SHIKSHA CLASSES

BOARD ANSWER PAPER

Subject : Physics **Topic: 3. Thermodynamics** **Total Marks : 20**
Class : XII

Q.1 : A) Select and write the most appropriate answer from given alternatives in each sub-question. **4M**

1) During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio of C_p/C_v of the gas is.

Ans. : a) 3/2

Given : $P \alpha T^3$

but we know adiabatic process,

Pressure $P \times T^{\gamma/\gamma-1}$ so

$\frac{\gamma}{\gamma-1} = 3 \qquad \gamma = \frac{3}{2}$

$$\boxed{\frac{C_P}{C_V} = \frac{3}{2}}$$

2) If 300 ml of a gas at 27^0 C is cooled to 7^0 C at constant pressure, then its volume will be.

Ans. : b) 280 ml

3) The internal energy of ideal gas depends upon.

Ans. : b) Temperature

4) The state of thermodynamic system is represented by

Ans. : b) Pressure, volume, temperature

Q.1 : B) Very short answers type questions. **2M**

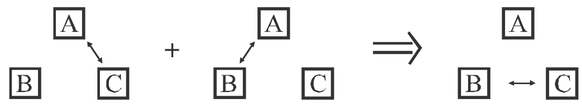
1) Define reversible and irreversible process.

Ans. : **Reversible Process :** The process can return back in such a way that both the system and the surrounding return to their original state, with no other change any where else in the system are called Reversible Process.

Irreversible Process : The process cannot be restored to their original states at the same time is called Irreversible process.

2) **State and explain zeroth law of thermodynamics.**

Ans.: ''If two systems are each in thermal equilibrium with a third system, they are also in thermal equilibrium with each other''.



Schematic representation of Zeroth law of thermodynamics

Shows a schematic representation of the Zeroth law of thermodynamics. The double arrow represents thermal equilibrium between systems. If system A and C are in thermal equilibrium, and systems A and B are in thermal equilibrium, then systems B and C must be in thermal equilibrium. Then systems A, B and C are at the same temperature.

Q.2 : Attempt any THREE. **6M**

1) **Distinguish between isothermal process & adiabatic process.**

Ans.:

Isothermal Process	Adiabatic Process
1. There is an exchange of heat between the system and the outside surrounding.	1. There is no exchange of heat between the system and the outside surrounding.
2. The temperature of the material involved remains same.	2. The temperature of the material involved may increase.
3. Heat can be added or released from the system just to keep the same temperature.	3. There is no heat added or released from the system.
4. Here transformation is slow.	4. Here transformation is fast.
5. Here temperature of the system remains constant.	5. In these types of process total heat content of the system remains constant

2) **What will be rise temperature if ideal gas at 27^0 C is compressed adiabatically to 8/27 of its original volume?** $(\gamma = 5/3)$

Ans.: In an adiabatic process,

$TV^{\gamma-1} =$ constant

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} \qquad \frac{300}{T_2} = \left(\frac{\frac{8}{27}V}{V}\right)^{\frac{5}{3}-1} = \left(\frac{8}{27}\right)^{\frac{2}{3}} = \frac{4}{9}$$

$$T_2 = 300 \times \frac{9}{4} = 675K$$

$\therefore$ Rise in temperature $= 675 - 300 = 375K$

3) A system is given 300 calories of heat and it does 600 joules of work. How much does internal energy change in this process (J= 4.18 Joules/cal)

Ans. : Work = 600 Joules, Q = 300 calories

J = 4.18 Joule / cal

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

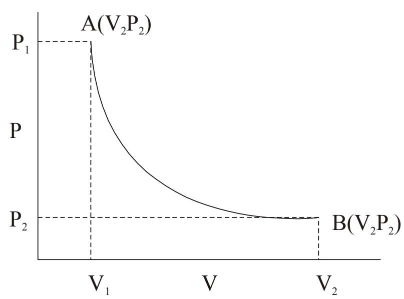
$\Delta U = J\Delta Q + \Delta W$

$\Delta U = 4.18 \times 300 - 600$

$\boxed{\Delta U = 654 \text{ Joule}}$.

4) Draw a p-v diagram and explain concept of positive and negative work. Give one example each.

Ans. :



P – V Diagram

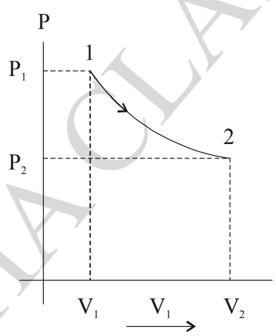
V_1 – Initial volume

V_2 – Final volume

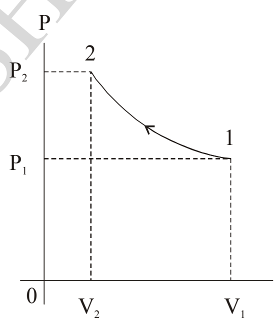
P_1 – Initial pressure

P_2 – Final pressure

Positive work :



In above Figure, Volume changes due to outward displacement of piston and pressure of the gas decreases the work done by the gas in this case is positive because the volume of the gas has increased.

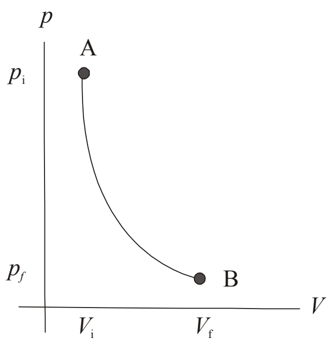


Similarly above fig. shows compression due to inward displacement of the piston. The pressure of the gas is increased and the work done by the gas is now negative.

Q.3 : Attempt any one of following. 3M

1) **State the equation of adiabatic process, give the adiabatic relation between i) Volume and temperature and ii) Pressure and temperature.**

Ans. :



p-V diagram of adiabatic process

For an adiabatic process, we have,

$$pV^{\gamma} = \text{constant} = C \quad \text{---(i)}$$

γ - is the ratio of the specific heat at constant pressure to specific at constant volume, i.e. $\gamma = \dfrac{C_p}{C_V}$

γ is also called adiabatic ratio. The change in internal energy is

$$\Delta U = C_v(\Delta T)$$

The work done is,

$$W = \int_{V_i}^{V_f} pdV$$

From eq^n (i)

$$W = \int_{V_i}^{V_f} \frac{dV}{V^{\gamma}}$$

$$W = C \times \left[\frac{V^{(-\gamma+1)}}{1-\gamma}\right]_{V_i}^{V_f}$$

where V changes from V_i to V_f

$$W = \frac{C}{(1-\gamma)} \times \left[\frac{1}{V_f^{(\gamma+1)}} \frac{1}{V_i^{(\gamma-1)}}\right] \quad \text{---(iii)}$$

From eq^n (i)

$$pV^{\gamma} = C \text{ or } p_i V_i^{\gamma} = p_f V_f^{\gamma}$$

From eq^n (iii)

$$W = \frac{1}{(1-\gamma)} \times \left[\frac{p_f V_f^{\gamma}}{V_f^{(\gamma-1)}} - \frac{p_i V_i^{\gamma}}{V_i^{(\gamma-1)}} \right]$$

$$W = \frac{1}{(1-\gamma)} \times (p_f V_f - p_i V_i) \quad \text{----(iv)}$$

$$W = \frac{nR(T_i - T_f)}{(1-\gamma)} = \frac{(p_f V_f - p_i V_i)}{(1-\gamma)} \quad \text{---(v)}$$

eq^n (v) implies that when work is done by the gas i.e. when the gas expands.

2) 2 mole of a gas at temp 300 K expands isothermally from an initial volume of 3.0L to final volume of 6.0L.what is the work done by the gas? How much heat is supplied to the gas? (R = 8.31 mol^{-1} k^{-1})

Ans. : **Given :** a) $W = nRT\, In \left(\frac{V_f}{V_i} \right)$

$V_f = 6.0L$
$V_i = 3.0L$
$W = 2 \times 300.\, In \left(\frac{6L}{3L} \right) \times 8.31$

$$= W = 2 \times 8.31 \times 300 \times In(2)$$

$$= W = 2 \times 8.31 \times 300 \times 0.693$$

$$W = 3459.40$$

$$\boxed{W = 3.459 KJ}$$

b) Heat supplied isothermal system, is spent to do work an a system,
(First law of thermodynamist)

$$\boxed{Q = W = 3.459\ KJ}$$

Q.4 : Attempt any one. **05M**

1) a) A mixture of fuel and oxygen is burned in a constant-volume chamber surrounded by a water bath. It was noticed that the temperature of water increased during the process. Treating the mixture of fuel and oxygen as the system. a) Has heat been transferred? a) Has work been done? c) What is the sign of ΔU?

Ans. : A mixture of fuel and oxygen is burned in a constant - volume chamber surrounded by a water bath it was noticed that the temperature of water increased during the process.

a) Has heat been transferred?

→ Yes heat is transferred from the system to water.

b) Has work been done?

→ No, work is not done because there is no volume change.

c) What is the sign of ΔU ?

→ ΔU mean internal energy of the system. When amount of heat Q is added to the system and the system does not do any work during process, its internal energy increases by amount, $\boxed{\Delta U = Q}$.

b) 104 kJ of work is done on certain volume of a gas. If the gas releases 125 kJ of heat, calculate the change in internal energy of the gas.

Ans. : Work done on gas, W = – 104 KJ

& heat released by the gas

Q = – 125 KJ

∴ First law of thermodynamics,

$$\Delta U = |Q| - |W|$$

$$\Delta U = (125 - 104)$$

$$\boxed{\Delta U = -21\,KJ}$$

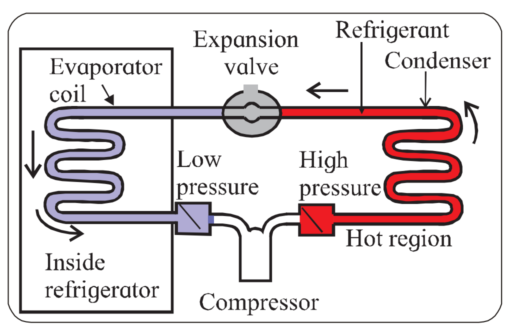
OR

a) What is refrigerator? Explain its working and obtain an expression for its coefficient of performance.

b) 1 mm³ of a gas compressed at 1 atmospheric pressure and temperature 27⁰ C to 627⁰ C. What is the final pressure under adiabatic condition? (γ for gas = 1.5)

Ans. : a) a Refrigerator consists of a compressor, an expansion valve, and a closed tube which carries the refrigerant. Part of the tube, called the cooling coil, is in the region which is to be cooled at lower temperature and lower pressure. The other part which is exposed to the surrounding (generally, the atmosphere) is at a higher temperature and higher pressure.

Consider the energy flow diagram of a refrigerator fig. It shows the relation between the work and heat involved in transferring heat from a low temperature region to a high temperature region. This is a cyclic process in which the working substance, the refrigerant in this case, is taken back to the initial state.



(a): Schematics of a refrigerator.

For a refrigerator, the heat absorbed by the working substance is Q_C and the heat rejected by it is Q_H. A refrigerator absorbs heat at lower temperature and rejects it at higher temperature, therefore, we have, $Q_C > 0$, $Q_H < 0$, and $W < 0$. Hence, we write, |W| and $|Q_H| = -Q_H$. In this case, we apply the first law of thermodynamics to the cyclic process. For a cyclic process, the internal energy of the system in the initial state and the final state is the same, therefore, from Eq., we have

$Q_H + Q_C = W$, or $| Q_H + Q_C - W = 0$

$\therefore \quad -Q_H = Q_C - W$

For a refrigerator, $Q_H < 0$, and $W < 0$, therefore,

$| Q_H | = | Q_C | + | W|$ ---(i)

From the fig., we realize that the heat $|Q_H|$ rejected by the working substance at the hot reservoir is always greater than the heat Q_C received by it at the cold reservoir. Note that the Eq. (i), derived for a refrigerator and the Eq., derived for a heat engine, are the same. They are valid for a heat engine and also for a refrigerator.

The ratio $\frac{|Q_C|}{|W|}$ indicates the performance of a refrigerator and is called the coefficient of performance (CoP), K, or quality factor, or Q-value of a refrigerator. Larger is the ratio, better is the refrigerator. That means a refrigerator has the best performance when the heat extracted by the refrigerant at the cold reservoir is maximum by doing minimum work in one operating cycle.

From Eq, $| W | = | Q_C | - | Q_H |$

$$\therefore K = \frac{|Q_C|}{|W|} = \frac{|Q_C|}{|Q_C| - |Q_H|} \quad \text{---(ii)}$$

All the quantities on the right side of Eq. (ii) represent energy and are measured in the same energy units. The coefficient of performance, K of a refrigerator is, therefore, a dimensionless number. For a typical household refrigerator, $K \approx 5$.

b) $p = 10^5$ N/m^2, $T_1 = 27 + 273 = 300$ K

$T_2 = 627 + 273 = 900$ K $\gamma = 3/2$

For adiabatic change $\frac{P^{\gamma}}{P^{\gamma} - 1}$ = constant

$$\left(\frac{P_2}{P_1}\right)^{1/2} = \left(\frac{T_2}{T_2}\right)^{3/2}$$

$$\left(\frac{P_2}{10^5}\right)^{1/2} = \left(\frac{900}{300}\right)^{3/2}$$

$$\boxed{\therefore P_2 = 27 \times 10^5 \ N/m^2}$$

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