Class XI

Thermodynamics worksheet 3

1. What is the foundation of Thermodynamics? 1

Ans. The foundation of thermodynamics is the law of conservation of energy and the fact the heat flows from a hot body to a cold body.

2. State Carnot's Theorem? 1

Ans. According to Carnot's Theorem, no engine working between two temperatures can be more efficient than a Carnot's reversible engine working between the same temperatures.

3. Differentiate between isothermal and adiabatic process? 2

Ans.

Isothermal process	Adiabatic process
In this, temperature remains constant	In this, temperature remains constant
It occurs slowly	It occurs suddenly.
System is thermally conducting to surroundings	System is thermally insulated from surroundings.
PV = constant	PV^{γ} = constant

4. A Carnot engine develops 100 H.P. and operates between 27 ^{0}C and 227 ^{0}C. Find 1) thermal efficiency; 2) heat supplied3) heat rejected? 3

Ans.

$$W = 100\,H.P = 100 \times 746\,W = \frac{74600}{4.2}\,cal/s$$

$$T_1 = 227\,^0C = 227 + 273 = 500K$$

$$T_2 = 27\,^0C = 27 + 273 = 300K$$

1) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{500} = \frac{2}{5} = 0.4 = 40\%$

2) $\eta = \frac{W}{Q_1}$

$$\frac{2}{5} = \frac{74600}{4.2Q_1}$$

$$Q_1 = 4.44 \times 10^4\,cal/s$$

3) $\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$

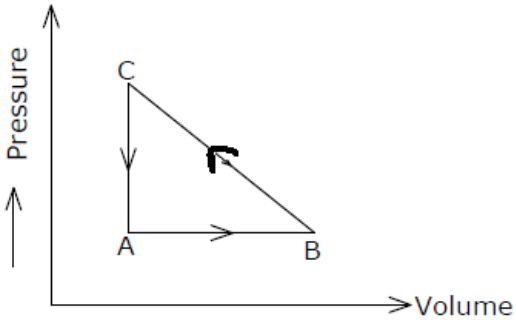
$$\frac{Q_2}{4.44 \times 10^4} = \frac{300}{500}$$

$$Q_2 = 2.6 \times 10^4\,cal/s$$

5. The internal energy of a compressed gas is less than that of the rarified gas at the same temperature. Why? 2

Ans. The internal energy of a compressed gas is less than that of rarified gas at the same temperature because in compressed gas, the mutual attraction between the molecules increases as the molecules comes close. Therefore, potential energy is added to internal energy and since potential energy is negative, total internal energy decreases.

6. Consider the cyclic process ABCA on a sample 2 mol of an ideal gas as shown. The temperature of the gas at A and B are300 K and 500K respected. Total of 1200 J of heat is withdrawn from the sample. Find the work done by the gas in part BC? 3



Ans. The change in internal energy during the cyclic process is zero. Therefore, heat supplied to the gas is equal to work done by it.

$W_{AB} + W_{BC} + W_{CA} = -1200J$

The work done during the process AB is

$W_{AB} = P_A(V_B - V_A) = nR(T_B - T_A) = 2 \times 8.3 \times (500 - 300) = 3320J$

$W_{CA} = 0J$ [volume of gas remains constant]

$3320 + W_{BC} + 0 = -1200J$

$W_{BC} = -1200 - 3320 = -4520J$

7. A refrigerator placed in a room at 300 K has inside temperature 264K. How many calories of heat shall be delivered to the room for each 1 K cal of energy consumed by the refrigerator, ideally? 3

Ans.

$$\beta = \frac{T_2}{T_1 - T_2} = \frac{264}{300 - 264} = \frac{22}{3}$$

$$\beta = \frac{Q_2}{W}$$

$$\frac{22}{3} = \frac{Q_2}{1}$$

$$Q_2 = \frac{22}{3} Kcal$$

$$W = Q_1 - Q_2$$

$$1 = Q_1 - \frac{22}{3}$$

$$Q_1 = \frac{25}{3} Kcal = 8.33 Kcal$$

8 If the door of a refrigerator is kept open in a room, will it make the room warm or cool? 1

Ans. Since a refrigerator is a heat engine that operates in the reverse direction i.e. it extracts heat from a cold body and transforms it to hot body. Since it exhaust more heat into room than it extracts from it. Therefore, the net effect is an increase in temperature of the room.

9 Five moles of an ideal gas are taken in a Carnot engine working between 100 ^{0}C and 30 ^{0}C. The useful work done in 1 cycle is 420J. Calculate the ratio of the volume of the gas at the end and beginning of the isothermal expansion? 3

Ans. $W = 420J$

$T_1 = 100\,^0C = 100 + 273 = 373K$

$T_2 = 30\,^0C = 30 + 273 = 303K$

$n = 5$

$$\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$$

$$Q_2 = \frac{303}{373}Q_1$$

$$W = Q_1 - Q_2$$

$$420 = Q_1 - \frac{303}{373}Q_1$$

$$420 = \frac{70}{373}Q_1$$

$$Q_1 = 2238J$$

$$Q_2 = Q_1 - W = 2238 - 420 = 1818J$$

When the gas is carried through Carnot cycle, the heat absorbed Q_1 during isothermal expansion is equal to the work done by gas.

In isothermal expansion

$$Q_1 = 2.303nRT_1 \log_{10}\left(\frac{V_2}{V_1}\right)$$

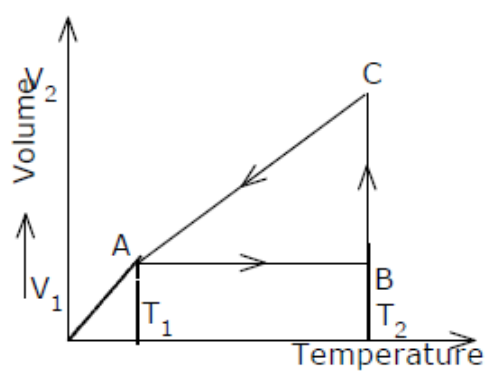
$$2238 = 2.303 \times 5 \times 8.4 \times 373 \times \log_{10}\left(\frac{V_2}{V_1}\right)$$

$$\log_{10}\left(\frac{V_2}{V_1}\right) = \frac{2238}{2.303 \times 5 \times 8.4 \times 373}$$

$$\log_{10}\left(\frac{V_2}{V_1}\right) = 0.062$$

$$\frac{V_2}{V_1} = 1.15$$

10. The following figure shows a process ABCA per formed on an ideal gas, find the net heat given to the system during the process? 3



Ans. Since the process is cyclic, the change in internal energy is zero. Therefore, the heat given to the system is equal to work done by it.

The net work done by the gas in the process ABCA is $W = W_{AB} + W_{BC} + W_{CA}$

During path AB, volume remains constant so $W_{AB} = 0$

During path BC, temperature remains constant so $W_{BC} = nRT_2 \log\left(\frac{V_2}{V_1}\right)$

During path AC, $V \ \alpha \ T$ so $\frac{V}{T} = const.$

$i.e.\ P = \frac{nRT}{V} = const.$

$\therefore\ W_{CA} = P\left(V_1 - V_2\right) = nR\left(T_1 - T_2\right) = -nR\left(T_2 - T_1\right)$

So, $W = 0 + nRT_2 \log\left(\frac{V_2}{V_1}\right) - nR\left(T_2 - T_1\right) = nR\left[T_2 \log\left(\frac{V_2}{V_1}\right) - \left(T_2 - T_1\right)\right]$