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CMRIT — CMR Institute of Technology, Bengaluru

Internal Assessment Test 1 – April. 2019

Sub:	Elements of Mechanical Engineering				Sub Code:	18ME25	Branch:	CS/CV/IS
Date:		Duration:	90 min's	Max Marks: 50	Sem / Sec:	II/ A,B,C,D,E,F & G		OBE

Answer all the Questions

(Use of Steam Tables is permitted)

		MARKS	CO	RBT
1.	Explain the working of a 4 stroke petrol engine with a neat sketch. (Or) Give the differences between i) 2-stroke & 4-stroke engines ii) Petrol & diesel engines.	[10] [5+5]	CO2	L2
2	Define the following terms: i) System ii) State iii) Boundary iv) Point function v) Path function. Discuss briefly the concept of work and heat and compare the same. (Or) Explain formation of steam with the help of T-h diagram at constant pressure.	[10] [10]	CO2	L1
3.	State and explain Zeroth, First and Second Laws of thermodynamics. (Or) Briefly discuss the construction and working of a centrifugal pump and explain the concept of cavitation.	[10] [10]	CO2	L2
4.	A trial carried out on a 4 stroke single cylinder engine has the following data: Cylinder diameter: 250mm, Stroke: 400 mm, Diameter of brake drum : 1000 mm, Mean effective pressure: 4 bar, Engine speed : 500 rpm, Effective brake load: 400N. Determine i) I.P ii) B.P iii) η_{mech} iv) F.P v) η_{th} . Assume Calorific value of fuel as 42000 KJ/Kg and Fuel consumed: 4.2 kg/hr. (Or) A single cylinder two stroke petrol engine develops 7.5 kW at 2500 rpm. The mean effective pressure is 8 bar and Mechanical Efficiency is 80%. Calculate the diameter and stroke of the cylinder if stroke to bore ratio is 1.5. Also calculate the fuel consumption rate if the brake thermal efficiency is 28% and the calorific value of fuel is 43900 KJ/Kg.	[10] [10]	CO2	L3
5.	A fluid system, contained in a piston and cylinder machine, passes through a complete cycle of four processes. The sum of all heat transferred during a cycle is – 340 kJ. The system completes 200 cycles per min. Complete the following table showing the method for each item, and compute the net rate of work output in kW.	[10]	CO2	L3

Process	*Q (kJ/min)*	*W (kJ/min)*	*ΔE (kJ/min)*
1—2	*0*	*4340*	—
2—3	*42000*	*0*	—
3—4	*-4200*	—	*-73200*
4—1	—	—	—

(Or)

5 kg of wet steam of dryness 0.8, passes from a boiler to a super heater at constant pressure of 1 MPa. In the super heater, its temperature increases to 350°C. Determine the amount of heat supplied in the super heater. Assume the specific heat of super heated steam as 2.25 KJ/Kg K [10]

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MARKS | CO | RBT

Scheme of Evaluation

Q.No	Scheme	Marks
	Sketch	5
	Explanation	5
	i) 5 points	5
	ii) 5 Points	5
	Definitions	5
	Heat and work - 5 points	5
	Sketch	5
	Explanation	5
	Statement	6
	Expression	4
	Sketch	3
	Construction & Working	3
	Cavitation	4
4a)	Numericals 5 x 2	10
	Diameter	4
	Length	3
	Fuel Consumption	3
5a)	Numerical	10
	Enthalpies	6
	Degree of Super heat	2
	Heat Supplied	2

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	Answer all the Questions (Use of Steam Tables is permitted)						MARKS	CO	RBT

Solutions

Q.No	Solution
1a)	

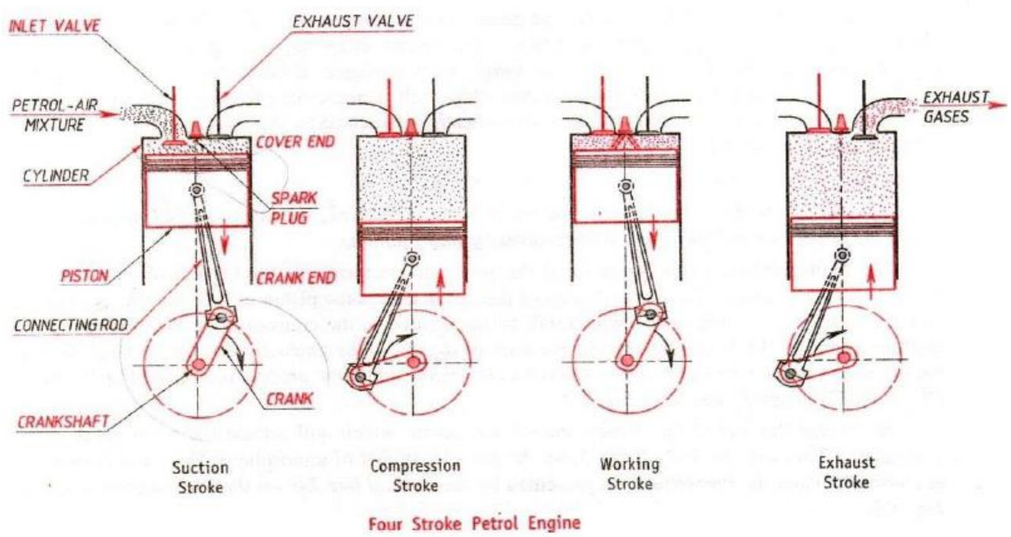


Fig. 3 Working of a 4-Stroke Petrol Engine

(a) Suction stroke:

At the beginning of the stroke, piston is in TDC and during the stroke, the piston moves from TDC to BDC. The inlet valve opens and the exhaust valve will be closed. As the piston moves downwards, suction is created in the cylinder as a result, fresh air-petrol mixture (charge) is drawn into the cylinder through the inlet valve. As the piston reaches BDC, the suction stroke completes and inlet valve closes. The suction stroke is represented by the line AB on P- V diagram as shown in the figure.4.

(b) Compression stroke:

At the beginning of the stroke piston is in BDC and during the stroke the piston moves from BDC to TDC. Both inlet and exhaust valves are closed. As the piston moves upwards, the air -petrol mixture in the cylinder is compressed adiabatically. The pressure and temperature of the charge increases and this is shown by the curve BC on the P- V diagram. When the piston reaches the TDC, the spark plug ignites the charge. The combustion of the fuel takes place at the constant volume and is shown by a line CD on the P- V diagram. The compression ratio in petrol engines ranges from 7:1 to 11:1.

(c) Power stroke/Expansion stroke/working stroke

At the beginning of the stroke, piston is in TDC and during the stroke piston moves from TDC to BDC.

	Both inlet and exhaust valves remain closed. The combustion of fuel liberates gases and these gases starts expanding. Due to expansion, the hot gases exert a large force on the piston and as a result the piston is pushed from TDC to BDC. The power impulse is transmitted down through the piston to the crank shaft through the connecting rod. This causes crankshaft to rotate at high speeds. Thus work is obtained in this stroke. Hence, this stroke is also called working stroke. Also gas expands and does work on the piston so this stroke is also called an expansion stroke. The expansion of gases is adiabatic in nature and this is shown by the curve DE on P- V diagram. As the piston reaches the BDC, the exhaust valve opens. A part of the burnt gases escape through the exhaust valve out of the cylinder due to their own expansion. **(d) Exhaust stroke:** At the beginning of the stroke piston is in BDC and during the stroke the piston moves from BDC to TDC. The inlet valve is closed and exhaust valve is opened. As the piston moves upward, it forces the remaining burnt gases out of the cylinder to the atmosphere through the exhaust valve. This is shown by the line EB and SA on P- V diagram. When the piston reaches the TDC, the exhaust valve closes and this completes the cycle.
1b)	i) 2 Stroke and 4 Stroke Engines

SI. No	2-Stroke Engine	4-Stroke Engine
1.	Requires two separate strokes to complete one cycle of operation.	Requires four separate strokes to complete one cycle of operation.
2.	Power is developed in every revolution of the crankshaft	Power is developed for every revolutions of the crankshaft.
3.	The inlet, transfer and exhaust ports are opened and closed by the movement of piston itself.	The inlet and exhaust are opened and closed by the valves.
4.	Turing moment is not uniform and hence requires a heavier flywheel.	Turing moment is uniform and hence Requires lighter flywheel.
5.	The charge is first admitted into the crankcase and then transferred to the engine cylinder.	The charge is directly admitted in to the engine cylinder during the suction stroke.

ii) Petrol and Diesel Engines

SI. No	Petrol Engine (SI Engine)	Diesel Engine (CI Engine)
1.	Draws a mixture of petrol and air during suction stroke .	Draws only air during suction stroke.
2.	The carburetor is employed to mix air and petrol in the required proportion and to supply it to the engine during suction stroke.	The injector is employed to inject the fuel at the end of compression stroke.
3.	Compression ratio ranges from 7: 1 to 12: I	Compression ratio ranges from 18:1 to 22:1
4.	The charge (Le petrol and air mixture) is ignited with the help of spark plug. This type of ignition is called spark ignition.	The ignition of the diesel is accomplished by the compressed air which will have been heated due to high compression ratio, to the temperature higher than the ignition temperature of the diesel. This type of ignition is called compression ignition.
5.	The combustion of fuel takes place approximately at constant volume.	The combustion of fuel takes place approximately at constant pressure.

2a) **i) System.** A system is *a finite quantity of matter or a prescribed region of space*

ii) Boundary. The *actual or hypothetical envelope enclosing the system* is the boundary of the system. The boundary may be fixed or it may move, as and when a system containing a gas is compressed or expanded. The boundary may be *real* or *imaginary.* It is not difficult to envisage a real boundary but an example of imaginary boundary would be one drawn around a system consisting of the fresh mixture about to enter the cylinder of an I.C. engine together with the remnants of the last cylinder charge after the exhaust process.

iii) State is the condition of the system at an instant of time as described or measured by its properties or each unique condition of a system is called a state.

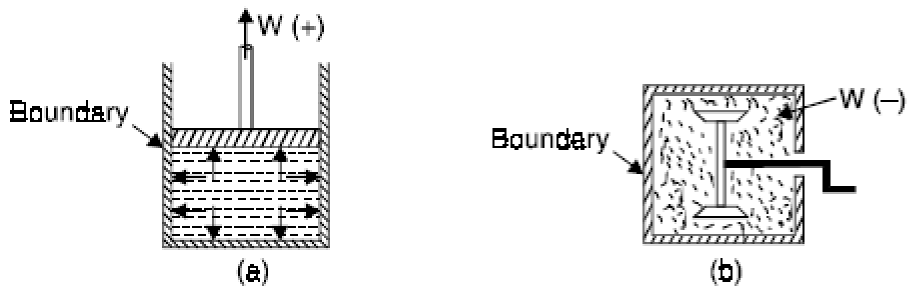
iv) Point Function: When two properties locate a point on the graph (co-ordinate axes) then those properties are called as point function. Examples. Pressure, temperature, volume etc.

v)Path Function: There are certain quantities which cannot be located on a graph by a *point* but are given by the *area* or so, on that graph. In that case, the area on the graph, pertaining to the particular process, *is a function of the path of the process.* Such quantities are called **path functions.** *Examples.* Heat, work etc

<u>Concept of Work and Heat</u>

Work

Work is said to be done when a *force moves through a distance*. If a part of the boundary of a system undergoes a displacement under the action of a pressure, the work done *W* is the product of the force (pressure × area), and the distance it moves in the direction of the force. Fig. 2.31 (*a*) illustrates this with the conventional piston and cylinder arrangement, the heavy line defining the boundary of the system. Fig. 2.31 (*b*) illustrates another way in which work might be applied to a system. A force is exerted by the paddle as it changes the momentum of the fluid, and since this force moves during rotation of the paddle work is done.



Sign convention :

_ If the work is done *by* the system *on* the surroundings, *e.g.*, when a fluid expands pushing a piston outwards, the work is said to be *positive*.

i.e., *Work output of the system* = + *W*

_ If the work is done *on* the system *by* the surroundings, *e.g.*, when a force is applied to a rotating handle, or to a piston to compress a fluid, the work is said to be *negative*.

i.e., *Work input to system* = – *W*

Heat

Heat (denoted by the symbol *Q*), may be, defined in an analogous way to work as follows :

"*Heat is 'something' which appears at the boundary when a system changes its state due to a difference in temperature between the system and its surroundings*".

Heat, like work, is a transient quantity which only appears at the boundary while a change is taking place within the system.

Sign convention :

If the heat flows *into* a system *from* the surroundings, the quantity is said to be *positive* and, conversely, if heat flows *from* the system to the surroundings it is said to be *negative*.

In other words :

Heat received by the system = + *Q*

Heat rejected or given up by the system = – *Q*.

2b) **Steam Formation**

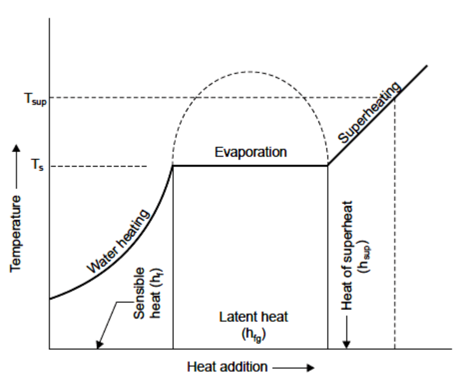
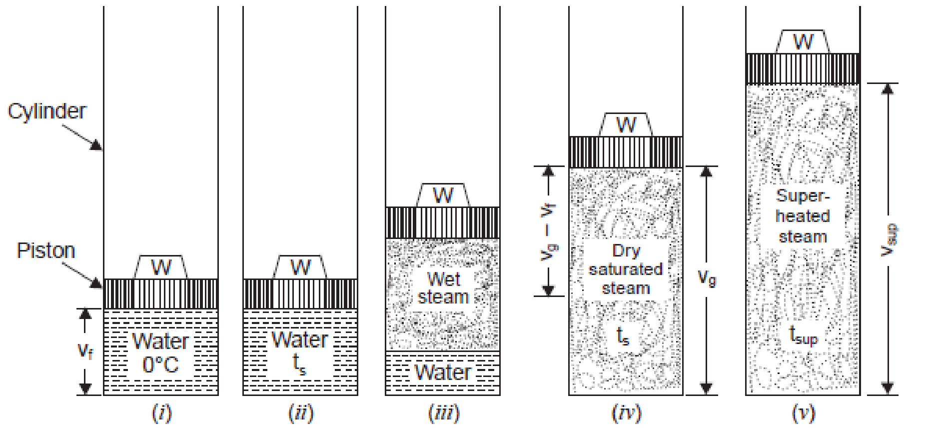


Fig. 3.10. Graphical representation of formation of steam.

	 Consider a cylinder fitted with a piston which can move freely upwards and downwards in it. Let, for the sake of simplicity, there be 1 kg of water at 0°C with volume *vf* m3 under the piston . Further let the piston is loaded with load *W* to ensure heating at constant pressure. Now if the heat is imparted to water, a rise in temperature will be noticed and this rise will continue till boiling point is reached. The temperature at which water starts boiling depends upon the pressure and as such for *each pressure* (under which water is heated) *there is a different boiling point*. This boiling temperature is known as the temperature of formation of steam or *saturation temperature*. It may be noted during heating up to boiling point that there will be slight increase in volume of water due to which piston moves up and hence work is obtained as shown. This work, however, is so *small* that is can be *neglected*. Now, if supply of heat to water is continued it will be noticed that rise of temperature after the boiling point is reached *nil* but piston starts moving upwards which indicates that there is increase is volume which is only possible if steam formation occurs. The heat being supplied does not show any rise of temperature but changes water into vapour state (steam) and is known as *latent heat* or *hidden heat*. So long as the steam is in contact with water, it is called *wet steam* and if heating of steam is further progressed such that all the water particles associated with steam are evaporated, the steam so obtained is called *dry and saturated steam*. Again, if supply of heat to the dry and saturated steam is continued at constant pressure there will be increase in temperature and volume of steam. The steam so obtained is called *superheated steam* and it *behaves like a perfect gas*. This phase of steam formation is illustrated in Fig
3a)	**First law of Thermodynamics** “When a system undergoes a thermodynamic cycle then the net heat supplied to the system from the surroundings is equal to net work done by the system on its surroundings.” or $\oint dQ = \oint dW$ where $\oint$ represents the sum for a complete cycle.

— The First Law of Thermodynamics may also be stated as follows :

"Heat and work are mutually convertible but since energy can neither be created nor destroyed, the total energy associated with an energy conversion remains constant".

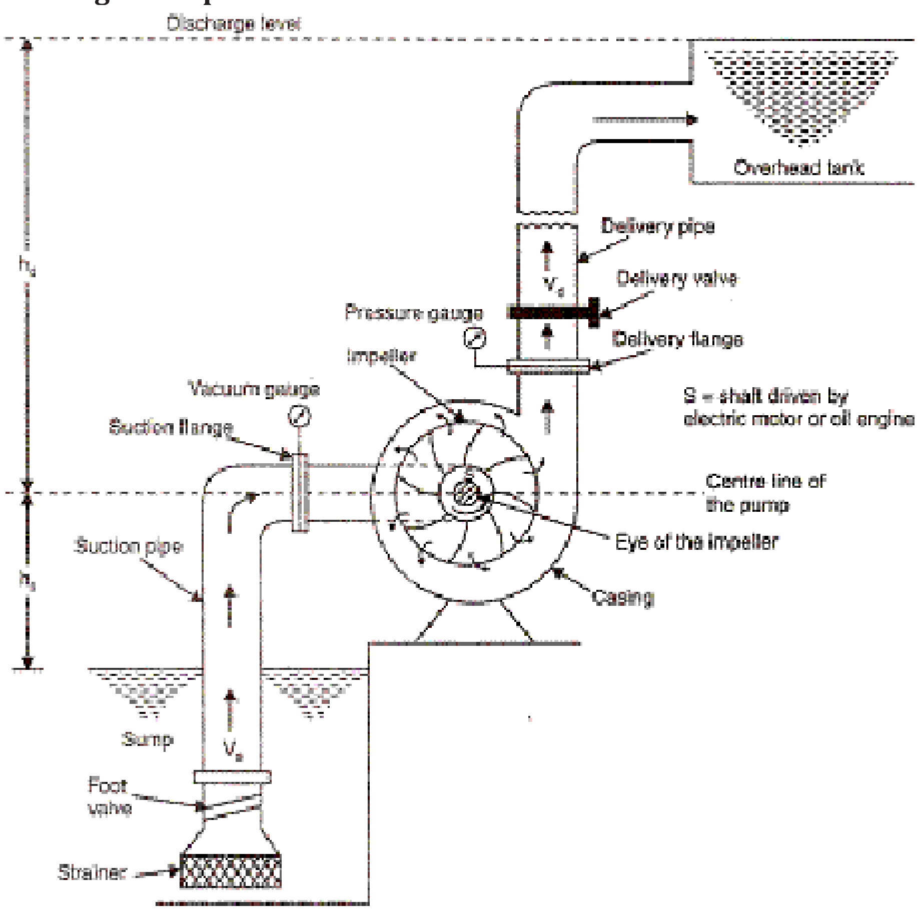
Or

— **"No machine can produce energy without corresponding expenditure of energy, *i.e.*, it is impossible to construct a perpetual motion machine of first kind".**

_ **'Zeroth law of thermodynamics'** *states that if two systems are each equal in temperature to a third, they are equal in temperature to each other*.

The Second Law of Thermodynamics states that the state of entropy of the entire universe, as an isolated system, will always increase over time. The second law also states that the changes in the entropy in the universe can never be negative.

3b) **Centrifugal Pump**



Construction

- Impeller
- Casing
- Delivery Pipe
- Suction Pipe

	Working • Priming is the most basic and first step in the working of centrifugal pump. • The process of filling the casing, suction pipe and delivery pipe up to the delivery valve before starting the pump is known as priming. In order to remove the air gap present in pump, it is filled by liquid. • Pressure developed inside the pump is directly proportional to the density of liquid in it. • If there is air in pump and an impeller is allowed to rotate then pressure energy cannot be developed as density of fluid is less due to presence of air. • So it is very important to prime a centrifugal pump carefully. • After the pump is primed the delivery valve is still kept closed and electric motor is started to rotate the impeller. • The delivery valve is kept closed in order to reduce valve is opened the liquid is made to flow in an outward radial direction there by vanes of impeller at the outer circumference with high velocity at outer circumference due to centrifugal action vacuum is created. • This cause liquid from sump to rush through suction pipe to eye of impeller thereby replacing long discharge from center circumference of the impeller is utilized in lifting liquid to required height through delivery pipe. • First priming is done before starting the pump. Delivery valve is still kept closed. • Now the motor starts. The rotation of impeller in the casing full of liquid accelerates liquid and there is generation of powerful centrifugal force which results in enhancement in liquid pressure. • This increase in pressure is directly proportional to the square of angular velocity and distance of point from the axis. • Therefore, if the impeller rotates with faster speed, there is greater amount of production of required pressure energy. • Now the delivery valve open and allow liquid to flow at desired location. **Cavitation** ▪ If pressure at any point in suction side drops below vapor pressure, water boils and vapor bubbles are formed. ▪ These bubbles move at very high velocity and impinge on impeller blades and collapse there. ▪ Due to this, blade surface corrodes, pits are formed leading to cavities. ▪ Considerable noise and vibrations are also produced.
4.a)	**Given Data** Cylinder diameter: 250mm, (D) = 0.25m Stroke: 400 mm (L) = 0.4m Diameter of brake drum : 1000 mm (D_b= 1m => R_{eff} = 0.5m Mean effective pressure: 4 bar ($P_m = 4 \times 10^5$ Pa) Engine speed : 500 rpm (N) Effective brake load: 400N (F) **To find:** i) I.P ii) B.P iii) η_{mech} iv) F.P v) η_{th} . Assume Calorific value of fuel as 42000 KJ/Kg and Fuel consumed: 4.2 kg/hr. single cylinder engine (n=1), 4 stroke => k = N/2 = 250 rpm IP = P x L x A x n x k/ 60000 Kw = **32.708 kW** T = F * R = 400 * 0.5 = 200Nm BP = 2πNT/60000 = **10.47 kW** FP = IP-BP = **22.24 kW** η_{mech} = BP/IP * 100 = **32%** η_{th} = BP/m* CV =**21.3%** (Brake thermal efficiency)

4b)

Sol^n :→ *Given*:⇒

$n = 1$

$B.P = 7.5\,kW$

$N = 2500\,rpm$

$P_m = 8\,bar = 8\times10^5\,N/m^2$

$\eta_{mech} = 80\% = 0.8$

$\frac{L}{d} = 1.5 \Rightarrow l = 1.5d$

$\eta_{bth} = 28\% = 0.28$

$C.V = 43900\,kJ/kg.$

To find:⇒ (a.) d (b). l (3). m_f.

$$\eta_{mech} = \frac{B.P}{I.P} \Rightarrow 0.8 = \frac{7.5}{I.P}$$

$$\Rightarrow I.P = 9.375\,kW.$$

$$\Rightarrow 9.375 = \frac{1\times8\times10^5\times\pi\times d^2\times1.5d\times2500}{60\times1000\times4}$$

$$\Rightarrow d^3 = 2.387\times10^{-4}\,m$$

$$\Rightarrow d = 0.062\,m \Rightarrow \boxed{d = 62\,mm}$$ (Ans)

$$L = 1.5\times d$$

$$= 1.5\times62$$

$$\Rightarrow \boxed{L = 93\,mm}$$ (Ans)

	Fuel consumption rate :- $\eta_{bth} = \frac{B.P}{m_f \times C.V}$ $\Rightarrow 0.28 = \frac{7.5}{m_f \times 43900} \rightarrow m_f = \frac{7.5}{0.28 \times 43900}$ $\Rightarrow m_f = 6.10 \times 10^{-4} \times 3600$ $\Rightarrow \boxed{m_f = 2.196\ kg/hr.}$ (Ans).
5a)	**Solution.** Sum of all heat transferred during the cycle = – 340 kJ. Number of cycles completed by the system = 200 cycles/min. **Process 1—2 :** $Q = \Delta E + W$ $0 = \Delta E + 4340$ $\therefore \Delta E = -4340$ kJ/min. **Process 2—3 :** $Q = \Delta E + W$ $42000 = \Delta E + 0$ $\Delta E = 42000$ kJ/min. **Process 3—4 :** $Q = \Delta E + W$ $-4200 = -73200 + W$ $\therefore W = 69000$ kJ/min. **Process 4—1 :** $\sum_{cycle} Q = -340$ kJ The system completes 200 cycles/min $\because Q_{1-2} = Q_{2-3} + Q_{3-4} + Q_{4-1} = -340 \times 200 = -68000$ kJ/min $0 + 42000 + (-4200) + Q_{4-1} = -68000$ $Q_{4-1} = -105800$ kJ/min. Now, $\int dE = 0$, since cyclic integral of any property is zero. $\Delta E_{1-2} + \Delta E_{2-3} + \Delta E_{3-4} + \Delta E_{4-1} = 0$ $-4340 + 42000 + (-73200) + \Delta E_{4-1} = 0$ $\therefore \Delta E_{4-1} = 35540$ kJ/min. $\therefore W_{4-1} = Q_{4-1} - \Delta E_{4-1}$ $= -105800 - 35540 = -141340$ kJ/min

The completed table is given below :

Process	$Q(kJ/min)$	$W(kJ/min)$	$\Delta E(kJ/min)$
1—2	0	4340	– 4340
2—3	42000	0	42000
3—4	– 4200	69000	– 73200
4—1	– 105800	– 141340	35540

Since $\sum_{cycle} Q = \sum_{cycle} W$

Rate of work output = – 68000 kJ/min $= -\frac{68000}{60}$ kJ/s or kW

= 1133.33 kW. (Ans.)

5b) **Given:**

P = 10 Bar, x = 0.8, m = 5kg

From Steam Tables corresponding to 10 bar,

Tsat = 179.88

h*f* = 762.52 KJ/Kg

h*fg* = 2014.6 KJ/Kg

Enthalpy of steam with dryness 0.8, h = hf + x hfg = 2374.2 KJ/Kg

Enthalpy of super heated steam , h sup = hf + hfg + Cp (Tsup-Tsat) = 3159.89 KJ/Kg

Amount of heat Supplied = h sup – h = 785.69 KJ/Kg

Total amount of heat supplied In super heater = mass * heat supplied per kg

= 5 x 785.69

= 3948.45 KJ