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(1) From the Gibbs Phase rule,

$\pi + f = N + 2$

- π: Number of phase present
- N: Number of components present
- f: the number of independent intensive properties to fix the state

(i) single component single phase

$\pi = 1$, $N = 1$

$1 + f = 1 + 2$

$f = 2$

(ii) single component two phase

$\pi = 2$, $N = 1$

$2 + f = 1 + 2$

$f = 1$

(iii) Single Component three phase

$\pi = 3$, $N = 1$

$3 + f = 1 + 2$

$f = 0$

2) Dead state of a system: when a system is in equilibrium with the surrounding and also there is no chemical reaction or mass transfer in it and the system has zero velocity with the minimum potential in it, This state of the system is known as the dead state.

(3) The thermodynamic property that is defined by the first law is → (D) Internal energy

According to the first law, when an ammount of heat is ~~applied~~ supplied to a system, some part of the heat is transformed to work and the rest part of it is stored as internal energy.

$\Delta E = Q - W$ [ΔE: Change in internal Energy
Q: heat supplied
W: work done

(A) quasi-static process: An infinitely slow process on which the system is in equilibrium with its surrounding on every state, is called quasi static process.

The characteristic features of quasi-static process is – (I) it is infitely slow.
(II) All the states of the system are always in equilibrium with the surrounding, during the entire process.

(5) <u>Zeroth law of thermodynamics:</u> When a body 'A' is in thermal equilibrium with a body 'B' and also with 'C' separately, then 'B' and 'C' will also be in thermal equilibrium with each other.

(6) The different forms of work transfer between a system and its surrounding are –
(I) p dV- work or displacement work.
(II) Electrical work
(III) shaft work
(IV) flow work
(V) magnetisation of a paramagnetic field
(VI) Stretching of a wire.
(VII) work done in changing the area of a surface film.
(VIII) Paddle- wheel work.

(7) Paddle wheel work is an irreversible process.

Paddle wheel work involves friction force. we know that, friction force is a non conservative force. hence, the process is irreversible.

(8) Enthalpy: The sum of internal energy and pv work is known as enthalpy.

Enthalpy depends on the ammount of the substance, therefore, enthalpy is an extensive property.

The significance is " It is a total content of heat ".

(9) The steady flow of energy equation is -

$$h_1 + \frac{V_1^2}{2} + Z_1 g + \frac{dQ}{dm} = h_2 + \frac{V_2^2}{2} + Z_2 g + \frac{dW_x}{dm}$$

The equation signifies that the amount of energy enters and leaves the control volume are equal.

10 PMM-1 stands for 'Perpetual motion machine of the first kind'. A fictious machiene which would continously supply mechanical work without ~~machiene is called~~ some other form of energy disappearing simultaneously, is called PMM-1.

It is impossible because such kind of machiene will violate the first law of thermodynamics or the conservation of energy.

(11) $2r = 0.40$ $\quad d = 0.485\,m$, $\quad$ total work $= 2\,kJ$

$r = 0.20\,m$ $\quad \omega = 840\,rpm$ $\quad t = 10 \times 60 = 600\,s$

$$= \frac{840 \times 2\pi}{60}$$

$$= 28\pi$$

total work done = displacement work + work done by the shaft

displacement work $= p \cdot \Delta V$

$$= p\{d \cdot \pi (r)^2\} \quad [\because$$

$$= 1.01 \times 10^5 \left(0.485 \cdot \pi (0.20)^2\right)$$

$$= 6155.6\,J$$

$$= 6.156\,kJ$$

work done by shaft $= 2 - 6.156$

$= -4.156$ ['−' sign signifies the work done on the gas-system by the shaft]

$\therefore$ Power output $= \frac{\text{work done by shaft}}{\text{time}}$

$= \frac{4.156 \text{ KJ}}{600 \text{ s}}$

$= 6.926 \times 10^{-3}$ K J/s

$= 6.926 \times 10^{-3} \times 10^{3}$ (J/s)

$= 6.926$ watt

Torque $= \frac{\text{Power}}{\text{Angular speed}}$

$= \frac{6.926}{28\pi}$

$= 0.079$ N.m

$\therefore$ The output power is 6.926 watt and the output torque is 0.079 N.m.

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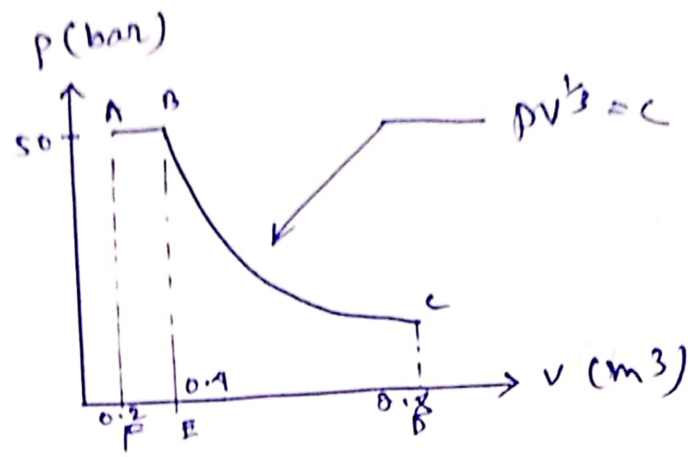


work done = Area under PV diagram

= Area ABFE + Area BCDE

Area ABFE = $50 \times (0.4 - 0.2) = \cancel{50}^{5} \times \frac{0.2}{\cancel{10}} = 10$

~~Applying the~~ putting the coordinates of B on $pv^{1/3} = c$

we get,

$50 \cdot (0.4)^{1.3} = c$

$c = 50 \cdot (0.4)^{1.3}$

$c = 15.2$

$\Rightarrow$ ~~$pv^{1.3} = 15.2$~~ $pv^{1.3} = 15.2$

$p = \frac{15.2}{v^{1.3}}$

Area under BCDE = $\int_{0.4}^{0.8} p \cdot dv$

$= \int_{0.4}^{0.8} \frac{15.2 \, dv}{v^{1.3}}$

$= 15.2 \left[\frac{v^{-1.3+1}}{-1.3+1} \right]_{0.4}^{0.8}$

$$= 15.2 \left[\frac{V^{-0.3}}{-0.3} \right]_{0.4}^{0.8}$$

$$= \frac{-15.2}{0.3} [-0.247]$$

$$= \frac{15.2 \times 0.247}{0.3}$$

$$= 12.515$$

$\therefore$ total work done $= 10 + 12.515$

$= 22.515$

13) we know that,

power = Pressure × flow energy

$$\text{pressure} = \frac{\text{Power}}{\text{flow energy}} \quad \text{—— (1)}$$

power $= 18 \times 10^3$ watt

flow energy $= 0.124 \, m^3/min$

$$= \frac{0.124 \, m^3}{60 \, s}$$

$= \cancel{2.067}$ 2.07×10^{-3}

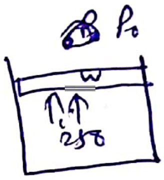
$$\therefore \text{pressure} = \frac{18 \times 10^3}{2.07 \times 10^{-3}} = 8.709 \times 10^6$$

(15) Area of piston = $\pi \left(\frac{0.1}{2}\right)^2 = 7.85 \times 10^{-3}$

weight of piston (w_p) = 50×9.8

Considering all the vertical forces, of the pressure is P_t when it stops,

$$P_t \cdot A = P_0 A + 50 \times 9.8$$



$$P_t = P_0 + \frac{50 \times 9.8}{A} \times \frac{1}{1000} \text{ K·Pa}$$

$$= 100 + \frac{50 \times 9.8}{1000 \times 7.85 \times 10^{-3}}$$

$$= 100 + \frac{50 \times 9.8}{7.85}$$

$$= 162.42 \text{ kPa}$$

Just before it starts to move down, the volume will be constant till that moment, so, we can apply gay-lussac formula,

(a) $$T_2 = T_1 \times \frac{P_2}{P_1} = (273+300) \times \frac{162.42}{250}$$

$$= 372.27 \text{ kelvin}$$

(b) Just after piston starts to move, the next process will be isobaric. from Charles law,

initial volume (V_1) $= 7.85 \times 10^{-3} \times 0.25 = 0.00196 \, m^3$

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

$$V_2 = \cancel{0.00196 \times \frac{293.15}{373.06}}$$

$$= 0.00196 \times \frac{293.15}{373.06}$$

$$= 1.54 \times 10^{-3}$$

$$V_2 - V_1 = A \cdot \Delta h$$

$$\Delta h = \frac{V_2 - V_1}{A}$$

$$= \frac{|1.54 \times 10^{-3} - 1.96 \times 10^{-3}|}{7.85 \times 10^{-3}}$$

$$= \frac{1.96 - 1.54}{7.85}$$

$$= 0.053\,m$$

∴ the piston has dropped 0.053m.

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we know that,

$h_1 + \frac{V_1^2}{2} + gz_1 + q = h_2 + \frac{V_2^2}{2} + gz_2 + W$

the nozzle is insulated, $q = 0$

$z_1 = z_2$ (since the nozzle is horizontal)

$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$

$h_1 = 100 \times 10^3$ J/kg (given)

$h_2 = h_1 + \frac{V_1^2}{2} - \frac{V_2^2}{2}$

$= 100 \times 10^3 + \frac{100^2}{2} - \frac{200^2}{2}$

$= 85000$ J

$= 85$ kJ

$\therefore$ The exit enthalpy is 85 kJ

19 $h_1 = u_1 + w_1$

$h_2 = u_2 + w_2$

$u_1 \approx u_2$ [$\because$ neglection of change in kinetic and potential energy

$w_{1\to2} = (h_1 - h_2)$ (when no heat is wasted)]

so the work done

$w_{1\to2} + q = (h_1 - h_2)$ [q is the abosulte amount of heat loss

$w_{1\to2} = (h_1 - h_2) - q$

$= (2993 - 226) - 50$

$= 2717 \text{ kJ/kg}$

$\therefore$ the work output of the turbine is 2717 kJ/kg

20 As the process is adibiatic and no other component of the energy of the system is charged, hence the total energy of the system will remain constant.

$\Delta \text{Energy} = 0$

$\Delta U + \frac{1}{2}m(v_2^2 - v_1^2) + mg(z_2 - z_1) + W_{1\to2} = 0$

$W_{1\to2} = -(\Delta U + \frac{1}{2}m(v_2^2 - v_1^2) + mg(z_2 - z_1))$

$= -(m c_v dT + \frac{1}{2}m(v_2^2 - v_1^2) + mg(z_2 - z_1))$

$$W_{1\to 2} = -\left(\underset{10\times 100}{\cancel{10\times 400}}\times 1 + \frac{1}{2}\times 10(20^2-10^2) + 10\times 10\times 20\right)$$

$$= -4500$$

$$= -4.5\ \text{kJ}$$