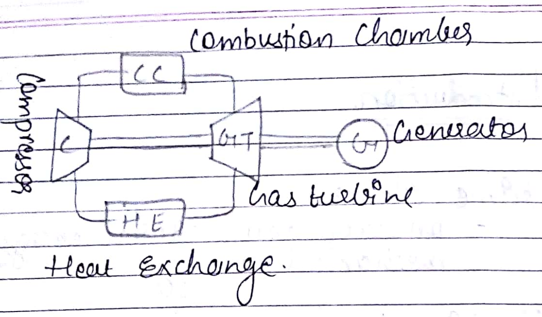
Introduction

→ Prime Mover.
- converts any natural energy into mechanical energy.

→ Classification on the basis of energy.

Prime movers
- non-thermal
  - Hydal
  - Tidal
  - wind
- thermal
  - fuel (H.E.)
  - Biogas
  - Geothermal
  - nuclear
  - Solar

H.E (Heat Engine)
- ICE (Internal Combustion Engine)
  - ICE (reciprocating piston)
  - Gas turbine (open)
- ECE (External Combustion Engine)
  - S.T. (rotatory) steam turbine
  - SE steam engine (reciprocating)
  - G.T (closed) gas turbine



→ Forces:- A push or a pull applied on a object that affects its state of motion, direction or shape.

$$F = \frac{d}{dt}(P) = \frac{d}{dt}(mv) = m\frac{dv}{dt} = ma.$$

Unit = N.

→ Pressure:- It is an expression of force exerted on a surface per unit area.

$P = \frac{F}{A}$ Unit = N/m^2

$1 N/m^2 = 1 Pa$ (Standard Unit of pressure.)

Atmospheric pressure is measured by Barometer. AP = pressure applied by atm. on the ground.

⇒ Standard atmospheric pressure, Patm.

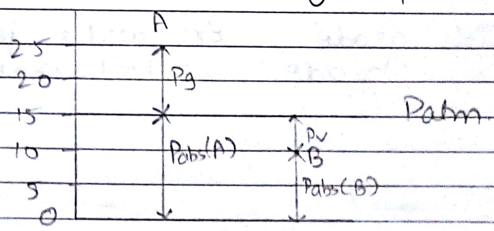
$P_{atm} = 1.01325$ bar
$= 760$ mm of Hg.

$1 \text{ bar} = 10^5$ Pa
$= 10^5 N/m^2$.

$P_{atm} < P_g$ ⇒ P_g = gauge pressure

$P_{atm} > P_v$ ⇒ P_v = Vacuum pressure.

⇒ Absolute pressure (P_{abs}) measured with reference to absolute zero pressure



$P_{abs}(A) = P_{atm} + P_g$.

$P_{abs}(B) = P_{atm} - P_v$.

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Power ⇒ $P = \frac{W}{t}$. Unit : J/s.

Brake power (BP) - available at final shaft.

Indicated power (IP) - power generated within the cylinder

$IP - BP = F.P$

$\eta = \frac{Output}{Input} = \frac{BP}{IP} , 0.$ ____ .

Energy :- Capacity to do work.
Unit : Joule

- High grade   Ex:- water jet
- Low grade.   ex:- heat, combustion of fuel.

- Stored energy
- Energy in transmission
- Internal Energy
- Heat
- temperature
- Enthalpy
- Process
- Path
- cycle

- change of state
- critical point
- triple point

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Que A steam engine piston having an area of 140 cm² moves a distance of 160mm inside the cylinder. Find the amount of work done if pressure exerted upon the piston is i) 80 KN/m² ii) 650 kPa.

A) $A = 140\ cm^2 = 140 \times 10^{-4}\ m^2$ $\quad W = (?)$

$d = 160\ mm = 160 \times 10^{-3}\ m$

$80\ KN/m^2 \quad 80\ kPa$

$W_1 = F.d$

$= P_1 A . d$

$= 80 \times 140 \times 10^{-4} \times 160 \times 10^{-3}$

$= 0.179\ J$

$650\ kPa$

$W_2 = F.d$

$= P_2 A . d$

$= 650 \times 140 \times 10^{-4} \times 160 \times 10^{-3}$

$= 1.456\ J$

Que Determine the power developed by the water turbine if it receive 800 kg/sec water per second at the pressure of 2 bar.

A) $\frac{m}{t} = 800\ kg/sec$ $\quad$ Power = (?)

$P = 2 \times 10^5\ Pa$

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Power = $\frac{w}{t}$ = F.d

$V = d.A$

$= \frac{F}{A}.d.A$

$= PV$

$= 2\times10^5 \times 0.8$

$= 1.6 \times 10^5$

$= 160\times10^6$ W

Power = 160 kW

Que In a water turbine, water is supplied at the rate 500 lit/sec under head of 20m it is discharge from the turbine at a velocity of 2m/sec. Determine the power developed by the turbine.

A) $m = 500$ lit/sec

$V = 2$ m/sec

$g = 9.81$ m/s^2

$h = 20$m

Power = (?)

$P.E = mgh$

$= 500 \times 9.81 \times 20$

$= 98100$ J

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$K.E = \frac{1}{2}mv^2 = \frac{1}{2} \times 500 \times 4 = 1000$ J

$P.E - K.E = 98100 - 1000$

$= 97100$

$P = 97100$ watt

$= 97.1$ kW

Que Steel having mass of 20 kg and the specific heat of 460 J/kg K is heated from 35°C - 150°C. Determine the heat required.

A) $m = 20$ kg

$T = 35°C - 150°C$ (308 - 423)K

$C = 460$ J/kg K

$Q = mC\Delta t$

$= mC(t_2 - t_1)$

$= 20 \times 460 \times (423 - 308)$

$= 20 \times 460 \times (115)$

$= 1058000$ J

$= 1058$ kJ

Specific Heat :- Amount of heat per unit mass required to raise the temperature by one degree Celsius

Que 3000 m³ of water is to be delivered in 50 min to a verticle piston of 20m. Find the power required neglect friction and other losses.

A

$V = 3000\ m^3$

$h = 20m$

$t = 50min$

$$P = \frac{w}{t} = \frac{f \cdot d}{t}$$

$$F = mg = 3000 \times 10^3 \times 9.81$$

$$P = \frac{3000 \times 10^3 \times 9.81 \times 20}{3000}$$

$P = 196.2$ kW.

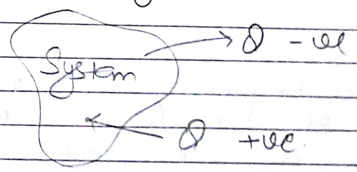
System:- region or a fixed quantity within space

Open System:- mass, energy both can exchange etc

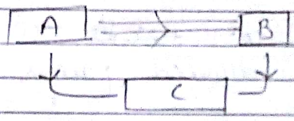
Closed system :- energy can exchange.

Isolated:- system that cannot exchange either energy or matter outside the boundaries of the system.

An isolated system differs from a closed system by the transfer of energy. Closed systems are only closed to matter, energy can be exchanged across the system's boundaries.



Zeroth Law:- If two systems are in thermodynamic equilibrium with a third system, the two original systems are in thermal equilibrium with each other.



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First Law:- The total energy of an isolated system is constant; energy can be transformed from one form to another, but can be neither created nor destroyed.

Que. A diesel engine consumes a fuel at the rate of 10 kg/hr. The engine is developed in 35 kW power. Calorific value of fuel is 43 MJ/kg. Calculate thermal efficiency.

A. $\eta_{th} = \frac{\text{Output power}}{\text{Input power}}$

$= \frac{\text{Break power}}{\text{Indicated power}}$

$IP = m \times C.V$

$= \frac{10}{3600} \times 43 \times 10^6 = 0.1194 \times 10^6$

$= 1.194 \times 10^5$

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$\eta_{th} = \frac{35 \times 10^3}{1.194 \times 10^5} = 29.3\%$

Que. A gas in a cylinder is at the pressure of 9 bar. It is expanded at a constant pressure from $0.5 \rightarrow 1.8\ m^3$. Determine the work done.

A. $P = 9$ bar $\quad 0.5 \rightarrow 1.8\ m^3$ (V_1, V_2)

$W = P\Delta V$

$= P(V_2 - V_1)$

$= 9 \times 10^5 (1.8 - 0.5)$

$= 11.7 \times 10^5$

Que. To pump 200 kg of water in a boiler 150×10^3 Nm of work is require. Find the pressure in the boiler.

A. $m = 200$ kg $\quad 1\ m^3 = 1000$ lit

$W = 150 \times 10^3$ Nm. $\quad 1$ lit $= 1$ kg

$W = f.d \quad$ (?) $= 200$ kg $= 200$ lit

$= \frac{f}{A}.d.A$

$= P\Delta V \quad 1\ m^3 = 1000$ lit, (?) 2000 lit

$150 \times 10^3 = P \times 0.2$

$P = 750 \times 10^3$. MPa.

Que In a compressor work done on the air 150 KJ, the heat rejected to the surrounding is 60 KJ. Find the change in internal energy.

A

$Q = U + W$

$Q - W = U$

$-150 + 60 = U$

$U = 90$ KJ.

Que 10 kg of air at 90°C is heated at constant pressure then at constant volume to final temperature 300°C if 1800 KJ of heat is supplied. Find the temperature at the end of constant pressure may be $C_p = 1.005$ kJ/kgK $C_v = 0.715$ KJ/kg K.

A

$C_p = 1.005$ KJ/kgK

$C_v = 0.715$ KJ/kgK

$m = 10$ kg

$Q = 1800$ KJ

$90°C \xrightarrow[1 \to 2]{P=C} t_2 \xrightarrow[2 \to 3]{V=C} 300°C$

$Q = mc\,\Delta t + mc\,\Delta t$

$Q = m C_p (t_2 - t_1) + m C_v (t_3 - t_2)$

$Q = 10 \times 1.005 (t_2 - 363) + 10 \times 0.715 (573 - t_2)$

$Q = 10 [1.005 t_2 - 364.815 + 409.695 - 0.715 t_2]$

$Q = 10 [0.29 t_2 + 44.88]$

Q =

$1800 = 2.9 t_2 + 448.8$

$\frac{1800 - 448.8}{2.9} = t_2$

$t_2 = 192$

Que In a cyclic process there are four heat transfer process which are as under $Q_{12} = 925$ KJ

$Q_{23} = -110$ KJ

$Q_{34} = -770$ KJ

$Q_{41} = 220$ KJ

The work done during the process.

$W_{12} = 70$ KJ

$W_{23} = -50$ KJ

$W_{41} = 170$ KJ

$W_{34} = (?)$. Calculate work done during process (34) find out the change in internal energy during cyclic process.

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A: $Q - W = 0$
$Q = W$

$\oint_1^4 Q = \oint_1^4 W$

$Q_{12} + Q_{23} + Q_{34} + Q_{41} = W_{12} + W_{23} + W_{34} + W_{41}$

$925 - 110 - 770 + 220 = 70 - 50 + W_{34} + 170$

$W_{34} = 265 - 70 + 50 - 170$
$= 75$

$Q_{12} = U_{12} + W_{12}$

$U_{12} = 925 - 70 = 865$
$U_{23} = -110 + 50 = -60$
$U_{34} = -770 - 75 = -845$
$U_{41} = 220 - 170 = 50$

$\Delta U = U_{12} + U_{23} + U_{34} + U_{41}$
$= 855 - 60 - 845 + 50$
$= 0$

Que: In a compression process 3KJ of mechanical work is supplied to 5KJ of working substance. the heat rejected to the cooling Jacket 700J. Calculate the specific internal energy.

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A: Work done on the system $W = -3KJ$
$m = 5kg$
heat is rejected $\therefore Q = -700$ J

$W = -3 \times 10^3$ J
$Q = -700$ J

$Q = U + W$
$U = Q - W$
$= -700 + 3 \times 10^3$
$= 2300$
$= 2.3$ kJ

Specific internal energy $= \frac{U}{m}$

$= \frac{2.3 \times 10^3}{5}$

$= 0.46$
$= 460$ J

Que: A gas enters in a system at an initial pressure of 0.5 MPa and flow rate of 0.15 m^3/s leaves the system at the pressure of 0.95 MPa and flow rate 0.09 m^3/sec. during the process change in internal energy is 22 kJ/sec. calculate the change in enthalpy.

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Ans

$\Delta H = \Delta U + \Delta PV$

$= (U_2 + P_2V_2) - (U_1 + P_1V_1)$

$= U_2 - U_1 + P_2V_2 - P_1V_1$

$= 22 + 0.5 \times 0.15 \times 10^6 - 0.95 \times 10^6 \times 0.09$

$= 22 + 10^6(0.075 - 0.0855)$

$= 22 \times 10^3 + 0.1605 \times 10^6$

$= 22 \times 10^3 + 10.5 \times 10^3$

$= 32.5 \times 10^3$

$= 32.5$ kJ

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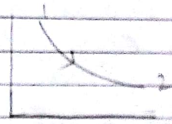
Properties of Gases

Perfect or Ideal Gas.

- The gas in which property remains unchanged when temperature and pressure changes
- The gas which obeys charles law, Boyles law and Gay Lussac law is called Ideal gas. (Real gases doesn't obeys these laws).
- Every real gas if subjected to min. P and max. T behaves like perfect gas.

1) Boyle's Law $(T = C)$



$V \propto \frac{1}{P_{abs}}$

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

$PV = C$

$P_1V_1 = P_2V_2$

Charle's Law $(P = C)$

$V \propto T_{abs.}$

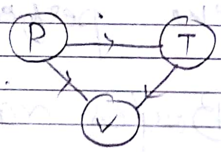
$V = CT$

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

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Gay Lussac's Law $(V = C)$

$P \propto T_{abs.}$



$P = CT$

$\frac{P}{T} = C$

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

Combined Gas Law

$V \propto \frac{1}{P}$ (Boyle's Law)

$V \propto T$ (Charles Law)

$\Rightarrow V \propto \frac{T}{P}$

$Pv = RT$ (R = specific gas constant or characteristic gas constant)

$\frac{PV}{m} = RT$

$v = \frac{V}{m}$ (specific volume)

$PV = mRT$

$R = 287\ J/kgK$ (Air)

m = mass

$R = \frac{J}{kgK}$

$R_o = MR$

M = molecular mass

$R_o = \frac{J}{molK}$

$PV = MRT$

$PV = R_oT$

$R_o = 8.314 \times 10^3$

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NTP
$T = 25°C$
$P = 1$ bar

STP
$T = 0°C$
$P = 1$ bar.

$1 \text{bar} = 1.01325 \times 10^5$ Pa.

$PV = R_0 T$

$$V = \frac{R_0 T}{P} = \frac{8.314 \times 10^3 \times 273}{1.01325 \times 10^5}$$

$$= 22.4 \text{ lit} = \frac{m^3}{mol}$$

$1 \text{lit} = 1 m^3$

Relation b/w C_p & C_v.

$Q = U + W$ (I law of Thermodynamics)

$$mC_p(t_2 - t_1) = mC_v(t_2 - t_1) + P(V_2 - V_1)$$

$$mC_p(t_2 - t_1) = mC_v(t_2 - t_1) + mR(t_2 - t_1)$$

$$C_p = C_v + R.$$

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$$\boxed{C_p - C_v = R}$$

Meyer's Eqn

Dividing above eqn by C_v

$$\frac{C_p}{C_v} - \frac{C_v}{C_v} = \frac{R}{C_v}$$

$$\frac{C_p}{C_v} - 1 = \frac{R}{C_v}$$

$$\gamma - 1 = \frac{R}{C_v} \qquad \left[\frac{C_p}{C_v} = \gamma\right]$$

$$C_v = \frac{R}{\gamma - 1}$$

γ = adiabatic index.

$$= \frac{.287}{1.4 - 1}$$

$\gamma = 1.67$ (monoatomic)
$= 1.4$ (diatomic)
$= 1.33$ (polyatomic)

$$\boxed{C_v = 0.715}$$

$$\boxed{C_p = 1.001}$$

Flow and Non-flow processes

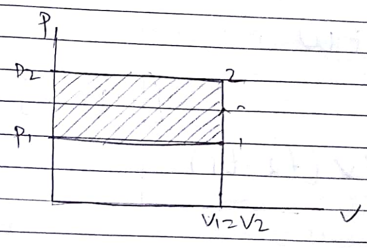
⇒ Flow processes
- applicable to open system
- mass can flow from system to surrounding & vice-a-versa.

⇒ Non-flow processes.
- applicable to closed system
- mass cannot flow

⇒ types of non-flow processes.

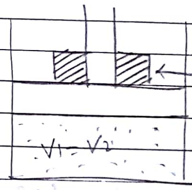
i) $V=C$ (isochoric)
ii) $P=C$ (isobaric)
iii) $T=C$ (isothermal)
iv) reversible adiabatic (isentropic)
$Q=0$, entropy $=C$ (ΔS).
v) polytropic
$pV^{\gamma}=C$.

1) Constant Volume Process.
($V=C$)

→ 

follows Gay Lussac's Law

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

→ 

← Dead weight

→ Work done, W

$W = P\,\Delta V$

$= P(V_2-V_1)$

$\boxed{W=0.}$

→ Change in Internal Energy, ΔU.

$\Delta U = mC_v\,\Delta t$

$= mC_v(t_2-t_1)$

→ $Q = \Delta U + W$

$Q = \Delta U$ $\quad [W = 0]$

$Q = mC_v(t_2 - t_1)$

heat supplied at const Volume

→ $\Delta H = H_2 - H_1$

$\because H = U + PV$

⇒ $\Delta H = (U_2 + P_2V_2) - (U_1 + P_1V_1)$

$= (U_2 - U_1) + (P_2V_2 - P_1V_1)$

$= \Delta U + V(P_2 - P_1)$

$= mC_v(t_2 - t_1) + (mRt_2 - mRt_1)$

$= mC_v(t_2 - t_1) + mR(t_2 - t_1)$

$= m(t_2 - t_1)(C_v + R)$

$\boxed{\Delta H = mC_p(t_2 - t_1)}$

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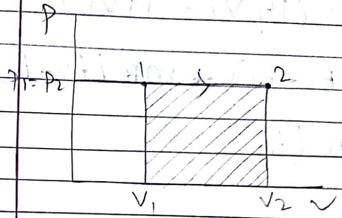
II) Constant pressure Process. ($P = C$).

→ 

follows Charle's Law

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$.

→ 

→ work done, $W = P(V_2 - V_1)$

$W = mR(t_2 - t_1)$

→ $\Delta U = mC_v(t_2 - t_1)$

→ $Q = U + W$

$= mC_v(t_2 - t_1) + mR(t_2 - t_1)$

$Q = mC_p(t_2 - t_1)$

→ $\Delta H = H_2 - H_1$

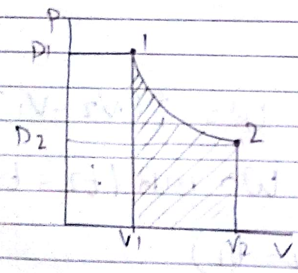
$= (U_2 + P_2V_2) - (U_1 + P_1V_1)$

$= \Delta U + (P_2V_2 - P_1V_1)$

$= mC_v(t_2 - t_1) + mR(t_2 - t_1)$

$\Delta H = mC_p(t_2 - t_1)$

iii) Constant Temperature Process.
$(T = C)$

→ 

follows Boyles law

$P_1V_1 = P_2V_2$

→ 

$W = \int_1^2 dw = \int_1^2 P\,dV$

$= \int_1^2 \frac{C}{V}\,dV$

$= C\int_1^2 \frac{1}{V}\,dV$

$= C[\log V]_1^2$

$= C[\log V_2 - \log V_1]$

$= C \log \frac{V_2}{V_1}$

$= P_1V_1 \ln \frac{V_2}{V_1} = P_2V_2 \ln \frac{V_2}{V_1}$

$= mRT_1 \ln \frac{V_2}{V_1} = mRT_2 \ln \frac{V_2}{V_1}$

$= mRT_1 \ln \frac{P_1}{P_2} = mRT_2 \ln \frac{P_1}{P_2}$

$= P_1V_1 \ln \frac{P_1}{P_2} = P_2V_2 \ln \frac{P_1}{P_2}$

$\rightarrow U = mC_v(t_2 - t_1)$
$= 0$

$\rightarrow Q = U + W$
$= W$

$\rightarrow \Delta H = mC_p(t_2 - t_1)$
$= 0$

IV) Adiabatic Process (Isentropic)
$(Q = 0)$

$dQ = du + dw = 0$

$\because du = mC_v dt$

$\Rightarrow C_v dt + P dV = 0 \quad [m = 1 kg]$

$PV = Rt$

$Pdv + Vdp = Rdt.$

$dt = \frac{Pdv + vdp}{R}$

$C_v\left[\frac{Pdv + Vdp}{R}\right] + Pdv = 0$

$C_v[Pdv + Vdp] + R\,Pdv = 0$

$C_v \cancel{Pdv} + C_v Vdp + C_p Pdv - \cancel{C_v Pdv} = 0$

$\frac{C_v Vdp}{PVC_v} + \frac{C_p \cdot Pdv}{PVC_v} = 0$

$\frac{dp}{P} + \gamma \frac{dv}{V} = 0$

$\ln P + \gamma \ln V = \ln C$

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

$\ln PV^{\gamma} = \ln C$

$\boxed{PV^{\gamma} = C}$

Adiabatic Law

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

$$\frac{P_1}{P_2} = \frac{T_1}{T_2} = \frac{V_2}{V_1}$$

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} \Rightarrow \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \frac{T_2}{T_1}$$

$$\Rightarrow W = \int_1^2 P\,dv$$

$$= \int_1^2 \frac{C}{V^{\gamma}}\,dv \quad \left[PV^{\gamma} = C \Rightarrow P = \frac{C}{V^{\gamma}}\right]$$

$$= C\int_1^2 \frac{1}{V^{\gamma}}\,dv$$

$$= C\int_1^2 V^{-\gamma}\,dv$$

$$= C\left[\frac{V^{-\gamma+1}}{-\gamma+1}\right]_1^2$$

$$W = \frac{C}{1-\gamma}\left[V^{-\gamma+1}\right]_1^2$$

$$= \frac{C}{1-\gamma}\left[V_2^{-\gamma+1} - V_1^{-\gamma+1}\right]$$

$$= \frac{1}{1-\gamma}\left[CV_2^{-\gamma+1} - CV_1^{-\gamma+1}\right]$$

$$= \frac{1}{1-\gamma}\left[P_2V_2^{\gamma}V_2^{-\gamma+1} - P_1V_1^{\gamma}\cdot V_1^{-\gamma+1}\right]$$

$$= \frac{1}{1-\gamma}\left[P_2V_2 - P_1V_1\right]$$

$$\boxed{W = \frac{P_1V_1 - P_2V_2}{\gamma-1}}$$

$$W = \frac{mR(t_1-t_2)}{\gamma-1}$$

$$\Rightarrow \boxed{W = mC_v(t_1-t_2)} \qquad \because \frac{C_p}{C_v} = \frac{C_v}{C_v} = \frac{R}{C_v}$$

$$\gamma - 1 = \frac{R}{C_v}$$

$$C_v = \frac{R}{\gamma-1}$$

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→ $\Delta U = mC_v(t_2 - t_1)$

→ $Q = U + W$

$Q = U + W$

$U = Q - W$

→ $\Delta H = mC_p(t_2 - t_1)$

Q. A tank contains $3m^3$ air at 25 bar pressure this air is pulled until its pressure and temp. decreases to 15 bar and 21°C. Determine change in internal energy, change in enthalpy and heat transfer. take $C_p = 1.005$ KJ/KgK and $C_v = 0.718$ KJ/Kg K.

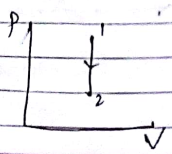
A

$V_1 = 3m^3$ $\quad$ $P_2 = 15$ bar

$P_1 = 25$ bar $\quad$ $T_2 = 21°C$

$C_p = 1.005$ Kg/kgK

$C_v = 0.718$ KJ/KgK.



i) $\Delta U =$

ii) $\Delta H =$

iii) $Q =$

?

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Q. 1 kg of air at 7 bar pressure and temp. 90°C. undergoes polytropic process. The law of expansion is $PV^{1.1} = C$. The pressure falls to 1.4 bar. Calculate final temp, work done, change in internal energy, heat exchange. Take $R = 287\ J/kgK$, $\gamma = 1.4$ for air

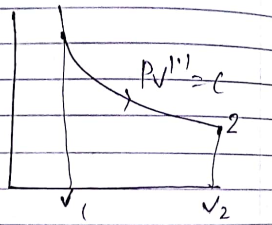
A. $\gamma = 1.4$

$m = 1kg$

$P_1 = 7$ bar

$T_1 = 90°C$

$P_2 = 1.4$ bar.



$PV^{1.1} = C$ law of expansion $V_1 < V_2$

$PV^n = C \Rightarrow n = 1.1$

$$\Rightarrow \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$T_2 = (90+273)\left(\frac{1.4}{7}\right)^{\frac{1.1-1}{1.1}}$$

$$\boxed{T_2 = 313.6\ K}$$

$$W = \frac{P_1V_1 - P_2V_2}{n-1}$$

$$= \frac{mR(t_1 - t_2)}{n-1}$$

$$= \frac{(1)(287)[\overset{363}{(90+273)} - (313.6)]}{1.1-1}$$

$$\boxed{W = 141.8\ KJ}$$

$$\Delta U = mC_v(t_2 - t_1)$$

$$= 1 \times (0.718)(313.6 - 363)$$

$$\boxed{\Delta U = -35.47\ KJ}$$

$$Q = \left(\frac{\gamma - n}{\gamma - 1}\right) \times W$$

$$= \left(\frac{1.4-1.1}{1.4-1}\right) \times 141.8$$

$$\boxed{Q = 106.35\ KJ}$$

Or $Q = U + W$

$= -35.47 + 141.8$

$$\boxed{Q = 106.33\ KJ}$$

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Q A balloon of spherical shape have 6m in diameter filled with hydrogen gas at a pressure of 1 bar and temperature 20°C. At the later time pressure of gas is 94% of initial pressure at same temperature.

i) What mass of original gas must have escaped if dimension of balloon is not changed?

ii) Find the amount of heat to be removed for the same condition if volume is constant.

Take molecular weight of hydrogen 2kg/mol, specific heat at constant volume, $C_v = 10400$ J/kg k.

A

$M = 2$ kg/mol

$C_v = 10400$ J/kg k

$D = 6$m

$P_1 = 1$ bar

$T_1 = 20°C$

$P_2 = 94\%$ of P_1

$= 0.94 P_1$

$\frac{4}{3}\pi r^3 = V$

H_2

$V = \frac{4}{3}\pi r^3$

$= 113.04\ m^3$

$P_1 V_1 = m_1 R T_1$ — ①

$P_2 V_2 = m_2 R T_2$ — ②

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$P_1 V_1 - P_2 V_2 = (m_1 - m_2) RT$
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