First law of thermodynamics:-

or

Energy conservation law / Joule's law.

or

Quantitative law

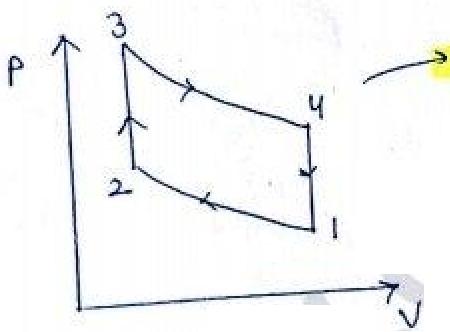
⇒ According to FLOT energy can neither be created nor be destroyed rather it converted from one form to another form

OR

⇒ According to FLOT for a close system undergoing a cyclic process the net heat interaction is equal to net work interaction when they are express in their own units

$$\boxed{\oint \delta Q = \oint \delta W} \quad -(1)$$

it is Applicable for both reversible as well as irreversible proces



$\rightarrow Q_{1-2} + Q_{2-3} + Q_{3-4} + Q_{4-1}$

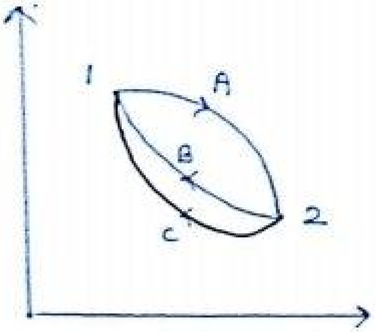
$= W_{1-2} + W_{2-3} + W_{3-4} + W_{4-1}$

Drawback of equation (1):- it is applicable only for a Cyclic process

or Not applicable for a single process.

Consequences of FLOT:-

① Heat transfer is a path function.



$$Q_{1-A-2} + Q_{2-B-1} = W_{1-A-2} + W_{2-B-1} \quad \text{— (A)}$$

$$Q_{1-A-2} + Q_{2-C-1} = W_{1-A-2} + W_{2-C-1} \quad \text{— (B)}$$

$$Q_{2-B-1} - Q_{2-C-1} = W_{2-B-1} - W_{2-C-1} \quad \text{— (C)}$$

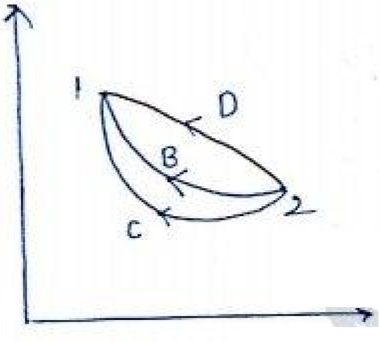
$$W_{2-B-1} - W_{2-C-1} \neq 0$$

therefor $Q_{2-B-1} - Q_{2-C-1} \neq 0$

Hence "Heat transfer" is a "path function"

② Energy is a property. (point of function)

using eqⁿ (C) $Q_{2-B-1} - Q_{2-C-1} = W_{2-B-1} - W_{2-C-1}$



$$Q_{2-B-1} - W_{2-B-1} = Q_{2-C-1} - W_{2-C-1}$$

$$= Q_{2-D-1} - W_{2-D-1}$$

$$\delta Q - \delta W = dE$$

$$\boxed{\delta Q = dE + \delta W} \quad \text{— (2)}$$

for a process.

$$dE = d(\underbrace{KE + PE}_{\text{macroscopic form}} + \underbrace{u}_{\text{Microscopic form}})$$

$\therefore\ dE = du$ [Neglate KE, PE]

use in eq ②

$$\boxed{\delta Q = du + \delta W} \quad -③$$

Condition for applying 'Pdv' work :-

(i) it should cross the boundary.

(ii) should be a reversible process.

(iii) should be a close system.

$$\boxed{\delta Q = du + Pdv} \quad -④$$

* This equation is applicable for a Closed System and reversible process.

③ Energy of a isolated system is constant

⇒ for a isolated system.

$$\delta Q = dE + \delta W$$

$$dE = 0$$

$$E_f - E_i = 0$$

$$\boxed{E_f = E_i}$$

④ PMM-1 is impossible

Perpetual Motion machine of first kind is impossible because it violet FLOT.

It is impossible to construct a device which produces work continuosly without consuming any form of energy.

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

Expression of Heat for different process.

Case① Constant Volume process:-

$$dQ = du + PdV$$

$$V = \text{Constant} \quad dV = 0$$

$$\boxed{dQ = du} \quad -①$$

$$\boxed{dQ = mC_v \Delta T} \quad -②$$

Compare eq① & ②

$$\boxed{du = mC_v \Delta T}$$

Note:- (i) Internal energy is a function of temprature only for ideal gas.

(ii) The expression $du = mC_v \Delta T$ is applicable for all process. because it contains all point function

Enthalpy :- It represents the total heat content of the system. The mathematical expression of enthalpy is

$$\boxed{H = U + PV}$$

Unit :- Joule $\rightarrow$ N - m

$\rightarrow$ force × Disp.

$\rightarrow$ mass × acc. × Disp.

$\rightarrow$ $kg \times m/sec^2 \times m$

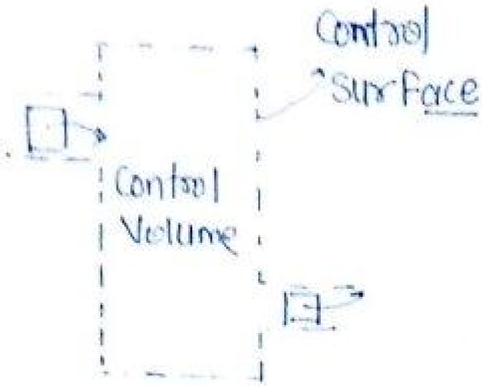
$\rightarrow$ $kg \frac{m^2}{sec^2} \Rightarrow ML^2T^{-2}$

Specific Enthalpy :- It is the summation of specific internal energy and flow work.

$$h = \frac{H}{m} = \frac{U}{m} + P\left(\frac{V}{m}\right)$$

$$h = u + Pv$$

Flow work (Pv) :- It is the amount of work which is require to displace a infinitely small fluid element into or out of control volume is known as flow work.



	MI	EI
Control mass (closed system)	✗	✓
Control Volume (open system)	✓	✓

Note:- Control mass is also known as close system and control volume is known as ~~Contro~~ open system.

② The boundary of Control Volume is known as Control surface

Case-2 Constant pressure:-

$$dQ = du + PdV$$

$$P = \text{Constant}$$

$$dQ = du + d(PV)$$

$$dQ = d(u + PV)$$

$$\boxed{dQ = dH} \quad -① \Rightarrow \quad \boxed{dQ = mC_p\Delta T} \quad -②$$

Compare eqn ① & ②

$$\boxed{dH = mC_p\Delta T}$$

* (i) The above expression is applicable for all process because it contain all properties

(ii) enthalpy is a function of temperature for ideal gas

Case(3) Constant temp. process:-

$$dQ = dU + dW$$

$$T = \text{constant}$$

$$dT = 0$$

$$mC_v\,dT = 0$$

$$du = 0$$

So
$$\boxed{\delta Q = \delta W = C \ln \frac{V_F}{V_I} = C \ln \frac{P_I}{P_F}}$$

$$C = P_I V_I = P_F V_F = mRT_I = mRT_F$$

Case(4) Adiabatic process:- A process said to be adiabatic in which there is no Heat interaction between system and surrounding.
e.g. Insulated tank.

Ques:- Prove that there is no heat interaction in adiabatic process.

Relation between C_p, C_v, R, γ :→

$$\frac{C_p}{C_v} = \gamma \quad , \quad C_p - C_v = R$$

$$\gamma C_v - C_v = R$$

$$C_v = \frac{R}{\gamma - 1}, \quad C_p = \frac{\gamma R}{\gamma - 1}$$

FLOT $dQ = du + Pdv$

$$dQ = mc_v(T_f - T_I) + \frac{P_I V_I - P_f V_f}{\gamma - 1}$$

$$dQ = m\frac{R}{\gamma - 1}(T_f - T_I) + \frac{mR(T_I - T_f)}{\gamma - 1}$$

$$dQ = 0$$

Question: Prove that PV^{γ} = constant for Reversiable adiabatic process.

Soln $PV^{\gamma} = C$

$$dQ = du + Pdv$$

Rev. adiabatic :- $dQ = 0$

$$du + Pdv = 0$$

$$mc_v\, dT = -Pdv. \quad -(1)$$

$\Rightarrow$ $H = U + PV$

Diff:- $dH = du + Pdv + Vdp$

$$dH = dQ + Vdp$$

$$\boxed{dQ = dH - Vdp}$$

Rev. addiabatic $dQ = 0$

$$dH = Vdp$$

$$mc_p dT = Vdp \quad -(2)$$

(2)/(1)

$$\frac{mc_p dT}{mc_v dT} = \frac{-VdP}{PdV}$$

$$\frac{c_p}{c_v} = \gamma = -\frac{V}{dV}\frac{dP}{P}$$

$$\int \frac{dP}{P} + \int \gamma \frac{dV}{V} = \int 0$$

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

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

Que:- Prove that $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$ for reversible adiabatic process executed by the gas

Sol^n

$PV = mRT \Rightarrow P$

$\frac{PV}{T} = \text{const}$ $\quad PV^{\gamma} = c$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \& \quad P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

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

$$\frac{P_1}{P_2} = \frac{T_1V_2}{V_1T_2} \quad -(1)$$

(1) & (2) $\frac{T_1V_2}{T_2V_1} = \left(\frac{V_2}{V_1}\right)^{\gamma} \Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

from (2)

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}\left(\frac{P_1}{P_2}\right)^{1/\gamma}$$

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

or $\quad pv = mRT \Rightarrow v = mR\left(\frac{T}{p}\right)$

$$pv^{\gamma} = \text{cont} \Rightarrow p\left(\frac{T}{p}\right)^{\gamma} = c$$

$$p^{1-\gamma}\, T^{\gamma} = c$$

$$p_1^{1-\gamma}\, T_1^{\gamma} = p_2^{1-\gamma}\, T_2^{\gamma}$$

$$\left(\frac{T_2}{T_1}\right)^{\gamma} = \left(\frac{p_1}{p_2}\right)^{1-\gamma} \Rightarrow \frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\gamma-1/\gamma}$$

$\Rightarrow \quad pv = mRT \Rightarrow p = mR\left(\frac{T}{v}\right)$

$$pv^{\gamma} = c \Rightarrow \left(\frac{T}{v}\right)v^{\gamma} = c \Rightarrow Tv^{\gamma-1} = \text{Const.}$$

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1}$$

Case-5 Polytropic Process:-

$$pv^{n} = c$$

$$dQ = du + p\,dv$$

$$\int dQ = \int mc_v\, dT + \int \frac{c\, dv}{v^{n}}$$

$$Q = mc_v(T_F - T_I) + c\left[\frac{v^{-n+1}}{-n+1}\right]_{v_I}^{v_F}$$

$$Q = mc_v(T_F - T_I) + c\left[\frac{v_F^{-n+1} - v_I^{-n+1}}{-n+1}\right]$$

$$c = P_I v_I^{n} = P_F v_F^{n}$$

$$Q = mc_v \Delta T + \left[\frac{P_F V_F^n V_F^{-n+1} - P_I V_I^n V_I^{-n+1}}{-n+1} \right]$$

$$Q = mc_v \Delta T + \frac{P_I V_I - P_F V_F}{n-1}$$

$$Q = \frac{(P_F V_F - P_I V_I) R}{\gamma - 1} + \frac{P_I V_I - P_F V_F}{n-1}$$

$$Q = \frac{P_I V_I - P_F V_F}{n-1} - \frac{P_I V_I - P_F V_F}{\gamma - 1}$$

$$Q = \left(\frac{P_I V_I - P_F V_F}{n-1} \right) \left(\frac{\gamma - n}{\gamma - 1} \right)$$

$$\boxed{dQ = \left(\frac{\gamma - n}{\gamma - 1} \right) W_{close}}$$

Polytropic Specific Heat :-

$$dQ = \frac{mR(T_I - T_f)}{n-1} \left(\frac{\gamma - n}{\gamma - 1} \right)$$

$$m C_{poly} \Delta T = \frac{mR(T_I - T_f)}{(n-1)} \left(\frac{\gamma - n}{\gamma - 1} \right)$$

$$C_{poly} = \frac{-R(\gamma - n)}{(n-1)(\gamma - 1)}$$

$$\boxed{C_{poly} = \frac{C_v (n-\gamma)}{n-1}}$$

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

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

Note:- The value of polytropic specific heat is negative for $\gamma > n > 1$

Prove ~~Proof~~ the Meyer's eqn:- $C_p - C_v = R$

$$C_p - C_v = R$$

$$dH = mC_p\,dT \, , \quad du = mC_v\,T$$

$$dH = du + d(pV) = du + d(mRT)$$

$$mC_p\,dT = mC_v\,dT + mR\,\Delta T$$

$$C_p - C_v = R \qquad \text{Hence proof}$$

*Important points Regarding Heat and work :-

Similarties:-

1. Both are path function.
2. Both are Inexact differential.
3. Both are boundary phenomenon.
4. Both are Energy in transit or Transiant phenomenon.

Differences:-

1. All form of energy interaction are work interaction except energy interaction due to temp.
2. Area under P-V provide work interaction and area under T-S provide heat interaction.

Note:- (i) All the work producing devices are shown in clock wise direction on P-V and T-S.

eg. carnot cycle, Otto cycle, Rankine cycle etc.

(ii) All the work absorbing devices are shown in anticlock wise direction on P-V & T-S.

eg:- Reverse carnot cycle, Reverse Brayton cycle etc.

Question:- A spherical ballon of 1 m dia Contains a gas at 150 kPa. The gas inside the ballon is filled until the pressure reaches 450 kPa. During the process of heating the pressure of gas inside the ballon is proportion to the cube of diameter of Volume than find out work done by gas inside ballon.

Sol^n Sphere

$D_1 = 1\ m$

$P_1 = 150\ kPa,\ P_2 = 450\ kPa$

$P \propto D^3$ $\quad W = ?$ $\quad V = \frac{4}{3}\pi R^3$

$P = kD^3$ $\quad V = \frac{\pi D^3}{6}$

$W = \int P\, dV$

$dV = \frac{\pi}{6} 3D^2\, dD$

$W = \int k D^3 \frac{\pi}{2} D^2\, dD$

$W = \frac{k\pi}{2} \int_{D_i}^{D_f} D^5\, dD$ $\quad P_1 = kD_1^3$

$150 \times 10^5 \times 1N/m^2 = k \times 1 m^3$

$W = \frac{k\pi}{2} \left. \frac{D^6}{6} \right|_{1m}^{D_f}$ $\quad k = \frac{150\ kPa}{m^3}$

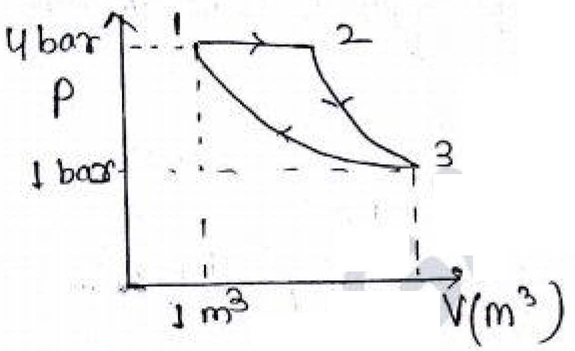
$P_2 = kD_2^3$

$W = \frac{150 kPa}{m^3} \times \frac{\pi}{2} \left[\frac{1.44^6 - 1^6}{6} \right] m^6$ $\quad 450 = 150\, D_2^3$

$W = 150 \times \frac{\pi}{2} \times \frac{8}{6}\ KJ$ $\quad D_2 = 1.44\ m$

$W = 314.159\ KJ$ Ans

Q.48:- A system undergoes three quasistatic process as shown in Fig. Process 1-2 isobaric, 2-3 polytropic with value of index $n = 1.4$ and 3-4 is isothermal then determine. (i) Volume of the system at point 2 in m^3 (ii) Net work output in KJ.



Soln

$P_1 = 4$ bar, $V_1 = 1\ m^3$ $\quad P_3 = 1$ bar

$P_2 = 4$ bar, $V_2 = ?$ $\quad V_3 = ?$

$P_3 V_3 = P_1 V_1$ (isothermal)

$1 \times V_3 = 4 \times 1 \Rightarrow V_3 = 4\ m^3$

Now 2-3 ~~isobar~~ polytropic.

$$P_2 V_2^{1.4} = P_3 V_3^{1.4}$$

$$4 (V_2)^{1.4} = 1 (4)^{1.4}$$

$$V_2 = 1.486$$

$$\cancel{\oint \delta Q = \oint \delta w}.$$

$$\oint dw = w_1 + w_2 + w_3$$

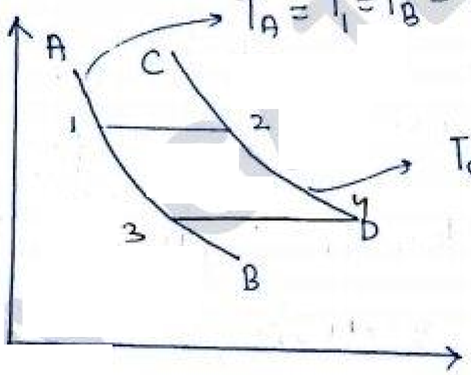
$$= 4(1.486-1) + \frac{4(1.486)-(1)(4)}{0.4} + 4 \times \ln\left(\frac{1}{4}\right)$$

$W = 1.26 \times 10^5 \ N/m^2$

$W = 126 \text{ KJ}.$

$$w_1 = P_1(V_2 - V_2), \quad w_2 = \frac{P_2V_2 - P_3V_3}{n-1}, \quad w_3 = P_3V_3 \ln\left(\frac{V_1}{V_3}\right)$$

Question:- Prove the validity or therwise of statement. For a perfect gas the workdone by constant pressure expansion from any point on a given isothermal to another given isothermal is constant.



$T_A = T_1 = T_B = T_3 \quad (P_1V_1 = P_3V_3)$

$T_C = T_2 = T_D \quad (P_2V_2 = P_4V_4)$

$$(1\text{-}2) :- \ W_{1-2} = P(V_F - V_I) = P_1(V_2 - V_1) = P_1V_1\left(\frac{V_2}{V_1} - 1\right) \quad -(1)$$

$$(3\text{-}4) :- \ W_{3-4} = P_3(V_F - V_F) = P_3(V_3 - V_4) = P_3V_3\left(\frac{V_4}{V_3} - 1\right) \quad -(2)$$

Now

$(1-2) \therefore P = C \Rightarrow PV = mRT \Rightarrow V = \left(\frac{mR}{P}\right)T \Rightarrow V \propto T$

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

$(3-4): P = C \Rightarrow PV = mRT \Rightarrow V \propto T \Rightarrow \frac{V_4}{V_3} = \frac{T_4}{T_3}$

$T_1 = T_3$ & $T_2 = T_4$

So ration is same $\frac{T_2}{T_1} = \frac{T_4}{T_3}$

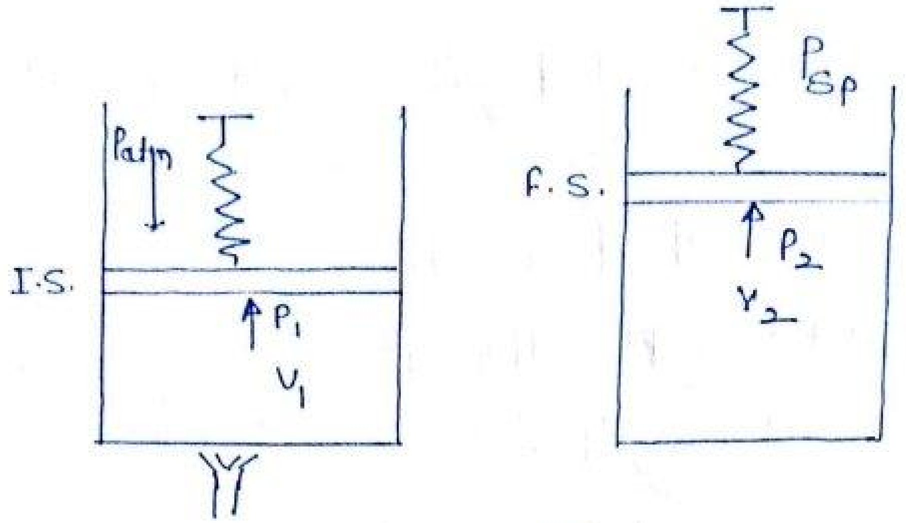
So $V_2/V_1 = V_4/V_3$

Use in 1 & 2

$w_{1-2} = w_{3-4}$ Independent (constant)

IES 10M

Question:— Air at an Initial temp. and Volume of 300 k & 0.002 m^3 is contrain in a piston cylinder arrangment. At this stage a linear which has a sprink Constant 10 kN/m is touching the piston but experting no force on it Now heat is added to the air and it expands slowly to occupie a final Volume of 0.003 m^3 Area of pistion is 0.02 m^2 at P_{atm} = 100 KPa Then determine the final pressure inside Cylinder.



$P_1 = P_{atm} + \cancel{P_{sp}}^{\,0}$ equilibrium.

$P_1 = P_{atm} = 100 \text{ KPa}$

$P_2 = P_{atm} + P_{sp}$

$P_2 = 100 + P_{sp}$ — (1)

$P_{sp} = \dfrac{F}{A_p}$

$P_{sp} = \dfrac{kx}{A_p}$

$P_{sp} = \dfrac{10x}{0.02}$ — (2)

$V_2 - V_1 = A_p x$

$(0.003 - 0.002)\ m^3 = 0.02(m^2) \times x$

$x = 0.05 \text{ m}$

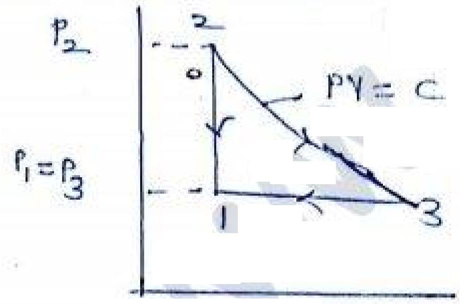
use in eq (2)

$P_{sp} = \dfrac{10 \times 0.05}{0.02} \dfrac{KN/m \times m}{m^2} = 25 \text{ KPa}$

So $P_2 = 100 + 25 = 125 \text{ KPa}.$

Ques. An ideal gas is heated at constant Volume until is temp. is 3 times to original temp. then it is expanded isothermally to reach it origional P. The gas is then cooled at const. P till it restored to origional state. Then determine net work done per kg of gas in terms of gas constant. Assuming (i) $T_1 = 350K$

Sol^n $T_1 =$



1-2 $V = Const.$ $T_2 = 3T_1$

$$\frac{P_2}{P_1} = \frac{T_2}{T_1} = 3$$

2-3 $P_2V_2 = P_3V_3 = P_1V_3$

$$\frac{P_2}{P_1 \text{ or } P_3} = \frac{V_3}{V_2} = 3$$

3-1 $P = C$ $\frac{V_3}{T_3} = \frac{V_1}{T_1}$ $T_3 = T_2$

$T_3 = 3T_1$

$V_3 = 3V_1$

$W_{1-2} \Rightarrow V = C \quad W = 0$

$$W_{2-3} = C \ln \frac{V_F}{V_I} = mRT_2 \ln\left(\frac{V_3}{V_2}\right)$$

$$W_{2-3} = 1 \times R \times 1050 \ln(3)$$

$$W_{2-3} = 1153.54R$$

$$W_{3-1} = P(V_1 - V_3) = (P_1V_1 - P_3V_3)$$

$$= mR(T_1 - T_3)$$

$$W_{3-1} = 1 \times R \times (350 - 1050) = -700R$$

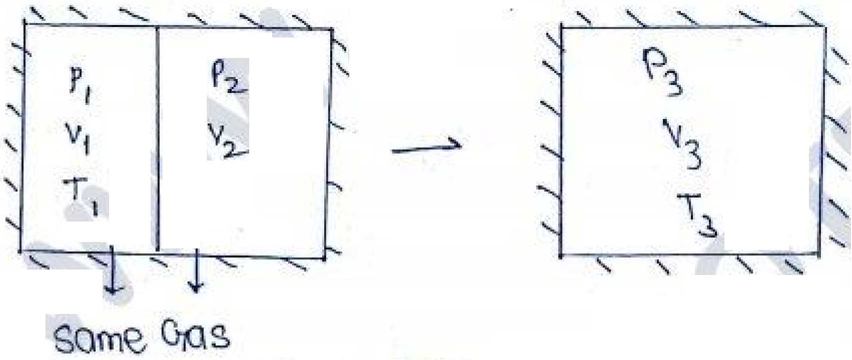
$$W_{net} = 0 + 1153.54R - 700R$$

$$W_{net} = 453.54R \ KJ/kg.$$

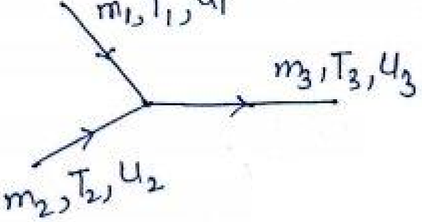
Ques. IAS 15M An insulated pressure vassel is devided into two parts by a movable piston. One part of the vessel is occupied by an ideal gas at a pressure P_1, Volume V_1, temp T_1. The other part is occupied by the same gas at P_2, V_2, T_2 the partitation is removed and two parts mixed adiabatically the prove that

$$P_3 = \frac{P_1V_1 + P_2V_2}{V_1+V_2}, \quad T_3 = \frac{P_1V_1 + P_2V_2}{\frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_2}}$$

Soln



ideal Gas $PV = mRT$



mass conservation

$$m_1 + m_2 = m_3$$

energy conservation

$$m_1u_1 + m_2u_2 = m_3u_3$$

$$m_1C_vT_1 + m_2C_vT_2 = m_3C_vT_3$$

$$m_1T_1 + m_2T_2 = m_3T_3$$

$$du = du + dw$$

$$du = 0$$

$$U_F - U_I = 0$$

$$U_F = U_I$$

$$U_3 = U_1 + U_2$$

$$u = U/m \Rightarrow U = mu$$

$$\Rightarrow \quad m_3 u_3 = m_1 u_1 + m_2 u_2$$

$$m_3 T_3 = m_2 T_2 + m_1 T_1 \quad (1)$$

$$T_3 = \frac{m_2 T_2 + m_1 T_1}{m_3} = \frac{m_1 T_1 + m_2 T_2}{m_1 + m_2}$$

$$T_3 = \frac{\frac{P_1 V_1}{RT_1} \times T_1 + \frac{P_2 V_2}{RT_2} \times T_2}{\frac{P_1 V_1}{RT_1} + \frac{P_2 V_2}{RT_2}} \Rightarrow \boxed{T_3 = \frac{P_1 V_1 + P_2 V_2}{\frac{P_1 V_1}{T_1} + \frac{P_2 V_2}{T_2}}}$$

$$PV = mRT \Rightarrow mT = \frac{PV}{R}$$

From eq (1) $\quad \frac{P_1 V_1}{R} + \frac{P_2 V_2}{R} = \frac{P_3 V_3}{R}$

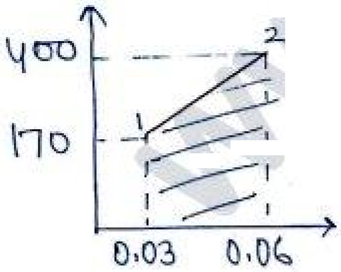
$$\boxed{P_3 = \frac{P_1 V_1 + P_2 V_2}{V_1 + V_2}}$$

$$m_1 + m_2 = m_3$$

$$\frac{P_1 V_1}{RT_1} + \frac{P_2 V_2}{RT_2} = \frac{P_3 V_3}{RT_3}$$

IAS Ques 15m

A Fluid is confined in a cylinder by spring loaded friction less piston so ~~that~~ pressure in fluid is a linear function of volume. $(P = a + bV)$ The internal energy of the fluid is given by $U = 34 + 3.15\,PV$, whe U in kJ, P in kPa and V is in m^3. If the fluid changes from a initial state of 170 kPa and 0.03 m^3 to ~~400 kPa~~ a final state of 400 kPa and 0.06 m^3 then determine the magnitude of work and Heat transfer



W = Area under Curve

$$W = \frac{1}{2}(170 + 400)(0.06 - 0.03)$$

$$W = 8.55 \text{ kJ}$$

$$dQ = du + dw$$

$$dQ = U_2 - U_1 + 8.55$$

$$= 3.15(P_2V_2 - P_1V_1) + 8.55$$

$$= 3.15(400 \times 0.06 - 170 \times 0.03) + 8.55$$

$$dQ = 68.08 \text{ kJ}$$

Que A 1 gram Nitrogen undergone the following sequence of process in a piston Cylinder arrangment

(a) An adiabatic expansion in which Volume double

(b) a constant P process in which volume is reduce to it intial Volume

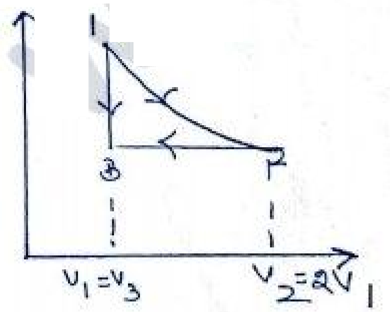
(c) a constant V process back to its intial state

Represent cycle on P-V diagram and Calculate the net work done

$t_1 = 150°C$, $P_1 = 1\, atm$, $R = 297\ J/kgK$

$\gamma = 1.4$.

Sol^n



$T_1 = 423K$

$P_1 = 1\, atm = 10^5 N/m^2 = 100\, kPa.$

$R = 297$

$1\text{-}2 \Rightarrow W_{1\text{-}2} = \dfrac{P_1V_1 - P_2V_2}{\gamma - 1} = \dfrac{mR(T_1 - T_2)}{\gamma - 1} = \dfrac{10^{-3} \times 297(423 - T_2)}{1.4 - 1}$ —(1)

$2\text{-}3 \Rightarrow W_{2\text{-}3} = P(V_3 - V_2) = P_3V_3 - P_1V_1 = mR(T_3 - T_2)$

$= 10^{-3} \times 297(T_3 - T_2)$ —(2)

1-2 $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \Rightarrow T_2 = 423\left(\frac{1}{2}\right)^{0.4} \Rightarrow T_2 = 320.56K$

2-3 $P = C \Rightarrow T \propto V \Rightarrow \frac{V_3}{V_1} = \frac{T_3}{T_2}$

$$T_3 = 160.25\ K$$

$$W_{1-2} = \frac{10^{-3} \times 297(423 - 320.56)}{0.4} = 76.05\ J$$

$$W_{2-3} = (-1)10^{-3} \times 297(320.56 - 160.25) = -47.6\ J$$

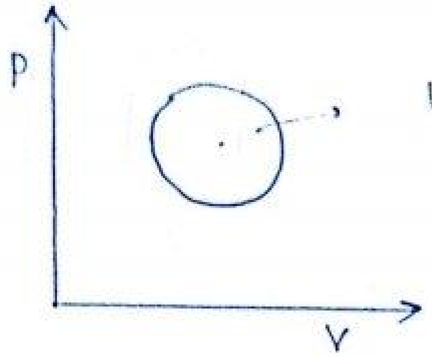
$$W_{net} = 76.08 - 47.6$$

$$W_{net} = \underline{\underline{28.45\ J}}$$

IFS

Question An imaginary engine receives heat and perform work on a slowly moving piston at such a rate that the cycle of operation for 1 kg of working fluid can be represented as a circle of 10 cm dia. on PV diagram on which 1 cm = 300kPa, 1 cm = 0.1 m^3/kg Then determine the work done by each ~~kg cycle~~ of ~~working~~ ~~open~~ 1 kg of working fluid for each Cycle.

Sol^n



$$W = \frac{\pi D^2}{4} = \frac{\pi}{4}(10)^2 = 78.4 \ cm^2$$

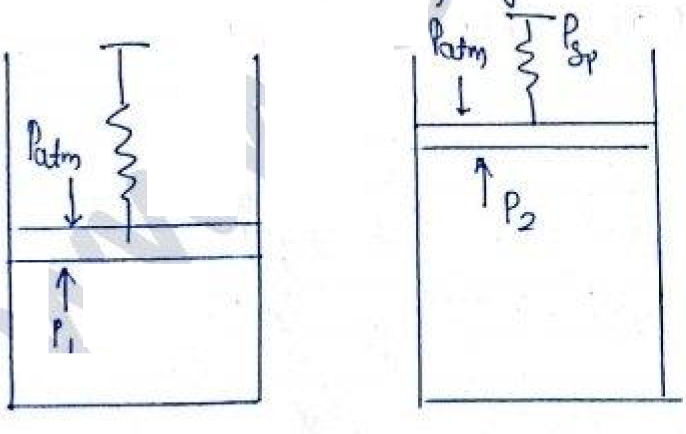
$$W = 78.4 \times 300 \times 0.1$$

$$W = 2356.19 \ KJ$$

Question:- A piston Cylinder device contain $0.05 \ m^3$ of a gas initialy at a pressure of 200 KPa and at this stage a linear spring which has a spring Constant of 150 KN/m is touching the piston but exerting No. force on heat Now heat is transfor to the gas causing the piston rises and to compress the spring until the volume inside the Cylinder doubles if x-section area of piston is $0.25 \ m^2$ then find

(i) Final pressure inside Cylinder

(ii) work done by gas.



$V_1 = 0.05 \ m^3$

$P_1 = 200 \ KPa$

$K_s = 150 \ KN/m$

$V_2 = 2V_1$

$A_p = 0.25 \ m^3$

$$P_1 = \cancelto{0}{P_{sp}} + P_{atm}$$

$$P_1 = P_{atm} = 200 kPa$$

$$P_2 = P_{atm} + P_{sp} \rightarrow \frac{F}{A} = \frac{kx}{A_p}$$

$$V_2 - V_1 = A_p x$$

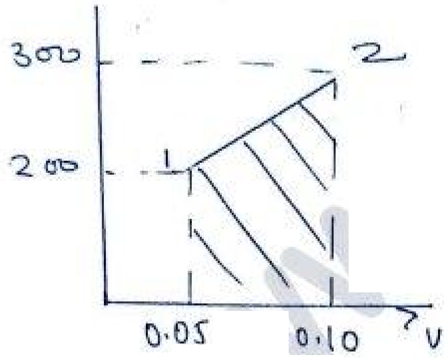
$$2V_1 - V_1 = 0.25x$$

$$0.05 = 0.25x$$

$$x = 0.2 m$$

$$P_2 = 200 + \frac{150x}{0.25}$$

$$P_2 = 320 kPa$$

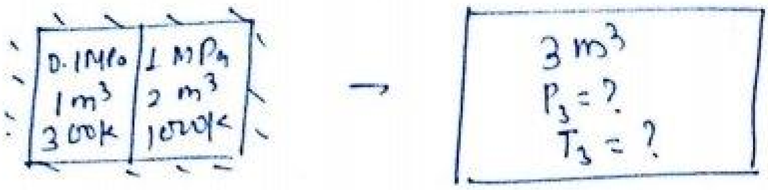


$$W = \frac{1}{2}(200+300)(0.05$$

$$W = 13 KJ$$

IAS

Ques:- A rigid insulated tank of $3 m^3$ volume is devided into two compartment. One compartment of volume $1 m^3$ and ideal gas contains at 0.1 MPa and 300 k while the second compartment of volume $2 m^3$ contain same gas at 1 MPa & 1000 K if the partitation b/w two compartmen is removed then calculate the final temp and pressure gas.



$$P_3 = \frac{P_1V_1 + P_2V_2}{V_1 + V_2} = \frac{0.1 \times 1 + 1 \times 2}{3}$$

$$P_3 = \frac{0.1 + 2}{3} = \frac{2.1}{3} = 0.7 \text{ MPa.}$$

$$T_3 = \frac{P_1V_1 + P_2V_2}{\frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_1}} = \frac{0.1\times 1 + 1\times 2}{\frac{0.1\times 1}{300} + \frac{1\times 2}{1000}} = \frac{2.1}{\frac{0.1}{300} + \frac{1}{500}}$$

$$T_3 = \frac{2100 \times 3}{7} = 900 K$$

<u>Workbook</u>

<u>Q.1</u>

$n = 70$ moles

$T_1 = 354 K$

$V_1 =$

$V_2 =$

$W = -206 kJ$

input

$$W = P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$$

$P_1V_1 = mRT$

$P_1V_1 = nRT$

$$-206 \times 10^3 = 70 \times 8.314 \times 354 \ln\left(\frac{V_2}{V_1}\right)$$

$$\ln\left(\frac{V_2}{V_1}\right) = -1$$

$$\frac{V_2}{V_1} = e^{-1}$$

$$V_1 = eV_2$$

Q.2 $dQ = \cancel{dU}^{0} + dW$

isothermal

$dQ = dW$

$$\frac{V_1}{V_0} = \frac{P_0}{P_1}$$

$$dW = P_0 V_0 \ln\left(\frac{V_1}{V_0}\right)$$

$$dW = R T_0 \ln\left(\frac{P_0}{P_1}\right)$$

$$dW = -R T_0 \ln\left(\frac{P_1}{P_0}\right)$$

Q.3

$$60 \times J/s \times 4 \times 60 \times 60 = m C_v \Delta T$$

$$60 \times 4 \times 60 \times 60 = m C_v (T_2 - T_1)$$

$$P_1 V_1 = m R T_1$$

$$m = \frac{100 \times 86.4 \times 10^3 \times N/m^2 \times m^3}{0.287 \times 10^3 \times J/kg\,K \times 305\,K}$$

$$m = 98.70.33$$

$$m = 98.7033$$

$$T_2 - T_1 = \frac{60 \times 4 \times 60 \times 60}{98.703 \times 718} \cong 12$$

$\Delta T = 12°C$ Hotter

work done on the system

So $T_f > T_I$

Q.7 $C_p - C_v = R = \frac{\bar{R}}{\text{Molwt}}$

$5.19 - C_v = \frac{8.1314}{4}$

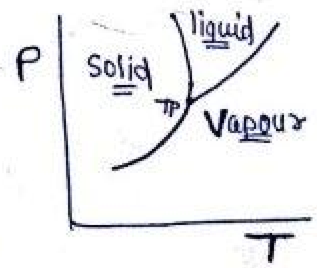
$C_v = 3.11 \; kJ/kgK$

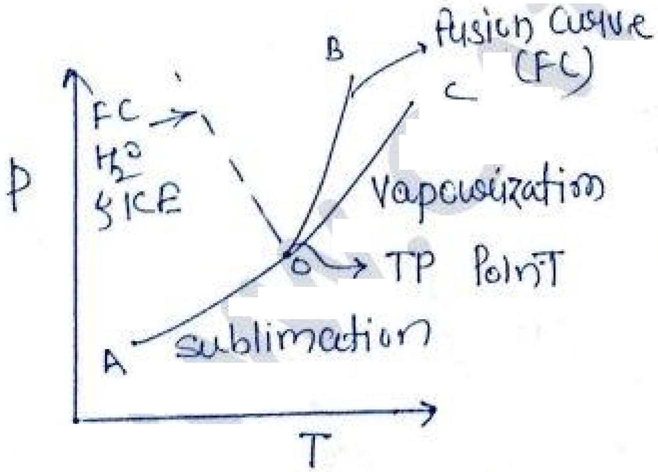
(a)

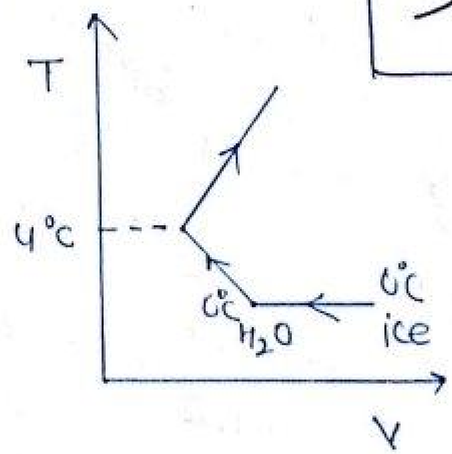
Note:- whenever work battery is Theire, there is only work interaction (No heat interaction)

* Density of water is max. at 4°C and during Frezing it will expand because the slope of fusion ~~cu~~ curve is negative ex

Triple point is a point on curve and line on P-V Curve







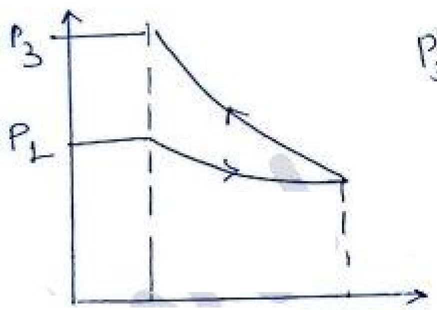
Sublimation :- directly solid to Gas
vapourization :- directly liquid to Gas
fusion :- solid liquid

Q.10 All the form of energy interaction is work except energy transfer due to ~~the~~ temp. it is heat

Q.12 $Q > 0$

(ice+water) first it will contract than expand so $W < 0$

Q.13



$P_3 > P_1$, $w < 0$

Q.21

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

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

$$\left(10 + \frac{a}{1}\right)1 = \left(P_2 + \frac{a}{4}\right)2$$

$$P_2 = 5 + \frac{a}{4} \qquad \underline{a > 0}$$

Q.20

3 equipment

$W = 3 \times 100 \times 15 \times 60$

$W = 270$ KJ

$Q = 0$

↳ incase of battery.

Q.23 (A)-C-(B)

$dQ = du + dW$

$180 = du + 30$

$du = 50$ KJ (point function

(A)-D-(B)

$dQ = 50 + 40$

$= 90$ KJ

Q25

$Q = \frac{\gamma - n}{\gamma - 1} W$ take $\gamma = 1.4$, $n = 1.2$ $\Rightarrow Q = \frac{0.2}{0.4} W$

$\gamma > n > 1$

$W = 2Q$

$W > Q$

$dQ = du + dW$

$du = dQ - dW \Rightarrow du < 0$

$mc_v \Delta T < 0$

$T_F < T_I$

because

Q29

$P_1 = 100\ kPa \quad V_1 = 15\ m^3 \quad T_1 = 293\ K$

$P_2 = 150\ kPa \quad V_2 = 25\ m^3 \quad T_2 = ?$

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

$$\frac{100 \times 15}{293} = \frac{150 \times 25}{T_2} \Rightarrow T_2 = 732.5\ K$$

$$W = \int P\,dV$$

$$= \int_{15}^{20} P_0\,dV + \int_{20}^{25} \left(P_0 + 2(V_0 - V)^2\right) dV$$

$$= (100 \times 5) + 100(5) + \frac{2}{3}(V-20)^3 \Big|_{20}^{25}$$

$$= 100 + \frac{2}{3} \times 125 = 1083.\ kJ$$

Q.30

$P_{gauge} = 1$ bar $V = 2500\ cm^3$ const

$t = 15°C$ $t = 5°C$

$T_1 = 288\ K$ $T_2 = 278\ K$

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

$(P_{abs})_1 = 2$ bar.

$$\frac{(P_{abs})_1}{T_1} = \frac{(P_{abs})_2}{T_2}$$

$(P_{abs})_2 = 1.9305$ bar

~~Pag~~ $P_{gauge} = P_{abs} - P_{atm}$.

$P_{gauge} = 1.93 - 1 = 0.93$ bar.

$$Q = m C_v \Delta T = \frac{C_v}{R}(P_2 V_2 - P_1 V_1)$$

$$Q = \frac{C_v}{R}(P_2 V_2 - P_1 V_1)$$

$$Q = \frac{718}{287}(1.930 - 2) \times 2500 \times 10^{-6} \times 10^5$$

$Q = -43.7\ J$

Q.33

$H = U + PV$

$$h = u + \frac{mRT}{m}$$

$h = u + RT$

temp tem

(A)

Q.31 $(P_{gauge})_2 = 1$ bar & $(P_{abs})_2 = 2$ bar.

So ~~$(P_{abs})_1 = (P_{gauge})_1 + P_{atm}$~~ $(P_{abs})_1 = 2.08$ bar

P_1

$(P_{gauge})_1 = 1.07$ bar

Steady Flow energy Equation :- (SFEE)

Steady Flow means the properties does not varies wrt to time i.e. mass flow rate at the entry and exit of control volume is same.

let us assume

h = specific enthalpy

KE = specific kinetic energy

PE = specific Potential energy

u = specific internal energy

Pv = Flow work

C = Velocity

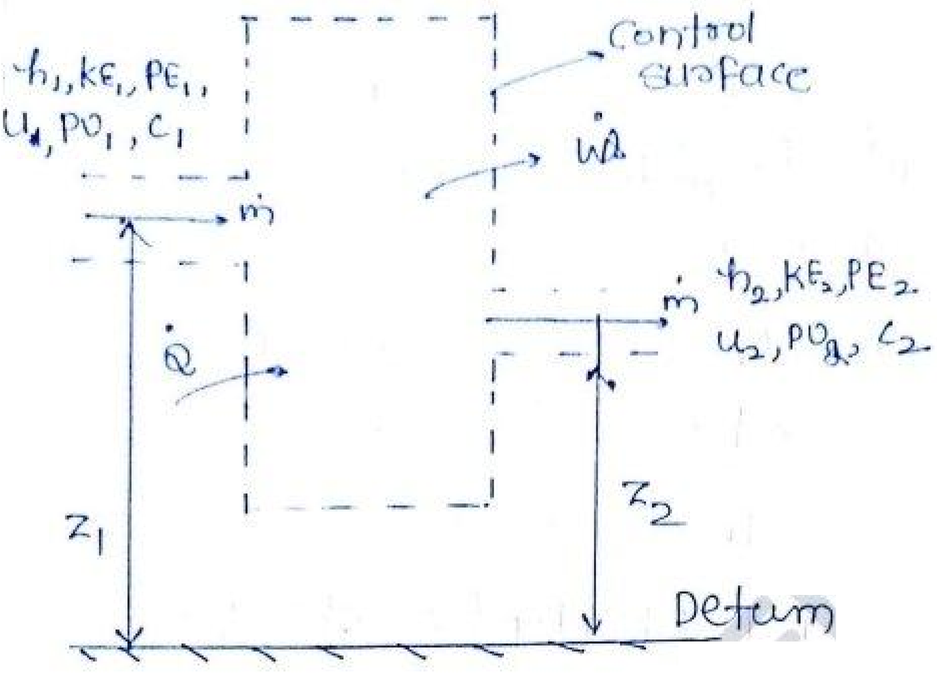
Z = Detum Head

Q = Heat

W = work

m = mass

Subscript 1, & 2 represent inlet and out let section.



Apply energy conservation.

$$\underbrace{u_1 + Pv_1} + KE_1 + PE_1 + Q = \underbrace{u_2 + Pv_2} + KE_2 + PE_2 + W$$

$$h_1 + KE_1 + PE_1 + Q = h_2 + KE_2 + PE_2 + W$$

$$\boxed{c_p T_1 + \frac{1}{2} c_1^2 + g z_1 + Q = c_p T_2 + \frac{1}{2} c_2^2 + g z_2 + W}$$

$c_p \rightarrow J/kg\,K.$

Note: $KE = \frac{1}{2} m c^2$

$J = kg \frac{m^2}{sec^2} \Rightarrow \boxed{\frac{m^2}{sec^2} = \frac{J}{kg}}$

$$\dot{m}\left[c_p T_1 + \frac{1}{2} c_1^2 + g z_1\right] + \dot{Q} = \dot{m}\left[c_p T_2 + \frac{1}{2} c_2^2 + g z_2\right] + \dot{W}$$

$$\Rightarrow \boxed{J/kg \times kg/s = W}$$

Special Cases:-

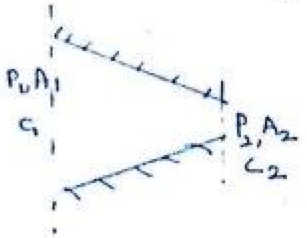
① Nozzle :- Nozzle is a mechanical device which use to increase the kinetic energy at the expense of pressure energy

Assumption: (i) Neglecting (PE) changes ($\Delta PE = 0$)

(ii) well insulated ($Q = 0$)

(iii) No work interaction ($W = 0$)

(iv) Neglecting initial Velocity ($V_2 >>> V_1$)



$$h_1 = h_2 + KE_2$$

$$h_1 = h_2 + \frac{1}{2}\frac{C_2^2}{\times 1000}$$

$$\frac{C_2^2}{2000} = h_1 - h_2$$

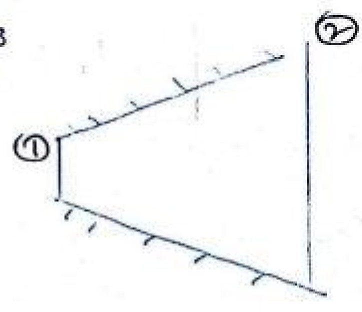
Imp $\boxed{C_2 = 44.7\sqrt{(h_1 - h_2)}}$ m/s

$M<1$ Nozzle may be diverging
$M>1$ may be converging

$h_1 \& h_2 \rightarrow$ KJ/kg

② Diffuser :- It is a device of variable cross-section use to decrease the velocity

$$\boxed{C_1 = 44.7\sqrt{(h_2 - h_1)}} \text{ m/s}$$



③ Turbine:- It is a work producing device in which energy is transferred from working fluid to rotar. In the case of turbine expansion of working fluid takes place which results a decreasing in Pressure.

In the case of turbine the value of net work output is positive.

Assumption:- i) Neglecting K.E changes

ii) Neglecting P.E changes

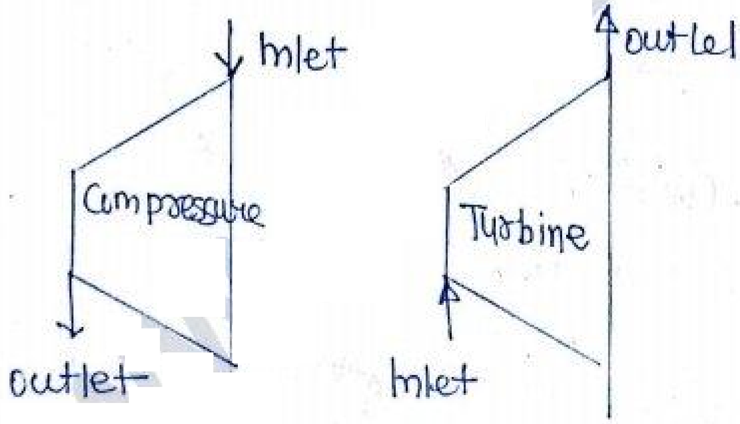
(iii) Assume it is well insulated

Using SFEE

$$h_1 + KE_1 + PE_1 + Q = h_2 + KE_2 + PE_2 + W$$

$$h_1 = h_2 + W$$

Turbine work $\boxed{W_{tur} = h_1 - h_2}$



(4) Compressor & Pump :- Both are work absorbing device in which the energy is transferred from Rotor to working fluid.

Compressor is used to increase both Pressure & temp. of working fluid and Generally used to handle gaseous phase of the working fluid. where as pump is used to increasing the pressure of working fluid and generally used to handle liquid phase of working fluid

$$\boxed{W_{\substack{comp \\ or\, pump}} = h_2 - h_1}$$ compressor/Pump work.

(5) Boiler and Evaporater :- Both are the type of Heat exchanger in which heat is absorbe by the working fluid at constant pressure.

Assumption (i) $\Delta KE = \Delta PE = 0$

(ii) No work interaction

Using SFEE :- $h_1 + KE_1 + PE_1 + Q = h_2 + KE_2 + PE_2 + W$

$$h_1 + Q = h_2$$

Boiler, evaporator Heat $\boxed{Q_{B/E} = h_2 - h_1}$

(6) Condenser :- It is a type of heat exchanger in which heat is rejected by working fluid at constant pressure.

$$\boxed{Q_{Cond.} = h_1 - h_2}$$

(7) Throttling :- Flow through a restricted passes, partially open valve, porous plug etc is know as throttling.

Assumption :- (i) Neglecting ΔKE & ΔPE
(ii) ~~Neglec~~ No work interaction
(iii) No heat interaction

Using SFEE

$$h_1 + KE_1 + PE_1 + Q = h_2 + KE_2 + PE_2 + W$$

$$\boxed{h_1 = h_2} \Rightarrow \boxed{U_1 + P_1 V_1 = U_2 + P_2 V_2}$$

Note :- (i) Throttling is known as isoenthalpic process

(ii) Throttling always results a decrease in pressure (expansion)

(iii) Throttling is a irreversible adiabatic process.
↓
entropy increase

Free expansion:- (unrestrained expansion)

Expansion against vaccum is known as free expansion and it is a case of irreversible process in which the value of

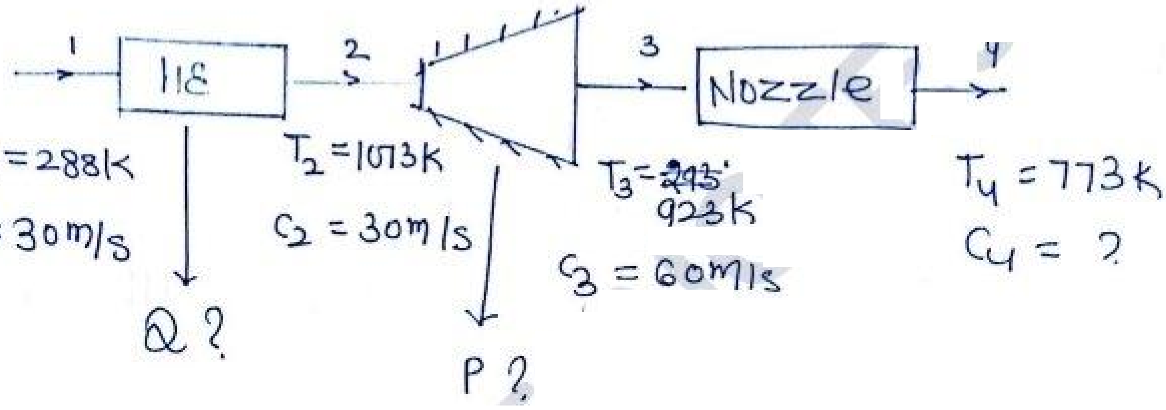
$$dQ = 0,\ dW = 0,\ dE = 0,\ dU = 0$$

It is also termed as unrestrained expansion

Question:- Air at a temp. of 15°c passes through a heat exchanger at a velocity of 30 m/s where the temprature is increase to 800°c It then enters the turbine with the same velocity of ~~300~~ 30 m/s and expands until the temp. decrease to 650°c on leaving the turbine the air is taken at velocity of 60 m/s to a nozzle where it expands until the temp. fallen to 500°c if air flow rate is 2 kg/s then calculate (i) Rate of heat transfer to the air in heat exchange in kW

(ii) Power output from the turbine assuming no heat loss in turbine

(iii) Velocity at exit from the nozzle assuming no heat loss in nozzle.



Apply SFEE B/w 1 & 2

$$h_1 + KE_1 + \cancel{PE_1} + Q = h_2 + KE_2 + \cancel{PE_2} + \cancel{W}$$

Assume $\Delta KE = 0$ $\qquad h_1 + Q = h_2$

$\Delta PE = 0$

$W = 0$ $\qquad Q = \dot{m} C_p (T_2 - T_1)$

$$= 2 \times 1.005 \times (1073 - 288)$$

$$Q = 1578 \text{ kW}$$

Apply SFEE b/w 2 & 3

$$h_2 + ke_2 + \cancel{PE_2} + \cancel{Q} = h_3 + ke_3 + \cancel{PE_3} + W$$

$$C_p T_2 + \frac{C_2^2}{2000} = C_p T_3 + \frac{C_3^2}{2000} + W$$

$W = 149.4$ kJ/kg $\qquad \dot{P} = \dot{m} \times W = 298.8$ kW

$$C_pT_3 + \frac{C_3^2}{2000} = C_pT_4 + \frac{1}{2000}C_4$$

$$C_4 = 552 \text{ m/s}.$$

<u>Chap 3</u>

<u>Q1</u>

$$T = C$$
$$dT = 0 \Rightarrow dQ = dU + dW$$
$$dQ = dW$$

<u>Q.2</u>

$$h_1 + \cancel{KE_1} + \cancel{PE_1} + Q = h_2 + \cancel{KE_2} + \cancel{PE_2} + \cancel{W}$$

$$C_p(500) + \frac{1}{2000}C_1^2 = C_p(T_2)^2 + \frac{C_2^2}{2000}$$

$$C_2 = 49 \text{ m/s} \quad C_1 = 150 \text{ m/s}$$

Diffuser.

<u>Q.3</u>

$$C_pT_1 + \frac{C_1^2}{2000} + \cancel{gZ_1} + \cancel{Q}^{0} = C_pT_2 + \frac{C_2^2}{2000} + \cancel{gZ_2} + \cancel{W}$$

$$1.005 \times 800 + \frac{1}{2000} \times 250 - 25 = 1.005 \times 650 + \frac{C_2^2}{2000}$$

$$C_2 = 504 \text{ m/sec}.$$

Q.4

$dQ = \delta U + dw$

$du = dQ - dw$ } - exact

Q.5

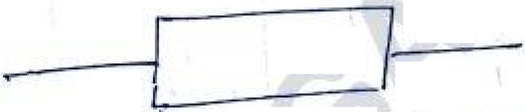
$h_1 + \cancel{KE_1} + \cancel{PE_1} + Q = h_2 + \cancel{KE_2} + \cancel{PE_2} + w$

(B)

$h_1 + Q = h_2 + w$

$w = h_2 - h_1$

Q.6



$C_p = 1.005$ kJ/kgK

$T_1 = 900K$

$C_1 \simeq 0$

$P_1 = 400 kPa$

$T_2 = ?$

$C_2 = ?$

$P_2 = 100 kPa$

$h_1 = h_2 + \frac{1}{2000} C_2^2$

$C_2^2 = 2000 \times 1.005 (675)$

$C_2 = 1164.8$ m/s.

$\frac{T_2}{P_1}$

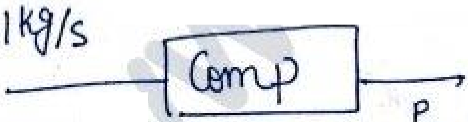
$P_1 \propto T_1$

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

$\frac{400}{900} = \frac{100}{T_2}$

$T_2 = 225K$

Q.8 $\dot{m} = 1 kg/s$



$P_2 = 1 MPa$

$P_1 = 0.1 MPa$

$T_1 = 300K$

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

$T_2 = \frac{1}{0.1} \times 300$

$T_2 =$

Q.6 $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{r-1}{r}}$

$$\frac{T_2}{900} = \left(\frac{100}{400}\right)^{\frac{0.4}{1.4}}$$

$$T_2 = 605.7K$$

(7) A

(8) $P = \dot{m} \times W_m$

$$= \dot{m} \; C_p \left(T_2 - T_1\right)$$

$$P = 1 \times 1.005 \times \left(T_2 - 300\right)$$

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

$$T_2 = 579K$$

(B) = $P = 280\,kW$

(9) B

(10) $\frac{P_1V_1 - P_2V_2}{r-1} = \frac{mR}{r-1}\left(T_1 - T_2\right)$

$$= C_v\left(T_1 - T_2\right)$$

(12) $dQ = dU + dW$

$$dU = dQ - dW$$

$$dQ - dW = 30.$$

(13) $\frac{dE}{dt} = 0.25 = Q - W$

$$0.25 = Q - 0.75$$

$$Q = 1$$

Q.14

$V = C$
1 - 2

$W_{1-2} = 0$

$dQ = du$

$U_2 - U_1 = 170$

$U_1 = 100$

$U_2 = 270$

2 - 3
$P = C$

$dQ = du + dW$

$-180 = du - 40$

$du = -140$

$U_3 - U_2 = -140$

$U_3 = 130$

$T_2 > T_1$

$T_2 > T_3$

(15)

(16) $r = 7/5$ $P = C$

$\frac{7}{5} - 1$

$dQ = du + dW$

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

$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{2/5}$

$dQ = mC_p \Delta T$

$= mC_p (T_2 - T_1) = mC_p T_1 \left(\left(\frac{V_1}{V_2}\right)^{2/5} - 1\right)$

$dQ = mC_p T_1 \left(\left(\frac{V_1}{V_2}\right)^{2/5} - 1\right)$

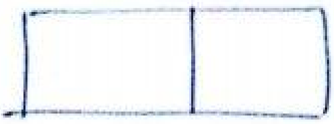
$du = mC_v T_1 \left(\left(\frac{V_1}{V_2}\right)^{2/3} - 1\right)$

$\frac{dQ}{du} = \frac{C_p}{C_v}$ $du = \frac{5}{7} dQ$ d

(17)

A

B



$m, \gamma = 1.4$

$T = 300\,K$

$m, \gamma = 1.4$

$T = 300\,K$

$$m_A = m_B$$

$$m_A c_p \Delta T_A = m_B c_p \Delta T_B$$

$\cancel{c_p}\ c_p$

$$\frac{C_p}{C_v} \Delta T_A = \Delta T_B$$

$$\Delta T_B = 1.4 \times 30$$

$$= \underline{\underline{42\ K}}$$

(18) $\delta W = 0$, $dQ < 0$

$\underline{\underline{a}}$

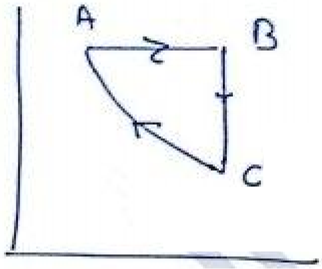
$$dQ = du + dW$$

$$du < 0$$

$$mC_v(T_2 - T_1) < 0$$

$$\underline{T_1 > T_2}$$

(19)



$$\oint \delta Q = 5\ kJ$$

$$\oint dW = 5\ kJ$$

$$W_{AB} + W_{C-A} = 5\,kJ$$

(+ve) (−ve)

$$W_{AB} = 10 \times 10^5 \times 2$$

$$= \underline{\underline{20\ kJ}}$$

$$W_{C-A} = -15\,\underline{\underline{kJ}}$$

(20) $\underline{\underline{a}}$

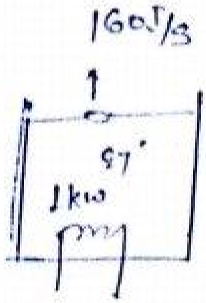
(21)

$$\rho = m/V$$

$\cancel{1000 \times J/s \times t} =$ $\quad m = \rho V$

$$(1000 - 160)\,t = 1000 \times \frac{2}{1000} \times 4.2$$

Q.21



$$\left(Q_{add} - Q_{rej}\right) \times t = m c_v \Delta T$$

$$\left(1000 - 160\right) \times t = 2(kg) \times 4.2 \times 10^3 \times 50$$

$$t = 500 sec.$$

$$t = \frac{500}{60} min = 8 \text{ min } 20 sec.$$

Q.22 $\underline{1 Kcal} = \underline{4.184 kJ}$

$$Q_{net} = -Q_{rej} + Q_{add} = -250 \times 4.184 - (+0.53 \times 60 \times 60)$$

$$= +1046 - (+36 w \times 0.53)$$

$$= +1046 + 1908$$

$$= -862 kJ$$

(24) $w = -260 W \quad Q = -10 W$

$$dQ = du + dW \Rightarrow du = dQ - dW = -10 + 260$$

$$du = 250 W = 250 \times 36 w = 900 kJ \uparrow$$

(28)

$P_1 = 20 bar$ $\qquad P_2 = ?$ $\qquad dQ = du + dw$

$V_1 = 15 cm^2$ $\qquad V_2 = 1500 cm^2$ $\qquad du = 0$

$dQ = dW = 0$

$$P_1 V_1 = P_2 V_2$$

$u_1 = u_2$

$$20 \times 15 = P_2 \times 1500$$

$T_1 = T_2$

$$P_2 = 0.2 bar.$$

31

$$C_p = 2.093 + \frac{41.87}{t+100} \ J/^\circ C$$

$$dQ = m C_p \Delta T$$

$$Q = \int \left(2.093 + \frac{41.87}{t+100}\right) dt$$

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

$$= 209.3 + 41.87 \ln\left(\frac{200}{100}\right)$$

$$Q = 209.3 + 29.02$$

$$Q = 238.32 \ J$$

$$W = Pdv = 1 \times 10^5 \left(400 \times 10^{-6}\right)$$

$$W = 40 \ J$$

$$dQ = du + dw \Rightarrow du = (238.32 - 40) \ J$$

$$du = 198.32 \ J$$

(T3)

$$\dot{m}\left[h_1 + KE_1 + PE_1\right] + \cancel{\dot{Q}}^{0} = \dot{m}\left[h_2 + KE_2 + PE_2\right] + W$$

$$20\left[3200 - 2600 + \frac{1}{2000}(160^2 - 100^2) + \frac{10 \times 4}{1000}\right] = W \text{ kW}$$

$$W = 12.157 \text{ MW}$$

(b)

$$\rho = 1000 \text{ kg/m}^3$$

$$\rho = m/v$$

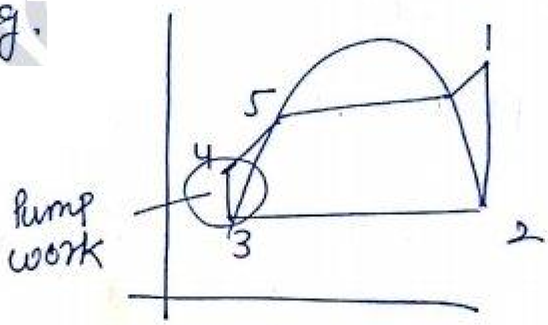
$$W = -v(P_2 - P_1)$$

$$v = \frac{m}{\rho}$$

$$W = -\left(\frac{70 \times 10^3 - 3 \times 10^6}{1000}\right)$$

$$v = \frac{1}{\rho}$$

$$W = +2.930 \text{ kJ/kg}$$



Unsteady Flow energy Equation :- (USFEE)

Unsteady Flow means the properties are varies wrt time therefore the mass Flow rate at the enetry and exit of Control Volume are different.

→ Unsteady state problem are solved by using two Conservation principles i.e. mass Conservation & energy Conservation

Let us assume

m_i - mass at the entry of Control Volume.

m_1 - Initial mass inside Control Volume.

m_2 - final mass inside Control Volume.

m_e - mass at the outlet of Control Volume

Apply ① mass conservation

$$\left(\frac{dm}{dt}\right)_{cons} = \dot{m}_i - \dot{m}_e = \frac{dm_i}{dt} - \frac{dm_e}{dt} \quad -①$$

② Energy Conservation.

$$\left(\frac{dE}{dt}\right)_{cons} = \frac{d}{dt}\left(m_i(h_i + KE_i + PE_i) + Q\right) - \frac{d}{dt}\left(m_e(h_e + KE_e + PE_e) + W\right) \quad -②$$

Assumption (i) Neglecting K.E. changes & P.E. changes

ii

$$\left(\frac{dE}{dt}\right)_{cons} = \frac{d}{dt}\left(\cancel{KE}^{0} + \cancel{PE}^{0} + U\right) = \frac{dU}{dt} \rightarrow \text{Internal energy}$$

$$\left(\frac{dU}{dt}\right)_{Consv.} = \frac{d}{dt}\left(m_i h_i + Q\right) - \frac{d}{dt}\left(m_e h_e + w\right) \quad -(3)$$

Assumption (ii) Neglecting the variation of enthalpy at inlet & outlet wrt time.

$$\frac{du}{dt} = \frac{d(m_i h_i)}{dt} + \frac{dQ}{dt} - \frac{d(m_e h_e)}{dt} - \frac{dw}{dt}$$

$$\frac{du}{dt} = \cancel{m_i \frac{dh_i}{dt}}^{0} + h_i \frac{dm_i}{dt} + \frac{dQ}{dt} - \cancel{m_e \frac{dh_e}{dt}}^{0} - h_e \frac{dm_e}{dt} - \frac{dw}{dt}$$

$$\frac{du}{dt} = \dot{m}_i h_i + \dot{Q} - \dot{m}_e h_i - \dot{w}$$

$$\boxed{\frac{du}{dt} = \left(\dot{m}_i h_i + \dot{Q}\right) - \left(\dot{m}_e h_e + \dot{w}\right)} \quad -(4)$$

Application of Unsteady flow:– (1) Charging and discharging of a tank

(2) Bottle filling process.

P.Q 18
W.P.

Q.32

using USFEE

$$\frac{dU}{dt} = (\dot{m}_i h_i + \dot{Q}) - (\dot{m}_e h_e + \dot{W})$$

$\dot{U}_f = ?$

$$d\dot{U} = \dot{m}_i h_i - \dot{m}_e h_e$$

P →

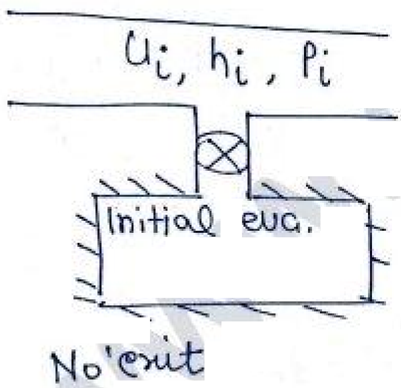
$\dot{U}_t = dU$

$$\dot{U}_f - \dot{U}_i = \dot{m}_i \cdot h_i - \cancel{\dot{m}_e h_e}^{0}$$

$m_1 = 0$ so

$$m_2 \dot{u}_f - \cancel{m_1 \dot{u}_i} = (m_2 - \cancel{m_1}) h_i$$

$$\boxed{u_f = h_i}$$



i
1
2
e

$$\left(\frac{dm}{dt}\right)_{cons} = \dot{m}_i - \cancel{\dot{m}_e}^{0} \quad -(1)$$

$$\left(\frac{dE}{dt}\right)_{con} = \frac{d}{dt}(m_i h_i + \cancel{KE_i} + \cancel{PE_i} + \cancel{Q}) - \frac{d}{dt}(\cancel{m_e h_e} + \cancel{KE_e} + \cancel{PE_e} + \cancel{W}) \quad -(2)$$

Assume (1) $\Delta KE = 0$ (5) $Q = 0$

(2) $\Delta PE = 0$ (6) $m_e = 0$

(3) $\frac{dh_i}{dt} = 0$ (7) $m_1 = 0$

(4) $\frac{dh_e}{dt} = 0$ (8) $W = 0$

from eq (1)

$$\left(\frac{dm}{dt}\right) = \dot{m}_i \quad -(3)$$

from eq (2)

$$\frac{d}{dt}(U + \cancel{KE} + \cancel{PE}^{0}) = \frac{d}{dt}(m_i h_i)$$

$$\frac{dU}{dt} = h_i \frac{dm_i}{dt} + \cancel{\dot{m}_i \frac{dh_i}{dt}}^{\,0}$$

$$\frac{dU}{dt} = \dot{m}_i h_i$$

$$\frac{dU}{dt} = \left(\frac{dm}{dt}\right)_{cons} h_i$$

$$\dot{U}_2 - \dot{U}_1 = (\dot{m}_2 - \dot{m}_1) h_i$$

$$u = \frac{U}{m}$$

$$\dot{m}_2 \dot{u}_1 - \cancel{\dot{m}_1 \dot{u}_1}^{\,0} = (\dot{m}_2 - \cancel{\dot{m}_1}^{\,0}) h_i$$

$$\dot{m}_2 \dot{u}_2 = \dot{m}_2 h_i$$

$$\boxed{u_2 = h_i}$$ Imp

★★ Gate

Note:- If the working fluid is ideal gas then the final temp inside the tank is 'γ' times the temp. of supply line.

$$u_2 = h_i$$

$$C_v T_2 = C_p T_i$$

$$T_2 = \frac{C_p}{C_v} T_i \Rightarrow \boxed{T_2 = \gamma T_i}$$

Q.23

c

$$\frac{du}{dt} = \frac{d}{dt}(m_i h_1 + Q) - \frac{d}{dt}(m_2 h_2 + w)$$

$$\frac{d}{dt}(mu) = h_1 \frac{dm_1}{dt} + \frac{dQ}{dt} - h_2 \frac{dm_2}{dt} - \frac{dw}{dt}$$

$$\frac{dh_i}{dt} = \frac{dh_2}{dt} = 0$$

25

a

$$\left(\frac{dm}{dt}\right) = m_i - m_e$$

$$\frac{d}{dt}(u) = \frac{d}{dt}(\cancel{m_i h_i} + \cancel{KE} + \cancel{PE} + \cancel{Q}) - \frac{d}{dt}(m_e h_e + \cancel{KE} + \cancel{PE} + Q)$$

$$\frac{d}{dt}(mu) = -\frac{d}{dt}(m_e h_e)$$

$$h_e \frac{dm_e}{dt} = \frac{d}{dt}(mu)$$

$$h_e \dot{m}_e = -\frac{d}{dt}(mu)$$

24

$w = -260$ watt

$Q = -10$ watt

$dQ = du + dw$

$dw = -10 - (-260)$

$= 250\,W = 900\,KJ$

27

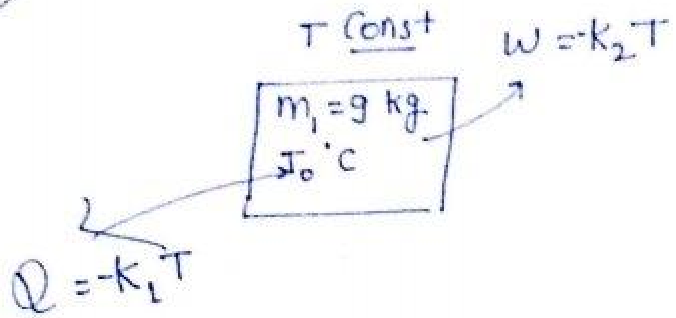
$h = 3264.5$ KJ/kg

$w = 2000$ KJ

$$m = \frac{2000}{3264.5} = 0.612\,Kg$$

Imp

26



$$\left(\frac{dE}{dt}\right) = \frac{d}{dt}(Q) - \frac{d}{dt}(W)$$

$$\frac{d}{dt}(m_2 u_2 - m_1 u_1) = -\frac{d}{dt}(k_1 T) - \frac{d}{dt}(-k_2 T)$$

$$\dot{m}_2 u_2 - \dot{m}_1 u_1 = -k_1 \frac{dT}{dt} + k_2 \frac{dT}{dt}$$

$$\frac{dU}{dt} = (-k_1 + k_2)\frac{dT}{dt}$$

$$\frac{d}{dt}(mcT) = (k_2 - k_1)\frac{dT}{dt}$$

$$\cancel{mc\frac{dT}{dt}} \quad mc\frac{dT}{dt} = (k_2 - k_1)T$$

$$T = T_0 \, e^{\frac{(k_2 - k_1)}{mc} t}$$

(B)