_1 = p_2 v_2$

Adiabatic

$dQ =$

$\int v\,dp = p_1$

$= (1$

$=$

$=$

$= 1$

Polytropi

$1W_2 = C_1$

flux process

$= p_1v_1 + \int p\,dv - p_2v_2$ this is when KE & PE are neglected.

cess.

Isometric or Isochoric

$V = C$, $V_1 = V_2$, $dV = 0$

isochoric flow work is non-zero where as isochoric non flow work is zero

$\int v\,dp = p_1V + 0 - p_2V$
$= V(p_1 - p_2)$

constant pressure process

$p = c$ $\quad {}_1W_2 = -\int v\,dp = 0$

$dp = 0$

isobaric flow work is zero
isobaric non flow work is not zero.

isothermal process

$T = C$

$dT = 0$

$p_1V_1 = p_2V_2$

$\int v\,dp = p_1V_1 + \int p\,dv - p_2V_2$

$\int v\,dp = \int p\,dv = p_1V_1 \ln\frac{V_2}{V_1}$

$= p_2V_1 \ln\frac{p_1}{p_2}$

$= mR\,T_1 \ln\frac{V_2}{V_1}$

flow work & non flow work are same in isothermal process, when K.E & P.E are neglected

stant pressure
thermal
Adiabatic
expansion process.

Adiabatic process

$dQ = 0$

$\int v\,dp = p_1V_1 + \int p\,dv - p_2V_2$

$= (p_1V_1 - p_2V_2) + \frac{(p_1V_1 - p_2V_2)}{\gamma - 1}$

$= \frac{\gamma}{\gamma - 1}(p_1V_1 - p_2V_2)$

$= \frac{\gamma}{\gamma - 1} R.m\,(T_1 - T_2)$

$= m\,c_p(T_1 - T_2)$

increases
decreasing

sion process

polytropic process

${}_1W_2 = (p_1V_1 - p_2V_2)\frac{n}{n-1}$

V_2

universal Gas equation

$pV = mRT$ — ① $p \Rightarrow$ pressure in N/m^2

$V \Rightarrow$ volm in m^3

$m \Rightarrow$ mass in kg's

$R \Rightarrow$ Gas constant J/kg K

$T \Rightarrow$ Temp in K

$p = \frac{m}{V}RT$ $\boxed{p = \rho RT}$ — ② ρ = density in kg/m^3

$p\frac{V}{m} = RT$ $\boxed{pv = RT}$ — ③ v = specific volume m^3/kg

$R = \frac{\bar{R}}{M}$ $\bar{R}$ = universal gas constant $\bar{R} = 8.314$ KJ/kg mole K

M = Molecular weight of gas $= 8314$ J/kg mole K

$pV = mRT$ $pV = m\frac{\bar{R}}{M}T$ $\boxed{pV = \frac{m}{M}\bar{R}T}$

n = no. of moles $= \frac{m}{M}$ n = no. of mole

$= \frac{\text{no. of molecule}}{\text{Avagodro number}} = \frac{N}{A}$

$\boxed{pV = n\bar{R}T = \frac{N}{A}\bar{R}T = N\frac{\bar{R}}{A}T = NkT}$

k = boltzsman function constant

$\boxed{k = \frac{\bar{R}}{A}}$ $\bar{R}$ = universal gas constant

A = Avagodro No.

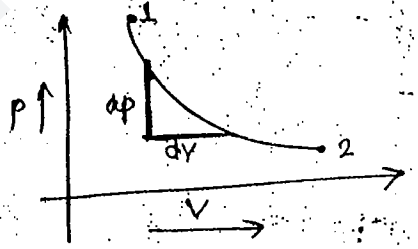
$k = \frac{8.314}{6.023 \times 10^{23}} = 1.38 \times 10^{-23}$

what is the slope of an isothermal curve on pv plane

$pv = C$

$pdv + vdp = 0$

$\left(\frac{dp}{dv}\right)_{T=C} = -\frac{p}{V}$



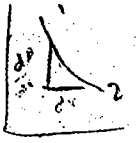
* what is slope of adiabatic curve on pv plane

slope of adiabatic > slope of isothermal.

$pv^r = C$

$dpv^r + p.r.v^{r-1}dv = 0$

$\left(\frac{dp}{dv}\right)_{s=c} = -\frac{rp}{V} = -r\left[\frac{dp}{dv}\right]_{T=C}$



* what is th
$TV^{r-1} = C$
$\left(\frac{dT}{dV}\right)_{s=c} = ($

* what is th
$Tp^{\frac{r-1}{r}} = C$,
$\left(\frac{dT}{dp}\right)_{s=c}$

* what is t
$pv = C$,
$\therefore \boxed{n = -1}$

* what is t
log p Vs log
$\Rightarrow pv^r = C$, ir

* what is
$\Rightarrow TV^{r-1} = C$

* what is
$Tp^{\frac{1-r}{r}} =$
$\therefore \ln T =$
$y =$

*what is the slope of an adiabatic curve on TV plane

$TV^{\gamma-1} = C$, $dT \cdot V^{\gamma-1} + T(\gamma-1)V^{\gamma-2}dV = 0$

$\left(\frac{dT}{dV}\right)_{Q=C} = (1-\gamma)\frac{T}{V}$

*what is the slope of adiabatic curve on TP plane

$TP^{\frac{\gamma-1}{\gamma}} = C$, $dT \cdot P^{\frac{1-\gamma}{\gamma}} + T\left(\frac{1-\gamma}{\gamma}\right)P^{\frac{1-\gamma}{\gamma}-1}dP = 0$

$\left(\frac{dT}{dP}\right)_{Q=C} = \left(\frac{\gamma-1}{\gamma}\right)\frac{T}{P}$

*what is the slope of an isothermal curve on log P Vs log V plane

$PV = C$, $\ln P + \ln V = \ln C$, $\ln P = \ln C - \ln V$, $y = C + mx$

$\therefore \boxed{m = -1}$

*what is the slope of an adiabatic curve on PV plane
log P Vs log V plane

$PV^{\gamma} = C$, $\ln P + \gamma \ln V = \ln C$, $\ln P = \ln C - \gamma \ln V$

$y = C + mx$

$\boxed{m = -\gamma}$

*what is the slope of an adiabatic curve on $\ln T$ Vs $\ln V$ plane

$TV^{\gamma-1} = C$ $\ln T + (\gamma-1)\ln V = \ln C$ $\therefore \ln T = \ln C - (\gamma-1)\ln V$

$y = C + mx$

$\boxed{m = 1-\gamma}$

*what is the slope of an adiabatic curve on $\ln T$ Vs $\ln P$ plane

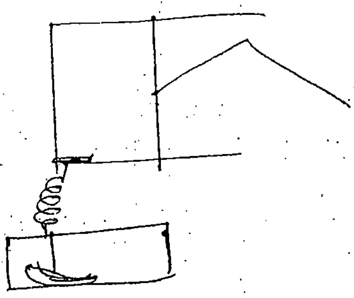
$TP^{\frac{1-\gamma}{\gamma}} = C$ $\therefore \ln T + \left(\frac{1-\gamma}{\gamma}\right)\ln P = \ln C$

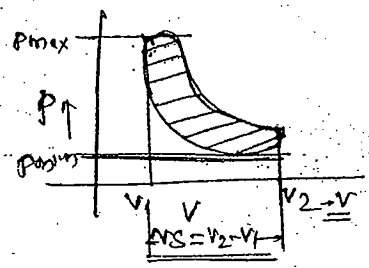
$\therefore \ln T = \ln C - \frac{1-\gamma}{\gamma}\ln P$

$y = C + mx$ $m = -\frac{\gamma-1}{\gamma}$

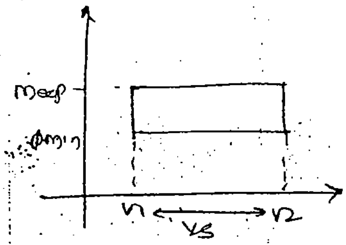
Indicator diagram

It is an instrument used for measuring the work done by I.C engine. The pressure and volume changes taking place inside the engine cylinder are sensed by a sensor which are transmitted to a Reed wright mechanism via spring loaded device and blocked of pv diagram is obtained and area of pv diagram represent workdone.





If the area of indicated diagram is uniformly distributed along the x-axis the altemate obtained is called as mean effective pressure (m.e.p)



P m.e.p is indication of the amount of workdone by I.C engine.

Indicated power

$$(I.P)(kW) = \frac{P_{mi} \cdot L \cdot A \cdot N \cdot n}{120{,}000 \;(\text{4 stroke}) \quad 60{,}000 \;(\text{2 stroke})}$$

P_{mi} = (mep) in pascal

L = stroke length in m.

A = c/s area in m2

N = rpm

n = no. of cylinder.

mep is obtained from the indicated diagram

$$mep = \frac{\text{Area of Indicator diagram}}{\text{length of indicator Diagram}} \times \text{Spring constant}$$

$$= \frac{m^2}{m} \times K \qquad k = MPa/m,\ kPa/m,\ Bar/cm,\ kN/m^2/m.$$

K is having pressure unit divided by length unit

$$\boxed{mep = \frac{A_d}{L_d} \times K}$$

First Law

$\oint \delta Q$

In a cycl

Sum of wo

$\oint \delta Q - \oint$

Q - W

Internal en

due to the

motion or

vibration th

rotational

having trans

above energy

Q - W =

dQ - dW =

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does not de

Specific h

the rat

temp of

Enthalpy

It is d

$Cp = \left(\frac{\partial h}{\partial t}\right.$

It is def

in temp

$Cp = \left(\right.$

C

Mc

First Law of Thermodynamics:

$$\oint \delta Q = \oint \delta W$$

In a cyclic process the sum of the heat interaction is equal Sum of work interaction

$$\oint \delta Q - \oint \delta W = 0$$

$$Q - W = K \qquad K \Rightarrow \text{constant of integration}$$

$K \Rightarrow I.E + P.E + K.E$ → Macroscopic
└ Microscopic

Internal energy basically due to the molecular motion or intermolecular forces. molecule are in state of vibration there having molecular state of rotation having rotational energy molecule in state of translation they are having translational energy and electron energy the sum of all the above energy is called as internal energy of the system.

$$Q - W = U$$

$$\boxed{dQ - dW = dU}$$

heat and work are path function internal energy is point function which is an exact differential it depend only on end state but does not depend upon the path followed.

Specific heat at cv

the ratio of change in internal energy to the change in temp at constant volume

Enthalpy:

It is defined as $h = U + PV$ PV = flow work, U = internal energy

$$cp = \left(\frac{\partial h}{\partial t}\right)_{p=c}$$ Specific heat at cp

It is defined as ratio of change in enthalpy to the change in temp at constant pressure

$$cp = \left(\frac{\partial h}{\partial t}\right)_{p=c}$$

$$cp - cv = R \qquad R = \frac{\bar{R}}{M}$$

$$Mcp - Mcv = \bar{R}$$

i.e., difference betn the molar specific heat at constant pressure and the molar specific heat at constant volume is equal to universal gas constant $\bar{R}$

$C_p - C_v = R$ $\quad \gamma = \frac{C_p}{C_v}$ which is called as ratio of specific heat

$\gamma = 1.67$ — monoatomic gas

$\gamma = 1.4$ — diatomic gases

$\gamma = 1.33$ — polyatomic gases

$C_v(\gamma - 1) = R \qquad C_v = \frac{R}{\gamma - 1}$

$C_p = \gamma C_v = \left(\frac{\gamma R}{\gamma - 1}\right)$

Monoatomic molecule having three translational motion therefore degree of freedom are 3.

diatomic molecule are having 5 degree of freedom 3 translational motion and 2 rotational motions and D.O.F are 5.

polyatomic molecules are having 6 or 7 D.O.F either 2 D.O.F or 3 D.O.F are omitted based on the type of bonding.

$$\boxed{\text{Internal energy} = \frac{x}{2} RT} \qquad x = \text{degree of freedom}$$

$$C_v = \frac{dv}{dt} = \frac{x}{2} R = \text{constant}$$

enthalpy $h = U + pV = \frac{x}{2} RT + RT = \left(\frac{x}{2} + 1\right) RT$

$$C_p = \left(\frac{\partial h}{\partial t}\right)_{p=c} = \left(\frac{x}{2} + 1\right) R$$

$$\gamma = \frac{C_p}{C_v} = \frac{\left(\frac{x}{2} + 1\right) R}{1 + \frac{2}{x}}$$

$x = 3$ for monoatomic gases $\quad \gamma = 5/3$

$x = 5$ for diatomic gases $\quad \gamma = 7/5$

$x = 6$ or 7 for polyatomic gases $\quad \gamma = 4/3$

C_p, C_v and γ l

For real g
values incre
whereas γ
with temp.

$dQ - dW =$

Isochoric pr

$\therefore dW$

In a cons
in internal e

Isothermal

In isotherm

Adiabatic

$dT = -\frac{dU}{C_V}$

Expansio

dW (+ve)

dT (−ve)

$d T_f - T_i <$

$T_f < T_i$

Adiabatic exp
a cooling eff

∴ puncture of
valve of bicy

Now let u

$dQ - dW$

dQ

dU

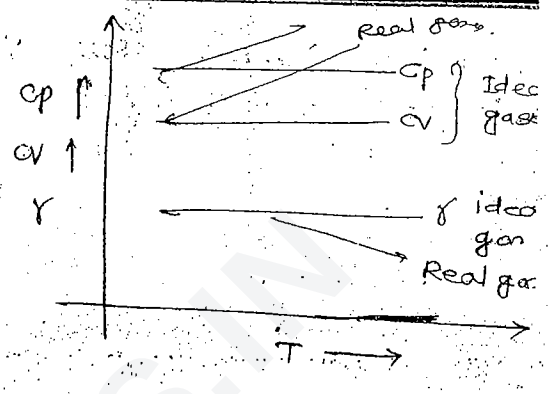
$\therefore dU$

U

U

Cp, Cv and γ values.

For real gase Cp and Cv values increase with temp whereas γ values decrease with temp.



$dQ - dW = dU$

Isochoric process :- $V = C$, $dV = 0$

$\therefore dW = 0$, $dQ = dU$

In a constant volm process heat transfer equal to change in internal energy of the system.

Isothermal process :- $T = C$ $dT = 0$, $dU = 0$ $\boxed{dQ = dW}$

In isotheral process heat transfer equal to work transfer

Adiabatic process :- $dQ = 0$, $dU = -dW$ $C_v dT = -dW$

$dT = -\frac{dW}{C_v}$

Expansion	Compression
dW (+ve)	dW (-ve)
dT (-ve)	dT (+ve)
$T_f - T_i < 0$	$T_f - T_i > 0$
$T_f < T_i$	$T_f > T_i$
Adiabatic expansion produces a cooling effect	Adiabatic compression produces a heating effect

∴ puncture of football, remove valve of bicycle (cooling effect produced)

Now let us apply 1st law to isolated system.

$dQ - dW = dU$

$dQ = 0$

$dW = 0$

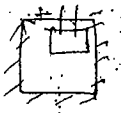
$\therefore dU = 0$

$U = C$

$\boxed{U_2 = U_1}$

For isolated system the internal energy remain constant

on a hot summer day the room is perfectly insulated and refrigerator door is kept open and will happen to temp of room. refrigerator is connected to external mean



$\Rightarrow \quad dQ - dW = dU$

$0 - dW = CV\,dT \qquad dT = \frac{-dW}{CV}$

$= -\left(\frac{-dW}{CV}\right)$ compression

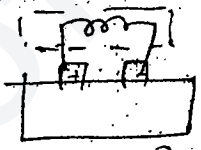
Expansion

$= \frac{dW}{CV} > 0$

$T_f - T_i > 0$

$\boxed{T_f > T_i}$

Across the terminal of battery a resistor is connected and if resistance is considered as a system what are the heat work & energy interaction.



$Q = 0, \quad W = -ve \quad U = +ve$

(fast process) (Adiabatic)

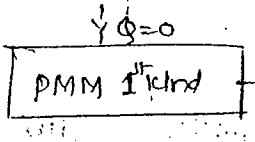
If considered battery as the system

$Q = 0 \quad W = +ve \quad U = -ve$

A battery is kept in open circuit for a long time what are the signs of heat, work and energy interaction. if battery is considered as the system.

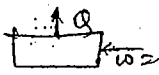
$\underline{Q = -ve} \quad W = 0 \quad U = -ve$

IST Law is qualitative law. It is directionless. It say that energy in one form is converted to energy in another form. but does not specify the directions

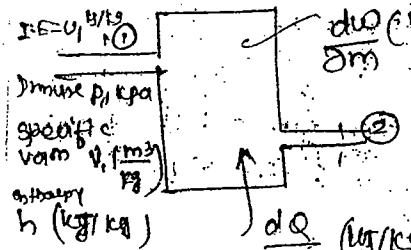


without energy input getting some output is called perpetual motion of 1st type, and PMM of 1st kind is impossible

The converse of the statement is also true with any some input getting heat input is also impossible.



Steady flow Energy equation (SFEE)



at section (2)

I.E = U_2 = kJ/kg
pressure p_2 = kpa
sp. volume = v_2 = (m^3/s)
enthalpy = h_2 = (kJ/kg)
velocity V_2 (m/s)
Elevation = Z_2 (kg/sec)
c/s Area → A_2 (m^2)

For steady flow condition to prevail two condition are to be satisfied

① Mass balance

$m_1 = m_2$

$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$

$\frac{A_1 V_1}{v_1} = \frac{A_2 V_2}{v_2}$

② Energy balance

* $K.E = \frac{1}{2} m v^2$

$\frac{K.E}{m} = \frac{v^2}{2}$ (J/kg)

$\frac{K.E}{m} = \frac{v^2}{2000}$ (kJ/kg)

* $P.E = mgz$ (J)

$\frac{P.E}{m} = gz$ (J/kg)

$\frac{P.E}{m} = \frac{gz}{1000}$ (kJ/kg)

Energy balance

I.E + FE + KE + PE + Heat energy
(flow energy) enthalpy

= I.E + FE + KE + PE + work energy

Energy balance

$$U_1 + p_1V_1 + \frac{V_1^2}{2000} + \frac{z_1 g}{1000} + \frac{dQ}{dm} = U_2 + p_2V_2 + \frac{V_2^2}{2000} + \frac{z_2 g}{1000} + \frac{dw}{dm}$$

$$\boxed{h_1 + \frac{V_1^2}{2000} + \frac{z_1 g}{1000} + \frac{dQ}{dm} = h_2 + \frac{V_2^2}{2000} + \frac{z_2 g}{1000} + \frac{dw}{dm}}$$

SFEE on mass basic

$$\boxed{h_1 + \frac{dQ}{dm} = h_2 + \frac{dw}{dm}}$$ — mass basic KE=PE=0

mass based eqn can be converted to time based eqn by multiplying with mass flow rate on both side

$$\dot{m}\left[h_1 + \frac{V_1^2}{2000} + \frac{z_1 g}{1000}\right] + \frac{dQ}{dm} \times \frac{dm}{dt}$$

$$= \dot{m}\left[h_2 + \frac{V_2^2}{2000} + \frac{z_1 g}{1000}\right] + \frac{dw}{dm} * \frac{dm}{dt}$$

$$\boxed{\dot{m}\left[h_1 + \frac{V_1^2}{2000} + \frac{z_1 g}{1000}\right] + \frac{dQ}{dt} = \dot{m}\left[h_2 + \frac{V_2^2}{2000} + \frac{z_2 g}{1000}\right] + \frac{dw}{dt}}$$

SFEE on time basis

if KE, PE=0

$$\boxed{\dot{m}h_1 + \frac{dQ}{dt} = \dot{m}h_2 + \frac{dw}{dt}}$$

SFEE & bernoulis eqn is special case of SFEE

SFEE is for compressible fluids

Bernoulis eqn is for incompressible fluids

hence it is special case

Applications

① Nozzle

energy

h_1 kJ/kg

V_1 m/sec

Insula

Apply SFEE

$V_1 = 0$

The enth

② Turbin

convertin

h_1 (kJ/kg)

$\frac{dQ}{dm} =$

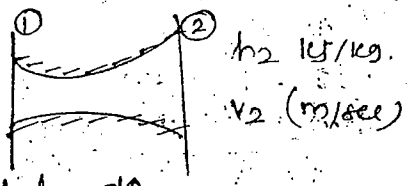
$h_1 +$

work

by the

Applications of SFEE

① **Nozzle** : A nozzle is a device which convert heat energy to KE



Insulated $\frac{dQ}{dm} = 0$

$\frac{dw}{dm} = 0$

Apply SFEE

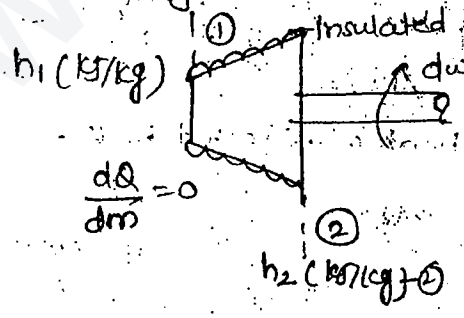
$$h_1 + \frac{v_1^2}{2000} + \frac{dQ}{dm} = h_2 + \frac{v_2^2}{2000} + \frac{dw}{dm}$$

$$\boxed{v_2 = \sqrt{v_1^2 + 2000(h_1 - h_2)}}$$

$v_1 = 0$ $\quad v_2 = 44.72\sqrt{\Delta h}$ $\quad \Delta h = kJ/kg.$

The enthalpy drop is converted into K.E

② **Turbine** : Turbine is device which is used for converting heat energy to work energy



$$h_1 + \frac{dQ}{dm} = h_2 + \frac{dw}{dm}$$

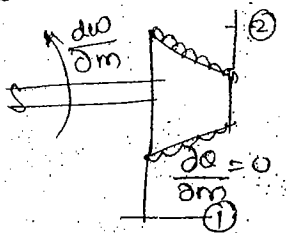
$$\boxed{\frac{dw}{dm} = h_1 - h_2 \text{ kJ/kg}}$$

Work is the and work is said to be done by the system.

In turbine high pressure fluid expand and in process does work.

Compressor

It is device which convert low pressure fluid to a high pressure fluid by doing external work



$$h_1 + \frac{dQ}{dm} = h_2 + \frac{dw}{dm}$$

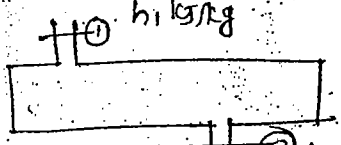
$$\frac{dQ}{dm} = 0$$

$$\boxed{\frac{dw}{dm} = h_1 - h_2} \text{ kJ/kg}$$

The ans is -ve, indicating that the external agent is doing work on the system.

Condenser

It is device which is used for rejecting heat



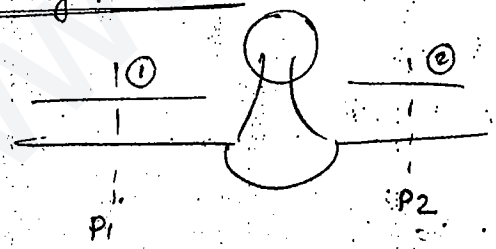
$$h_1 + \frac{dQ}{dm} = h_2 + \frac{dw}{dm}$$

$$\boxed{\frac{dQ}{dm} = h_2 - h_1} \text{ kJ/kg.}$$

Any -ve

Answer is -ve, indicating that heat is rejected by the system.

Throttling process



$P_2 ; P_1 > P_2$

$$\frac{dQ}{dm} = 0 \qquad \frac{dw}{dm} = 0$$

$h_1 + \frac{dQ}{dm} =$

$h_1 = h_2$

$c_p(T_1 - 0) =$

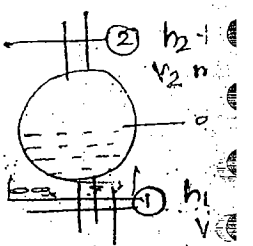
$T_1 = T_2$

$\therefore p_1 v_1 < p_2$

For steam

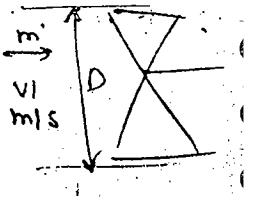
If $h_1 = h_2$ also

Boiler



$\dot{m}_f =$

Wind mill



power prod

it does work.

fluid to a

agent is

heat

kJ/kg.

ed by the

$h_1 + \frac{dQ}{dm} = h_2 + \frac{dw}{dm}$

$h_1 = h_2 \Rightarrow$

$c_p(T_1 - 0) = c_p(T_2 - 0)$

$T_1 = T_2 \rightarrow$ ideal gases

For ideal gases in a throttling process temp remain constant.

$U_1 + P_1V_1 = U_2 + P_2V_2$

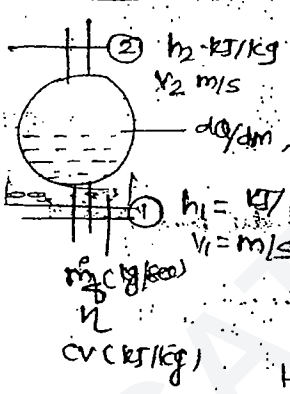
$\boxed{U_2 = U_1 + P_1V_1 - P_2V_2}$

$P_1V_1 > P_2V_2 \quad \therefore V_2 = V_1 + x \quad \therefore T_2 > T_1$

$\therefore P_1V_1 < P_2V_2 \quad V_2 = V_1 - x \quad T_2 < T_1 \longrightarrow$ This is for Real gases

For steam due to throttling temperature decreases. throttling process also called wire drawing process

Boiler : It is a device which is using wire for raising steam



$\frac{h_1 + V_1^2}{2000} + \frac{dQ}{dm} = h_2 + \frac{V_2^2}{2000} + \frac{dw}{dm}$

$\frac{dQ}{dm} = (h_2 - h_1) + \frac{V_2^2 - V_1^2}{2000}$ kJ/kg.

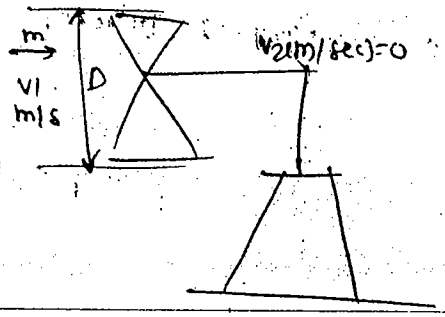
Let $\dot{m}_s$ kJ/s be the amount of steam generated. This is $\dot{m}_s$

Heat supplied by fuel = Heat required to raise the st

$\dot{m}_f \left(\frac{kg}{sec}\right) \times C_V (kJ/kg) \times \eta_C = \dot{m}_s (kg/sec) \times \frac{dQ}{dm} (kJ/kg)$

$\dot{m}_f = \frac{\dot{m}_s \times \frac{dQ}{dm}}{C_V \times \eta_C}$

Wind mill :



power (watt) $= \frac{1}{2} \dot{m} (V_1^2 - V_2^2)$

$= \frac{1}{2} \dot{m} V^2$

$\dot{m}$ = mass flow rate of air $= \rho a V$

$= \frac{1}{2} \rho V a V^2 = \frac{1}{2} \rho a V^3$

$= \frac{1}{2} \rho \frac{\pi}{4} D^2 V^3$

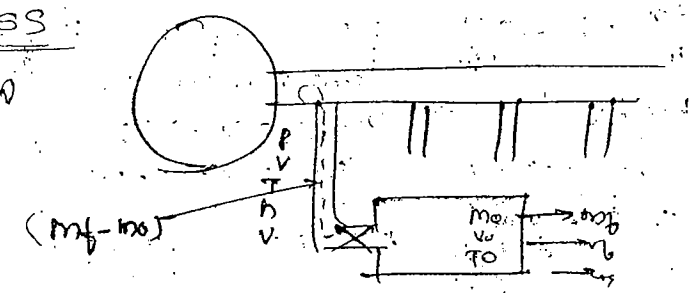
$P(w) = \frac{\pi}{8} \rho D^2 V^3$

$P \propto D^2 V^3$.

power produce in windmill is directly proportional square of its dia and cube of velocity

Charging process:

$W = -P(m_f - m_0)$



Intial energy $= E_1 = m_0 v_0 + (m_f - m_0) U$

final energy $= E_2 = m_f v_f$

$\therefore Q - W = \Delta E_2 = E_2 - E_1$

$Q + P(m_f - m_0) v = m_f v_f - [m_0 v_0 + (m_f - m_0) V]$

$Q = m_f v_f - m_0 v_0 - (m_f - m_0) V - Pv (m_f - m_0))$

$= m_f v_f - m_0 v_0 - (m_f - m_0)(U + Pv)$

$$\boxed{Q = m_f v_f - m_0 v_0 - (m_f - m_0) h} \quad \text{---(1)}$$

Let us asume Adiabatic final process

Adiabatic $Q = 0$, $m_0 = 0$

There is no mass of gases in the cylinder

$0 = m_f v_f - m_f h$

$h = v_f$

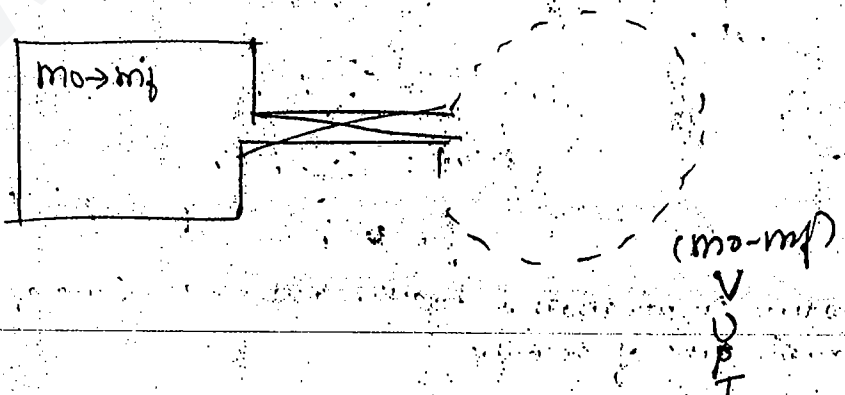
$C_p T = C_v T_f$

$T_f = \frac{C_p}{C_v} T$

$$\boxed{T_f = \gamma T} \text{ - is called as Charging process}$$

Discharging process:

The opposite to charging process is discharging process.



Initially in the cylinder the mass is m^0 and internal energy U^0 and temp is T^0 it become $m^0 u^0, T^0$

Amount of mass come out the system is $m^0 - m$

Initial Energy = $E_1 = m_0 v_0$

Final energy $= E_2 = m_f v_f + (m_0 - m_f) v$

$W = (m_0 - m_f) pv$

$E_2 - E_1$

$Q - (m_0 - m_f) pv = m_f v_f + (m_0 - m_f) v - m_0 v_0$

$Q = m_f v_f - m_0 v_0 + (m_0 - m_f) c + (m_0 - m_f) pv$

$Q = m_f v_f - m_0 v_0 + (m_0 - m_f) h$

let Imposes on

① Adiabatic ② final mass of gas inside the cylinder,

$0 = -m_0 v_0 + m_0 h$

$h = v_0$

$c_p(T - 0) = c_v(T_0 - 0)$ $T_0 = \frac{C_p}{C_v} T = \gamma T = \gamma_1$

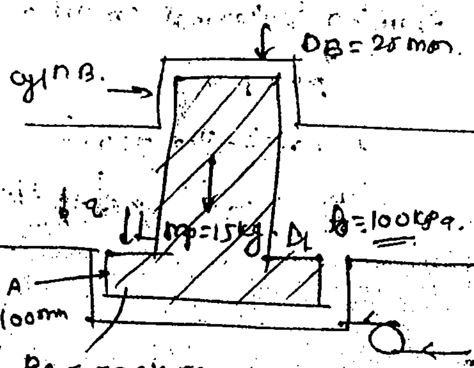
$$\boxed{T_0 = \frac{c_p}{c_v} T - \gamma_f}$$

problems on 1st law and work transfer

*

Pg. No 2.

Qu. No ①:



$F_{net} = P_a A_A - P_0 (A_A - A_B)$

$- \frac{m_p g}{1000}$

$= 800$

$= P_a \times \frac{\pi}{4} D_A^2 - P_0 \times \frac{\pi}{4} (D_A^2 - D_B^2)$ $P_A = 500$ kPa.

$- \frac{m_p \times g}{1000}$

$= 500 \times 0.7854 \times 10 \times 10^3 + 100 \times 0.7854 (10 \times 10^3 - 625) - \frac{15 \times 9.81}{1000}$

$= 3927 \times 10^3 - 736.3125 \times 10^3 - 0.14715$

$= \underline{3.1906 \times 10^6} N. = 3.042$ KN.

$$p_B = \frac{F_{net}}{A_B} = \frac{3.042}{\frac{\pi}{4} \times D_B^2} = \frac{3.042}{\frac{\pi}{4} \times (0.025)^2} = 6197.09 \text{ kg} = 6.2 \text{ MPa}.$$

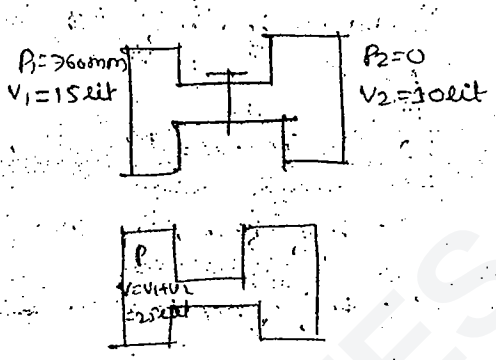
Qu.2 $p_{abs} = p_{atm} + p_g = 1.023 + 25 = 26.03 \text{ bar}$.

Qu.3 $p_1V_1 + p_2V_2 = pV$

$760 \times 15 + 0 \times 10 = p \times 25$

$p = \frac{760 \times 15}{25}$

$\boxed{p = 456 \text{ mm of Hg}}$



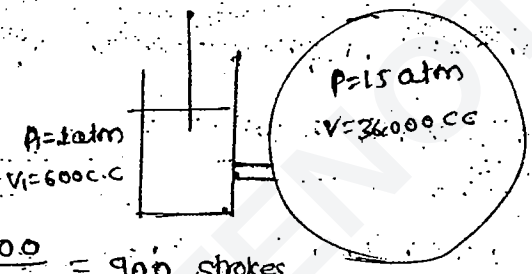
Qu.6

n = no. of stroke

Assuming condition

$np_1V_1 = pV$

$n = \frac{pV}{p_1V_1} = \frac{15 \times 36000}{1 \times 600} = 900 \text{ strokes}$

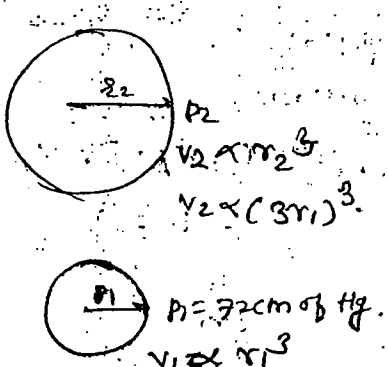


Qu.5 Assuming isothermal condition

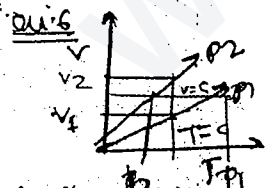
$p_1V_1 = p_2V_2$

$72 \times (r_1)^3 = p_2 \times 27r_1^3$

$\boxed{p_2 = 2.67 \text{ cm of Hg}}$



Qu.6



$p_1V_1 = p_2V_2$

$p_1 = \frac{p_2V_2}{V_1}$

$p_1 > p_2$

Ex. $T_1 > T_2$

$\frac{p_1}{T_1} = \frac{p_2}{T_2}$

$p_1 = p_2 \times \frac{T_1}{T_2}$

$p_1 > p_2$

Qu.7 $p_1 = p_$

$l_1 = 20$

$p_2 = p_{atm}$

$p_1V_1 = p_2V_$

$57 \times 20A = 95$

$l_2 = \frac{57 \times 2}{95}$

$\boxed{l_2 = 12 \text{ c}}$

Qu.11

$pV^{1.4} = 2.25$

$= 2.25$

$V^{1.4} = \left(\frac{2}{}\right.$

$V = 66$

$\alpha p = \frac{3}{}$

$dh = -$

$=$

$dh =$

$\int_0^h dh =$

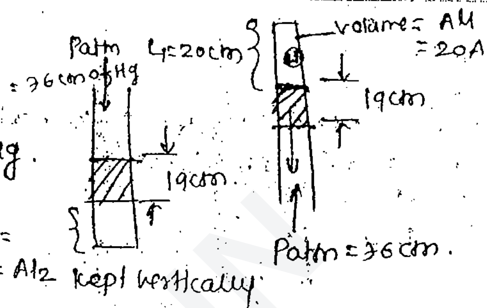
$=$

$=$

$= 6.2\ MPa$

Que 7) $P_1 = P_{atm} - 19 = 76 - 19 = 57$

$l_1 = 20\ cm$.



$P_2 = P_{atm} + 19 = 76 + 19 = 95$ cm of Hg.

$P_1 V_1 = P_2 V_2$

$57 \times 20A = 95 \times A\,l_2$

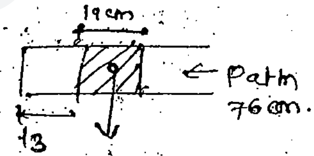
$l_2 = \frac{57 \times 20A}{95A}$

$\boxed{l_2 = 12\ cm.}$

$P_2 = 0$

$V_2 = 10\ lit$

if capallary tube is kept horizontal what is the length of air craft



$P_1 V_1 = P_2 V_2 = P_3 V_3$

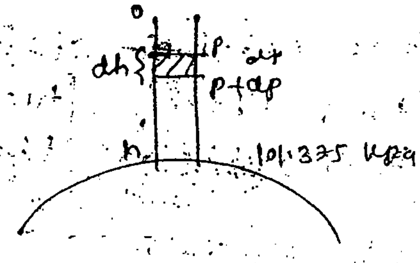
$57 \times 20A = 26 \times A\,l_3$

$V_3 = A\,l_3$

$P_3 = 26$

$\boxed{l_3 = 15\ cm}$

Que 11



$PV^{1.4} = 2.256\ bar\ \left(\frac{m^3}{kg}\right)$

$= 2.256 \times 10^5\ \left(\frac{m^3}{kg}\right)$

$V^{1.4} = \left(\frac{2.256 \times 10^5}{P}\right)^{1/1.4}$

$V = 6665.2\ P^{-1/1.4}$

$dP = \frac{\rho g\, dh}{g_c}$

$dh = \frac{g_c}{\rho g} dP$

$= \frac{g_c}{g} V \cdot dP$

$dh = \frac{1}{9.81} \times 6665.2\ P^{-1/1.4}\, dP$

$\int_0^h dh = \frac{1}{9.81} 6665.2 \int_0^{101325} P^{-1/1.4}\, dP$

$= 679.42 \left[\frac{P^{-\frac{1}{1.4}+1}}{-\frac{1}{1.4}+1}\right]_0^{101325}$

$= 679.42 \left[\frac{101325^{-\frac{1}{1.4}+1}}{-\frac{1}{1.4}+1}\right] = 64034.071\ m$

$= 64.034\ km.$

P_2

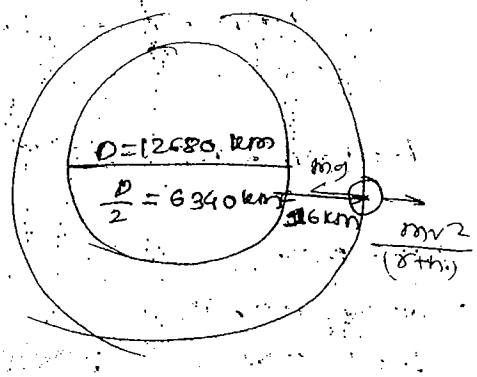
$V_2 \propto r_2^3$

$V_2 \propto (3r_1)^3$

$= 72$ cm of Hg.

$\propto r_1^3$

Qu.13



When centripetal force is balanced by gravitation force

$$mg = \frac{mv^2}{(R+h)}$$

$$g_1 = \frac{v^2}{R+h}$$

$$= \frac{(28,840 \times \frac{5}{18})^2}{(6340+816)10^3}$$

$$g_1 = 8.84$$

$$w = \frac{mg_1}{g_c} = \frac{86 \times 8.84}{1} = 760.65\,N$$

Qu.14: $t_a = a + bt_b + ct_b^2$

$t_a=0$ $t_b=0$	$t_a=51$
$t_a=100$ $t_b=100$	$t_b=50$

$$0 = a + 0 + 0$$

$$\boxed{a=0}$$

$$100 = 100b + 10^4 c$$

$$51 = 50b + 2500c$$

$$\boxed{b=1.04} \quad \boxed{c=-4\times10^{-4}}$$

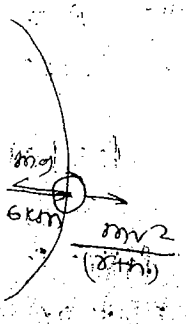
$$t_a = 1.04 t_b - 4\times10^{-4} t_b^2$$

$t_b = 26$

$$t_a = 1.04 \times 26 - 4\times10^{-4}(26)^2$$

$$t_a = 26.76^\circ C$$

unless construction feature of thermometer are known and the condition under which is known it is not possible to comment



Ques 15 $e = at + bt^2$

$= 0.2t - 5\times10^{-4}t^2$

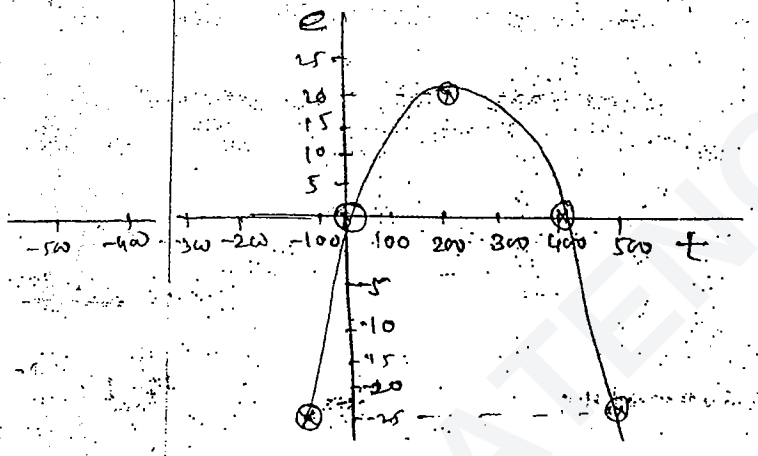
$t_1 = -100°C$ $e_1 = (0.2)(-100) - 5\times10^{-4}(-100)^2 = -25\,mV$.

$t_2 = 0$ $e_2 = 0$

$t_3 = (0.2)(200) - 5\times10^{-4}(200)^2 = \underline{20}\,mV$

$400 = t_4 = 0.2(400) - 5\times10^{-4}(400)^2 = 0$

$t_5 = 500°C = 0.2(500) - 5\times10^{-4}(500)^2 = \underline{-25\,mV}$



Ques 16 $t = a\ln K + b$

$t = 0$ $t = 100$

$K = 1.83$ $K = 6.98$

$0 = a\ln 1.83 + b$, $100 = a\ln 6.98 + b$.

$\boxed{a = 76.35}$ $\boxed{b = -46.14}$

$t = a\ln K + b$

$t = 76.35\ln K - 46.14$

$\boxed{K = 2.42}$

$t = 76.35\ln 2.42 - 46.14$

$\boxed{t = 21.34°C}$

Qu.18: $R_t = R_0(1+0.00393t)$

$t_1 = 30^\circ \quad R_{t_1} = 82\,\Omega$

$t_2 = ?$ when $R_{t_2} = 95\,\Omega$

$82 = R_0(1+0.00393\times30)$ — ①

$95 = R_0(1+0.00393\times t_2)$ — ②

eqn ① divide by eq ②

$$\frac{82}{95} = \frac{R_0(1.1179)}{R_0(1+0.00393\times t_2)}$$

$t_2 = 75.1^\circ c$ ~~X = 72.82~~

Qu.19 volume = constant

$t \propto p$

$t = ap + b$

when $t = 0^\circ c$, $p = 1000$ mm of Hg; $t = 100^\circ c$, $p = 1366$ mm of Hg

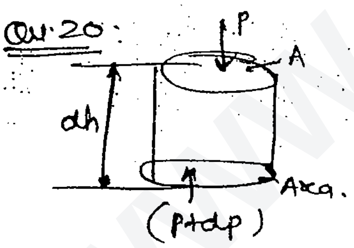
$0 = 1000a + b$ $\quad a = 0.273$

$100 = 1366a + b$ $\quad b = -273.22$

$t = 0.273\times1074 - 273$

$t = 20.20^\circ c$

Qu.20:



$$PA - (p+dp)A = \frac{\rho g\,dh}{g_c}\cdot A$$

$$-dp = \frac{\rho g}{g_c}\,dh$$

$$dh = -\frac{g_c}{g\rho}\,dp$$

$\rho = P/RT$ $\qquad dh = \dfrac{-g_c}{g\times P/RT}\cdot dp$

$$= -\frac{g_c RT}{g}\,\frac{dp}{P}$$

$\int_0 dh =$

$h = [$

$\ln\frac{P}{P_0} =$

$\frac{P}{P_0} =$

$P = P_0$

Qu.1 Pg.1

$\Delta p = d$

$\frac{950}{7}$

Qu.11 Pg.1

$$\int_0^h dh = -\int_{p_0}^{p} \frac{g_c RT}{g} \frac{dp}{p}$$

$$h = \left[\frac{-g_c RT}{g} \ln p\right]_{p_0}^{p}$$

$$\ln \frac{p}{p_0} = \frac{-gh}{g_c RT}$$

$$\frac{p}{p_0} = e^{-gh/g_c RT}$$

$$\boxed{p = p_0 e^{-\frac{gh}{g_c RT}}}$$

Qu.1 pg.1 $P_{barometer,\,base} = 750\,mm\,Hg$. $P_{top,\,barometer} = 600\,mm\,Hg$.

$\rho = 1\,kg/m^3$ $g = 10\,m/s^2$

$$\Delta p = dp = \frac{\rho g\,dh}{g_c}$$

$$\frac{750-600}{760} \times 101325 = \frac{1 \times 10 \times dh}{1}$$

$$19998.355 = 10\,dh$$

$$\boxed{dh = 2000\,m}$$

Qu.11 pg No (2)

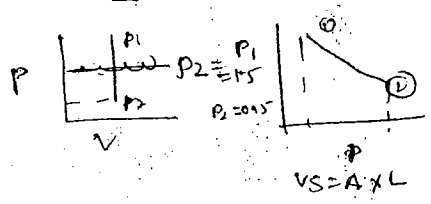
$$\frac{C - \text{Lower fixed point}}{\text{Upper fixed point} - \text{Lower fixed point}} = \frac{F - LFP}{UFP - LFP} = \frac{R - 0}{UFP - LFP}$$

$$\frac{C - 0}{100 - 0} = \frac{F - 32}{212 - 32} = \frac{R - 0}{80 - 0} = \frac{P - LFP}{UFP - LFP}$$

$$\frac{C}{100} = \frac{0 - 300}{100 - 300}$$

$$\boxed{C = 150°C}$$

Qu.5 Pg No: 6 $A = 0.12 m^2$, $P_1 = 1.5 MPa$ $P_2 = 0.15 MPa$.



$VS = A \times L = 0.12 \times 0.3 = 0.036 m^3$

workdone = Area of trapezium

$1W_2 = \frac{1}{2}(P_1 + P_2)VS$

$= \frac{1}{2}(1.5 + 0.15)\,0.036$

$= 0.0297$

$= 29.7$

Qu.6 $V_1 = 0.05 m^3$ $p = 10$ bar $W.D = ?$

$1 = 1000 kpa$

$P = \frac{A}{V^2} - \frac{B}{V}$ $V_2 = 0.1 m^3$ $P_2 = 1$ bar $= 100 kpa$.

$1000 = \frac{A}{(0.05)^2} - \frac{B}{(0.05)}$

$100 = 400A - 20B$

$100 = \frac{A}{(0.1)^2} - \frac{B}{0.1}$

$100 = 100A - 10B$

$A = 4$ $B = 30$

$P = \left(\frac{4}{V^2} - \frac{30}{V}\right) kpa$

$1W_2 = \int_{V_1}^{V_2} P\,dv = \int_{0.05}^{0.1} \left(\frac{4}{V^2} - \frac{30}{V}\right) dv$

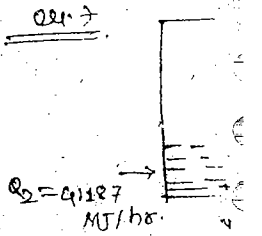
$= \left[4 \frac{V^{-2+1}}{-2+1}\right]_{0.05}^{0.1} - (30 \ln V)_{0.05}^{0.1}$

$= \left[4\frac{(0.1)^{-1}}{-1} - \frac{(0.05)^{-1}}{-1}\right] - 30\ln(0.1) - \ln(0.05)$

$= 40 - 20.39$

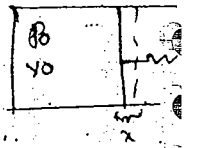
$= Ans\ 19.20$ kJ

Qu.7

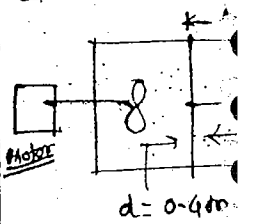


Type of c

* In a pi
initial vo
a spring
expand
the piste



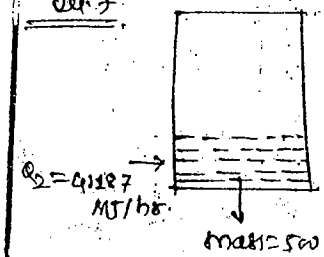
Qu.9:



Powe

P =

Qu-7

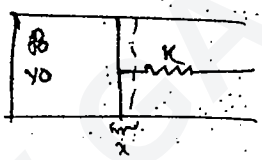


Heat removed from milk
= mass cp_{milk} ΔT
= 500 × 4.187 × 40
= 83740 kJ

Net heat removal rate
= $Q_1 - Q_2$
= 37.68 MJ/hr
= 37,680 kJ/hr

Time of cooling = $\frac{\text{heat removed from milk}}{\text{Net heat removal rate}} = \frac{83740}{37680} = 2.22$ hr

* In a piston cylinder mechanism the initial pressure p_0, initial volume is V_0 and cls Area is 'A' it is connected by a spring stiffness 'k' as shown in the figure the volume expand from V_0 to V. what is the final pressure acting on the piston



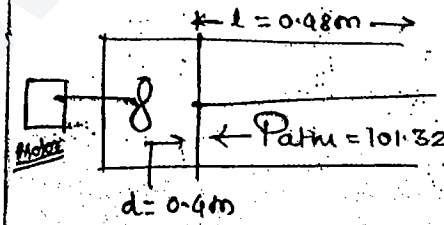
$\Rightarrow x = \frac{V - V_0}{A}$ Final force = Initial force + Spring force

$P_f A = P_0 A + kx$

$= P_0 A + k\left(\frac{V - V_0}{A}\right)$

$P_f = P_0 + k\left(\frac{V - V_0}{A^2}\right)$

Qu-9:



N = 840 rpm
t = 10 min

W_{net} = 2 kJ

$W_{net} = \int pdv - W_{stirr}$

$= 101.325 \times \pi/4 \times 0.4^2 \times L - W_S$

$2 = 6.111 - W_S$

$W_S = 4.11$ kJ

Power of stirrer = $\frac{W_S}{\text{time}} = \frac{4.128}{1 \times 60} = 6.85 \times 10^{-3}$ kW

$= 6.85$ kW.

$P = \frac{2\pi NT}{60}$ $T = 0.098$ Nm

Qu.10:

$$\left(P+\frac{a}{V^2}\right)(V-b) = mRT$$

$\frac{a}{V^2}$ = correction for interaction molecule of attraction

b = correction for vol occupied by molecule.

$$P+\frac{a}{V^2} = \frac{mRT}{V-b} \qquad P = \frac{mRT}{V-b} - \frac{a}{V^2}$$

$$_1W_2 = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2}\left(\frac{mRT}{V-b} - \frac{a}{V^2}\right) dV$$

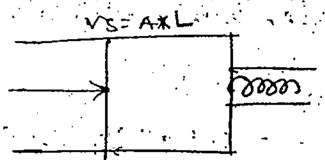
T = C
m = 10 kg
$V_1 = 1m^3$, $V_2 = 10 m^3$
T = 293K
$a = 15.7\times10^4$ Nm^4
$b = 1.07\times10^{-2}$
R = 0.278 kJ/kg K

$$= \left[mRT\ln(V-b)\right]_{V_1}^{V_2} - a\cdot\left[\frac{V^{-2+1}}{-2+1}\right]_{V_1}^{V_2}$$

$$= mRT\ln\left(\frac{V_2-b}{V_1-b}\right) + a\left[\frac{1}{V_2}-\frac{1}{V_1}\right]$$

$$= +139.4165\times10^3 \text{ kJ}$$

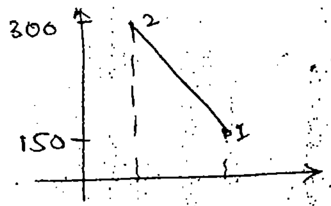
Qu.4 pg no 106:



c/s A = 220 cm^2

$V_S = 220\times10^{-4}$ m^2 × 0.2 m

$V_S = 4\times10^{-3}$ m^3



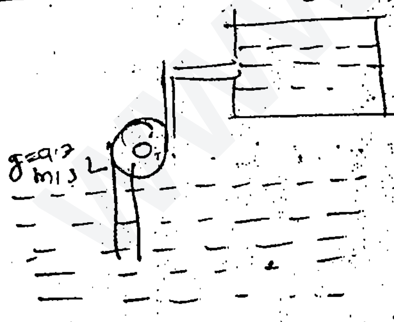
$$_1W_2 = \frac{1}{2}(P_1+P_2)V_S$$

$_1W_2$ = 0.9 kW

= ~~900~~ W ~~900 W~~ 3990 kJ

Qu.3

V = 37.5 m^3, T_2 = 25°C, P_2 = 2. Volume of water (V of 80%)
V_w = 37.5 m^3



W = work of pump + work of compression of air

$$= \frac{-mgh}{g_c} + P_1V_1\ln\frac{V_2}{V_1}$$

$$= \frac{-V\rho gh}{g_c} + P_1V_1\ln\frac{V_2}{V_1}$$

$$= \frac{-37.5\times10^3\times9.7\times35}{1000\times1} + 100\times50\ln\frac{12.5}{50}$$

= −12731.25 −

Ans = −19662.721 kJ

Qu.2

m_w = 500
T_1 = 25°C

So it is an

$_1W_2$ =

Qu.1

4
0.2m
P_1 = 100 kPa
0.2m
V_1 = 0.01 m
A_1 = 0.05

Qu.11: S-1

correction for interaction molecule of attraction

correction for vol^m occupied by molecule.

$= C_1$

10kg.

$m^3, V_2 = 10 m^3$

293K

$= 7\times10^4$ Nm4

1.07×10^{-2}

278 kJ/kg K

1kJ

(3/4, 0.6 ...)

m3

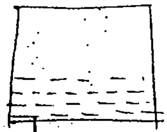
+ work of compression of air

$v_1 \ln \frac{V_2}{V_1}$

$P_1V_1 \ln \frac{V_2}{V_1}$

$\frac{5.35}{} + 100\times 50 \ln \frac{12.5}{50}$

Qu.2



$m_w = 500$ kg

$T_1 = 25^\circ C$

$\rho_w = 1000$ kg/m3

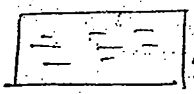
$Volume_w = \frac{m_w}{\rho_w}$

$V_w = 0.5 m^3$

$P_1 = 100$ kPa

$V_1 = 4 - 0.5 = 3.5 m^3$

total volume = 4 m3



Addition mass 500kg

$m_w = 1000$ kg

$\rho_w = 1000$ kg/m3

$V_w = 1$ m3

$V_2 = 3$ m3

$P_2 = ?$

$T_2 = 25^\circ C$

So it is an isothermal process

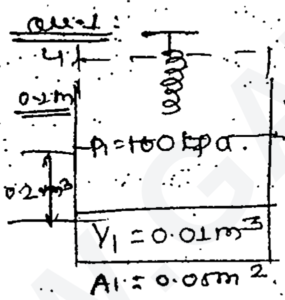
$$P_1V_1 = P_2V_2$$

$$100\times3.5 = P_2\times3$$

$$\boxed{P_2 = 116.67} \text{ kPa}$$

$$_1W_2 = P_1V_1 \ln\frac{V_2}{V_1} = 100\times3.5 \ln\left(\frac{3}{3.5}\right) = -53.95 \text{ kJ}$$

Qu.1



$k = 2.5$ kN/m.

$V_2 = A l_2$

$l_2 = 0.6$ m

$l_1 = \frac{V_1}{A_1} = 0.2$

$P_1 = 100$ kPa.

$V_1 = 0.01 m^3$

$A_1 = 0.05 m^2$

$V_2 = 3V_1$

$l_2 = 3l_1$

W = Work of expansion + Work on spring

$= pdv + \frac{1}{2}kx^2$

$= 100\times(0.03 - 0.01) + \frac{1}{2}\times 25 \times (0.6-0.4)$

$= 2 + 0.5$

2.5

Qu.11: $I.P(kW) = \frac{P_{mi} LANn}{120000 \rightarrow 4 \text{ stroke}}$

$60,000 \rightarrow 2$ stroke

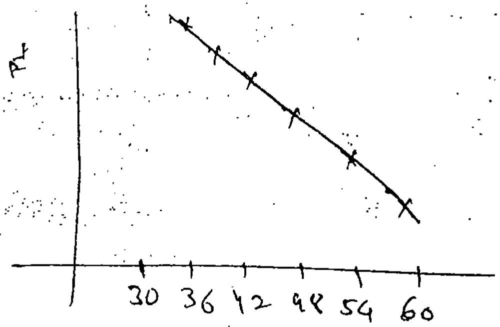
$$= \frac{\left(\frac{Ad}{Ld}\times k\right)\cdot L\cdot A\,N\,n}{120,000}$$

$$4 = \frac{\frac{Ad}{0.1L}\times 25\times10^6 \times L \times 0.7854\times(0.15)^2 \times \frac{216}{60}\times 1}{120,000}$$

$\boxed{Ad = 0.03018}$ m2 area

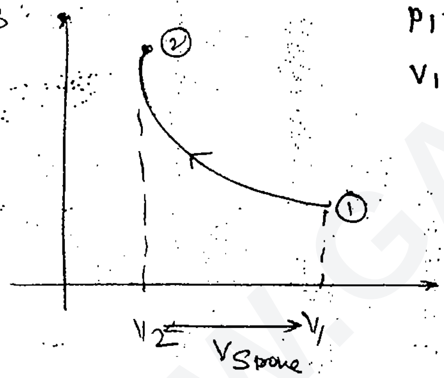
Ans 503 mm2 3602.321

X	Pg bar	Pabs Pgage in kPa	Pabs = Patm+Pg	F = P × A
				$= P \times \pi/4 D^2 - P \times \pi/4 (0.03)^2 = P \times 0.0696 \times 10^{-3}$
60	0.0	0	101.325	= 0.07162
54	0.17	17	118.325	= 0.0836
48	0.77	77	178.325	= 0.12605
42	0.87	87	188.325	= 0.1331
36	0.95	95	196.325	= 0.13877
30	1.43	143	244.325	= 0.1727



area under curve is workdone.

Qu. 13



$P_1 = 101.325$ kPa

$V_1 = ?$

$V_2 = \frac{V_1}{5}$

$V_s = \pi/4 \times D^2 L$

$V_1 - \frac{V_1}{5} = \pi/4 \times (0.15)^2 \times (0.25)$

$V_1 - \frac{V_1}{5} = 4.4178 \times 10^{-3}$

$5V_1 - V_1 = 0.022$

$V_1 = 5.52 \times 10^{-3}$ m³

$V_2 = \frac{V_1}{5} = 1.1044 \times 10^{-3}$ m³

$P_1 V_1^n = P_2 V_2^n$

$P_1 V_1^{1.2} = P_2 V_2^{1.2}$

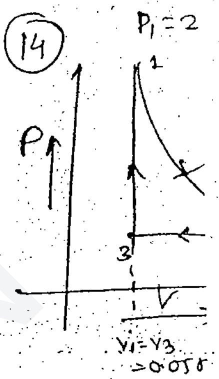
$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{1.2}$

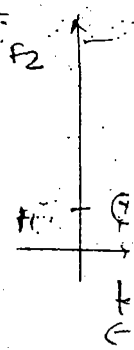
$= 101.325 \left(\frac{V_1}{\frac{V_1}{5}}\right)^{1.2}$

699 ≃ 700 kPa

$_1W_2 = \frac{P_1 V_1 - P_2 V_2}{n-1}$

$W_{12} = \frac{101.325 \times 5.52 \times 10^{-3} - 699 \times 1.1044 \times 10^{-3}}{1.2 - 1} = \frac{-1.0645}{}$



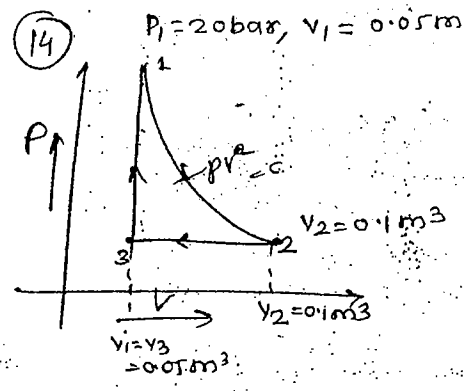


7.

power (KW) = work/stroke/cylinder × compressions/cycle/sec × No. of cylinders

$= 500 \times 1.06 \times \frac{500}{60} \times 0.2 = \underline{17.6}$ kW

(14)



process 1-2

$pV^2 = C$

$P_1V_1^2 = P_2V_2^2$

$P_2 = P_1\left(\frac{V_1}{V_2}\right)^2$

$= 20\left(\frac{1}{2}\right)^2$

$= 5$ bar

$1W_2 = \frac{P_1V_1 - P_2V_2}{n-1} = \frac{2000 \times 0.05 - (500 \times 0.1)}{2-1}$

$= 50$

$\boxed{1W_2 = 50 \text{ kJ}}$

process 2-3. $P = C$

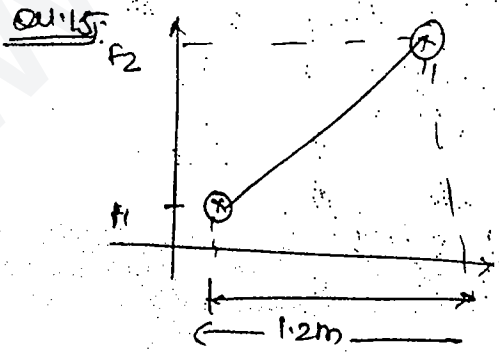
$2W_3 = P(V_3 - V_2) = 500(0.05 - 0.1) = -25$ kJ

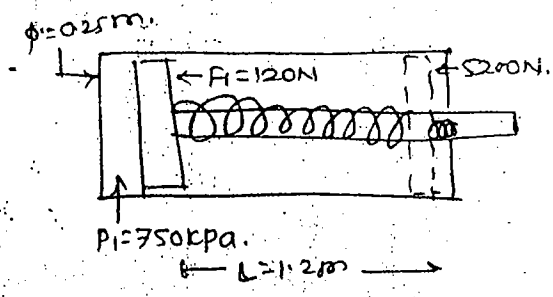
process $V = C$

$3W_1 = 0$

$W_{net} = 1W_2 + 2W_3 + 3W_1 = 50 - 25 + 0 = 25$ kJ

Ans.





Work done = area of diagram = area of trapezium

$W = \frac{1}{2}(F_1 + F_2)S$

$= \frac{1}{2}(120 + 500) \times 1.2$

$= \underline{3072 \text{ J}}$

Qu-1 pg No 4

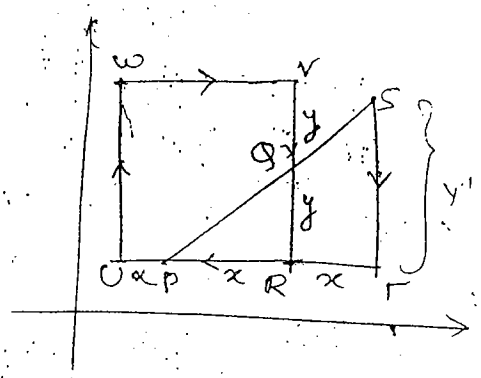
$UP = PR = RT = x$

$VR = QR = y$

WVUR

$2x \times 2y = 48$

$xy = 12$



Area PST

PQR ; PST are similar triangle

$\frac{y}{x} = \frac{y'}{2x}$ $\quad y' = 2y$

$\frac{1}{2} \times 2x \times 2y$

$= 2xy$

$= 2 \times 12 = 24$ Nm

Qu-2 $V_1 = 0.1\ m^3$, $P_1 = 1$ bar $\quad T_2 = 0$ $\quad P_1 = 100$ kPa $\quad T = 25^\circ C = 300K$ $\quad V_2 = 0.04\ m^3$ $\quad P_2 = 5$ bar

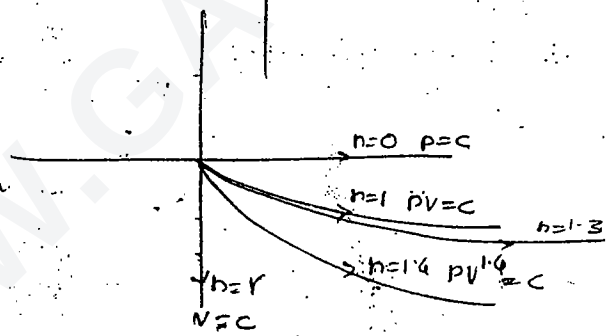
$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{100 \times 0.1}{300} = \frac{500 \times 0.04}{T_2}$$

$$\boxed{T_2 = 600K}$$

Qu-5

Area under gives work done



Qu-6 (a) $Q_S = 300$kJ, $Q_R = 100$kJ, $W_E = 300 + 250 = 550$

$W_C = 250 + 100 = 350$

$W_{net} = W_E - W_C = 550 - 350 = 200$

$\eta_R = \frac{W_{net}}{W_E} = \frac{200}{550} = 0.3636$

$\eta_{th} = \frac{W_{net}}{Q_S} = \frac{200}{300} = 66\%$

Qu-8

$P_1V_1 = P_2$

Qu-19

Qu-1 pg N

$dQ = dW$

$dQ - dW =$

insulated

Rigid

($T_2 = T_1$)

isothermal

$P_1V_1 = P_2$

$20 \times 15 = P_2$

$P_2 = 0$

Qu-2

insulated

rigid cylin

free expan

Qu.8:

$p_1V_1 = p_2V_2 \quad \therefore p_1V_1 = \frac{p_1}{10} \times 0.55$

$V_1 = 0.055\ m^3$

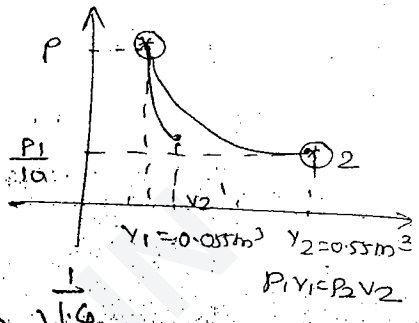
$V_2' = ?$

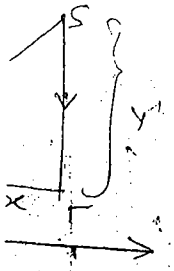
$p_1V_1^{\gamma} = p_2V_2'^{\gamma}$

$\therefore \left(\frac{V_2'}{V_1}\right)^{\gamma} = \frac{p_1}{p_2}$

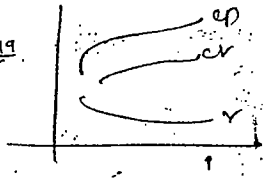
$\therefore V_2' = V_1\left(\frac{p_1}{p_2}\right)^{1/\gamma} = 0.055\left(\frac{p}{\frac{p}{10}}\right)^{\frac{1}{1.4}}$

$= 0.28$





Qu.19



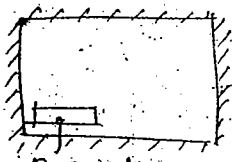
$P_2 = 5$ bar

1st Law Thermodynamic

Qu.1 pg No 9

$V_2 = 1500\ c.c$

$P_0 = ?$



$P_1 = 20$ atm

$V_1 = 15\ c.c$

$T_1 = 40°C$

$dQ = dw = du$

$dQ - dw = C_v dT$

insulated $dQ = 0$

Rigid $dW = 0$

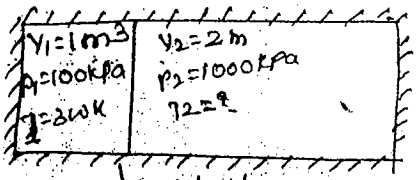
$(T_2 = T_1)$ isothermal $\quad dT = 0$

$P_1V_1 = P_2V_2$

$20 \times 15 = P_2 \times 1500$

$\boxed{P_2 = 0.2\ atm}$

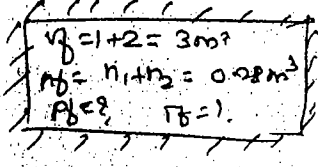
Qu.2



$n_1 = \frac{P_1V_1}{RT_1} = \frac{100 \times 1}{8.314 \times 300} = 0.04$

$n_2 = \frac{P_2V_2}{RT_2} = \frac{1000 \times 2}{8.314 \times 1000} = 0.24$

mixed both



insulated $dQ = 0$

rigid cylinder free expan: $dw = 0$

$\boxed{dU = 0}$

$(dU)_I + (dU)_{II} = 0$

$n_1 C_v (T_f - T_1) + n_2 C_v (T_f - T_2) = 0$

$n_1 C_v (T_f - T_1) = n_2 C_v (T_2 - T_f)$

$= 0.04(T_f - 300) = 0.24(1000 - T_f)$

$0.04T_f - 12 = 240 - 0.24T_f$

$0.04T_f + 0.24T_f = 240 + 12$

$\boxed{T_f = 900K}$

$P_f = \frac{n_f R T_f}{V_f} = \frac{0.28 \times 8.314 \times 900}{3} = 700 kPa = 0.7 MPa$

Ans.3

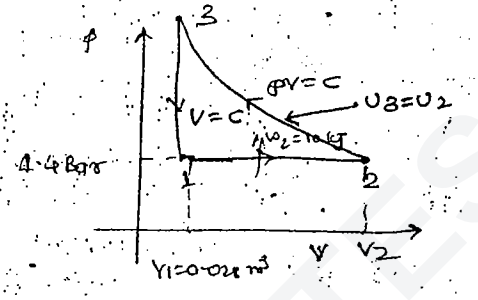
$P_1 = P_2 = 1.4$ bar

$V_1 = 0.024 m^3$

$U_2 = 10 kJ$

$U_1 - U_3 = -26.4 kJ$ $\boxed{U_3 = U_2}$

$U_1 - U_2 = -26.4 kJ$



1-2 $P = C$

$1W_2 = P(V_2 - V_1)$

$10.5 = 140(V_2 - 0.028)$

$10.5 = 140V_2 - 3.92$

$\boxed{V_2 = 0.103 m^3}$

$1Q_2 - 1W_2 = 1U_2$

$1Q_2 - 10.5 = U_2 - U_1 = -(U_1 - U_2)$

$1Q_2 - 10.5 = (U_2 - U_1) = -(-26.4)$

$= 26.4$

$\boxed{1Q_2 = 36.9 kJ}$

2-3 $T = C$

$2Q_3 = 2W_3 = P_2 V_2 \ln \frac{V_3}{V_2}$

$= 140 \times 0.103 \ln\left(\frac{0.028}{0.103}\right)$

$= -18.282 kJ$

3-1 $V = C$ $dW = 0$

$3Q_1 - 3W_1 = 3U_1$

$3Q_1 = 3U_1$

$3Q_1 = U_1 - U_3 = \boxed{+26.4 kJ}$

Ans.4 Sta

process

Ans.5

SFEE

$\Sigma Q = 1Q_2 + 2Q_3 + 3Q_1 = -36.9 - 18.78 - 26.3 = -8.28$ KJ

$\Sigma W = 1W_2 + 2W_3 + 3W_1 = 10.5 + (-18.78) + 0 = -8.28$ KJ

$\Sigma Q = \Sigma W$ 1st law proved

Qu.4:

State 1-2

$1Q_2 - 1W_2 = 1E_2 = E_2 - E_1$

$1Q_2 - P(V_2 - V_1) = E_2 - E_1$

$1Q_2 = -100(0.3 - 0.003) = E_2 - 0$

$0 - 29.7 = E_2$

$E_2 = -29.7$ KJ

Process 2-3

$2Q_3 - 2W_3 = E_3 - E_2$

$2Q_3 - P(V_3 - V_2) = E_3 - (-29.7)$

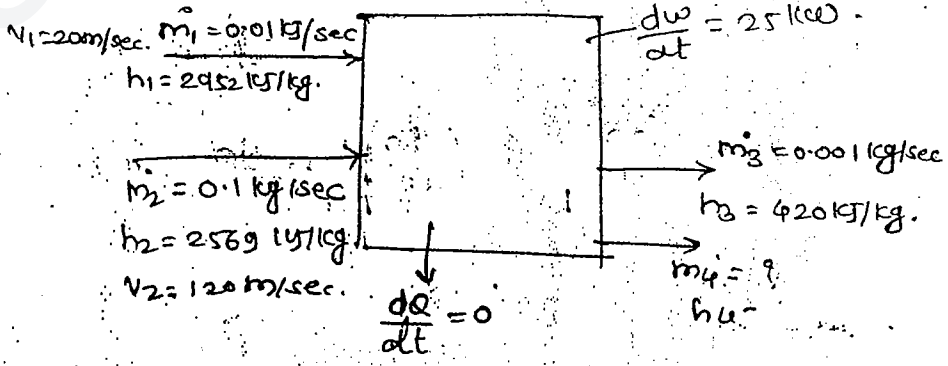
$2Q_3 - 100(0.06 - 0.3) = E_3 + 29.7$

$2Q_3 + 24 = E_3 + 29.7$

$-105 + 24 = E_3 + 29.7$

$E_3 = -110.7$ KJ

Qu.5



SFEE

Mass balance

$\dot{m}_1 + \dot{m}_2 = \dot{m}_3 + \dot{m}_4$

$0.01 + 0.1 = 0.001 + \dot{m}_4$

$\dot{m}_4 = 0.109$ kg/sec

Energy entering = Energy leaving.

$\dot{m}_1\left(h_1 + \frac{V_1^2}{2000}\right) + \dot{m}_2\left(h_2 + \frac{V_2^2}{2000}\right) + \frac{dQ}{dt} = \dot{m}_3(h_3 + \dots) + \dot{m}_4 h_4 + \frac{dw}{dt}$

$$\Rightarrow 0.01\left(2952+\frac{20^2}{2000}\right)+0.1\left(2589+\frac{120^2}{2000}\right)+0 =$$

$$0.001\times 420 + 0.1\,h_4 + 25$$

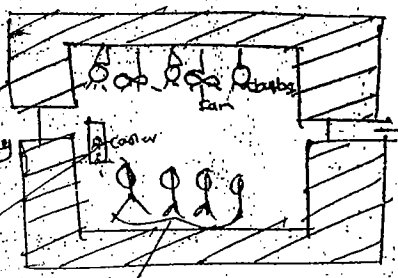
$$= 29.52 + 257.62 = 0.42 + 0.1\,h_4 + 25$$

$$287.14 = 25.42 + 0.1\,h_4$$

$$261.72 = 0.1\,h_4$$

$$\boxed{h_4 = 2401.1 \text{ kJ/kg}}$$

Qu. 6:



$\dot{m} = 80$ kg/hr, $h_1 = 84$ kJ/kg

$\left(\frac{dQ}{dt}\right)_{bulbs} = -3\times 0.1 = -0.3$ kW.

$\dot{m} = 80$ kg/hr, $h_2 = 59$ kJ/kg.

$\left(\frac{dQ}{dt}\right)_{fans} = -2\times 0.18 = -0.36$ kW.

$\left(\frac{dQ}{dt}\right)_{person} = 4\times 630$ kJ/hr $= 2520$ kJ/hr

$\left(\frac{dQ}{dt}\right)_{bulb} + \left(\frac{dQ}{dt}\right)_{fan} = -0.66$ kW

$\left(\frac{dQ}{dt}\right)_{room\,cooler} =$

SFEE

$$\dot{m}h_1 + \left(\frac{dQ}{dt}\right)_{person} + \left(\frac{dQ}{dt}\right)_{\substack{room\\cooler}} + \frac{dQ}{dt} = \dot{m}h_2 + \frac{dW}{dt}$$

$$\frac{80\times 84}{3600} + 2520 + \left(\frac{dQ}{dt}\right)_{R.C} = \frac{80\times 59}{3600} - 0.66$$

$$2521.86 + \left(\frac{dQ}{dt}\right)_{R.C} = 0.651$$

$$\left(\frac{dQ}{dt}\right)_{R.C} = \underline{-1.91 \text{ kW}}$$

Qu. 7:

$C_v = a + bt + ct^2$

$dQ = \int_{T_1}^{T_2} C_v dT = \int_{T_1}^{T_2} (a + bt + ct^2)\, dT$

$= [aT]_{T_1}^{T_2} + \left(\frac{bT^2}{2}\right)_{T_1}^{T_2} + \left[\frac{cT^3}{3}\right]_{T_1}^{T_2}$

$= a(T_2 - T_1) + \frac{b}{2}(T_2^2 - T_1^2) + \frac{c}{3}(T_2^3 - T_1^3)$

Qu. 8: $p = a + bv$ $\quad p_1 = 1000\,kPa$ $\quad p_2 = 200\,kPa$.

$v_1 = 0.20\,m^3$ $\quad v_2 = 1.20\,m^3$.

$p_1 = a + bv_1$ — (1)

$1000 = a + b \times 0.20$

$p_2 = a + bv_2$

$200\,kPa = a + b \times 1.20$

$\boxed{a = 1160}$ $\quad \boxed{b = -800}$

$p = 1160 - 800v$

$W_2 = \int_{V_1}^{V_2} p\, dV$

$= \int_{0.2}^{1.2} (1160 - 800v)\, dv$

$= \left[1160v - \frac{800v^2}{2}\right]_{0.2}^{1.2}$

$= 1160(1.2 - 0.2) - 800\frac{(1.2^2 - 0.2^2)}{2}$

$= 1160 - 560$

$= 600\,kJ$

$U = \{1.5pv - 85\}$ kJ/kg.

$= \left(1.5\,P\frac{V}{m} - 85\right)$ kJ/kg

$= 1.5 \times (pv - 85)$ kJ/kg

$v_1 = p_1 v_1 - 85$

$= 1000 \times 0.20 - 85$

$= 115$ kJ/kg

$v_2 = p_2 v_2 - 85 = 155$ kJ/kg.

$m = 1.5$

$\Delta U = U_2 - U_1$

$= 155 - 115$

$= 40$ kJ/kg

change in ΔU

$= 40 \times 1.5$

$= 60\,kJ$.

$dq - dw = du$ ∴ $dq - 600 = 60$

$$\boxed{dq = 60 + 600 = 660 \text{ kJ}}$$

$u = (pv - 85)$ kJ/kg

$p = a + bv$

$u = (a + bv)v - 85$

$u = av + bv^2 - 85$ kJ/kg.

u = function of vol^m.

$$\frac{du}{dv} = a + 2bv = 0$$

$$v = -\frac{a}{2b} = \frac{-1160}{2 \times (-800)} = 0.725 \text{ m}^3$$

$$u_{max} = 1160 \times 0.725 - 800 \times (0.725)^2 - 85$$

$$= 84 - 420.5 - 85$$

$$= 335.5 \text{ kJ/kg}$$

$$u_{max} = 1.5 \times 335.5$$

$$= 503.25 \text{ kJ}$$

$u = pv - 85$ $\quad p = a + bv$

$bv = p - a$

$$v = \frac{p - a}{b}$$

$$u = \frac{p(p-a)}{b} - 85 = \frac{p^2}{b} - \frac{ap}{b} - 85 = f(p)$$

$$\frac{dv}{dp} = \frac{2p}{b} - \frac{a}{b} = 0 \qquad \boxed{p = a/2}$$

$$p = \frac{1160}{2} = 580$$

$$u_{max} = \frac{580^2}{-800} - \frac{1160 \times 580}{-800} - 85$$

$$= -420.5 + 841 - 85 \quad 335.5 \text{ kJ/kg}$$

$$= 503.25 \text{ kJ} = \text{——}$$

$(u_{max})_{about} = 1.5 \times 335.5$

$= 503.25$ kJ

$A_1 = 0.1 \text{ m}^2$

$v_1 = 0.18 \text{ m}^3/\text{kg}$

$h_1 = 3000$ kJ/kg

$V_1 = 60$ m/sec.

$V_2 =$

$V_2 =$

$\boxed{V_2 =}$

$\dot{m} =$

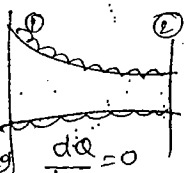
$\frac{A_2}{v}$

Qu. 10.

$\dot{m}(h_1 +$

0.92

Qu.9



$A_1 = 0.1\ m^2$

$v_1 = 0.18 \frac{m^2}{kg}$

$h_1 = 3000\ kJ/kg$

$V_1 = 60\ m/sec.$

$\frac{dQ}{dm} = 0$

$\frac{dw}{dm} = 0.$

$h_2 = 2962\ kJ/kg$

$V_2 = ?$

$A_2 = ?$

$h_2 = 2962\ kJ/kg.$

$v_2 = 0.498\ m^3/kg.$

$$V_2 = \sqrt{V_1^2 + 2000(h_1 - h_2)}$$

$$V_2 = \sqrt{(60)^2 + 2000(3000 - 2962)}$$

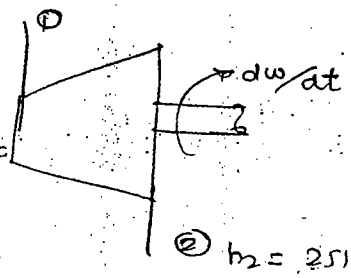
$$\boxed{V_2 = 692.53\ m/sec}$$

$$\dot{m} = \frac{A_1 V_1}{v_1} = \frac{0.1 \times 60}{0.182} = 32.08\ kg/sec.$$

$$\frac{A_2 V_2}{v_2} = \frac{A_2 \times 692.5}{0.498} = 32.08$$

$$A_2 = 0.023\ m^2.$$

Qu.10



$\dot{m}$ (kg/sec)

$h_1 = 2785\ kJ/kg$

$V_1 = 33.33\ m/sec$

$z_1 = 3\ m.$

$\frac{dQ}{dt} = -0.29\ kw.$

$\dot{m} = 0.42\ kg/s.$

$h_2 = 2512\ kJ/kg.$

$V_2 = 100\ m/sec$

$z_2 = 0$

$$\dot{m}\left(h_1 + \frac{V_1^2}{2000} + \frac{z_1 g}{1000}\right) + \frac{dQ}{dt} = \dot{m}\left(h_2 + \frac{V_2^2}{2000}\right) + \frac{dw}{dt}$$

$$0.42\left(2785 + \frac{33.33^2}{2000} + \frac{3 \times 9.81}{1000}\right) + (-0.29) = 0.42\left(2512 + \frac{(100)^2}{2000}\right) + \frac{dw}{dt}$$

$$1169.655 = 1057.14 + \frac{dw}{dt}$$

$$\boxed{\frac{dw}{dt} = 112.51\ kJ}$$

Qu.11 $c_p = \left(2.093 + \frac{41.87}{t+100}\right)$ J/°C

$$Q = \int_{T_1}^{T_2} c_p \, dT$$

$$= \int_0^{100} \left(2.093 + \frac{41.87}{t+100}\right) dT$$

$$= \left[2.093T + 41.87 \ln(t+100)\right]_0^{100}$$

$$= 2.093(100) + 41.87 \ln(100+100) - (0+100)$$

$$= 238.32 \text{ J}$$

$$W = p\,dV$$

$$= 101.325 (V_2 - V_1)$$

$$= 101.325 (2000 - 2000) \times 10^{-6}$$

$$= 40.5 \text{ J}$$

$$Q - W = U$$

$$\boxed{U = 197.825 \text{ J}}$$

Qu.12 - Pg No 11

1-2

$$1Q_2 - 1W_2 = 1U_2 = U_2 - U_1$$

$$100 - 100 = U_2 - U_1$$

$$U_2 - U_1 = 0$$

$$U_2 = U_1$$

2-3

$$2Q_3 - 2W_3 = 2U_3$$

$$-150 - 2W_3 = U_3 - U_2$$

$$-150 - 2W_3 = U_2 - U_2 = U_3 - U_1 = 200$$

$$-2W_3 = 350$$

$$2W_3 = -350$$

2-4 : $3Q_4 - 3W_4 = 3U_4$

$3W_4 + 250 = 3U_4$

$3W_4 + 250 = U_4 - U_3$

$3W_4 + 250 = (U_4 - U_1) - (U_3 - U_1)$

$= -50 - 200 = -250$

$\boxed{3W_4 = -500\,kJ}$

4-1 $4Q_1 - 4W_1 = 4U_1$

$4Q_1 - 300 = U_1 - U_4 = 50$

$\boxed{4Q_1 = 350}$

$\Sigma Q = 1Q_2 + 2Q_3 + 3Q_4 + 4Q_1$

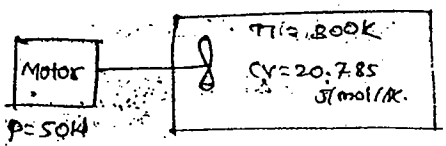
$= 100 - 150 - 500 + 350 = -200\,kJ$

$\Sigma W = 1W_2 + 2W_3 + 3W_4 + 4W_1$

$= 100 - 350 - 250 + 300 = -200\,kJ$

$\Sigma Q = \Sigma W$ 1st law is proved.

Qu: (13)



P = 50W

t = 2 min = 120 sec

$dQ - dW = dU$

$Q - \text{power} \times \text{time} = C_V\,dT$

(external work doing on system taken -ve)

$-(-pt) = n C_V dT$

$50 \times 120 = 1 \times 20.785 (T_2 - T_1)$

$6000 = 20.785 (T_2 - 300)$

$\boxed{T_2 = 588.66\,K}$

$V = C$

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\frac{100}{300} = \frac{P_2}{588}$

$\boxed{P_2 = 196.223\,kPa}$

Qu. 5 Pg No 18

Degree of freedom

Molecule ex.	Translational	Rotational	total.
Monoatomic He	3	0	3
Diatomic O_2	3	2	5
polyatomic CH_4	3	3	6.

C_V	$C_P = C_V + R$
$\frac{3}{2}R$	$\frac{3}{2}R + R = \frac{5}{2}R$
$\frac{5}{2}R$	$\frac{5}{2}R + R = \frac{7}{2}R$
$3R$	$3R + R = 4R$.

n degree of freedom

$C_V = \frac{nR}{2}$ $C_P = \frac{n}{2}R + R = \left(\frac{n}{2}+1\right)R = \left(\frac{n+2}{2}\right)R$.

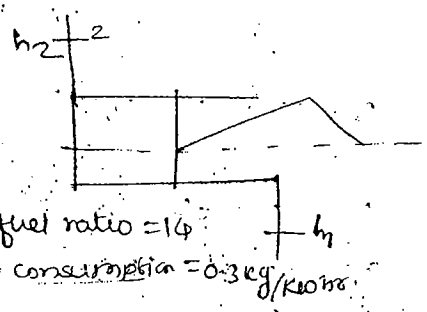
$\frac{C_P}{C_V} = \frac{\left(\frac{n}{2}+1\right)R}{\left(\frac{n}{2}\right)R} = \left(\frac{n+2}{2}\right)\left(\frac{2}{n}\right) = \frac{n+2}{n} = \boxed{1+\frac{2}{n}}$

(14)

$$bsfc = \frac{\dot{m}_f\ (kg/hr)}{bp\ (kw)}$$

$$= \frac{\dot{m}_f}{26} = 0.3$$

$$\Rightarrow \dot{m}_f = 7.8\ kg/hr$$



basic specific fuel consumption = 0.3 kg/kw hr

$$\dot{m}_a = 14\dot{m}_f = 109.2\ kg/hr.$$

$$\dot{m} = \dot{m}_a + \dot{m}_f = 117\ kg/hr. = \frac{117}{3600} = 0.0325\ kg/sec.$$

$$\dot{m}h_1 + \frac{dQ}{dt} = \dot{m}h_2 + \frac{dw}{dt}$$

$$\dot{m}(h_2 - h_1) = \frac{dQ}{dt} - \frac{dw}{dt}$$

$$0.0325(h_2 - h_1) = -35 - 26$$

$$(h_2 - h_1) = \Delta h = \frac{-61}{0.0325} = -1877\ kJ/kg.$$

Qu.15

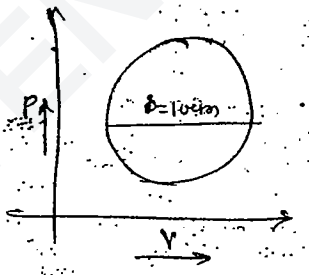
1 cm on x axis = 300 kPa.

1 cm on y axis = 0.1 m³/kg.

$1\ cm^2$ i = $(100)_x \times (100)_y$

$= 300 \times 0.1$

$\Leftarrow$ 30 kJ/cy.



$W = \pi/4(D)^2 = \pi/4(D)^2 = \pi/4 \times (10)^2 = 78.5\ cm^2$

$= 78.5 \times 30 = 2356\ kJ/kg.$

$Q_R = 100\ kJ/kg.$

$Q_S = w + Q_R = 2456\ kJ/kg.$

$$\eta_R = \frac{w}{Q_S} = \frac{2356}{2450} \times 100 = 96.16\%$$

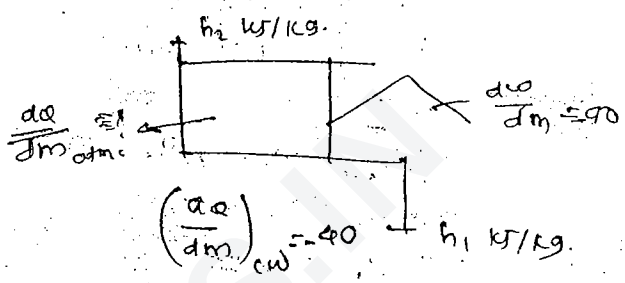
Pg-No (8) Qu-1

$dQ - dW = dU$

Pg-No (8) Qu-2

$h_1 + \left(\frac{dQ}{dm}\right)_{cw} + \left(\frac{dQ}{dm}\right)_{air}$

$= h_2 + \frac{dW}{dm}$



$(h_2 - h_1) = 30$

$\left(\frac{dQ}{dm}\right)_{air} = (h_2 - h_1) + \frac{dW}{dm} - \frac{dQ}{dm}$

$= 30 - 90 - (-40) = -20$ KJ heat is rejected.

Qu-5 $\frac{dT}{T} = \frac{v\,dp}{T}$ $\therefore \frac{dT}{T} = \frac{R}{p}dp$

$\therefore M\,dx + N\,dy$ $M = \frac{1}{T}$ $N = -R/p$

$\frac{\partial M}{\partial p} = 0$ $\frac{\partial N}{\partial T} = 0$ $\therefore \frac{\partial M}{\partial p} = \frac{\partial N}{\partial T}$

hence it is exact differential at point & hence eqn (i) represent a point function.

Qu-6 $E = 25 + 0.25\,t$ KJ

$dW = 0.75$ KN-m

$E_2 - E_1 =$ $E_1 = 25 + 0.25\,t_1$, $E_2 = 25 + 0.25\,t_2$

$(E_2 - E_1) = 0.25(t_2 - t_1) = 0.25 \times 1 = 0.25$ KJ

$dQ - dW = dE$

$dQ - 0.75 = 0.25$ $\boxed{dQ = 1 \text{ KJ}}$

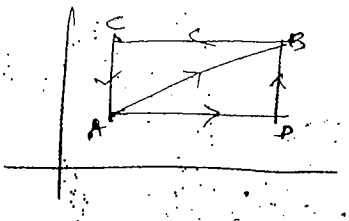
Qu-7 1st case Q -ve (rigid) $W = 0$ U = -ve

IInd case $Q = 0$ W = +ve, U = -ve

IIIrd case $Q = 0$ $W = 0$ $U = 0$

IVth case $Q = 0$ W = -ve U = +ve

Qu:8



Q. A-C-B

$A Q_B - A W_B = A U_B$

$190 - 130 = 50 = U_B - U_A$

ADB

$A Q_B - A W_B = A U_B$

$A Q_B - A W_B = U_B - U_A$

$A Q_B - 40 = 50$

$\boxed{A Q_B = 90 \text{ KJ}}$

what is change in path is AB.

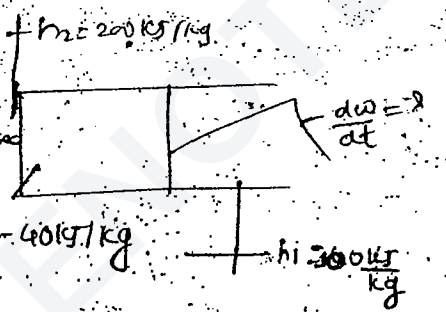
Path AB: $A W_B = 85 \quad A U_B = 50$

$A Q_B - A W_B = A U_B$

$A Q_B - 50 = 80$

$\boxed{A Q_B = 135 \text{ KJ}}$

Qu:10



Apply SFEF

$\dot{m} h_1 + \dot{m} \frac{dQ}{dm} = \dot{m} h_2 + \frac{dw}{dt}$

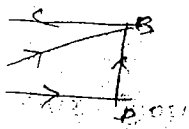
$\frac{dw}{dt} = \dot{m}(h_1 - h_2) + \dot{m} \frac{dQ}{dm}$

$= 0.5 (100 - 200) + 0.5 \times (-40)$

$= -70$

Qu:11

$W = 474 - 180 = 294 \text{ KJ/min.} = \frac{294}{60} = 4.9 \text{ KW}$



pg.No 51, Qu.13

$$\left(P_1 + \frac{a}{V_1^2}\right) V_1 = \left(P_2 + \frac{a}{V_2^2}\right) V_2$$

$$\left(10 + \frac{a}{12}\right) 1 = \left(P_2 + \frac{a}{2^2}\right) 2$$

$P_2 > P_1$ because a is +ve

$$P_2 = 5 + \frac{a}{2}$$

$P_2 > P_1$

Ans (b)

Qus pg NO 53 Qu. 24 & 25

$P_{abs} = P_{atm} + P_g$ 101.325

$P_{abs} = 101.325 + 100 = 201.325$ kPa

$V_1 = 2500\ cm^3$ $T_1 = 288K$

$$m = \frac{P_1 V_1}{RT_1} = \frac{201.325 \times 2500 \times 10^{-6}}{0.287 \times 288} = 6.08 \text{ gms} = 6.08 \times 10^{-3} \text{ kg}$$

Volume = constant $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$$\frac{201.325}{288} = \frac{P_2}{278} \qquad \boxed{P_2 = 194.334 \text{ kPa}}$$

$P_{gauge} = 194.334 - 101.325 = 93$ kPa.

$-\frac{dw}{dt} = ?$

360 kJ/kg

For V=C $dw = 0$

$dQ = dU$ $dQ = mcv\,dT$

$= 6.08 \times 10^{-3} \times 0.718 \times (15-5)$

$= 0.0436$ kJ

$= 43.68$ J.

kW

(26) $P_1 = ?$ $T_1 = 288$ $T_2 = 201.325$, $T_2 = 278$

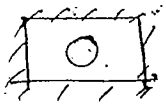
$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad \frac{P_1}{288} = \frac{P_2}{278} \qquad \frac{P_1}{288} = \frac{201.325}{278}$$

$P_1 = 208.24$ kPa

$P_g = 208.24 - 101.325$

$= 106.915$ kJ

Pg-50 Qu-33

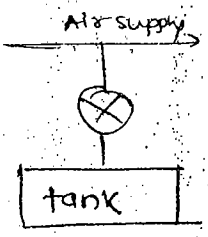


$dQ=0 \quad dW=0$

$\Rightarrow dU=0 \Rightarrow cv\,dT=0$

$\Rightarrow dT=0 \Rightarrow T_2=T_1$

Qu-34:



$m_0=0$ initial evaluated

$P_1=1$ MPa $T_1=300°C$

insulated tank $Q=0$

$m_0=0$ } charging process

$Q=0$ }

$T_f=\gamma T_1$

$=$

$T_f > 350°C$

II^{o}M La

TER: ⇒ T

Any amou

amount o

change

Hot

Hot Source:

fs does no

eg: sun, t

Cold sink

temp does

eg: Atmos

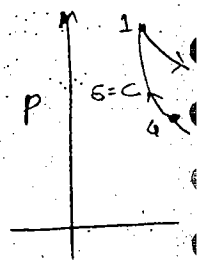
MER ⇒

eg spring

whenever

carnot cy

Carnot cy

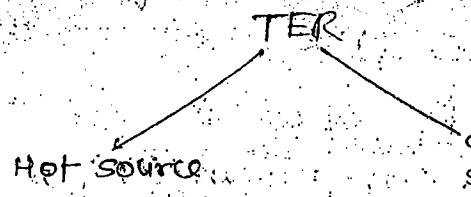


In the pr

II nd Law of thermodynamic

TER :⇒ Thermal energy reservoir

Any amount of heat withdrawn from heat source any amount of heat is supplied to heat if temp does not change then it is said to be a reservoir



Hot source : any amount of heat is withdrawn if the temp is does not change then it is called as hot source.

eg : sun, furnace,

Cold sink Any amount of heat is rejected to it if the temp does not change then it is called as cold sink

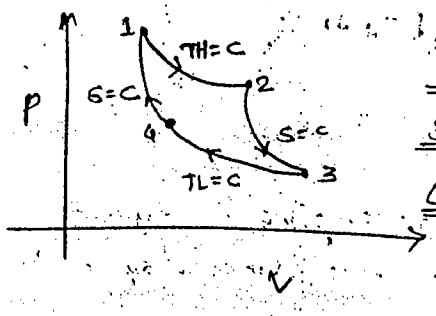
eg : Atmosphere, river water, sea waters, condenser

MER ⇒ Mechanical energy reservoir

eg spring in watch, flywheel for an engine

whenever we talks of heat engine we talk of carnot cycle

Carnot cycle



1-2 Reversible isothermal heat supplied

2-3 Reversible adiabatic expansion

3-4 Reversible isothermal heat rejection

4-1 Reversible adiabatic compression

In the process 1-2 isothermal T=C

$P_1V_1 = P_2V_2$ $\quad 1Q_2 = 1W_2 = P_1V_1 \ln \frac{V_2}{V_1}$

$= RT_H \ln \frac{V_2}{V_1}$ —(1)

process 2-3 : Reversible adiabatic expansion

$P_2V_2^{\gamma} = P_3V_3^{\gamma}$, $T_2V_2^{\gamma-1} = T_3V_3^{\gamma-1}$, $\boxed{\frac{V_3}{V_4} = \frac{V_2}{V_1}}$

$T_2P_2^{\frac{1-\gamma}{\gamma}} = T_3P_3^{\frac{1-\gamma}{\gamma}}$ $\quad \frac{T_2}{T_3} = \left(\frac{V_3}{V_2}\right)^{\gamma-1} = \frac{T_H}{T_L}$

$\frac{T_1}{T_4} = \left(\frac{V_4}{V_1}\right)^{\gamma-1} = \frac{T_H}{T_L}$ $\quad \frac{V_3}{V_2} = \frac{V_4}{V_1}$

$${}_2W_3 = \frac{P_2V_2 - P_3V_3}{\gamma-1} = \frac{R(T_2-T_3)}{\gamma-1} = C_V(T_2-T_3) \quad —②$$

process 3-4 $\quad T = C$

$$P_3V_3 = P_4V_4 \qquad {}_3Q_4 = {}_3W_4 = P_3V_3 \ln\left(\frac{V_4}{V_3}\right) \text{ or}$$

$$= P_3V_3 \ln\left(\frac{V_3}{V_4}\right)$$

$$= RT_L \ln \frac{V_3}{V_4}$$

process 4-1 Reversible adiabatic compression

$$P_4V_4^{\gamma} = P_1V_1^{\gamma} ;$$

$$T_4V_4^{\gamma-1} = T_1V_1^{\gamma-1}$$

$$T_4P_4^{\frac{1-\gamma}{\gamma}} = T_1P_1^{\frac{1-\gamma}{\gamma}}$$

$${}_4W_1 = \frac{P_4V_4 - P_1V_1}{\gamma-1} = \frac{R(T_4-T_1)}{\gamma-1} = C_V(T_4-T_1) = C_V(T_L-T_H)$$

$$\eta_{thermal} = \frac{W}{Q_S} = \frac{Q_S - Q_R}{Q_S} = \frac{RT_H \ln\frac{V_2}{V_1} - RT_L \ln\frac{V_3}{V_4}}{RT_H \ln\frac{V_2}{V_1}}$$

$$= \frac{T_H - T_L}{T_H} \quad \because \left(\frac{V_3}{V_4} = \frac{V_2}{V_1}\right)$$

The thermal efficiency of carnot engine is depend only on temp limits but does not depend upon the medium

Kinet is le but thermo can have a efficiency. practical ca
① Isotherm process is heat supp during ac and this mechanism not possib
② During engine adiabati and this material hence it
used for
$\eta = 1 -$
$\left(\frac{d\eta}{dT_L}\right.$
changing when cor

Carnot engine having double expansion process kinetic is less stroke volume is high and m.e.p is less but thermal efficiency is maximum and no engine can have an efficiency greater than or equal to carnot efficiency. carnot engine is only theoritical engine not practical engine because of following reasons.

① Isothermal process is a very very slow process. Adiabatic process is a very very fast process. during isothermal heat supplied the engine should run very very slowly during adiabatic expansion it should run very very fast and this is to be done alternately. and there is no mechanism which can run like this hence carnot is not possible engine

② during isothermal heat supplied process the head of the engine should acts as a perfect conductor during adiabatic expansion it should act as perfect insulator and this should happen alternately. and there is no material in the universe which can operate like this hence it is an impossible carnot engine.

It is basically a reference engine and is used for defining the thermodynamic temp scale

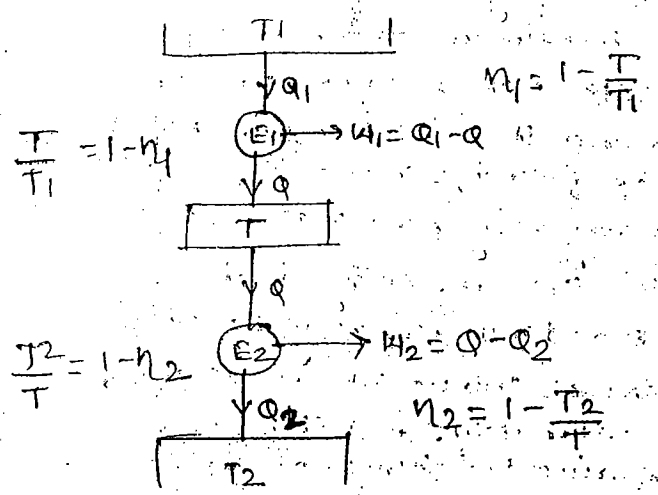
$$\eta = 1 - \frac{T_L}{T_H}$$

$$\left(\frac{d\eta}{dT_L}\right)_{T_H=C} = -\frac{1}{T_H} = -\frac{1}{T_H} \times \frac{T_H}{T_H} = \frac{-T_H}{T_H^2}$$

$$\left(\frac{d\eta}{dT_H}\right)_{T_L=C} = \frac{T_L}{(T_H)^2}$$

$$\left(\frac{d\eta}{dT_L}\right)_{T_H=C} > \left(\frac{d\eta}{dT_H}\right)_{T_L=C}$$

changing the sink temp: gx has a greater improvement in η when compared to changing the source temp.



Equal work output

$W_1 = W_2$

$Q_1 - Q = Q - Q_2$

$Q = \frac{Q_1 + Q_2}{2}$

$\eta \propto$ Temp

$T = \frac{T_1 + T_2}{2}$

For equal work output condition the intermediate temp is the arithmatic mean of remaining two temp.

$$\boxed{\frac{Q_1}{T_1} = \frac{Q}{T} = \frac{Q_2}{T_2}}$$

Equal efficiency

$\eta_1 = \eta_2$

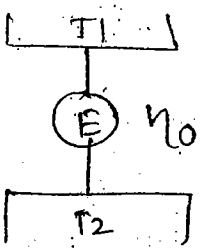
$1 - \frac{T}{T_1} = 1 - \frac{T}{T_2}$

$T = \sqrt{T_1 T_2}$

For equal η condition the intermediate temp is geometric mean of remaining temp.

$$\boxed{\frac{Q_1}{T_1} = \frac{Q}{T} = \frac{Q_2}{T_2}}$$

overall efficiency



$\eta_0 = 1 - \frac{T_2}{T_1}$ $\quad \frac{T_2}{T_1} = 1 - \eta_0$

$\frac{T_2}{T_1} = \frac{T_2}{T} \times \frac{T}{T_1}$

$(1-\eta_0) = (1-\eta_2) \times (1-\eta_1)$

$$\boxed{\eta_0 = \eta_1 + \eta_2 - \eta_1\eta_2}$$

overall efficiency of coupled cycle.

$\eta_1 = 30\%$ $\quad \eta_2 = 40\%$ $\quad \eta_0 = ?$

$\eta_0 = \eta_1 + \eta_2 - \eta_1\eta_2 = 0.3 + 0.4 - 0.3 \times 0.4 = 0.58$

η_0 of coupled cycle is greater than the individual η

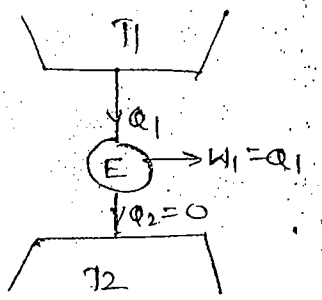
For n cycle:

$(1-\eta_0) = (1-\eta_1)(1-\eta_2) \cdots (1-\eta_n)$

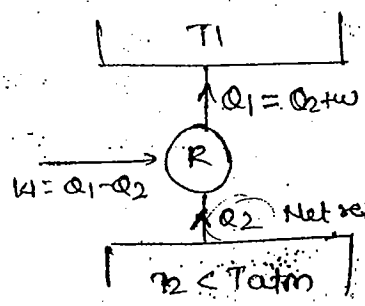
IInd law a Qualative law. It is a direction, law
It's imposes a limitation on the amount of heat energy that can be converted to work

Kelvin and plank have defined IInd law with respect to an engine. which is called as IInd Law of thermodynamic
"It is impossible to construct an engine whose only purpose is absorbs of heat from a high temp reservoir and it's conversion to work"
an engine with 100% is impossible.
A device which convert 100% heat to 100% work is called perpetual motion of IInd kind and IInd law state perpetual motion machine IInd kind (PMMSK) is impossible

If work is to produced by an engine so amount of heat has rejected to a low temp reservoir unless you reject some heat you can not do work.



Refrigerator : It is device which maintain a temperature less than the atmospheric by continuously removing heat from a low temp reservoir and transfer it to a high temp reservoir by doing external work.



$$(C.O.P)_{Ref} = \frac{\text{Net refrigerating effect}}{\text{work}}$$

$$= \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2} = T_2 (T_1 - T_2)^{-1}$$

In co-p improved

① whether source temp or sink temperature should be changed.

$$\left(\frac{dc}{dT_2}\right)_{T_1 = c} = 1(T_1 - T_2)^{-1} + T_2(-1)(T_1 - T_2)^{-2}(-1)$$

$$= \frac{1}{T_1 - T_2} + \frac{T_2}{(T_1 - T_2)^2}$$

$$= \frac{T_1 - T_2 + T_2}{(T_1 - T_2)^2} = \frac{T_1}{(T_1 - T_2)^2}$$

f of heat reject

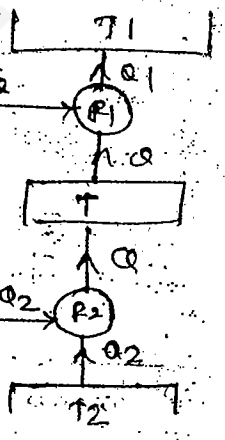
$$C = T_2(T_1 - T_2)^{-1}$$

$$\left(\frac{dc}{dT}\right)_{T_2=C} = T_2(-1)(T_1-T_2)^{-2}(1) = \frac{-T_2}{(T_1-T_2)^2}$$

$$\left(\frac{dc}{dT_2}\right)_{T_1=C} > \left(\frac{dc}{dT_1}\right)_{T_2=C}$$

Changing the T_{sink} has a great improvement in C.O.P while compare to change in T_{source}.

Coupled refrigerators



$$\text{@}(C.O.P)_I = \frac{T}{T_1 - T} = \frac{1}{\frac{T_1}{T} - 1}$$

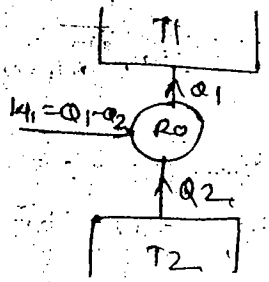
$$\frac{T_1}{T} = 1 + \frac{1}{(C.O.P)_I}$$

$$(C.O.P)_{II} = \frac{T_2}{T - T_2} \cdot \frac{T}{T_2}$$

$$= 1 + \frac{1}{(C.O.P)_{II}} = \frac{1}{\frac{T}{T_2} - 1}$$

$$(C.O.P)_R = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$$

$$(C.O.P)_{overall} = \frac{T_2}{T_1 - T_2} = \frac{1}{\frac{T_1}{T_2} - 1}$$



$$\frac{T_1}{T_2} = 1 + \frac{1}{(C.O.P)_{overall}}$$

Equal work input

$$W_1 = W_2$$

$$Q_1 - Q = Q - Q_2$$

$$Q = \frac{Q_1 + Q_2}{2}$$

$$T = \frac{T_1 + T_2}{2}$$

∴ Intermediate temp is the arithmatic mean of remaining two temp.

$$\boxed{\frac{Q_1}{T_1} = \frac{Q}{T} = \frac{Q_2}{T_2}}$$

Equal (C.O.P)

$$\frac{T_1}{T} = 1 + \frac{1}{c_1} \; ; \; \frac{T}{T_2} = 1 + \frac{1}{c_2}$$

$$\frac{T_1}{T} = \frac{T}{T_2} \qquad T^2 = T_1 T_2 \qquad T = \sqrt{T_1 T_2}$$

For equal c.o.p condition the intermediate temp is geometric mean of remaining two temperature.

$$\boxed{\frac{Q_1}{T_1} = \frac{Q}{T} = \frac{Q_2}{T_2}}$$

Overall c.o.p

$$\frac{T_1}{T_2} = \frac{T_1}{T} + \frac{T}{T_2}$$

$$1 + \frac{1}{(C.O.P)_{overall}} = \left(1 + \frac{1}{(C.O.P)_I}\right) + \left(1 + \frac{1}{(C.O.P)_{II}}\right)$$

$$\frac{1}{(C.O.P)_{overall}} = \frac{1}{(C.O.P)_I} + \frac{1}{(C.O.P)_{II}} + \frac{1}{(C.O.P)_I (C.O.P)_{II}}$$

If $(C.O.P)_I = 2$, $(C.O.P)_{II} = 3$ what is the $(C.O.P)_{overall}$ of coupled cycle

$$\frac{1}{C_O} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_1 C_2}$$

$$= \frac{1}{2} + \frac{1}{3} + \frac{1}{2 \times 3} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6} = 1$$

$(C_O) = 1$ $\quad \boxed{C_O < C_1}$ $\quad \boxed{C_O < C_2}$

Clausius

"It is im
device wh
absorbs H
temp reser
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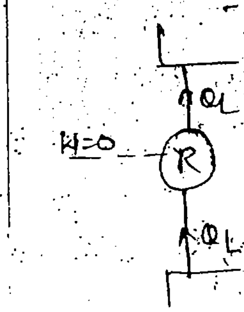
statement

① False claus
② False kelvin
hence kelvin
in all respe

(I.S.F) —C



Let the
absorb du
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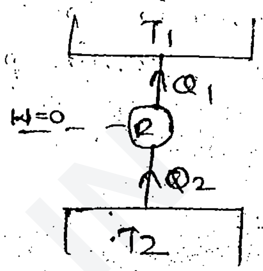
Clausius statement of IInd Law of thermodynamics

"It is impossible to construct a device whose only purpose is absorbs the heat from low temp reservoir and its transfer to the high temp reservoir without any external work input"



If heat is to be transferred from a low temp reservoir to a high temp reservoir work should be done.

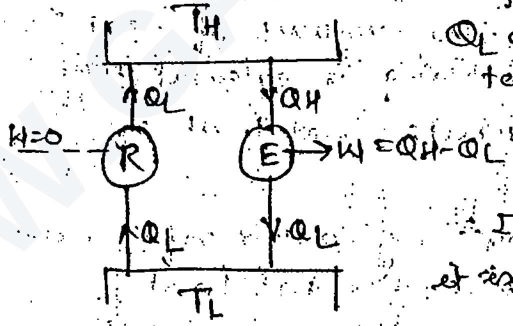
Proof of equivalence of kelvin plank statement and clausius statement

1) False clausius statement implies false Kelvin plank statement

2) false kelvin plank statement implies false clausius statement

hence kelvin plank statement & clausius statement are identical in all respect

(Ist) $-C \Rightarrow -K$ let the ref operate both temp limit T_L & T_H which absorb Q_L amount of heat from the low temp reservoir and transverse it to high temp reservoir without any external work input



∴ It is false refrigerator hence it is falsity of clausius statement

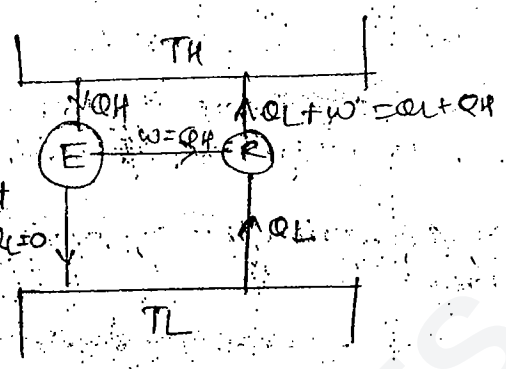
Let the engine operate in reverse direction which absorb ~~during~~ Q_H amount of heat from high temp reservoir and reject Q_L amount of heat with low temp reservoir and does work $Q_H - Q_L$. hence it is a true engine and ~~Pro~~ truth of kelvin and plank statement.

If both the engine and refrigerator together are considered as a self acting device the net heat interaction with the low temp reservoir is Zero and the high temp reservoir is $Q_H - Q_L$

and amount of work done is also $Q_H - Q_L$ i.e. 100% heat converted to 100% work hence it is a false engine and falsity of Kelvin plank statement

$\therefore \quad -C \Rightarrow -K$

(II) $-K \Rightarrow -C$



Let an engine operates between the temp limit T_H and T_L which absorbs Q_H amount of heat from a high temp reservoir rejects no heat Q_L amount of heat to the low temp reservoir and does work $W = Q_H$ hence it is false engine and falsity of Kelvin plank statement

Let a refrigerator operate between temp limit T_L and T_H which absorbs Q_L amount of heat from the low temp reservoir and transverse $Q_L + W$ amount of heat to the high temp reservoir by using an external work input hence it is a true refrigerator and truth of clausius statement

If consider engine and refrigerator together as a self acting device the net heat interaction with high temp reservoir Q_L and with the low temp reservoir is also Q_L and Q_L amount of heat is transferred from low to high without any work input hence it is false refrigerator and falsity of clausius statement and hence

$-K \Rightarrow -C$

$\therefore$ hence $-K \Rightarrow -C$; $-C \Rightarrow K$

$\therefore \quad \boxed{K \Rightarrow C}$ K is $\boxed{K \nRightarrow C}$

Heat pump

heat pu
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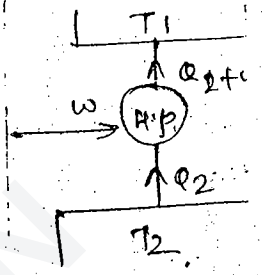
and by doi



(C.O.P

(C

To impro
whether

$C = C.O.P = -$

$\left(\frac{dC}{dT_1}\right)_{T_2=C}$

- 100% heat engine and

$W = Q_1 + Q_4$

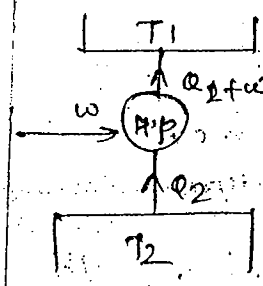
Q.4 in plank

Tl and TH ... temp ... of heat to ... nal work ... th of

refrigerator ... eat ... d with ... amount ... ithout any ... md

Heat pump

heat pump is device which maintain a temp above that of atmospheric by continuously supplying heat to and by doing external work



$T_1 > T_{atm}$

$$(C.O.P)_{HP} = \frac{Q_1}{Q_1 - Q_2} = \frac{Q_1}{W} = \frac{T_1}{T_1 - T_2}$$

Reciprocal of η of engine is $(C.O.P)_{HP}$

$$(C.O.P)_{HP} = \frac{Q_1 - Q_2 + Q_2}{Q_1 - Q_2}$$

$$= \frac{Q_1 - Q_2}{Q_1 - Q_2} + \frac{Q_2}{Q_1 - Q_2} = \frac{1}{\eta_E}$$

$$(C.O.P)_{HP} = 1 + (C.O.P)_R = \frac{1}{\eta_E}$$

$$\boxed{(C.O.P)_R = \frac{1}{\eta_E} - 1 = \frac{1 - \eta_E}{\eta_E}}$$

To improve the c.o.p of H.P what should be done whether we should change Tsource or Tsink

$$c = C.O.P = \frac{T_1}{T_1 - T_2} = T_1 (T_1 - T_2)^{-1}$$

$$\left(\frac{dc}{dT_1}\right)_{T_2 = c} = 1\,(T_1 - T_2)^{-1} + T_1(-1)(T_1 - T_2)^{-2}(1)$$

$$= \frac{1}{T_1 - T_2} - \frac{T_1}{(T_1 - T_2)^2}$$

$$= \frac{T_1 - T_2 - T_1}{T_1 - T_2} = \frac{-T_2}{(T_1 - T_2)^2}$$

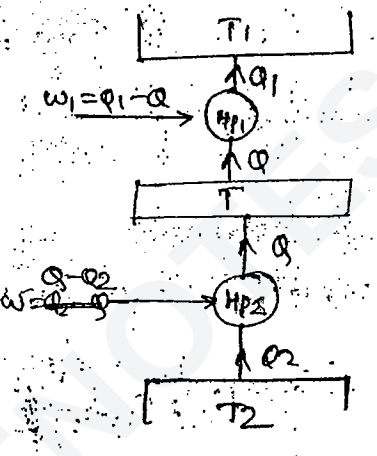
$$\left(\frac{dC}{dT_2}\right) = T_1(-1)(T_1-T_2)^{-2}(-1)$$

$$\left(\frac{dC}{dT_2}\right)_{\eta=C} = \frac{T_1}{(T_1-T_2)^2}$$ (-ve sign indicate only direction)

$$\left(\frac{dC}{dT_2}\right)_{\eta=C} > \left(\frac{dC}{dT_1}\right)_{T_2=C}$$

Hence change in sink temp an greater improvement in C.O.P than changing the source temperature

Coupled heat pump



$$(C.O.P)_I = \frac{T_1}{T_1-T} = \frac{1}{1-\frac{T}{T_1}}$$

$$\frac{T}{T_1} = 1-\frac{1}{C_1}$$

$$(C.O.P)_{II} = \frac{T}{T-T_2} = \frac{1}{1-\frac{T_2}{T}}$$

$$\frac{T_2}{T} = 1-\frac{1}{C_2}$$

$$(C.O.P)_{HP} = \frac{Q_1}{Q_1-Q_2}$$

$$(C.O.P)_{overall} = \frac{T_1}{T_1-T_2} = \frac{1}{1-\frac{T_2}{T_1}}$$

$$\boxed{\frac{T_2}{T_1} = 1-\frac{1}{CO}}$$

Equal work input

$$W_1 = W_2$$

$$Q_1-Q = Q-Q_2$$

$$Q = \frac{Q_1+Q_2}{2} \qquad Q \propto T$$

$$T = \frac{T_1+T_2}{2}$$

For equal work input condition the intermedate temp is arithmatic mean of remaining two temp

$$\frac{Q_1}{T_1} = \frac{Q}{T} = \frac{Q_2}{T_2}$$

Equal C.O.P

$$\frac{T}{T_1} = 1 - \frac{1}{C_1} \quad ; \quad \frac{T_2}{T} = 1 - \frac{1}{C_2}$$

$$C_1 = C_2$$

$$\frac{T}{T_1} = \frac{T_2}{T} \qquad T^2 = T_1 T_2 \qquad \boxed{T = \sqrt{T_1 T_2}}$$

Apply condition

$$\boxed{\frac{Q_1}{T_1} = \frac{Q}{T} = \frac{Q_2}{T_2}}$$

For equal C.O.P the intermediate temp is the Geometric mean of remaining two temp.

$$(C.O.P)_{overall} \qquad \frac{T_2}{T_1} = \frac{T_2}{T} * \frac{T}{T_1}$$

$$\left(1 - \frac{1}{C_0}\right) = \left(1 - \frac{1}{C_1}\right)\left(1 - \frac{1}{C_2}\right)$$

$$\boxed{\frac{1}{C_0} = \frac{1}{C_1} + \frac{1}{C_2} - \frac{1}{C_1 C_2}}$$

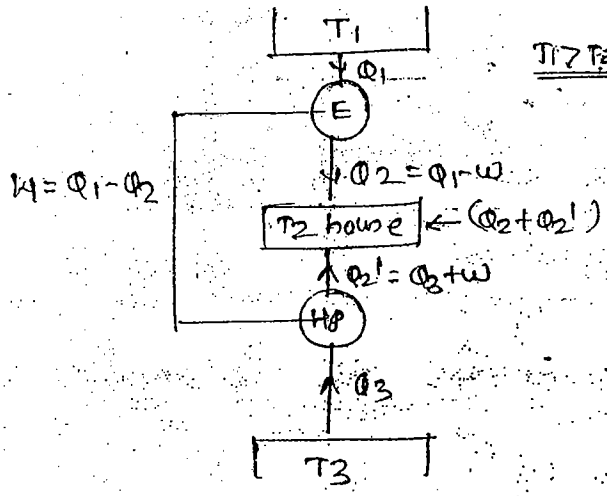
If $C_1 = 2$ $C_2 = 3$ what is $(C.O.P)_{overall}$ of coupled heat pump

$$\frac{1}{C_0} = \frac{1}{2} + \frac{1}{3} - \frac{1}{2 \times 3} = \frac{5}{6} - \frac{1}{6} = 4/6 = 2/3 \qquad = 3/2 = 1.5$$

$C_0 < C_1$

$C_0 < C_2$

Lord Kelvin was the 1st person to suggest that A phenominal large amount of heat can be supplied to a house by using very little energy as input hence this is done by using a engine & heat pump combination. this system are widely used in all cold countries for heating purposes. to save on fuel consumed



T1 > T2 > T3

$$\text{Multiplication factor} = \frac{\text{Heat Supplied to house}}{\text{Heat Supplied to engine}}$$

$$\text{Multiplication factor} = \frac{Q_2 + Q_2'}{Q_1}$$

$$\eta_E = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$

$$\boxed{Q_2 = \frac{T_2}{T_1} - Q_1} \quad \text{---(1)}$$

$$(C.O.P)_{H.P} = \frac{T_2}{T_2 - T_3} = \frac{Q_2'}{W}$$

$$Q_2' = \frac{T_2}{T_2 - T_3} \cdot W$$

$$= \left(\frac{T_2}{T_2 - T_3}\right)(Q_1 - Q_2)$$

$$= \left(\frac{T_2}{T_2 - T_3}\right)\left(Q_1 - \frac{T_2}{T_1} Q_1\right)$$

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

$$Q_2' = \frac{T_2}{T_2 - T_3}$$

$Q_2 + Q_2'$

* Multi

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$T_1 = 200$
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MF =

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$$= \left(\frac{T_2}{T_2-T_3}\right)\left(\frac{T_1-T_2}{T_1}\right) Q_1$$

$$\boxed{Q_2' = \frac{T_2}{T_1}\left(\frac{T_1-T_2}{T_2-T_3}\right) Q_1}$$

$$Q_2 + Q_2' = \frac{T_2}{T_1} Q_1 + \frac{T_2}{T_1}\left(\frac{T_1-T_2}{T_2-T_3}\right) Q_1$$

$$= \frac{T_2}{T_1} \cdot Q_1 \left[1 + \frac{T_1-T_2}{T_2-T_3}\right]$$

$$= \frac{T_2}{T_1} Q_1 \left[\frac{T_1-T_3}{T_2-T_3}\right]$$

* Multiplication factor $MF = \frac{Q_2 + Q_2'}{Q_1} = \frac{T_2}{T_1}\left[\frac{T_1-T_3}{T_2-T_3}\right]$

house
engine

A large amount of heat supplied to house using only little energy as heat input

$T_1 = 200°C$ $T_2 = 20°C$ $T_3 = -10°C$ the multiplication factor is

$$MF = \frac{T_2}{T_1}\left[\frac{T_1-T_3}{T_2-T_3}\right]$$

$$= \frac{20}{200}\left[\frac{200-(-10)}{20-(-10)}\right]$$

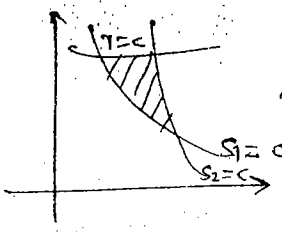
$$= 0.1 \quad \frac{(20+273)}{(200+273)}\left[\frac{(200+273)-(-10+273)}{(20+273)-(-10+273)}\right]$$

$$= 4.33$$

if MF is 4.33 which tells that if 4 KJ of fuel is burned with engine then 4.33 KJ can be supplied to the house. this is the maximum possible and the actual supply is less than this

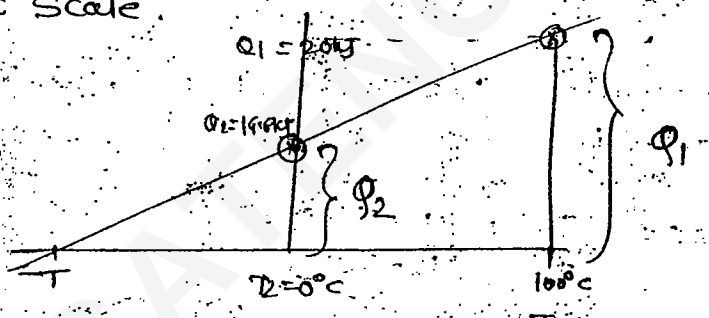
why not

⇒ let asume path intersect



let them we connected by an isothermal line. the area under diagram represent work done and work is done only in heat is transfer only in the isothermal process. and work is produced by exchanging heat with only one thermal reservoir which is a violation of kelvin plank statement hence the assumption made two adiabatic intersect is false

* 20kJ heat is supplied at a temp have 100°C and 14.6kJ heat is rejected at a temp of 0°C what is the absolute 0 temp on the thermodynamic scale.



$$\frac{Q_1}{100+T} = \frac{Q_2}{0+T}$$

$$\frac{20}{100+T} = \frac{14.6}{T}$$

$$\boxed{T = -270.8\,^{\circ}C}$$

if not

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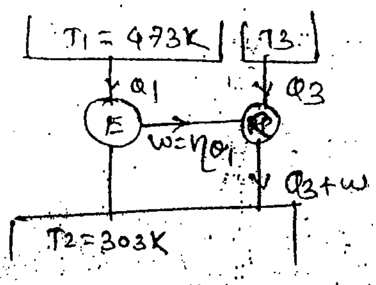
e 100°C
0°C

Q_1

Pg No 14 Qu:3 :



$\frac{Q_1}{Q_3} = ?$

$Work = \eta Q_1$

$= \left(\frac{T_1 - T_2}{T_1}\right) Q_1$

$= \left(\frac{473 - 303}{473}\right) Q_1$

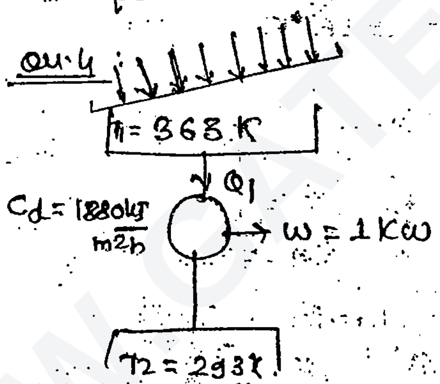
$\boxed{w = 0.359\, Q_1}$

$(C.O.P)_R = \frac{Q_3}{w} = \frac{T_3}{T_2 - T_2}$

$\frac{Q_3}{0.359\, Q_1} = \frac{243}{303 - 243}$

$\boxed{\frac{Q_3}{Q_1} = 1.45}$ or $\boxed{\frac{Q_1}{Q_3} = \frac{1}{1.45} = 0.687}$

Qu:4



Cd = collection density

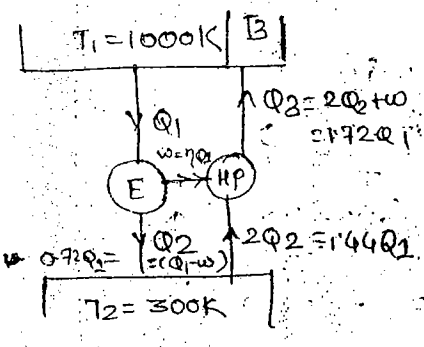
For minimum collector area condition the work output is maximum and maximum work output for carnot efficiency

$\eta_c = \frac{W}{Q_1} = \frac{T_1 - T_2}{T_1}$

$\frac{1\ kW}{Q_1} = \frac{363 - 293}{363}$

$Q_1 = 5.1857\ kW$

$Area = \frac{Q_1}{cd} = \frac{5.185\ kW}{\frac{1880}{3600}\ \frac{kW}{m^2}} = 9.93\ m^2$



$$\eta_E = \frac{T_1 - T_2}{T_1} = \frac{W}{Q_1}$$

$$\frac{1000-300}{1000} = \frac{W}{Q_1}$$

$$W = 0.7 Q_1$$

$W_{actual} = 0.4 \times 0.7 Q_1$

$= 0.28 Q_1$

$$(C.O.P)_{HP} = \frac{Q_3}{W} = \left(\frac{T_3}{T_3 - T_2}\right) 0.5$$

$Q_3 = 1.72 Q_1$

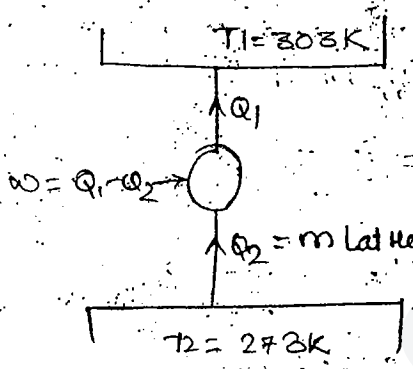
$= 1.72 \times 50$

$= 86$ kW.

$$\frac{1.72 Q_1}{0.28 Q_1} = 0.5 \left[\frac{T_3}{T_3 - 300}\right]$$

$T_3 = 326$ K

Qu.9 :



$$(C.O.P)_R = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$$

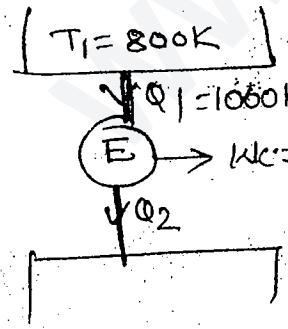
$$= \frac{\text{mass. Lat. ice}}{W} = \frac{T_2}{T_1 - T_2}$$

$$= \frac{1000 \times 335}{W} = \frac{273}{303 - 273}$$

$W = 36,813$ kJ

1 kW/hr = 3600 kJ

Electrical work $= \frac{36,813}{3600} = 10.22$ kW hr



$$W_C = \eta Q_s = \left(\frac{T_1 - T_2}{T_1}\right) Q_s$$

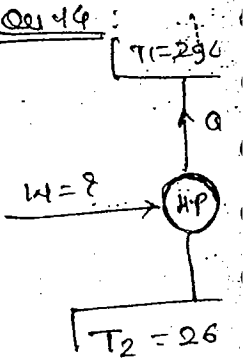
$$= \left(\frac{800-400}{800}\right) 1000$$

$= 500$

$W_{act} > W_{carnot}$ hence claim is not justified

Qu.13 :

Qu.14 :



Monthly

with H.P

with elect

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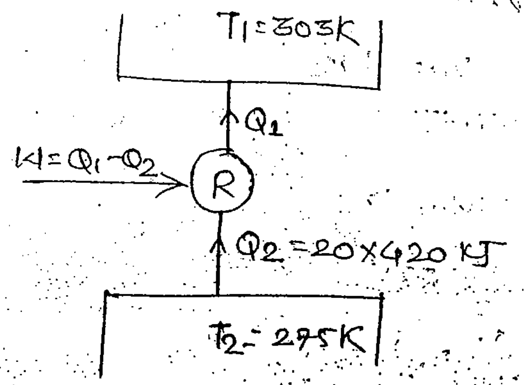
Qu 10 :



$(C.O.P)_{actual} = 0.15\,(C.O.P)_{max}$

$= 0.15 \times \frac{T_2}{T_1 - T_2} = \frac{Q_2}{W}$

$= 0.15 \times \frac{275}{303 - 275} = \frac{20 \times 42}{W}$

$W = 5701$ kJ/day

1 kW hr = 3600 kJ

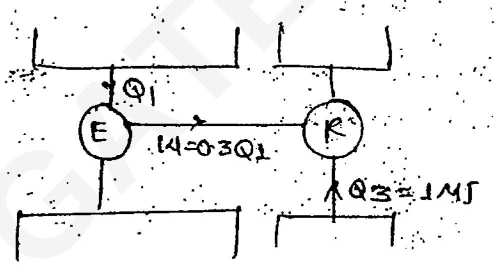
$= \frac{5701}{3600} = 1.58$ kW hr/day

Monthly bill $=$ No. of unit/day $\times$ No. of days $\times$ cost/unit

$= 1.58 \times 30 \times 0.32$

$= \underline{15.168}$ /-

Qu. 13 :

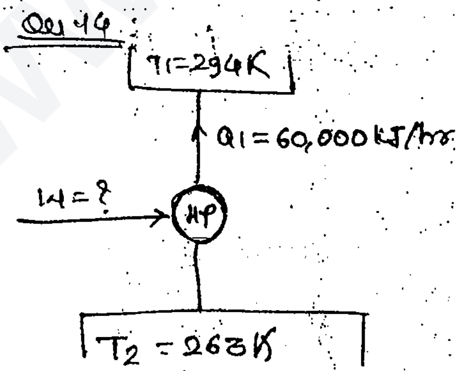


$(C.O.P)_R = 5 = \frac{Q_3}{W}$

$5 = \frac{1MJ}{0.3Q_1}$

$Q_1 = 0.67$ MJ

Qu 14 :



$(C.O.P)_{H.P} = \frac{Q_1}{W} = \frac{T_1}{T_1 - T_2}$

$= \frac{60{,}000}{W} = \frac{294}{294 - 263}$

$W = 6326.53$ kJ/hr

$\frac{W_{HP}}{W_{EH}} = \frac{6326.53}{60{,}000}$

$= \underline{0.1054}$

With H.P initial investment is high but running cost is less with electrical heater, the initial investment is less but running cost is high.

0.5

$\frac{3}{-300}$

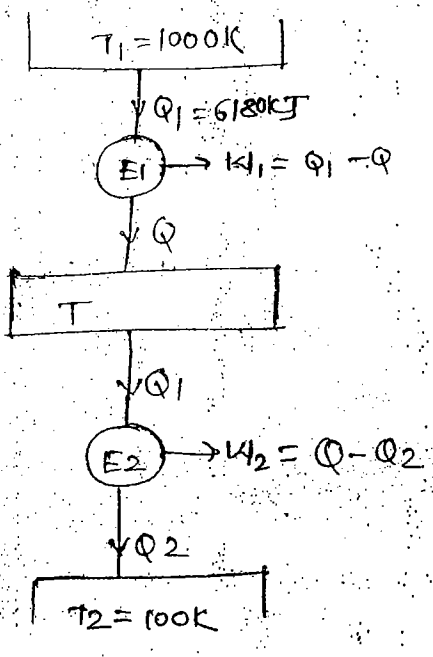
$\frac{T_2}{T_1 - T_2}$

$\frac{273}{33 - 273}$

kW hr

justified

Qu.16 :



Equal works

$W_1 = W_2$

$T = \frac{T_1 + T_2}{2}$

$= \frac{1000 + 100}{2}$

$= 550\ K$

$\frac{Q_1}{T_1} = \frac{Q}{T} = \frac{Q_2}{T_2}$

$\frac{1680}{1000} = \frac{Q}{550} = \frac{Q_2}{100}$

$\boxed{Q = 924}$, $\boxed{Q_2 = 168}$

$\eta_1 = \frac{T_1 - T}{T_1} = \frac{1000 - 550}{1000} = 0.45$

$\eta_2 = \frac{T - T_2}{T_1} = \frac{550 - 100}{550} = 0.818$

equal efficiency

$\eta_1 = \eta_2$

$T = \sqrt{T_1 T_2} = \sqrt{1000 \times 100} = 316.2\ K$

$\eta_1 = \frac{T_1 - T}{T_1} = \frac{W_1}{Q_2}$

$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q}{T}$

$\frac{6180}{1000} = \frac{Q_2}{100} = \frac{Q}{316.2}$

$Q_2 =$

$W_1 = Q_1 - Q$

$W_2 = Q - Q_2$

Qu.18

Qu.20

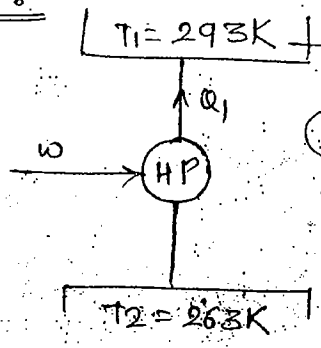
$\eta_E = 0.27$

$(COP)_{HP} = 4$

$W = \eta_E \times Q_1$

$= 0.27 \times Q_1$

Qu.18



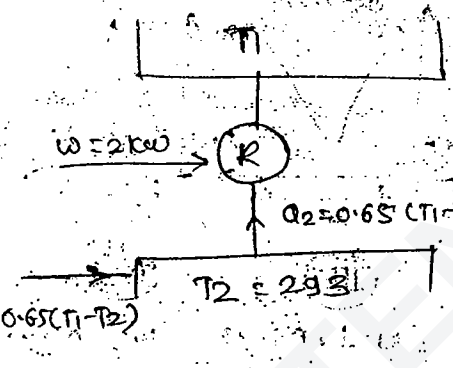
$Q_1 = 0.65(T_1 - T_2) = 0.65(293 - 263) = 19.5$

$(C.O.P)_{H.P} = \frac{T_1}{T_1 - T_2} = \frac{Q_1}{W}$

$= \frac{293}{293 - 263} = \frac{19.5}{W}$

$W = 1.98 \text{ kW} \approx 2 \text{ kW}$

Q2 / 100



$(C.O.P)_R = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$

$\frac{0.65(T_1 - 293)}{2} = \frac{293}{T_1 - 293}$

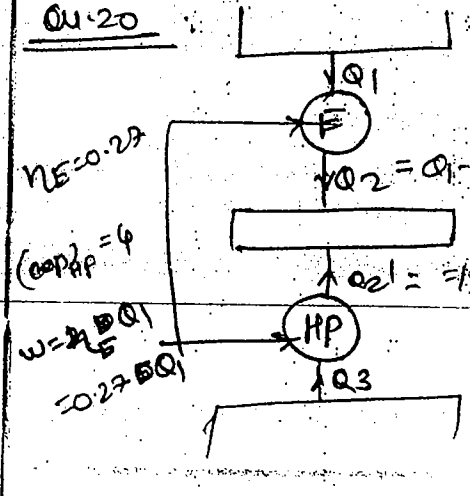
$\frac{0.65T_1 - 190.45}{2} = \frac{293}{T_1 - 293}$

$\frac{0.65T_1}{2} = \frac{293}{T_1 - 293} + 190.45$

$0.65T_1(T_1 - 293) = 293 \times 2 + 190.45$

$T_1 = 323 \text{ K}$

Qu.20



$(C.O.P)_{HP} = \frac{Q_2'}{W}$

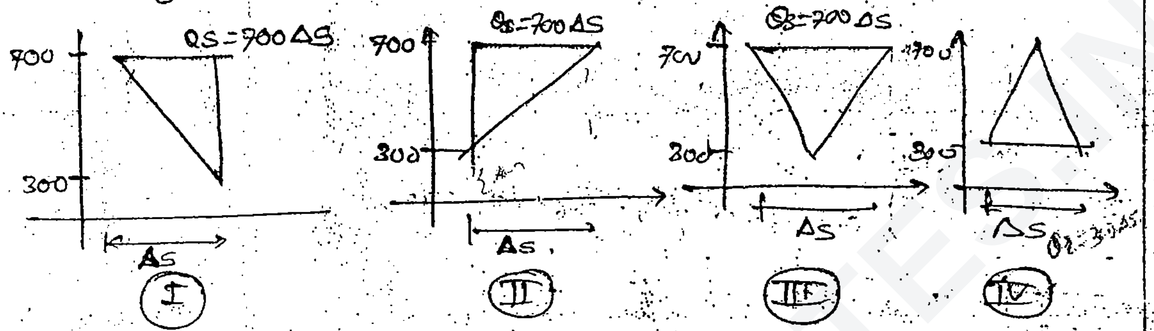
$4 = \frac{Q_2'}{0.27Q_1}$

$Q_2' = 1.08Q_1$

$$Q_2 + Q_2' = 0.73\,Q_1 + 1.08\,Q_1$$
$$= 1.81\,Q$$

$$\frac{Q_2 + Q_2'}{Q_1} = 1.81$$

which engine having the highest $\eta_{thermal}$ among the four



I	II	III	IV
$W = \frac{1}{2} \times \Delta S \times 400$	$W = \frac{1}{2}\Delta S \times 400$	$W = \frac{1}{2} \times \Delta S \times 400$	$W = \frac{1}{2}\Delta S \times 400$
$Q_S = 700\,\Delta S$	$Q_S = 700\,\Delta S$	$Q_S = 700\,\Delta S$	$Q_R = 300\,\Delta S$
$\eta_I = \frac{2}{7}$	$\eta_{II} = \frac{2}{7}$	$\eta_{III} = \frac{2}{7}$	$Q_S = Q_R + W = 500\,\Delta S$
			$\eta = \frac{200}{500} = 0.4\,\%$

$$\eta_{max} = 4^{th}$$

Pg. NO. 212 Qu. 2

$$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$

$$\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$$

$$\frac{Q_2}{40} = \frac{300}{1200}$$

$$Q_2 = 10\,kW$$

Qu. 4 po

η_{carnot}

η_{actu}

Qu 5 η_{car}

Qu 6

$Q_2 +$

$0.6\,Q_1 +$

Qu.3 $Q_s = 36 \times 10^8$ KJ/hr.

$= \frac{36 \times 10^8}{3600 \times 10^3}$ MW

$= 1000$ MW

$Q_R = Q_s - W$

$= 1000 - 400 = 600$ MW

Qu.4 power = 50 KW

$Q_s = \dot{m}_f \times CV$

↓

kg/sec × KJ/kg

$= \frac{3 \times 75000}{3600} =$

$\eta = \frac{50}{\frac{3 \times 75000}{3600}} = 0.8$

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

$= \frac{627 - 27}{(627+273)} = \frac{600}{1000} = 67\%$

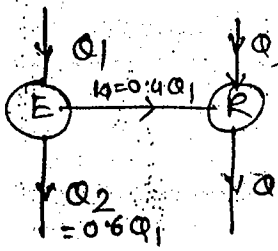
$\eta_{actual} < \eta_{carnot}$ hence engine is not possible

Qu5 $\eta_{carnot} = 0.75$ ..... $(C.O.P)_{ref} = ?$

$(C.O.P)_{ref} = \frac{1 - \eta_E}{\eta_E}$

$= \frac{1 - 0.75}{0.75} = 1/3 = 0.33$

Qu-6



$Q_2 + Q_4 = 3Q_1$

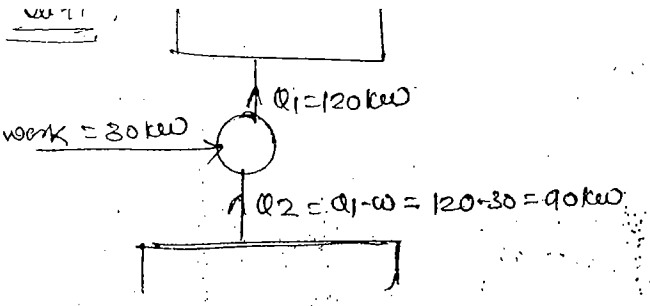
$0.6Q_1 + Q_3 + 0.4Q_1 = 3Q_1$

$Q_3 = 2Q_1$

$(C.O.P)_R = \frac{Q_3}{W}$

$= \frac{2Q_1}{0.4Q_1}$

$= 5$



$$(C.O.P)_R = \frac{Q_2}{W} = \frac{90}{30} = 3$$

Q.17

$$\eta_1 = \frac{W}{Q_1} = \frac{8.2}{\frac{1500}{60}} = 0.328$$

$$\eta_2 = \frac{8.75}{\frac{1600}{60}} = 0.328$$

$$\eta_3 = \frac{9.3}{\frac{1700}{60}} = 0.328$$

$$\eta_4 = \frac{9.85}{\frac{1800}{60}} = 0.328$$

$$\eta = \frac{W}{Q_1}$$

$$0.328 = \frac{W}{\frac{2000}{60}} \quad \therefore \boxed{W = 10.95}$$

Q.20 :-

ENTROPY

CLASSIUS INEQUALITY

In cyclic process heat transfer to the temp is less than or equal to zero.

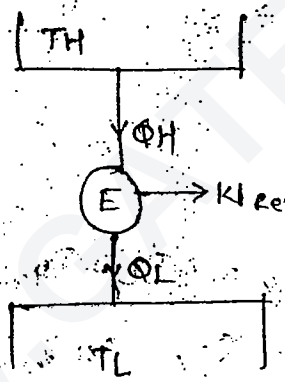
$$\oint \frac{dQ}{T} \leq 0 \quad \ldots (1)$$

$\oint \frac{dQ}{T} = 0$ Reversible cycle

$\oint \frac{dQ}{T} < 0$ irreversible cycle

$\oint \frac{dQ}{T} > 0$ impossible cycle (violate the IInd law)

Reversible engine (no losses) : (carnot cycle)



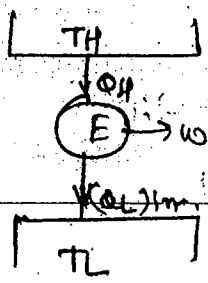
$$\delta Q = Q_H - (Q_L)_{rev} > 0$$

$$\oint \frac{dQ}{T} = \frac{Q_H}{T_H} - \frac{(Q_L)_{rev}}{T_L} = 0$$

For reversible engine $dQ > 0$ and $\oint \frac{dQ}{T} = 0$

clausius inequility is proved for reversible engine.

Irreversible engine



$$\delta Q = Q_H - (Q_L)_{irrev} > 0$$

irreversible engine means ... are losses ...

irreversible work < reversible work

$$(W)_{irr} < (W)_{rev}$$

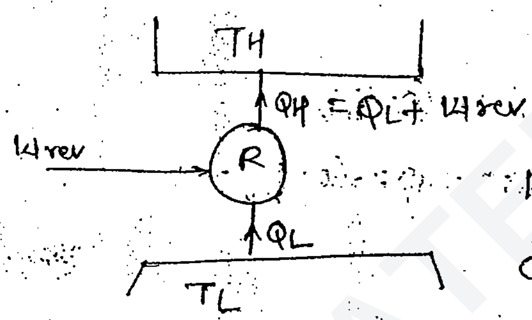
$$(Q_H) - (Q_L)_{irr} < (Q_H) - (Q_L)_{rev}$$

$$\boxed{(Q_L)_{irr} > (Q_L)_{rev}}$$

$$\oint \frac{dQ}{T} = \frac{Q_H}{T_H} - \frac{(Q_L)_{irr}}{T_L} < 0$$

Clausius Inequality is proved for a reversible and irreversible engine

Refrigerator

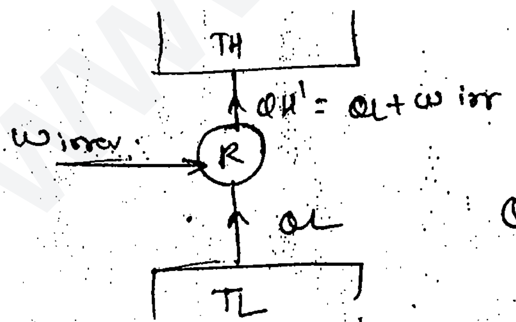


$$W_{rev} = Q_L - Q_{H\,rev}$$

$$\delta Q = Q_L - (Q_H)_{rev} < 0$$

$$\oint \frac{dQ}{T} = \frac{-(Q_H)_{rev}}{T_H} + \frac{Q_L}{T_L} = 0$$

irreversible refrigerator



$$\delta Q = Q_L - Q_H' < 0$$

$$W_{irr} > W_{rev}$$

$$Q_L + Q_H' > Q_L + Q_H$$

$$Q_H' > Q_H$$

$$\oint \frac{dQ}{T} = -\frac{Q_H'}{T_H} - \frac{Q_L}{T_L} < 0$$

$\oint \frac{dQ}{T}$ is a ...

for a irre...

entropy c...

$(ds)_{iso}$

$(ds)_{isc}$

$dQ = \ldots$

$h = u \ldots$

$\frac{dh}{d} = \ldots$

$dh = \ldots$

$dQ = \ldots$

$Tds = \ldots$

$ds = \ldots$

$=$

$\int_1^2 ds = \ldots$

$(S_2 - S_1) \ldots$

for irreversible Refrigerator $\delta Q < 0$, and $\oint \frac{dQ}{T}$ is also < 0 hence clausius inequality is proved for a irreversible refrigerator.

entropy change $\Delta S \geq \frac{dQ}{T}$

$$(S_2 - S_1) \geq \frac{dQ}{T}$$

$(ds)_{isolated} \geq 0$ (irreversible isolated system)

$(ds)_{isolated} = 0$ is called reversible isolated system

$dQ = du + dw = du + p\,dv$

$h = u + pv$

$\frac{dh}{d} = du + p\,dv + v\,dp$

$dh = dQ + v\,dp$

$dQ = dh - v\,dp$

$T\,ds = du + p\,dv$

$= c_v\,dT + p\,dv$

$ds = \frac{c_v\,dT}{T} + \frac{p}{T}\,dv$

$= c_v \frac{dT}{T} + \frac{R}{V}\,dv$

$$\int_1^2 ds = \int_1^2 c_v \frac{dT}{T} + \int_1^2 \frac{R}{V}\,dv$$

$$\boxed{(S_2 - S_1) = c_v \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1}}$$

change in entropy when Tem & volm change

$= c_v \ln \frac{T_2}{T_1} + (c_p - c_v) \ln \frac{V_2}{V_1}$

$= c_v \ln \frac{T_2 V_1}{T_1 V_2} + c_p \ln \frac{V_2}{V_1}$

$$(S_2 - S_1) = C_v \ln \frac{P_2}{P_1} + C_p \ln \frac{V_2}{V_1}$$

$$\boxed{\frac{S_2 - S_1}{C_v} = \ln \frac{P_2}{P_1} + \gamma \ln \frac{V_2}{V_1}}$$

$$dQ = dh - v\,dp$$

$$T\,ds = c_p\,dT - v\,dp$$

$$ds = \frac{c_p\,dT}{T} - \frac{v}{T}\,dp$$

$$= \int_1^2 c_p \frac{dT}{T} - \int_1^2 \frac{R}{p}\,dp$$

$$\boxed{S_2 - S_1 = c_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}}$$

$$\frac{S_2 - S_1}{c_p} = \ln \frac{T_2}{T_1} - \frac{R}{c_p} \ln \frac{P_2}{P_1}$$

$$= \ln \frac{T_2}{T_1} - \left(1 - \frac{1}{\gamma}\right) \ln \frac{P_2}{P_1}$$

$$= \ln \frac{T_2}{T_1} - \left(\frac{\gamma - 1}{\gamma}\right) \ln \frac{P_2}{P_1}$$

$$c_p = \frac{\gamma R}{\gamma - 1}$$

$$\boxed{\frac{R}{c_p} = \frac{\gamma - 1}{\gamma}}$$

let us all this to specific process.

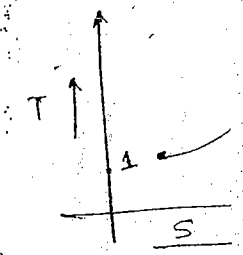
$$T\,ds = c_v\,dT + p\,dv$$

$\underline{\underline{v = c}}$ (isochoric or isometric)

$$dv = 0$$

$$T\,ds = c_v\,dT$$

$$\left(\frac{dq}{ds}\right)_v$$



$$\int_1^2 ds =$$

* T ds

P=

Tds =

$\frac{dT}{ds} =$

$\left(\frac{dT}{ds}\right)_{p=c}$ =

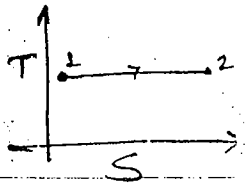
$c_p > c_v$

$\left(\frac{dT}{ds}\right)_{p=c}$

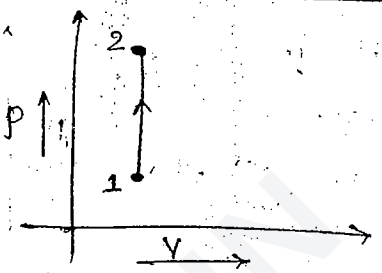
* T =

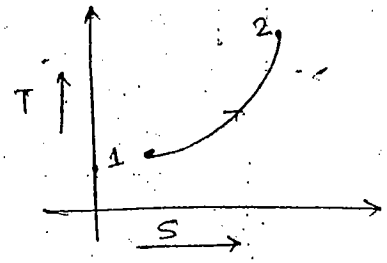
dQ =

∴ dQ



$$\left(\frac{dT}{ds}\right)_{V=C} = \frac{T}{C_V}$$





$$\int_1^2 ds = \int_1^2 C_V \frac{dT}{T}$$

$$\boxed{\therefore (S_2 - S_1) = C_V \ln \frac{T_2}{T_1}}$$

* $T\,ds = C_p\,dT - V\,dp$

$p = C \quad \therefore \boxed{dp = 0}$ constant pressure or isobar

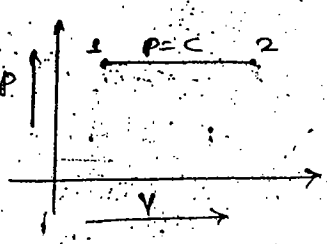
$$T\,ds = C_p\,dT$$

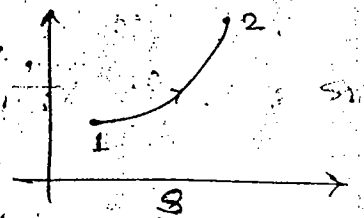
$$\frac{dT}{ds} = \frac{T}{C_p}$$

$$\left(\frac{dT}{ds}\right)_{p=C} = \frac{T}{C_p}$$

$C_p > C_V$

$$\left(\frac{dT}{ds}\right)_{p=C} < \left(\frac{dT}{ds}\right)_{V=C}$$

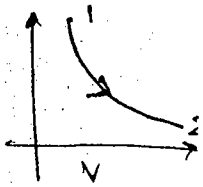




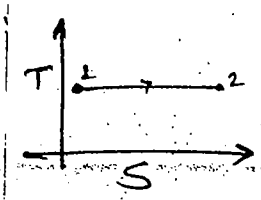
* $T = C$ Isothermal / constant Temp.

$$dQ = dW = p_1 V_1 \ln \frac{V_2}{V_1} = p_1 V_1 \ln \frac{p_1}{p_2}$$

$$= mRT_1 \ln \frac{V_2}{V_1} = mRT_1 \ln \frac{p_1}{p_2}$$



$$\therefore ds = \frac{dQ}{T} = \frac{mRT_1 \ln \frac{V_2}{V_1}}{T_1} = \frac{mRT_2 \ln \frac{p_1}{p_2}}{T_2}$$

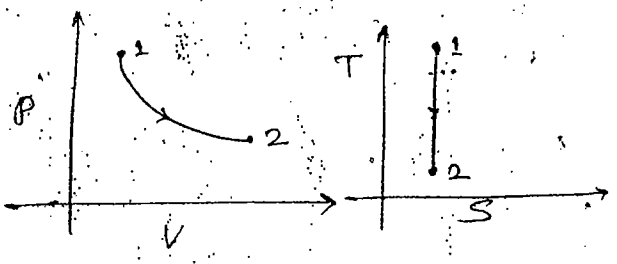


$$= mR \ln \frac{V_2}{V_1} = mR \ln \frac{p_1}{p_2}$$

Adiabatic process

$$dQ = 0$$

$$ds = \frac{dQ}{T} = 0$$



polytropic process

$$PV^n = C$$

$$TV^{n-1} = C$$

$$TP^{\frac{1-n}{n}} = C$$

$$= \frac{n-1}{n} \times \text{workdone}$$

$$S_2 - S_1 = C_V \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1}$$

$$T_1 V_1^{n-1} = T_2 V_2^{n-1}$$

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

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

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

$$S_2 - S_1 = C_V \ln \frac{T_2}{T_1} + R \ln \left(\frac{T_2}{T_1}\right)^{\frac{1}{1-n}}$$

$$= \frac{R}{\gamma - 1} \ln \left(\frac{T_2}{T_1}\right) + \frac{R}{1-n} \ln \left(\frac{T_2}{T_1}\right)$$

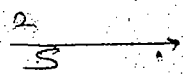
$$= R \ln \frac{T_2}{T_1} \left[\frac{1}{\gamma - 1} + \frac{1}{1-n}\right]$$

$$= R \ln \frac{T_2}{T_1} \left[\frac{1-n+\gamma-1}{(\gamma-1)(1-n)}\right]$$

$$\boxed{S_2 - S_1 = \frac{\gamma - n}{(\gamma-1)(1-n)} R \ln \frac{T_2}{T_1}}$$

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

$$S_2 - S_1 = \frac{(\gamma - n)}{(\gamma - 1)(1-n)} R \ln \left(\frac{V_2}{V_1}\right)^{1-n}$$



$$\boxed{S_2 - S_1 = R\left(\frac{\gamma - n}{\gamma - 1}\right) \ln \frac{V_2}{V_1}}$$

$$\because \quad P_1 V_1^n = P_2 V_2^n$$

$$\left(\frac{V_2}{V_1}\right)^n = \frac{P_1}{P_2}$$

$$\boxed{\frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{1/n} = \left(\frac{P_2}{P_1}\right)^{-1/n}}$$

$$S_2 - S_1 = R \frac{(\gamma - n)}{(\gamma - 1)} \ln \left(\frac{P_2}{P_1}\right)^{-1/n}$$

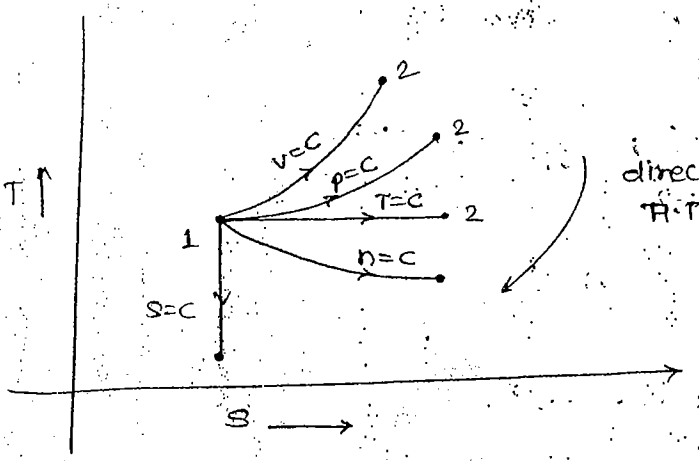
$$= -\frac{R}{n} \frac{(\gamma - n)}{(\gamma - 1)} \ln \frac{P_2}{P_1}$$

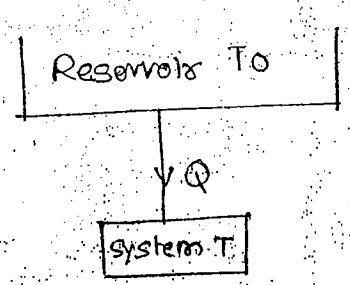
$$\boxed{S_2 - S_1 = \frac{R}{n}\left(\frac{n - \gamma}{\gamma - 1}\right) \ln \frac{P_2}{P_1}}$$

on a P-V diagram for a process the area under the curves gives workdone and for thermodynamic cycle the area enclosed gives the workdone.

on T-S diagram for a process the area under the curve gives the heat supplied

for a T-S diagram for thermodynamic cycle the area enclosed gives the workdone





$(ds)_{system} = + \frac{Q}{T}$

$(ds)_{Reservoir} = - \frac{Q}{To}$ $\quad To > T$

$(ds)_{universe} = Q\left[\frac{1}{T} - \frac{1}{To}\right]$

$= Q\left[\frac{To - T}{T\,To}\right] \geq 0$

$(ds)_{universe} \geq 0$ irreversible in nature

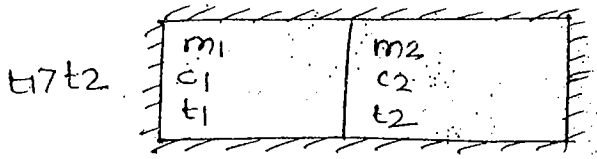
$(ds)_{universe} = 0$ reversible in nature

$(ds)_{universe} < 0$ violate the II^nd law of thermodynam

For a process the entropy change can be +ve' or 0 zero.

if System and Surrounding are considered the entropy change is only +ve' or zero

Adiabatic mixing of two fluids



Consider insulated vessel divided into two part on one side their is mass m_1, specific heat c_1 and temp T_1 on other side it is mass m_2, specific heat c_2 and temp T_2 further $T_1 \neq T_2$. Let the membrane, be ruptured two fluid mixed to get final temp T_f. using IST law

heat lost = heat gained

$$m_1 c_1 (t_1 - t_f) = m_2 c_2 (t_f - t_2)$$

$$t_f = \frac{m_1 c_1 t_1 + m_2 c_2 t_2}{m_1 c_1 + m_2 c_2}$$

$$m_1 = m_2 = m$$
$$c_1 = c_2 = c$$
$$t_f = \frac{t_1 + t_2}{2}$$

IInd law apply

$$ds_1 = m_1 c_1 \ln \frac{t_f}{t_1}$$
$$ds_2 = m_2 c_2 \ln \frac{t_f}{t_2}$$

$$(ds)_{system} = ds_1 + ds_2 = m_1 c_1 \ln \frac{t_f}{t_1} + m_2 c_2 \ln \frac{t_f}{t_2}$$

$$(ds)_{surrounding} = 0$$

$$(ds)_{universe} = (ds)_{system}$$

$$(ds)_{universe} = m_1 c_1 \ln \frac{t_f}{t_1} + m_2 c_2 \ln \frac{t_f}{t_2}$$

$m_1 = m_2 = m$

$c_1 = c_2 = c$

$$= mc \ln \frac{t_f^2}{t_1 t_2}$$

$$= 2mc \ln \frac{t_f}{\sqrt{t_1 t_2}} = 2mc \ln \frac{t_1 + t_2}{2\sqrt{t_1 t_2}}$$

$$\left(\frac{t_1 + t_2}{2}\right) > \sqrt{t_1 t_2}$$

Arithmatic mean > Geometric mean

Answer > 0 hence it is irreversible process

For polytropic process heat rejected given by formula

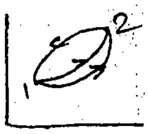
$$Q_R = C_v \frac{\gamma - n}{1 - n} dT \qquad C_v \frac{\gamma - n}{1 - n} = C_n dT$$

$$Q_R = C_n dT$$

C_n = polytropic specific heat

Expansion		Compression process	
$1 < n < \gamma$	$n > \gamma$	$1 < n < \gamma$	$n > \gamma$
C_n (-ve) dT is (-ve) Q is +ve	C_n (+ve) dT (-ve) Q_R is -ve	C_n is -ve dT (+ve) Q_R (-ve)	C_n is (+ve) dT (+ve) Q_R (+ve)

In expansion process or in a compression process heat transfer can be +ve or -ve for a polytropic process depending on the value of 'n'



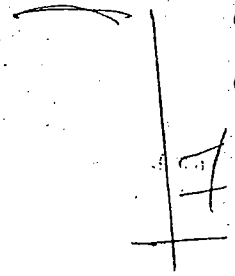
Entropy is point function It depend only on end state and that it is independent of path followed and it is an exact differential

sum to some the
the entrop

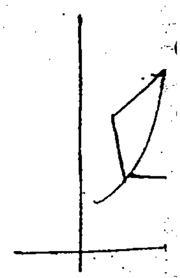
Entropy
and beco
equilibri

Separated
parameter
which ma
when $\frac{ds}{dx}$
which is
when the
entropy co

All adiab
isentropic
reversible



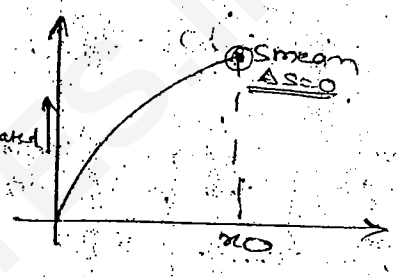
expansion



Entropy

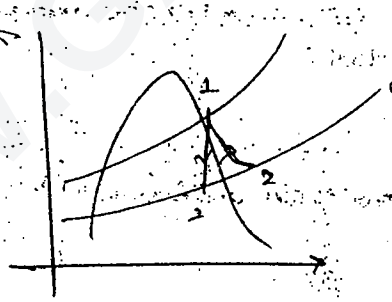
Sum total
Some ~~throttle~~ energy in universe remain constant
the entropy of universe tends to maximise itself.

Entropy of an isolated system always increases and becomes a maximum at the state of equilibrium



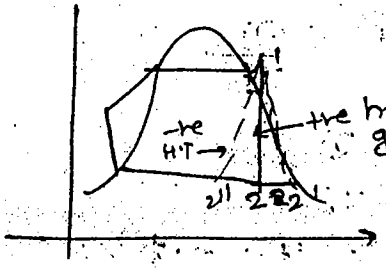
Isolated system with parameter x, there is x0 which maximise the entropy when $\frac{ds}{dx} = 0$ which is called as the state of equilibrium when the system is at the peak of entropy hill entropy considerable change in entropy would be zero.

All adiabatic processes are not isentropic, all isentropic process are not adiabatic. only reversible adiabatic process is called as isentropic



dQ=0 but ds≠0

expansion of steam in steam turbine



dQ≠0
& ds=0

expn is turbine is isentropic not adiabatic.

Entropy of a system

① By heat interaction in which there is entropy of transfer.

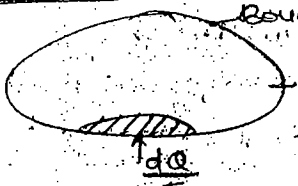
② By internal irreversibilities or dissipate the effect in which work is dissipate into increase in internal energy,

$$ds \geq \frac{dQ}{T} \quad \therefore (S_2 - S_1) \geq \int \frac{dQ}{T}$$

$$(S_2 - S_1) - \int \frac{dQ}{T} = S_{gen} = S_{production}$$

↑ entropy change ; ↑ entropy transfer ; = entropy of generation

closed system :



First law :

$$dQ - dW = dU$$

$$(S_2 - S_1) \geq \int_1^2 \frac{dQ}{T}$$

$$S_2 - S_1 = \int \frac{dQ}{T} = S_{gen} = S_{production}$$

Any thermodynamic process is accompanied by S_{gen} or S_{prod}. if entropy of generation is zero. it is called a reversible process.

$S_{gen} > 0$ is called an irreversible process.

S_{gen} quantifies intrinsic irreversibilities

$(S_{gen})_A > (S_{gen})_B$ then process A is said to be more irreversible than B.

$$S_2 - S_1 = S_{gen} + \sum \frac{Q_j}{T_j}$$

$$\frac{ds}{dt} = \dot{S}_{gen} + \sum \frac{\dot{Q}_j}{T_j}$$

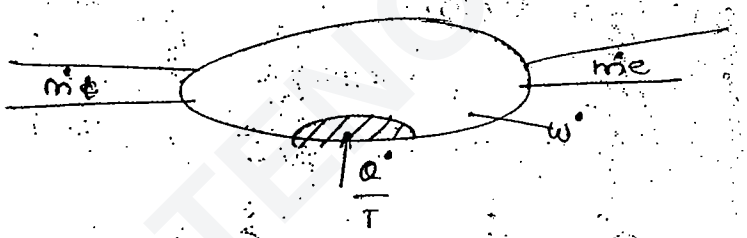
Heat transfer to a system increases the entropy and heat transfer from a system decreases the entropy

100% conversion of work to heat is possible where as Low conversion of heat to work is not possible with work transfer there is no entropy change only wit heat transfer entropy change is associated.

entropy change as a result of reversible heat transfer is called entropy of flow and does not involve any entropy of generation where as process always occurs in a direction of increase in entropy.

The principle of conservation of entropy is not valid

Entropy of Generation in a open system



$$\sum_i \dot{m}_i = \sum_e \dot{m}_e = \frac{\partial M}{\partial t}$$

$$\sum_i \dot{m}_i \left(h + \frac{V^2}{2} + gz\right) - \sum_e \dot{m}_e \left(h + \frac{V^2}{2} + gz\right) + \dot{Q} - \dot{W} = \frac{\partial E}{\partial t} \quad \text{— I st law}$$

$$\sum_i \dot{m}_i s_i - \sum_e \dot{m}_e s_e + \frac{\dot{Q}}{T} \leq \frac{\partial S}{\partial t} \quad \text{— II nd law.}$$

$$\dot{S}_{gen} = S_{production} = \frac{\partial S}{\partial t} - \sum_i \dot{m}_i s_i + \sum_e \dot{m}_e s_e - \frac{\dot{Q}}{T}$$

* $S_{gen} = 0$ is called a reversible process

* $S_{gen} > 0$ is called a irreversible process.

For steady state condition

$$\sum_i \dot{m}_i = \sum_e \dot{m}_e$$

$$\frac{\partial E}{\partial t} = 0 = \dot{Q} - \dot{W} + \sum_i \dot{m}\left(h + \frac{v^2}{2} + gz\right) - \sum_e \dot{m}\left(h + \frac{v^2}{2} + gz\right)$$

$$\frac{\partial S}{\partial t} - \sum_i \dot{m}_i s_i + \sum_e \dot{m}_e s_e - \frac{\dot{Q}}{T} = S_{gen}$$

for steady state condition

$$\dot{m}_i = \dot{m}_e = \dot{m}$$

$$\frac{\partial S}{\partial t} = 0$$

$$\dot{m}(S_e - S_i) - \frac{\dot{Q}}{T} = \dot{S}_{gen}$$

$$\dot{m}(S_e - S_i) = \frac{\dot{Q}}{T} + \dot{S}_{gen}$$

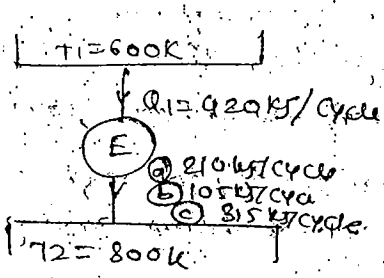
$$\boxed{(S_e - S_i) = \frac{\dot{Q}}{\dot{m}T} + \frac{\dot{S}_{gen}}{\dot{m}}}$$

what is

Orderly energy : It is can be readily converted into disorderly energy but disorderly energy can be converted into orderly energy there is natural limitation which is given by IInd law of thermodynamics.

entropy is degree of randomness, degree of disorder

Pg-140 20 Qu-No 12



cycle (a)

$$\oint \frac{dQ}{T} = \frac{Q_1}{T_1} - \frac{Q_2}{T_2}$$

$$= \frac{420}{600} - \frac{210}{300} = 0$$ Reversible

cycle (b)

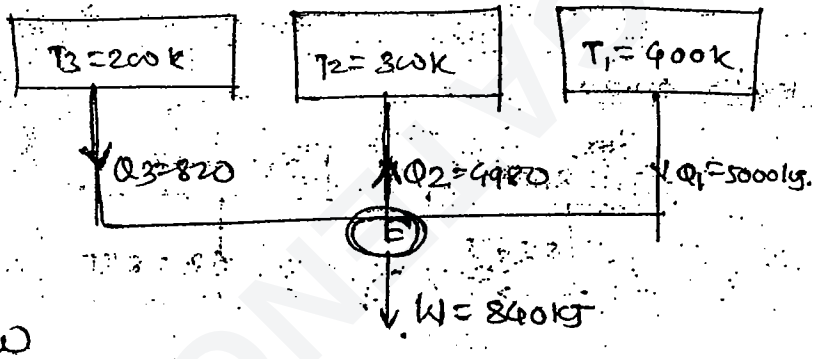
$$\oint \frac{dQ}{T} = \frac{Q_1}{T_1} - \frac{Q_2}{T_2} = \frac{420}{600} - \frac{105}{300} = 0.35$$

Impossible

Cycle (c):

$$\oint \frac{dQ}{T} = \frac{Q_1}{T_1} - \frac{Q_3}{T_3} = \frac{420}{600} - \frac{315}{300} = -0.35$$ irreversible

Qu 1.6 Pg No 20



First law:

$$\Sigma Q = \Sigma W$$

$$Q_1 + Q_2 + Q_3 = W$$

$$5000 + Q_2 + Q_3 = 840$$

$$Q_2 + Q_3 = -4160 \text{ kJ}$$

condition is reversible engine

$$\oint \frac{dQ}{T} = 0$$

$$\frac{Q_1}{T_1} + \frac{Q_2}{T_2} + \frac{Q_3}{T_3} = 0$$

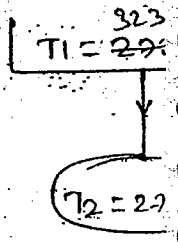
$$\therefore \frac{5000}{400} + \frac{Q_2}{300} + \frac{Q_3}{200} = 0$$

$$2Q_2 + 3Q_3 = -7500$$

$$\boxed{Q_2 = -4980 \text{ kJ}} \quad \boxed{Q_3 = 820 \text{ kJ}}$$

Reg

System



$(ds)_1 = mc_p$ 1st stage

$(ds)_2 =$ IInd stage

(ds) unr

Entropy is randomness or degree of disorder, higher the degree of disorder higher is the entropy
disorder due to heat flow only result in entropy

Boltzmann try to define disorder in terms of thermodynamic probability and given the law

$$S = k \ln W$$

k = boltzmann constant
W = thermodynamic probability of disorder

if $W = 1$, $S = 0$ called as greatest order

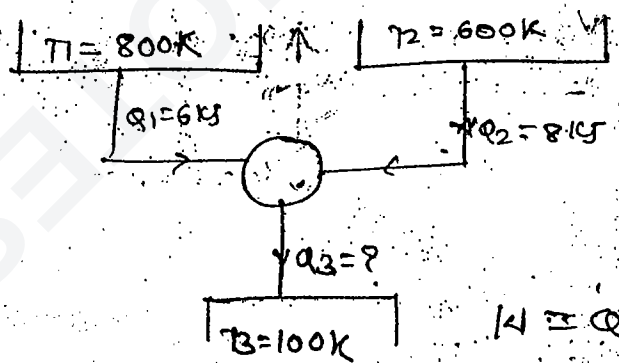
Third law of thermodynamics

Entropy of pure crystalline substance at absolute zero temperature is zero.

Nernst-simons statement of III rd Law

$$\lim_{T \to 0} \Delta S = 0$$

Pg-13 Qu.20.



$$\oint \frac{dQ}{T} = 0$$

$$\frac{Q1}{T1} + \frac{Q2}{T2} - \frac{Q3}{T3} = 0$$

$$\frac{6}{800} + \frac{8}{600} - \frac{Q3}{100} = 0$$

$$\boxed{Q3 = 2.083 \text{ kJ}}$$

$$W = Q1 + Q2 - Q3$$

$$= \underline{11.917}$$

$$\eta_{th} = \frac{W}{Q_S}$$

$$= \frac{11.917}{6+8} \times 100$$

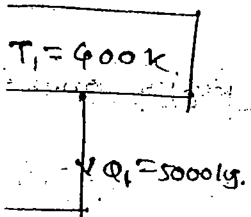
$$= 85\%$$

/cycle

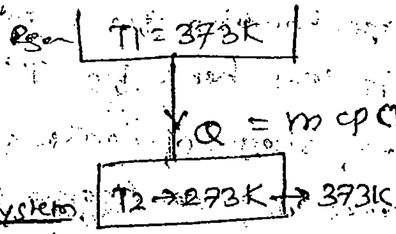
cle a cycle

possible

irreversible



Ques 8



$$(\Delta S)_{reservoir} = \frac{-mc_p(T_1-T_2)}{T_1}$$

$$=$$

$$(\Delta S)_{system} = mc_p \ln\frac{T_1}{T_2}$$

$$(\Delta S)_{universe} = (\Delta S)_{reser.} + (\Delta S)_{system}$$

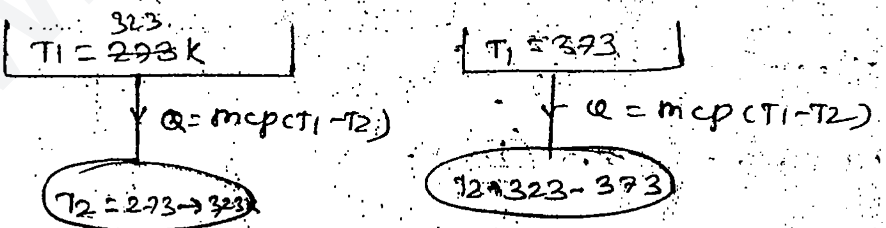
$$= mc_p\left[\ln\frac{T_1}{T_2} - \left(\frac{T_1-T_2}{T_1}\right)\right]$$

$$= 1\times 4.187\left[\ln\left(\frac{373}{273}\right) - \left(\frac{373-273}{373}\right)\right]$$

$$= 1\times 4.187\,[\ln(1.36) - 0.2680]$$

$$= 4.187\,[0.044]$$

$$= \underline{0.18467\ kJ/K}$$



$$(ds_1)_{1st\ stage} = mc_p\left[\ln\frac{T_1}{T_2} - \left(\frac{T_1-T_2}{T_1}\right)\right] = 1\times 4.187\left[\ln\frac{323}{273} - \frac{(323-273)}{323}\right] = 0.0560\ kJ$$

$$(ds_2)_{II^{nd}\ stage} = mc_p\left[\ln\frac{T_1}{T_2} - \left(\frac{T_1-T_2}{T_1}\right)\right]$$

$$= 4.187\left[\ln\frac{373}{323} - \left(\frac{373-323}{373}\right)\right]$$

$$= \underline{0.04135\ kJ/K}$$

$$(ds)_{universe} = (ds)_I + (ds)_{II} = 0.0560 + 0.04135 = 0.097$$

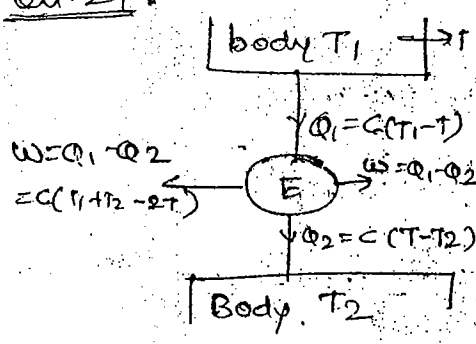
$\frac{3}{00}$ =0

−7500

3 &

when compared to single stage heating (ΔS) universe is less hence for IInd case irreversibility is less: so no of stages of heating goes are increasing the (ΔS)universe goes on decreasing. by increasing the no of stage of heating infinitely water can be heated without any change in Δ entropy of universe

Qu·21:



For a body if heat is withdrawn temp decreases and heat is supplied temp increases, to a reservoir heat is supplied temp does not change or heat is withdrawn temp does not change

heat capacity = mass x specific heat.

Max work is possible engine is reversible

For the condition of reversibility entropy change of universe must be zero

$$(\Delta S)_{I^{st} body} = C \ln\left(\frac{T}{T_1}\right) =$$

$$(\Delta S)_{II^{nd} body} = C \ln\left(\frac{T}{T_2}\right) =$$

$$(ds)_{universe} = (\Delta S)_I + (\Delta S)_{II} = C \ln \frac{T^2}{T_1 T_2}$$

$$C \ln \frac{T^2}{T_1 T_2} = 0$$

$$\ln \frac{T^2}{T_1 T_2} = 0$$

$$\ln \frac{T^2}{T_1 T_2} = \ln 1$$

$$T^2 = T_1 T_2$$

$$T = \sqrt{T_1 T_2}$$

$$\frac{T^2}{T_1 T_2} = 1$$

Qu·20:

$W = Q_1 - Q_2$

Work = Q

$(\Delta S)_{I\ body}$

$(\Delta S)_{II\ bod}$

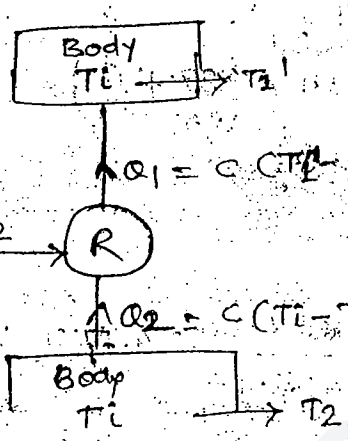
$(\Delta S)_{universe}$

For min
has to re
must be

$$W_{max} = C\left(T_1 + T_2 - 2\sqrt{T_1 T_2}\right)$$

$$= C\left[\sqrt{T_1} - \sqrt{T_2}\right]^2$$

Ans 20:



$$Work = Q_1 - Q_2 = C\left[T_1' - T_i\right] - C\left[T_i - T_2\right]$$

$$= C\left[T_1' + T_2 - 2T_i\right]$$

$$(\Delta S)_{I\ body} = C \ln \frac{T_1'}{T_i}$$

$$(\Delta S)_{II\ body} = C \ln \frac{T_2}{T_i}$$

$$(\Delta S)_{universe} = (\Delta S)_I + (\Delta S)_{II\ body}$$

$$= C \ln \frac{T_1' T_2}{T_i^2}$$

For min work done condition the refrigerator has to reversible for condition reversibility $(\Delta S)_{universe}$ must be zero

$$\ln \frac{T_1' T_2}{T_i^2} = 0 = \ln 1$$

$$\frac{T_1' T_2}{T_i^2} = 1$$

$$W_{min} = C\left[\frac{T_i^2}{T_2} + T_2 - 2T_i\right]$$

$$T_1' = \frac{T_i^2}{T_2}$$

Qu. 13:

0.7 MPa

water 0°C T_1

↓

water 164.97°C T_2

↓

steam 164.97°C.

$$ds_1 = m c_p \ln \frac{T_2}{T_1}$$

$$= 1 \times 4.187 \ln \left(\frac{437.97}{273}\right)$$

$$= 1.979 \text{ kJ/kg K}$$

$$ds_2 = \frac{mL}{T}$$

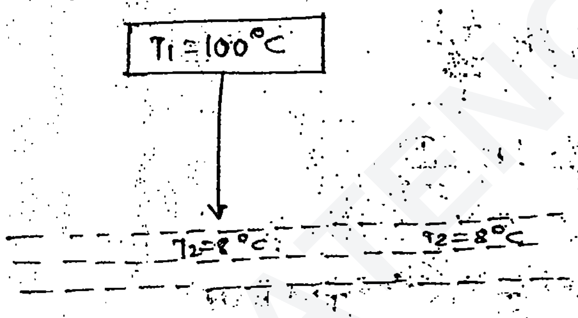
$$= \frac{1 \times 2066.3}{273 + 164.97} = 4.717 \text{ kJ/K}$$

$$\therefore \Delta S = ds_1 + ds_2 = 1.979 + 4.717 = \underline{6.69} \text{ kJ/K.}$$

Qu. 14

m = 600 gm

$c_p = 150$ J/K



$$(ds)_{river} = \frac{dQ}{T_2} = \frac{C(T_1 - T_2)}{T_2} = \frac{150(100-8)}{281} = \underline{49.11} \text{ J/K.}$$

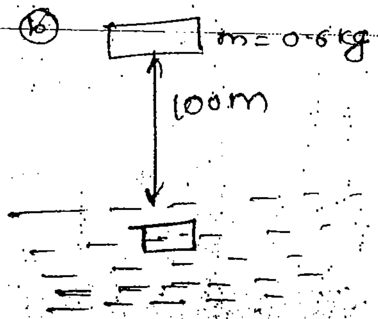
$$(ds)_{block} = \int_{T_1}^{T_2} \frac{dQ}{T} = c \ln \frac{T_2}{T_1} = 150 \ln \frac{273+8}{273+100} = \underline{-42.48} \text{ J/K}$$

$$(ds)_{universe} = (ds)_{river} + (ds)_{block}$$

$$= 49.11 - 42.48$$

$$= \underline{\underline{6.63}} \text{ J/K}$$

(b)



$(ds)_{block} = 0$

$(ds)_{river} = \frac{mgh}{t}$

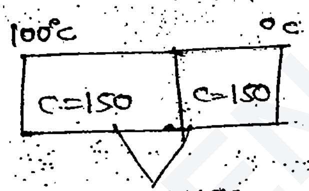
$= \frac{0.6 \times 9.81 \times 100}{281}$

$= \underline{2.094}$ J/K.

$(\Delta S)_{universe} = (ds)_{block} + (ds)_{river}$

$= \underline{2.094 \text{ J/K}}$

(c)



$T_f = \frac{T_1+T_2}{2} = \frac{100+0}{2} = 50°c$

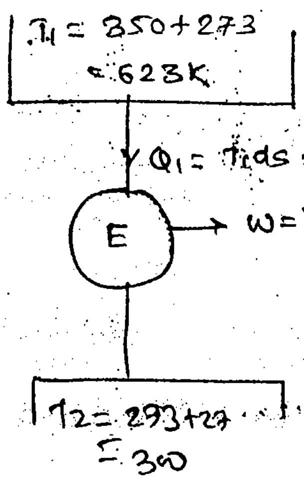
$(\Delta S)_I = c \ln \frac{T_f}{T_1} = 150 \times \ln\left(\frac{323}{373}\right) = -21.588$ kJ/K

$(\Delta S)_{II} = c \ln \frac{T_f}{T_2} = 150 \ln\left(\frac{323}{273}\right) = 25.22$ kJ/K.

$(\Delta S)_{universe} = (\Delta S)_I + (\Delta S)_{II}$

$= -21.588 + 25.22 = \underline{3.632}$ J/K

(12)



$Q_1 = T_1 ds = 623 \times 1.44 = 897.12$

$w = \eta Q_1$

$= \frac{T_1 - T_2}{T_1} \times Q_1$

$= \frac{T_1 - T_2}{T_1} \times T_1 ds$

$= (T_1 - T_2) ds.$

$= (623 - 300) 1.44$

$= \underline{465.12}$ kJ/kg

= kJ/K

17 = 6.69 kJ/K

= 49.11 J/K

+8 / +100 = -42.48 J/K

power (kW) = $\dot{m}_s$ (kg/sec) w (kJ/kg)

$20 = \dot{m}_s \times 465.1$

$\dot{m}_s = \frac{20}{465.1} = 0.043$ kJ/sec.

---

(11) $C_p = a + bT$

$dq = \int_{T_1}^{T_2} C_p dT = \int_{T_1}^{T_2} (a+bT)dT = aT\Big]_{T_1}^{T_2} + \frac{bT^2}{2}\Big]_{T_1}^{T_2}$

$dQ = a(T_2 - T_1) + \frac{b(T_2^2 - T_1^2)}{2}$

$ds = \int_{T_1}^{T_2} \frac{dQ}{T} = \int_{T_1}^{T_2} \frac{C_p\, dT}{T} = \int_{T_1}^{T_2} \frac{(a+bT)dT}{T}$

$= a \ln T\Big]_{T_1}^{T_2} + bT\Big]_{T_1}^{T_2}$

$= a \ln\left(\frac{T_2}{T_1}\right) + b(T_2 - T_1)$

$\therefore C_p = a + bT$

25.2×10^{-3} @ $T = 500$K

$C_p = 80.1 \times 10^{-3}$, $T = 1200$K

$25.2 \times 10^{-3} = a + 500b$

$80.1 \times 10^{-3} = a + 1200b$

$\boxed{a = 21700}$ $\boxed{b = 7}$

$dQ = 21700(1200 - 500) + \frac{7(1200^2 - 500^2)}{2}$

$= 15.19 \times 10^6 + 4.165 \times 10^6$

$= 19.355 \times 10^6$

$ds = 21700 \ln\left(\frac{1200}{500}\right) + 7(1200 - 500)$

$= 18997.6716 + 4900$

$= 23897.69$ K

$(\Delta S)_{universe} = -0.088 + \frac{28.5 - \omega}{273}$

$0 = -0.088 + \frac{28.5 - \omega}{273}$

$\boxed{W = 4.476}$

Qu.8. m = 10 g

$T_1 = 20°C$ H_2O
↓
$T_2 = 0°C$ H_2O
↓
$T_2 = 0°C$ Ice
↓
$T_3 = -10°C$ Ice

$dS_1 = m c_{p_w} \ln \frac{T_2}{T_1}$

$= 10 \times 4.2 \times \ln \frac{273}{293}$

$= -2.96$ J/K

$dS_2 = \frac{-m L_{ice}}{T_2}$ (-ve remaining)

$= \frac{-10 \times 335}{273} = -12.27$

variable temp process integral

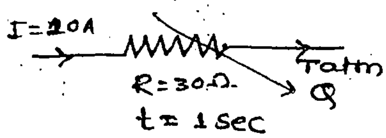
$dS_3 = m \cdot c_{p_{ice}} \ln \frac{T_3}{T_2}$

$= 10 \times 2.1 \ln \left(\frac{263}{273}\right) = -0.78$ J

$(dS)_{universe} = dS_1 + dS_2 + dS_3 = -2.96 - 12.27 - 0.78$

$= -16.01$ J/Kg

Qu.7



$(dS)_{sys} = 0$

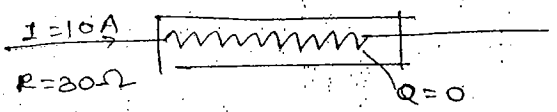
$(dS)_{surrounding} = \frac{I^2 R t}{T_{atm}}$

$= \frac{(10)^2 \times 30 \times 1}{300}$

$= 10$ J/K

$(\Delta S)_{universe} = (dS)_{resistor} + (dS)_{surrounding}$

$(\Delta S)_{universe} = 10$



I^2RT = mass of wire × c_p wire $(T_2 - T_{atm})$

$I^2RT = m_w \times c_{pw} (T_2 - T_{atm})$

$(10)^2 \times 30 \times 1 = 10 \times 10^{-3} \times 0.9 \times 10^3 (T_2 - 300)$

$$\boxed{T_2 = 633.33K}$$

$$(\Delta S)_{wire} = m_{wire} c_{pwire} \ln \frac{T_2}{T_1}$$

$$= 10 \times 10^{-3} \times 0.9 \times 10^3 \times \ln \frac{633}{300}$$

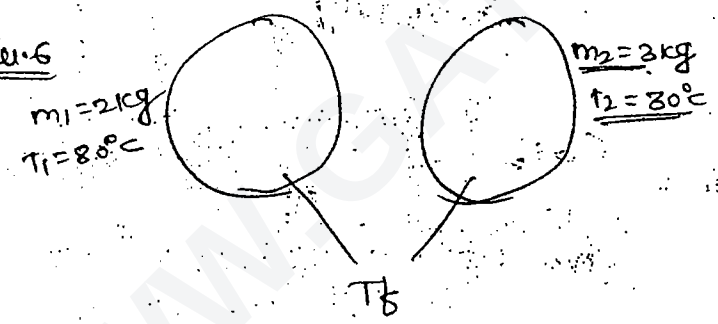
$$= \underline{6.720} \text{ J/K}$$

$(\Delta S)_{surrounding} = 0$

$(\Delta S)_{universe} = (\Delta S)_{wire} + (\Delta S)_{surrounding}$

$= 6.720 + 0 = \underline{6.72}$

Qu.6



$m_1 \cdot c_{pw} (T_1 - T_f) = m_2 c_{pw} (T_f - T_2)$

$2(80 - T_f) = 3(T_f - 30)$

$160 - 2T_f = 3T_f - 90$

$$\boxed{T_f = 50°C} = 323K$$

$(\Delta S)_{I\,water} = m_1 \cdot C_{pw} \ln \frac{T_f}{T_1} = 2 \times 4.187 \ln \frac{323}{303}$

$= -0.7432$ KJ/K

$(\Delta S)_{II\,water} = m_2 C_{pw} \ln \frac{T_f}{T_2} = 3 \times 4.187 \ln \frac{323}{303}$

$= 0.9278$ KJ/K

$(\Delta S)_{universe} = (\Delta S)_I + (\Delta S)_{II}$

$= -0.7432 + 0.9278$

$= 0.1841$ KJ/K

Ans: $(\Delta S)_{mixing} = (\Delta S)_{segregation}$

In isothermal process $T = C$

$\delta Q = dW$

$dQ = T(dS)_{mixing}$

$X_{N_2} = 0.79$

$N_{O_2} = 0.21$

$(\Delta S)_{mixing} = -nR \sum x_i \ln x_i$

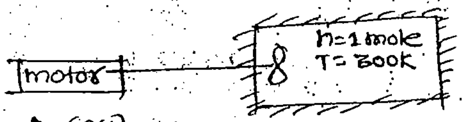
$= -nR \left[x_{N_2} \ln x_{N_2} + x_{O_2} \ln x_{O_2} \right]$

$= -1 \times 8.314 \left[0.79 \ln 0.79 + 0.21 \ln 0.21 \right]$

$= -1 \times 8.314 \left[-0.18622 + (-0.32232) \right]$

$= 4.2222$

$dW = dQ = T(dS) = 300 \times 4.2222 = 1281$ KJ



P = 60 W

t = 120 sec

$C_v = 18.956 + 4.93\times10^{-3}\,T$

$dQ - dW = dU = C_v\,dT$

$0 - (-Pt) = \int_{300}^{T_2} (18.956 + 4.93\times10^{-3}\,T)\,dT$

$60\times120 = \left[18.956\,T\right]_{300}^{T_2} + \left[4.93\times10^{-3}\,\frac{T^2}{2}\right]_{300}^{T_2}$

$= 18.956(T_2 - 300) + 4.93\times10^{-3}(T_2^2 - (300)^2)$

$7200 = 18.956\,T_2 - 5686.8 + 4.93\times10^{-3}\,T_2^2 - 443.7$

$7200 = -6130.5 + 18.956\,T_2 + 4.93\times10^{-3}\,T_2^2$

$4.93\times10^{-3}\,T_2^2 + 18.956\,T_2 - 13330.5 = 0$

$T_2 = 638\,K,\ -8328\,K$ (×)

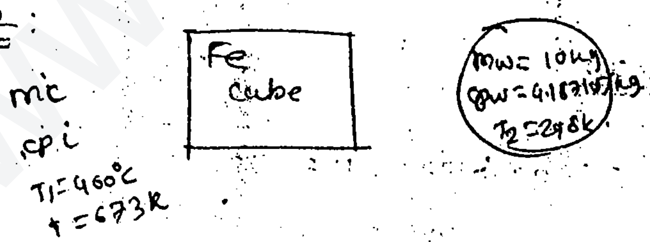
$ds = \int_{T_1}^{T_2} \frac{n\,C_v\,dT}{T} = 1\,\frac{(18.956 + 4.93\times10^{-3}\,T)\,dT}{T}$

$= \left[18.956\ \ln T\right]_{300}^{638} + \left[4.93\times10^{-3}\,T\right]_{300}^{638}$

$= 18.956\ \ln(638/300) + (4.93\times10^{-3}(638 - 300))$

$= 15.96$

Q.2:



$T_f = 50°$

Heat lost = Heat gained

$m_i\,c_{pi}\,(T_1 - T_f) = m_w\,c_{pw}\,(T_f - T_2)$

$m_i\,c_{pi}\,(673 - T_f) = 10\times4.187\,(T_f - 298)$

(given) $T_f = 50 + 273 = 323$

~~mi cpi = 2.98~~

$(ds)_{iron} = m_i c_{pi} \ln \frac{T_f}{T_i} = 2.98 \ln \frac{323}{673} = -2.18759$

$(ds)_{iron} = m_w c_{pw} \ln \frac{T_f}{T_2} = 10 \times 4.187 \ln \frac{323}{298} = 3.37$

$(\Delta S)_{universe} = (ds)_{iron} + (ds)_{iron}$

$= 1.1870$ hence it is irreversible pro

$293 \times (10^{-3} T)\, dT$

$2 \Big]_{300}^{T_2}$

$- (300)^2 \Big]$

$- 443.7$

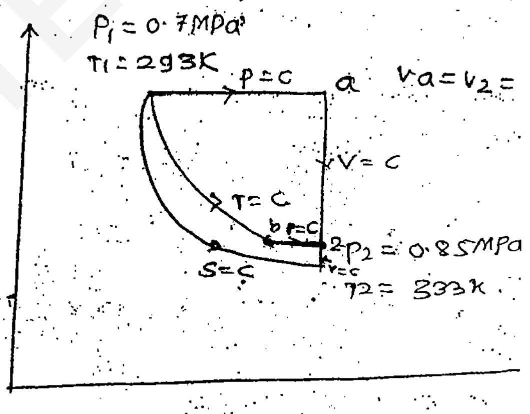
Q1.1

$PV = 0.287T$

$V_1 = 0.287 T_1$

$= \frac{0.287 \times 293}{700}$

$= 0.12 \frac{m^3}{kg}$



$V_2 = \frac{0.287 T_2}{P_2}$

$= \frac{0.287 \times 333}{350}$

$= 0.273\ m^3/kg$

process 1-a $p = c$

$\frac{V_1}{T_1} = \frac{V_a}{T_a}$

$\frac{0.12}{293} = \frac{0.273}{T_a}$

$\boxed{T_a = 666.57 K}$

$\Delta S_a = c_p \ln \frac{T_a}{T_1} = 1.005 \ln \frac{666.57}{293} = 0.82\ kJ/K.$

$\Delta S_2 = c_v \ln \frac{T_2}{T_a} = 0.718 \ln \frac{333}{666} = -0.498\ kJ/K$

$\Delta S_2 = \Delta S_a + \Delta S_2 = 0.328\ kJ/K.$

1-b-2

1-b T=c

$$1S_b = R\ln\frac{P_a}{P_b} = R\ln\frac{V_b}{V_a} = 0.287\ln\left(\frac{0.35}{700}\right)$$

$$= +0.198 \text{ kJ/K}.$$

$$bS_2 = c_p \ln\frac{T_2}{T_b} = 1.005\ln\frac{333}{293} = 0.1286 \text{ kJ/K}.$$

$$1S_2 = 1S_b + bS_2 = 0.328 \text{ kJ/K}.$$

1-c-2

1-c s=c $1S_c = 0$

$$T_1 V_1^{\gamma-1} = T_c V_c^{\gamma-1}$$

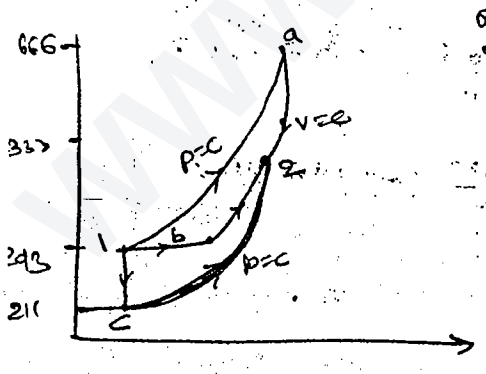
$$T_c = T_1\left(\frac{V_1}{V_c}\right)^{\gamma-1} = 293\times\left(\frac{0.12}{0.273}\right)^{0.4} = 210.89 \text{ K}$$

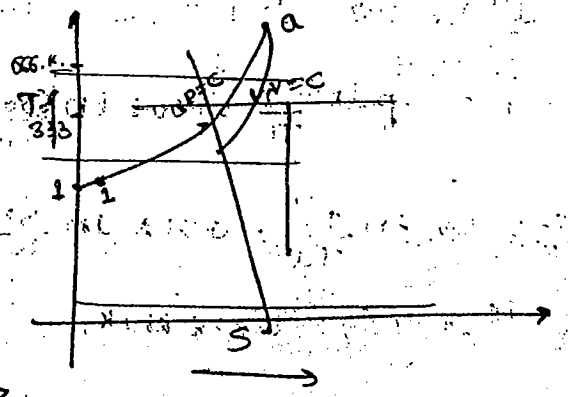
$$cS_2 = c_v \ln\frac{T_2}{T_c} = 0.718\ln\frac{333}{211} = 0.329.$$

$$1S_2 = 1S_c + cS_2 = 0 + 0.329 = 0.327 \text{ kJ/K}.$$

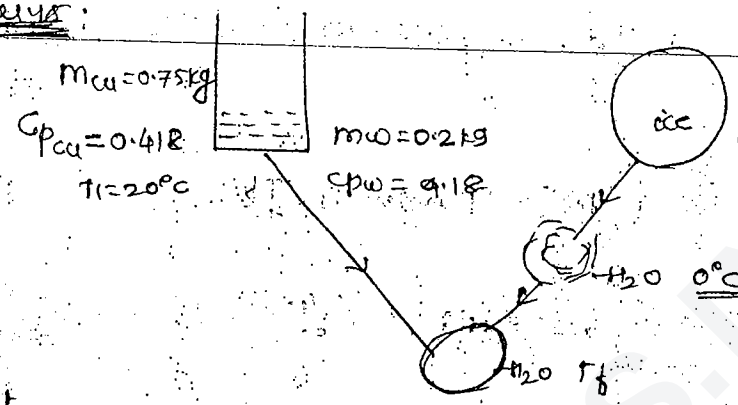
It is point function not path fn

In all the cases the ΔS change is same which proves that entropy is point function and it is independent of the path followed.





Solution:



let x = heat required to cool the water & calorimeter to 0°C

y = heat required to completely melts the ice at water at

If $x > y$ entire ice will melt and the resultant temp is in between 0 to 20°C

If $x = y$ the ice completely melts and resultant temp is

If $x < y$ resultant temp is 0°C on only the portion of ice melt and remaining ice is in ice form

$$x = (m_{cu} C_{p_{cu}} + m_w C_{p_w})(T_i - 0)$$

$$= (0.75 \times 0.418 + 0.2 \times 4.18)(20) = 22.99 \text{ KJ}$$

$$y = m_i L_{ice} = 0.05 \times 333 = 16.65 \text{ KJ}$$

$x > y$ the entire ice will melt and the resultant temp is between 0 to 20

$$m_{cu} C_{p_{cu}} (T_i - T_f) + m_w C_{p_w} (T_i - T_f) = m_{ice} L_{ice} + m_{ice} C_{p_w} (T_f - 0)$$

$$= 0.75 \times 0.418 (20 - T_f) + 0.2 \times 4.18 (20 - T_f) = 0.05 \times 333 + 0.05 \times 4.18 \times (T_f - 0)$$

$$= 6.27 - 0.3135 T_f + 16.72 - 0.836 T_f = 19.985 + 0.209 (T_f)$$

$$= \boxed{T_f = 4.67^\circ C}$$

$$(ds)_{calorimeter} = m_{cu} C_{p_{cu}} \ln \frac{T_f}{T_i}$$

$$= 0.75 \times 0.418 \times \ln \left(\frac{273 + 4.67}{273 + 20} \right)$$

$$= -0.01684 \text{ KJ/K}$$

$(ds)_{water} = m_w c_{pw} \ln \frac{T_b}{T_1} = 0.2 \times 4.18 \times \ln \frac{(273+4.07)}{273+20} = -0.044$

$(ds)_{ice} = \frac{m_{ice} L_{ice}}{T_2} + m_{ice} c_{p\,water} \ln \frac{T_b}{T_2}$

$= \frac{0.05 \times 333}{273} + 0.05 \times 4.18 \ln \left(\frac{4.67}{273} \right)$

$= 0.06098 - 0.85027$

$=$ ~~0.78~~ 0.0645 kJ/K

$(ds)_{system} = (ds)_{calor} + (ds)_{water} + (ds)_{ice}$

$= -0.01684 + (-0.044) + 0.0645$

$=$

$(ds)_{surrounding} = 0$

$(ds)_{universe} = (ds)_{sy} + (ds)_{surr} = 3.60 \times 10^{-3} > 0$

hence it is reversible process

min work $=$ $T\,ds$ $t_1 = 20°C$

pg-No. 20

Qu.19: $m_{ice} = 1.5$ kg $c_{pice} = 2.07$

$T_1 = 260$ K
↓ $Q_1 = m_i c_{pi}(T_2 - T_1)$
$T_2 = 273$ K ice
↓ $Q_2 = m L_{ic}$
$T_2 = 273$ K H_2O
↓ $Q_3 = m c_{pw} \Delta T$
$T_3 = 293$ K H_2O

$Q_1 = m_i c_{pi} (T_2 - T_1)$
$= 1.5 \times 2.07 (273 - 260)$
$= 40.365$ kJ

$Q_2 = m L_{ic} = 1.5 \times 334 = 500.1$

$Q_3 = m c_{pw} \Delta T$
$= 1.5 \times 4.2 (293 - 273)$
$= 126$ kJ

$(q_{s1}) = \ldots$

$(ds_2) = \ldots$

$(ds_3) = \ldots$

$(\Delta S)_{system}$

$Q = Q_1 \ldots$

$(S_2 - S_1) \ldots$

$2.421 - \ldots$

pg. No 16

$\Delta ds = \ldots$

Qu.2

Qu.8

$\frac{4.67}{+20} = 0.044$

$(ds_1) = m_{ice} c_{pice} \ln \frac{T_2}{T_1} = 1.5 \times 2.07 \ln\left(\frac{273}{260}\right) = 0.1576$ kJ/

$(ds_2) = \frac{m_{ice} L_{ice}}{T} = \frac{1.5 \times 333.4}{273} = 1.83$ kJ/K.

$(ds_3) = m_{ow} c_{pw} \ln \frac{T_3}{T_2} = 1.5 \times 4.2 \ln\left(\frac{293}{273}\right) = 0.4451$ kJ/

$(\Delta S)_{system} = ds_1 + ds_2 + ds_3 = 2.4264$

$Q = Q_1 + Q_2 + Q_3 = 666.465$ kJ

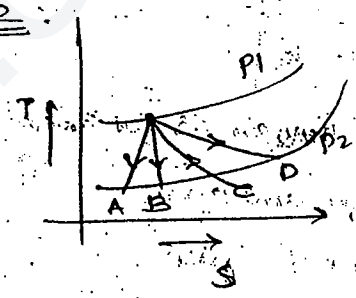
$(S_2 - S_1) - \int \frac{dQ}{T} = S_{gen} = S_{production}$

$2.421 - \frac{666.465}{293} = 0.1463 = S_{gen} = S_{production}$

pg. NO 16 Qu. 1

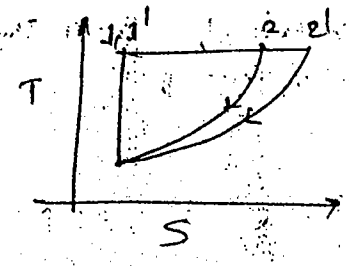
$\Delta ds = \frac{power \times time}{temp} = \frac{5 \times 3600}{293} = 61.43$ J/K

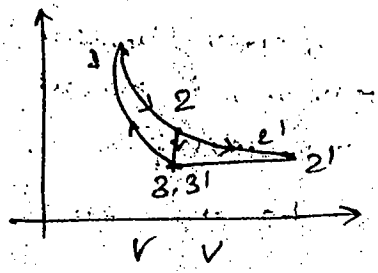
Qu. 2



Ans (A)

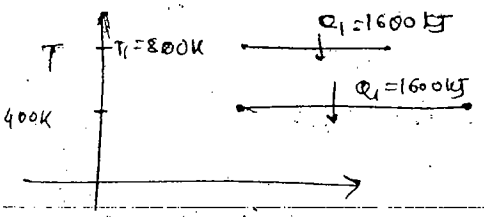
Qu. 3





C
$p_i(T_2 - T_1)$
ice
to
H_2O
$mc_{pw}\Delta T$
H_2O

Qu.6 ;



$(S_2 - S_1) - \int \left(\frac{dQ}{T}\right) = S_{gen}$

$= \frac{1600}{400} - \left[\frac{1600}{800}\right] = S_{gen}$

$= \boxed{2 = S_{gen}}$

$(dS)_{sever} = \frac{-1600}{800} = -2$

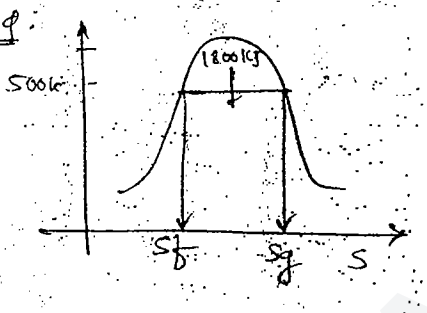
$(ds)_{system} = \frac{1600}{400} = 4$

$(ds)_{universe} = (ds)_{system} + (ds)_{sever} = 2$

Qu.8 $\oint \frac{dQ}{T} = \frac{400}{300} + \frac{Q_1}{T_1} - \frac{Q_2}{T_2} = \frac{600}{1000} - \frac{450}{300} = -0.9$ kJ/K

$\eta = \frac{Q_1 - Q_2}{Q_1} = \frac{600 - 450}{600} = 25\%$

Qu.9 ;



$S_g - S_f = \frac{h_{fg}}{T_{sat}}$

$S_g - 2.6 = \frac{1800}{500}$

$\boxed{S_g = 6.2\ kJ/K}$

(13) $dQ = dE + dW$ = eqn is valid for any process rev, irrev or for any system

$dQ = du + dW$ eqn is valid for any process undergone by a close stationary system

$dQ = du + pdv$ this eqn is valid for closed system when only pdv work is present this is true for reversible quasistatic Process.

$Tds = dQ$ This eqn is valid for reversible process.

$Tds = du + pdv$ This eqn is valid for any process reversible or irreversible undergone by a closed system

$Tds = dH - Vdp$ This eqn holds good for any process since there is no path fn in the sequence

) = Sgen.

= Sgen

= -0.9 kJ/K

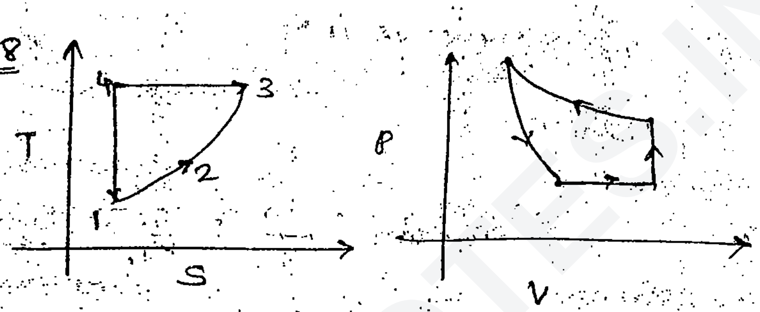
Qu.16 $(ds)_{system} = 100(0.4-0.3) = 10$

$(ds)_{surrounding} = 75-80 = -5$

$(ds)_{universe} = (ds)_{system} + (ds)_{surrounding} = 5 > 0$

Irreversible process.

Qu.18



Qu.22 $\oint \frac{dQ}{T} = \frac{Q_1}{T_1} - \frac{Q_2}{T_2}$

$= \frac{1000}{(285+273)} - \frac{492}{(273+5)}$

$= 0.02$

$\oint \frac{dQ}{T} > 0$ impossible

Qu.24 : $Q = \alpha T + \beta T^2$

$ds = \int \frac{dQ}{T} = \int \frac{d(\alpha T + \beta T^2)}{T}$

$= \int_{T_1}^{T_2} \alpha \frac{dT}{T} + \frac{2\beta T dT}{T}$

$= \alpha \ln \frac{T_2}{T_1} + 2\beta (T_2 - T_1)$

motor for any system

all system

Pg.No 47 Qu (5)

$dQ - dw = du$

$-2000 - (-5000) = du$

$du = 3000 kJ$

Pg.No 48 Qu (7) : (a)

Qu (8) (d)

Qu.11 c

Pg.No (50) Qu.1 (a)

rc process.

any process

closed system

for any sequence

Pg No 50 Qu. (5) 5&6

$$m = \frac{PV}{RT} = \frac{200 \times 1}{\frac{8.314}{28} \times 298} = 2.26 \text{ kg}$$

$$dQ = dw = nRT \ln \frac{V_2}{V_1}$$

$$= 2.26 \times \frac{8.314}{28} \times 298 \ln \frac{2}{1}$$

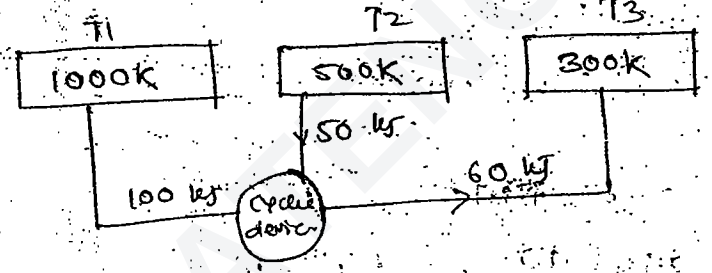
$$= 138.6 \text{ kJ}$$

$$(ds)_{system} = 0 \quad (ds)_{surrounding} = \frac{dQ}{T} = \frac{138.6}{298} = \underline{0.4652}$$

$$(\Delta S)_{universe} = \underline{0.4652}$$

Qu.22 Pg No 53 E-G-J-K-N (a)
F-H-J-K-M

Qu.32



$$\oint \frac{dQ}{T} = \frac{Q_1}{T_1} + \frac{Q_2}{T_2} - \frac{Q_3}{T_3}$$

$$= \frac{100}{1000} + \frac{50}{500} - \frac{60}{300} = 0$$

It's reversible engine

Availability

High grade energy	Low grade energy
– Mechanical work, electrical energy, water power, wind power, kinetic energy of jet and tidal power	– heat or thermal energy, heat derived from nuclear fission and fusion. heat derived from combustion of fossil fuel.

$\epsilon = 0.6652$

complete conversion of low grade energy to high grade energy is impossible and it is limited by IInd law of thermodynamics. Maximum work output obtainable from a certain heat input in a cyclic engine is called as available energy

Q_1 = Available energy + unavailable energy

$Q_1 = AE + UE$

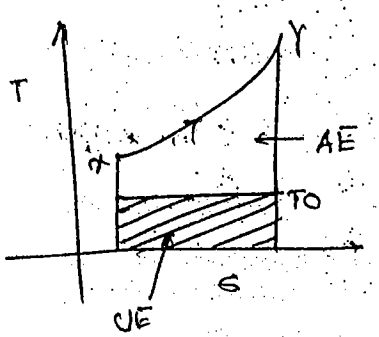
$W_{max} = AE = Q_1 - UE$

AE = exergy UE = Anergy

$W_{max} = \left(1 - \frac{T_0}{T_1}\right) Q$

$$\int_x^y dw_{max} = \int_x^y \left(1 - \frac{T_0}{T_1}\right) dq_1$$

$W_{max} = Q_{xy} - T_0 (S_y - S_x)$



$AE = Q_{xy} - T_0 (S_y - S_x)$

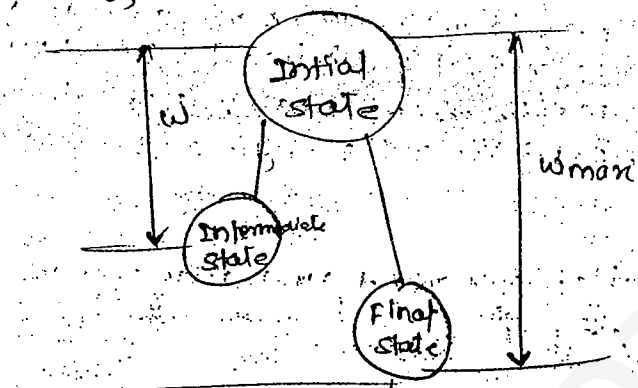
$UE = T_0 (S_y - S_x)$ — change in ent
└ Lowest temp

Work = f(initial state ; process path ; final state)

Dead State: Thermodynamic equilibrium with surrounding i.e. thermal & mechanical equilibrium

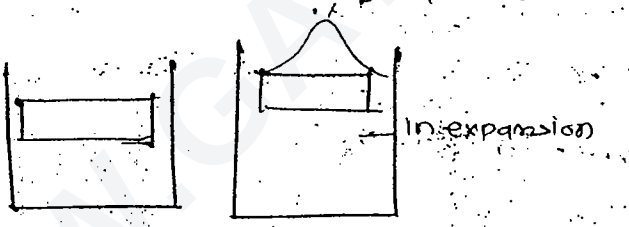
It is generally $P_0 = 1$ atm, $T_0 = 25^\circ C$

ho ≠, So,



$W_{actual} < W_{max}$

The W_{max} is upper limit on the amount of work a device can deliver without violating any thermodynamic loss.



$W_U = W - W_{surrounding}$

$= W - P_0(V_2 - V_1)$

$W_{surrounding}$

W_U = useful

Irreversibility = $W_{rev} - W_U$

$W_{rev} > W_{Useful}$ it called as work producing device

$W_{rev} < W_{useful}$ work consuming device.

Availability in closed System

$Q - W = U_2 - U_1$ ⟶ 1st law for closed syst

$$S_{gen} = (S_2 - S_1) - \frac{Q}{T_0}$$

$S_2 - S_1$ = entropy change of system

$\frac{Q}{T_0}$ = entropy of transfer.

$$Q = T_0 (S_2 - S_1) + T_0 S_{gen}$$

$$W = Q - (U_2 - U_1)$$

$$W = T_0 (S_2 - S_1) - T_0 S_{gen} - (U_2 - U_1)$$

$W_{useful} = W - W_{surroun}$

$= W - P_0 (V_2 - V_1)$

$$W_U = T_0 (S_2 - S_1) - T_0 S_{gen} - (U_2 - U_1) + P_0 (V_2 - V_1)$$

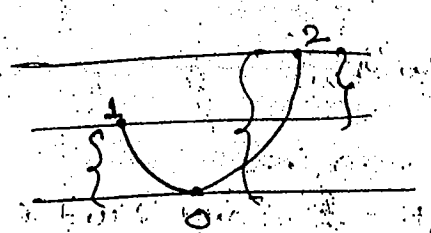
$$W_U = (U_1 - U_2) + P_0 (V_1 - V_2) - T_0 (S_1 - S_2) - T_0 S_{gen}$$

Maximum useful work is obtained when the process is reversible and for reversible process $S_{gen} = 0$

$$W_U = (U_1 - U_2) + P_0 (V_1 - V_2) - T_0 (S_1 - S_2)$$

Availability function for non flow process

$$\phi = (U + P_0 V - T_0 S)$$

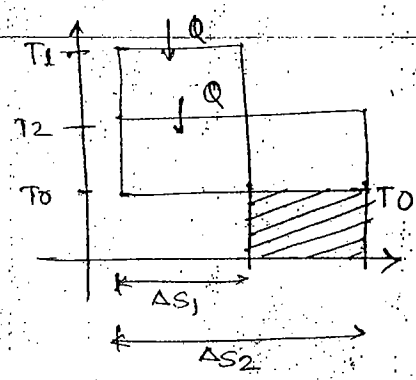


$$\phi_1 - \phi_0 = (U_1 - U_0) + P_0 (V_1 - V_0) - T_0 (S_1 - S_0)$$

$$\phi_2 - \phi_0 = (U_2 - U_0) + P_0 (V_2 - V_0) - T_0 (S_2 - S_0)$$

$$\phi_1 - \phi_2 = (U_1 - U_2) + P_0 (V_1 - V_2) - T_0 (S_1 - S_2)$$

decrease in available energy when heat is transffered from a higher temp reservoir to a lower temp reservoir



$Q = T_1 ds_1 = T_2 ds_2$

$ds_1 = \frac{Q}{T_1}$, $ds_2 = \frac{Q}{T_2}$

$T_1 > T_2$

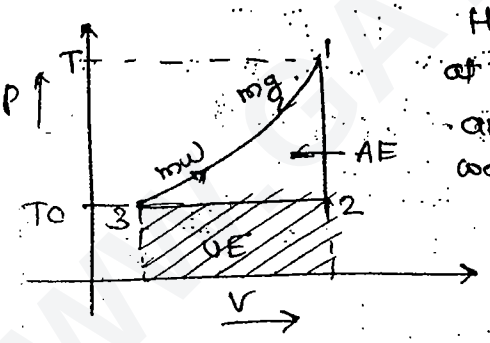
$\therefore \boxed{ds_2 > ds_1}$

$W_1 = Q - T_0 ds_1$ $\quad W_2 = Q - T_0 ds_2$ $\quad \therefore W_2 < W_1$

$\boxed{\text{Loss work} = W_1 - W_2 = T_0 (ds_2 - ds_1)}$ ← loss in available energy

Temp difference bet^n T_1 & T_2 is high the loss in available energy is high. if the difference bet^n temp is less the loss in available energy is less.

Available energy from a finite energy source



Hot gases 'mg' are available at temp 'T' which are cooled to 'T0' and are used for heating the water from a temp 'T0' to 'T'

Heat loss by gases = Heat gained by water

$m_g C_{pg} (T - T_0) = m_w C_{pw} (T - T_0)$

$\boxed{m_g C_{pg} = m_w C_{pw}}$

The heating process is reversible i.e. the temp difference bet^n the gas and fluid is always zero; then the fluid expands from state 1 to state 2 in turbine and reject heat Q_2 in the process 2-3, do

In the process he does work.

In heating process

$$(ds)_{gas} = m_g C_{p_g} \ln \frac{T_0}{T}$$

$$(ds)_{water} = m_w C_{p_w} \ln \frac{T}{T_0} = m_g C_{p_g} \ln \frac{T}{T_0}$$

$$(ds)_{gas} + (ds)_{water} = 0 = (\Delta S_{universe}) \text{ reversible process}$$

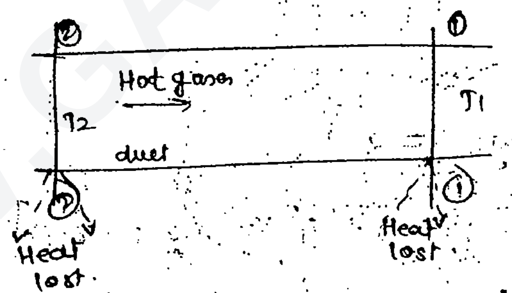
*Available energy = $Q - T_0 ds$ (Q-ve write then we write T/T_0)

$$\therefore m_g C_{p_g}(T - T_0) - T_0 \cdot m_g C_{p_g} \ln \frac{T}{T_0}$$

$$= m_g C_{p_g}\left[(T - T_0) - T_0 \ln \frac{T}{T_0}\right]$$

$$m_g C_{p_g} \ln \frac{T}{T_0} = m_w C_{p_w}\left[(T - T_0) - T_0 \ln \frac{T}{T_0}\right]$$

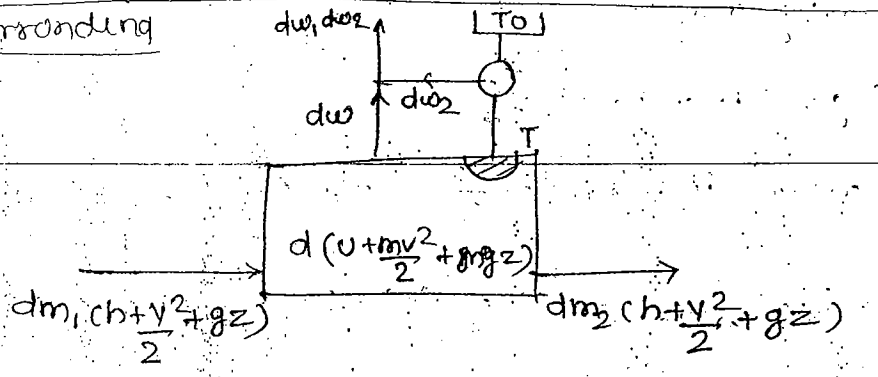
Quality of energy



$T_1 > T_2$

When gases are flowing in duct at two different section the temp are T_1 & T_2. the heat lost at higher temp is greater than heat lost at lower temp. this is called as the Quality of energy.

Reversible work in open system exchanging heat with surrounding



on applying the Ist law and IInd law to the system we can get the maximum amount of work possible

$$dW_{max} = dm_1\left[h_1 - T_o s_1 + \frac{v_1^2}{2} + gz_1\right] - dm_2\left[h_2 - T_o s_2 + \frac{v_2^2}{2} + gz_2\right] - d\left[U - T_o S + \frac{mv^2}{2} + mgz\right]$$

For steady flow process :

$$dm_1 = dm_2 = dm$$

$$d\left(U - T_o S + \frac{mv^2}{2} + mgz\right) = 0$$

$$dW_{max} = dm\left[(h_1 - h_2) - T_o(s_1 - s_2) + \frac{v_1^2 - v_2^2}{2} + g(z_1 - z_2)\right]$$

$h - T_o s$ = Keenan function

$$= dm\left[(b_1 - b_2) + \frac{v_1^2 - v_2^2}{2} + g(z_1 - z_2)\right]$$

$$= \left(B_1 + \frac{mv_1^2}{2} + mgz_1\right) - \left(B_2 + \frac{mv_2^2}{2} + mgz_2\right)$$

$$\psi = B + \frac{mv^2}{2} + mgz$$

$$\boxed{\psi_1 - \psi_2 = (B_1 - B_2) + m\left(\frac{v_1^2 - v_2^2}{2}\right) + m(z_1 - z_2)g}$$

when K.E = P.E = 0

$$\boxed{\psi_1 - \psi_2 = B_1 - B_2}$$

closed system

$$dm_1 = dm_2 = 0$$

$$dW_{max} = -d\left[U - T_0 S + \frac{mv^2}{2} + mgz\right]$$

$$= -d\left[E - T_0 S\right]$$

$$\boxed{dW_{max} = (E_1 - E_2) - T_0(S_1 - S_2)}$$

if KE, PE = 0

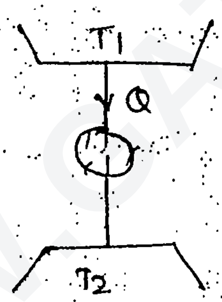
$$\boxed{dW_{max} = (U_1 - U_2) - T_0(S_1 - S_2)}$$

system possible

GUDY - STODALA Equation

$$I = T_0 (dS)_{universe} = T_0 S_{gen} + T_0 S_{production}$$

Heat transferred through finite temp difference



when heat is transferred from high to low its result a loss of available energy as no work is done and

Work loss = carnot work

$$W_L = W_C = \frac{Q(T_1 - T_2)}{T_1}$$

$$(S_2 - S_1) - \int \frac{dQ}{T} = S_{gen}$$

$$\frac{Q}{T_2} - \frac{Q}{T_1} = Q\left(\frac{T_1 - T_2}{T_1 T_2}\right) = S_{gen}$$

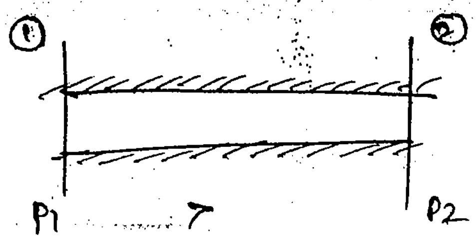
$$I = \boxed{W_{lost} = T_2 \cdot S_{gen}}$$

$z_1 - z_2)]$

$z_2)$

$z_2)g$

heat transfer through finite temp difference is equal to destruction of its availability



$$\Delta p = (p_1 - p_2)$$

$$\boxed{W_{lost} = T_0 S_{gen} = mRT_0 \frac{dp}{p_1}}$$

Efficience IInd Law

It is defined Ratio of change in available energy of system to change in available energy of source.

Efficiency IInd Law for compressor

$$\eta_{\text{IInd law compressor}} = \frac{B_2 - B_1}{W} = \frac{(h_2 - h_1) - T_0(S_2 - S_1)}{W}$$

Efficiency IInd law for turbine

$$\eta_{\text{IInd law turbine}} = \frac{W}{B_1 - B_2} = \frac{W}{(h_1 - h_2) - T_0(S_1 - S_2)}$$

Efficiency IInd law for engine

$$\eta_{\text{engine}} = \frac{\eta_{\text{Actual}}}{\eta_{\text{Carnot}}}$$

Efficiency IInd law, Refrigerator / Heat pump

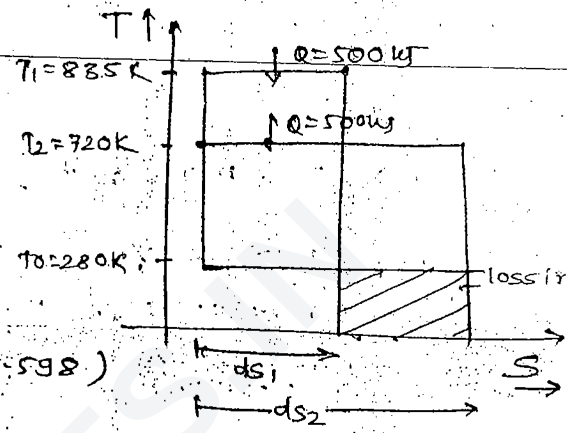
$$\eta_{\text{IInd law Ref/H.P}} = \frac{(C.O.P)_{\text{Actual}}}{(C.O.P)_{\text{Carnot}}}$$

able energy
gy of source.

Pg. No 23 Qu. 9

$ds_1 = \frac{Q}{T_1} = \frac{500}{835} = 0.598$

$ds_2 = \frac{Q}{T_2} = \frac{500}{720} = 0.694$



loss in AE $= T_0(S_2 - S_1)$

$= 280(0.694 - 0.598)$

$= \underline{26.88}$ kJ

Qu. 10 $m = 1000kg$, $c_p = 0.5 kJ/kg K$, $T_1 = 1200K$, $T_0 = 300K$.

$T_2 = 400K$ is kept

$AE = Q - T_0 ds = mc_p(T_1 - T_2) - mc_p T_0 \ln \frac{T_1}{T_2}$

$= 1000 \times 0.5 (1200 - 400) - 1000 \times 0.5 \times \ln \frac{1200}{400} \times 3$

$= 400 \times 10^3 - 549.306 \times 300$

$= 399.45 \times 10^3$ ~~ans~~ $\underline{235.20 \times 10^3}$ kJ

Qu. 11:

$\underline{WU} = [u_1 + p_0 v_1 - T_0 s_1] - [u_2 + p_0 v_2 - T_0 s_2]$

$= [(h_1 - p_1 v_1) + p_0 v_1 - T_0 s_1] - [(h_2 - p_2 v_2) + p_0 v_2 - T_0 s_2]$

$= (2993.5 - 3000 \times 0.08114) + 100 \times 0.08114 - 300 \times 6.$

$- [2706.7 - 200 \times 0.8857 - 300 \times 7.7271]$
$+ 100 \times 0.8857$

$= \underline{\hspace{3em}}$

Qu. 12:

$I = T_0 \cdot S_{gen}$

$= T_0 \cdot mR \frac{\Delta P}{P_1}$

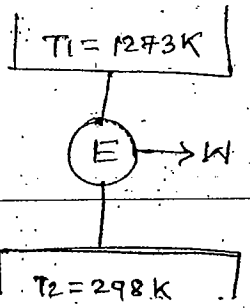
$= 300 \times 3 \times 0.287 \times \frac{0.1 P_1}{P_1}$

$= 300 \times 3 \times 0.287 \times 0.1$

$= \underline{25.83}$

$m = 3 kg/sec$
$T_0 = 300K$
$R = 0.287$
$\Delta P = 0.1 P_1$

Qu·8 $T_0 = 298\ K = T_2$



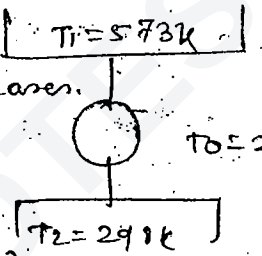
$AE_1 = Q - T_0 dS$

$= mcp(T_1 - T_2) - mcp(T_0) \ln \frac{T_1}{T_2}$

$= \frac{5000}{3600} \times 1 (1273 - 298) - \frac{5000 \times 1 \times 298 \ln \frac{1273}{298}}{3600}$

$= 753+1$ ~~753+100~~

IInd case: hot gases are used to heat up the air upto a temp of 300°C and hot gases are used to run the engine



Heat gained by air = heat lost by hot gases.

$\dot{m}_a C_{p_{air}} (T_1 - T_2) = \dot{m}_s \cdot C_{p_s} (T_1 - T_2)$

$\dot{m}_a (573 - 298) = \frac{5000}{3600} \times 1 (1273 - 298)$

$\dot{m}_a = 4.9242$ kg

$AE_2 = \dot{m}_a C_{pa} (T_3 - T_2) - \dot{m}_a C_{pa} \cdot T_0 \ln \frac{T_3}{T_2}$

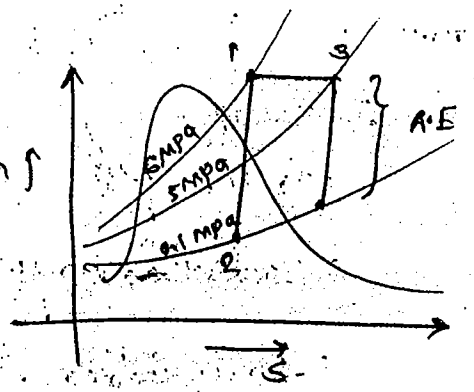
$= 4.92 \times 1 \times (573 - 298) - 4.93 \times 1 \times 298 \ln \frac{573}{298}$

$= 396.4$ KW

loss in AE = 753 - 396.4 = 358.7

Qu·7 IInd case

$AE_1 = \psi_1 - \psi_0$



$AE = \psi_1 - \psi_0 = (h_1 - h_0) - T_0(s_1 - s_0) = (3177.2 - 83.95) - 293(6.5408 - 0.2966)$

$= 1263$

IInd case: $AE_2 = \psi_3 - \psi_0 = (h_3 - h_0) - T_0(s_3 - s_0)$

$= (3177.2 - 83.96) - 293(6.63 - 0.2966) = 1237.5$

loss in $AE = AE_1 - AE_2$

$= 1263 - 1237.5$

$= \underline{25.5}$ kJ

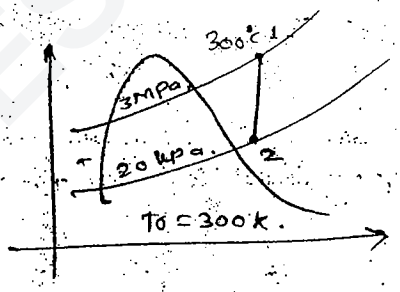
air upto
d to run

3K

$T_0 = 298K$.

K

Qu-6:



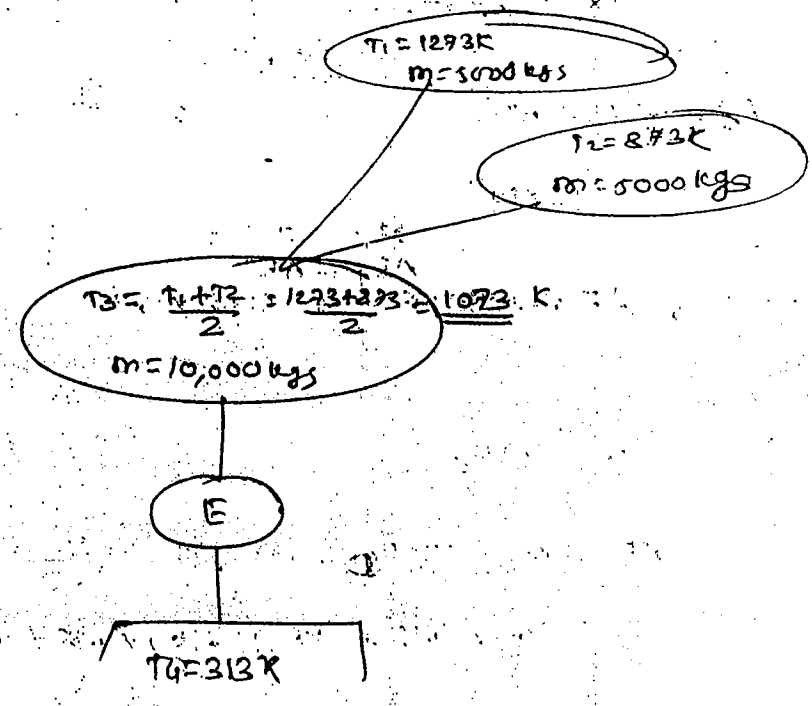
$\eta_{\text{maximum work (turbine)}} = \dfrac{h_1 - h_2}{(h_1 - h_2) - T_0(s_1 - s_2)}$

$= \dfrac{2993.5 - 2609.7}{(2993.5 - 2609.7) - 300(6.539 - 7.9085)}$

$= \dfrac{383.8}{383.8 - (-410.85)}$

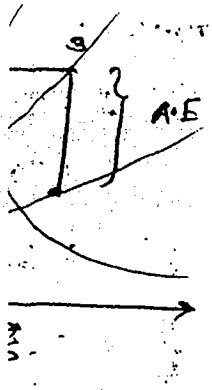
$= \underline{0.4829}$

Qu-9:



$T_0 = 298K$

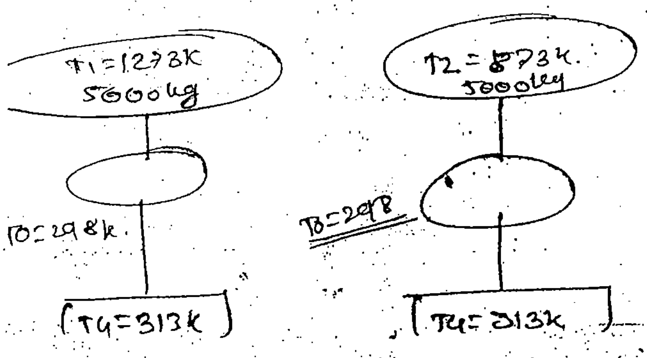
73
18



$AE_1 = mc_p(T_3 - T_4) - mc_p T_0 \ln \frac{T_3}{T_4}$

$= 10{,}000 \times 1 \, (1073 - 313) - 10{,}000 \times 1 \times 298 \ln \left(\frac{1073}{313}\right)$

$= \underline{3.92 \times 10^{8}}$ $= 3928.608 \text{ kJ}$



$AE_1 = mc_p(T_1 - T_4) - mc_p T_0 \ln \frac{T_1}{T_4}$

$= 5000 \times 1 \times (1273 - 313) - 5000 \times 1 \ln \frac{1273}{313} \times 298$

$= 2.709 \times 10^{6}$

$AE_2 = mc_p(T_2 - T_4) - mc_p T_0 \ln \frac{T_2}{T_4}$

$= 5000 \times 1 \times (873 - 313) - 5000 \times 1 \times \ln \frac{873}{313} \times 298$

$= 1.271 \times 10^{6}$

$AE = AE_1 + AE_2$

$= \underline{3.98 \times 10^{6}}$

Loss of AE = $AE_1 - AE$ = $3928.608 - 3.98 \times 10^{6}$

<u>Qu.3</u> $m = 100 \text{ kg}$

$AE = mc_p(T - T_0) - mc_p T_0 \ln \frac{T}{T_0}$

$= 100 \times 4.187 \, (90 - 0) - 100 \times 4.187 \times 273 \ln \frac{363}{273}$

$= \underline{5113.929 \text{ kJ}}$

$W = U_1 - \ldots$

Ans 3

Pg. 50 Qu

$AE = m \ldots$

Pg. 54 Qu.

Qu.1

$P_1 = 1\ MPa$, $T_1 = 300K$ → $P_2 = 0.1\ MPa$

$T_0 = 300K$

$W = U_1 - U_2 - T_0(S_1 - S_2)$

$= -T_0(S_1 - S_2)$

$= T_0(S_2 - S_1)$

$= 300\ T_0 mR \ln \frac{P_1}{P_2}$

$= 300 \times 8.314 \ln\left(\frac{1}{0.1}\right)$

$= 5743.107\ kJ$

$AE = mR \ln$

Ans 3.

pg. 50 qu. 7.

$m = 2000\ kg$, $T_1 = 1250K$ → $T_2 = 450K$.

$C_p = 0.5$

$T_0 = 303K$.

$AE = mc_p(T_1 - T_2) - mc_p(T_0 \ln \frac{T_1}{T_2})$

$= 2000 \times 0.5(1250 - 450) - 2000 \times 0.5 \times 303 \ln\left(\frac{1250}{303}\right)$

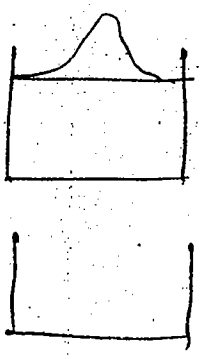
pg. 54 qu. 31:

$KU_{useful} = KU - KU_{surr}$

$= pdv - p_0 dv$

$= 300 \times 0.1 - 100 \times 0.01$

$= 29\ kJ$



pure s
ion, chem
phase.
wate
H_2O +
Air + li
Air + pe
Air + oi

Vapor

Every
a pa
satur
temp

Psa
Tsa
Psa

Dryne

Drynes

Properties of pure substance

pure substance is homogeneous in composition invari is chemical aggregation. it may exist in more than one phase.

water is a pure substance, air is a pure substances

H_2O + ice + vapor → pure substances

Air + liquid → Not a pure substance

Air + petrol vapor → is a pure substance

Air + Diesel vapor → not a pure substances

Vapor pressure curve:

Every liquid boils at a particular temp corresponding a particular pressure the pressure is called as saturation pressure & temp is called as saturation temp.

$P_{sat} \Rightarrow T_{sat}$

$T_{sat} \Rightarrow P_{sat}$

$P_{sat} \Rightarrow T_{sat}$

Dryness fraction x

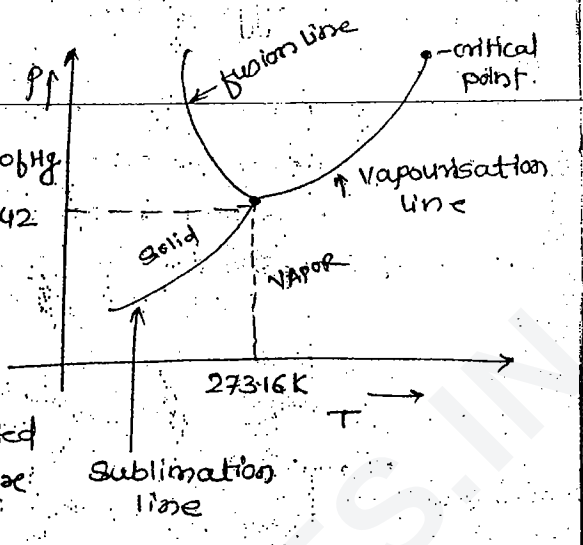
$$\text{Dryness fraction } x = \frac{\text{mass of vapor}}{\text{mass of vapor} + \text{mass of liquid}}$$

$$= \frac{m_v}{m_v + m_l}$$

$$= \frac{1}{1 + \frac{m_l}{m_v}}$$

$$\boxed{\frac{m_l}{m_v} = \frac{1-x}{x}}$$

Every substance has a triple point of its own, triple point is a point which exist as a solid, liquid and vapor.

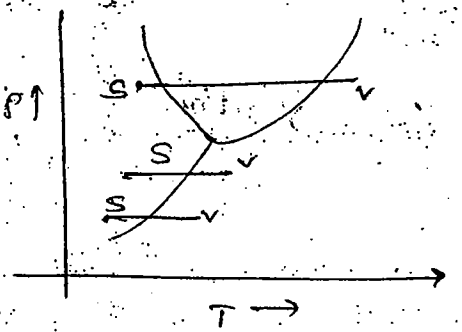


Sublimation & vapor line having +ve slope where as fusion line having -ve slope this is due to anamolous expansion of water

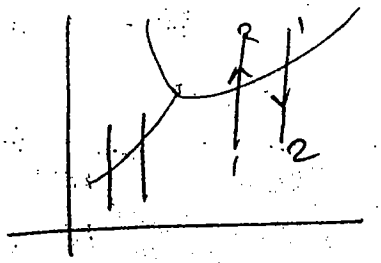
Any substance is heated below its triple point pressure solid become a vapor and process is called sublimation.

Any substance cooled below the triple point pressure vapor becomes a solid and the principle is called ablimation

Any substance is heated above its triple point solid become liquid, liquid becomes a vapor



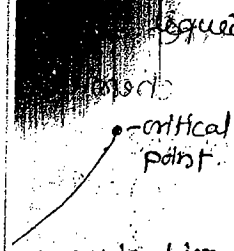
Isothermal compression of liquid beyond the triple point temp converts a vapor to liquid. isothermal expansion of liquid beyond its triple point temp convert a liquid to vapor



isothermal compression of liquid less than the triple point temp convert a vapor to solid form.

Isothermal expansion liquid less than the triple point of temp convert solid to vapor form

Gibb's phase rule



" It state that

$$P + F = C + 2$$

C = No. of component
F = Degree of freedom
P = No. of phases

A pure substance always says a single compor substance F represent no. of degree of freedom Degree of freedom means the no. of independent coordinate required to specify the state of system

$$F = C + 2 - P$$

How many D.O.F are there at triple point of H_2O

P = 3, C = 1

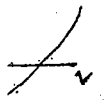
$$F = 1 + 2 - 3 = 0$$

triple point or

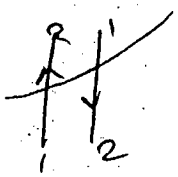
How many D.O.F at liquid vapor Separation line

$F = C + 2 - P$ $C = 1$ $P = 2$

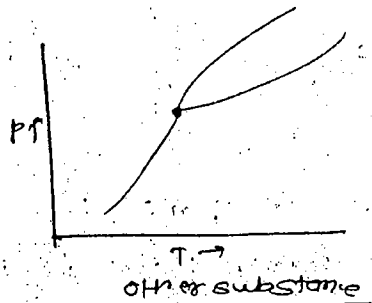
$$F = 1$$



only for H_2O, Antimony and bismouth the fusion line is having -ve slope whese as for all the remaining substance the fusion line having +ve slope.



P = a



P = C

H_2O $T_1 = 0°C$

↓

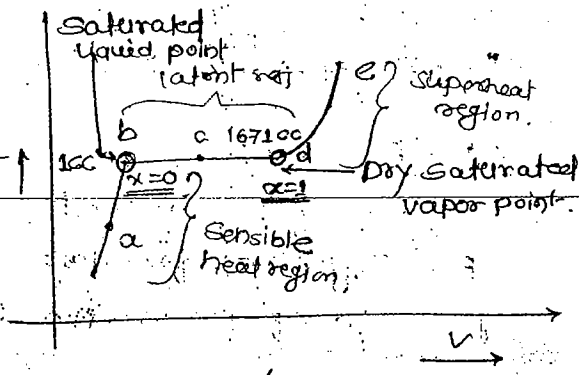
H_2O $T_2 = 100°C$

↓

steam T_2 100°C

↓

team T_3 > 100°C



This is at a ⇒ subcooled state / compressed liquid state in this $T_a < T_{sat}$

Degree of Subcooling = $T_{sat} - T_a$

b ⇒ Saturated liquid state

This is maximum point at which liquid is in liquid form and this point onward the liquid start getting converted to vapor. that is the **x=0**

c ⇒ Here it is partly the form liquid & partly the form of vapor. liquid proportion having liquid properties and vapor portion having vapor properties **0 < x < 1**

d ⇒ here completely vapor state and x=1 no water mass of liquid is zero.

e ⇒ Superheated vapor state here $T_e > T_{sat}$

Degree of Superheat = $T_e - T_{sat}$

In the liquid region when heat is supplied if temp changes it is called as sensible heating region. when heat is supply temp does not change it is called as latent heat.

In the superheated region when heat is supplied temp is change it is called as superheat region.

~~If the experiment is repeated at different pressure~~ a family of curves is obtained.

Superheat region

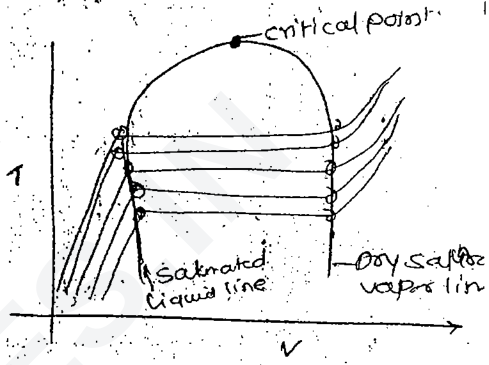
Dry saturated vapor point

v

ssed liquid state

The locus of all the saturated liquid point is called as saturated liquid line.

The locus of all the dry saturated vapor point is called as dry saturated vapor line.



Both this line meeted critical point

The critical point is the point at which the curve change it slope from +ve to -ve

critical point is called as zero slope point or point of inflection. at zero slope point latent heat is zero.

is in liquid the $x=0$

$$\left(\frac{\partial p}{\partial v}\right)_{T=T_{critical}} = 0$$

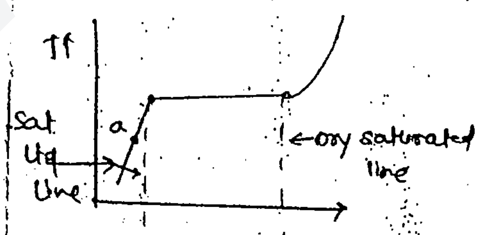
partly wing vapor

$$\left(\frac{\partial^2 p}{\partial v^2}\right)_{T=T_{critical}} = 0$$

$x=1$

As the pressure goes on increasing the latent heat of steam goes on decreasing

e > Tsat



a = subcooled state

$h_a = h_f - C_{p_l}(T_{sat} - T_a)$

$s_a = s_f - C_{pl} \ln \frac{T_{sat}}{T_a}$

Corresponding to temp T_a calculate are the h_f & h_a values are same as the calculated values.

enthalpy h_f | $h_g - h_f = h_{fg} = L$ | h_g

s_f | $\frac{s_g - s_f}{s_{fg}}$ | s_g

v_f | $\frac{v_{fg}}{v_g - v_f}$ | v_g

$v_g - v_f \simeq v_g$

$v_f << v_g$

f h_f

g region.

ge it is

region

is called as

c ⇒ liquid + vapor state
here it is partly in form of liquid partly form of vapor.

$h_c = (1-x)h_f + x h_g$

$= h_f + x(h_g - h_f)$

$= h_f + x h_{fg}$

$\boxed{h_c = h_f + xL}$

$s_c = (1-x)s_f + x s_g$

$= s_f + x(s_g - s_f)$

$\boxed{s_c = s_f + x s_{fg}}$

$v_c = (1-x)v_f + x v_g$

$= v_f + x(v_g - v_f)$

$v_c = v_f + x v_{fg}$ but $v_f << v_s$

$\boxed{v_c = x v_g}$

e ⇒ superheated vapor state

$T_e > T_{sat}$

$h_e = h_g + c_{p_v}(T_e - T_{sat})$

$s_e = s_g + c_{p_v} \ln \frac{T_e}{T_{sat}}$

$\boxed{\frac{v_e}{v_g} = \frac{T_e}{T_{sat}}}$

$\boxed{s_g - s_f = \frac{h_g - h_f}{T_{sat}}}$

$\boxed{s_g - s_f = \frac{\text{Latent heat, enthalpy}}{T_{sat}}}$

on a P
like a
like a l

Temp
-5°C
↓
0°C
↓
0°C
↓
100°C
↓
100°C
↓
100°C

In the
two pha
critical
loss
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dry satu
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on a pressure temp plane the triple point is mtly forms like a point. on a pv plane the triple point like a line on a UV plane it is like a triangle

Temp-Entropy diagram (T-S diagram)

$-5^\circ C$ T_1 ice

$\downarrow$ $ds_1 = cp_{ice} \ln \frac{T_2}{T_1}$

$0^\circ C$ T_2 ice

$\downarrow$ $ds_2 = \frac{L_{ice}}{T_2}$

$0^\circ C$ T_2 H_2O

$\downarrow$ $ds_3 = cp_w \ln \frac{T_3}{T_2}$

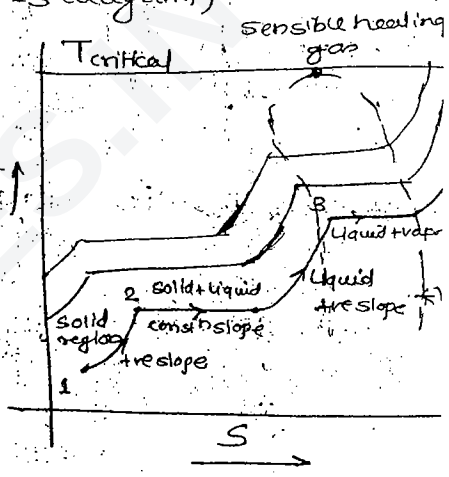
$100^\circ C$ T_3 H_2O

$\downarrow$ $ds_4 = \frac{\text{Latent heat steam}}{T_4}$

$100^\circ C$ T_4 steam

$\downarrow$ $ds_5 = cp_{steam} \ln \frac{T_5}{T_4}$

$>100^\circ C$ T_5 steam.



In the single phase region the slope are +ve In two phase region the slope are constant beyond critical temp it is called as superheated gas gas ~~does~~ ~~are~~ exactly followed in this region because the molecular separation is very high. between dry saturated vapor line and critical temp line is called as superheated vapor. and gas laws are approximated in this region because molecular separation is not high and ideal gas behaviour is not exactly followed in this region. but it is approximated

Latent heat, enthalpy

Sat

h-s diagram / Mollier diagram

$Tds = dh - vdp$

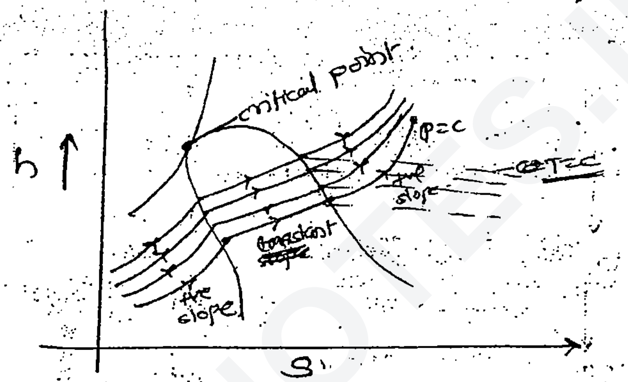
if $p = C$ $\quad dp = 0$

$Tds = dh$

$\frac{dh}{ds} = T$

** slope of mollier diagram is equal to its temperature

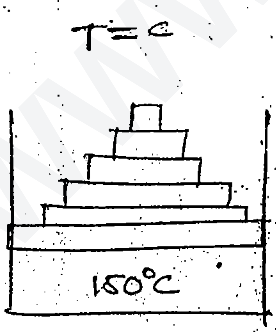
H_2O T_1 $0°C$
↓
H_2O T_2 $100°C$
↓
steam T_2 $100°C$
↓
steam $T_3 > 100°C$

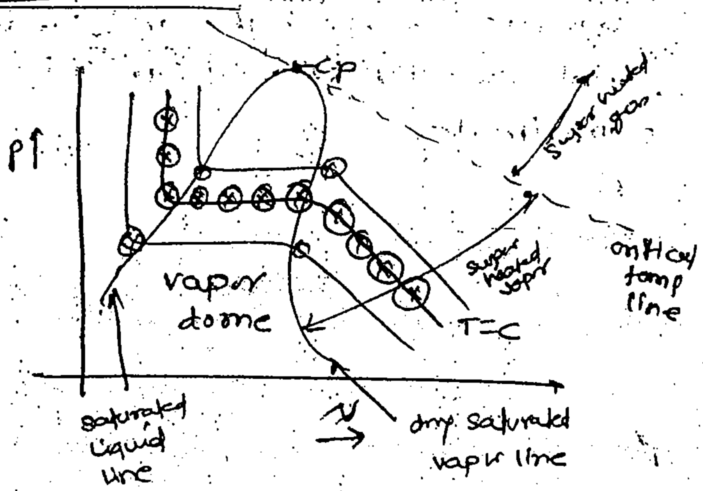


The constant pressure line are closed spaced in the liquid region. whereas constant pressure lines are divergent in the superheated region. The constant temp line are drooping line in the superheated region.

pv diagram or isothermal

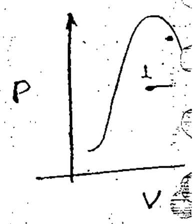
T=C



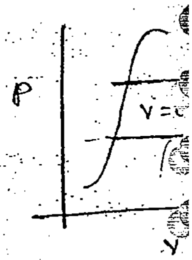


in the line. in hyperbola

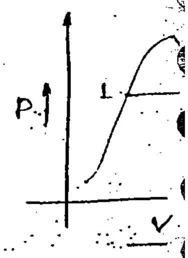
p=c



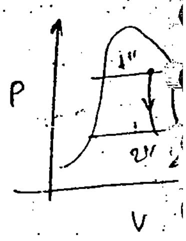
v=c is



T=c i



S=c A



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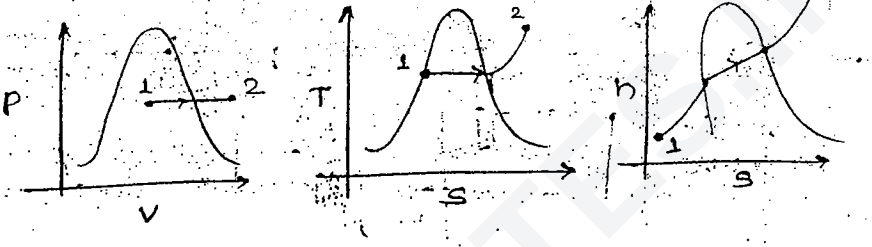
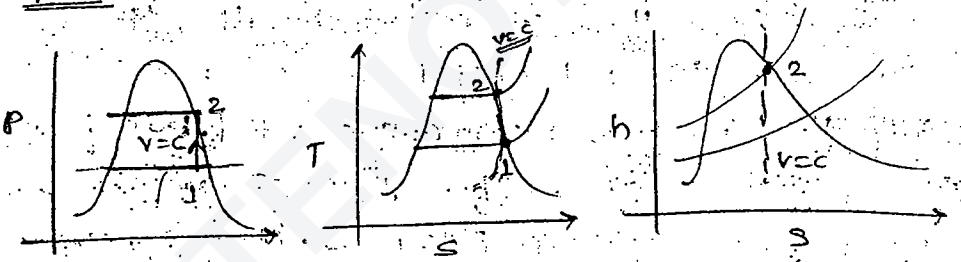
In the vapor dome isothermal line is horizonta line. in the superheated region it is a rectangle hyperbola

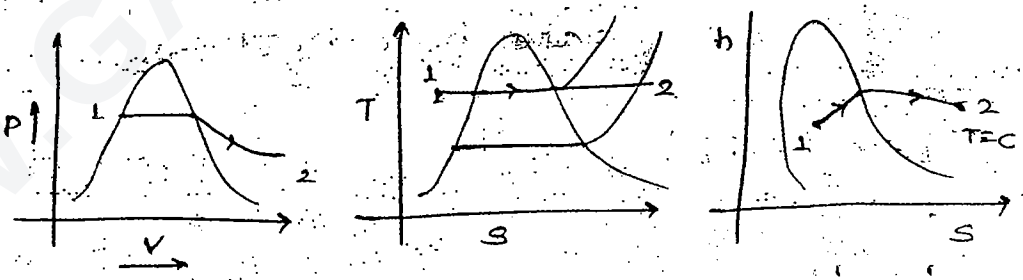
$p = c$ isobaric



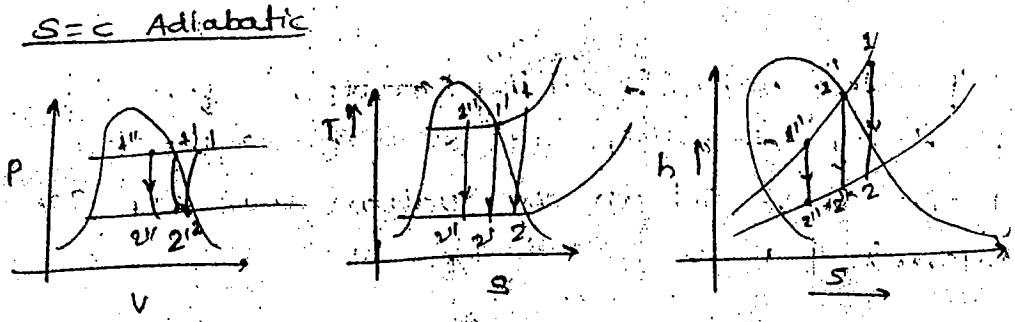
$V = c$ isochoric

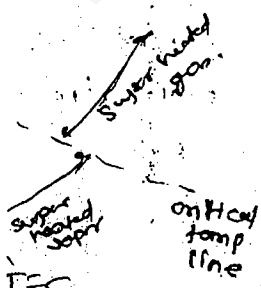


$T = c$ isothermal



$S = c$ Adiabatic

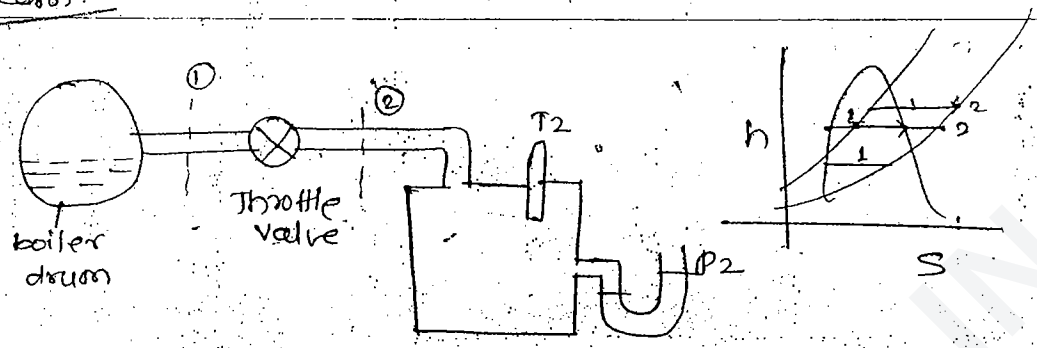




For determining the dryness fraction of steam we can be using different Methods

1. Throttling calorimeter
2. Separating & throttling calorimeter
3. electrical calorimeter

using any one of the above the dryness fraction can be determined. throttling calorimeter is used for determining the dryness fraction of high quality steam.



In this Method the steam is throttled to a higher pressure to a lower pressure. after throttling the temp & pressure are noted. but for good results the degree of superheat after throttling must be atleast 5 to 10°C. knowing the pressure and knowing the temp from the superheat table the enthalpy h_2 is calculated. befor throttling the steam is in wet state hence $h_2 = h_1$ or

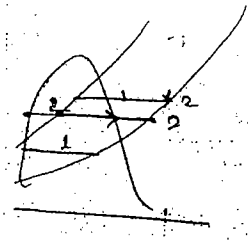
$h_2 = h_1$

$= h_{f1} + x(h_{g_1} - h_{f1})$

$$x = \frac{h_2 - h_{f1}}{h_{g_1} - h_{f1}}$$

for minimum quality condition after throttling steam should dry and saturated using the above set up any quality above x_1 can be determined by this Method. quality above 90% can be determined by the above set up by throttling Method.

is fraction
is used for
quality.



S

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- throttling
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rated
x_1' can
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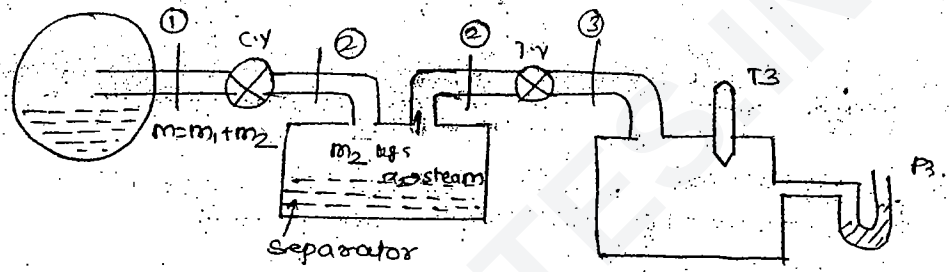
by

for low quality steam separating and throttling calorimeter used.



mass of water = m_1 kgs.

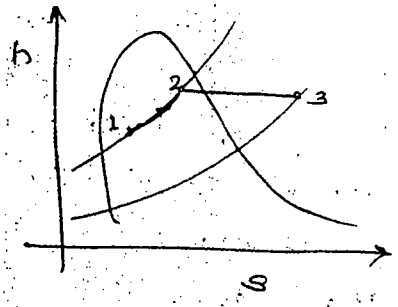
Dryness fraction in separator = $\frac{\text{mass of steam}}{\text{total mass}}$

$= \frac{m_2}{m_1+m_2}$

In the separator water is separated and low quality steam is converted to high quality steam and high quality steam is throttled to higher pressure to lower pressure.

After throttling the pressure and temp are measured and from superheat tables the enthalpy h_3 can be calculated.

After throttling the pressure at P_3 and temp T_3 are noted from which enthalpy calculated.



$h_3 = h_2 = h_{f2} + x_2 (h_{g2} - h_{f2})$

$x_2 = \frac{h_3 - h_{f2}}{h_{g2} - h_{f2}}$

mass of vapor = $x_2 m_2$

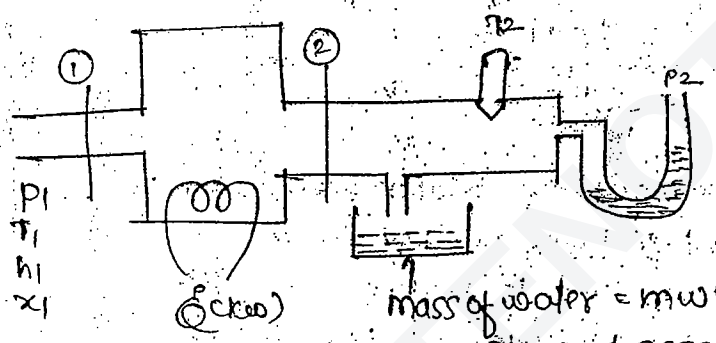
whatever is the mass of vapor ... final stage is nothing but mass of vapor generate in the boiler

Dryness fraction in steam of boiler = x

$$x = \frac{\text{mass of vapor}}{\text{total mass}} = \frac{x_2 m_2}{m_1 + m_2}$$

$$\boxed{x = x_2 x_1}$$

Electrical calorimeter:



$$\text{mass flow rate} = \dot{m} = \frac{m_w}{t} \ (kg/sec)$$

The steam flowing is heated by means of heater afterwards the pressure P_2 and temp T_2 are noted and pressure P_2 and temp T_2 enthalpy h_2 is calculated

Apply SFEE

$$\dot{m}h_1 + \dot{Q} = \dot{m}h_2 + \dot{w}$$

$$h_1 = h_2 - \frac{\dot{Q}}{\dot{w}}$$

$$h_{f1} + x(h_{s1} - h_{f1}) = h_2 - \frac{\dot{Q}}{\dot{m}}$$

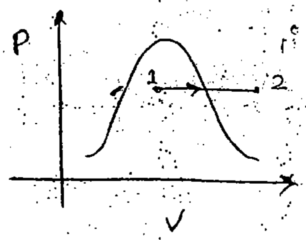
$$\boxed{x = \frac{\left(h_2 - \frac{\dot{Q}}{\dot{m}}\right) - h_{f1}}{(h_{g1} - h_{f1})}}$$

Generate in

Various processes involving steam

Non-flow process :

Isobaric :- $p_1 = p_2 = p$



$$ {}_1Q_2 - {}_1W_2 = {}_1U_2 $$

$$ {}_1Q_2 = {}_1W_2 + {}_1U_2 $$

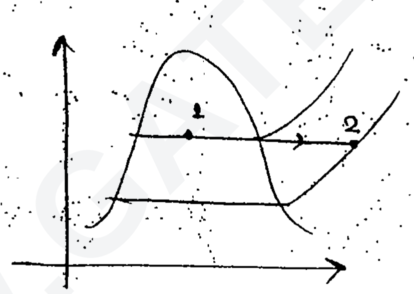
$$ = p(V_2 - V_1) + {}_1U_2 $$

$$ = (p_2V_2 - p_1V_1) + U_2 - U_1 $$

$$ = (U_2 + p_2V_2) - (U_1 + p_1V_1) $$

$$ \boxed{{}_1Q_2 = (h_2 - h_1)} $$

Isothermal process : $T = C$



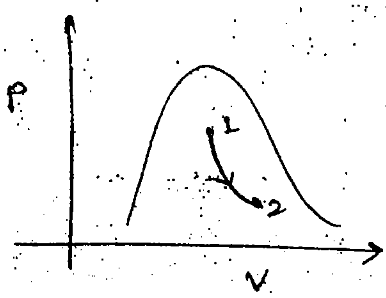
$$ {}_1Q_2 - {}_1W_2 = {}_1U_2 $$

$$ {}_1W_2 = {}_1Q_2 - {}_1U_2 $$

$$ \boxed{{}_1W_2 = T(S_2 - S_1) - (U_2 - U_1)} $$

Hyperbolic process

of heater
is are
alpy h_2 is



$pv = RT$ eqn is not valid in the vapor dome but

$p_1v_1 = p_2v_2$ is valid.

$$ \boxed{pv \neq RT} $$

$$ {}_1Q_2 - {}_1W_2 = {}_1U_2 $$

$$ {}_1Q_2 = (U_2 - U_1) + {}_1W_2 $$

$$ = (U_2 - U_1) + p_1V_1 \ln \frac{V_2}{V_1} $$

$$ = \left[(h_2 - p_2v_2) - (h_1 - p_1v_1)\right] + p_1v_1 \ln \frac{v_2}{v_1} $$

$$ = (h_2 - h_1) + p_1v_1 \ln \frac{v_2}{v_1} $$

Constant volume process $v=c$ $V_1 = V_2$

$V_1 = V_2$

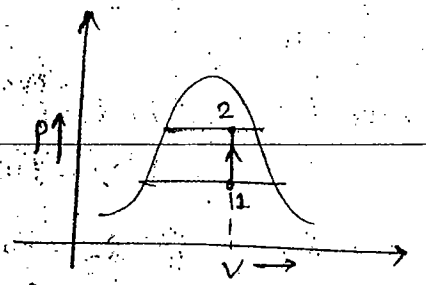
$x_1 v_{g_1} = x_2 v_{g_2}$

$1Q_2 - 1W_2 = 1U_2$

$1Q_2 = 1U_2 = U_2 - U_1$

$= (h_2 - p_2V_2) - (h_1 - p_1V_1)$

$$\boxed{1Q_2 = (h_2 - h_1) - V(p_2 - p_1)}$$



Polytropic process $pv^n = c$

$1Q_2 - 1W_2 = 1U_2$

$1Q_2 = (U_2 - U_1) + 1W_2$

$= (U_2 - U_1) + \frac{p_1V_1 - p_2V_2}{n-1}$

$\left[(h_2 - p_2V_2) - (h_1 - p_1V_1)\right] + \frac{p_1V_1 - p_2V_2}{n-1}$

$$\boxed{1Q_2 = (h_2 - h_1) + \frac{n}{n-1}(p_1V_1 - p_2V_2)}$$

Flow process

$h_1 + Q_1 = h_2 + W$

constant volume $v = c$

$V_1 = V_2 = V$

$1W_2 = V(p_1 - p_2)$

$Q = (h_2 - h_1) + W$

$= (h_2 - h_1) + V_1p_1 - V_2p_2$

$= (h_2 - p_2V_2) - (h_1 - p_1V_1)$

$= (U_2 - U_1)$

Constan

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Adiab

Polyt

$1Q_2$

$1Q_2$

For c

a ref

for c

steam

triple

h_{triple}

h_{TP}

Constant pressure $W=0$

$$Q = (h_2 - h_1)\ kJ/kg.$$

Isothermal process

$$h_1 + Q = h_2 + w$$

$$Q = h_2 - h_1 + w$$

$$Q = (h_2 - h_1) + p_1 v_1 \ln\left(\frac{v_2}{v_1}\right)$$

Adiabatic process

$$Q = 0$$

$$h_1 = h_2 + w$$

$$w = (h_1 - h_2)\ kJ/kg.$$

polytropic process $pv^n = c$

$$1Q_2 = 1W_2 + (h_2 - h_1)$$

$$1Q_2 = (p_1 v_1 - p_2 v_2)\frac{n}{n-1} + (h_2 - h_1)$$

$$\boxed{1Q_2 = \left(\frac{p_1 v_1 - p_2 v_2}{n-1}\right) + (u_2 - u_1)}$$

For construction a steam table we required a refeserce point. what is the reference point for construction a steam table.

A reference point for the constructed steam table is triple point of water at the triple paint of water we assume that $v=0$, $s=$

$$\boxed{h_{\text{triple point (TP)}} = p_{TP} - v_{TP}}$$

$h_{TP} \neq 0$

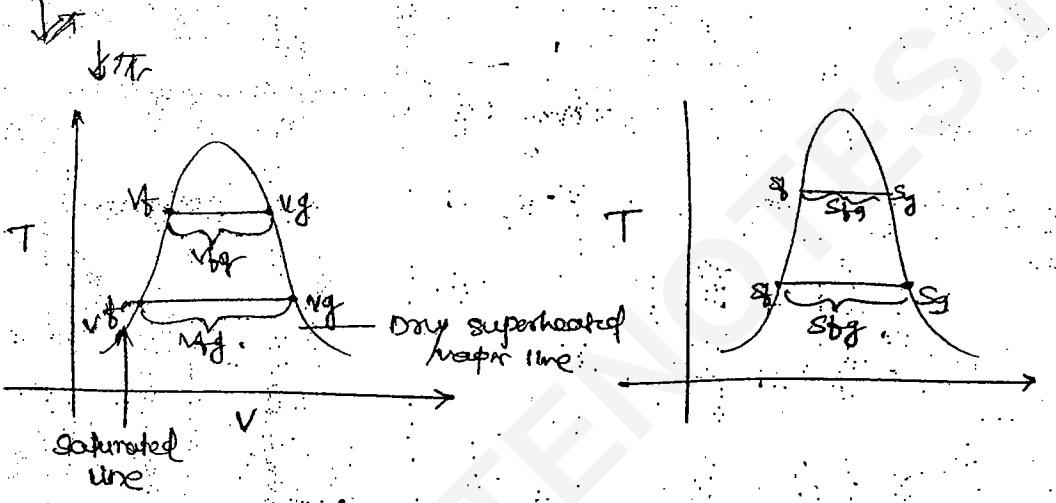
Next Steam table classification

① pressure classification
② Temp classification
③ Superheat tables

$P_{sat} \rightarrow T_{sat}, v_f, v_g, h_f, h_g, h_{fg}, s_f, s_g,$

$T_{sat} \rightarrow P_{sat}, P_f, P_g, h_f, h_g, h_{fg}, s_f, s_g.$

$P_{sat} \rightarrow T_{sat} \rightarrow \downarrow T, h, v, S$



$P_{sat} \uparrow T_{sat} \uparrow v_f \uparrow v_g \downarrow v_{fg} \downarrow s_f \uparrow s_g \downarrow s_{fg} \downarrow h_f \uparrow$

h_g increases up to particular value later its start decreases. and h_{fg} decreases

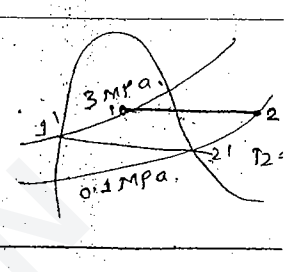
h_g goes on increasing upto 240°C from 240°C to critical temp h_g values start decreasing.

Pg No 25 Qu 1.5

$P_2 = 100 kpa$

$T_{sat} = 99.6°C$

$T_2 > T_{sat}$



$100 kpa \quad T_2 = 120°C \quad h_2 = 2716.2 kJ/kg$

$h_2 = h_1 + x(h_{g_1} - h_{f_1})$

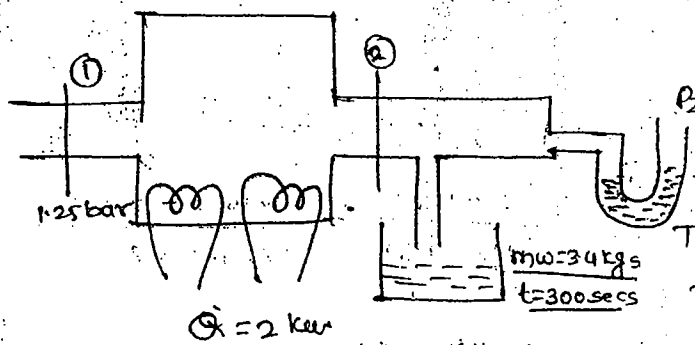
$2716.2 = 1008.3 + x(2802.3 - 1008.3)$

$x = \frac{2716.2 - 1008.3}{2802.3 - 1008.3}$

$x = 0.95$ (high quality steam)

For minimum quality condition the enthalpy after throttling. Any quality above minimum quality can be determined using the existing set-up.

Qu 1.6



$h_2 = 2736.2 kJ/kg.$

Apply SFEE

$\dot{m}h_1 + \dot{Q} = \dot{m}h_2 + \omega$

$h_1 = h_2 - \frac{\dot{Q}}{\dot{m}} = h_{f_1} + x(h_{g_1} - h_{f_1})$

$\dot{m} = \frac{m_\omega}{t} = \frac{3.4}{300} = 0.113 kg/sec$

$h_1 = h_2 - \frac{\dot{Q}}{0.0013} = 2736.2 - \frac{2}{0.0113}$

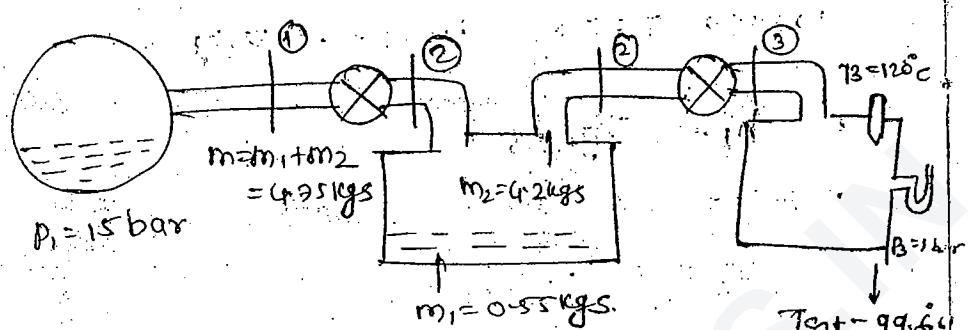
$= 2559.72 kJ/kg.$

$h_{f1} + x(h_{g_1} - h_{f1}) = h_4$

$444.4 + x(2685.2 - 444.4) = 2559.72$

$\boxed{x = 0.944}$

Qu 12:

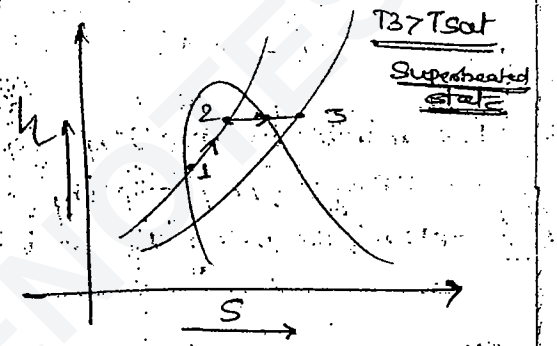


x_4 = dryness fraction in Separator

$= \frac{m_2}{m_1 + m_2}$

$= \frac{4.2}{4.75}$

$= 0.884$



from Superheated table

$h_3 = 2716.2$ kJ/kg

$h_{f_2} + x_2(h_{g_2} - h_{f_2}) = h_3$

$x_2 = \frac{h_3 - h_{f_2}}{h_{g_2} - h_{f_2}} = \frac{2716.2 - 844.6}{2789.9 - 844.6} = 0.962$

Mass of vapor $= x_2 m_2$

$= 0.962 \times 4.2$

$= 4.04$ kg/s

Whatever the mass of vapor coming at final stage is nothing but mass of vapor generated in boiler.

dryness fraction in boiler $= \frac{m_v}{m_1 + m_2}$

$= \frac{4.04}{4.75}$

$x = 0.85$

Qu 13:

$x < x_4$

Mass b

ma

$\dot{m}_2$

5000

Ener

$\dot{m}$

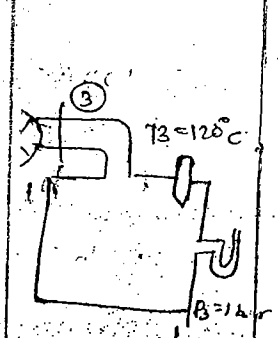
50

$x = x_1 x_2$

$= 0.884 \times 0.962 = 0.85$

$\boxed{x < x_1 < x_2}$

Ques 3:



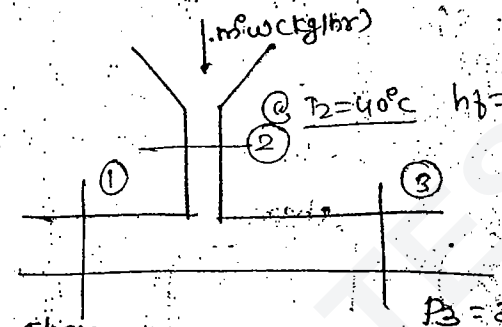
$T_{sat} = 99.6$

$T3 > T_{sat}$

Superheated state

3

$= 0.962$



$P_1 = 5$ bar

$T_1 = 300°C$

$T_{sat} = 151.9°C$

$T_1 > T_{sat}$ hence it is in superheated state

$h_1 = 3064.8$ kJ/kg

$\dot{m}_s = 5000$ kg/hr.

$P_3 = 3$ bar

$x_3 = 0.95$

$h_3 = h_{f3} + x_3 (h_{g3} - h_f)$

$h_3 = h_{f3} + x_3 (h_{g3} - h_{f3})$

$= 651.4 + 0.95 (2724.7 - 651.4)$

$= 2621$ kJ/kg.

$\dot{m}_3 = \dot{m}_s + \dot{m}_w$

Mass balance

mass entering = Mass leaving

$\dot{m}_s + \dot{m}_w = \dot{m}_3$

$5000 + \dot{m}_w = \dot{m}_3$

Energy balance

$\dot{m}_s h_1 + \dot{m}_w \times h_{f2} = \dot{m}_3 h_3$

$5000 \times 3064.8 + \dot{m}_w \times 167.5 = (5000 + \dot{m}_w) 2621$

$\dot{m}_w = 904$ kg of water

cal stage

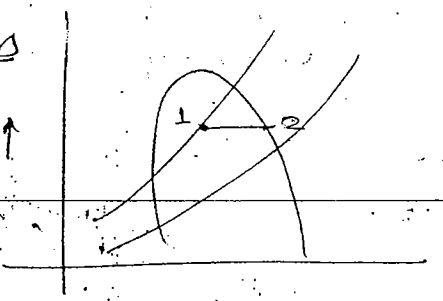
in boiler.

Throttling process

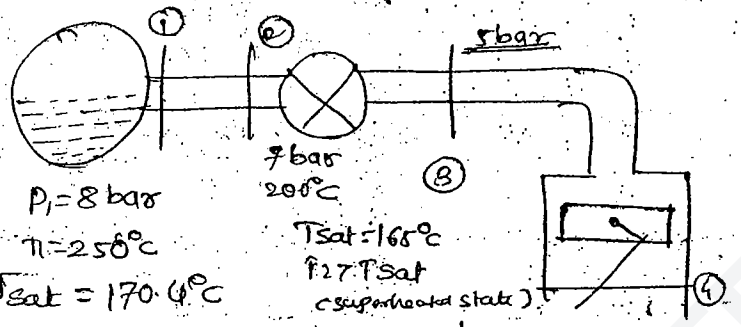
$h_1 = h_2$

T↓ S↑ x↑

P↓ v↑



Qu 4:



$P_1 = 8$ bar

$T_1 = 250°C$

$T_{sat} = 170.4°C$

$T_2 = 200°C$

$T_{sat} = 165°C$

$T_2 > T_{sat}$ (superheated state)

$P_4 = 0.1$ bar

T_4 x = 0.9

$T_2 > T_{sat}$ (superheated state)

$h_2 = 2864$ kJ/kg.

$h_1 = 2930$ kJ/kg

$S_1 = 6.815$ kJ/kg

$S_2 = 6.886$ kJ/kg K

a) 3 at 5 bar

$T_{sat} = 151.9°C$

$h_g = 2747.5$ kJ/kg.

as it is throttling process $h_2 = h_3$ & $h_3 > h_g$ at 5 bar

$h_3 = h_g + C_{p\,vapor}(T_3 - T_{sat})$

$2864.2 = 2747.5 + 2.1(T_3 - 151.9)$

$\boxed{T_3 = 197.9\ °C}$

$S_3 = S_g + C_{p\,vapor} \ln\left(\frac{T_3}{T_{sat}}\right)$

$= 6.819 + 2.1 \ln\left(\frac{273 + 197.9}{273 + 151.9}\right)$

$= 7.03$ kJ/kg K

$h_4 = h_{f4} + x(h_{g4} - h_{f4})$

$h_4 = 191.8 + 0.9(2584.8 - 191.8)$

$= \underline{2345.5}$

$S_4 = S_{f4} + x(S_{g4} - S_{f4})$

$= 0.649 + 0.9(8.151 - 0.649)$

$= 7.4$ KJ/kg.

Apply SFEE : pipeline work = 0

$h_1 + Q_p = h_2 + W$

$Q_p = (h_2 - h_1)$

$= 2846 - 2930$

heat loss $= -86$ KJ/kg.

Temp drop $= (T_2 - T_3) = 200 - 197.9 = \underline{2.1°C}$

$= 0.1$ bar

$x = 0.9$

Work out of engine we assume $Q = 0$

$h_3 + Q = h_4 + W$

$W = h_3 - h_4$

$= 2846 - 2345.5$

$= \underline{498.5}$ KJ/kg

5 bar

entropy change in throttle valve $= (S_3 - S_2)$

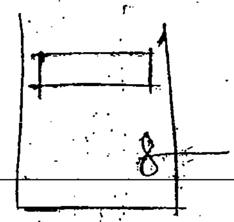
$(S_3 - S_2) = 7.03 - 6.886 = \underline{0.144}$

entropy change in engine $= (S_4 - S_3)$

$(S_4 - S_3) = (7.4 - 7.03)$

$= \underline{0.37}$

Q.4



$p_2 = 700$ kpa.
$T_2 = 400°c$.
~~$h_2 = 3269$ KJ/kg~~
$v_2 = 0.44\ m^3/kg$
$U_2 = h_2 - P_2 V_2$
$= 3269 - 700 \times 0.44$
$= 2961$ KJ/kg.

$P_1 = 700$ kpa
$T_1 = 300°C$
$h_1 = 3059$
$V_1 = 0.371$
$U_1 = h_1 - P_1 V_1$
$= 3059 - 700 \times 0.371$
$= \underline{2799.3}$ KJ/kg.

Work $= P(V_2 - V_1)$
$= 700\,(0.44 - 0.371)$
$= \underline{48.3}$ KJ/kg.

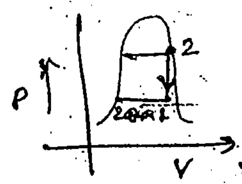
$U_1 + Q = U_2 + W_S - W_P$
$Q = (U_2 - U_1) + (W_S - W_P)$
$0 = (2961 - 2799.3) + 48.3 - W_P$
$W_P = +210$ KJ/kg

$\Delta h = (h_2 - h_1)$
$= (3269 - 3059) = \underline{\underline{210}}$

$\Delta U = U_2 - U_1 = 2961 - 2799.3 =$ ~~160~~ $\underline{\underline{161.7}}$

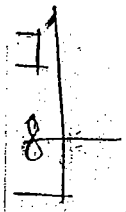
Q.7: Pg No: 25

$V = 3m^3$
$m = 5kgs$
$P = 200kpa$
sp vol^m $= v = \frac{volume}{mass} = \frac{3}{5} = 0.6\ m^3/kg$.



$v_{g_1} = 0.885\ \frac{m^3}{kg}$

$v_1 = 0$
$0.6 =$
x_1
$h_1 = h$
$= 50$
$= 19$
$U_1 = h$
$= 1$
$=$
$Q_1 =$
table sc
300 k
810 k
$\Delta p =$
ΔV
$\Delta p'$
2742.7 − h



$v_1 = 0.6 \frac{m^3}{kg} = x_1 v_{g_1}$

$0.6 = x_1 \times 0.885$

$x_1 = \frac{0.6}{0.885} = 0.628$

$h_1 = h_{f1} + x_1 (h_{g_1} - h_{f1})$

$= 504.7 + 0.678 (2706.3 - 504.7)$

$= 1997.3848$ kJ/kg.

$U_1 = h_1 - p_1 v_1$

$= 1997.38 - 200 \times 0.6$

$= 1887$ kJ/kg.

$v_1 = v_1 = 0.6$ m³/kg but condition is dry and saturated therefore refering the vg column for a value of 0.6 m³/kg

800 kPa ← P_2	0.6053 ← 0.6	2724.7 ← h_2
810 kPa	0.5872	2726.1

$\Delta p = -10$ kPa $\Delta v = 0.0181$ $\Delta h = 1.4$

$\Delta v' = 0.0053$ $\Delta h' = ?$

$\Delta p' = \frac{\Delta v'}{\Delta v} \times \Delta p$ $\frac{0.0053}{0.0181} \times (-10)$

$8150 - P_2 = -2.928$

$\boxed{P_2 = 302.92 \text{ kPa}}$

$\boxed{\Delta h' = \frac{\Delta v'}{\Delta v} \times \Delta h}$

$2742.7 - h_2 = \frac{0.0053}{0.0181} \times (-1.4)$

$\boxed{h_2 = 2743.109}$

$U_2 = h_2 - p_2 v_2$

$= \underline{2725.1 - 302.92 \times 0.6} = 2543.348$ kJ/kg.

$v_{g_1} = 0.885 \frac{m^3}{kg}$

$= 700 \times 0.331$

99.3 kJ/kg.

ner) cy process $W_2 = 0$

$U_1 + Q = Q_2 + 0$

$Q = U_2 - U_1$

$= 2543 - 1877$

$= 666$ kJ/kg.

total heat transfer : $5 \times 666 = 3330$

pg No 26 Qu. No 9 :

$\dot{m}_1 = 3$ kg/min

$P_1 = 2$ MPa

$T_1 = 300°C$

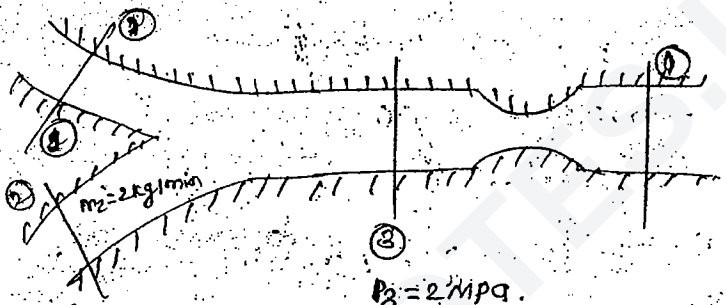
~~T=~~ $T_{sat} = 212°C$

$T_1 > T_{sat}$

Superheated state

$h_1 = 3025$ kJ/kg

$s_1 = 6.77$ kJ/kg K



$P_2 = 2$ MPa

$T_2 = 400°C$

$T_{sat} = 212°C$

$T_2 > T_{sat}$ / Superheated state

$h_2 = 3248.6$ kJ/kg

$S_2 = 7.13$ kJ/kg K

$P_3 = 2$ MPa.

Mass balance

Mass entering = Mass leaving

$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$

$\dot{m}_3 = 2 + 3 = 5$ kg/min

Energy balanced

Energy entering = Energy leaving

$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$

$3 \times 3025 + 2 \times 3248.6 = 5 h_3$

$h_3 = 3114.44$ kJ/kg

$P_3 = 2$ MPa.

300°C 3025 6.77

T_3 3114.44 S_3

350°C 3138.6 ~~4.96~~

$\Delta T = -50°C$ $\Delta h = -113.6$

$\Delta S = -0.19$

$\Delta h' = -89.4$

$\Delta T' = ?$ $\Delta S' = ?$

$\Delta T' = \frac{\Delta h'}{\Delta h} \times \Delta T$

$= \frac{-89.4}{-113.6} \times (-50)$

$= -39.34$ °c

$300 - T_3 = -39.35$

$39.35 = T_3$ °c.

$$\Delta S^1 = \frac{\Delta h^1}{\Delta h} \times \Delta S = \frac{-89.4}{-113.6} \times (-0.19) = -0.15$$

$$6.77 - s_3 = -1.5$$

$$\boxed{s_3 = 6.919 \text{ kJ/kg}}$$

$$\Delta S_{system} = m_3 s_3 - m_1 s_1 - m_2 s_2$$

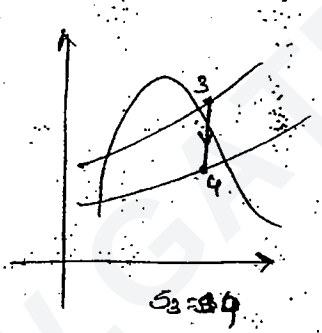
$$= 5 \times 6.919 - 3 \times 6.72 - 2 \times 7.13$$

$$= 0.0275 \text{ kJ/k min}$$

$$(\Delta S)_{surr} = 0$$

$$(\Delta S)_{min} = (ds)_{surr} + (ds)_{sy} = 0.0275 \text{ kJ/k min}$$

value is > 0 this is irreversible process



$$6.919 = s_{f4} + x(s_{g4} - s_{f4})$$

$$= 0.0106 + x(8.977 - 0.106)$$

$$x = \frac{6.919 - 0.106}{8.977 - 0.106}$$

$$x = 0.768$$

$$h_4 = h_{f4} + x(h_{g4} - h_{f4})$$

$$= 129.3 + 0.768(2514.4 - 29.3)$$

$$= 1937.86 \text{ kJ/kg}$$

$$v_4 = x v_{g4}$$

$$= 0.768 \times 129.4$$

$$= 99.36 \text{ m}^3/\text{kg}$$

$V = 44.72\sqrt{(h_3 - h_4)}$

$= 44.72\sqrt{(3114.41 - 1937.86)}$

$= 1533.9$ m/sec

$\dot{m} = \frac{AV}{v}$

$\frac{5}{60} = \frac{A \times 1533.9}{999.38}$

$A = 5.395 \times 10^{-3}\ m^2$

$A = \pi/4\ d^2$

$d = \sqrt{\frac{5.395 \times 10^{-3} \times 4}{\pi}} = 0.02620$

Qu 10

$P_1 = 15$ bar

$T_1 = 200°C$

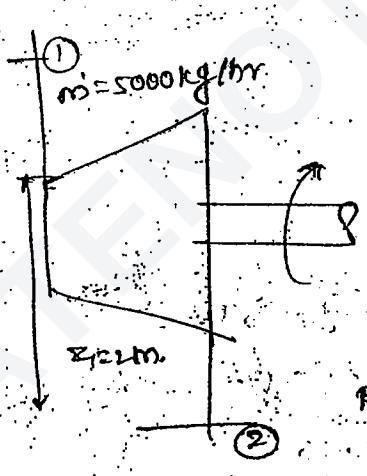
$T_{sat} = 188°C$

$T_1 > T_{sat}$

Superheated steam

$h_1 = 3038.9$ KJ/kg

$S_1 = 6.921$ KJ/kg.



Velocity initial $V_1 = 80$ m/s

$P_2 = 0.1$ bar

$x_2 = 0.96$

$h_2 = h_{f2} + x_2(h_{g_2} - h_{f2})$

$= 191.8 + 0.96(2584.9 - 191.8)$

$= 2489.17$ KJ/kg

$V_2 = x_2 \times v_{g2}$

$= 0.96 \times 14.67$

$= 14.08$ m³/kg.

$V_2 = 60$ m/s.

Qu 11

bar

96

$x_2(h_{g_2} - h_{f_2})$

$0.961(2584.9 - 191.8)$

17 kJ/kg

7

kJ/kg.

Apply SFEE:

$$\dot{m}\left(h_1 + \frac{V_1^2}{2000} + \frac{z_1 g}{1000}\right) + \frac{dQ}{dt} = \dot{m}\left(h_2 + \frac{V_2^2}{2000} + \frac{z_2 g}{1000}\right) + \frac{dW}{dt}$$

$$\frac{dW}{dt} = \dot{m}(h_1 - h_2) + \dot{m}\left(\frac{V_1^2 - V_2^2}{2000}\right) + \frac{\dot{m}(z_1 - z_2)g}{1000}$$

$$= \frac{5000}{3600}(3038.9 - 2489.17) + \frac{5000}{3600}\left(\frac{80^2 - 40^2}{2000}\right) + \frac{5000}{3600}\frac{(2)\,9.81}{1000}$$

$$= 763.513 + \cancel{666.67}\,3.33 + 0.02725$$

$$= 742\,kW$$

$$\left(\frac{dW}{dt}\right)_{KE=PE=0} = 763.51\ kW.$$

$$\left(\frac{dW}{dt}\right)_{\text{with } KE \,\&\, PE} = 766.81\ kW$$

$$\dot{m} = \frac{AV}{v}$$

$$\frac{5000}{3600} = \frac{A_1 \times 80}{0.1697} = \frac{A_2 \times 40}{14.08}$$

$$A_1 = 2.9486\ m^2$$

$$A_2 = 0.488\ m^2.$$

$$\frac{\pi}{4} d_1^2 = 2.9486$$

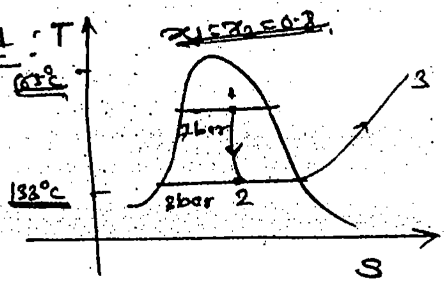
$$\frac{\pi}{4} d_2^2 = 0.488$$

$$d_1 = 1.9375$$

$$d_2 = 0.788$$

~~Qu.11~~

Qu.11 :



$$h_1 = h_{f_1} + x_1(h_{g_1} - h_{f_1})$$

$h_1 = 6473 + 0.8(2702 - 6473)$

$= 2349.06$ kJ/kg

$s_1 = s_{f1} + x_1(s_{g1} - s_{f1})$

$= 1.992 + 0.8(6.705 - 1.992)$

$= \underline{5.762}$ kJ/kg K

State 2: $h_2 = h_{f2} + x_2(h_{g2} - h_{f2})$

$= 651.4 + 0.8(2924.7 - 651.4)$

$= 2310.04$ kJ/kg

$s_2 = s_{f2} + x_2(s_{g2} - s_{f2})$

$= 1.672 + 0.8(6.991 - 1.672)$

$= 5.927$ kJ/kg K

State 3: $T_3 - T_{sat} = 66.5°C$

$T_3 - 133.5 = 66.5$

$T_3 = \underline{200°C}$

$h_3 = 2865.5$ kJ/kg

$s_3 = 7312$ kJ/kg K

1-2

$\Delta h = h_2 - h_1$

$= 2310.04 - 2349.06$

$= -39.02$ kJ/kg

$\Delta s = s_2 - s_1$

$= 5.927 - 5.962$

$= \underline{0.165}$ kJ/kg K

2-3

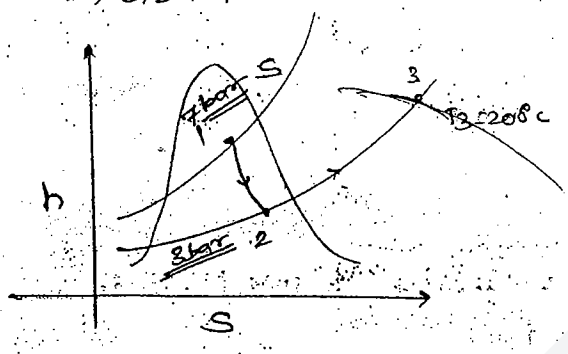
$\Delta h = h_3 - h_2$

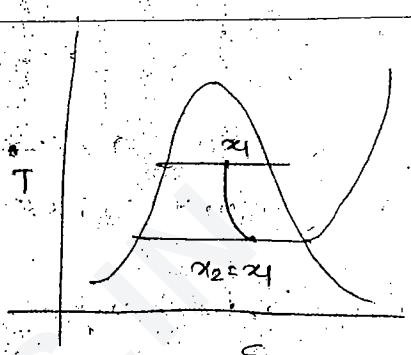
$= 2865.5 - 2310.04$

$= 555.46$

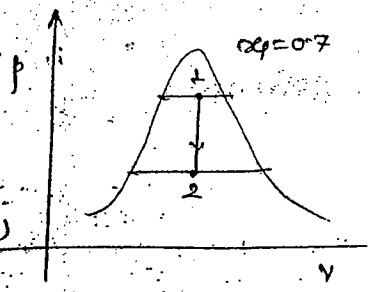
$\Delta S = S_3 - S_2$

$= 7.312 - 5.927 = 1.38$





Qu·3 $V = 1 m^3$



State ① $v_1 = v_{f1} + x_1 (v_{g1} - v_{f1})$

$= v_{f1} + x_1 (v_{fg_2} - v_{f1})$

$= 0.001073 + 0.7 (0.6058 - 0.001073)$

$= 0.424 \frac{m^3}{kg}$

$h_1 = h_{f1} + x (h_{fg})_1$

$= 561.47 + 0.7 (2163.8)$

$= 2076$ KJ/kg

$U_1 = h_1 - P_1 V_1 = 2076 - 300 \times 0.424 = 1948.8$ KJ/kg.

State ② $v_1 = v_2$

$0.424 = v_{f2} + x_2 (v_{g_2} - v_{f2})$

$= 0.001061 + x_2 (0.8857 - 0.00106)$

$x_2 = 0.47$

$h_2 = h_{f2} + x_2 (h_{g_2} - h_{f2}) =$

$= 504.7 + 0.47 (2201.9)$

$= 1539.5$ KJ/kg

$U_2 = h_2 - P_2 V_2 =$

$= 1539.5 - 200 \times 0.424$

$= 1454.87$ KJ/kg

$m = \frac{V_1}{v_1} = \frac{1}{0.429} = 2.358$ kgs

mass of vapor = $0.7 \times 2.35 = 1.645$

mass of liquid = $0.3 \times 2.35 = 0.705$

Energy loss = change

It is a non flow process volume is constant work done is zero. heat transfred

$Q = m(u_2 - u_1)$

$= 2.35\ (1952.87 - 1968.8)$

$= -1160.7355$ kJ

heat loss to surrounding

Pg.No 52 Qu.No 17 & 18

Ans 17 :

u_f	h_f	s_f	s_g	u_g	h_g
85.76	89.05	0.3057	5.6155	1249.5	1418.0

Ans (d)

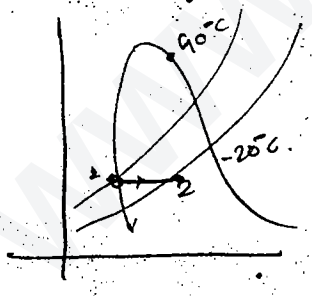
$s_g - s_f = \frac{h_g - h_f}{T_{sat}}$ $\quad h_f > u_f$, $h_g > u_g$.

$253\left[5.6155 - 0.3657\right] = 1418 - 89.05$

Single digit values are entropy

double & triple digit are u_f & h_f

four digit value are h_g & u_g



$h_1 = h_2$

@ 40°C

$h_1 = h_2 = h_{f2} + x_2(h_{g2} - h_{f2})$

$391.48 = 89.05 + x_2(1418 - 89.05)$

$x_2 = 0.212$

(17)

v_f at

(u_f)

(h_f)

150 bar

pg NO 23 Qu

Qu.2 :

Qu.3 (d)

Qu.4 :

Qu.5 :

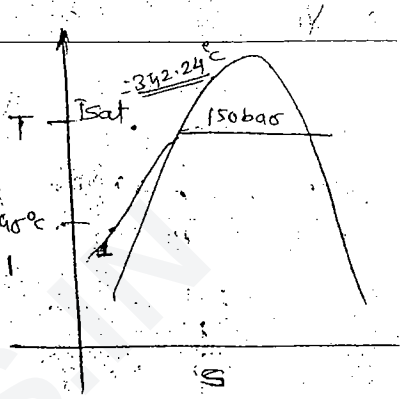
(19).

v_f at 45°C = 0.001010 m^3/kg.

$(v_f)_{45°C} = (h_f)_{45°} - P_b v_f$

$= 188.45 - \frac{150 \times 100 \times 0.00101}{0.0959}$

$= \cancel{173.3}$ 188.44 kJ/kg.

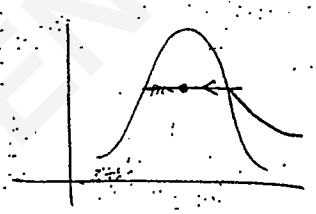


$(h_f)_{150bar,45°C} = \cancel{150bar} = (v_f)_{45°C} + P(v_f)_{45°C}$

$= 188.44 + 150 \times 100 \times 0.0010$

$= 203.60$ kJ/kg.

pg NO 23 QU.NO 1



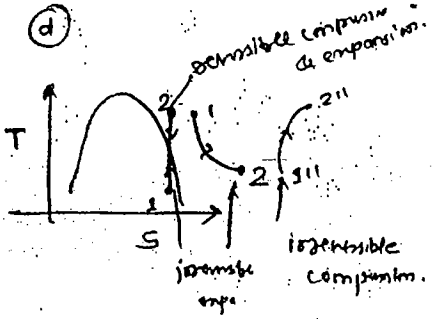
Qu.2 ↑ Psat ↙ Tsat ↑ → h_{fg} ↓ Tsat ↑ – (h_{fg}) ↓

Psat ↓ = specific volume ↑

x ↑ – s ↑

Qu.3 (d)

Qu.4:



Qu.5: $v_g - v_f = \frac{dT_S}{dP} \times \frac{h_{fg}}{T_{sat}}$

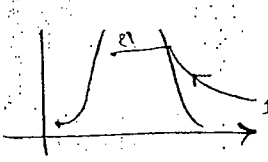
$= \frac{K}{kPa} \times \frac{kJ/kg}{K}$

$\frac{kJ}{kPa \cdot kg} = \frac{m^3}{kg}$

Qu.6 R-solid region
S - solid + liquid
T - liquid region
M - liquid + vapor
U - superheated vapor
X - superheated gas
V - solid + vapor.

05)

Qu. 1 (c) Isothermal



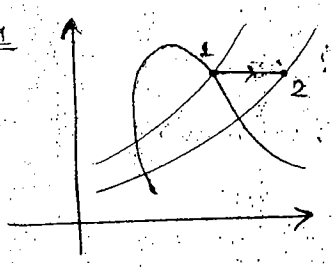
Qu. 8

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{0.286} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}$$

$$\frac{n-1}{n} = 0.286$$

$$\boxed{n = 1.4}$$

Qu. 9



h constant in throttling

P↓ x↑ 0 T↓ S↑

STIRLIN

A Stirlin

Regenerat

heat to

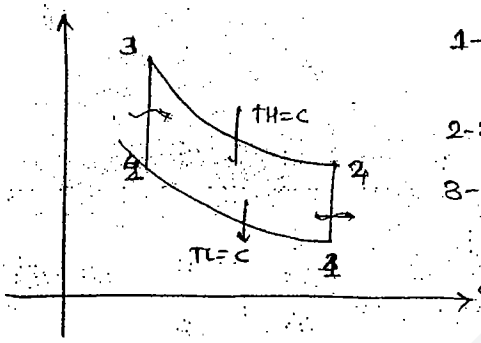
1-2 T=

Q_2

2-3

AIR CYCLE

STIRLING CYCLE

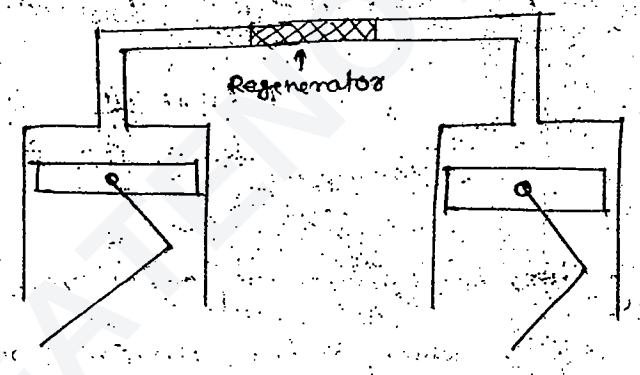


1-2 ⇒ Reversible isothermal heat rejection

2-3 ⇒ constant volume heat supply (internal)

3-4 ⇒ Reversible isothermal heat supply

4-1 ⇒ constant volm heat rejection (internal)



A stirling cycle function in combination with a regenera Regenerator is a device which alternately stored & reject heat to run the engine

1-2 $T=C$

$$1Q_2 = 1W_2 = p_1V_1 \ln\left(\frac{V_2}{V_1}\right)$$

$$= RT_L \ln\left(\frac{V_2}{V_1}\right)$$

$$= RT_L \ln\left(\frac{V_1}{V_2}\right)$$

2-3 $V=C$

$$\frac{P_2}{T_2} = \frac{P_3}{T_3}$$

$$2Q_3 = C_V(T_3 - T_2)$$

3-4 $T = C$

$$3Q_4 = 3W_4 = P_3 V_3 \ln \frac{V_4}{V_3}$$

$$= RT_H \ln \frac{V_4}{V_3}$$

4-1 $V = C$

$$\frac{P_4}{T_4} = \frac{P_1}{T_1}$$

$$4Q_1 = C_v (T_4 - T_1)$$

$$\eta_{thermal} = \frac{Q_S - Q_R}{Q_S} = \frac{RT_H \ln \frac{V_4}{V_3} - RT_L \ln \frac{V_2}{V_1}}{RT_H \ln \frac{V_4}{V_3}}$$

$$\boxed{\eta_{th} = \frac{T_H - T_L}{T_H}}$$

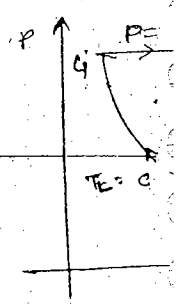
η thermal of stirling cycle is same as η carnot cycle.

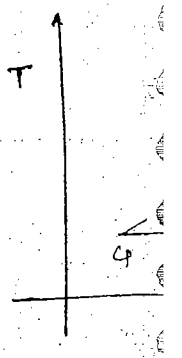
A regenerator is a device which automatally stored and reject heat hence it is never having 100% effiency.

∴ The actual effiiciency of stirling cycle is less than the carnot cycle

In stirling back work, pump work or compressive work is less Wnet is high and stroke volume is less when compared to carnot cycle, and M.E.P is high when compared to carnot cycle.

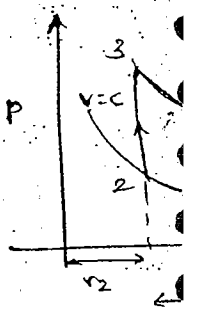
Stirling cycle ran at 27 rpm with 0.3% thermal effiiency

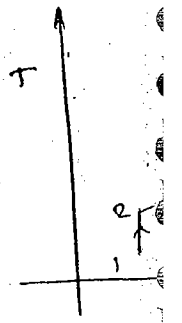




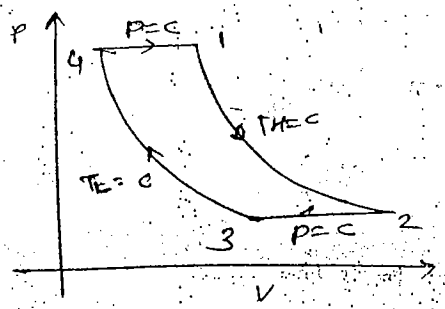
Erlass
here bac
and m.e

Otto

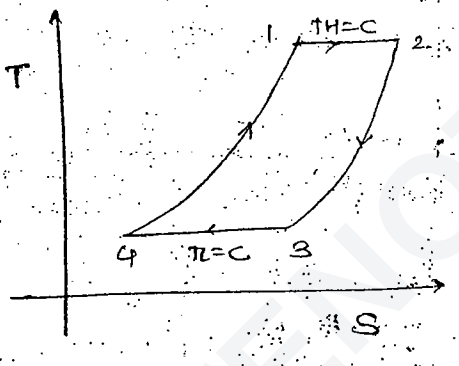




ERICSON CYCLE



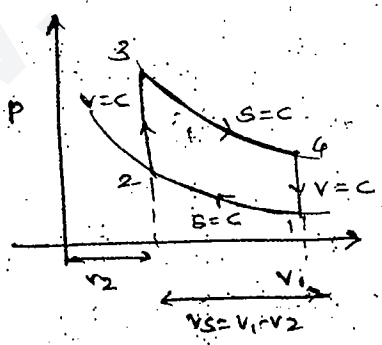
1-2 = Reversible isothermal expansion
2-3 = constant pressure heat rejection
internal
3-4 = Reversible isothermal comp
4-1 = constant pressure heat sup
internal



$$\eta = \frac{TH - TL}{TH}$$

Ericson cycle is an example of ideal gas turbine cycle here back work is less. Net is high stroke volm is le and m.e.p is high. when compared to carnot cycle

Otto cycle / SI cycle

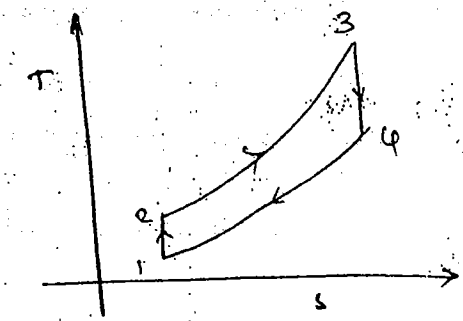


1-2 = Reversible adiabatic compressi
2-3 = constant volm heat supplied
3-4 = reversible adiabatic expansion
4-1 = constant volm heat rejection

compression ratio

$$\gamma R = \frac{V1}{V2} = \frac{VS + VC}{VC}$$

$$\frac{VS}{VC} = (\gamma R - 1)$$



1-2 - Reversible adiabatic compression

2-3 Constant volume heat supply

3-4 Reversible adiabatic expansion

4-1 Constant volume heat rejection

1-2 Reversible adiabatic compression

$Q = 0 \quad S = C$

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{\gamma} = P_1 \left(\frac{1}{k}\right)^{\gamma}$ ——— (1)

$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_1 \left(\frac{1}{k}\right)^{\gamma-1}$ ——— (2)

$T_1 P_1^{\frac{1-\gamma}{\gamma}} = T_2 P_2^{\frac{1-\gamma}{\gamma}}$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$ ——— (3)

$W_2 = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}$

$= \frac{R(T_1 - T_2)}{\gamma - 1} = C_V (T_1 - T_2)$ ——— (4)

2-3 $V = C$

$\frac{P_2}{T_2} = \frac{P_3}{T_3}$

$T_3 = T_2 \left(\frac{P_3}{P_2}\right)$ ——— (5)

$2Q_3 = C_V (T_3 - T_2)$ ——— (6)

3-4 Reversible adiabatic expansion

$Q=0, \quad S=C$

$$P_3 V_3^{\gamma} = P_4 V_4^{\gamma}$$

$$P_3 = P_4 \left(\frac{V_4}{V_3}\right)^{\gamma}$$

$$= P_4 (\varepsilon_E)^{\gamma} \quad \text{—(7)}$$

$$T_3 V_3^{\gamma-1} = T_4 V_4^{\gamma-1}$$

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

$$T_3 = T_4 (\varepsilon_E)^{\gamma-1} \quad \text{—(8)}$$

$$T_3 P_3^{\frac{1-\gamma}{\gamma}} = T_4 P_4^{\frac{1-\gamma}{\gamma}}$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{—(9)}$$

$$\delta 14_\phi = \frac{P_3 V_3 - P_4 V_4}{\gamma - 1}$$

$$= \frac{R(T_3 - T_4)}{\gamma - 1}$$

$$= C_V (T_3 - T_4) \quad \text{—(10)}$$

4-1 $V=C$

$\varepsilon_E = \varepsilon_k$

$$\frac{P_4}{T_4} = \frac{P_1}{T_1}$$

$$T_4 = \frac{P_4}{P_1} \times T_1 \quad \text{—(11)}$$

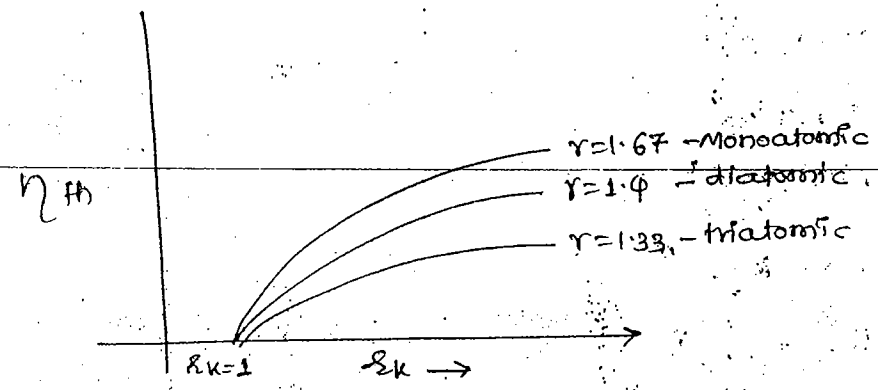
$$4Q_1 = C_V (T_4 - T_1) \quad \text{—(12)}$$

$$\eta_{\text{Thermal}} = \frac{Q_S - Q_R}{Q_S}$$

$$= 1 - \frac{Q_R}{Q_S}$$

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

$$= f(\varepsilon_k, \gamma)$$



ε_k = constant $\quad r \uparrow \ \eta_{th} \uparrow$

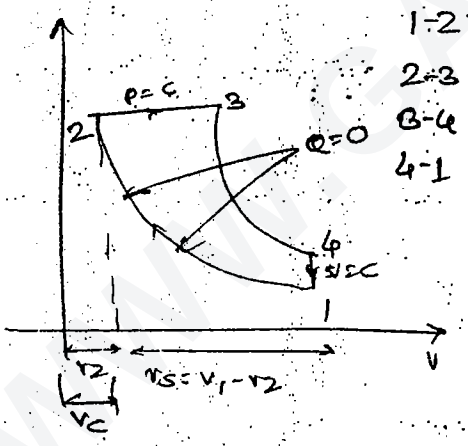
$r \downarrow \ \eta_{th} \downarrow$

r = constant $\quad \varepsilon_k \uparrow \ \eta_{th} \uparrow$

$\varepsilon_k \downarrow \ \eta_{th} \downarrow$

The maximum compression ratio up to which we can operate a SI engine/otto cycle is limited to 10 this is because of the detonating characteristic of fuel under consideration

Diesel cycle



1-2 ⇒ reversible adiabatic compression

2-3 ⇒ constant pressure heat supply

3-4 ⇒ reversible adiabatic expansion

4-1 ⇒ constant volume heat rejection

Comp ratio $= \varepsilon_k = \frac{V_1}{V_2}$

cut off ratio $\varepsilon_c = \frac{V_3}{V_2}$

Expansion ratio $= \varepsilon_E = \frac{V_4}{V_3} = \frac{V_1}{V_3}$

$$\frac{V_1}{V_2} = \frac{V_1}{V_3} \times \frac{V_3}{V_2}$$

$$\boxed{r_k = r_E \times r_c}$$

<u>1-2</u> $Q=0$ S=constant } Reversible adiabatic process

$$p_1 v_1^{\gamma} = p_2 v_2^{\gamma}$$

$$p_2 = p_1 \left(\frac{v_1}{v_2}\right)^{\gamma} = p_1 \, r_k^{\gamma} \quad \text{—①}$$

$$T_1 v_1^{\gamma-1} = T_2 v_2^{\gamma-1}$$

$$T_2 = T_1 \left(\frac{v_1}{v_2}\right)^{\gamma-1} = T_1 \, r_k^{\gamma-1} \quad \text{—②}$$

$$T_1 p_1^{\frac{1-\gamma}{\gamma}} = T_2 p_2^{\frac{1-\gamma}{\gamma}}$$

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{—③}$$

$${}_1W_2 = \frac{p_1 v_1 - p_2 v_2}{\gamma - 1}$$

$${}_1W_2 = \frac{R(T_1 - T_2)}{\gamma - 1} = c_v (T_1 - T_2) \quad \text{—④}$$

<u>2-3</u> constant pressure process

$$\frac{V_2}{T_2} = \frac{V_3}{T_3}$$

$$T_3 = \frac{V_3}{V_2} \times T_2 \quad \text{—⑤}$$

$${}_2Q_3 = c_p (T_3 - T_2) \quad \text{—⑥}$$

<u>3-4</u> $Q=0$ S=constant (reversible Adiabatic)

$$P_3 V_3^{\gamma} = P_4 V_4^{\gamma}$$

$$P_3 = P_4 \left(\frac{V_4}{V_3}\right)^{\gamma}$$

$$= P_4 (r_E)^{\gamma} \quad \text{—⑦}$$

$$\boxed{r_E < r_k}$$

we can
to 10
c of fuel

compression
at supply
expansion
at rejection

$\frac{V_1}{V_2}$

$\frac{V_3}{V_2}$

$= \frac{V_4}{V_3} = \frac{V_1}{V_3}$

$$T_3 V_3^{\gamma-1} = T_4 V_4^{\gamma-1}$$

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

$$= T_4 \left(\varepsilon_E\right)^{\gamma-1} \quad \text{---(8)}$$

$$T_3 P_3^{\frac{1-\gamma}{\gamma}} = T_4 P_4^{\frac{1-\gamma}{\gamma}}$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{---(9)}$$

$$_3W_4 = \frac{P_3V_3 - P_4V_4}{\gamma-1} = \frac{R(T_3-T_4)}{\gamma-1} = C_v(T_3-T_4) \quad \text{---(10)}$$

4-1 $V=C$

$$\frac{P_4}{T_4} = \frac{P_1}{T_1}$$

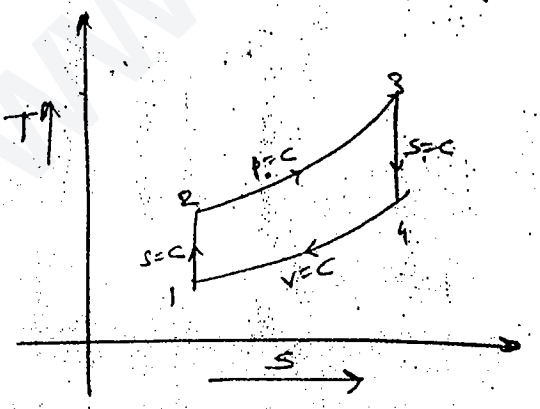
$$T_4 = T_1\left(\frac{P_4}{P_1}\right) \quad \text{---(11)}$$

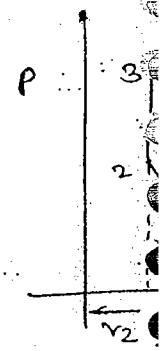
$$_4Q_1 = C_v(T_4-T_1) \quad \text{---(12)}$$

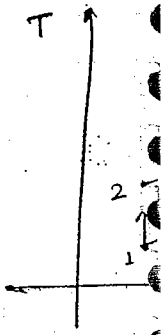
$$\eta_{thermal} = \frac{1-Q_R}{Q_S}$$

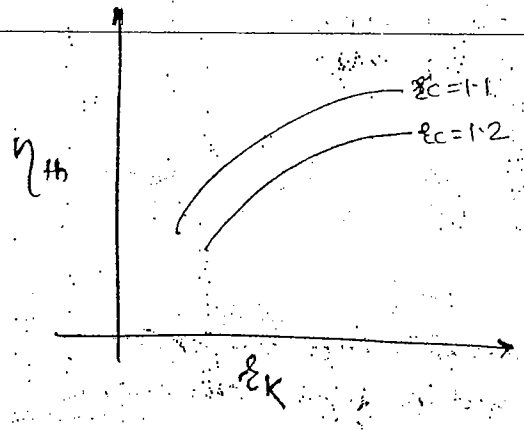
$$= 1 - \frac{C_v(T_4-T_1)}{C_p(T_3-T_2)}$$

$$= 1 - \frac{1}{\gamma \varepsilon_k^{\gamma-1}}\left[\frac{\varepsilon_c^{\gamma}-1}{(\varepsilon_c-1)}\right] = f(\varepsilon_k, \varepsilon_c, \gamma)$$









ε_K constth, γ constth → $\varepsilon_c \uparrow$ $\eta_{th} \downarrow$; $\varepsilon_c \downarrow$ $\eta_{th} \uparrow$

ε_c, γ const → $\varepsilon_K \uparrow$ $\eta_{th} \uparrow$; $\varepsilon_K \downarrow$ $\eta_{th} \downarrow$

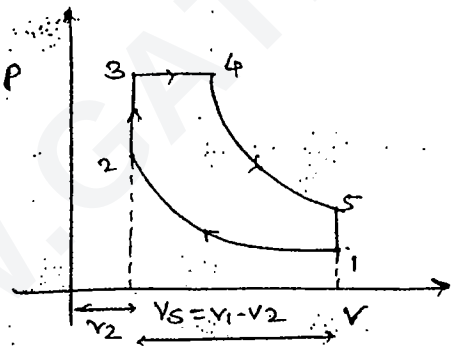
ε_K, ε_c const → $\gamma \uparrow$ $\eta_{th} \uparrow$; $\gamma \downarrow$ $\eta_{th} \downarrow$

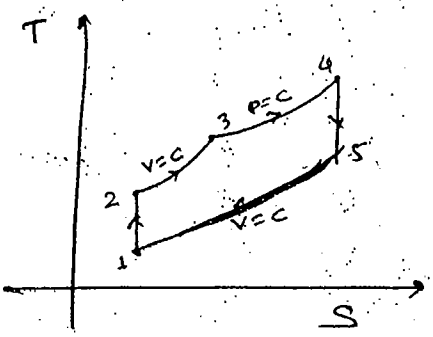
$^{\gamma-1}$
$-T_4)$ ——— (10)

The operating range of ε_K for diesel cycle are between 12 to 21 the optimum being around 16 to 20:1 because ε_K is used high the η_{th} of diesel cycle is greater than η_{th} of otto cycle.

$\varepsilon_K, \varepsilon_c, \gamma)$

Dual CYCLE / SABATHE CYCLE





compression ratio = $\varepsilon_K = \frac{V_1}{V_2}$

cutt off ratio = $\varepsilon_c = \frac{V_4}{V_3} = \frac{V_4}{V_2}$

Expansion ratio = $\varepsilon_E = \frac{V_5}{V_4} = \frac{V_1}{V_2}$

$Q_S = C_v (T_3 - T_2) + C_p (T_4 - T_3)$

$Q_R = C_v (T_5 - T_1)$

ε_p = pressure ratio = explosion ratio

$\varepsilon_p = \frac{P_3}{P_2} = \frac{P_4}{P_2}$

$\eta_{thermal} = 1 - \frac{Q_R}{Q_S}$

$= 1 - \frac{C_v (T_5 - T_1)}{C_v (T_3 - T_2) + C_p (T_4 -$

$\eta_{thermal} = 1 - \frac{1}{\varepsilon_K^{\gamma-1}} \left\{ \frac{\varepsilon_p \varepsilon_c^{\gamma} - 1}{(\varepsilon_p - 1) + \gamma \varepsilon_p (\varepsilon_c - 1)} \right\}$

$= f(\varepsilon_K, \varepsilon_p, \varepsilon_c, \gamma)$

If $r_p = 1$ dual cycle converted to diesel cycle

$$(\eta)_{dual} = (\eta)_{diesel}$$

If $r_c = 1$

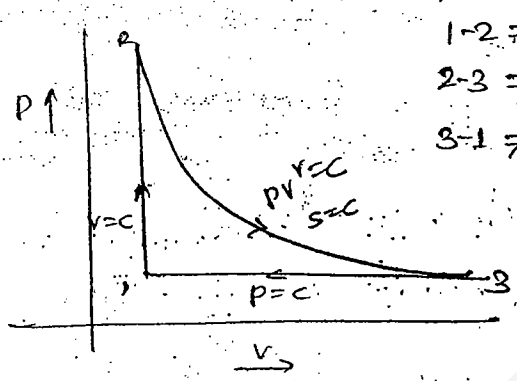
$$(\eta)_{dual} = (\eta)_{otto}$$

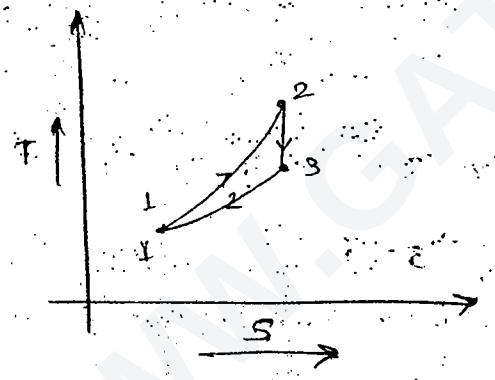
Modified rankine cycle is another cycle which is having 5 processes and is used in for steam engine

Lenoir cycle

- It is used in pulse jet engine

1-2 ⇒ constant volume heat supply
2-3 ⇒ Reversible adiabatic expansion
3-1 ⇒ constant pressure heat rejection





1-2 $v = c$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$T_2 = \frac{P_2}{P_1} \times T_1 \quad \text{——} (1)$$

$$Q_2 = C_v (T_2 - T_1) \quad \text{——} (2)$$

2-3 Reversible adiabatic expansion

$$P_2 V_2^{\gamma} = P_3 V_3^{\gamma}$$

$$T_2 V_2^{\gamma-1} = T_3 V_3^{\gamma-1}$$

$$T_2 P_2^{\frac{1-\gamma}{\gamma}} = T_3 P_3^{\frac{1-\gamma}{\gamma}}$$

$$2W_3 = \frac{P_2 V_2 - P_3 V_3}{\gamma - 1} = \frac{R(T_2 - T_3)}{\gamma - 1}$$

rich is in engine

3-1 P=C

$$P \frac{V_3}{T_3} = \frac{V_1}{T_1}$$

$$3Q_1 = C_p (T_3 - T_1)$$

at supply expansion at rejection

Pressure ratio = Expansion ratio = $\frac{P_2}{P_1} = \delta_p$

$$\eta_{thermal} = 1 - \frac{Q_R}{Q_S}$$

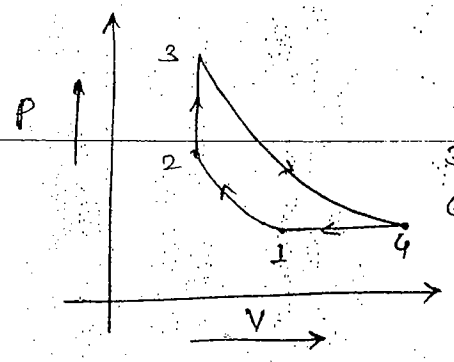
$$= 1 - \frac{C_p (T_3 - T_1)}{C_v (T_2 - T_1)}$$

$$= 1 - \gamma \left[\frac{\delta_p^{1/\gamma} - 1}{\delta_p - 1} \right]$$

$$= f(\gamma, \delta_p)$$

no back work is here no compress work work is high because The moving part are less. The work ratio is unity

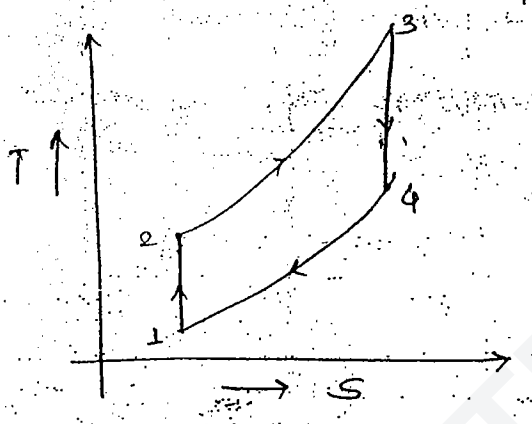
ATKINSON CYCLE



1-2 ⇒ reversible adiabatic compression
2-3 ⇒ constant volume heat supplied
3-4 ⇒ Reversible adibatic expansion
4-1 ⇒ constant pressure heat rejection

Compression ratio $\varepsilon_K = \frac{V_1}{V_2}$

Expansion ratio $\varepsilon_E = \frac{V_4}{V_3}$



$\boxed{\varepsilon_E > \varepsilon_K}$ in atkinson cycle.

heat supplied $Q_S = C_V(T_3 - T_2)$

heat rejected $Q_R = C_p(T_4 - T_1)$

$$\eta_{thermal} = 1 - \frac{Q_R}{Q_S}$$

$$\eta = 1 - \frac{C_p(T_4 - T_1)}{C_V(T_3 - T_2)}$$

$$= 1 - \gamma \frac{[\varepsilon_E - \varepsilon_K]}{[\varepsilon_E^{\gamma} - \varepsilon_K^{\gamma}]}$$

Technica

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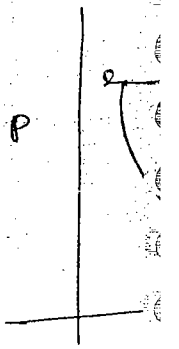
Brayton



1-2 ⇒ Rever
2-3 ⇒ Consta
3-4 ⇒ Rever
4-1 ⇒ Consta

Comp

Expar

pressu

Heat supp

Heat rej

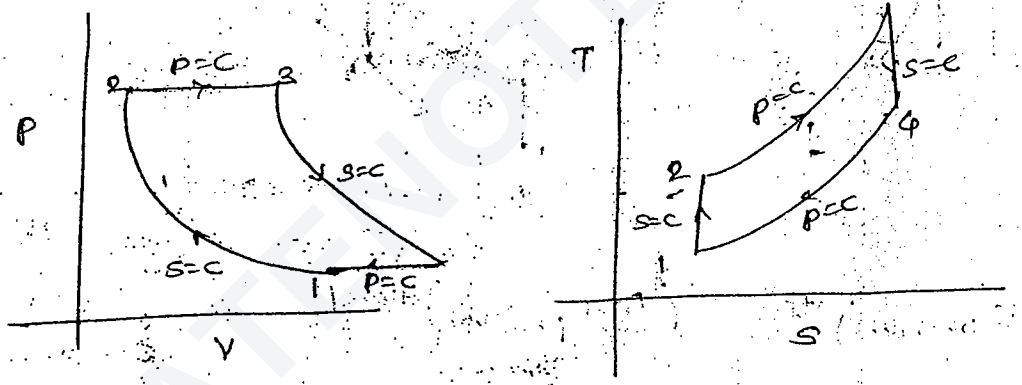
η_{ther}

Technically speaking Atkinson cycle is higher η and higher work output when compared to otto cycle. It is was successful it could have been present day I.C engine cyc for converting Cv heat rejection to cp heat rejection. at toggle joint is used. excessive wear and tear of the toggle joint resulted in the failure of the cycle

i compression
eat supplied
xpansion
eat rejection

xson cycle:

Brayton cycle or Joule cycle



1-2 ⇒ Reversible adiabatic compression
2-3 ⇒ constant pressure heat supplied
3-4 ⇒ Reversible adiabatic expansion
4-1 ⇒ Constant pressure heat rejection

Compression ratio $= r_K = \frac{V_1}{V_2}$

Expansion ratio $= r_E = \frac{V_4}{V_3}$

pressure ratio $= r_p = \frac{P_2}{P_1} = \frac{P_3}{P_4}$

Heat supplied $Q_S = c_p (T_3 - T_2)$

Heat rejected $Q_R = c_p (T_4 - T_2)$

$$\eta_{thermal} = 1 - \frac{Q_R}{Q_S}$$

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

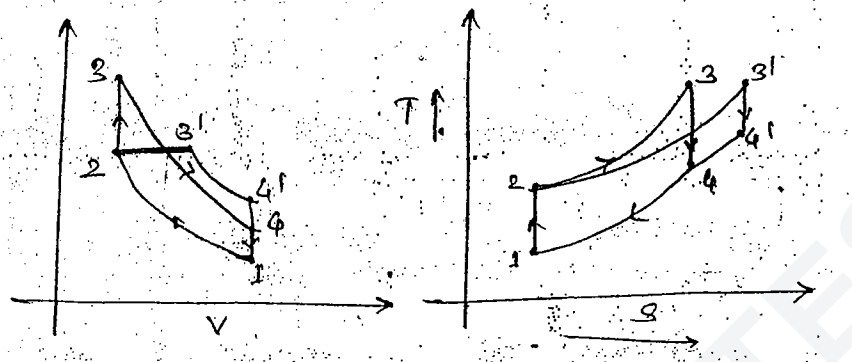
$$= 1 - \left(\frac{1}{r_p}\right)^{\frac{\gamma-1}{\gamma}} = 1 - \left(\frac{1}{r_K}\right)^{\gamma-1} = f(r_K, \gamma)$$

$$= f(r_p, \gamma)$$

Comparison cycle

Whenever we compare we compare only 3 cycles i.e. otto, diesel and dual. For any comparison dual cycle is always in between otto & diesel

(1) Compression ratio and heat supplied constant.



$(\text{Peak pressure})_{\text{otto}} > (\text{Peak pressure})_{\text{diesel}}$

$(\text{Expansion ratio})_{\text{otto}} > (\text{Expansion ratio})_{\text{diesel}}$

$(\text{Peak temp})_{\text{otto}} > (\text{Peak temp})_{\text{diesel}}$

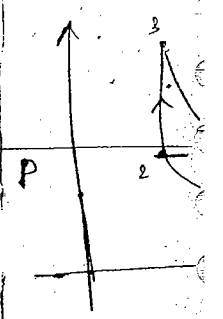
$(\text{Heat rejected})_{\text{otto}} < (\text{Heat rejected})_{\text{diesel}}$

$(\text{Temp at beginning of heat rejection})_{\text{otto}} < (\text{Temp at beginning of heat rejection})_{\text{diesel}}$

$(\text{Work in otto cycle})_{\text{otto}} > (\text{Work in diesel})$

$(\eta_{\text{thermal}})_{\text{otto}} > (\eta_{\text{thermal}})_{\text{diesel}}$

(2) Compr



(Peak

(Peak te

(Work)

(Heat s

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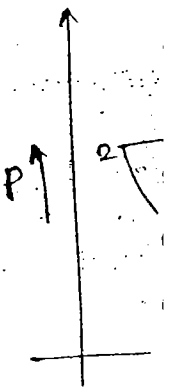
(3) Peak



(Cor

(Temp
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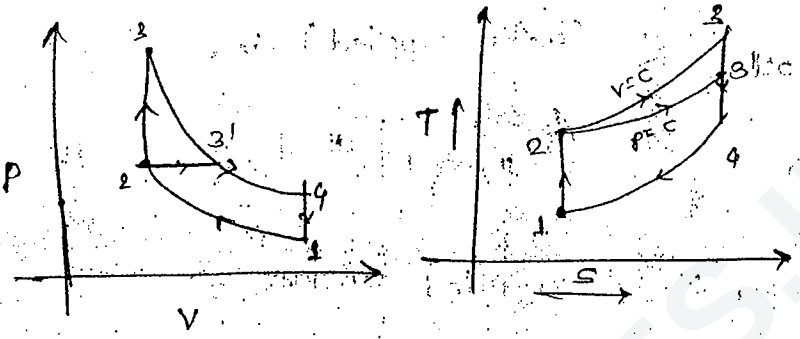
cycles
on dual

ond.

② compression ratio and heat rejection constant.



(Peak pressure)otto > (Peak pressure) diesel

(Peak temp) otto > (Peak temp) diesel

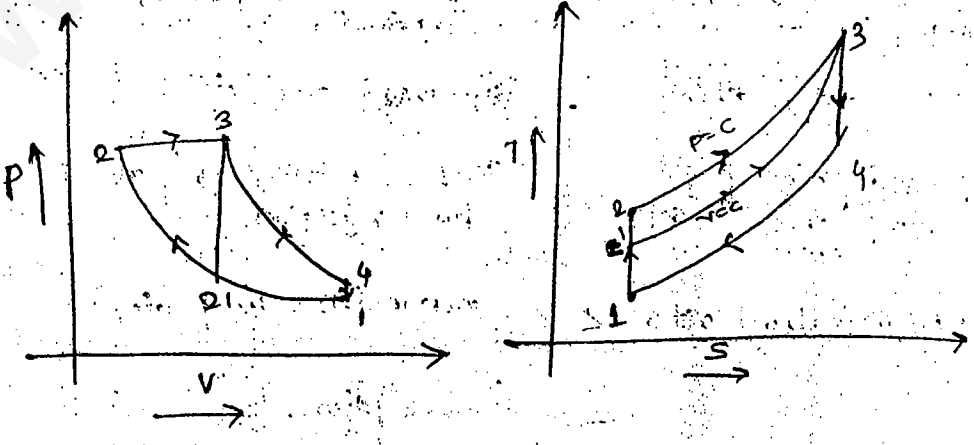
(Work) otto > (Work) diesel

(Heat supplied) otto > (Heat supplied) diesel

($\eta_{thermal}$) otto < (η thermal) diesel

(Expansion ratio) otto > (Expansion ratio) diesel

③ Peak pressure, peak temp, heat rejected constant



(compression ratio) otto < (compression ratio) diesel.

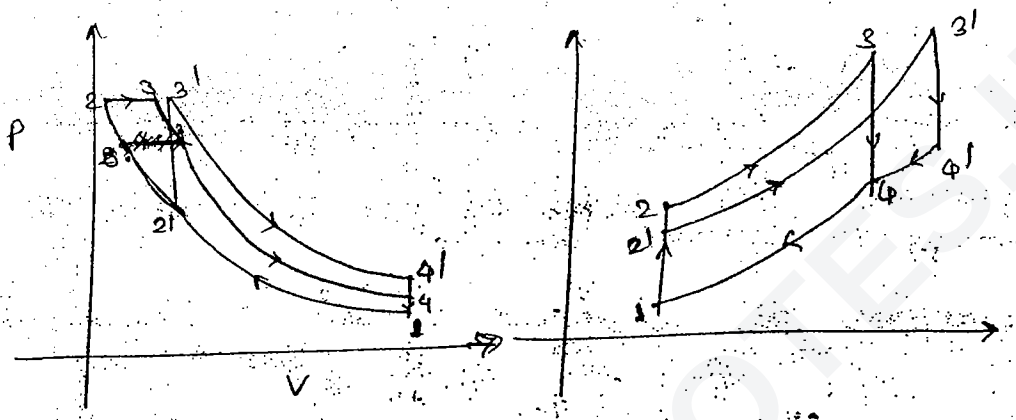
(Temp at end of compression) otto < (Temp at end of compression) die

$(\text{work})_{otto} < (\text{work})_{diesel}$

$(\text{Heat supplied})_{otto} < (\text{Heat supplied})_{diesel}$

$(\eta_{thermal})_{otto} < (\eta_{thermal})_{diesel}$

Peak pressure and heat supplied constant



$(\text{Compression ratio})_{otto} < (\text{Compression ratio})_{diesel}$

$(\text{Peak temp pressure})_{otto} > (\text{Peak temp})_{diesel}$

$(\text{Temp at end of compression})_{otto} > (\text{Temp at end of compression})_{diesel}$

$(\text{Heat rejected})_{otto} > (\text{Heat rejected})_{diesel}$

$(\text{Temp @ begining of heat rejection})_{otto} > (\text{Temp @ begining of heat rejection})_{diesel}$

$(\text{Expansion ratio})_{otto} < (\text{expansion ratio})_{diesel}$

$(\text{Work})_{otto} < (\text{work})_{diesel}$

$(\eta_{thermal})_{otto} < (\eta_{thermal})_{diesel}$

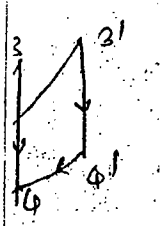
peak pressure and workdone is constant.

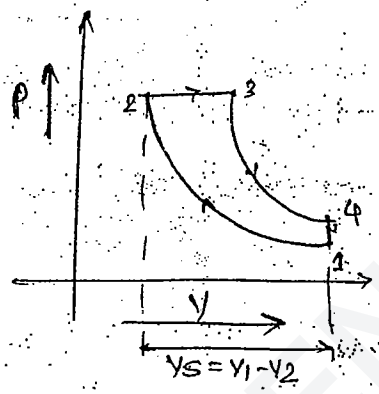
figure is same as previous

all comparison is same as previous except

(heat supplied) otto ? (heat supplied) diesel

pg NO:20 prbNO13 :-----





$\varepsilon_K = \frac{V_1}{V_2} = 15$

$V_1 = 15 V_2$

cut off $= (V_3 - V_2)$

$V_3 - V_2 = \frac{6.5}{100}(V_1 - V_2)$

$= \frac{6.5}{100}(15V_2 - V_2)$

$V_3 = 1.91 V_2$

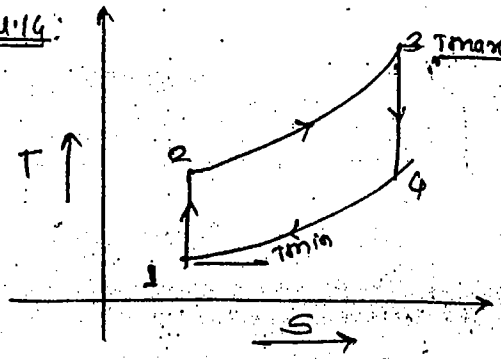
$\varepsilon_{cutoff} = \frac{V_3}{V_2} = 1.91$

$\eta_{thermal} = 1 - \frac{1}{\gamma \varepsilon_K^{\gamma-1}} \cdot \frac{\varepsilon_c^{\gamma} - 1}{\varepsilon_c - 1}$

$= 1 - \frac{1}{(1.4)(15)^{0.4}} \times \left(\frac{1.91^{1.4} - 1}{1.91 - 1}\right)$

$= \underline{60.8\%}$

Qu:14



work $= Q_S - Q_R$

$W = C_V(T_3 - T_2) - C_V(T_4 - T_1)$

$= C_V[T_3 - T_2 - T_4 + T_1]$

$\frac{T_2}{T_1} = \varepsilon_K^{\gamma-1}$

$\frac{T_3}{T_4} = \varepsilon_K^{\gamma-1}$

$T_4 = T_3 \varepsilon_K^{\gamma-1}$

$$W = c_v\left[T_3 - \frac{T_3}{\varepsilon_k^{\gamma-1}} - T_1\,\varepsilon_k^{\gamma-1} + T_1\right]$$

$$W = f(\varepsilon_k)$$

$$\frac{dW}{d\varepsilon_k} = -c_v T_3 (1-\gamma)\varepsilon_k^{1-\gamma-1} - c_v T_1(\gamma-1)\varepsilon_k^{\gamma-1-1} = 0$$

$$-c_v T_3(1-\gamma)\varepsilon_k^{-\gamma} = c_v T_1(\gamma-1)\varepsilon_k^{\gamma-2}$$

$$\frac{T_3}{T_1} = \frac{\varepsilon_k^{\gamma-2}}{\varepsilon_k^{-\gamma}} = \varepsilon_k^{2(\gamma-1)}$$

$$(\varepsilon_k)_{optimum} = \left(\frac{T_3}{T_1}\right)^{\frac{1}{2(\gamma-1)}}$$

$$= \left(\frac{T_{max}}{T_{min}}\right)^{\frac{1}{2(\gamma-1)}}$$

$$= \left(\frac{T_{min}}{T_{max}}\right)^{\frac{1}{2(1-\gamma)}}$$

$$T_2 = T_1\,\varepsilon_k^{\gamma-1}$$

$$= T_1\left[\left(\frac{T_3}{T_1}\right)^{\frac{1}{2(\gamma-1)}}\right]^{\gamma-1}$$

$$T_2 = \sqrt{T_1T_3}$$

$$T_4 = \frac{T_3}{(\varepsilon_k)^{\gamma-1}}$$

$$= \frac{T_3}{\left[\left(\frac{T_3}{T_1}\right)^{\frac{1}{2(\gamma-1)}}\right]^{\gamma-1}}$$

$$= \sqrt{T_1T_3}$$

when we operating at optimum workdone condition the temp at end of expansion = temp end of compression.

and $T_2 = T_4 = \sqrt{T_1T_3}$ —— (2)

W_{max}

W_{max}

Q.15:

$l_e = \frac{L}{2} +$

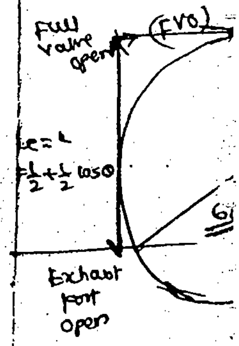
$= 7 +$

$r_{se} = \frac{\pi}{4}$

$\varepsilon_{ke} =$

$\eta_{thermal} =$

Q.16: $l =$



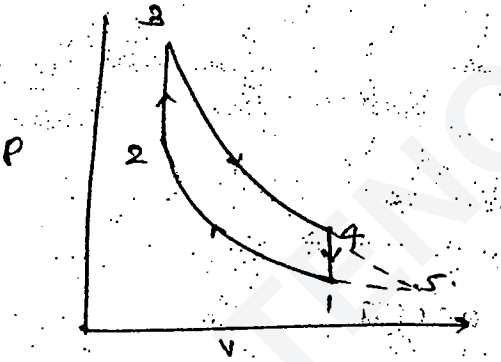
$\frac{dn}{n} = -0.01367$

$\frac{dn}{n} \times 100 = -1.367\%$.

if cr increase by 2% efficiency decreases by.

1.32%.

Pg.No.29 Qu.No ①



$rk = 6 = \frac{V1}{V2}$

$P_1 = 0.1\ MPa = 100 kPa$.

$T_1 = 27 + 293 = 300 K$

$T_3 = 1595 + 293 = 1868 K$.

$P_4 = T_4 = ?$

$\gamma = 1.4$.

process 1-2

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$\left(\frac{V_1}{V_2}\right)^{\gamma} = \frac{P_2}{P_1}$

$P_2 = 1228.603 kPa$.

$V_1 = \frac{RT_1}{P_1} = \frac{0.287 \times 300}{100} = 0.861$

$V_2 = \frac{RT_2}{P_2} = 0.287 \times$

$V_1 = 6V_2$ $\quad \boxed{V_2 = 0.1435}$

$V_2 = V_3$

$V_4 = V_1$

process 3-4

$P_3 V_3^{\gamma} = P_4 V_4^{\gamma}$

$\left(\frac{V_3}{V_4}\right)^{\gamma} = \frac{P_4}{P_3}$

$\left(\frac{0.1435}{0.861}\right)^{1.4} = \frac{P_4}{P_3}$.

$P_3 = 8735.99$

$$T_3 V_3^{\gamma-1} = T_4 V_4^{\gamma-1}$$

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

$$\left(\frac{0.1435}{0.861}\right)^{0.4} = \frac{T_4}{T_3} \qquad \boxed{T_4 = 912.255\ K}$$

For 4-1:

$$\frac{P_4}{T_4} = \frac{P_1}{T_1}$$

$$P_4 = \frac{100 \times 912.255}{800}$$

$$= 804.085$$

lowest possible pressure is 100 kPa

$$P_3 V_3^{\gamma} = P_5 V_5^{\gamma}$$

$$\left(\frac{V_3}{V_5}\right)^{\gamma} = \frac{P_5}{P_3}$$

$$\frac{V_3}{V_5} = \left(\frac{P_5}{P_3}\right)^{\frac{1}{\gamma}}$$

$$\frac{0.1435}{V_5} = \frac{100}{3325.99}$$

$$\boxed{V_5 = 5.3611}$$

$$\varepsilon_E = \frac{V_5}{V_3} = 13.28$$

$$\varepsilon_E = 13.28$$

$$\eta_{th} = 1 - \gamma \frac{(\varepsilon_E - \varepsilon_k)}{\varepsilon_E^{\gamma} - \varepsilon_k^{\gamma}}$$

put the value of T_2 & T_4 in eqn (1)

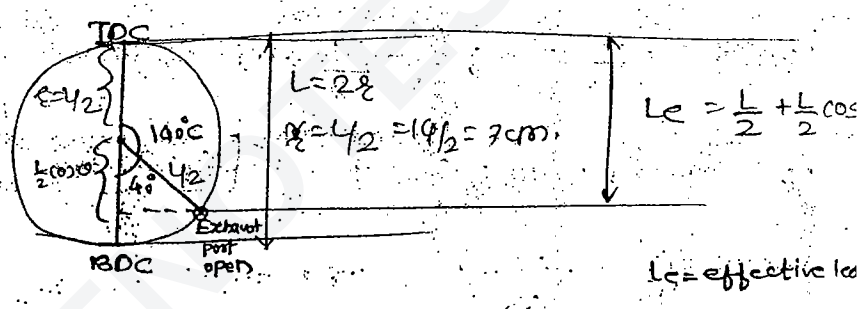
$$W_{max} = C_V \left[T_3 - \sqrt{T_1 T_3} - \sqrt{T_1 T_3} + T_1 \right]$$

$$= C_V \left[T_3 + T_1 - 2\sqrt{T_1 T_3} \right]$$

$$\boxed{W_{max} = C_V \left[\sqrt{T_3} - \sqrt{T_1} \right]^2}$$

Max work done in otto cy

Qu 15:



$$L_e = \frac{L}{2} + \frac{L}{2}\cos\theta = \text{effective stroke length}$$

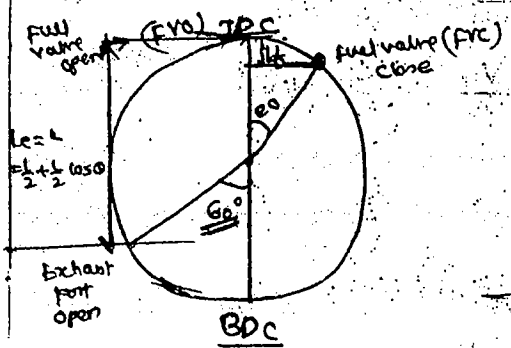
$$= 7 + 7\cos 40 = 12.36 \text{ cm}$$

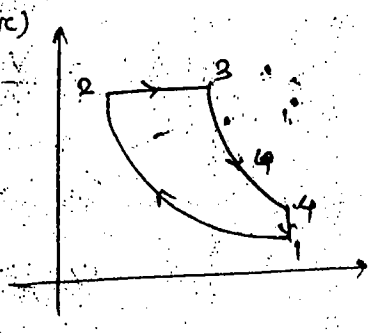
$$V_{se} = \frac{\pi}{4} D^2 L_e = \frac{\pi}{4} \times 10^2 \times 12.36 = 970.7521 \text{ cm}^3 \text{ or c.c.}$$

$$r_{ke} = \frac{V_{se} + V_c}{V_c} = \frac{970.75 + 157}{157} = 7.183$$

$$\eta_{thermal} = 1 - \left(\frac{1}{r_{ke}}\right)^{\gamma - 1} = 1 - \left(\frac{1}{7.183}\right)^{0.4} = 54.55\%$$

Qu 16: $L = 14$ cm, $D = 10$ cm, $V_c = 40.2$ cm^3 or c.c





no condition
- compression.

$\Rightarrow L_e = \frac{L}{2} + \frac{L}{2}\cos\theta = 7 + 7\cos 0 = 10.5$ cm

$\Rightarrow V_{\text{stroke effect}} = V_{se} = \frac{\pi}{4} D^2 L_e = \frac{\pi}{4}(10)^2 \times 10.5 = \underline{824.66}\ cm^3$

$\Rightarrow \varepsilon_{k_{eff}} = \frac{V_{se} + V_c}{V_c} = \frac{824.66 + 40.2}{40.2} = \underline{21.5}$

$\Rightarrow L_f = \frac{L}{2} - \frac{L}{2}\cos\theta = 7 - 7\cos 20 = 3.8$ $\underline{0.422}$ cm

$\Rightarrow (V_3 - V_2) = \frac{\pi}{4} D^2 L_f = \frac{\pi}{4} \times (10)^2 \times 0.422 = 33.14$

$V_3 = 40.2 + 33.14 = 73.34$ $\boxed{V_3 = 73.34}$

$\varepsilon_c = \frac{V_3}{V_2} = \frac{73.34}{40.2} = 1.82$

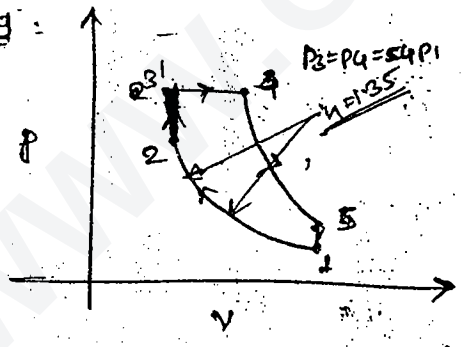
ε_c = cut off ratio

$$\left(\eta_{\text{thermal}}\right)_{\text{diesel}} = 1 - \frac{1}{\gamma\, \varepsilon_k^{\gamma-1}} \cdot \frac{\varepsilon_c^{\gamma} - 1}{\varepsilon_c - 1}$$

$$= 1 - \frac{1}{1.4 \times 21.5^{0.4}} \cdot \frac{1.82^{1.4} - 1}{1.82 - 1}$$

$= \underline{64.8\%}$

Qu.9 :



$\varepsilon_k = \frac{V_1}{V_2} = 12$

$\varepsilon_c = \frac{V_4}{V_3} = \frac{V_4}{V_2} = 1.615$

$\varepsilon_k = \varepsilon_c \times \varepsilon_E$

$12 = 1.615 \times \varepsilon_E$

$\varepsilon_E = \frac{12}{1.615} = 7.43 = \frac{V_5}{V_4} = \frac{V_1}{V_4}$

824.66 cm³

2 cm

3.14

15

$= \frac{V_5}{V_4} = \frac{V_1}{V_4}$

*** Process 1-2** $\quad PV^n = C$

$P_1V_1^n = P_2V_2^n$

$P_2 = P_1\left(\frac{V_1}{V_2}\right)^n$

$= P_1 (12)^{1.35}$

$\boxed{P_2 = 28.63\, P_1}$

$_1W_2 = \frac{P_1V_1 - P_2V_2}{n-1} = \frac{P_1V_1 - 28.63P_1 \times \left(\frac{V_1}{12}\right)}{1.35 - 1}$

$_1W_2 = -3.96\, P_1V_1$

*** 2-3** $\quad V = C \quad {}_2W_3 = 0$

*** 3-4** $\quad P = C \quad {}_3W_4 = P_4(V_4 - V_3) = 54P_1(1.615V_2 - V_2)$

$_3W_4 = 54P_1(0.615 \times V_2) = 54P_1\left(0.615 \times \frac{V_1}{12}\right)$

$= 2.76\, P_1V_1$

*** 4-5** $\quad P_4V_4^n = P_5V_5^n$

$P_5 = P_4 \times \left(\frac{V_4}{V_5}\right)^n$

$= 54P_1\left[\frac{1}{7.43}\right]^{1.35}$

$= 3.6\, P_1$

$_4W_5 = \frac{P_4V_4 - P_5V_5}{n-1} = \frac{54P_1 \times 1.615V_2 - 3.6P_1 \times V_1}{1.35-1}$

$= \frac{54P_1 \times 1.615\frac{V_1}{12} - 3.6P_1V_1}{1.35-1} = 10.47\, P_1V_1$

*** 5-1** $\quad V = C \quad {}_5W_1 = 0$

$W_{net} = {}_1W_2 + {}_2W_3 + {}_3W_4 + {}_4W_5 + {}_5W_1$

$= -3.96P_1V_1 + 0 + 2.76P_1V_1 + 10.47 + 0$

$= 9.27\, P_1V_1$

$$\text{m.e.p} = \frac{\text{wnet}}{\text{stroke vol}^m} = \frac{\text{wnet}}{VS} = \frac{9.297 P_1 V_1}{V_1 - \frac{V_1}{12}} = \frac{9.297 P_1 V_1}{\frac{12V_1 - V_1}{12}}$$

$$= \frac{12 \times 9.297 P_1 V_1}{11 V_1} = 10 P_1$$

Pg.NO 29 Qu.5 :

r_k = compression ratio

$\frac{dcv}{cv} \times 100 = 2$

$r_k = 6$

$\frac{dcv}{cv} = 0.02.$

$\eta = 1 - \left(\frac{1}{r_k}\right)^{\gamma-1}$

$\eta = 1 - \left(\frac{1}{r_k}\right)^{\gamma-1}$ $= 0.5116$

$\eta = 1 - \left(\frac{1}{r_k}\right)^{\frac{R}{cv}}$

$\frac{R}{\gamma-1} = cv$

$\frac{R}{cv} = \gamma - 1$

$\log \eta = 1 - \left(\frac{1}{r_k}\right)^{\frac{R}{cv}} = 1 - \eta$

$1 - \eta = \left(\frac{1}{r_k}\right)^{\frac{R}{cv}}$

$\ln(1-\eta) = \frac{R}{cv} \ln\left(\frac{1}{r_k}\right)$

partial differentiation

$\frac{1}{\eta - 1 - \eta} d\eta = \frac{-R}{cv^2} dcv \ln\left(\frac{1}{r_k}\right)$

$-\frac{d\eta}{1-\eta} = -\frac{R}{cv^2} \cdot dcv \ln\left(\frac{1}{r_k}\right)$

$d\eta = 1 - \eta \frac{R}{cv} \cdot \frac{dcv}{cv} \ln\left(\frac{1}{r_k}\right)$

divide by η

$\frac{d\eta}{\eta} = \frac{1-\eta}{\eta} \cdot \frac{R}{cv} \cdot \frac{dcv}{cv} \ln\left(\frac{1}{r_k}\right)$

$\frac{d\eta}{\eta} = \frac{1 - 0.5116}{0.5116} \cdot \frac{0.287}{0.718} \times 0.02 \ln\left(\frac{1}{6}\right)$

Pg.NO. 2

process

$V_1 = R$

$V_2 = \frac{R}{P}$

process

$$= 1 - \frac{1.4(13.28 - 6)}{13.28^{1.4} - 6^{1.4}}$$

$$= 59.36.$$

improvement in efficiency.

$$= \frac{59.36 - 51.1}{51.1} \times 100$$

$$= 16.16\%.$$

pg.No 99 Qu 12 Ans (b).

pg.No 50 Qu.3

Fuel air ratio $= \frac{\dot{m}_f}{\dot{m}_a} = 0.05 = \frac{1}{20}$

$\dot{m}_a = 20$ $\dot{m}_f = 1$

$\eta_{volumetric} = 0.9$

$\eta_v = \frac{\dot{m}_a}{\dot{m}_{theoretical}}$

$\dot{m}_{theoretical} = \frac{20}{0.9} = 22.22$

Stroke volume $= V_S = \dot{m}_{theoretical} * S = 22.22 \times 1 = 22.$

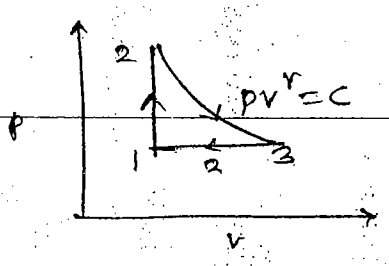
$W = \dot{m}_f \times CV \times \eta_{th}$

$= 1 \times 45000 \times 0.3$

$= 13500$ KJ

$mep = \frac{W}{V_S} = \frac{13500}{22.22} = 607.56$

Pg.NO 27 Q4 9)



process 1-2 $v = c$

$Q_S = C_v(T_2 - T_1)$

process 3-1 $p = c$

$Q_R = C_p(T_3 - T_1)$

$$\eta = 1 - \frac{Q_R}{Q_S} = 1 - \frac{C_p(T_3 - T_1)}{C_v(T_2 - T_1)}$$

$$= 1 - \frac{T_1 C_p\left(\frac{T_3}{T_1} - 1\right)}{T_1 C_v\left(\frac{T_2}{T_1} - 1\right)}$$

$$= 1 - \frac{C_p\left(\frac{T_3}{T_1} - 1\right)}{C_v\left(\frac{T_2}{T_1} - 1\right)}$$

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

process 1-2

$$\frac{P_2}{T_2} = \frac{P_1}{T_1}$$

$$\frac{P_2}{P_1} = \frac{T_2}{T_1}$$

process 3-1

$$= 1 - \gamma \frac{\left(\frac{V_3}{V_1} - 1\right)}{\left(\frac{P_2}{P_1} - 1\right)}$$

$$= 1 - \gamma \frac{\left(\frac{V_3 - V_1}{V_1}\right)}{\frac{P_2 - P_1}{P_1}}$$

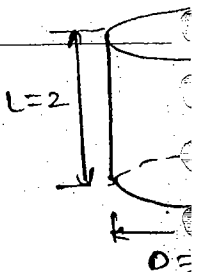
$$\frac{V_1}{T_1} = \frac{V_3}{T_3}$$

$$\frac{T_3}{T_1} = \frac{V_3}{V_1}$$

$$= 1 - \gamma \frac{(V_3 - V_1)}{P_2 - P_1} \times \frac{P_1}{V_1}$$

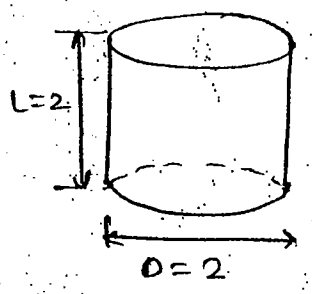
pg.NO

Q116



pg.No 29

Ques :



$$\text{Area} = 2 \times \frac{\pi}{4} \times D^2 + \pi D L$$

$$= 2 \times \frac{\pi}{4} \times (2)^2 + \pi \times 2 \times 2$$

$$= 6\pi$$

Butane is burned with stoichometric air determine the air fuel ratio

⇒ stoichometric means chemically correct formula for air

In every 4.76 mole air there is 1 mole of oxygen when a fuel is burned with chemically correct quantity of air the product of combustion of carbon di-oxide water vapour and nitrogen

$$C_4H_{10} + a(O_2 + 3.76N_2) \rightarrow 4CO_2 + 5H_2O + N_2$$

(6.5; N_2 → 2444)

$$2a = 4\times2 + 5\times1$$

$$\boxed{a = 6.5}$$

$$\left(\text{Air fuel ratio}\right)_{\text{chemically correct}} = \frac{m_a}{m_f}$$

$$= \frac{6.5\left[2\times16 + 3.76\times28\right]}{4\times12 + 1\times10}$$

$$= 15.38$$

$$\text{(fuel air ratio)} = \frac{m_f}{m_a}$$

$$= \frac{1}{15.38}$$

$$= 0.065$$

Butane is burned with 120% theoretical air : what is the partial pressure of water vapour in the exhaust products.

As per chemical eqn the product of combustion with excess air CO_2, O_2 oxygen, water vapour and Nitrogen.

Air fuel ratio $= \frac{m_a}{m_f}$

$= \frac{12.94\,[2\times16 + 3.76\times28]}{133\times12 + 37.12\times1}$

$= \underline{15.86}$

Relative fuel air ratio

$\phi = \frac{(\text{Fuel air ratio})_{actual}}{(\text{Fuel air ratio})_{chemically\ correct}}$

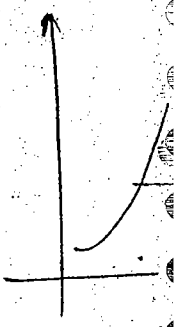
If $\phi = 1$ — chemically correct mixture

$\phi > 1$ — Rich mixture

$\phi < 1$ — lean mixture

As per

Psychrom



partia

satura

Saturati

superhe

Humidit

It is

Specific

humidit

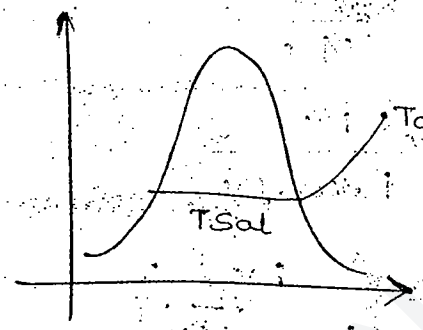
m

Psychrometry

As per dalton's law of partial pressure

$$P_{air} + P_{vapor} = P_{atm}$$

Psychrometry is study of air vapor mixture

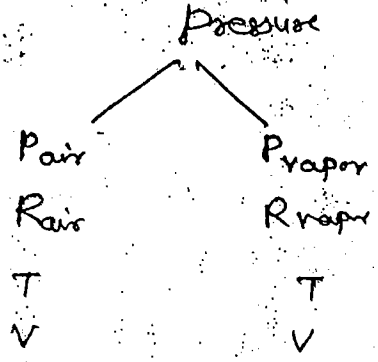


∴ water vapor present in superheated state corresponding partial pressure of vapor whatever is the temp is called a saturation temp but the atm temp is greater than saturation temp, hence the water vapor is present in superheated state and it is not visible to naked eye

Humidity ratio or specific humidity

It is ratio of mass of vapor to the mass of air

Specific humidity or (ω) = humidity ratio $= \frac{\text{mass of vapor}}{\text{mass of air}}$



$$\omega = \frac{m_v}{m_a}$$

$$m_v = \frac{P_v \cdot V}{R_v \cdot T} \qquad m_a = \frac{P_a \cdot V}{R_a \cdot T}$$

$$\omega = \frac{m_v}{m_a} = \frac{\frac{P_v \cdot V}{R_v \cdot T}}{\frac{P_a \cdot V}{R_a \cdot T}} = \frac{P_v}{P_a} \times \frac{R_a}{R_v}$$

$$= \frac{P_v}{P_a} \times \frac{\frac{\bar{R}}{M_a}}{\frac{\bar{R}}{M_v}} = \frac{P_v}{P_a} \times \frac{M_v}{M_a}$$

$$= \frac{18}{29} \times \frac{P_v}{P_{atm} - P_v}$$

$$= 0.622 \left\{ \frac{P_v}{P_{atm} - P_v} \right\}$$

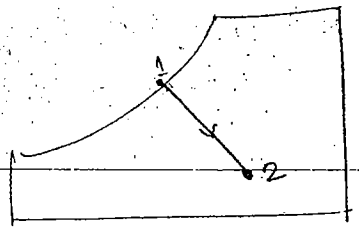
Relative humidity

The max amount of water vapor air can hold is called saturated mass if actual amount of water vapor is less than the saturated mass hence air is said to have relative humidity

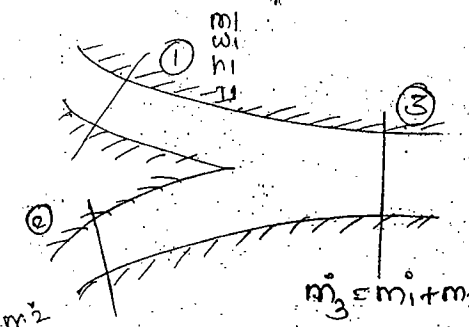
Relative humidity is defined as the ratio of mass of vapor to the saturated mass

$$\text{Relative humidity } (\phi) \quad \frac{m_{vap}}{m_{sat}} = \frac{m_v}{m_{sat}} = \frac{P_v}{P_{sat}}$$

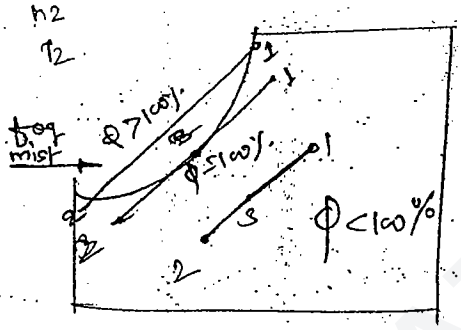
DBT ↑ WBT → h →
ω ↓ DPT ↓ RH ↓



Adiabatic mixing of two steams of air



$\dot{m}_2$
ω_2
h_2
T_2



high RH, high tem air mixes with high R.H low temp air we may get situation of fog or mist $\phi > 100\%$

yellow light used penetrate fog in cold countries

As per mass balance

$$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$$

As per water balanced

$$\dot{m}_1\omega_1 + \dot{m}_2\omega_2 = \dot{m}_3\omega_3$$

$$= (\dot{m}_1 + \dot{m}_2)\omega_3$$

$$\dot{m}_1(\omega_1 - \omega_3) = \dot{m}_2(\omega_3 - \omega_2)$$

$$\frac{\dot{m}_1}{\dot{m}_2} = \frac{\omega_3 - \omega_2}{\omega_1 - \omega_3}$$

Energy balance

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$$

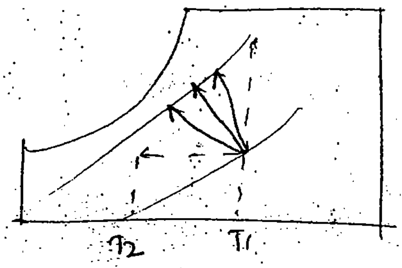
$$= (\dot{m}_1 + \dot{m}_2) h_3$$

$$\dot{m}_1(h_1 - h_3) = \dot{m}_2(h_3 - h_2)$$

$$\boxed{\frac{\dot{m}_1}{\dot{m}_2} = \frac{h_3 - h_2}{h_1 - h_3}}$$

ror at
le to
cess
WBT ↑
↑
at
h ↓
↑ Depending on
→ curve

Cooling and humidification :-

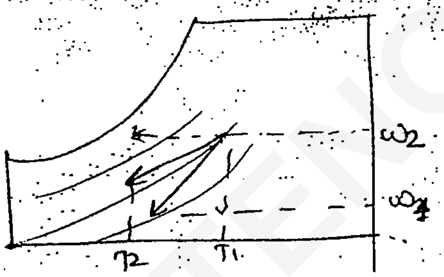


The temp of H_2O spray in spray chamber should be greater than DPT of air and should be less than DPT of air.

DBT ↓ WBT ↑→↓ h ↑→↓

ω ↑ DPT ↑ R.H ↑

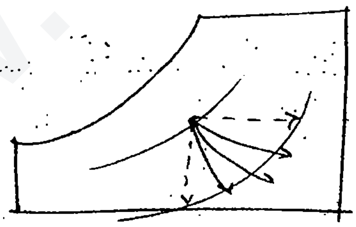
Cooling and dehumidification



DBT ↓ WBT ↓ h ↓ ω ↓

DPT ↓ RH ↑→↓

Heating and dehumidification



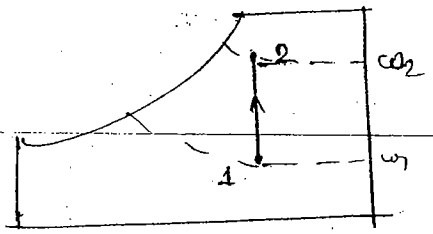
DBT ↑ WBT ↑→↓ h ↑→↓ ω ↓

DPT ↓ RH ↓

Chemical dehumidification process

by using a chemical a moisture present in air can removed and process is called chemical dehumidification by using hydroscopic material silica gel, H_2SO_4 activated alumina, calcium hydroxide the water in vapor can be removed and process is called chemical dehumidifica

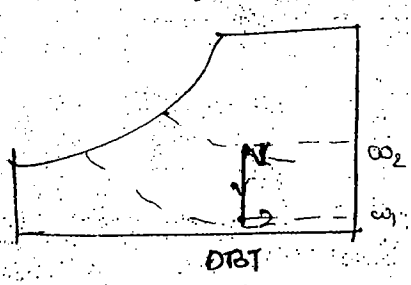
Humidification



Adding water vapor at constant DBT leads to humidification process

DBT is constant WBT ↑ h ↑ ω ↑ DPT ↑ R.H ↑

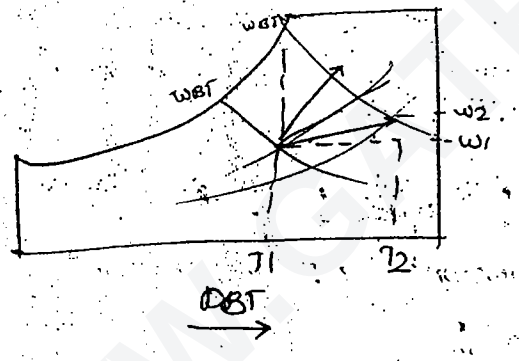
dehumidification



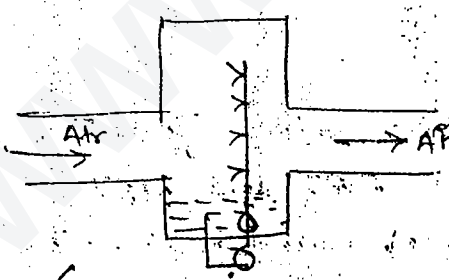
Removing water vapor at constant temp

DBT constant WBT ↓ h ↓ ω ↓ DPT ↓ R.H. ↓

Heating and humidification



DBT ↑ WBT ↑ h ↑ ω ↑ DPT ↑ R.H ↑ ↓ Depending on curve



$(Temp)_{H_2O} > (DBT)_{Air}$

If $\omega = 0.011$ kg of vapor per kg of dry air determine the humid specific heat

$$C_{phs} = C_{pa} + 1.88\omega$$

$$= 1.005 + 1.88 \times 0.011$$

$$= 1.025 \quad \text{— humid specific heat}$$

Density of moist air

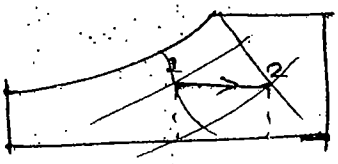
$$\rho_{\text{moist air}} = \rho_{air} + \rho_{vapor}$$

$$= \frac{P_a}{R_a T} + \frac{P_v}{R_v T}$$

$$= \frac{1}{T}\left[\frac{P_a}{R_a} + \frac{P_v}{R_v}\right]$$

Psychrometric process

Sensible Heating

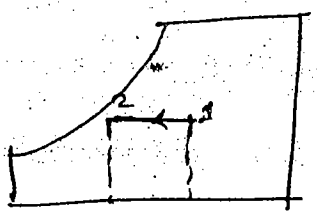


DBT ↑ WBT ↑ h ↑

ω constant DPT is constant

R.H(ϕ) ↓

Sensible cooling



For sensible cooling final Temp of air both DBT and DPT then only it called as sensible cooling

DBT ↓ WBT ↓ h ↓

ω constant DPT is constant

R.H (ϕ) ↑

enthalpy of vapor

at 0°C

$$h_v = (h_{fg})_{0°C} + c_{p_{vapor}} (T - 0)$$

at DPT

$$h_v = c_{p_{liquid}} (DPT - 0) + (h_{fg})_{DPT} + c_{p_{vapor}} (T - DPT)$$

at Tatm

$$h_v = c_{pl} (T_{atm} - 0) + (h_{fg})_{T_{atm}}$$

enthalpy of mixture

$$h = h_a + \omega h_v$$

$$= c_{p_a}(T-0) + \omega \left((h_{fg})_{0°C} + c_{p_v}(T-0) \right)$$

$$= (c_{p_a} + \omega c_{p_v})(T-0) + \omega (h_{fg})_{0°C}$$

$c_{p_{hs}}$ = humid specific heat

$$= c_{p_{hs}} (T-0) + \omega (h_{fg})_{0°C}$$

$$c_{p_{hs}} = c_{p_a} + \omega c_{p_v}$$

$$c_{p_{hs}} = c_{p_a} + 1.81\omega$$

$$= c_{p_a} + \omega c_{p_v} (T-0) + \omega (2500)$$

$$= c_{p_{hs}} (T-0) + 2500\omega$$

If ω = the h

c_{phs}

Densit

ρ_{moist} air

Psychro

Sensil

Sensib

i.e..

DBT is

dew present

air is

dew condenses.

The curved lines on chart is called relative humid

curved line RH 100% for parallel is called decreasing R

horizontal lines with uniform spacing are called as specific humidity lines.

with specific humidity lines meet RH 100% lines are get DPT

Dew point temp lines also horizontal lines with uniform spacing.

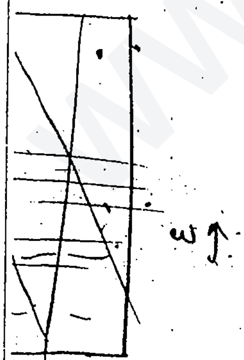
WBT lines are inclined lines sloping downward startin from RH 100% curves.

constant enthalpy lines are also inclined lines starting from RH 100% curve and sloping downwards

technically speaking there is small deviation between WBT lines and enthalpy lines but the deviat is not very significant hence WBT lines and enthalpy lines are parallel lines for all practical purposes.

lines with higher inclination slopping downwards are constant specific volume line

horizontal line with non uniform spacing on the psychrometric chart are called as vapor pressure lines



enthalpy

$h = h_{air} + \omega h_{vapor}$

enthalpy of vapor can be defined with respect to 0°C with respect to Dew point & atm temp

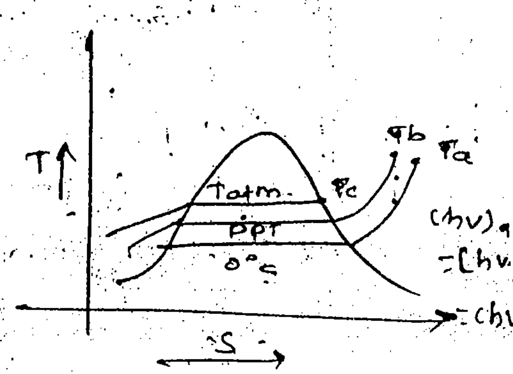


chart is

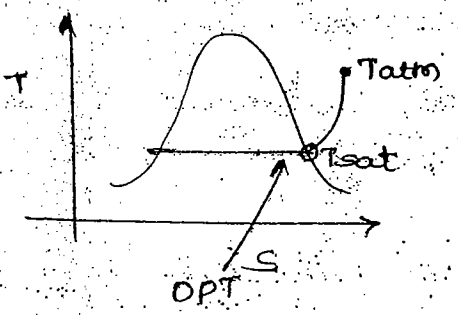
When ϕ of air is 0 WBT is ...

Air coolers are used in places where DBT is very high and ϕ is very less

Dew point temp

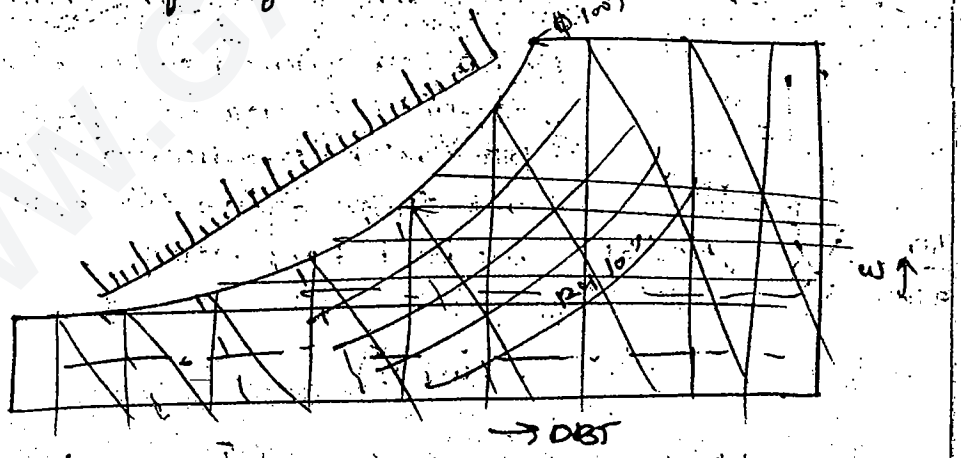
The temp. at which the water vapor present in air start condensing. if atm temp of air is equal to saturation temp then water vapor condenses which is called as dew point temp

at $\phi = 100\%$ → DBT = WBT = DPT



Psychrometric chart

It is drawn for fixed pressure



vertical line with uniform spacing in chart is called as DBT lines.

Degree of saturation (μ)

$$\mu = \frac{\omega}{\omega_{sat}} = \frac{0.622 \cdot \frac{P_v}{P_{atm} - P_v}}{0.622 \cdot \frac{P_{sat}}{P_{atm} - P_{sat}}}$$

$$= \frac{P_v (P_{atm} - P_{sat})}{P_{sat} (P_{atm} - P_v)}$$

$$= \phi \left[\frac{P_{atm} - P_{sat}}{P_{atm} - P_v} \right]$$

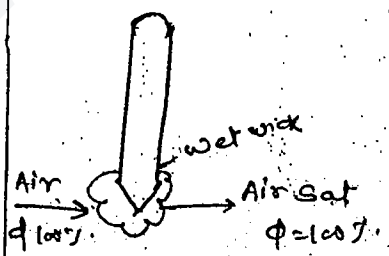
when $\mu = 0$ ϕ is 0%.

when $\mu = 1$ ϕ is 100%.

For other values of μ relative humidity is between 0 to 100%.

Dry bulb temperature

It is temp recorded with a ordinary thermometer



When unsatured air is blown on a wet wick evaporation of water take place which produced a cooling effect and temp drops this temp is called wet bulb temperature

Wet bulb depression (WBD)

$$WBD = BB\ DBT - WBT$$

if WBD is 0 then DBT = WBT and ϕ is 100%.

ADP = Apparatus dew point

$h_f \Rightarrow (ADP)_{Temp.}$

Apply SFEE:

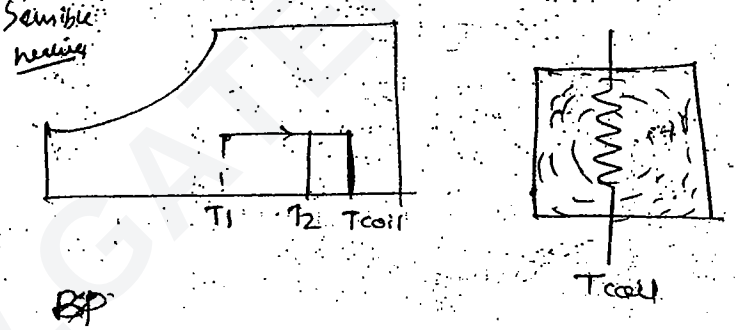
$$\dot{m}_a h_1 - \dot{Q} = \dot{m}_a h_2 + \dot{m}_f h_f$$

$$\dot{m}_a h_1 - \dot{Q} = \dot{m}_a h_2 + \dot{m}_a(\omega_1 - \omega_2) h_f$$

$$\boxed{\dot{Q} = \dot{m}_a (h_1 - h_2) - \dot{m}_a (\omega_1 - \omega_2) h_f}$$

$$SHL = \dot{m}_a (h_3 - h_2)$$

1-2 – cooling and dehumidification process is ideal process it is never practical because of bypass air in actual case bypass factor.



BP

Bypass factor $BPF = \dfrac{T_{coil} - T_2}{T_{coil} - T_1}$

BPF depend upon velocity in chamber the velocity is temp is becoming less and BPF is higher.

If velocity of air is less temp is becoming high BPF is less

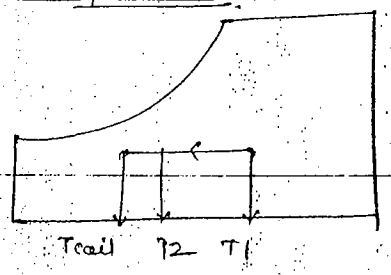
contact factor (C.F.) $\dfrac{T_2 - T_1}{T_{coil} - T_1}$

$$\boxed{\text{Contact factor} + BPF = 1}$$

ed (THL)

tr (SHF)

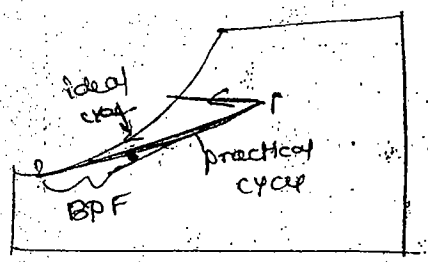
coming out air coil as a equal to mp or the point temp



$$BPF = \frac{T_2 - T_{coil}}{T_1 - T_{coil}}$$

$$CF = \frac{T_1 - T_2}{T_1 - T_{coil}}$$

Cooling and dehumidification



$$BPF = \frac{h_c - h_2}{h_1 - h_2}$$

$$= \frac{\omega_c - \omega_2}{\omega_1 - \omega_2}$$

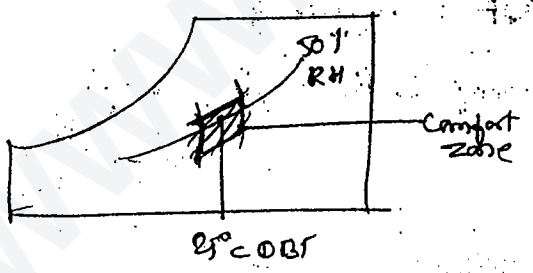
$$= \frac{T_c - T_2}{T_1 - T_2}$$

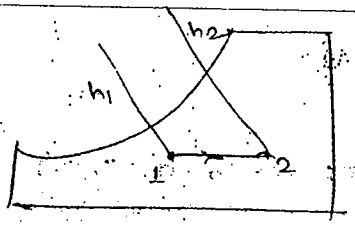
Summer air conditioning is cooling and dehumidification followed by sensible cooling heating

comfort conditions are

DBT = 22°C

RH = 50%





Sensible heat load (kw)

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

$= \dot{m}_a \cdot cp_{hs} (T_2 - T_1)$

$= \dot{m}_a (cp_a + \omega cp_v)(T_2 - T_1)$

At 2B DBT 20°c and R.H 50% the density of air considered as 1.2 kg/m³ and Cp_{hs} is considered as 1.0218 KJ/kgK. the flow rate of air measured as 1 cubic meter per minute

flow rate of air = $\dot{V}$ cmm

Sensible heat load (SHL) $= \dot{m}_a cp_{hs} (T_2 - T_1)$

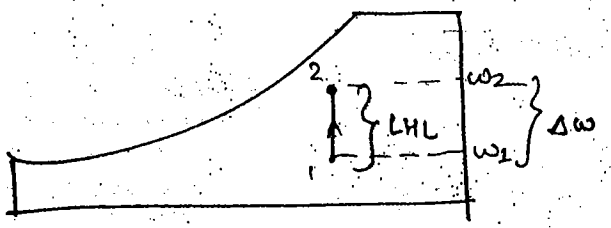
$= \frac{\dot{V}}{60} \rho cp_{hs} (T_2 - T_1)$

$= \frac{\dot{V}}{60} \times 1.2 \times 1.0216 (\Delta T)$

$= 0.0204 \dot{V} (\Delta T)$ kw

Humidification process

LHL: Latent heat load



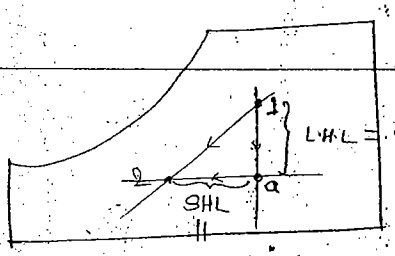
LHL (kw) $= \dot{m}_a (\omega_2 - \omega_1) (h_{fg})_{0°c}$

$= \frac{1.2}{60} \times 2500 \times \dot{V} \Delta\omega$

$= 50 \dot{V} \Delta\omega$

Cooling and dehumidification:

It is an summer air conditioning proces



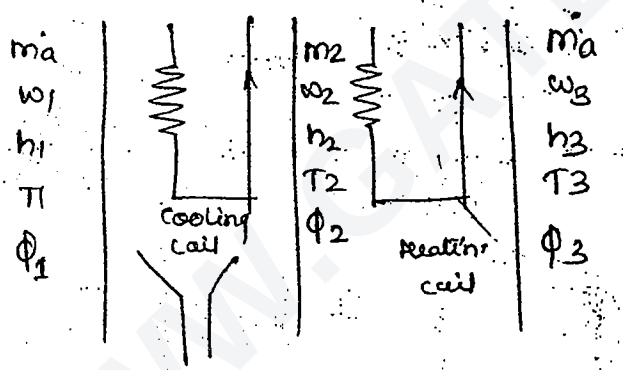
Total heat load (THL) = SHL + LHL

Sensible heat factor (SHF) = SHL / (SHL + LHL)

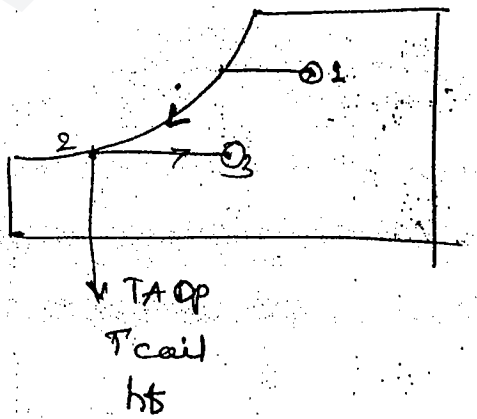
$$SHF = \frac{0.0204\,\dot{V}\,\Delta T}{0.0204\,\dot{V}\Delta T + 50\,\dot{V}\,\Delta\omega} \qquad SHF = \frac{SHL}{THL}$$

$$= \frac{1}{1 + \frac{50}{0.0204}\left(\frac{\Delta\omega}{\Delta T}\right)} = \frac{1}{1 + 2451\left(\frac{\Delta\omega}{\Delta T}\right)}$$

Cooling and dehumidification



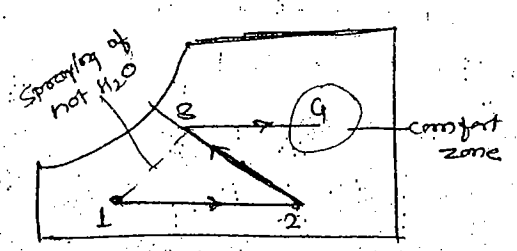
$\dot{m}_f = \dot{m}_a(\omega_1 - \omega_2)$



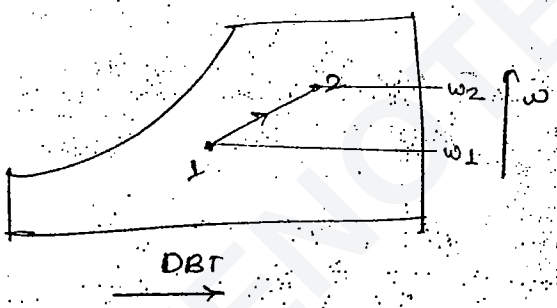
h_f = water coming out from air coil as a enthalpy equal to the coil temp or the apparatus dew point temp

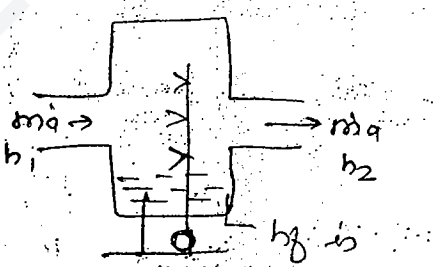
Winter air conditioning

1-3 is process substitute for 1-2 to 2-3



Heating and humidification



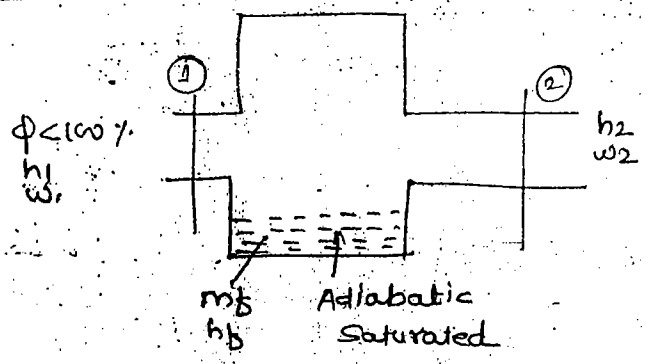


$$\dot{m}_a h_1 + \dot{m}_f h_f = \dot{m}_a h_2$$

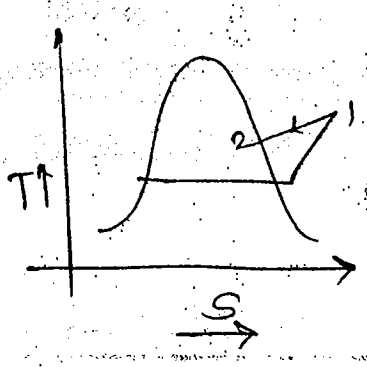
$$\boxed{\dot{m}_a h_1 + \dot{m}_a(\omega_2 - \omega_1) h_f = \dot{m}_a h_2}$$

humidification

Adiabatic saturation process



$$\dot{m}_f = \dot{m}_a(\omega_2 - \omega_1)$$



1-2 ⇒ Adiabatic saturation process

Adiabatic saturation temp & WBT are same for air vapor mixtures. for other gas vapor mixture adiabatic Saturation temp and wet bulb temp are different

Problems: pg NO 32 Qu.1

$T = 20^\circ C \quad P_{sat} = 2.337 \text{ kpa}$

$$\phi = \frac{P_v}{P_{sat}}$$

$$0.7 = \frac{P_v}{2.337} \qquad P_v = 0.337 \times 0.7 = 1.636 \text{ kpa.}$$

$$\omega = 0.622 \frac{P_v}{P_{atm} - P_v}$$

$$= 0.622 \times \frac{1.636}{101.325 - 1.636} = 0.0102 \frac{\text{kg vapor}}{\text{kg. of dry air}}$$

Qu.2 $T = 25^\circ C \quad P_{sat} = 3.166 \text{ kpa}$

$$\phi = \frac{P_v}{P_{sat}}$$

$$0.74 = \frac{P_v}{3.166}$$

$$P_v = 0.74 \times 3.166$$

$$= 2.34 \text{ @} \rightarrow T_{sat} = 20^\circ C.$$

$$\omega = 0.622 \frac{P_v}{P_{atm} - P_v}$$

$$= 0.622 \times \frac{2.34}{101.325 - 2.34}$$

$$= 0.0147 \frac{\text{kg vap}}{\text{kg dry air}}$$

for air
adiabatic
effect

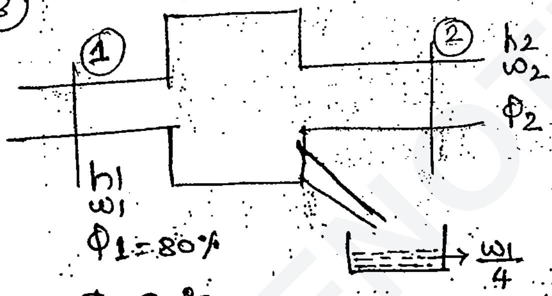
If the Tatm drops from 25°C to 20°C then cloud form start so dropping temp. $dT = 5°C$ or $5K$

for $6.5K \rightarrow 1000m$
$5K \rightarrow ?$

$$\frac{5}{6.5} \times 1000 = 770m$$

cloud formation start at 770m

③



6 kPa

$\phi_1 = 80\%$

$T_1 = 20°C$

↓

$P_{sat} = 2.337 \text{ kPa}$

$$\phi_1 = \frac{P_{V1}}{T_{sat}}$$

$$0.8 = \frac{P_{V1}}{2.337}$$

$P_{V1} = 1.87$

vapor / of dry air

$$\omega_1 = 0.622 \frac{P_{V1}}{P_{atm} - P_{V1}}$$

$$= 0.622 \cdot \frac{1.87}{100 - 1.87}$$

$$= 0.09185 \frac{\text{kg vap}}{\text{kg dry air}}$$

$$\omega_2 = \frac{3\omega_1}{4}$$

$$= \frac{3 \times 0.0185}{4} =$$

$$= 0.622 \frac{P_{V2}}{P_{atm} - P_{V2}}$$

°C.

$$\frac{3 \times 0.0185}{4} = 0.622 \frac{P_{V2}}{100 - P_{V2}}$$

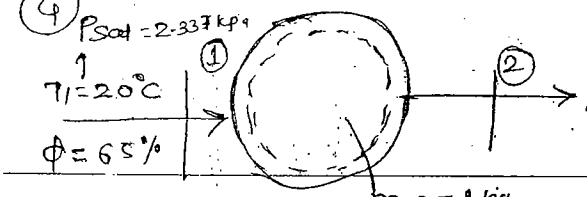
$P_{V2} = ~~12.41~~ \ 1.41 \text{ kPa}$

↓

$T_2 = 12°C$

Temp. of air leaving the dehumidifier is 12°C.

④



$\phi_1 = \frac{Pv}{Psat}$

$0.65 = \frac{Pv}{2.337}$

$Pv = 1.52$

$w_1 = 0.622 \frac{Pv_1}{Patm - Pv_1}$

$= 0.622 \times \frac{1.52}{100 - 1.52}$

$= 0.0096 \frac{kg\ vap}{kg\ dry\ air}$

$w_2 = 0.622 \frac{Pv_2}{Patm - Pv_2}$

$= 0.622 \times \frac{9.557}{100 - 9.557}$

$= 0.0657 \frac{kg\ vap}{kg\ dry\ air}$

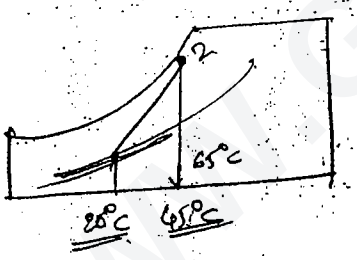
$\dot{m}a(w_2 - w_1) = \frac{mw}{t}$

$\dot{m}a(0.0657 - 0.0096) = \frac{1}{2400}$

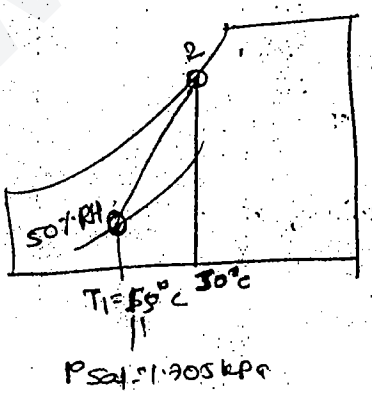
$\dot{m}a = 0.00242$ kg/sec

$= 0.00242 \times 3600$

$= 26.78$ kg/hr



⑤



$\phi = \frac{Pv}{Psat}$

$0.5 = \frac{Pv}{1.705}$

$Pv = 0.8525$ kPa

$w_1 = 0.622 \frac{Pv_1}{Patm - Pv_1}$

1.557 kPa

= 9.557 kPa.

$= 0.622 \frac{P_{v2}}{P_{atm} - P_{v2}}$

$0.622 \times \frac{9.557}{100 - 9.557}$

0.065 kg vap / kg dry air

$\omega_1 = 0.622 \times \frac{0.8525}{101.325 \times 0.8525}$

$= 0.0052 \frac{\text{kg vap}}{\text{kg of dry air}}$

$T_2 = 30^\circ C$

$P_{sat} = 4.241$ kPa

$\phi = \frac{P_v}{P_{sat}}$

$P_v = 4.241$ kPa

$\omega_2 = 0.622 \frac{P_{v2}}{P_{atm} - P_{v2}}$

$= 0.622 \times \frac{4.241}{101.325 - 4.2}$

$= 0.0272 \frac{\text{kg vap}}{\text{kg of dry air}}$

$\dot{m}_a = \frac{PV}{RT} = \frac{P_a}{R_a} \cdot \frac{V}{T}$

$= \frac{(101.325 - 0.8525)}{0.287 \times 288}$

$= 12.155$ kg/sec

Amount of H_2O vapor removed

$= \dot{m}_a (\omega_2 - \omega_1)$

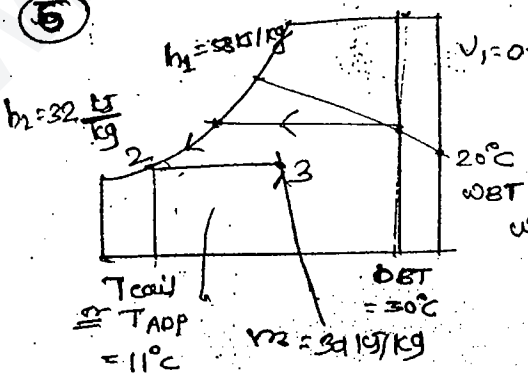
$= 12.15 (0.0272 - 0.0052)$

$= 0.2662$ kg/sec

$= 0.2662 \times 3600$ kg/hr

$= 958.32$ kg/hr.

(5)

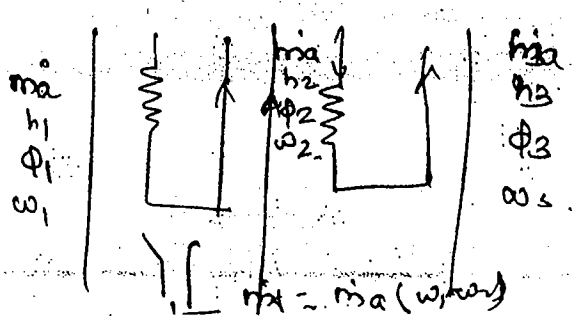


$v_1 = 0.873 \frac{m^3}{kg}$

$\omega_1 = 0.0105 \frac{\text{kg vap}}{\text{kg of dry air}}$

$\omega_2 = \omega_3 = 0.008 \frac{\text{kg vap}}{\text{kg dry air}}$

$Ch_f)_{at\ T_{ADP}} = 46.2$ kJ/kg



$\dot{m}_f = \dot{m}_a(\omega_1 - \omega_2)$

$\downarrow$

$h_f = 46.2$ kJ/kg

Apply SFEE

~~$\dot{m}_a h_1 + \dot{m}_f h_f = \dot{m}_a h_2$~~ $\quad \dot{m}_a h_1 - \dot{Q} = \dot{m}_a h_2 + \dot{m}_f h_f$

~~$\dot{m}_a h_1 + \dot{m}_a(\omega_1 - \omega_2) h_f =$~~ $\quad = \dot{m}_a h_2 + \dot{m}_a(\omega_1 - \omega_2) h_f$

$\dot{V} = 200 \frac{m^3}{min}$

$\dot{m} = \frac{\dot{V}}{v_1} = \frac{200}{60} \times \frac{1}{0.873} = 3.82$ kg/sec

$3.82 \times 58 - \dot{Q} = 3.82 \times 32 + 3.82[0.0105 - 0.008]\,46.2$

$\dot{Q} = 98.87$ kW

SHL (kW) $= \dot{m}_a(h_3 - h_2)$

$= 3.82(39 - 32)$

$= 26.74$ kW

Qu.7 $\ln p = 19.013 - \frac{5325}{T}$

$P_{atm} = 960 \times 10^{-3} \times 10^2$

$= 96$ kPa

Temp $= 30^\circ C$

$\phi = 60\%$

$\ln P_{sat} = 19.013 - \frac{5325}{303}$

$P_{sat} = 4.1253$ kPa

$\phi = \frac{P}{P_s}$

$0.6 = \frac{P}{C}$

$Pv = 2$

$\omega_{sat} =$

Degree of

The tem

as dew

enthalpy

$\phi = \frac{p_v}{p_{sat}}$ $\quad \omega = 0.622 \frac{p_v}{p_{atm} - p_v}$

$0.6 = \frac{p_v}{4.215}$ $\quad = 0.622 \frac{2.53}{96 - 2.53}$

$\boxed{p_v = 2.529 \text{ kPa}}$ $\quad = \underline{0.0168} \frac{\text{kg vap}}{\text{kg dry air}}$

$+ \dot{m}_f h_f$

$\dot{m}_a(\omega_1 - \omega_2) h_f$

$\omega_{sat} = 0.622 \frac{p_{sat}}{p_{atm} - p_{sat}}$

$= 0.622 \times \frac{4.215}{96 - 4.215}$

$= 0.0285 \frac{\text{kg vap}}{\text{kg of dry air}}$

ec

0.008] 96.2

Degree of saturation $\mu = \frac{\omega}{\omega_{sat}} = \frac{0.0168}{0.0285}$

$= \underline{0.58}$

The temp corresponding partial pressure in air is call as dew point temp

$\ln p_v = 19.013 - \frac{5325}{DPT}$

$\ln 2.53 = 19.013 - \frac{5325}{DPT}$

$\boxed{DPT = 294.94 \text{ K}}$ or $\underline{21.44^\circ C}$

Enthalpy steam $C_{p\,air}$

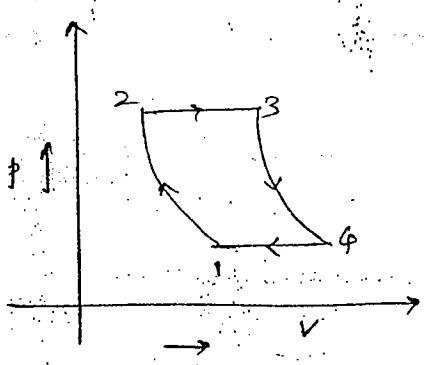
$h = c_{p_a}(T - 0) + \omega \left(h_{fg} + c_{p_v}(T - 0) \right)$

$= 1 (30 - 0) + 0.0168 \left(2514 + 1.88 (30 - 0) \right)$

$= 73.18 \text{ kJ/kg of dry air}$

GAS TURBINE

Joule cycle or Brayton cycle

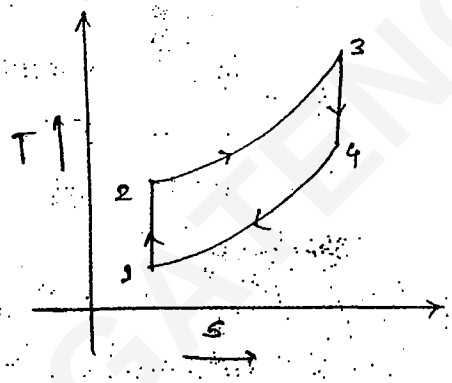


1-2 ⇒ Reversible Adiabatic compre
2-3 ⇒ constant pressure heat supp
3-4 ⇒ Reversible Adiabatic expans
4-1 ⇒ cp heat rejection.

Compression ratio = $r_R = \frac{V_1}{V_2}$

Expansion ratio = $r_E = \frac{V_4}{V_3}$

pressure ratio = $r_p = \frac{P_2}{P_1} = \frac{P_3}{P_4}$



1-2 ⇒ Reversible Adiabatic compression
$Q = 0$ s = constant

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{\gamma} = P_1 r_R^{\gamma} \quad \text{—— (1)}$$

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_1 r_R^{\gamma-1} \quad \text{—— (2)}$$

$$T_1 P_1^{\frac{1-\gamma}{\gamma}} = T_2 P_2^{\frac{1-\gamma}{\gamma}}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{—— (3)}$$

$$W_{1-2} = \frac{\gamma}{\gamma-1}\left[P_1 V_1 - P_2 V_2\right]$$

$$= \frac{mR\gamma}{\gamma-1}\left[T_1 - T_2\right]$$

$$= m \cdot c_p (T_1 - T_2) \quad \text{—— (4)}$$

$$= m \cdot (h_1 - h_2) \quad \text{—— (5)}$$

2-3 p=c heat supply

$$\frac{V_2}{T_2} = \frac{V_3}{T_3}$$

$$T_3 = \frac{V_3}{V_2} \times T_2 \quad \text{—— (6)}$$

$$_2Q_3 = c_p (T_3 - T_2) \quad \text{—— (7)}$$

3-4 Reversible Adiabatic Expansion

$Q = 0 \quad S = C$

$$P_3 V_3^{\gamma} = P_4 V_4^{\gamma}$$

$$P_3 = P_4 \left(\frac{V_4}{V_3}\right)^{\gamma}$$

$$= P_4 (\varepsilon_E)^{\gamma} \quad \text{—— (8)}$$

$$T_3 V_3^{\gamma-1} = T_4 V_4^{\gamma-1}$$

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

$$= T_4 (\varepsilon_E)^{\gamma-1} \quad \text{—— (9)}$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{—— (10)}$$

$$_3W_4 = \frac{\gamma}{\gamma-1} (P_3 V_3 - P_4 V_4)$$

$$= \frac{\gamma}{\gamma-1} mR (T_3 - T_4) \quad \text{—— (11)}$$

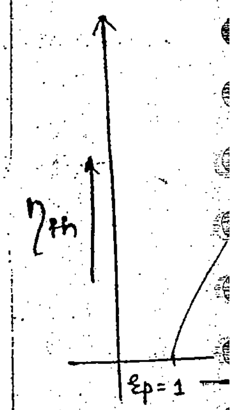
$$= m (h_3 - h_4) \quad \text{—— (12)}$$

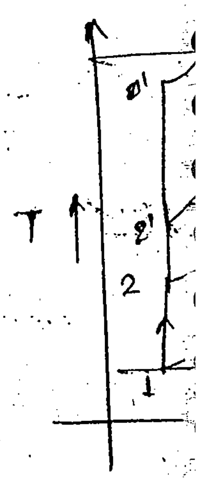
4-1 p=c heat rejection

$$\frac{V_4}{T_4} = \frac{V_1}{T_1}$$

$$T_4 = \frac{V_4}{V_1} \times T_1 \quad \text{—— (13)}$$

Thermal





$$4Q_1 = C_p(T_4 - T_1) \quad \text{——(14)}$$

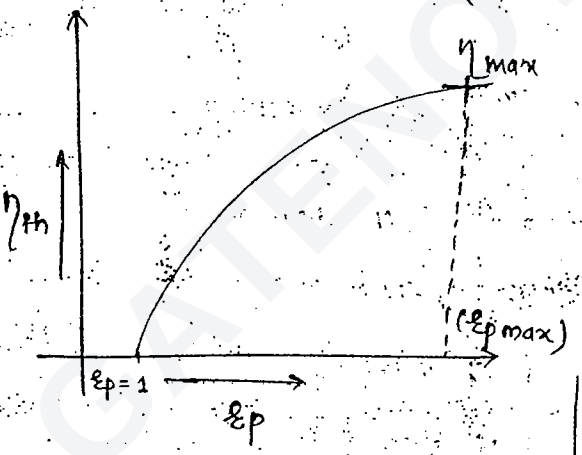
Thermal efficiency =

$$\eta_{th} = 1 - \frac{Q_R}{Q_S}$$

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

$$= 1 - \left(\frac{1}{\varepsilon_p}\right)^{\frac{\gamma-1}{\gamma}} = f(\varepsilon_p, \gamma)$$

$$= 1 - \left(\frac{1}{\varepsilon_k}\right)^{\gamma} = f(\varepsilon_k, \gamma)$$



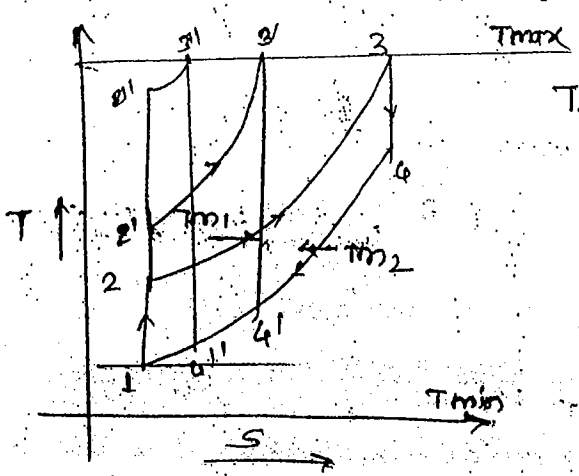
The Max efficiency of any cycle is carnot efficiency

$$\eta_{th} = 1 - \left(\frac{1}{\varepsilon_{p\,max}}\right)^{\frac{\gamma-1}{\gamma}}$$

$$= 1 - \left(\frac{T_{min}}{T_{max}}\right)$$

$$\boxed{\varepsilon_{p\,max} = \left[\frac{T_{max}}{T_{min}}\right]^{\frac{\gamma}{\gamma-1}}}$$

At the above pressure ratio the η_{th} of the brayton cycle is maximum



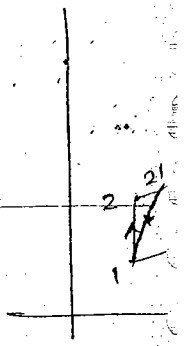
T_{m_1} = Mean temp of heat sup

$$= \frac{h_3 - h_2}{s_3 - s_2}$$

$$= \frac{C_p(T_3 - T_2)}{C_p \ln \frac{T_3}{T_2}} = \frac{T_3 - T_2}{\ln \frac{T_3}{T_2}}$$

T_{m_2} = Mean temp of heat rejected

$$= \frac{h_4 - h_1}{s_4 - s_1} = \frac{c_p (T_4 - T_1)}{c_p \ln \frac{T_4}{T_1}} = \frac{T_4 - T_1}{\ln \frac{T_4}{T_1}}$$



$$\eta_{th} = 1 - \frac{Q_R}{Q_S}$$

$$= 1 - \left(\frac{h_4 - h_1}{h_3 - h_2}\right)$$

$$= 1 - \frac{T_{m_2}(s_4 - s_1)}{T_{m_1}(s_3 - s_2)}$$

$$= 1 - \frac{T_{m_2}}{T_{m_1}} \Rightarrow f(T_{m_1}, T_{m_2})$$

T_{m_1} constant T_{m_2} constant increases η_{th} decreases

T_{m_1} constant T_{m_2} decreases η_{th} increases

T_{m_2} constant T_{m_1} increases η_{th} increases

T_{m_2} constant T_{m_1} decreases η_{th} decreases

T_{m_1} decreases η_{th} decreases, T_{m_1} increases η_{th} increases

T_{m_2} increases η_{th} decreases T_{m_2} decreases η_{th} increases

r_p increases T_{m_1} increases

r_p increases T_{m_2} decreases

r_p increases $T_{m_1} \rightarrow T_{m_2}$ $\quad (\eta_{th})_{Brayton} \Rightarrow (\eta_{th})_{Carnot}$

r_p increases $T_{m_2} \rightarrow T_{m_1}$

when we operating at higher pressure ratios expansion work is almost equal to compression work.

and net work availability is less through the efficiency is maximum and net work availability is less will not be operating at pressure ratios

In olden the rang very less Now a hence th Gas turbi

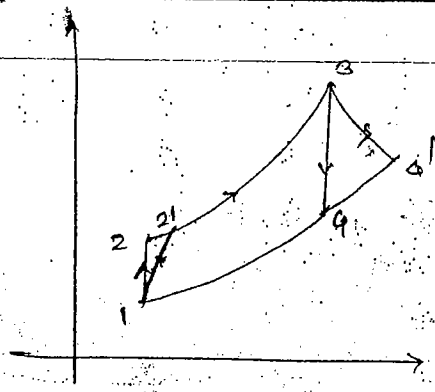
Work expa

Work comp

back w expans

back

Work &



1-2 ⇒ isentropic compression

1-2' ⇒ Actual compression

$\eta_{compressor} = \frac{Work_{isentropic}}{Work_{Actual}}$

$= \frac{cp(T_2 - T_1)}{cp(T_2' - T_1)}$

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

$T_2' =$

$\eta_{turbine} = \frac{cp(T_3 - T_4')}{cp(T_3 - T_4)}$

$\boxed{T_4' = T_3 - \eta_{turbine}(T_3 - T_4)}$

In olden day the compressor turbine efficiency are the range of 60 to 70%. hence the cycle effiency are very less and Gas turbine are not popular in 1920

Now a days compressor turbine effiency are greater than hence the $\eta_{thermal}$ improved to 27% now a days.

Gas turbine are very popular

$Work_{expansion} = cp(T_3 - T_4)$

$Work_{compressor} = cp(T_2 - T_1)$

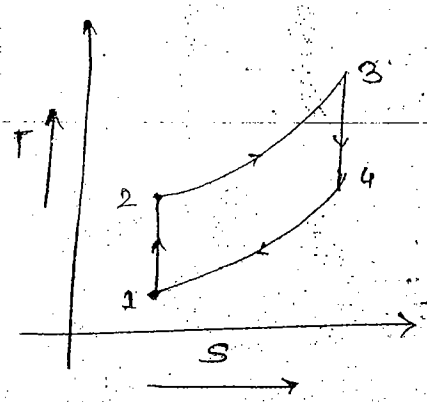
back work ratio defined in ratio of compressor work expansion work

$\boxed{\text{back work ratio} = \frac{WC}{WE} = \frac{cp(T_2 - T_1)}{cp(T_3 - T_4)} = \frac{T_2 - T_1}{T_3 - T_4}}$

$\text{Work ratio} = \frac{W_{net}}{WE}$

$= \frac{WE - WC}{WE} = 1 - \frac{WC}{WE} = \frac{1 - cp(T_2 - T_1)}{1 - cp(T_3 - T_4)}$

Optimum workdone in Gas turbine cycle



$$W = Q_S - Q_R$$

$$W = c_p(T_3 - T_2) - c_p(T_4 - T_1)$$

$$= c_p\left(T_3 - T_2 - T_4 + T_1\right)$$

$$\frac{T_2}{T_1} = r_p^{\frac{\gamma-1}{\gamma}} \qquad \frac{T_3}{T_4} = r_p^{\frac{\gamma-1}{\gamma}}$$

$$T_2 = T_1 r_p^{\frac{\gamma-1}{\gamma}} \qquad T_4 = \frac{T_3}{r_p^{\frac{\gamma-1}{\gamma}}}$$

$$W = c_p\left(T_3 - T_1 r_p^{\frac{\gamma-1}{\gamma}} - \frac{T_3}{r_p^{\frac{\gamma-1}{\gamma}}} + T_1\right) = f(r_p)$$

$$\frac{dW}{dr_p} = -c_p T_1\left(\frac{\gamma-1}{\gamma}\right) r_p^{\frac{\gamma-1}{\gamma}-1} - c_p T_3\left(\frac{1-\gamma}{\gamma}\right) r_p^{\frac{1-\gamma}{\gamma}-1} = 0$$

$$(r_p)_{optimum} = \left(\frac{T_3}{T_1}\right)^{\frac{\gamma}{2(\gamma-1)}} = \left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{2(\gamma-1)}}$$

$$\boxed{\frac{dW}{dr_p} = \sqrt{(r_p)_{max}}}$$

$$T_2 = T_1 r_p^{\frac{\gamma-1}{\gamma}}$$

$$= T_1\left[\left(\frac{T_3}{T_1}\right)^{\frac{\gamma}{2(\gamma-1)}}\right]^{\frac{\gamma-1}{\gamma}} = \sqrt{T_1 T_3}$$

$$T_4 = \frac{T_3}{(r_p)^{\frac{\gamma-1}{\gamma}}}$$

$$= \frac{T_3}{\left[\left(\frac{T_3}{T_1}\right)^{\frac{\gamma}{2(\gamma-1)}}\right]^{\frac{\gamma-1}{\gamma}}}$$

when cycle is operating at optimum pressure ratio th
temp end of expansion equal to temp end of comp

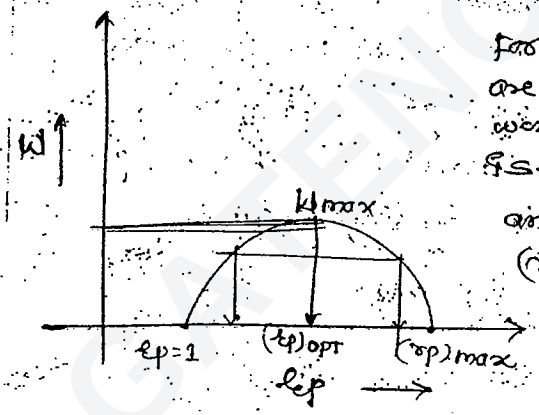
$$T_2 = T_4 = \sqrt{T_1 T_3}$$

$$W_{max} = C_p \left[T_3 - \sqrt{T_1 T_3} - \sqrt{T_1 T_3} + T_1 \right]$$

$$= C_p \left[\sqrt{T_3} - \sqrt{T_1} \right]^2$$

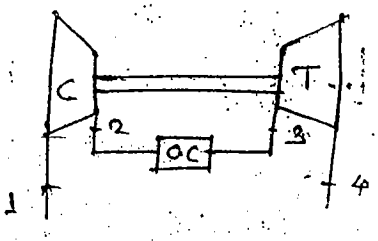
At optimum pressure ratio

$$\eta_{th} = 1 - \sqrt{\frac{T_{min}}{T_{max}}}$$



for work less than max work there are two pressure ratio at which th work is same. one pressure ratio is between r_{p_1} and $r_{p\,optimum}$ another pressure ratio is in between $(r_p)_{optimum}$ and $(r_p)_{maximum}$.

Open cycle gas turbine



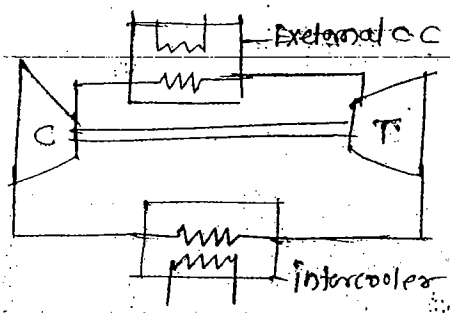
every time freshed air is sucked from atmosphere it combusted in the combustion chamber and it is exhausted i turbine

In the compressor only air is flo in the turbine Air + fuel is flow hence the mass flowing through turbine is greater than mass flowin through the compressor.

As dust particle are entering the system the wear and tear compressor plate & turbine plate is very high. it is light in weight hence it is used for aircraft engine.

closed cycle gas turbine

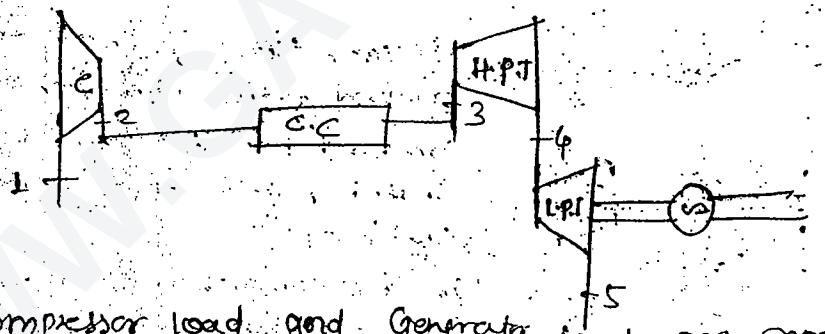
CC-GT closed cycle Gas turbine plant



here external combustion chamber is used as it is external combustion chamber any type of fuel can be used. In closed cycle any type of medium can be used

If the medium is helium which is having higher ratio of specific heat the thermal efficiency will be high here the interpole is used to cool the hot gases coming out of turbine. two extra H.E are used hence weight is high and cost is high C.C.G.T are generally used in Nuclear power plant. As the weight is high they cannot be used in aircraft engines

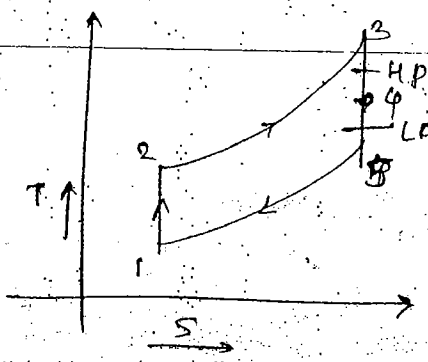
Free shaft turbine



here compressor load and Generator load are separated the work output on high pressure turbine is used to operate compressor. where work output of L.P.T is used to operate Generator

As the compressor load and Generator load are separated it respond to part load operation.

al combustion
used as it
ombustion
ry type of
used. In
ry type of
be used
is helium
e thermal
d to cool the
are used
T are
the weight is
fines



$(Work)_{Comp} = W_{HPT}$

$C_p(T_2 - T_1) = C_p(T_3 - T_4)$

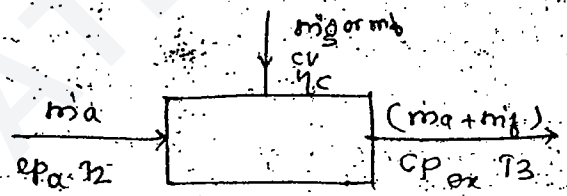
$(W)_{LPT} = C_p(T_4 - T_5)$ = Generator load,

This is used for part load operation

$$\frac{P_2}{P_1} = \frac{P_3}{P_4} \times \frac{P_4}{P_5}$$

$$\boxed{(\eta_p)_{comp} = (\eta_p)_{HPT} \times (\eta_p)_{LPT}}$$

Open cycle combustion chamber



$$\dot{m}_a C_{p_a} T_2 + \dot{m}_f (CV)\eta_c = (\dot{m}_a + \dot{m}_f) C_{p_{ex}} T_3$$

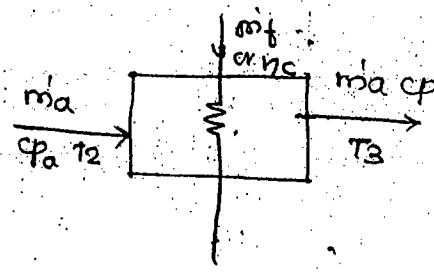
$$\frac{\dot{m}_a}{\dot{m}_f} \cdot C_{p_a} T_2 + (CV)\eta_c = \left(\frac{\dot{m}_a}{\dot{m}_f} + 1\right) C_{p_{ex}} T_3$$

$$\boxed{(\text{Air fuel ratio}) C_{p_a} T_2 + (CV)\eta_c = (AFR + 1) C_{p_{ex}} T_3}$$

separated
used to
T is used to

Generator
operator.

Closed cycle combustion chamber



$$\dot{m}_a C_{p_a} T_2 + \dot{m}_f (CV)\eta_c = \dot{m}_a \cdot C_{p_a} \cdot T_3$$

$$\frac{\dot{m}_a}{\dot{m}_f} \cdot c_{pa} T_2 + (cv)\eta_c = \frac{\dot{m}_a}{\dot{m}_f} c_{pa} T_3$$

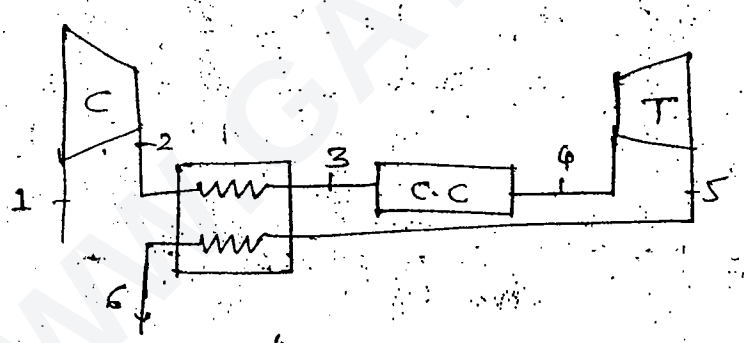
$$\boxed{(A.F.R)\, c_{pa} T_2 + (cv)\eta_c = AFR \cdot c_{pa} \cdot T_3}$$

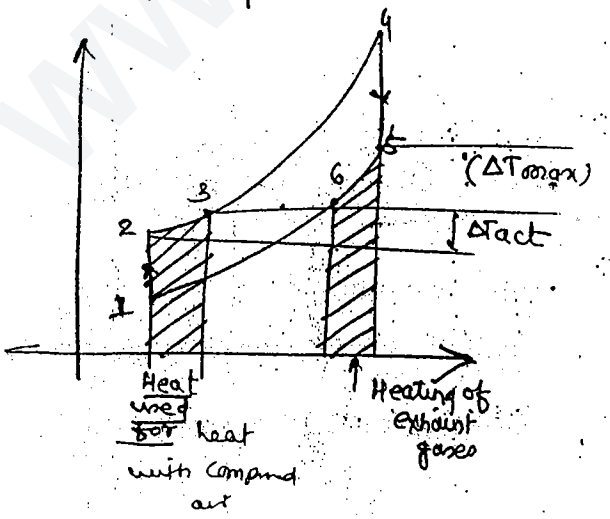
Methods for improving thermal efficiency of of Gas turbine cycle

1. Method of Regeneration
2. Method of Reheating
3. Method of intercooling

Method of Regeneration

In this Method the heat of exhaust gases is used to heat the compressed air as a result air enters the combustion chamber at a higher temp and consequently the amount of fuel burned will be less hence thermal efficiency improves.





effectiveness of H.E

$$\epsilon = \frac{(\Delta T)_{act}}{(\Delta T)_{max}}$$

$$\epsilon = \frac{T_3 - T_2}{T_5 - T_2}$$

W_T is constant W_C is constant W_{net} is constant

Q_S decreases

$T_{m1} \uparrow \quad T_{m2} \downarrow \quad \eta_{th} \uparrow$

Air rate remain constant and heat rate decreases

Heat supplied $Q_S = h_4 - h_3$

Heat rejected $Q_R = h_6 - h_1$

$$(\eta_{th})_{\substack{\text{ideal} \\ \text{regenerator} \\ \text{cycle}}} = 1 - \frac{T_{min}}{T_{max}} \cdot r_p^{\frac{\gamma-1}{\gamma}}$$

$$= 1 - \frac{T_1}{T_4} r_p^{\frac{\gamma-1}{\gamma}}$$

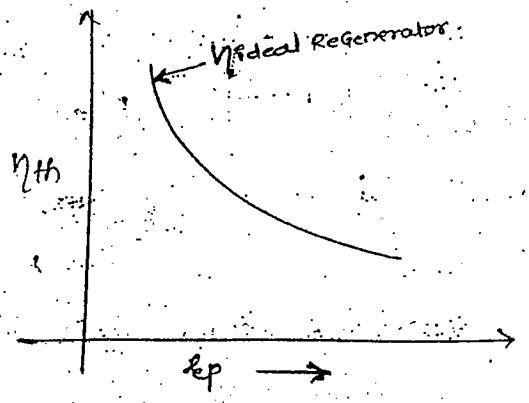
@ $(r_p)_{critical}$

$\eta_{\substack{\text{Ideal} \\ \text{Regenerator}}} = \eta_{brayton}$

$$1 - \frac{T_{min}}{T_{max}} (r_{pc})^{\frac{\gamma-1}{\gamma}} = 1 - \left(\frac{1}{r_{pc}}\right)^{\frac{\gamma-1}{\gamma}}$$

$$r_{pc} = \left[\frac{T_{max}}{T_{min}}\right]^{\frac{\gamma}{2(\gamma-1)}}$$

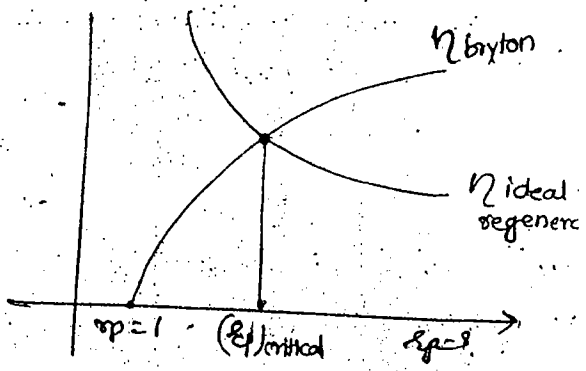
$$\boxed{r_{pc} = \sqrt{(r_p)_{max}}}$$



At $r_p = 1$ and $r_p = critical$

- $\eta_{\substack{\text{ideal} \\ \text{regenerative}}} > \eta_{brayton}$

greater than r_p critical brayton efficiency is greater than ideal regenerative hence the principle of regeneration is not effective when the pressure ratio is greater than critical pressure ratio

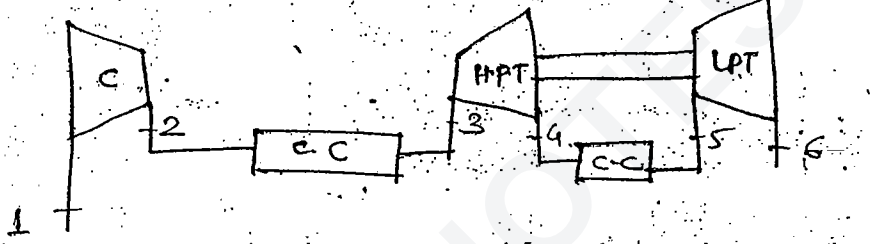


@ $(r_p)_{critical}$ $\eta_{brayton} = \eta_{ideal\ regenerator}$

If pressure ratio is greater than (rp) critical the temp at end of compression is greater than temp end of exhaust hence instead of air being heated up gets cooled in the H.E and consequently thermal efficiency falls. don't use regeneration beyon (rp) critical

Method of Reheating

In this the heating is done in two stages stage 1 and stage 2 ccw and expands is done in two turbine

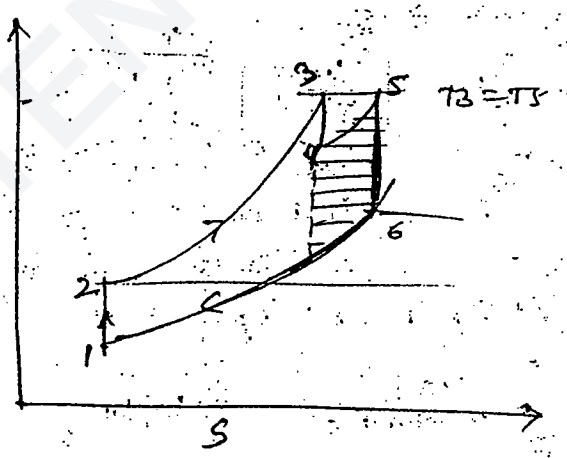


$W_T = (h_3 - h_4) + (h_5 - h_6)$

$W_C = (h_2 - h_1)$

$Q_S = C_p(T_3 - T_2) + C_p(T_5 - T_4)$

$Q_R = C_p \cdot (T_6 - T_1)$



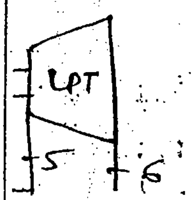
Turbine work increases when compared to simple cycle W_{net} increases W_C is same Q_S increases Q_R ↑

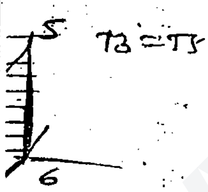
A_R ↓ η_{th} ↓ ∴ Air rate (A_R) ↓ Heat rate ↑

Turbine exhaust temp increases. The gap of turbine exhaust temp increases

the temp
end of
up gets
efficiency
ficad

pes
done by





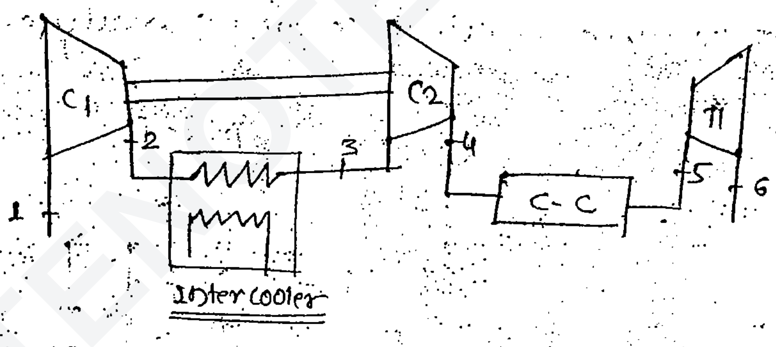
T3 = T5

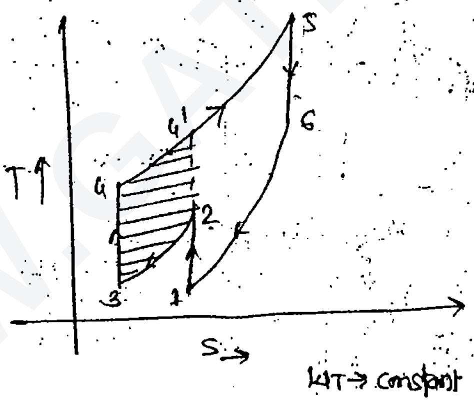
nple cycle
QR ↑
ate ↑
bine

- the principle of regeneration can be applied here
- only reheating will reduce η_{th} of the cycle. but reheating and regeneration will always improved the η_{th} of cycle

Method of intercooling: (Intercooled cycle)

Instead of single stage compression, multistage compression with intercooling adopted to improved the η_{th} of cycle





WT → constant

$W_T = h_5 - h_6$

$W_C = (h_2 - h_1) + (h_4 - h_3)$

$Q_S = h_5 - h_4$

$Q_R = (h_6 - h_1) + (h_2 - h_3)$

$W_T \rightarrow$ $W_C \downarrow$ $W_{net} \uparrow$ $Q_S \uparrow$

$\eta_{th} \downarrow$ $T_{m1} \downarrow$ $T_{m2} \uparrow$ AR ↓ HR

AR = Air rate

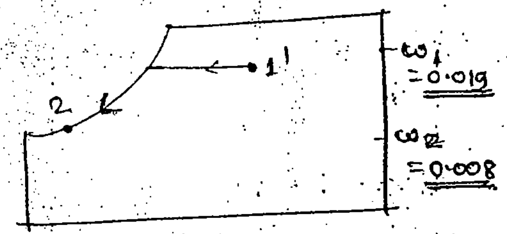
HR = Heat rate

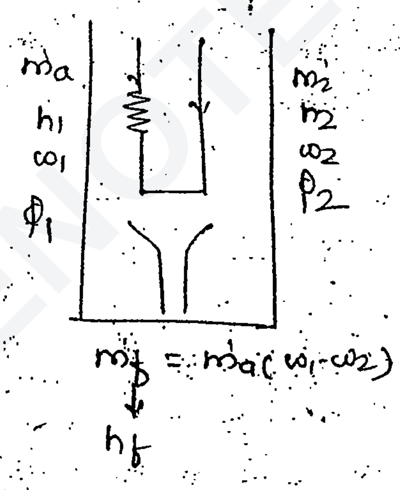
The gap between Turbine exhaust & compressor exist Increase consequently and hence princi of regeneration can be employed. only intercoolin reducing η_{th} ~~bit~~ of cycle but intercooling and regeneration will always Improve η_{th} of cycle.

Psychrometry

Atm air at a flow rate of 3kg/s on dry basis enters a cooling and dehumidifying coil with an enthalpy of 85 kJ/kg of dry air and humidity ratio of 19 gms/kg of dry air the air leaves the coil with an enthalpy of 43 kJ/kg of dry air and a humidity ratio of 8 gms/kg of dry air the condensate water leaves the coil with an enthalpy of 67 kJ/kg. the required cooling capacity coil in kW is

(a) 75 (b) 123.8 (c) 128.2 (d) 159





$h_1 = 85$ kJ/kg

$h_2 = 43$ kJ/kg

$h_f = 67$ kJ/kg

Apply SFEE :

$$\dot m_a h_1 - \dot Q = \dot m_a h_2 + \dot m_f h_f$$

$$= \dot m_a h_2 + \dot m_a(\omega_1 - \omega_2) h_f$$

$$\dot Q = \dot m_a (h_1 - h_2) - \dot m_a(\omega_1 - \omega_2) h_f$$

$$= 3(85-43) - 3(0.019 - 0.008)\,67$$

$$= \underline{123.8}$$

A thin l... former ... temp 20°... steam t...

Temp 0°C

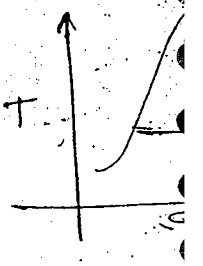
Sat pressure kPa

neglec... the ... is req...

(a) 10.3

⇒ Tsat =

Psat



The fo...

(1) cond... the...

(2) con... the...

(3) con...

(4) cond... wr...

(a) 23

basis
with an
idity ratio
re coil
nd a
re
enthalpy of
d in kW is

A thin layer of water in a film field is formed after former has water it the ambient air condition are temp 20^0 and relative humidity 5% and extraction of steam table 0°c

Temp °C	-15	-10	-5	0.01	5	10	15	20
Sat pressure kpa	0.1	0.26	0.4	0.61	0.89	1.23	1.71	2.34

Neglecting the heat transfer betn water and Ground the water temp in the field after face equilibrium is reache equals

(a) 10.3 (b) -10.3 (c) -14.5 (d) +14.5

m_2'
h_2
ω_2
P_2

⇒ $T_{sat} = 20°C$

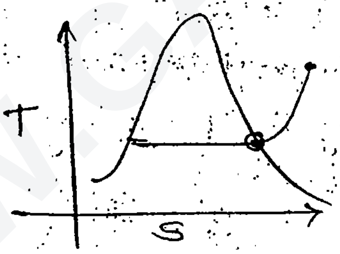
$P_{sat} = 2.34$

$\phi = \frac{P_v}{P_{sat}} =$

$0.05 = \frac{P_v}{2.34}$ $P_v = 0.117 kpa$

Closer to 0.1

$\omega_1 - \omega_2)$



The following statement concerni psychometric chart

(1) constant ϕ lines are upcale straight St lines to the right

(2) constant WBT lines are down hill straight line to the right

(3) constant specific volume lines are downhill straight line to the right

(4) constant enthalpy lines are coincident with constant WBT lines.

67

which statement are correct

(a) 2,3 (b) 1,2, (c) 1,3 (d) 2,4

Air at at DBT at 40°C and WBT at 20°C is dehumidified in air washer operating with continuous water recirculation the WBT at exists is 25% of that inlet. the DBT at the exit of air washer is closes to

(a) 10°C (b) 20°C (c) 25°C (d) 30°C

$\Rightarrow (WBD)_{entrance} = 40 - 20 = 20°C$

$(\text{wet bulb depression})_{exist} = 0.25\,(WBD)_{entrance}$

$= 0.25 \times 20$

$= 5$

$(DBT - WBT)_{exist} = 5$

$(DBT - 20) = 5$

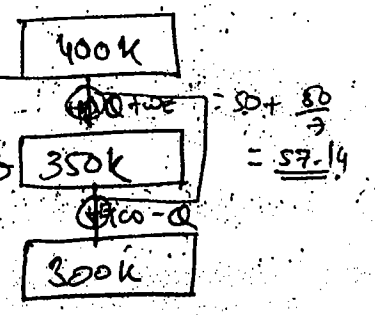
$DBT = 25°C$

A heat transformer is a device that transfers a part of heat supplied to it at intermediate temp to a high temp reservoir while rejecting the remaining part to a low temp heat sink. in such a transformer 100 kJ of heat is supplied at 350K the max amount of heat in kJ that can be transffered to 400K when the rest is rejected to heat sink at 300K is

(a) 12.5 (b) 14.29 (c) 33.33 (d) 57.14

$\Rightarrow \oint \frac{dQ}{T} = \frac{100}{350} - \frac{Q}{400} - \frac{(100-Q)}{300}$

$= 0$



$= 80 + \frac{80}{7} = 57.14$

humidified
ter
hot inlet
to a

$$KE = \left(\frac{350-300}{350}\right)(100-\phi)$$

$$(C.O.P)_{H.P} = \left(\frac{400}{400-350}\right) = \frac{Q+WE}{WE} = 1+\frac{Q}{WE}$$

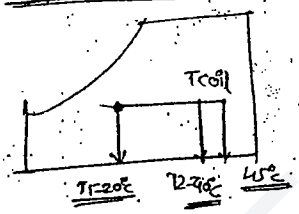
$$\frac{Q}{WE} =$$

$$Q = 7WE$$

$$= 7\left[\frac{100-\phi}{7}\right]$$

$$\boxed{Q = 50}$$

Psychrometer :



$$BPF = \frac{T_{coil} - T_2}{T_{coil} - T_1}$$

$$= \frac{45-40}{45-20}$$

Qu.10

$$N = \frac{\omega}{\omega_s} = \frac{0.623 \cdot \frac{P_V}{P_{sat}-P_V}}{0.622 \cdot \frac{P_{sat}}{P_{atm}-P_{sat}}}$$

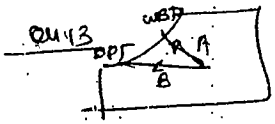
$$= \frac{P_V}{P_{sat}} \times \left(\frac{P_{atm}-P_{sat}}{P_{atm}-P_V}\right)$$

$$= \phi \times \left(\frac{P_{atm}-P_{sat}}{P_{atm}-P_V}\right)$$

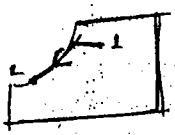
sfers
te temp
remaining
L

350K
ransferred
sink at

Qu.13



Qu.14



Qu.15 $SHF = \frac{SHL}{SHL+LHL}$

$$= \frac{SHL}{SHL+0.2\,SHL}$$

$$= 0.8$$

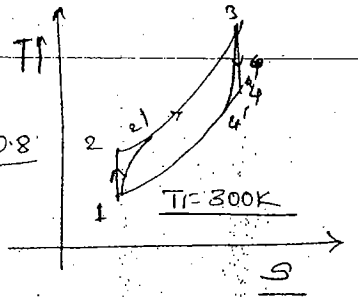
$$= 50 + \frac{50}{7}$$

$$= \underline{57.14}$$

Gas turbine : Problems

conventional

Qu. 1



$\eta_c = 0.8$

$T_3 = 875 + 273 = 1148K$

$\eta_T = 0.85$

$r_p = 4$

$C_V = 42000$ KJ/kg

$T_2' = T_1 + \frac{(T_2 - T_1)}{\eta_c}$

$T_2 = T_1 (r_p)^{\frac{\gamma-1}{\gamma}}$

$= 300 (4)^{\frac{0.4}{1.4}}$

$= 446K$

$T_2' = T_1 + \frac{T_2 - T_1}{\eta_c} = 300 + \frac{446 - 300}{0.8}$

$= 483K$

$\eta_T = \frac{T_3 - T_4'}{T_3 - T_4}$ =

$T_4 = \frac{T_3}{(r_p)^{\frac{\gamma-1}{\gamma}}} = \frac{1148}{(4)^{\frac{0.4}{1.4}}} = 792.5K \Rightarrow 793K$

$\eta_T = \frac{T_3 - T_4'}{T_3 - T_4}$

$T_4' = T_3 - \eta_T (T_3 - T_4)$

$= 1148 - 0.85 (1148 - 793)$

$= 829.25K$

$W_T = C_p (T_3 - T_4)$

$= 1 (1148 - 830)$

$= 318$ KJ/kg

$W_C = C_p (T_2' - T_1)$

$= 1 (483 - 300)$

$= 183$ KJ/kg

$Q_S = C_p(T_3 - T_2')$

$= 1(1148 - 483)$

$= 665$ kJ

$Q_R = C_p(T_4' - T_1)$

$= 1(830 - 300)$

$= 530$ kJ

$W_{net} = W_T - W_C$

$= 318 - 183$

$= 135$

work ratio $= \frac{W_{net}}{W_T} = \frac{135}{318} = 0.42$

back work ratio $= \frac{W_C}{W_T} = \frac{183}{318} = 0.57$

$\eta_{th} = \frac{Q_S - Q_R}{Q_S} = \frac{665 - 530}{665} = 0.2$

Air rate $= \frac{3600}{W_T - W_C} = \frac{3600}{315}$

Heat rate $= \frac{3600}{0.2} = 18000$ kJ/kWhr

$t = 723$K

Mean temp of heat supplied $= T_{m_1} = \frac{C_p(T_3 - T_2')}{C_p \ln(T_3/T_2')}$

$= \frac{T_3 - T_2'}{\ln(T_3/T_2')}$

$= \frac{1148 - 483}{\ln \frac{1148}{483}}$

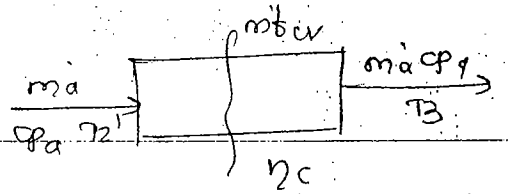
$= 768.1$

Mean temp of heat rejected $T_{m_2} = \frac{C_p(T_4' - T_1)}{C_p \ln(T_4'/T_1)}$

$= \frac{830 - 300}{\ln \frac{830}{300}}$

$= 520.8$

Air fuel ratio =



Apply the energy balance eqn.

$$\dot{m}_a \cdot c_{pa} \cdot T_2' + \dot{m}_f (CV)\eta_c = \dot{m}_a c_{pa} T_3$$

Divide by $\dot{m}_f$

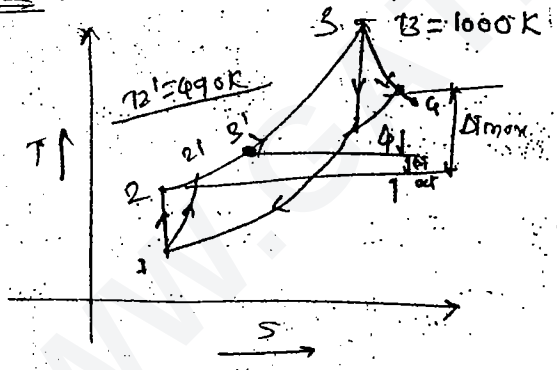
$$\frac{\dot{m}_a}{\dot{m}_f} c_{pa} T_2' + (CV)\eta_c = \frac{\dot{m}_a}{\dot{m}_f} c_{pa} T_3$$

$$(AFR)\, c_{pa} T_2' + (CV)\eta_c = (AFR)\, c_{pair} T_3$$

$$(AFR)(1)\ 483 + (42\times10^3)(0.9) = (AFR)\ 1\times1148$$

$$\boxed{A.F.R = 56.8\phi}$$

Qu.2



process 1-2 :

$$T_2 = T_1 (r_p)^{\frac{\gamma-1}{\gamma}}$$

$$= 300 (5)^{\frac{0.4}{1.4}}$$

$$= 475.14$$

$$T_2' > T_2$$

$$T_4 = \frac{T_3}{(r_p)^{\frac{\gamma-1}{\gamma}}} = \frac{1000}{5^{\frac{0.4}{1.4}}} = 632\text{ K}$$

$$\eta_T = \frac{T_3 - T_4'}{T_3 - T_4}$$

$$T_4' = T_3 - \eta_T (T_3 - T_4)$$

$$= 1000 - 0.8(1000 - 632)$$

$$= 705\text{ K}$$

$$\text{effectiveness} \cdot e = \frac{(\Delta T)_{act}}{(\Delta T)_{max}}$$

$$= \frac{T_3' - T_2'}{T_4' - T_2'}$$

$$0.8 = \frac{T_3' - 490}{705 - 490}$$

$$T_3' = 662\text{ K}$$

$$Q_S = C_p (T_3 - T_3')$$

$$= 338\text{ kJ}$$

$$\Delta T = C_p (T_3 - T_4')$$

$$= 295\text{ kJ}$$

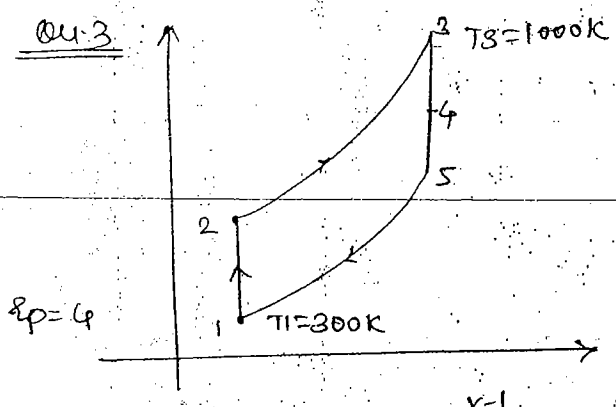
$$W_C = C_p (T_2' - T_1)$$

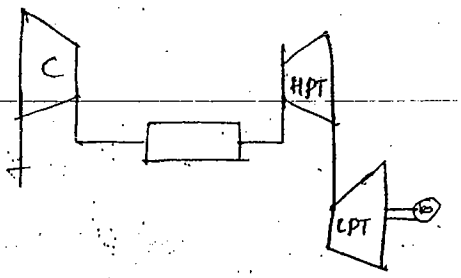
$$= 1 (490 - 300)$$

$$= 190\text{ kJ}$$

$$\eta_T = \frac{W_{net}}{Q_S} = \frac{295 - 190}{338} = 0.31$$

Qu·3





$$T_2 = T_1 (r_p)^{\frac{\gamma-1}{\gamma}}$$

$$= 300 (4)^{\frac{0.4}{1.4}}$$

$$= 446\ K$$

$$W_C = W_T$$

$$C_p (T_2 - T_1) = C_p (T_3 - T_4)$$

$$446 - 300 = (1000 - T_4)$$

$$146 = 1000 - T_4$$

$$\boxed{T_4 = 854\ K}$$

$$\frac{T_3}{T_4} = (r_p)^{\frac{\gamma-1}{\gamma}}_{HPT}$$

$$\frac{1000}{854} = (r_p)^{\frac{0.4}{1.4}}$$

$$1.17 = (r_p)^{0.2857}_{HPT}$$

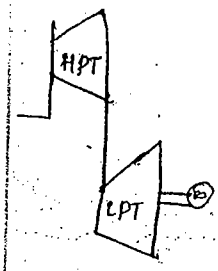
$$(r_p) = 1.73$$

$$(r_{pC}) = (r_p)_{LPT} \times (r_p)_{HPT}$$

$$4 = (r_p)_{LPT} \times 1.73$$

$$(r_p)_{LPT} = 2.32$$

$$\frac{T_4}{T_5} = (\delta p)_{LPT}$$



$$\frac{854}{T_5} = \frac{2.32}{1}$$

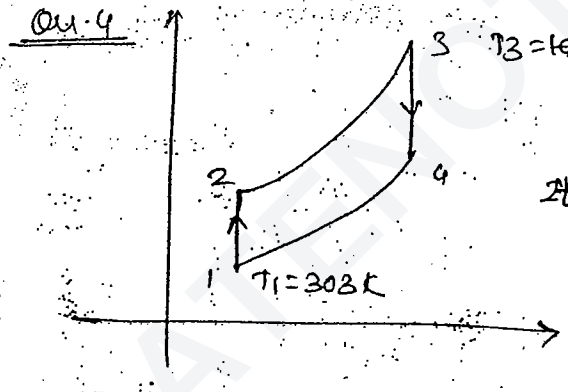
$$\boxed{T_5 = 673\,K}$$

$W_{generator} = c_p(T_4 - T_5)$

$= 1(854 - 673)$

$= 181\ kJ/kg$

Qu.4



No need of regenerator mean
its operating at critical pressu
ratio

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or critical pensure rati

$T_2 = T_4 = \sqrt{T_1 T_3}$

$= \sqrt{303 \times 1073}$

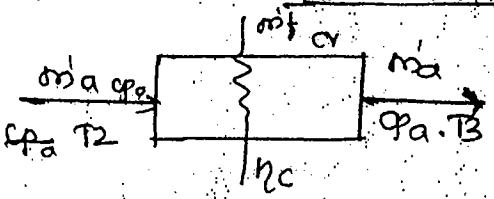
$W_{net} = c_p(\sqrt{T_3} - \sqrt{T_1})^2$

$= 1(\sqrt{1073} - \sqrt{303})^2$

$= 235.6\ kJ/kg$

power = 100 kW = $\dot{m}_a$ (kg/sec) W_{net} (kJ/kg)

$\dot{m}_a = 0.424\ kJ/sec$



Apply ~~SFEE~~ energy balance

$\dot{m}_a c_{pa} T_2 + (\dot{m}_f)(CV)\eta_c = \dot{m}_a c_{pa} T_3$

divide by $\dot{m}_f$

$\frac{\dot{m}_a}{\dot{m}_f} c_{pa} T_2 + (CV)\eta_c = \frac{\dot{m}_a}{\dot{m}_f} c_{pa} T_3$

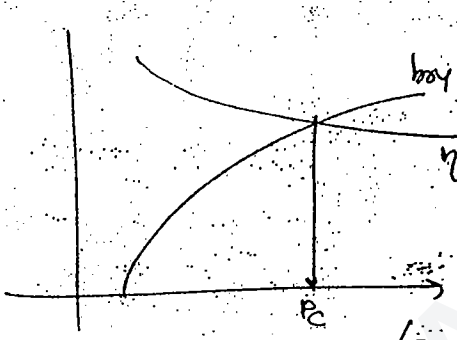
$(AFR) \times 1 \times 570.2 + 45000 \times 1 = (AFR)(1)$

$(AFR)\,570.2 + 45000 = (AFR)\,1073$

$AFR = 89.49 = \frac{\dot{m}a}{\dot{m}f} = \frac{0.424}{\dot{m}f}$

$$\boxed{\dot{m}f = 4.73 \times 10^{-3}}$$

* The min & max temp in cycle are 300K & 1200K respectively. It is operating at 60% of critical pressure ratio then what is the efficiency of a simple brayton cycle and also an ideal regenerative cycle and what is the gaining efficiency due to ideal regeneration



$$(r_{pc}) = \left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{2(\gamma-1)}}$$

$$= \left(\frac{1200}{300}\right)^{\frac{1.4}{2\times 0.4}} = 11.31$$

$$(r_p)_{actual} = 0.6\,(r_p)_c$$

$$= 0.6 \times 11.32$$

$$= 6.79$$

$$\eta_{brayton} = 1 - \left(\frac{1}{r_p}\right)^{\frac{\gamma-1}{\gamma}}$$

$$= 1 - \left(\frac{1}{6.79}\right)^{\frac{0.4}{1.4}}$$

$$= 0.42$$

78

$(\eta)_{\text{ideal regen}} = 1 - \frac{T_{min}}{T_m}(r_p)^{\frac{\gamma-1}{\gamma}}$

$= 1 - \frac{300}{1200}(6.79)^{\frac{0.4}{1.4}}$

$= 0.567$

$\eta = \frac{0.567 - 0.42}{0.567}$

$= ~~0.26~~\ 25\%$

424

rf

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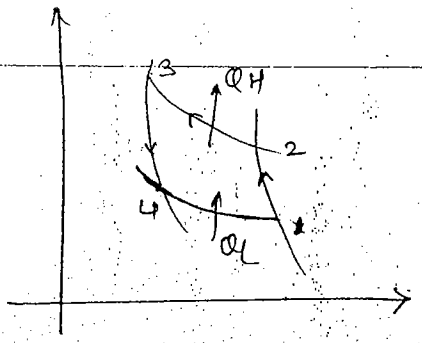
regenerative
ey due to

Qu. 9 If there were many of expansion reheating done to same temp reversible adiabatic expansion become isothermal expansion and reversible adiabatic compression become isothermal compression and brayton cycle become Ericsson cycle

Qu. In regenerative cycle
$W_T \rightarrow W_C \rightarrow W_{net} \rightarrow$
η_0 dependent on Q_S

Refrigeration

Ideal refrigerator function or reversed carnot cycle



1-2 ⇒ Reversible Adiabatic compression
2-3 ⇒ Isothermal heat rejection
3-4 ⇒ Reversible Adiabatic expansion
4-1 ⇒ Isothermal heat absorption

$$(C.O.P) = \frac{T_L}{T_H - T_L} = \frac{1}{\frac{T_H}{T_L} - 1}$$

$$T_1 V_1^{\gamma-1} = T_H V_2^{\gamma-1}$$

$$\frac{T_H}{T_L} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = \varepsilon_k^{\gamma-1}$$

ε_k = compression ratio $= \frac{V_1}{V_2}$

ε_p = pressure ratio $= \frac{P_2}{P_1}$

$$T_L \cdot P_1^{\frac{1-\gamma}{\gamma}} = T_H \cdot P_2^{\frac{1-\gamma}{\gamma}}$$

$$\frac{T_H}{T_L} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \varepsilon_p^{\frac{\gamma-1}{\gamma}}$$

$$C.O.P = \frac{1}{\frac{T_H}{T_L} - 1} = \frac{1}{\varepsilon_k^{\gamma-1} - 1} = \frac{1}{\varepsilon_p^{\frac{\gamma-1}{\gamma}} - 1}$$

1 ton of refrigeration:

1 ton of refrigeration defined as amount of heat removed from 200 pounds of H_2O at 32°F to converted into ice at 32°F in 24 hrs.

1 ton c

SI defi

from 100
in 24 hrs

1 ton of

rnot cycle

e comprension
rejection
expansion
bsorption

1 ton of refrigeration = $\frac{\text{mass of ice} \times \text{latent heat of ice}}{\text{time}}$

$= \frac{2000 \text{ (lbs)} \times 144 \frac{\text{Btu}}{\text{lb}}}{24 \text{ hr}}$

$= 12000 \frac{\text{Btu}}{\text{hr}}$

$= 3000 \text{ kcal/hr} \rightarrow \text{MKS}$

$= 50 \text{ kcal/min}$

$= 211 \text{ kJ/min}$

$= 3.517 \text{ kW}$

SI defination:

It is defined as the amount of heat removed from 1000 kg of water at 0°C to convert into ice at 0°C in 24 hrs.

1 ton of ref = $\frac{\text{mass of ice} \times \text{Latent heat of ice}}{\text{time}}$

$= \frac{1000 \text{ kg} \times 336 \text{ kJ/kg}}{24 \text{ (hrs)}}$

$= 14000 \text{ kJ/hr}$

$= 233.33 \text{ kJ/min}$

$= 3.88 \text{ kW}$ (we are not using)

f heat
to

Cooling load calculation

m_w, c_{pw} — Let us Assume All happening in θ hrs

$T_1°C$ H_2O → cooling → $T_f°C$ H_2O → $T_f°C$ ice → $-T_2°C$ ice

$Q_1 = m c_{pw} (T_1 - T_f)$

Q_2 = mass × latent heat of ice

$Q_3 = \text{mass} \times c_{p\,ice} (T_f + T_2)$

cooling load in (kw):

$$(C.L) = \frac{Q_1 + Q_2 + Q_3}{3600\,\theta}$$

$$= \frac{m}{3600\,\theta}\left[c_{pw}(T_1 - T_f) + L_{ice} + c_{pi}(T_f + T_2) \right]$$

For water $T_f = 0$

$$C.L\ (kw) = \frac{m}{3600\,\theta}\left[c_{pw} T_1 + L_{ice} + c_{pi} T_2 \right]$$

$$CL\ (\text{tons of refrigeration}) = \frac{C.L\,(kw)}{3.517}$$

* 1000 kg of water at 40°C is to be cooled to water at −20°C in 6 hrs. the freezing temp of H_2O is 0°C what is cooling loads in tonnes of refrigeration

⇒ $m = 1000$ kg $\quad t = 40°C \quad t_2 = -20$

$$C.L(kW) = \frac{m}{3600\theta}\left[C_{pw}T_1 + L + C_{pi}T_2\right]$$

$$= \frac{1000}{3600\times 6}\left[4.2\times 40 + 336 + 2.1\times 20\right]$$

$$= \underline{25.25\ kW}$$

$$\text{Cooling load (TR)} = \frac{25.25}{3.517} = \underline{7.18}$$

* 5000 kg of fish at 25°C is to be cooled to fish at −30°C in 24 hrs the freezing temp of fish is −5°C. Specific heat of liquid fish is 2 kJ/kg K. latent heat of fish is 200 kJ/kg and specific heat of solid fish is 1 kJ/kg K. what is the cooling load in

$\Rightarrow m = 5000$

$$C.L(kW) = \frac{Q_1 + Q_2 + Q_3}{3600}$$

$$= \frac{m}{3600\theta}\left[C_{pw}(T_1 - T_f) + L + C_{p\,ice}(T_f + T_2)\right]$$

$$= \frac{5000}{3600\times 24}\left[2(25-(-5)) + 200 + 1(-5-(-30)\right.$$

$$= 16.5\ kW$$

$$C.L(TR) = \frac{16.5}{3.517} = 4.68$$

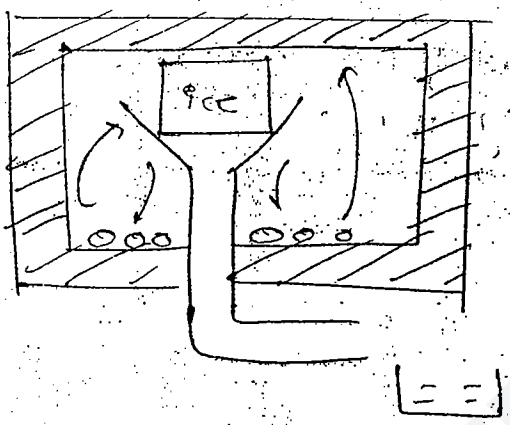
Relative c.o.p or relative efficiency:-

$$(\text{Relative})_{c.o.p} \text{ or } (\text{Relative})_{\eta} = \frac{(c.o.p)_{act}}{(c.o.p)_{theoretical}}$$

$(c.o.p)_{ther} = (c.o.p)_{carnot}$

Methods of refrigeration:

Ice refrigeration:



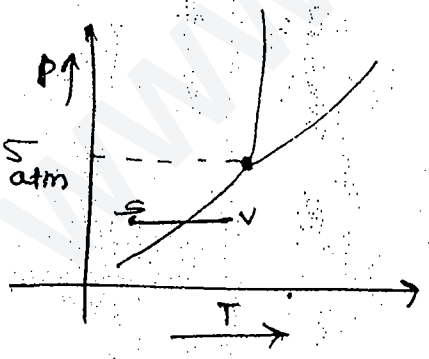
Convection principle used.

used for temp > 0°C

Dry ice refrigeration:

Dry ice is solid carbon dioxide.

solid carbon dioxide has a triple point pressure of 5 atm



If any substance is heated if it is kepted 1 atm pressure it absorbs the heat from surrounding get converted from solid to vapour and process is called sublimation

This method is used for storage of fruits, vegetable in transit

Evaporative refrigeration

Evaporation produces a cooling effect and this is the principle of refrigeration. it is adiabatic transfer of heat from air to water

evaporation rate depend upon area and velocity velocity of air is high the evaporation is high

Area exposed is high evaporation is high . evapor produces a cooling effect

principle uses is Adiabatic evo transfer of heat cooling of water & ponds are example of evaporativ refrigeration

Air refrigeration

Air refrigeration of air Adiabatic expansion of a from high pressure to lower pressure is called as air refrigeration.

$$T_2 = T_1 \cdot \left(\frac{1}{p}\right)^{\frac{\gamma-1}{\gamma}}$$

$P_1 = 5$ Bar

$T_1 = 300K$

$P_2 = 1$ bar

$T_2 = ?$

$$T_2 = 300\left(\frac{1}{5}\right)^{\frac{0.4}{1.4}}$$

$$= 189K \cong -84^\circ C$$

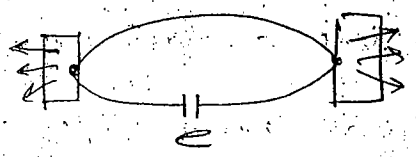
The low temp of air circulated around the space which is to be refrigerated

principle Adiabatic exp of air from high pressure to low p

Thermoelectric refrigeration

It based on principle of peltier effect

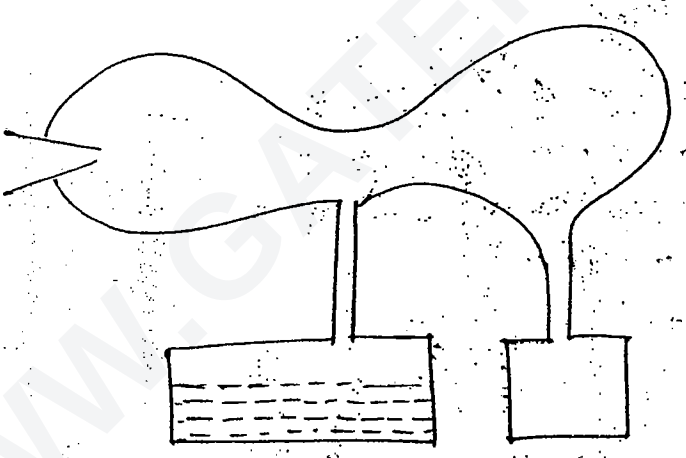
Peltier effect is opposite of seeback effect



A thermocouple emf is given then heat is absorbed in one junction and heat is liberated the other junction and the principle is called peltier effect

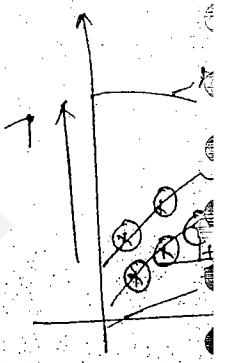
This is light in weight highly reliable but efficiency is very less it is basically used in air craft for refrigeration purpose

Steam jet refrigeration:



low pressure steam is required for this purpose when low pressure steam is expanded nozzle at the throat very low pressure is produced. which will reduced the pressure from the surface of water to about 6.5 cm of H_2O and water boils at low temp of on 6.5°c or at water evaporates it produces a cooling effect in the remaining water

Joul



The sto
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temp of
and tre

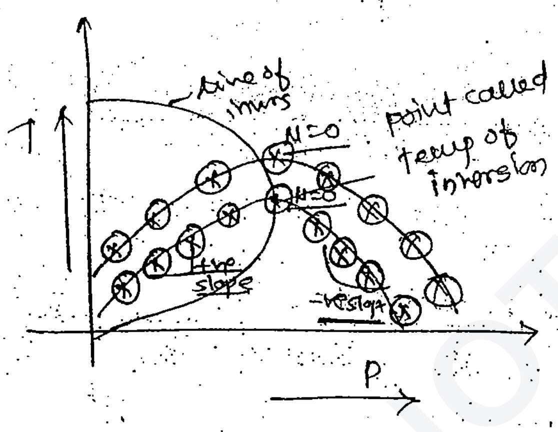
M(+ve)
dp is -ve
dT is -ve
$T_f - T_i < 0$

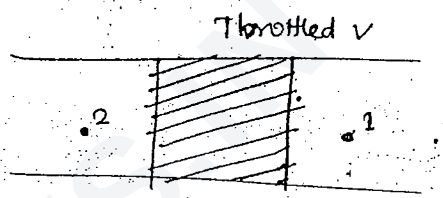
$T_f < T_i$

cooling ef

Joule thomson coefficient or throttling process

$$\left(\mu = \frac{\partial T}{\partial P}\right)_{h=c}$$





The sto point of where slope of curve is zero is called a the temp of inversion i.e. the point where the curve chan it slope. Temp behaviour of fluid due to throttling proce is given by the Joule thomson coefficient. The locus of all the temp of inversions is called as line of inversion. The line of inversion meet $p=0$ at T_{max} which is called as the the max temp of inversion.

every substance will have its own maximum temp of inversion below the maximum temp of inversion and +ve sloped region only the refrigeration is produced

μ (+ve)	μ (-ve)
dp is -ve	dp is (+ve)
dT is -ve	dT is +ve
$T_f - T_i < 0$	$T_f - T_i > 0$
$T_f < T_i$	$T_f > T_i$
cooling effect	Heating effect

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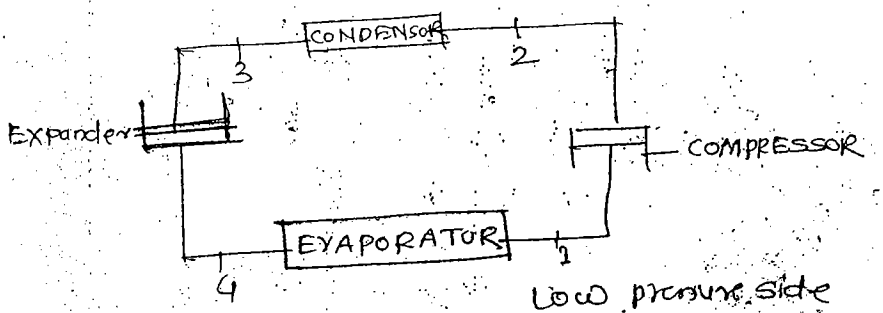
Bell coleman cycle / Reversed joule cycle / Reversed bryton cycle

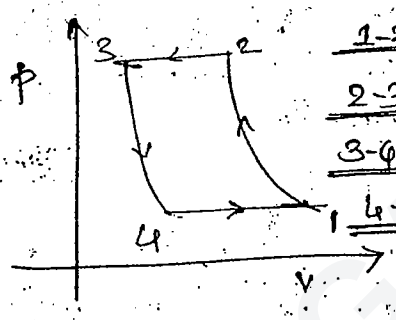
High pressure side



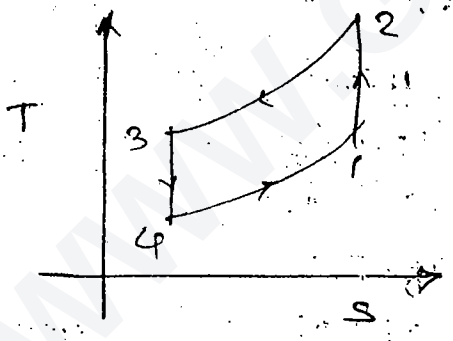
Low pressure side

The compressor connect the low pressure side to high pressure side and expander connects a high pressure side to low pressure side

Reversed Joule cycle / Bryton cycle



1-2 : Reversible Adiabatic compression
2-3 : Constant pressure heat rejection
3-4 : Reversible Adiabatic expansion
4-1 : Constant pressure heat absorption.



r_p = pressure ratio $= \frac{P_3}{P_4} = \frac{P_2}{P_1}$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$ also $\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$

ycle/

ycle

e to

s a high

compression

rejection

expansion

absorption.

$= \frac{P_2}{P_1}$

$= \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$

~~ε_k = compression ratio~~ $= \frac{V_1}{V_2}$

Net refrigerating effect$_{(NRE)}$ = $C_p(T_1 - T_4)$

Heat rejected $Q_R = C_p(T_2 - T_3)$

$W = Q_R - NRE$

$= C_p(T_2 - T_3) - C_p(T_1 - T_4)$

$$c.o.p = \frac{NRE}{W} = \frac{C_p(T_1 - T_4)}{C_p(T_2 - T_3) - C_p(T_1 - T_4)}$$

$$= \frac{1}{\left[\frac{T_2 - T_3}{T_1 - T_4}\right] - 1}$$

General expression of c.o.p of a system Assuming polytropic expansion & polytropic compression is given by

$$(c.o.p) = \frac{T_1}{\left(\frac{n}{n-1}\right)\left(\frac{\gamma-1}{\gamma}\right)(T_2 - T_1)}$$

$$= \frac{T_4}{\left(\frac{n}{n-1}\right)\left(\frac{\gamma-1}{\gamma}\right)(T_3 - T_4)}$$

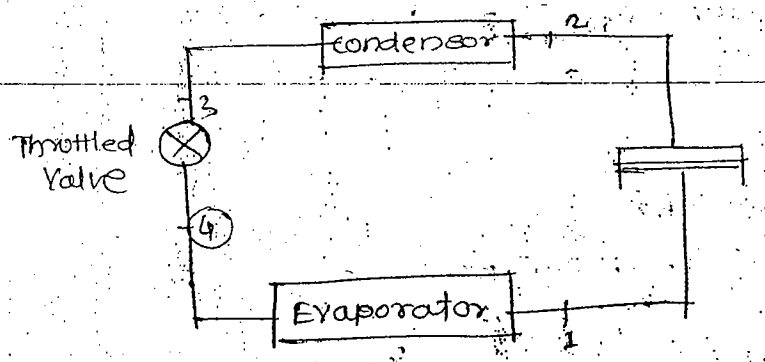
If $n = \gamma$

$$c.o.p = \frac{T_1}{T_2 - T_1}$$

$$c.o.p = \frac{T_4}{T_3 - T_4}$$

This system is light in weight uses a cheap refrigerant i.e.. air and it is non toxic i.... why it is used in air craft engine.

Vapor compression refrigeration System (VCR)



SFEE:

$$h_i + Q = h_e + W$$

4-1 Evaporater:

No work done only heat absorption.

Apply SFEE

$$h_4 + Q_E = h_1 + 0$$

$$\boxed{Q_E = h_1 - h_4 \text{ kJ/kg}}$$

Q_E called as Net refrigerating effect

1-2 compressor

$$Q = 0 \quad S = C$$

Apply SFEE

$$h_1 + 0 = h_2 + W_C$$

$$\boxed{W_C = h_1 - h_2 \text{ kJ/kg}} \text{ or } \underline{h_2 - h_1 \text{ kJ/kg}}.$$

-ve indicating that work is being done on the system

VCR)

2-3 condensor

No work is done W=0

$$h_2 + Q_C = h_3 + 0$$

$$\boxed{Q_C = h_3 - h_2 \text{ KJ/kg}} \text{ or } h_2 - h_3 \text{ KJ/kg}$$

The answer is -ve indicating that heat is rejected by the system.

3-4 throttle valve

W=0 Q=0

$$h_3 + 0 = h_4 + 0$$

$$\boxed{h_3 = h_4}$$

here state 3 saturated liquid state where as state 4 liquid + vapor state

$$h_3 = h_4$$
$$= h_{f4} + x(h_{g4} - h_{f4})$$

$$\boxed{x = \frac{h_3 - h_{f4}}{h_{g4} - h_{f4}}}$$

x is called dryness fraction flash gas

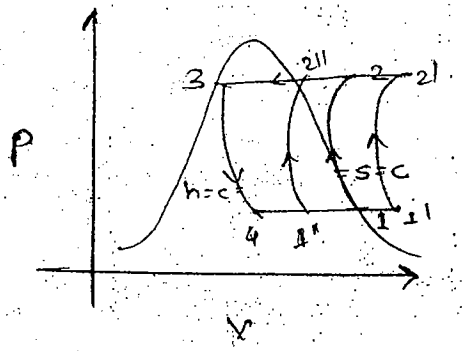
RE = refrigerating effect

flash gas does not contribute to refrigerating effect hence the value of x is less it indicate high net RE

$$C.O.P = \frac{NRE}{Work} = \frac{h_1 - h_4}{h_2 - h_3}$$

The compressor connect low pressure side to high pressure side and throttle valve connect high pressure side to the low pressure side

VCR on various plane

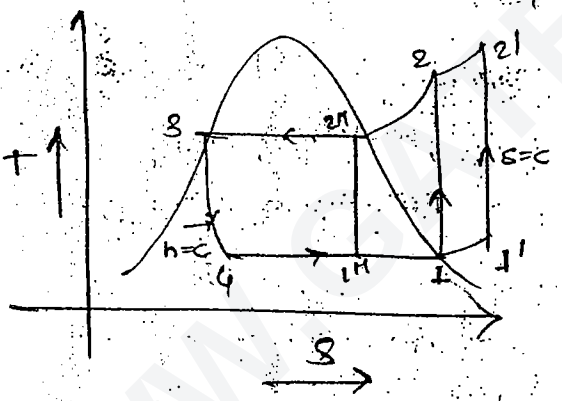


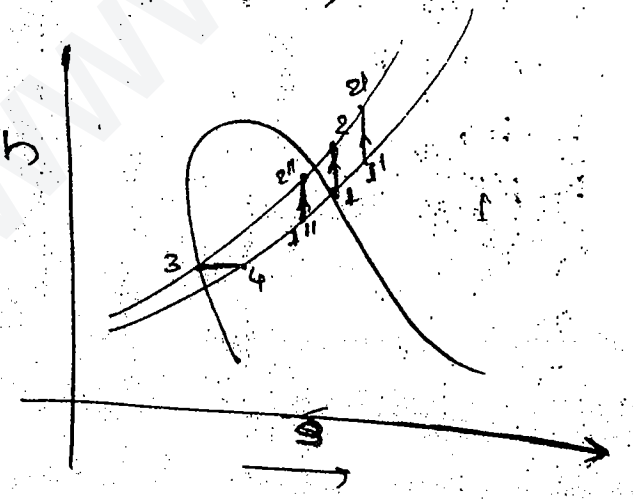
The compression start on the dry and saturated vapor line it is called as standard vapor compression cycle and after condensation the refrigerator is in saturated liquid state

1-2-3-4 :- Standard V.C.R. cycle

1'-2'-3'-4' :- superheated V.C.R cycle

1''-2''-3''-4'' → wet V.C.R cycle





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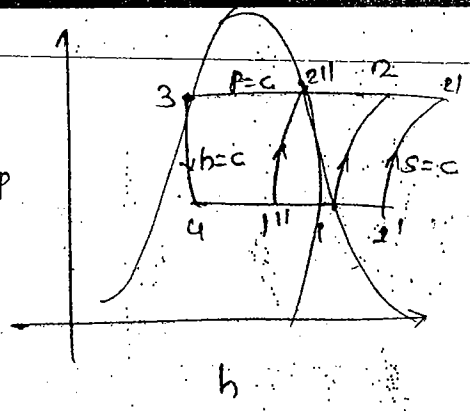
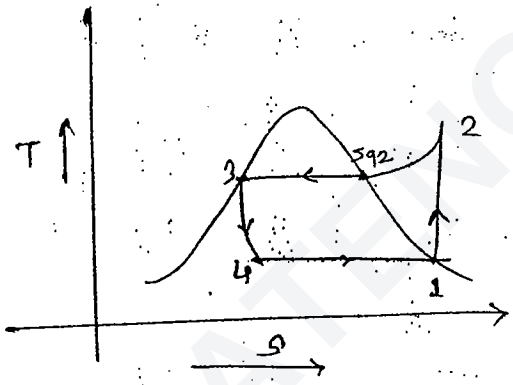


Design of VC system for x tons of refrigeration



$$NRE = (h_1 - h_4)\ KJ/kg$$

$$NEE\ (KW) = 3.517\ x$$

$$\dot{m}_r \left(\frac{kg}{sec}\right) (h_1 - h_4)\ (KJ/kg) = NRE\ (kw)$$

$$\dot{m}_r \left(\frac{kg}{sec}\right) = \frac{3.517\ x}{h_1 - h_4}$$

here 1-2 $S_1 = S_2$ $S_2 > S_{g2}$ ∴ after compression it is superheated state

$$\therefore S_2 = S_{g2} + C_{pv} \ln \frac{T_2}{T_{sat}}$$

$$\ln \frac{T_2}{T_{sat}} = \frac{S_2 - S_{g2}}{C_{pv}}$$

$$\boxed{T_2 = T_{sat}\ e^{\left(\frac{S_2 - S_{g2}}{C_{pv}}\right)}}$$

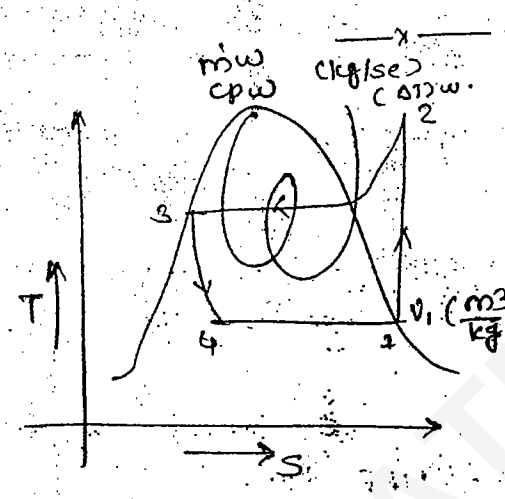
$$h_2 = h_{g2} + c_{pv}(T_2 - T_{sat})$$

$$W_c = (h_2 - h_1) \text{ KJ/kg}$$

$$W_c \text{ (KW)} = \dot{m}_s \left(\frac{kg}{sec}\right)(h_2 - h_1) \text{ KJ/kg}$$

$$W_c \text{ (KW)} = \frac{3.517 \times}{(h_1 - h_4)} (h_2 - h_1)$$

$$C.O.P = \frac{NRE \text{ (KW)}}{W_c \text{ (KW)}}$$

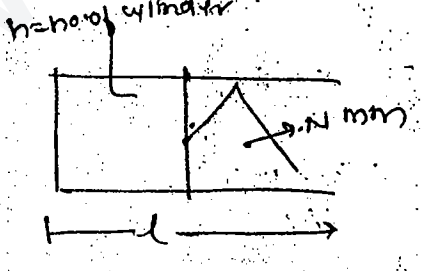


Heat gained by H_2O = Heat lost by refrigerant

$$\dot{m}_w c_{pw} (\Delta T)_w = \dot{m}_s (kg/sec)(h_2 - h_3) \text{ KJ/kg}$$

$$= \frac{3.517}{(h_1 - h_4)} (h_2 - h_3)$$

$$(\Delta T)_w = \frac{3.517}{(h_1 - h_4)} \times \frac{(h_2 - h_3)}{c_{pw} \dot{m}_w}$$



Volume flow rate $\dot{m}$ (m³/sec) = $\dot{m}_2$ (kg/sec) v_1 (m³/kg)

$= \frac{\pi}{4} D^2 L n \times \frac{N}{60} \times \eta_{vol}$

(theoritical stroke volm)

TSR flow rate (m³/sec)

Actual SVFR (m³/sec)

$\eta_{vol} = 1 + c - c\left(\frac{p_2}{p_1}\right)^{1/n}$

c → clearance ratio

$\frac{p_2}{p_1}$ → pressure ratio

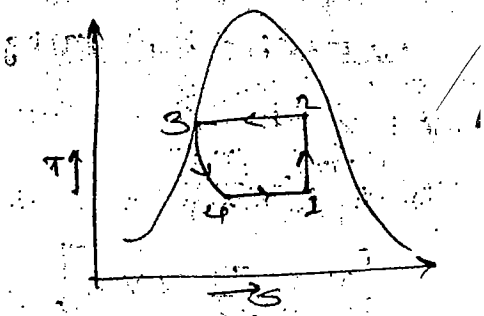
n → polytropic index

Wet compression

condition of refrigerant before compression 1 is given

$s_1 = s_{f1} + x_1 (s_{g1} - s_{f1})$

$h_1 = h_{f1} + x_1 (h_{g1} - h_{f1})$



at $s_1 = s_2$ $s_2 < s_{g2}$ (wet state)

$s_2 = s_{f2} + x_2 (s_{g2} - s_{f2})$

$$x_2 = \frac{s_2 - s_{f2}}{s_{g2} - s_{f2}}$$

$h_2 = h_{f2} + x_2 (h_{g2} - h_{f2})$

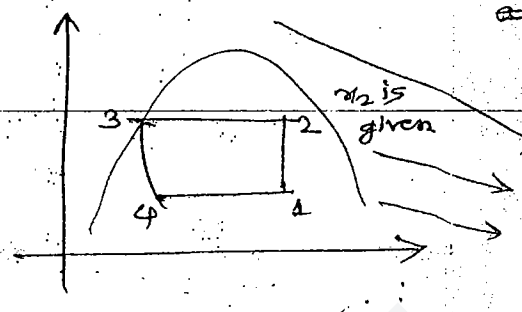
$v_1 = v_{f1} + x_1 (v_{g1} - v_{f1})$

condition of refrigerant after compression x_2 is given

$$s_2 = s_{f2} + x_2 (s_{g2} - s_{f2})$$

$$h_2 = h_{f2} + x_2 (h_{g2} - h_{f2})$$

$s_2 = s_1$ $s_1 > s_{g1}$ wet state



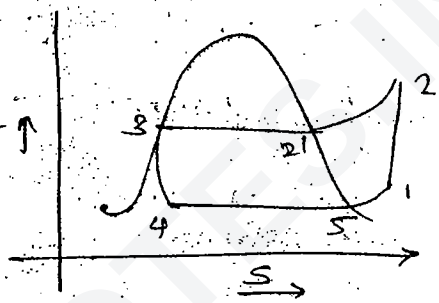
Superheated compression

If superheateding is done inside evaporator

NRE = $(h_1 - h_4)$ kJ/kg

If superheating is outside the evaporator is

NRE = $(h_5 - h_4)$ kJ/kg



Superheated vapor compression cycle

NRE = ch

$$\frac{V_1}{T_1'} = \frac{V_5}{T_5}$$

$$\boxed{V_1 = \frac{T_1}{T_5} \times V_5}$$ — specific volm at suction

$$s_1 = s_5 + c_{pv} \ln \frac{T_1}{T_5}$$

$$\ln \frac{T_1}{T_5} = \frac{s_1 - s_5}{c_{pv}}$$

$$\frac{T_1}{T_5} = e^{\left(\frac{s_1 - s_5}{c_{pv}}\right)}$$

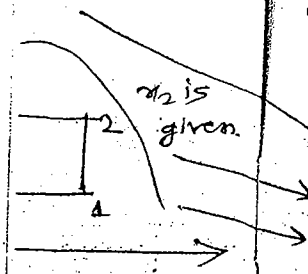
$$T_1 = T_5 \, e^{\left(\frac{s_1 - s_5}{c_{pv}}\right)}$$

$$s_1 = s_2 + s_2' + c_{pv} \ln \frac{T_2}{T_2'}$$

$$\ln \frac{T_2}{T_2'} = \frac{s_1 - s_2'}{c_{pv}}$$

$$T_2 = T_1' \left\{ e^{\frac{s_1 - s_2'}{c_{pv}}} \right\}$$

x_2 is given — $h_2 = h_2' + c_{pv}(T_2 - T_2')$



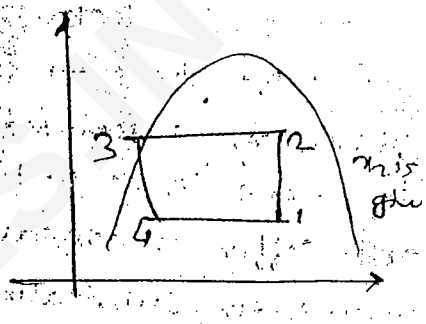
x_2 is given.

(condition for refrigerant after compression x_2 is given

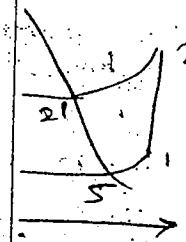
$S_2 = S_{f2} + x_2 (S_{g_2} - S_{f_2})$

$h_2 = h_{f2} + x_2 (h_{g_2} - h_{f_2})$

$S_2 = S_1$ $S_1 > S_g$ wet state



x_1 is giv



$S_1 = S_{f1} + x_2 (S_{g_1} - S_{f1})$

$$x_1 = \frac{S_1 - S_{f1}}{S_{g_1} - S_{f1}}$$

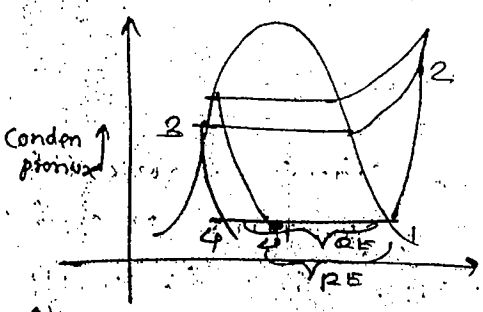
$h_1 = h_{f1} + x_1 (h_{g_1} - h_{f_1})$

$V_1 = V_{f1} + x_1 (V_{g_1} - V_{f1})$

vapour

when nothing is mentioned about the condition of problem we assume std VCR and processed with problems.

effect of operating variable on the performan of a VCR cycle



NRE (KW) is constant

NRE (KJ/kg) decreases

$\dot{m}_r$ (kg/sec) increases

V_1 (m3/kg) is constant

Volume flow rate (m3/sec) ↑

pressure ratio ↑ $\eta_{volumetric}$ ↓ WC ↑ (KJ/kg) W (KW) ↑

C.O.P ↓ condenser load (KW) ↑ $\dot{m}_w$ (kg/sec) ↑

Compressor discharge increases.

Continued on page no (4)

NRE (KJ/kg) ↑ $\dot{m}_r$ (KJ/kg) ↓ v_1 (m^3/kg) → Page no (3)

volume flow rate (m^3/kg) ↓ η_{vol} →

cylindrical dimension ↓ W_c (KJ/kg) → C.O.P ↑ W_c (KW) ↓

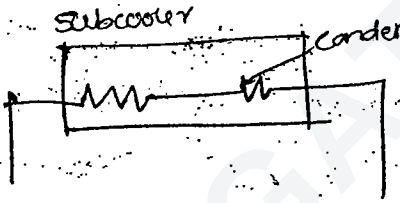
Condenser load (KW) ↓ $\dot{m}_w$ (kg/sec) compressor

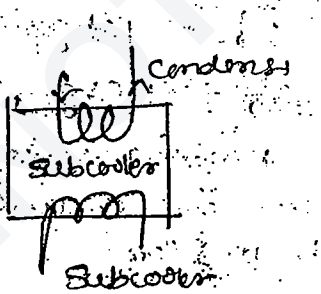
discharge temp → flash gas ↑ x ↓

when dry saturated vapor is send into the cylinder it comes in contact with the cold cylindrical wall and suffer condensation the liquid refrigerant washes a cylinder lubricating oil and increases corrosion it will reduce in life of the cylinder the overcome this problem refrigerant is heated superheated before it is send to compressor.

wet compression offered for NH3

In series subcooler the condenser temp height increase

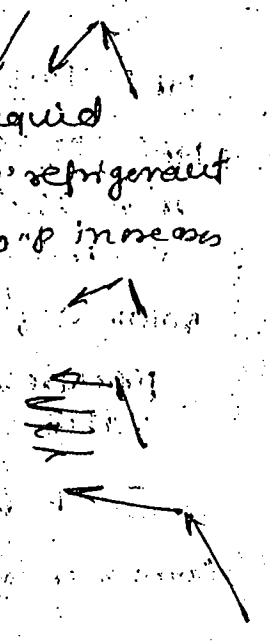




Liquid vapor H.E

(not cross)

In liquid vapor HE subcooling of liquid refrigerating and superheating of the refrigerant vapor simultaneously as a result C.O.P increases as well as life cylinder increases.



1) → page no (3)

↑ W_c (kW) ↓
nor

the cylinder
al well
trait washes
piston it
become this
before it

ms1

quid
refrigerant
P increases

Horse power per tonne of refrigeration

$$HP/TR = \frac{\dot{W}(kW)}{\dot{Q}^{o}(kW)}$$

$$= \frac{W^{o}}{0.746} \times \frac{1}{\frac{\dot{Q}^{o}(TR)}{3.517}}$$

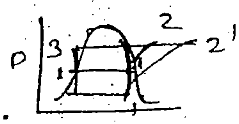
$$\boxed{HP/TR = \frac{4.72}{C.O.P}}$$

page No (4)

Multistage V.C System

~~when the difference betn the~~ evaporative pres

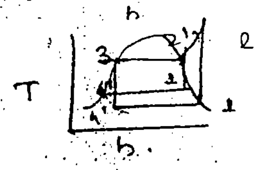
flash gas % increases, cylindrical dimension ↑ evapora pressure ↓



NRE (kW) is always constant

NRE (kJ/kg) is always decreases

$\dot{m}_2$ (kg/sec) v_1 (m3/kg) ↑



vol^{m} flow rate ↑ (m3/sec) $\dot{m}_2$ (kg/sec) pressure ratio ↑

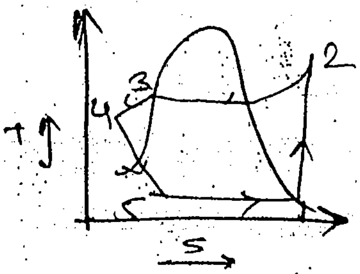
η_{vol^m} ↓ cylindrical dimensions decrease

W_c (kJ/kg) ↑ W_c (kW) ↑ COP ↓ condensor load (kW) ↑

$\dot{m}_{wc}$ (kg/sec) ↑ change discharge temp ↑ flash gas % ↑

Effect on subcooling on a performance of avcr

Subcooling is process by which the temp is reduced to a value less than the saturation temp

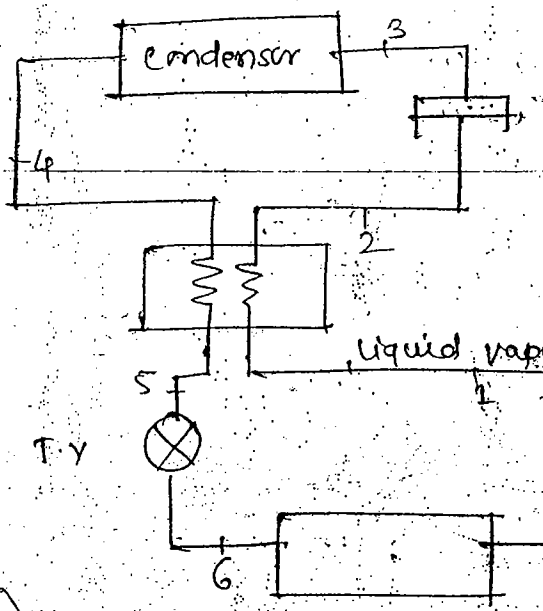


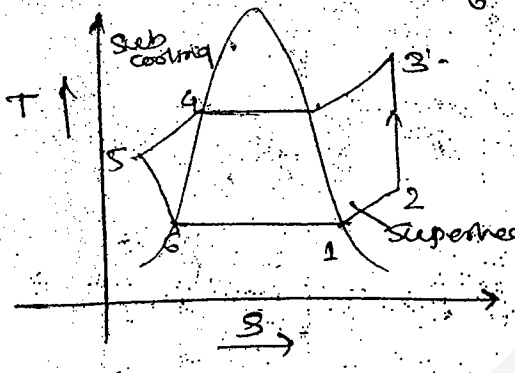
NRE (kW)

$$h_4 = h_3 - C_p (T_3 - T_4)$$

$$\boxed{h_5 = h_4}$$

(continued to back page)





$$cp_v(T_2 - T_1) = cp_l(T_4 - T_5)$$

because of the liquid vapor heat exchanger the liquid leaving the condenser will have the condenser lower temp and refrigerant leaving evaporator has a higher temp

Horse power per tonne of refrigeration

$$HP/TR = \frac{\dot{W}(kW)}{\dot{Q}(kW)}$$

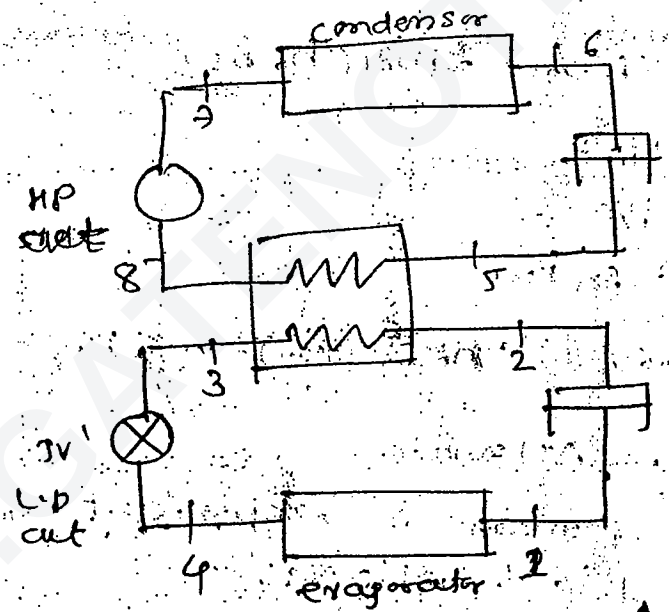
$$= \frac{\omega^\circ}{0.746} \times \frac{1}{\frac{\dot{Q}}{3.517}(TR)}$$

$$\boxed{HP/TR = \frac{4.72}{C.O.P}}$$

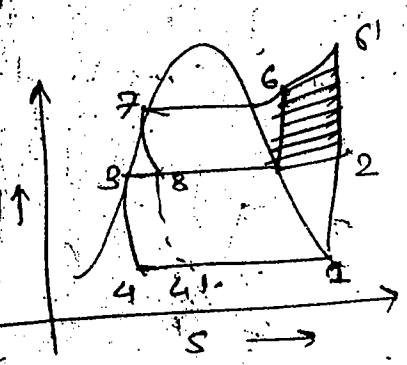
Multistage V.C. System

when the difference bet the evaporating pressure and condenser pressure is very high it is better go for multistage comp system because

① It reduce the work of compression
② Reduce the compressor discharge temp.
③ Increase the volumetric efficiency
④ and increases the c.o.p of the system



$P_i = \sqrt{P_H P_L}$.



The evaporator of high pressure cut act as the condenser for the low pressure cut.

$\dot{m}_i$ (kg/sec) $(h_1 - h_4)$ kJ/kg.

$= NRE\ (kW) = 3.517\ x$

$$\dot{m}_L = \frac{3.517\ x}{h_1 - h_4} \quad kg/sec$$

evaporator of high pressure cut
= condenser of lp cut

$\dot{m}_H (h_5 - h_8) = \dot{m}_L (h_2 - h_3)$

$\dot{m}_H = \dot{m}_L \frac{(h_2 - h_3)}{(h_5 - h_8)}$

$(h_2 - h_3) > (h_5 - h_8)$

$\dot{m}_H > \dot{m}_L$

$W_C (kW) = \dot{m}_L (h_2 - h_1) + \dot{m}_H (h_6 - h_5)$

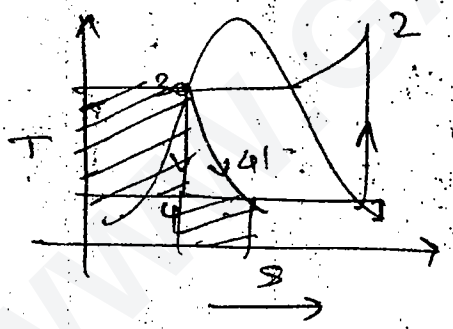
$C.O.P = \frac{NRE}{WC}$

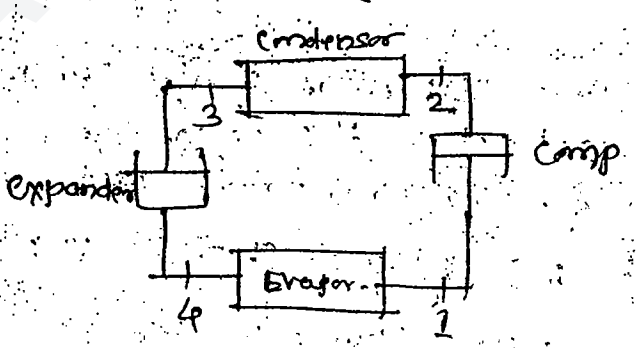
Condenser load in kW

$= \dot{m}_H (h_6 - h_7) = NRE (kW) + WC (kW) =$

$\dot{m}_w C_{p_w} (\Delta T)$ water.

having an expander in a refrigerant cut
when compared to throttle valve





$W_C = h_2 - h_1$

$W_{Expansion} = (h_3 - h_4)$

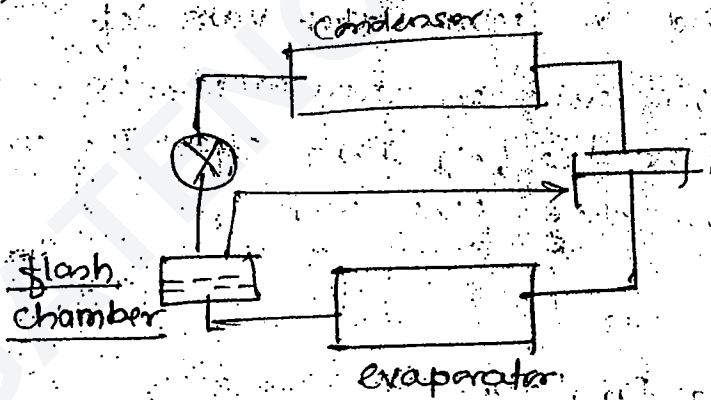
If $W_{net} \downarrow = W_C - W_E$

then $\uparrow NRE = (h_1 - h_4)$

$C.O.P = \uparrow$

the expansion stage or sat liquid line has because of friction and eddy losses whatever gaining work is lost in friction and hence the net advantage practically is very less.

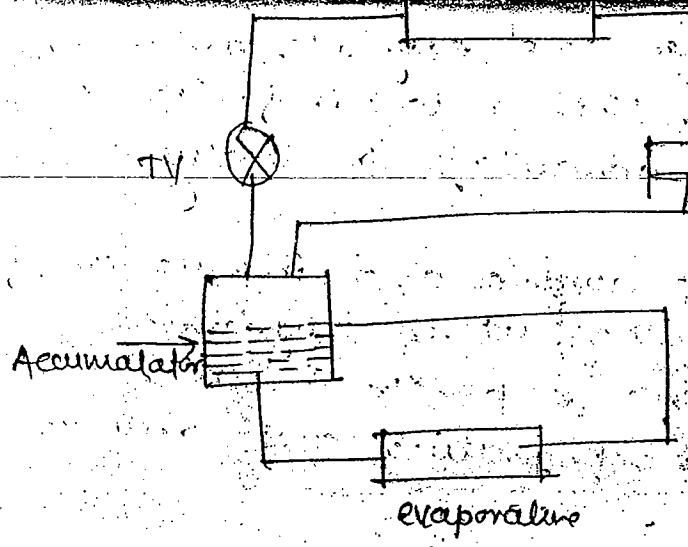
Cost almost doubles and imbalances will result as dynamic imbalanced hence expander is never incorporated in refrigerant cycle ~~flash chamber~~.



Now flash chamber separate vapour and liquid refrigerant and allows only liquid refrigerant to enter the evaporator and vapour refrigerant directly feed to compressor. The size of evaporator decreases but providing a flash chamber does not having effect on NRE work of compression and COP

providing a accumulator in Ref cycle

providing a accumulator separated the vapour & liquid separated before evaporation as well as after evaporation



by providing an accumulator vapor ref separated providing an accumulator has no effect on heat refrigerating effect the work of compressor and the c.o.p.

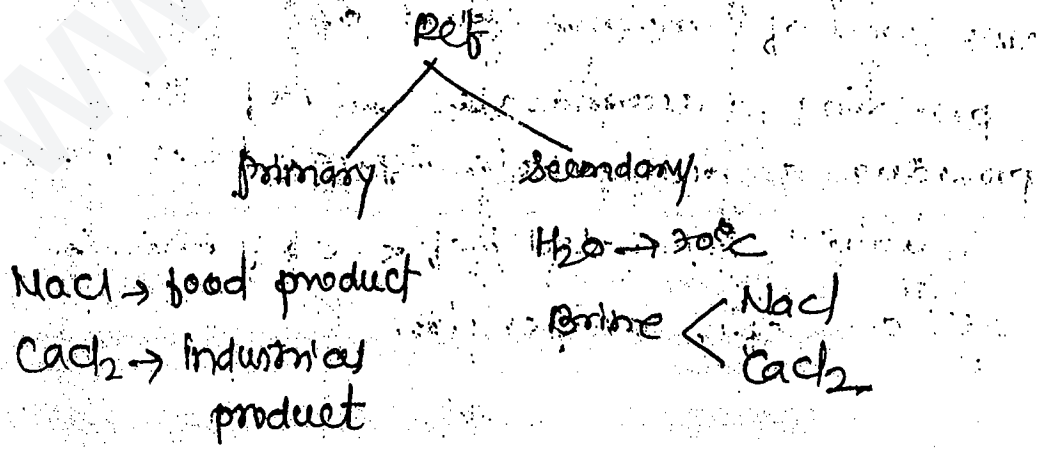
Refrigerant

having two type

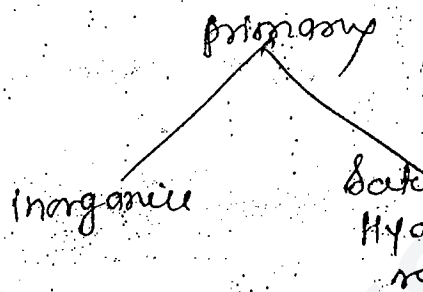
(I) primary

(II) Secondary

primary refrigerant take direct part in refrigerating system. Secondary refrigerants take indirect part in refrigerating system



$CaCl_2$ provide have a deteriorated effect on food item hence they are not used



Inorganic rf are belong to 7xx series
eg NH_3, water sulphur dioxide carbon di oxide

$NH_3 \Rightarrow 700+17 = 717$

$H_2O \Rightarrow 700+18 = 718$

$SO_2 \Rightarrow 700+64 = 764$

$CO_2 \Rightarrow 700+44 = 744$

If molecular weight is added 700 we get the refrigerating number

Saturated Hydro Carbon

C_nH_{2n+2}

Ref: $C_mH_nF_pCl_q$

$$n+p+q=2m+2$$

n is hydrogen atom

p fluorine atom

q chlorine atom

m carbon atom

Refrigerant no. $R(m-1)(n+1)p$

Chloroflouro carbon

q → chlorine atom are causing ozone depletion potential

Chlorine atoms are providing physiological stability and hydrogen atoms are causing flammability

$R12 \rightarrow R_{012}$

$p = F = 2$

$n+1=1 \quad n=0, \quad H_2=0$

$m-1=0, \quad m=1, \quad C$

$$n+p+q=2m+2$$

$$0+2+q=2\times1+2$$

$$\boxed{q=2}$$

The formula CCl_2F_2 → dichlorodifluoromethane.

R113

- L = 3 = F
- n+1 = 1 → n = 0
- m-1 = 1 → m = 2 C

$n+p+q = 2m+2$

$0+3+q = 2\times2+2$

$q = 3$ → Cl

$C_2Cl_3F_3$

$C_2(H_6)$ ⇒ dichloro trifluoro ethane

---

ption

tability

lity

R134

- p = 4, F =
- n+1 = 3 → n = 2 H2
- m-1 = 1 → m = 2 C

$n+p+q = 2m+2$

$2+4+q = 2\times2+2$

$q = 0$

R134 & R134a have the same molecular formula but it different molecular formula arrangement here it is called isomers

no methane

$CFCl_3$:

- q = 3
- p = 1
- m = 1

$n+p+q = 2m+2$

$n+1+3 = 2\times1+2$

$n = 0$

$R(m-1)(n+1)p$

$R_{0\,1\,1} \Rightarrow \underline{R11}$

$CH_2Cl_3F_2$

- $p=2$
- $q=3$
- $n=1$
- $m=2$

$R(m-1)(n+1)p$

R_{122}

Unsatured hydrocarbon series:

C_nH_{2n}

$n+p+q=2m$

$R_{1(m-1)(n+1)p}$

R_{1150}

- $p=0$ F
- $n+1=5$ $n=4$ H2
- $m-1=1$ $m=2$ Carbon.

$n+p+q=2m$

$4+0+q=2\times2$

$\boxed{q=0}$

C_2H_4 :

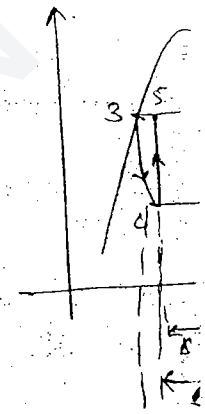
isobutane having formula R600. dap not fitted to nomenclature.

CF_2Cl

CF_2

Brominative bromine

Ewin



if con
c·o·p·
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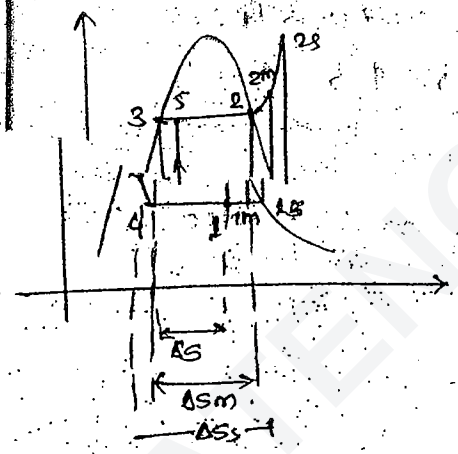
$CF_2Cl_2 \longrightarrow R_{12}$

$CF_2ClBr \longrightarrow R_{12}Br$

Brominating refrigerant the base chlorine atom replaced by bromine atom.

Ewings construction:



$$c.o.p = \frac{h_1 - h_4}{h_2 - h_1}$$

$$= \frac{h_1 - h_4}{(h_2 - h_4) - (h_1 - h_4)}$$

$$= \frac{\frac{h_1 - h_4}{\Delta S}}{\left(\frac{h_2 - h_4}{\Delta S}\right) - \left(\frac{h_1 - h_4}{\Delta S}\right)}$$

$$= \frac{TO}{\left(\frac{h_2 - h_4}{\Delta S}\right) - TO}$$

if compression start at "4" NRE is "zero" and c.o.p is zero, As we go from 4 to 1 NRE increases c.o.p increases but work of compression almost same beyond 1" if we go the work of compression increases and we find that it continuous to.

Technically speaking the c.o.p should decrease after 1. but it is found to increase upto 1M for certain substance and upto 1S for other substance this is because the slope "$\frac{h_2 - h_4}{\Delta S_m}$"

and $\frac{h_{2S} - h_4}{\Delta S_S}$ is minimum at 2m and 2S respectively.

not fitted

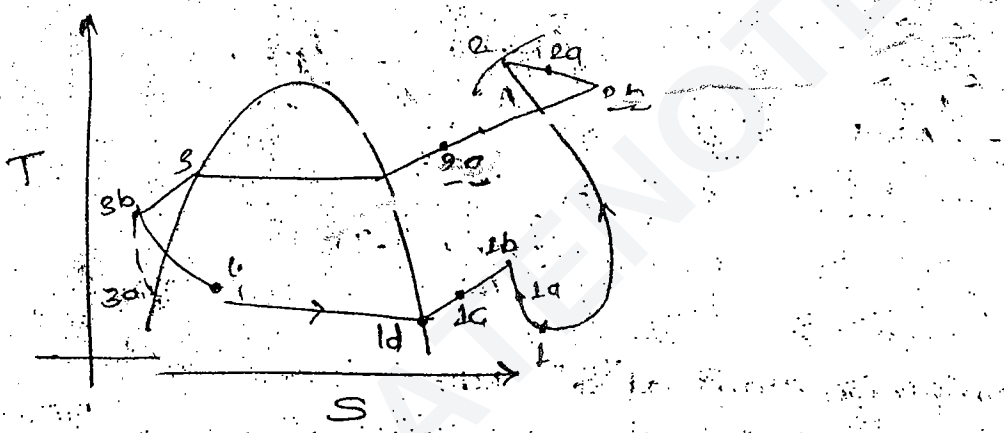
hence $c.o.p = \frac{T_o}{T_{2m} - T_o}$

$$c.o.p = \frac{T_o}{T_{2s} - T_o}$$

For certain substance wet compression preffered and for other substance superheated compression is preffered.

wet compression is preffed for NH_3 or R_{11} & R_{22} and superheated compression is preffed for R_{12} isobutane and R134a

Deviations of VCR cycle from the ideally



1d-1c ⇒ superheating of vapor in the evaporator

1c-1b ⇒ Heat gained and superheat of vapor at suction line

1b-1a ⇒ pressure drop in suction line

1a-1 ⇒ pressure drop due to throttling or wire drawing in the suction valve

1-2 ⇒ polytropic compression

2-2a ⇒ pressure drop in compressor discharge valve

2a-2b ⇒ pressure drop in delivery line

2b-2c ⇒ heat loss and desuperheating of vapor in delivery line.

2c-3 ⇒ pressure drop in condenser.

3-3d ⇒ Subcooling in the condenser.

3a-3b ⇒ heat gained in the liquid line

4-1d ⇒ pressure drop in evaporator

3b-4 ⇒ throttling process in throttle valve.

Δp = pressure drop is basically momentum pressure drop + frictional pressure drop

In the condenser vapor refrigerant is getting converted to liquid refrigerant and momentum pressure drop is -ve where as frictional pressure drop is possible and pressure drop is less significant in the condenser. So and the evaporator liquid refrigerant is getting converted into the vapor refrigerant velocity of vapor is more than liquid and momentum pressure drop & frictional pressure drop is possible. hence pressure drop is very significant in evaporator

The evaporator can not be under design or over design as effect the performance very much and generally condenser is over design.

$$CCl_2F_2 \xrightarrow{\text{sunlight}} CClF_2 + Cl$$

$$O_3 + Cl \longrightarrow ClO + O_2$$

The conversion of ozone to oxygen is a serious problem as it is causing ozone depletion, and this leads to harmful radiati

reaching the earth. hence chlorofluro carbon are gradually replacing with ~~hct~~ hydrochlorofluro carbon HCFC and HFC

R_{12} replaced with R_{134} a

R_{22} with R_{123}

* Important point

1) pull down period
2) Ice making time

The time taken to bring the refrigerator from atm temp to evaporative temp is called as pull down period. if this period is less the refrigerator is good

Ice making time :: the time required for converting water to ice is called as ice making.

domestic compr ~~11.2 C~~ 11.7 mm dia
17.2 mm length

NRE = 1
= 1
= 5

$\dot{m}_f$ (kg/sec
= NRE
$\dot{m}_f$ (195
$\dot{m}$

KJC (KJ/

KJC (KW

c.o.p =

bon are

tion HCFC

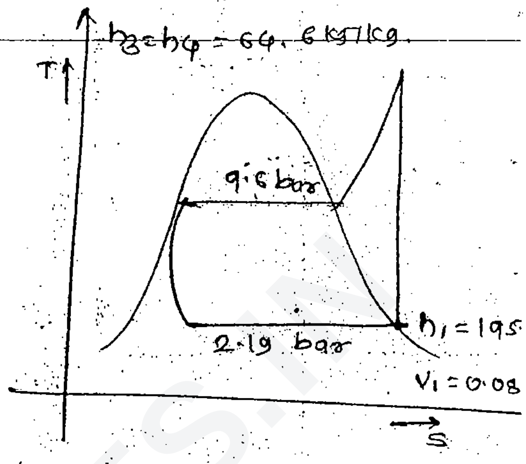
for from

cs

1.

using

page 41 Qu. 1



NRE = 15 tons

$= 15 \times 3.157$ kw

$= 52.75$ kw.

$\dot{m}_f$ (kg/sec) $(h_1 - h_4)$ kJ/kg

= NRE (kw).

$\dot{m}_f (195.7 - 64.6) = 52.75$

$\dot{m}_f = 0.402$ kg/sec

$$W_c \,(\text{kJ/kg}) = \frac{n}{n-1} p_1 v_1 \left[\left(\frac{p_2}{p_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

$$= \frac{1.13}{1.13 - 1} \times 219 \times 0.082 \left[\left(\frac{9.6}{2.19} \right)^{\frac{1.13-1}{1.13}} - 1 \right]$$

$= 28.92$ kJ/kg

W_c (kw) $= \dot{m}_f$ (kJ/sec) W_c (kJ/kg)

$= 0.402 \times 28.92$

$= 11.63$ kw

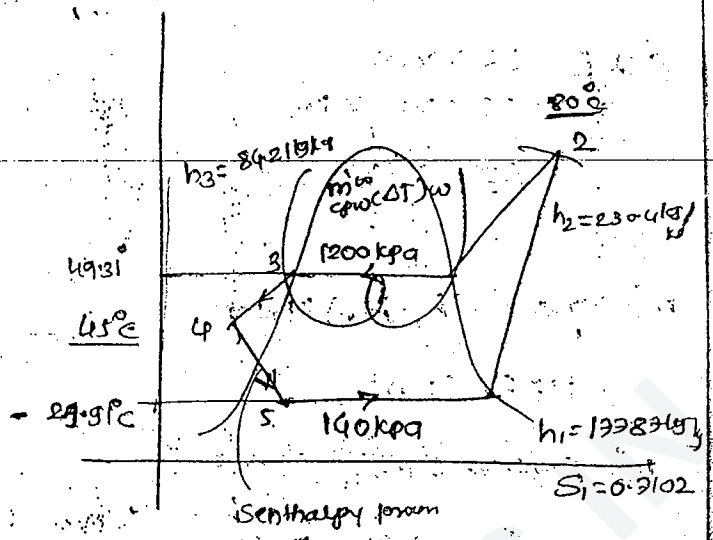
$$\text{c.o.p} = \frac{\text{NRE (kw)}}{W_c \text{ (kw)}}$$

$$= \frac{52.75}{11.63}$$

$= \underline{\underline{4.535}}$

Q1.2 · $\dot{m}_{ice} = 0.2$ KJ/sec

$C_{p\,liquid} = 1$ kJ/Kg.K



$h_4 = h_3 - C_{pl}(T_3 - T_4)$

$= 84.21 - 1\,[49.31 - 45]$

$= 79.9$ kJ/kg $= h_5$

$NRE\,(kW) = \dot{m}_{ice}\,(kg/sec)\,(h_1 - h_4)$ kJ/kg

$= 0.2\,(h_1 - h_4)$

$= 0.2\,(177.87 - 79.9)$

$= 19.6$ kW

$= \frac{19.6}{3.517} = 5.57$ tonnes

$W_c\,(kW) = \dot{m}\,(kg/sec)\,(h_2 - h_1)$ kJ/kg

$= 0.2\,(280.4 - 177.87)$

$= 10.50$ kW.

$C.O.P = \frac{NRE\,(kW)}{W_c\,(kW)} = \frac{19.6}{10.5} = 1.866$

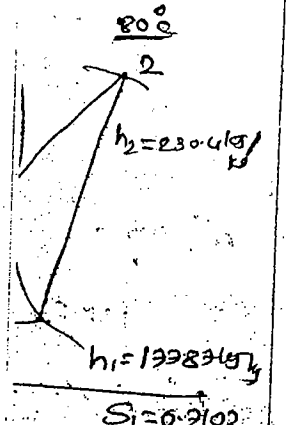
$\dot{m}_w$

Heat gained by water = Heat lost in condenser

$\dot{m}_w c_{pw} (\Delta T)_w = \dot{m}_s$ (kg/sec) $(h_2 - h_4)$ kJ/kg

$\dot{m}_w \times 4.18 \times 10 = 0.2\ (280.4 - 79.9)$ kJ

$\dot{m}_w = 0.72$



$S_1 \neq S_2$

$S_1 = S_2{}' = 0.7102$

0.7514	280.4	h_2	0.7514
0.7060	214.8		0.7060

← 0.7102

$\Delta h = 15.6$ $\Delta S = 0.0454$

$\Delta h' = ?$

$\Delta S' = 0.0412$

$\Delta h' = \frac{\Delta s'}{\Delta s} \times \Delta h$

$280.4 - h_2 = \frac{0.0412}{0.0454} \times 15.6 =$

$\boxed{h_2 = 216.8 \text{ kJ/kg}}$

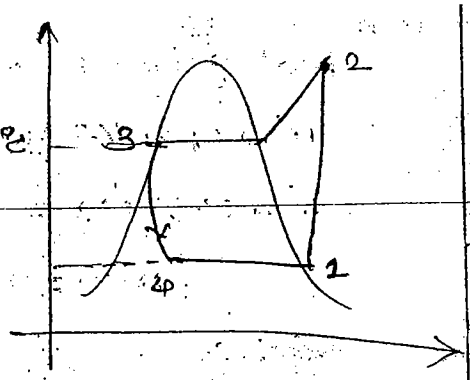
$\eta_c = \frac{kJ}{kJ}$

$= \frac{h_2 - h_1}{h_2 - h_1}$

$= \frac{216.8 - 193.87}{280.4 - 193.87}$

$= 0.73$

Qu.3 :



C.O.P = 6.5

$\dot{W}_C$ = 50 kW

$h_2' = 201.45$ kJ/kg

$C_{pv} = 0.06155$ kJ/kg°C

$h_1 = 187.53$ kJ/kg

$h_3 = h_4 = 69.5$ kJ/kg

C.O.P = 6.5

$\dot{W}_C$ = 50 kW

$$C.O.P = \frac{NRE\ (kW)}{\dot{W}_C\ (kW)}$$

$$6.5 = \frac{NRE}{50}$$

$$\boxed{NRE = 325\ kW}$$

$$\dot{m}_g \left(\frac{kg}{sec}\right)(h_1 - h_4)\frac{kJ}{kg} = NRE\ (kW)$$

$$\dot{m}_g (187.53 - 69.5) = 325$$

$$\dot{m}_g = 2.759\ kg/sec.$$

$$W_C (kW) = \dot{m}_g \left(\frac{kg}{sec}\right)(h_2 - h_1)\ kJ/kg.$$

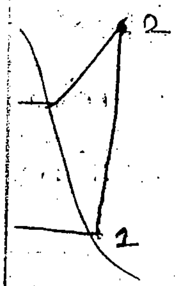
$$50 = 2.759 \times (h_2 - 187.53)$$

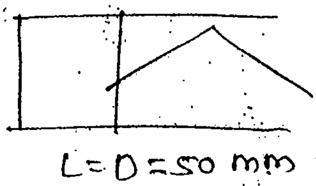
$$h_2 = 205.67\ \frac{kJ}{kg} = h_2' + C_{pv}(T_2 - T_2')$$

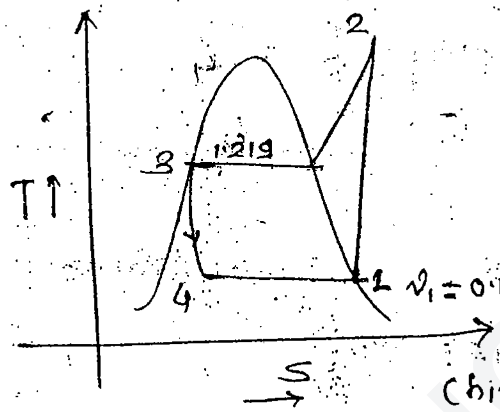
$$205.67 = 201.45 + 0.6155\,(T_2 - 35)$$

$$T_2 = 41.82°C$$

Q.4 :







$C = 0.05$

$n = 1.18$

$v_1 = 0.11 \frac{m^3}{kg}$

$(h_1 - h_4) = 94.7 \ kJ/kg$

Vol m. flow rate in (kg/s) $= \dot{m}_r \left(\frac{kg}{sec}\right) v_1 \left(\frac{m^3}{kg}\right)$

$= \frac{\pi}{4} D^2 L n \times \frac{N}{60} \times \eta_{vol}$

= Theoretical stroke volume

= Theoretical stroke vol m flow rate (m³/

= Actual stroke vol m flow rate (m³/

$= \frac{\pi}{4} D^2 L n \times \frac{N}{60} \times \left[1 + C - C\left(\frac{p_2}{p_1}\right)^{1/}\right.$

$\dot{m}_r (0.11) = \frac{\pi}{4}(50 \times 10^{-3})^2 (50 \times 10^{-3}) \times 1$

$\times \frac{1460}{60} \left[1 + 0.05 - 0.05\left(\frac{1.219}{0.151}\right)^{1/1.2}\right.$

$\dot{m}_r$ (kg/sec) = 0.016

NRE (kW) = $\dot{m}_r$ (kg/sec) $(h_1 - h_4)$ kJ/kg

= 0.016 × 94.7

= 1.50 kW

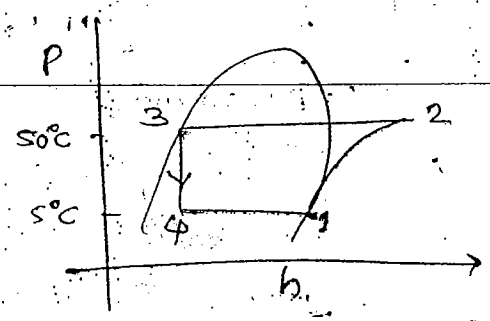
T2)

(T2-35)

Qu.5 : NRE = 15 tons

$= 15 \times 3.517 = 52.75$ kW

$h_3 = h_4 = 263.3$ kJ/kg



$h_1 = 407.1$ kJ/kg

$v_1 = 0.0404 \frac{m^3}{kg}$

$\eta_{vol} = 0.92$

$\left(\frac{\pi}{4} D^2 L n \times \frac{N}{60} \right) = ?$

$\dot{m}_\varepsilon \left(\frac{kg}{sec}\right) (h_1 - h_4) \frac{kJ}{kg} = NRE(kW)$

$\dot{m}_\varepsilon (407.1 - 263.3) = 52.75$

$\boxed{\dot{m}_\varepsilon = 0.366 \text{ kg/sec}}$

Vol^m flow rate $(m^3/sec) = \dot{m}_\varepsilon \left(\frac{kg}{sec}\right) v_1 \left(\frac{m^3}{kg}\right)$

$= \frac{\pi}{4} D^2 L n \times \frac{N}{60} \times \eta_{vol}$

$= x \times$ ISVFR (m^3/sec)

$= 0.366 \times 0.0404 = x \times 0.92$

$\boxed{x = 0.0205}$ $m^3/sec.$

If $l/D = 1.5$ and no. of cylinder = 1 rpm = 900

determine cylinder dimensions.

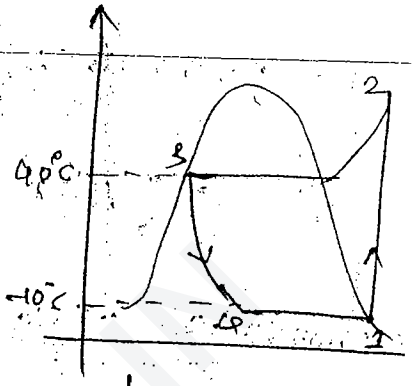
$\frac{\pi}{4} \times D^2 \times 1.5D \times 1 \times \frac{900}{60} = 0.0205$

$D^2 =$

$D =$

$l =$

Qu.6



$h_3 = h_4 = 74.5$ kJ/kg

Cooling load = 0.15 kW

N = 720 rpm

$\eta_{vol} = 0.8$

$\frac{\pi}{4} D^2 L n = ?$ (T.S.V)

$h_1 = 183$ kJ/kg

$v = 0.08$ m3/kg.

$\dot{m}$ (kg/sec) $(h_1 - h_4)$ kJ/kg = NRE (kW)

$\dot{m}(183 - 74.5) = 0.15$

$\dot{m} = 0.00142$ kg/sec.

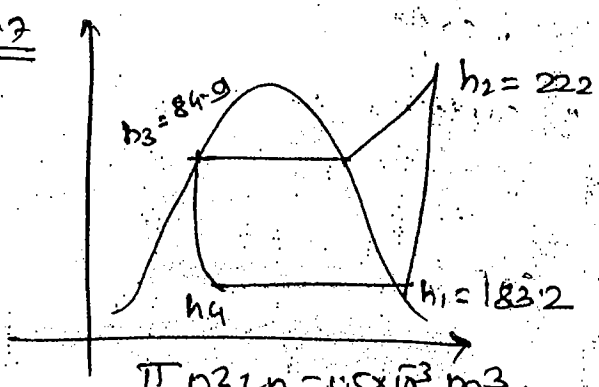
Vol^m flow rate (m3/sec) = $\dot{m}$ (kg/sec) V_1 (m3/kg) =

$\frac{\pi}{4} D^2 L n \times \frac{N}{60} \times$

$0.00142 \times 0.08 = x \times \frac{720}{60} \times 0.8$

$x = 1.18 \times 10^{-5}$ m3

Qu.7



$\frac{\pi}{4} D^2 L n = 1.5 \times 10^{-3}$ m3.

N = 1000 rpm

$\eta_{vol} = 0.8$

$V_1 = 0.0262$ m3/kg

Vol flow rate (m^3/sec) = $\dot{m}_s$ (kg/sec) v_1 ($\frac{m^3}{kg}$)

$\dot{m}_s = \frac{\pi}{4} D^2 L n \times \frac{N}{60} \times \eta_{vol}$ $\quad \frac{N}{60} = 26.69$

$\dot{m}_s \times 0.0767 = 1.5 \times 10^{-3} \times 26.69 \times 0.8$

$\dot{m}_s = 0.4172$ kg/sec.

$N_{REF(kW)} = \dot{m}_s$ (kg/sec) $(h_1 - h_4)$ kJ/sec

$N_{REF(kW)} = \dot{m}_s (h_1 - h_4)$

$= 0.417 (183.2 - 84.9)$

$= 41.01$

$W_{c(kW)} = \dot{m}_s$ (kg/sec) $(h_2 - h_1)$ kJ/kg

$= 0.412 (222.6 - 183.2)$

$= 16.23$

Small question:

Qu. 3: $C.O.P = \frac{T_2}{T_1 - T_2}$

- $(T_1 - T_2) \downarrow$ C.O.P ↑
- $T_1 \to T_2 \uparrow$ $(T_1 - T_2) \downarrow$ C.O.P ↑

- $T_1 \uparrow$ $(T_1 - T_2) \uparrow$ C.O.P ↓
- $T_2 \to$ $T_1 \uparrow$ $T_2 \downarrow$
- $(T_1 - T_2) \uparrow$ C.O.P ↓

Qu 11:

Qu 12

kW input =

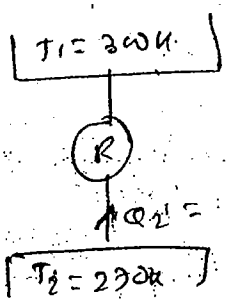
$\left(\frac{m^3}{kg}\right)$

$\frac{W}{68} = 26.69$

Qu 11:

Min power is when c.o.p is maxm

and maxm c.o.p carnot c.o.p



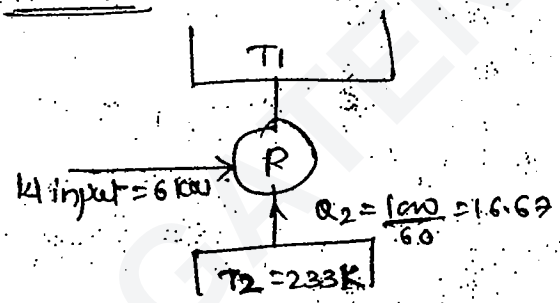
$(C.O.P)_R = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$

$\frac{5 \times 10^6}{\frac{3600}{W}} = \frac{270}{300 - 270}$

$138888 =$

$W = 154.32$ kW

Qu 12:



$C.O.P_R = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$

$2.77 = \frac{233}{T_1 - 233}$

$2.77(T_1 - 233) = 233$

$T_1 = 317$ or $44°C$

(13) $\dot{m}_2 \left(\frac{kg}{sec}\right)(h_1 - h_4)\frac{kJ}{kg} = 3.517 \times 100$

$\dot{m}_2 (h_1 - h_4) = 3.517$

$\dot{m}_2 \times 105 = 3.517$

$\dot{m}_2 = 0.0233 \text{ kg/sec}$

NH_3 having more compressor ratio than pervious R