

CLASS – 11

WORKSHEET- THERMODYNAMICS

A. INTRODUCTION TO THERMODYNAMICS

(1 Mark Questions)

1. The zeroth law of thermodynamics for three systems A, B and C in contact demands that
(a) A and B are in thermal equilibrium (b) B and C are in thermal equilibrium
(c) A and C are in thermal equilibrium (d) A, B and C are in thermal equilibrium

Sol. (a)

2. What does the zeroth law of thermodynamics tell us about measuring the temperature of an object?

Sol. The zeroth law of thermodynamics states that if two bodies are each in thermal equilibrium with some third body, then they are also in equilibrium with each other.

3. Which one of the following is not a thermodynamic variable?

(a) pressure (b) temperature (c) volume (d) none of these

Sol. (d)

All are thermodynamic variables.

4. Define thermodynamic system.

Sol. Thermodynamic system is a branch that deals with heat, work and temperature, and their relation to energy, radiation and physical properties of matter.

5. What is equation of state?

Sol. In physics, chemistry, and thermodynamics, an equation of state is a thermodynamic equation relating state variables, which describe the state of matter under a given set of physical conditions, such as pressure, volume, temperature, or internal energy.^[1] Most modern equations of state are formulated in the Helmholtz free energy. Equations of state are useful in describing the properties of pure substances and mixtures in liquids, gases, and solid states as well as the state of matter in the interior of stars.

6. What are extensive state variables?

Sol. Extensive variables are variables that scale proportionally system size such as total volume or mass. Examples of extensive variables include mass (m), moles (n), internal energy (U), enthalpy (H), entropy (S), Gibb's energy (G), heat capacity (C_p).

(3 Marks Questions)

7. When is a system said to be in the state of thermodynamic equilibrium?
- Sol. A system is said to be in the state of thermodynamic equilibrium if the microscope variables describing the thermodynamic state of the system do not change with time.
- (i) Mechanical equilibrium: There is not unbalanced force in its interior or between the system and the surroundings.
- (ii) Thermal equilibrium: All parts of the system and the surroundings are at the same temperature.
- (iii) Chemical equilibrium: The system does not undergo any spontaneous change in its internal structure due to chemical reaction, diffusion, etc.
8. Define internal energy of a gas. Explain whether it is an extensive or intensive variable? How internal energy of a gas can be changed?
- Sol. Internal energy is the sum of the kinetic energies and potential energies of the molecular constituents of the system. It does not include the overall kinetic energy of the system. Internal energy is an extensive variable because it depends upon the mass and size (volume) of the system. Intensive variables like temperature, pressure does not depend upon the mass and size of the system.
- Change in internal energy does not depend on the path of the process. ΔU depends only on the initial and final states of the system, i.e. $\Delta U = U_f - U_i$.
9. What do you mean by extensive and intensive state variables? Explain using suitable example.
- Sol. Extensive variable depends on the size or mass of the system. Example: Volume, total mass, entropy, internal energy, heat capacity, etc. Intensive variables do not depend on the size or mass of the system. Example: Temperature, pressure, specific heat capacity, density, etc.

B. HEAT, WORK AND INTERNAL ENERGY

(1 Mark Questions)

1. If no external energy is supplied to an expanding gas, will the gas do any work? If yes, then what will be the source of energy?
- Sol. Yes the gas will do work at the expense of its internal energy.
2. Which of the following is not a path function?
- (a) ΔQ (b) $\Delta Q + \Delta W$ (c) ΔW (d) $\Delta Q - \Delta W$
- Sol. (d)

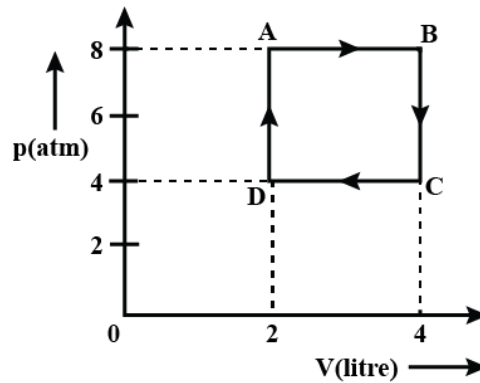
$$\Delta Q = \Delta U + \Delta W \quad \Delta Q - \Delta W = \Delta U$$

ΔU is internal energy which is independent of path.

3. During an isothermal expansion, a confined ideal gas does -150J of work against its surroundings. This implies that
- (a) 150J of heat has been removed from the gas
 - (b) 150J of heat has been added to the gas
 - (c) no heat is transferred because the process is isothermal
 - (d) 150J of heat has been added to the gas

Ans. (b)

4. One mole of an ideal gas undergoes a cyclic process ABCDA as shown in the PV diagram. The net work done in the process is ($1\text{ atm} = 10^6\text{ dyne cm}^{-2}$)



- (a) 500J (b) 700J (c) 800J (d) 900J

Sol. (c)

From the P-V diagram,

Work done, $W = \text{area under the P-V diagram}$

$$W = AB \times BC$$

$$W = 2\text{litre} \times 4\text{atm}$$

$$W = 2 \times 10^{-3} \times 4 \times 1.03 \times 10^5 \text{ or } W = 8 \times 100 \text{ or } W = 800\text{J}$$

The correct option is C.

5. A given system undergoes a change in which the work done by the system equals the decrease in its internal energy. What kind of thermodynamic process does the system undergoes?

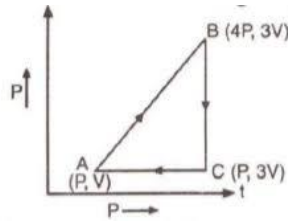
Sol. Given $dW = -dU$

$$\text{So, } dW + dU = 0$$

$$\text{So, } dQ = 0$$

The process is adiabatic.

6. A sample of an ideal monatomic gas is taken round the cycle ABCA as shown in the figure. What is the work done during the cycle?



- Sol. Work done is given by the area enclosed by the three steps; i.e. the area of the triangle.

$$W = \frac{1}{2} (3V - V)(4P - P) = 0.5(2V)(3P) = 3PV$$

7. Can two isothermal curves intersect?

- Sol. No, if two isothermal intersect, then this would mean that the pressure and volume of a gas are the same at two different temperatures.

8. Can we convert internal energy into work?

- Sol. The steam locomotive engine is one perfect example of turning internal energy into mechanical energy. Liquid water is heated past the point of vaporization. Through a controlled mechanical process, the expanding water vapor is allowed to push a piston.

9. If hot air rises up, why is it cooler at the top of mountain than near the sea level? Explain.

- Sol. As warm air rises up a mountain side, it loses pressure, expands, and cools.

10. Why a gas is cooled when expanded?

- Sol. When gas expands, the decrease in pressure causes the molecules to slow down. This makes the gas cold.

11. What is isobaric process?

- Sol. An Isobaric process is a thermodynamic process taking place at constant pressure. The term isobaric has been derived from the Greek words “iso” and “baros” meaning equal pressure. As such, the constant pressure is obtained when the volume is expanded or contracted. This basically neutralizes any pressure change due to the transfer of heat.

12. What is isochoric process?

- Sol. A thermodynamic process taking place at constant volume is known as the isochoric process. It is also sometimes called as an isometric process or constant-volume process. The term isochoric has been derived from the Greek words “iso” meaning “constant” or “equal” and “choric” meaning “space” or “volume.”

(2 Marks Questions)

13. Give difference between heat and work.

Sol. Heat is the transfer of thermal energy between systems, while work is the transfer of mechanical energy between two systems. This distinction between the microscopic motion (heat) and macroscopic motion (work) is crucial to how thermodynamic processes work.

14. What do you mean by internal energy of a system?

Sol. The total of the kinetic energy due to the motion of molecules and the potential energy associated with the vibrational motion and electric energy of atoms within molecules constitutes the internal energy of a system with some specific boundaries.

15. State the sign conventions used in the measurement of heat, work and internal energy.

Sol. Sign conventions used: (i) Heat absorbed by a system is positive. Heat given out by a system is negative. (ii) Work done by a system is positive, Work done on a system is negative. (iii) The increase in internal energy of a system is positive. The decrease in internal energy of a system is negative.

16. A system is given 200 calories of heat and it does 600 joules of work. How much does the internal energy of the system change in this process. ($J = 4.18 \text{ joule/cal}$)?

Sol. $J\Delta Q = \Delta U + \Delta W. \Delta U = J\Delta Q - \Delta W$
 $\Delta U = 4.18 \times 200 - 600 = 236 \text{ joule.}$

(3 Marks Questions)

17. State first law of thermodynamics and apply it to the boiling process of liquid.

Sol. The First Law of Thermodynamics states that energy cannot be created or destroyed; it can only be converted from one form to another.

Boiling process: Let the heat of mass m of a liquid at its boiling point so that it changes into vapour at pressure P . Let V_1 be the volume of the liquid and V_2 that of vapour. Clearly $dW = PdV = P(V_2 - V_1) \dots(i)$

If the latent heat of vapourization is L_v , heat absorbed during the boiling process is given by, $dQ = mL_v \dots(ii)$

From the first law of thermodynamics, $dQ = dU + dW \dots(iii)$

From (i), (ii), (iii)

$$mL_v = dU + P(V_2 - V_1) \text{ or } dU = mL_v - P(V_2 - V_1)$$

Thus knowing m , L_v , P , V_1 and V_2 we can easily calculate the gain in internal energy (dU) when a liquid changes into a vapour.

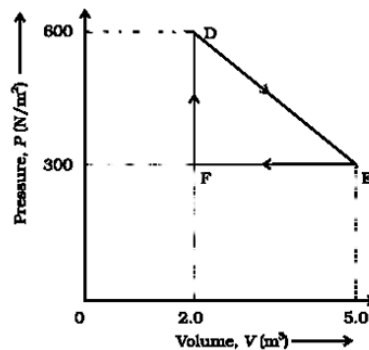
18. When heat energy of 1500J is supplied to a gas at constant pressure, $2.1 \times 10^5 \text{ Nm}^{-2}$, there was an increase in its volume equal to $2.5 \times 10^{-3} \text{ m}^3$. What is the increase in its internal energy?

Sol. Heat supplied to the gas, $\Delta Q = 1500\text{J}$

$$\text{Work done by the gas, } \Delta W = P\Delta V = (2.1 \times 10^5 \text{ Nm}^{-2})(2.5 \times 10^{-3} \text{ m}^3) = 5.25 \times 10^2 \text{ Nm} = 525\text{J}$$

$$\begin{aligned} \text{According to first law of thermodynamics, } \Delta Q &= \Delta W + \Delta U \\ &= 1500\text{J} - 525\text{J} = 975\text{J}. \end{aligned}$$

19. A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in figure.



Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the total work done by the gas from D to E and E to F.

Sol. Total work done by the gas from D to E to F, $W = W_{DE} + W_{EF}$

$$= \text{Area of trapezium DEGHD} - \text{Area of rectangle EFGH}$$

$$= \text{Area of triangle DEF} = \frac{1}{2} DF \times FE = \frac{1}{2} (600 - 300) \text{ Nm}^{-2} \times (5.0 - 2.0) \text{ m}^3 = 450\text{J}.$$

C. THERMODYNAMIC PROCESS

(1 Mark Questions)

1. State first law of thermodynamics.

Sol. The First Law of Thermodynamics states that energy cannot be created or destroyed; it can only be converted from one form to another.

2. First law of thermodynamics does not forbid flow of heat from lower temperature to higher temperature. Comment.

Sol. First law of thermodynamics simply tells about the conversion of mechanical energy into heat energy and vice-versa. It does not put any condition as to why heat cannot flow from lower temperature to higher temperature.

3. When is the heat supplied to a system equal to the increase in its internal energy?

Sol. The first law of thermodynamics states that the change in internal energy of a system equals the net heat transfer into the system minus the net work done by the system. In equation form, the first law of thermodynamics is $\Delta U = Q - W$. Here ΔU is the change in internal energy U of the system.

4. In an adiabatic change the specific heat of a gas is
 (a) increase with increase in temperature (b) decrease with increase in temperature
 (c) not depend upon change in temperature (d) always zero

Ans. (d)

5. An ideal gas having molar specific heat capacity at constant volume is $3/2R$, the molar specific heat capacities at constant pressure is

- (a) $1/2R$ (b) $5/2R$ (c) $7/2R$ (d) $9/2R$

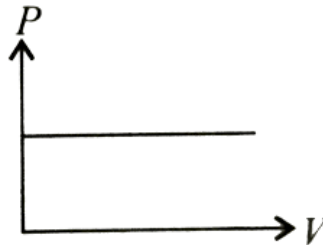
Sol. (b)

$$C_p - C_v = R$$

$$C_p - 3/2R = R$$

$$C_p = 5/2R$$

6. Which of the following process is correct for given P-V diagram?



- (a) Adiabatic process (b) isothermal process (c) Isobaric process (d) Isochoric process

Ans. (c)

(2 Marks Questions)

7. Two bodies at different temperatures T_1 and T_2 if brought in thermal contact do not necessarily settle to the mean temperature $(T_1 + T_2)/2$. Explain.

Sol. Let m_1, m_2 and c_1, c_2 be the masses and specific heats of the two bodies. Let T be their common temperatures when these are brought in thermal contact.

From the principle of calorimetry, $m_1c_1[T_1 - T] = m_2c_2[T - T_2]$ (taking $T_1 > T_2$)

For $T = (T_1 + T_2)/2$

$$m_1c_1 \left[T_1 - \frac{T_1 + T_2}{2} \right] = m_2c_2 \left[\frac{T_1 + T_2}{2} - T_2 \right] \text{ or } m_1c_1 \left[\frac{T_1 - T_2}{2} \right] = m_2c_2 \left[\frac{T_1 - T_2}{2} \right]$$

Or $m_1c_1 = m_2c_2$ i.e. heat capacities of the two bodies should be equal.

8. Which is greater C_P or C_V and why?

Sol. C_p is greater than C_v . When a gas is heated at constant volume, all the heat supplied is used to increase the temperature or internal energy of the gas.

9. Can a system be heated but its temperature remains constant?

Sol. From first law of thermodynamics, $\Delta Q = \Delta U + \Delta W$

Or $\Delta Q = nC \cdot \Delta T + \Delta W$ (since $\Delta U = nC \cdot \Delta T$)

If system has constant temperature in spite of heat supplied then $\Delta T = 0$ and $\Delta Q = \Delta W$. It means heat supplied (ΔQ) to the system is used in doing work (ΔW) against the surroundings.

10. If at 50°C and 75cm of mercury pressure, a definite mass of gas is compressed (i) slowly (ii) suddenly, then what will be the final pressure and temperature of the gas in each case if the final volume is one-fourth of the initial volume ($\gamma = 1.5$).

Sol. When the gas is compressed slowly, the change is isothermal.

Therefore $P_2 V_2 = P_1 V_1$

$P_2 = P_1 V_1 / V_2 = (75 \times V_1 / V_1) \times 4 = 300$ cm of mercury

Temperature remains constant at 50°C

(ii) When the gas is compressed suddenly, the change is adiabatic

As per $P_2 V_2^\gamma = P_1 V_1^\gamma$

$P_2 = P_1 (V_1 / V_2)^\gamma$

$= 75 \times (4)^{1.5}$

$= 600$ cm of Hg

Also $T_2 V_2^{\gamma-1} = T_1 V_1^{\gamma-1}$

$T_2 = T_1 (V_1 / V_2)^{\gamma-1}$

$= 323 \times (4)^{(1.5-1)} = 646\text{K}$

$= 646 - 273 = 373^\circ\text{C}$

11. The slope of an adiabatic process is greater than an isothermal process. Give reason.

Sol. Because the adiabatic curve is steeper than the isothermal curve, the amount of work done in the adiabatic process is greater than in the isothermal process.

12. Show that the slope of an adiabatic curve at any point is γ times the slope of an isothermal curve at the corresponding point.

Sol. isothermal

$PV = \text{constant}$

$p = k/v$

$dp/dv = -k/v^2$

$= -k/v \times v$
 so $-p/v$
 for adiabatic
 $p V^Y = k$
 $dp/dv = -YK/V^{(Y+1)}$
 $= -Y K/V^Y \times V$
 As $p = k/V^Y$
 so it's $-Y P/V$
 hence it's Y times

13. Under what conditions would an ideal heat engine be cent per cent efficient?

Sol. If there is no loss of energy in any form and temperature of the sink is zero, then the heat engine will be 100% efficient.

14. A cylinder with a movable piston contains 3 moles of hydrogen at standard temperature and pressure. The walls of the cylinder are made of a heat insulator, and the piston is insulated by having a pile of sand on it. By what factor does the pressure of the gas increase if the gas is compressed to half its original volume?

Sol. The cylinder is completely insulated from its surroundings. As a result, no heat is exchanged between the system (cylinder) and its surroundings. Thus, the process is adiabatic.

Initial pressure inside the cylinder $=P_1$

Final pressure inside the cylinder $=P_2$

Initial volume inside the cylinder $=V_1$

Final volume inside the cylinder $=V_2$

Ratio of specific heats, $\gamma = C_p/C_v = 1.4$

For an adiabatic process, we have:

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

The final volume is compressed to half of its initial volume.

$$\therefore V_2 = V_1/2$$

$$P_1 V_1^\gamma = P_2 (V_1/2)^\gamma$$

$$P_2/P_1 = V_1^\gamma / (V_1/2)^\gamma$$

$$= 2^{1.4} = 2.64$$

Hence, the pressure increases by a factor of 2.64.

(3 Marks Questions)

15. Prove that $C_P - C_V = R$ for ideal gas

Sol. Consider one mole of an ideal gas. Heat the gas to raise its temperature by ΔT . According to the first law for thermodynamics, the heat supplied ΔQ is used partly to increase the internal energy and partly in doing the work of expansion. That is $\Delta Q = \Delta U + P\Delta V$

If the heat ΔQ is absorbed at constant volume, then $\Delta V = 0$ and we have

$$C_V = \left(\frac{\Delta Q}{\Delta T}\right)_V = \left(\frac{\Delta U}{\Delta T}\right)_V = \left(\frac{\Delta U}{\Delta T}\right)$$

We have dropped the subscript V because the internal energy U of an ideal gas depends only on its temperature T.

If now the heat ΔQ is absorbed at constant pressure, then

$$C_P = \left(\frac{\Delta Q}{\Delta T}\right)_P = \left(\frac{\Delta U}{\Delta T}\right)_P + P \left(\frac{\Delta V}{\Delta T}\right)_P = \left(\frac{\Delta U}{\Delta T}\right) + P \left(\frac{\Delta V}{\Delta T}\right)_P$$

Again we dropped the subscript P from the first terms because U of an ideal gas depends only on T.

$$\text{Therefore } C_P - C_V = P \left(\frac{\Delta V}{\Delta T}\right)_P$$

But for one mole of an ideal gas, $PV = RT$.

Differentiating both sides w.r.t. T for constant pressure, $P \left(\frac{\Delta V}{\Delta T}\right)_P = R$

Hence $C_P - C_V = R$

This is required relation between C_P and C_V . It is also known as Mayer's formula.

16. Establish the relation between two principal specific heats of a gas on the basis of first law of thermodynamics.

Sol. Same as 15.

17. Two cylinders A and B of equal capacity are connected to each other via a stopcock. The cylinder A contains a gas at standard temperature and pressure, while the cylinder B is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. Answer the following:

(a) What is the final pressure of the gas in A and B?

(b) What is the change in internal energy of the gas?

(c) What is the change in temperature of the gas?

(d) Do the intermediate states of the system (before settling to final equilibrium state) lie on its P-V-T surface?

Sol. (a) Cylinders, A and B are of equal capacity, so when the stopcock is suddenly opened, the pressure in both the cylinders decreases to half the initial value. Since volume is inversely proportional to pressure, therefore when the stopcock is opened, the volume gets doubled for the gas and hence pressure gets halved.

(b) The internal energy of the gas can change only when work is done by or on the gas. Since in this case no work is done by or on the gas, the internal energy of the gas will not change.

(c) Since no work is being done by the gas during the expansion of the gas, the temperature of the gas will not change at all.

(d) The given process is a case of free expansion. It is rapid and cannot be controlled. The intermediate states do not satisfy the gas equation and since they are in non-equilibrium states, they do not lie on the P-V-T surface of the system.

18. Write two essential conditions for a perfect isothermal change and the two essential conditions for a perfect adiabatic change.

Sol. They are two essential conditions for an isothermal process to take place. First, the system should be perfectly conducting to the surroundings and second, the process must be carried out very slowly so that there is required time for exchange of heat with the surroundings to maintain temperature constant.

19. Consider one gram mole of an ideal gas of ratio of specific heats γ , enclosed in a cylinder with perfectly non conducting walls fitted with a smooth non conducting piston. Find an expression for work done by the gas when it expands such that its temperature changes from T_1 to T_2 .

20. Ten moles of hydrogen at NTP is compressed adiabatically so that its temperature become 400°C . How much work is done on the gas? What is the increase in the internal energy of the gas ($R = 8.4 \text{ J mol}^{-1} \text{ K}^{-1}$, $\gamma = 1.4$)

Sol. Given $T_1 = 0^\circ\text{C} = 273\text{K}$, $T_2 = 400^\circ\text{C} = 673\text{K}$

$$\text{Work done, } W = \frac{nR}{\lambda-1} (T_2 - T_1) = \frac{10 \times 8.4 \times 400}{\left(\frac{7}{5}-1\right)} = 83000\text{J} = 83.0\text{kJ}$$

21. Determine the PV relation for a monatomic gas undergoing an adiabatic process.

Sol. We know that monatomic gas has 3 degree of freedom.

$$C_p/C_v = \gamma,$$

$$\gamma = \frac{f+2}{f} = \frac{3+2}{3} = \frac{5}{3}$$

Monatomic ideal gas in adiabatic change is

$$PV^\gamma = \text{constant.}$$

So putting the value of γ we get $PV^{5/3} = \text{constant.}$

22. Derive an expression for work done during isothermal process.

Sol. Suppose 1 gm mole of an ideal gas enclosed in a cylinder of conducting walls. Let P_1 , V_1 , T be initial pressure, volume, and temperature. Let gas expand to volume V_2 where pressure reduces to P_2 and temperature remains constant.

If A is the area of piston $F = P \times A$

$$dW = F \times dx = P \times A \times dx$$

$$W = \int_{V_1}^{V_2} PdV \quad [\because Adx = dv]$$

But, $PV = RT$

$$W = \int_{V_1}^{V_2} \frac{RT}{V} dV$$

$$W = RT [\log_e V]_{V_1}^{V_2}$$

$$W = RT [\log_e V_2 - \log_e V_1]$$

$$W = 2.303 RT \log_{10} \frac{V_2}{V_1}$$

23. A refrigerator freezes water at 0°C into 10kg ice at 0°C in time interval of 30 min. Assuming the room temperature to be 20°C , calculate the minimum amount of power needed to make 10kg of ice.

Sol. Amount of heat required to convert water into ice at 0°C ,

$$Q_2 = mL = (5\text{Kg}) \times (80)\text{Kcal/Kg}$$

$$= 400 \text{ Kcal}$$

$$\text{Now } T_1 = 20^\circ\text{C} = 273 + 20 = 293\text{K}$$

$$T_2 = 0^\circ\text{C} = 0 + 273 = 273 \text{ K}$$

$$\text{We know that } Q_2/W = T_2/(T_1 - T_2)$$

$$\text{Or } W = Q_2 \times (T_1 - T_2)/T_2$$

$$= 400 \times (293 - 273) / 273$$

$$= 29.3 \text{ Kcal} = 29.3 \times 4.2 \times 10^3 \text{ J}$$

$$= 123 \times 10^3 \text{ J}$$

$$\text{Time } t = 20 \text{ min} = 20 \times 60 = 1200\text{s}$$

$$\text{Power needed } P = W/t = 123 \times 10^3 / 1200 = 102.5 \text{ W}$$

24. A geyser heats water flowing at the rate of 3.0 litres per minute from 27°C to 77°C . If the geyser operates on a gas burner, what is the rate of consumption of the fuel if its heat of combustion is $4.0 \times 10^4 \text{ J/g}$?

Sol. Given, the water is flowing at a rate of 3.0 litre/ min, temperature changes from 27°C to 77°C and the heat of combustion is $4.0 \times 10^4 \text{ J/g}$.

Let specific heat of water be c .

Let Q be the total heat used, then

$$Q = mc\Delta T$$

Here, m is the mass of water flowing, ΔT is the temperature change.

Substitute the values in the above expression.

$$Q = 3000 \times 4.2 \times (77 - 27) = 6.3 \times 10^5 \text{ J/min}$$

Let R be the rate of consumption of the fuel, then

$$R = \frac{Q}{\text{heat of combustion}}$$

Substitute the value in the above expression,

$$R = \frac{6.3 \times 10^5}{4 \times 10^4} = 16 \text{ g/min}$$

Hence, the rate of combustion of the fuel is 16 g/min.

25. What amount of heat must be supplied to 2.0×10^{-2} kg of nitrogen at room temperature to raise its temperature by 45°C at constant pressure? Given molecular weight of N_2 is 28 and $R = 8.3 \text{ J mol}^{-1} \text{ K}^{-1}$ and C_v (diatomic gases) = $7/2 R$.

Sol. Given, the mass of nitrogen is 20×10^{-2} kg or 20 g, rise in temperature of nitrogen is 45°C , molecular mass of nitrogen is 28 and universal gas constant is $8.3 \text{ J/mol}\cdot\text{K}$.

Let n be the number of moles, then $n = \frac{m}{M}$

Here, m is the mass of nitrogen and M is the molar mass of nitrogen.

Substitute the value in the above expression.

$$n = \frac{20}{28} = 0.714$$

Let C_p be the molar specific heat at constant pressure for a diatomic gas, then

$$C_p = \frac{7}{2} R$$

Here, R is the universal gas constant.

Substitute the value in the above expression.

$$C_p = \frac{7}{2} \times 8.3 = 29.05 \text{ J/mol}\cdot\text{K}$$

Let Q be the amount of heat supplied to nitrogen, then

$$Q = n C_p \Delta T$$

Here, ΔT is the temperature rise.

Substitute the values in the above expression,

$$Q = 0.714 \times 29.05 \times 45 = 934 \text{ J}$$

Hence, the amount of heat supplied to nitrogen is 934 J.

26. In changing the state of a gas adiabatically from an equilibrium state A to another equilibrium state B, an amount of work equal to 22.3J is done on the system. If the gas is taken from state A to B via process in which the net heat absorbed by the system is 9.35 cal, how much is the net work done by the system in the latter case? (take $1 \text{ cal} = 4.19\text{J}$)

Sol. In the first case, the process is adiabatic. i.e $\Delta Q = 0$

$$22.3\text{J work is done on the system i.e. } \Delta W = -22.3\text{J}$$

$$\Delta Q = \Delta U + \Delta W$$

$$0 = \Delta u - 22.3$$

$$\Delta u = 22.3\text{J}$$

In the later process, the initial and final states are same as those in the former process, Δu will remain same for the later case.

In the later case, net heat absorbed by the heat is 9.35cal

$$\Delta Q = 9.35 \times 4.2$$

$$\Delta Q = 39.3 \text{ J}$$

$$\Delta W = \Delta Q - \Delta u$$

$$\Delta W = 39.3 - 22.3$$

$$\Delta W = 17 \text{ J}$$

The net work done in the system in this case is 17J.

27. Two cylinders A and B of equal capacity are connected to each other via a stopcock. The cylinder A contains a gas at standard temperature and pressure, while the cylinder B is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened.

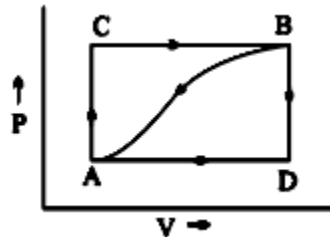
Answer the following:

- (i) What is the final pressure of the gas in A and B?
- (ii) What is the change in internal energy of the gas?
- (iii) What is the change in temperature of the gas?
- (iv) Do the intermediate states of the system (before settling to final equilibrium state) lie on its P-V-T surface?

Sol. Same as 17.

(5 Marks Questions)

28. When a system is taken from state A to state B along the path ACB, 80 kcal of heat flows into the system and 30 kcal of work is done



- (a) How much does heat flows into the system along path ADB if the work done is 10kcal?
- (b) When the system is returned from B to A along the curved path the work done is 20kcal. Does the system absorb or liberate heat?
- (c) If $U_A = 0$ and $U_D = 40\text{kcal}$, find the heat absorbed in the process AD.

Sol. Since ΔU is independent of path.

$$\therefore \Delta U(A \rightarrow B) = q(ACB) + w(ACB) = 80 - 30 = 50J$$

$$(a) \Delta U = 50J = q(ADB) + w(ADB)$$

$$\Rightarrow q(ADB) = 50 - (10) = 40J$$

$$(b) q(B \rightarrow A) = \Delta U(B \rightarrow A) - w(B \rightarrow A) = (-50) - 20 = -70J [\because \Delta U(A \rightarrow B) = -\Delta U(B \rightarrow A)]$$

Hence the system liberates heat.

$$(c) \Delta U(ADB) = \Delta U(A \rightarrow D) + \Delta U(D \rightarrow B)$$

$$\Rightarrow \Delta U(D \rightarrow B) = 50 - 40 = 10J$$

Again,

$$\Delta U(D \rightarrow B) = q(D \rightarrow B) + w(D \rightarrow B)$$

$\because V(D \rightarrow B)$ is constant.

$$\therefore w(D \rightarrow B) = 0$$

$$\therefore q(D \rightarrow B) = \Delta U(D \rightarrow B) = 10J$$

Now,

$$q(ADB) = q(A \rightarrow D) + q(D \rightarrow B)$$

$$\Rightarrow q(A \rightarrow D) = 40 - 10 = 30J [\because q(ADB) = 40J]$$

29. Describe melting and boiling process on the basis of first law of thermodynamics.

Sol. Melting process: Let us consider a solid of mass m . Let dQ be the amount of heat absorbed during the process of melting. Clearly, $dQ = mL_f \dots(i)$

Where L_f is the latent heat of fusion.

During melting, the change in volume is negligibly small, i.e. $dV = 0$

Thus $dW = PdV = 0 \dots(ii)$

From first law of thermodynamics, $dQ = dU + dW \dots(iii)$

From (i), (ii), (iii) we get

$$mL_f = dU \text{ or } dU = mL_f.$$

Thus by knowing m and L_f the gain in internal energy (dU) when a solid changes into a liquid can be easily calculated.

Boiling process: Refer to Q 17 Sec B.

30. Consider a PV diagram in which the path followed by one mole of perfect gas in a cylindrical container is shown in figure.

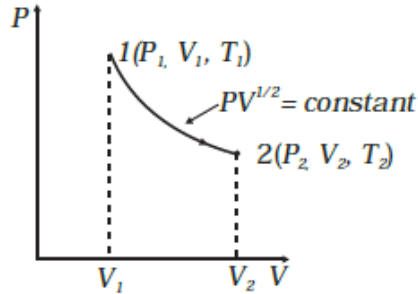


Fig. 12.9

- (a) Find the work done when the gas is taken from state 1 to state 2.
 (b) What is the ratio of temperature T_1/T_2 if $V_2 = 2V_1$?
 (c) Given the internal energy for one mole of gas at temperature T is $(3/2)RT$, find the heat supplied to the gas when it is taken from state 1 to state 2 with $V_2 = 2V_1$.

Sol. Given $PV^{1/2} = \text{constant} = C$

$$\begin{aligned} \text{(a) Work done by the gas, } \Delta W &= \int_{V_1}^{V_2} P dV = \int_{V_1}^{V_2} \frac{C}{\sqrt{V}} dV \\ &= C \left[\frac{V^{1/2}}{1/2} \right]_{V_1}^{V_2} = 2C[\sqrt{V_2} - \sqrt{V_1}] \end{aligned}$$

$$\text{Therefore } \Delta W = 2P_1\sqrt{V_1}(\sqrt{V_2} - \sqrt{V_1}) \dots \text{(i)}$$

(b) Since $PV = nRT$

$$\Rightarrow \frac{C}{\sqrt{V}} V = nRT \Rightarrow T = \frac{C}{nR} \sqrt{V}$$

$$\Rightarrow T \propto \sqrt{V} \dots \text{(ii)}$$

$$\therefore \frac{T_1}{T_2} = \frac{\sqrt{V_1}}{\sqrt{V_2}} = \frac{\sqrt{V_1}}{\sqrt{2V_1}} = \frac{1}{\sqrt{2}} \dots \text{(iii) (as } V_2 = 2V_1)$$

(c) Given $U = 3/2 RT$

$$\Rightarrow \Delta U = 3/2 R \Delta T = 3/2 R (T_2 - T_1)$$

$$\Rightarrow \Delta U = 3/2 RT_1(\sqrt{2} - 1) \text{ [using eqn (iii)]}$$

From eqn (i)

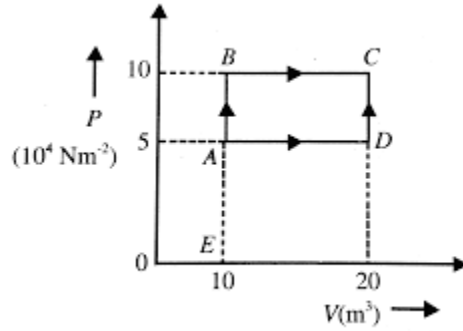
$$\Delta W = 2C[\sqrt{V_2} - \sqrt{V_1}] = 2C\sqrt{V_1}(\sqrt{2} - 1) \text{ [Using eqn (iii)] (as } PV^{1/2} = C)$$

$$= 2RT_1(\sqrt{2} - 1) \text{ [Using eqn (i) for one mole of gas]}$$

Therefore from first law of thermodynamics, $\Delta Q = \Delta U + \Delta W$

$$= 7/2 RT_1(\sqrt{2} - 1)$$

31. A sample of 2kg of monatomic helium (assumed ideal) is taken through the process ABC and another sample of 2kg of the same gas is taken through the process ADC (figure). Given molecular mass of Helium = 4, $R = 8.3 \text{ J mol}^{-1} \text{ K}^{-1}$.



- (a) What is the temperature of Helium in each of the states of A, B, C and D?
 (b) How much is the heat involved in each of the process ABC and ADC?

Sol. (a) Number of moles of He, $n = \frac{\text{Mass of He}}{\text{Molecular mass}} = \frac{2000}{4} = 500$

As $P_A V_A = nRT_A$

Therefore $T_A = \frac{P_A V_A}{nR} = \frac{5 \times 10^4 \times 10}{500 \times 8.3} = 120.5\text{K}$

For the isochoric process AB ($V = \text{constant}$).

$$\frac{T_B}{T_A} = \frac{P_B}{P_A} \therefore T_B = \frac{P_B}{P_A} \times T_A = \frac{10}{5} \times 120.5 = 241\text{K}$$

For the isobaric process BC ($P = \text{constant}$)

$$\frac{T_C}{T_B} = \frac{V_C}{V_B} \therefore T_C = \frac{V_C}{V_B} \times T_B = \frac{20}{10} \times 241 = 482\text{K}$$

For the isochoric process DC,

$$\frac{T_D}{T_C} = \frac{P_D}{P_C} \therefore T_D = \frac{P_D}{P_C} \times T_C = \frac{5}{10} \times 482 = 241\text{K}$$

(b) Heat involved in the process ABC, $Q_{ABC} = \Delta U_{AC} + W_{ABC} = nC_V(T_C - T_A) + W_{BC}$
 $= nC_V(T_C - T_A) + P_B(V_C - V_A)$
 $= 500 \times (3/2) \times 8.3 \times (482 - 120.5) + 10 \times 10^4 \times (20 - 10)$ (since $C_V = 3/2R$)
 $= 2.25 \times 10^6 + 10^6 = 3.25 \times 10^6\text{J} = 3.25\text{MJ}$

Heat involved in the process ADC, $Q_{ADC} = \Delta U_{AC} + W_{ADC} = \Delta U_{AC} + W_{AD}$
 $= 2.25 \times 10^6 + P_A(V_D - V_A) = 2.25 \times 10^6 + 5 \times 10^4 \times (20 - 10)$
 $= 2.75 \times 10^6\text{J} = 2.75\text{Mj}$

32. A mixture of 1.78kg of water and 262g of ice at 0°C is in a reversible process, brought to a final equilibrium state where the water/ice ratio by mass is 1:1 at 0°C .
- (i) Calculate the entropy change of the system during this process
- (ii) The system is returned to the first equilibrium state, but in an irreversible way (by using a Bunsen burner for instance). Calculate the entropy change of the system during this process.

Sol. a) Mass of water = 1.78 kg

Mass of ice = 262 g

So the total mass of ice and water mixture will be,

Mass of ice-water mixture = (Mass of water) + (Mass of ice)

$$= (1.78 \text{ kg}) + (262 \text{ g}) = (1.78 \text{ kg}) + (262 \text{ g} \times 10^{-3} \text{ kg/1 g}) = 1.78 \text{ kg} + 0.262 \text{ kg} = 2.04 \text{ kg}$$

If eventually the ice and water have the same mass, then the final state will have 1.02 kg (2.04 kg/2) of each.

Thus the mass of the water that changed into ice m will be the difference of mass of water m_w and mass of final state m_s .

So, $m = m_w - m_s$

To obtain mass of water that changed into ice m , substitute 1.78 kg for mass of water m_w and 1.02 kg for mass of final state m_s in the equation $m = m_w - m_s$,

$$m = m_w - m_s$$

$$= 1.78 \text{ kg} - 1.02 \text{ kg} = 0.76 \text{ kg}$$

The change of water at 0°C to ice at 0°C is isothermal.

To obtain the change in entropy ΔS of the system during this process, substitute 0.76 kg for mass m , $333 \times 10^3 \text{ J/kg}$ for heat of fusion of water L and 273 K for T in the equation

$$\Delta S = -mL/T,$$

$$\Delta S = -mL/T = -(0.76 \text{ kg}) (333 \times 10^3 \text{ J/kg}) / (273 \text{ K}) = -927 \text{ J/K}$$

From the above observation we conclude that, the change in entropy ΔS of the system during this process will be -927 J/K.

(b) Now the system is returned to the first equilibrium state, but in an irreversible way.

Thus the change in entropy ΔS of the system during this process is equal to the negative of previous case.

$$\text{So, } \Delta S = -(-927 \text{ J/K}) = 927 \text{ J/K}$$

From the above observation we conclude that, the change in entropy ΔS of the system would be 927 J/K.

33. Explain why:

(a) Two bodies at different temperature T_1 and T_2 (if brought in thermal contact do not necessarily settle to mean temperature $(T_1 + T_2)/2$.

(b) The coolant in a chemical or a nuclear plant (i.e. the liquid used to prevent the different parts of a plant from getting too hot) should have high specific heat.

(c) At pressure in a car tyre increases during driving.

(d) The climate of a harbour town is more temperate than that of a town in a desert at the same latitude.

Sol. (a) Law of conservation of Energy says that the energy is transferred from one body to another and from one format to another.

If we consider ideal conditions for heat transfer, when two bodies of temperature T_1 and T_2 come in thermal contact, heat transfer takes place from body of higher temperature to body of lower temperature.

The quantity thermal energy is the function of mass and temperature. Hence, the mean temperature of the bodies in contact will be given by the weighted average not normal average.

$$\therefore T_{\text{avg}} = (m_1 T_1 + m_2 T_2) / (m_1 + m_2)$$

Hence only when $m_1 = m_2$, then $T_{\text{avg}} = (T_1 + T_2) / 2$

(b) A coolant is required to have high heat capacity so that its temperature does not change much during heat transfer. Due to this, the coolant is able to hold more heat and allows quicker temperature drop in the hot body.

(c) As the car moves, temperature of the gas inside the tyre increases.

$$PV = nRT$$

Since volume is almost constant, air pressure increases.

(d) Water has a very high value of specific heat capacity. Due to this, the temperature of the water bodies do not change easily. Hence, climate near a harbour town is moderate.

Sand has a very low value of specific heat capacity. Due to this, the temperature of the sand changes rapidly. Hence, climate of a desert is extreme.

D. IIND LAW OF THERMODYNAMICS HEAT ENGINE AND REFRIGERATOR

(1 Mark Questions)

1. A heat engine has an efficiency η . Temperatures of source and sink are each decreased by 100K. The efficiency of the engine

- (a) increases (b) decreases (c) remains constant (d) becomes 1

Ans. (a)

2. When the door of a refrigerator is kept open then the room temperature starts

- (a) cool down (b) hot up
(c) first cool down and then hot up (d) neither cool down nor hot up

Sol. (b)

If a refrigerator's door is kept open, then room will become hot, because then refrigerator exhaust more heat into the room than earlier. In this way, temperature of the room increases and room becomes hot. No refrigerator is efficient.

3. Give two examples of heat pump.

Sol. Common types are air source heat pumps, ground source heat pumps, water source heat pumps and exhaust air heat pumps. They are also used in district heating systems.

4. State second law of thermodynamics.

Sol. The second law of thermodynamics asserts that heat cannot move from a reservoir of lower temperature to a reservoir of higher temperature in a cyclic process.

5. The conclusion of second law of thermodynamics is that

- (a) no heat engine can have efficiency η equal to zero.
- (b) no heat engine can have efficiency η equal to one.
- (c) no heat engine can have efficiency η greater than one.
- (d) no heat engine can have efficiency η less than one.

Sol. (b)

The efficiency $\eta = 1$ is maximum efficiency, it shows that the heat engine is 100% efficient which is practically not possible.

6. When the door of refrigerator is kept open we cannot cool the room. It may be against

- (a) conservation of energy
- (b) first law of thermodynamics
- (c) conservation of momentum
- (d) second law of thermodynamics

Ans. (d)

7. Which of the following processes described below is irreversible?

- (a) the increase in temperature of an iron rod by hammering it.
- (b) a gas in a small container at a temperature T_1 is brought in contact with a big reservoir at a higher temperature T_2 which increase the temperature of the gas.
- (c) an ideal gas is enclosed in a piston cylinder arrangement with adiabatic walls. A weight W is added to the piston resulting in compression of gas.
- (d) all of the above

Sol. (a)

The increase in temperature of an iron rod by hammering it is the irrevesible process.

8. Consider a Carnot cycle operating between source temperature 750K and sink temperature 350K producing 1.25kJ of mechanical work per cycle, the heat transferred to the engine by the reservoirs

- (a) 1.34 kJ
- (b) 3.24kJ
- (c) 3.34kJ
- (d) 4.34kJ

Ans. (b)

9. A Carnot engine absorbs 750J of heat energy from a reservoir at 137°C and rejects 500J of heat during each cycle, then the temperature of sink is

- (a) 0.25°C (b) 0.34°C (c) 0.44°C (d) 0.54°C

Ans. (b)

For carnot engine-

$$T_L/T_H = Q_L/Q_H$$

$$T_L/(137+273) = 500/750$$

$$T_L = (500 \times 410) / 750 = 273.333 \approx 273.34\text{K} = 0.34^\circ\text{C}$$

10. What are two essential features of Carnot ideal heat engine?

Sol. (i) Source and sink have infinite heat capacities. (ii) Each process of the engine's cycle is fully reversible.

(2 Marks Questions)

11. A refrigerator maintains eatables, kept inside at 9°C. If the room temperature is 36°C, calculate the coefficient of performance of the refrigerator.

Sol. Temperature inside the refrigerator, $T_1 = 9^\circ\text{C} = 282\text{ K}$
Room temperature, $T_2 = 36^\circ\text{C} = 309\text{ K}$

$$\begin{aligned} \text{Coefficient of performance} &= \frac{T_1}{T_2 - T_1} \\ &= \frac{282}{309 - 282} \end{aligned}$$

$$= 10.44$$

Therefore, the coefficient of performance of the given refrigerator is 10.44.

12. State the limitations of second law of thermodynamics.

Sol. One of the limitations of the second law of thermodynamics is that the entropy of the system must always remain the same or increase, in a closed system. However, creating a truly closed system is nearly impossible, so it is sometimes hard to apply to a natural system.

13. No real engine can have an efficiency greater than that of a Carnot engine working between the same two temperatures. Give reason.

Sol. The gas molecules have point sizes and have no attractive forces between them. Real engines cannot fulfil these conditions. Hence no heat engine working between the same two temperatures can have efficiency greater than that of a Carnot engine.

14. Can a Carnot engine be realized in practice?

Sol. No, because Carnot engine is an ideal heat engine whose conditions are not realized in practice.

(3 Marks Questions)

15. What is Carnot engine? What is its efficiency?

Sol. The Carnot engine is a theoretical thermodynamic cycle proposed by Leonard Carnot. It estimates the maximum possible efficiency that a heat engine during the conversion process of heat into work and, conversely, working between two reservoirs can possess.

16. A steam engine works with reservoirs at temperatures of 207°C and 37°C while a gasoline combustion engine has temperatures of 1550°C and 475°C. Which of the two engines is more efficient?

Sol. Efficiency of Carnot cycle = $1 - \frac{T_2}{T_1}$ where T_1 is temperature of reservoir and T_2 the temperature of engine.

$$\eta_A = 1 - \frac{1550}{207} = -6.5$$

$$\eta_B = 1 - \frac{475}{37} = -11.85$$

So, efficiency of A is greater than B.

17. A Carnot engine has efficiency 25%. It operates between reservoirs of constant temperatures with temperature difference of 80°C. What is the temperature of the low temperature reservoir?

Sol. Efficiency, $\eta = 1 - \frac{T_2}{T_1} = \frac{T_1 - T_2}{T_1} \cdot \frac{25}{100}$
 $= \frac{T_1(T_1 - 80)}{T_1} \cdot \frac{1}{4} = \frac{80}{T_1}$

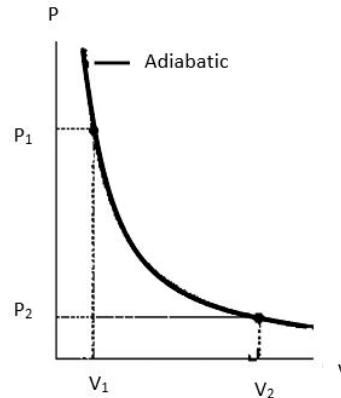
$$T_1 = 320 \text{ K } T_1 = 320 - 273 = 47^\circ\text{C}$$

The temperature of the low temperature reservoir = $47 - 80 = -33^\circ\text{C}$.

18. Derive the work done in an Adiabatic process.

Sol. Suppose we have a one-gram molecule of a perfect gas which has been enclosed in a non-conducting cylinder having a non-conducting piston. The gas will expand, if we move the piston slowly outwards and hence will do some work without any energy being supplied

from outside and thus adiabatic expansion will take place. And since the energy hasn't been used from outside, the temperature of the gas in the cylinder will fall.



Let us say the initial temperature, pressure and volume of the cylinder be T_1 , P_1 and V_1 and in its final state be T_2 , P_2 and V_2 .

Now, let the cross-sectional area of the piston be A and we move the piston through a small distance dx which makes the gas expand by a volume of dV . And for small expansion, the pressure change will be almost the same, say P . Now, for an adiabatic change $PV^\gamma = K$ (constant)

Therefore, $P = K/V^\gamma$

Thus, the work done, $W = \int_{V_1}^{V_2} P dV$

$$\Rightarrow W = \int_{V_1}^{V_2} \frac{K}{V^\gamma} dV = K \int_{V_1}^{V_2} V^{-\gamma} dV$$

$$\therefore W = K \left[\frac{V^{1-\gamma}}{1-\gamma} \right]_{V_1}^{V_2} = \frac{K}{1-\gamma} (V_2^{1-\gamma} - V_1^{1-\gamma})$$

Since, in adiabatic expansion, we know that

$$P_1 V_1^\gamma = P_2 V_2^\gamma = k$$

$$\text{Thus, } W = \left(\frac{1}{1-\gamma} \right) (P_2 V_2 V_2^{1-\gamma} - P_1 V_1 V_1^{1-\gamma})$$

$$\Rightarrow W = \left[\frac{R}{1-\gamma} \right] (P_2 V_2 - P_1 V_1)$$

Using, $PV = RTPV = RT$, we can also write the work done as,

$$W = \left[\frac{R}{1-\gamma} \right] (T_2 - T_1)$$

This is the equation for work done in adiabatic expansion.

19. A steam engine delivers 5.4×10^8 J of work per minute and services 3.6×10^9 J of heat per minute from its boiler. What is the efficiency of the engine? How much heat is wasted per minute? [Ans. 3.1×10^9 J]

Sol. Given, the work delivered by the steam engine per minute is 5.4×10^8 J and heat energy accepted by boiler per minute is 3.6×10^9 J.

Let W be the work done by engine and Q be the heat energy accepted by the boiler, so Efficiency = W/Q

Substitute the values in the above expression.
 Efficiency = $(5.4 \times 10^8) / (3.6 \times 10^9) = 0.15$ or 15%
 Hence, the efficiency of the engine is 15%.

Let H be the amount of heat wasted, so
 $H = W - Q$

Substitute the values in the above expression,
 $H = 3.6 \times 10^9 - 5.4 \times 10^8 = 3.1 \times 10^9 \text{ J}$

Therefore, the amount of heat wasted per minute is $3.1 \times 10^9 \text{ J}$.

20. A refrigerator is to maintain eatables kept inside at 9°C . If room temperature is 36°C , calculate the coefficient of performance.

Sol. Same as 11.

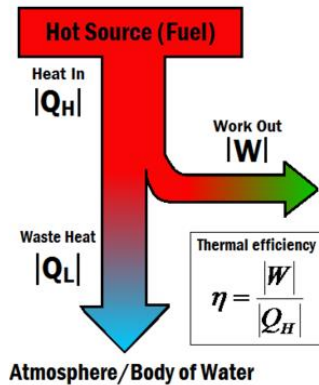
(5 Marks Questions)

21. (a) Explain the basic principle of a heat engine.

(b) Can the efficiency of a heat engine be 100%? Give reason for your answer.

Sol (a) A heat engine can be defined as a device that converts thermal energy into work. The thermal energy results from a temperature difference that is provided by a hot and a cold reservoir. The heat engine utilizes this difference in a thermodynamic cycle.

(b) It is impossible for heat engines to achieve 100% thermal efficiency (η) according to the Second law of thermodynamics. This is impossible because some waste heat is always produced in a heat engine, shown in Figure by the term. Although complete efficiency in a heat engine is impossible, there are many ways to increase a system's overall efficiency.



22. A refrigerator whose coefficient of performance β is 5 extracts heat from the cooling component at the rate of 250J per cycle.

(a) How much work per cycle is required to operate the refrigerator cycle?

(b) How much heat per cycle is discharged to the room which acts as high temperature reservoir?

Sol. (a) Work done per cycle $W = \frac{Q_2}{K} = \frac{250}{5} = 50\text{J}$

(b) Heat discharged per cycle $= Q_1 = Q_2 + W = 250 + 50 = 300\text{J}$.

23. State Carnot theorem. Prove that the efficiency of a reversible heat engine is maximum.

Sol. Carnot's theorem, also known as Carnot's rule, or the Carnot principle, can be stated as follows: No heat engine operating between two heat reservoirs can be more efficient than a reversible heat engine operating between the same two reservoirs.

A Reversible Heat Engines has the maximum efficiency

This is proved by assuming that there is a super heat engine with greater efficiency and showing that it contradicts Carnot's assumption. Consider the case where both the reversible heat engine and the super heat engine remove the same amount of heat energy from the hot reservoir. If the reversible heat engine delivers work out W and deposits heat $Q_c = Q - W$ in the colder reservoir, then the super heat engine delivers work $W_s = W + DW$ - additional work for the same heat input because it is more efficient - and heat $Q = Q - W - DW$ to the cold reservoir. Note that the super heat engine puts less heat into the cold reservoir because its greater efficiency turns more of the original heat into its extra work. Now if we operate the reversible heat engine in reverse taking W of the $W + DW$ work from the super heat engine to operate taking Q_c out of the cold reservoir and putting Q into the hot one. The combined operation of the two engines results in no change in the hot reservoir since one takes out Q and the other puts back Q . Heat energy is taken out of the cold reservoir since the reversible heat engine takes out slightly more than the super heat engine puts in and it shows up as extra work. This taking heat from a single reservoir and turning it to work with no other changes is a contradiction to the Carnot assumption.

Thus to stay consistent:

No heat engine can have efficiency greater than a reversible heat engine.

E. ASSERTION REASON TYPE QUESTION:

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of assertion.

(c) If assertion is true but reason is false

(d) If both assertion and reason are false

(e) If assertion is false but reason is true

1. Assertion: Specific heat of a body is always greater than its thermal capacity.

Reason: Thermal capacity is heat required for raising temperature of unit mass of the body through unit degree.

Ans. (d) Both Assertion and Reason are false

Specific heat of a body is amount of heat required to raise the temperature of unit mass of the body through unit degree. When mass of a body is less than unity, then its thermal capacity is less than its specific heat and vice-versa.

2. Assertion: In an adiabatic process, change in internal energy of a gas is equal to work done on or by gas in the process.

Reason: Temperature of gas remain constant in a adiabatic process.

Ans. (c) Assertion is true but reason is false

In an adiabatic process, no exchange of heat is permissible i.e., $dQ = 0$.

As $dQ = dU + dW = 0$. Therefore $dU = -dW$.

3. Assertion: A cloudy night is hotter than a clear sky night.

Reason: In the cloudy night, temperature of earth does not fall.

Ans. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

Since all radiation from the earth is reflected back to earth by clouds due to which temperature of the earth does not fall.

4. Assertion: Radiation is the speediest mode of heat transfer.

Reason: Radiation can be transmitted in zig-zag motion.

Ans. (c) Assertion is true but reason is false

Actually, the process of radiation does not require any material medium for transmission of heat. Thermal radiation travels with the velocity of light and hence the fastest mode of the transfer. Thermal radiation is always transmitted in a straight line.

5. Assertion: Animals curl into a ball, when they feel very cold.

Reason: Animals by curling their bodies reduces the surface area.

Ans. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

When the animals feel cold they curl their bodies into a ball so as to decrease the surface area of their bodies. As total energy radiated by body varies directly as the surface area of the body, the loss of heat due to radiation would be reduced.