U218-155(T1)

OCTOBER 2018/ IN-SEM (T1)

S. Y. B. TECH. (MECHANICAL ENGINEERING) (SEMESTER - I)

COURSE NAME : Thermodynamics

COURSE CODE : MEUA21175

(PATTERN 2017)

Marking Scheme

Q.1) a) 2 marks for each point
Min. 3 points

b) 2 marks for formula
2 marks for data substitution
2 marks for correct answer

c) 1 mark for definition
1 mark for example

Q.2) a) 1 mark for each statement - 2 marks
4 marks for energy is a property of the system

b) 1 marks - network transferred
1 mark - direction of work transfer
2 marks - change in internal energy
2 marks - total energy during the cycle

c) 1 mark definition & example
1 mark diagram

Q.3) a) 2 marks COP
2 marks heat transfer

1 mark each for correct formula

b) 2 marks each

c) 2 marks each

Q.4) a) 2 marks thermal efficiency
2 marks rate of heat rejection
1 mark each for correct formula

b) 2 marks for diagram
2 marks for explanation

c) 2 marks each point for explanation

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Solution

Q.1) a)

Macroscopic approach	Microscopic approach
In this approach a certain quantity of matter is considered without taking into account the events occurring at molecular level. In other words this approach to thermodynamics is concerned with gross or overall behavior. This is known as classical thermodynamics.	The approach considers that the system is made up of a very large number of discrete particles known as molecules. These molecules have different velocities and energies. The values of these energies are constantly changing with time. This approach to thermodynamics which is concerned directly with the structure of the matter is known as statistical thermodynamics
The analysis of macroscopic system requires simple mathematical formulae.	The behavior of the system is found by using statistical methods as the number of molecules is very large. So advanced statistical and mathematical methods are needed to explain the changes in the system.
The values of the properties of the system are their average values. For example, consider a sample of a gas in a closed container. The pressure of the gas is the average value of the pressure exerted by millions of individual molecules. Similarly the temperature of this gas is the average value of translational kinetic energies of millions of individual molecules. These properties like pressure and temperature can be measured very easily. The changes in properties can be felt by our senses.	The properties like velocity, momentum, impulse, kinetic energy, force of impact etc. which describe the molecule cannot be easily measured by instruments. Our senses cannot feel them.
In order to describe a system only a few properties are needed.	Large numbers of variables are needed to describe a system. So the approach is complicated.

b) Given:

$m = 4$ kg / s
$p_1 = 6$ bar
$p_2 = 1.25$ bar
$C_1 = 300$ m / s
$C_2 = 200$ m / s
$u_1 = 2000$ kJ
$u_2 = 1500$ kJ
$v_1 = 0.3$ m3 / kg
$v_2 = 1.2$ m3 / kg
$q = 40$ kJ / kg

Solution:
Using SFEE,

$$u_1 + \frac{C_1^2}{2} + Z_1 g + p_1 v_1 + Q = u_2 + \frac{C_2^2}{2} + Z_2 g + p_2 v_2 + W$$

$Z_1 = Z_2$

$$\frac{300^2}{2} + 500 \times 10^3 + (6 \times 10^5 \times 0.3) - 40 \times 10^3 = \frac{200^2}{2} + 375 \times 10^3 + (1.25 \times 10^5 \times 1.2) + W$$

W = 140 kJ / Kg
W = 560 kW

c) **Intensive properties.** These properties do not depend on the mass of the system.
Example : Temperature, Pressure etc.
Extensive properties. These properties depend on the mass of the system.
Example : Volume, Enthalpy etc.

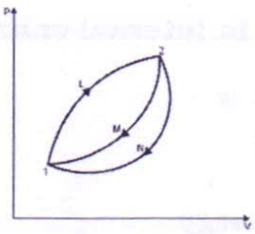
Q.2) a) 1. When a system undergoes a thermodynamic cycle then the net heat supplied to the system from the surroundings is equal to net work done by the system on its surroundings.

$$\oint dQ = \oint dW$$

where $\oint$ represents the sum for a complete cycle.

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

ENERGY—A PROPERTY OF SYSTEM



Consider a system which changes its state from state 1 to state 2 by following the path L, and returns from state 2 to state 1 by following the path M. So the system undergoes a cycle.

Writing the first law for path L

$$Q_L = \Delta E_L + W_L$$

and for path M

$$Q_M = \Delta E_M + W_M$$

The processes L and M together constitute a cycle, for which

$$\oint dW = \oint dQ$$

$$W_L + W_M = Q_L + Q_M$$

$$Q_L - W_L = W_M - Q_M$$

$$\Delta E_L = -\Delta E_M$$

$$\Delta E_L = -\Delta E_N$$

$$\Delta E_M = \Delta E_N$$

Thus, it is seen that the change in energy between two states of a system is the same, whatever path the system may follow in undergoing that change of state. If some arbitrary value of energy is assigned to state 2, the value of energy at state 1 is fixed independent of the path the system follows. Therefore, energy has a definite value for every state of the system. Hence, it is a point function and a property of the system.

b) Given:

$Q_1 = 120$ kJ

$Q_2 = -16$ kJ

$Q_3 = -48$ kJ

$Q_4 = 12$ kJ

Solution:

i) network transferred

$$\oint dQ = \oint dW$$

$$W = Q_1 + Q_2 + Q_3 + Q_4$$

$$= 120 - 16 - 48 + 12$$

$$= 68 \text{ kJ}$$

ii) direction of work transfer

As network transfer is +ve Work is done by the system

iii) **change in internal energy**

$$Q = \Delta U + W$$

$$\Delta U = 0 \text{ kJ}$$

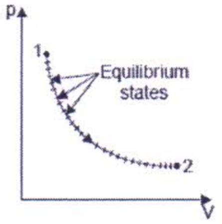
iv) **total energy**

$$Q = \Delta E + W$$

$$\Delta E = Q - W$$

$$\Delta E = 0 \text{ kJ}$$

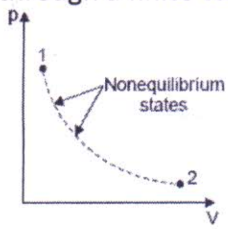
c) **Reversible process.** A reversible process (also sometimes known as quasi-static process) is one which can be stopped at any stage and reversed so that the system and surroundings are exactly restored to their initial states.



Examples

(i) Frictionless relative motion.
(ii) Expansion and compression of spring.
(iii) Frictionless adiabatic expansion or compression of fluid.
(iv) Polytropic expansion or compression of fluid.
(v) Isothermal expansion or compression.
(vi) Electrolysis.

Irreversible process. An irreversible process is one in which heat is transferred through a finite temperature.



Examples

(i) Relative motion with friction
(ii) Combustion
(iii) Diffusion
(iv) Free expansion
(v) Throttling
(vi) Electricity flow through a resistance
(vii) Heat transfer
(viii) Plastic deformation

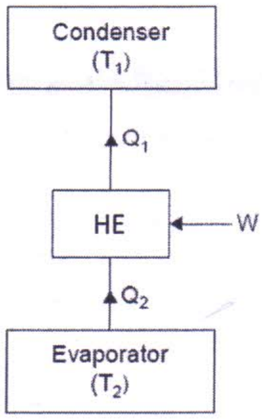
An irreversible process is usually represented by a dotted (or discontinuous) line joining the end states to indicate that the intermediate states are indeterminate

Q.3) a) Given:

$Q_2 = 12000$ kJ / h

W = 0.75 kW

Solution:



$$(\text{C.O.P.})_{refrigerator} = \frac{\text{Heat absorbed at lower temperature}}{\text{Work input}}$$

$$\therefore \quad \text{C.O.P.} = \frac{Q_2}{W} = \frac{12000}{0.75 \times 60 \times 60} = 4.44$$

Hence **C.O.P. = 4.44.**

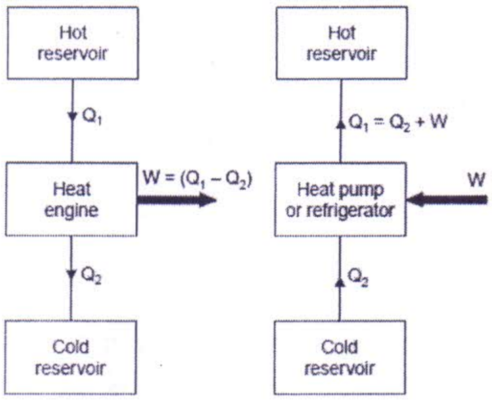
b) **i) Clausius Statement**

It is impossible for a self acting machine working in a cyclic process unaided by any external agency, to convey heat from a body at a lower temperature to a body at a higher temperature.

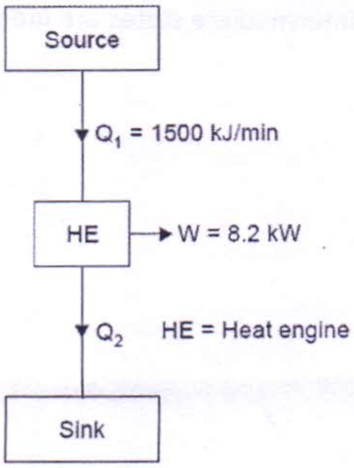
ii) Kelvin-Planck Statement

It is impossible to construct an engine, which while operating in a cycle produces no other effect except to extract heat from a single reservoir and do equivalent amount of work

c)



Q.4) a)



Solution. Heat received by the heat engine,

$$Q_1 = 1500 \text{ kJ/min}$$

$$= \frac{1500}{60} = 25 \text{ kJ/s}$$

Work output, $W = 8.2 \text{ kW} = 8.2 \text{ kJ/s}$.

(*i*) Thermal efficiency, $\eta_{th} = \frac{W}{Q_1}$

$$= \frac{8.2}{25} = 0.328 = 32.8\%$$

Hence, **thermal efficiency = 32.8%.**

(*ii*) Rate of heat rejection,

$$Q_2 = Q_1 - W = 25 - 8.2$$

$$= 16.8 \text{ kJ/s}$$

Hence, **the rate of heat rejection = 16.8 kJ/s.**

b) **Clausius Inequality**

The system to which the heat transfer is effected is neither concerned with the source of energy it receives nor with the method of transfer, save that it must be reversible. Associated with the small heat transfer dQ to the original system is a small work transfer dW and for this system the first law gives

$$\sum_{\text{cycle}} (\delta Q - \delta W) = 0$$

Now consider the engine replacing the reservoirs and apply the second law If the new system is not a perpetual motion machine of second kind, no positive work transfer is possible with a single reservoir.

$$\sum_{\text{cycle}} (\delta W - \delta W_R) \le 0$$

But by the definition of thermodynamic temperature in equation

$$\frac{\delta W_R}{\delta Q} = \frac{\delta Q_0 - \delta Q}{\delta Q} = \frac{T_0 - T}{T}$$

$$T_0 \sum_{\text{cycle}} \left(\frac{\delta Q}{T}\right) \le 0 \text{ but } T_0 \ne 0 \text{ and therefore ;}$$

$$\sum_{\text{cycle}} \left(\frac{\delta Q}{T}\right) \le 0$$

This is known as **Clausius inequality.**

c) It has been observed that energy can flow from a system in the form of heat or work. The first law of thermodynamics sets no limit to the amount of the total energy of a system which can be caused to flow out as work. A limit is imposed, however, as a result of the principle enunciated in the second law of thermodynamics which states that heat will flow naturally from one energy reservoir to another at a lower temperature, but not in opposite direction without assistance. This is very important because a heat engine operates between two energy reservoirs at different temperatures.

Further the first law of thermodynamics establishes equivalence between the quantity of heat used and the mechanical work but does not specify the conditions under which conversion of heat into work is possible, neither the direction in which heat transfer can take place. This gap has been bridged by the second law of thermodynamics.