THERMODYNAMICS

ONE Mark questions and answer

1. What do you understand by pure substance?

A pure substance is defined as one that is homogeneous and invariable in chemical composition throughout its mass.

2. Define thermodynamic system.

A thermodynamic system is defined as a quantity of matter or a region in space, on which the analysis of the problem is concentrated.

3. Name the different types of system.

1. Closed system (only energy transfer and no mass transfer)
2. Open system (Both energy and mass transfer)
3. Isolated system (No mass and energy transfer)

4. What is meant by closed system? Give an example

When a system has only heat and work transfer, but there is no mass transfer, it is called as closed system.

**Example**: Piston and cylinder arrangement.

5. Define a open system, Give an example.

When a system has both mass and energy transfer it is called as open system. **Example**: Air Compressor.

6. Define an isolated system
Isolated system is not affected by surroundings. There is no heat, work and mass transfer take place. In this system total energy remains constant.

**Example:** Entire Universe

7. **Define: Specific heat capacity at constant pressure.**

   It is defined as the amount of heat energy required to raise or lower the temperature of unit mass of the substance through one degree when the pressure kept constant. It is denoted by $C_p$.

8. **Define: Specific heat capacity at constant volume.**

   It is defined as the amount of heat energy required to raise or lower the temperature of unit mass of the substance through one degree when volume kept constant. It is denoted by $C_v$. 
9. What is meant by surroundings?

Any other matter outside the system boundary is called as surroundings.

10. What is boundary?

System and surroundings are separated by an imaginary line is called boundary.

11. What is meant by thermodynamic property?

Thermodynamic property is any characteristic of a substance which is used to identify the state of the system and can be measured, when the system remains in an equilibrium state.

12. Name and explain the two types of properties.

The two types of properties are intensive property and extensive property.

**Intensive Property**: It is independent of the mass of the system.
Example: pressure, temperature, specific volume, specific energy, density.

**Extensive Property**: It is dependent on the mass of the system.

Example: Volume, energy. If the mass is increased the values of the extensive properties also increase.

13. What is meant by thermodynamic equilibrium?

When a system is in thermodynamic equilibrium, it should satisfy the following three conditions.

(a) Mechanical Equilibrium :- Pressure remains constant

(b) Thermal equilibrium :- Temperature remains constant

(c) Chemical equilibrium: There is no chemical reaction.

14. Explain Mechanical equilibrium.
If the forces are balanced between the system and surroundings are called Mechanical equilibrium

15. Explain Chemical equilibrium.

If there is no chemical reaction or transfer of matter form one part of the system to another is called Chemical equilibrium

16. Explain Thermal equilibrium.

If the temperature difference between the system and surroundings is zero then it is in Thermal equilibrium.

17. What is Quasi – Static process?
The process is said to be quasi – static, it should proceed infinitesimally slow and follows continuous series of equilibrium states at all times. Therefore, the quasi static process may be a reversible process.

**18. Define Path function.**

The work done by a process does not depend upon the end of the process. It depends on the path of the system follows from state 1 to state 2. Hence work is called a path function.

**19. Define point function.**

Thermodynamic properties are point functions. The change in a thermodynamic property of a system is a change of state is independent of the path and depends only on the initial and final states of the system.

**20. Explain homogeneous and heterogeneous system.**

The system consist of single phase is called homogeneous system and the system consist of more than one phase is called heterogeneous system.

**21. What is a steady flow process?**

Steady flow means that the rates of flow of mass and energy across the control surface are constant.

**TWO MARKS QUESTION-**

**22. Prove that for an isolated system, there is no change in internal energy.**

In isolated system there is no interaction between the system and the surroundings. There is no mass transfer and energy transfer. According to first law of thermodynamics as

\[
dQ = dU + dW; \quad dU = dQ - dW; \quad dQ = 0, \quad dW = 0,
\]

Therefore \(dU = 0\) by integrating the above equation \(U = \text{constant}\), therefore the internal energy is constant for isolated system.
23. Indicate the practical application of steady flow energy equation.


24. Define state.

The condition of the system at particular time.

25. Define the term process and path

Process

Any change that a system undergoes from one equilibrium state to another is called a process.

Path

Series of states through which a system passes during a process is called the path.
26. **Define the term Cycle**

It is defined as a series of state changes such that the final state is identical with the initial state.

27. **Define Zeroth law of Thermodynamics.**

When a body A is in thermal equilibrium with body B and also separately with a body C, then B and C will be in thermal equilibrium with each other.

28. **What are the limitations of first law of thermodynamics?**

1. According to first law of thermodynamics heat and work are mutually convertible during any cycle of a closed system. But this law does not specify the possible conditions under which the heat is converted into work.

2. According to the first law of thermodynamics it is impossible to transfer heat from lower temperature to higher temperature.

3. It does not give any information regarding change of state or whether the process is possible or not.

4. The law does not specify the direction of heat and work.

29. **What is perpetual motion machine of first kind or PMMI?**

It is defined as a machine, which would continuously supply mechanical work without some other form of energy disappearing simultaneously. It is impossible to obtain in actual practice, because no machine can produce energy of its own without consuming any other form of energy.
30. Define the term enthalpy?

The Combination of internal energy and flow energy is known as enthalpy of the system. It may also be defined as the total heat of the substance.

Mathematically, enthalpy \((H) = U + PV\) KJ

3 Marks Questions

5. A thermos bottle containing coffee is shaken. If coffee is considered as a system
   (i) Does its temperature rise
   (ii) has heat been added to it
   (iii) has work done on it
6. Two samples of a gas initially at same temperature & pressure are compressed from a volume \(v\) to \(\frac{v}{2}\). One sample is compressed isothermally and the other adiabatically. In which sample is the pressure greater.
7. Draw the PV diagram showing Isothermal & Adiabatic Processes for an Ideal Gas.
8. Compare the slopes of an Isothermal & Adiabatic.

   or

   Show that Adiabatic is steeper than an Isothermal
9. Distinguish between Cyclic & Non Cyclic Process. Give one example each.
10. What are Intensive Variables and Extensive Variables. Give three examples each.
5 Marks Questions

1. Define Specific heat at Constant Pressure and Specific heat at constant volume. Derive Mayer’s relation.

2. State & explain First law of Thermodynamics. Apply First law of Thermodynamics to
   (1) Isothermal Process       (2) Isochoric Process
   (3) Adiabatic Process       (4) Isobaric Process


4. Derive an expression for the efficiency of a Carnot’s Engine. On what factors does it depend?

5. Show that for a Carnot Engine efficiency
   \[ \eta = 1 - \frac{T_2}{T_1} \]

6. What is a refrigerator. Describe the constructions & obtain the expression for its coefficient of performance.

7. State First law of Thermodynamics. Apply First law of Thermodynamics to derive an expression for the change in internal energy during melting and boiling processes.

NUMERICALS (level –I)

1. A heat engine is operated between ice point and boiling point of water find its efficiency.

2. If work done on a system is 20J. Its final energy is 10J. Then find its initial internal energy for isothermal process.

3. Find the value of $c_v$ for one mole of neon gas.

4. Find value of $c_p$ for a diatomic gas.

5. If the change in internal energy for an ideal gas is 5J. Find the amount of work done if heat given to the system is 12J.

NUMERICALS (level –II)

1. What is the efficiency of a Carnot Engine working between ice point and steam point?

   Solution

   Temperature of source,
   
   $T_1$ = Steam point = 373 K

   Temperature of sink,
   
   $T_2$ = Ice point = 273 K

   Efficiency,
   
   $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{273}{373} = 0.268 = 26.8\%$

2. The source temperature of a Carnot Engine is $127^\circ C$. It takes 500 cal of heat from the source and rejects 400 cal to the sink during each cycle. What is temperature of the sink?

   Solution

   Here $T_1 = 127 + 273 = 400$ K,

   $Q_1 = 500$ cal, $Q_2 = 400$ cal

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

   $\therefore T_2 = \frac{Q_2}{Q_1} \times T_1 = \frac{400}{500} \times 400$

   $= 320$ K $= 320 - 273 = 47^\circ C$
3. A Carnot engine takes $3 \times 10^6 \text{cal}$ of heat from a reservoir at 627°C and gives it to a sink at 27°C. Find the work done by the engine.

Solution

Here $T_1 = 627 + 273 = 900 \text{ K}$

$T_2 = 27 + 273 = 300 \text{ K}, \quad Q_1 = 3 \times 10^6 \text{cal}$

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

$Q_2 = \frac{T_2}{T_1} \times Q_1 = \frac{3 \times 10^6 \times 300}{900} = 10^6 \text{cal}$

Work done by the engine,

$W = Q_1 - Q_2 = 3 \times 10^6 - 10^6 \text{cal} = 2 \times 10^6 \text{cal}$

$= 2 \times 10^6 \times 4.2 \text{ J} = 8.4 \times 10^6 \text{ J}$

4. An engine has been designed to work between source and sink at temperatures 177°C and 27°C respectively. If the energy input is 3600 J, what is the work done by the engine?

Solution

Here $T_1 = 177 + 273 = 450°C$,

$T_1 = 27 + 273 = 300°C, \quad Q_1 = 3600 \text{J}$

$Q_2 = \frac{T_2}{T_1} \times Q_1 = \frac{300 \times 3600}{4500} = 2400 \text{J}$

$\therefore W = Q_1 - Q_2 = 3600 - 2400 = 1200 \text{J}$

5. A Carnot engine absorbs 1000 J of heat from a reservoir at 127°C and rejects 600 J of heat during each cycle. Calculate (i) efficiency of the engine (ii) temperature of the sink and (iii) amount of the useful work done during each cycle.

Solution

(i) $Q_1 = 1000 \text{J}, \quad Q_2 = 600 \text{J}$

$T_1 = 127 + 273 = 400 \text{K}$

$\therefore \eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{600}{1000} = 0.4 = 40\%$

$T_2 = \frac{Q_2}{Q_1} \times T_1 = \frac{600}{1000} \times 400 = 240 \text{ K} = -33°C$
(iii) \[ W = Q_1 - Q_2 = 1000 - 600 = 400 \text{ J} \]

6. A reversible heat engine operates with an efficiency of 50%. If during each cycle it rejects 150 cal to a reservoir of heat at 30°C, then (i) what is the temperature of the other reservoir and (ii) how much work does it carry out per cycle?

Solution

Here \( Q_1 = 150 \text{ cal} \),

\[ T_2 = 30 + 273 = 303 \text{ K} , \eta = 50\% = \frac{1}{2} \]

(i) As \( \eta = 1 - \frac{T_2}{T_1} \), \( \therefore \frac{1}{2} = 1 - \frac{303}{T_1} \)

or \( T_1 = 606 \text{ K} = 333°C \)

(ii) \( Q_1 = \frac{T_1}{T_2} \times Q_2 = \frac{606}{303} \times 150 = 300 \text{ cal} \)

\[ \therefore W = Q_1 - Q_2 = 300 - 150 = 150 \text{ cal} \]

\[ = 150 \times 4.2 \text{ cal} = 630 \text{ J} \]

7. The efficiency of a Carnot cycle is 1/6. If on reducing the temperature of the sink by 65°C, the efficiency becomes 1/3, find the initial and final temperatures between which the cycle is working.

Solution

Given \( \eta_1 = \frac{1}{6} \), \( \eta_2 = \frac{1}{3} \)

If the temperatures of the source of the and the sink between which the cycle is working are \( T_1 \) and \( T_2 \), then the efficiency in the first case will be

\[ \eta_1 = \frac{T_2}{T_1} \times \frac{1}{6} = 1 - \frac{T_2}{T_1} \quad \text{..... (1)} \]

In the second case, the temperature of the sink is reduced by 65°C Hence

\[ \eta_2 = 1 - \frac{T_2 - 65}{T_1} \times \frac{1}{3} = 1 - \frac{T_2 - 65}{T_1} \quad \text{..... (2)} \]

Solving equations (1) and (2), we get

\[ T_1 = 390 \text{ K} = 117°C, \quad T_2 = 325 \text{ K} = 52°C \]
8. A reversible engine converts one sixth of heat input into work. When the temperature of the sink is reduced by 62 C, its efficiency is doubled. Find the temperature of the source and the sink.

Solution

Here \( \eta = 1 - \frac{T_2}{T_1} \) or \( \frac{5}{6} \)

When the temperature of the sink is reduced by 62 C or 62 K, efficiency is doubled.

\[ T'_2 = T_2 - 62, \eta' = \frac{1}{6} \times 2 = \frac{1}{3} \]

\[ T_1 = 372 \text{ K} \]

\[ T_2 = 5/6 \times T_1 = 5/6 \times 372 = 310 \text{ K} \]

9. A Refrigerator has to transfer an average of 263 J of heat per second from temperature 10 C to 25 C. Calculate the average power consumed assuming no energy losses in the process.

Solution. \( T_1 = 298 \text{ K} \)

\[ T_2 = 263 \text{ K} \]

\[ \frac{Q_1}{Q_2} = \frac{T_1}{T_2} \]

\[ Q_2 = 298 \text{ J/s} \]

Average power consumed \( W = 298 - 263 = 35 \text{ W} \)

NUMERICALS (LEVEL - 3)

1. A lead bullet penetrates into a slid object and melts. Assuming that 50% of K.E. was used to heat it, calculate the initial speed of bullet. The initial temperature of bullet is 27 C and its melting point is 327 C. Latent heat of fusion of lead = 2.5 X 10^4 J Kg^-1 K^-1.

Ans. Here, let \( m \) be the mass of bullet. Heat required to raise its temperature from 27 C to 327 C.

Since, 327 C = 600 K

\[ 27 \text{ C} = 300 \text{ K} \]

\[ \Delta Q_1 = mc\Delta T = 125 \times m \times (600 - 300) = (3.75 \times 10^4)m \text{ J.} \]

Heat required to melt the bullet

\[ \Delta Q_2 = mL = m \times 2.5 \times 10^4 \text{ J} \]

If \( v \) is the initial velocity of the bullet, then K.E. of bullet = \( \frac{1}{2} \)mv^2

As heat developed = \( \frac{1}{2} \) K.E. = \( \frac{1}{2} \times \frac{1}{2} \)mv^2

Therefore, \( 3.75 \times 10^4m + 2.5 \times 10^4m = \frac{1}{4} \)mv^2
6.25 X 10^4 m = \frac{1}{2} mv^2, this implies v = \sqrt{4 \times 6.5 \times 10^4} \\
This implies v = 5 \times 10^3 m/s.

2. In an experiment on the specific heat of the metal, a 0.2 kg block of the metal at 150°C is dropped in a copper calorimeter (of water equivalent 0.025 kg) containing 150 c.c. of water is at 27°C. The final temperature is 40°C. Calculate the specific heat of the metal. If heat losses to the surrounding are not negligible, is your answer greater or smaller than the actual value of specific heat of the metal.

Ans. Here, mass of metal \( m = 0.2 \) kg

fall in temperature of metal \( \Delta T = 110^0C \)

if \( c \) is specific heat of the metal, then heat lost by the metal,

\[ \Delta Q = mc\Delta T = 200 \times c \times 110 \]

As, \( \frac{Q_2}{Q_1} = \frac{T_2}{T_1} \)

\[ Q_2 = \left(\frac{T_2}{T_1}\right) Q_1 \]

Or, \( Q_2 = \frac{400}{500} \times 6 \times 10^5 = 4.8 \times 10^5 \text{cal} \)

Therefore, work done per cycle

\[ W = Q_1 - Q_2 \]

\[ = 6 \times 10^5 - 4.8 \times 10^5 \]

\[ = 1.2 \times 10^5 \text{CAL} \]

\[ = 1.2 \times 4.2 \times 10^5 \text{J} \]

\[ = 5.04 \times 10^5 \text{J}. \]

3. Calculate the heat required to convert 0.6 kg of ice at -20°C, kept in a calorimeter to steam at 100°C at atmospheric pressure. Given the specific heat of capacity of ice = 2100 Jkg\(^{-1}\)K\(^{-1}\), latent heat of ice = 3.35 \( \times 10^5 \) Jkg\(^{-1}\), and latent heat of steam = 2.256 \( \times 10^6 \) Jkg\(^{-1}\).

Ans. Heat required to convert ice at -20°C to 0°C

\[ Q_1 = ms_{(\text{ice})} \times \Delta T_1 \]

\[ = 0.6 \times 2100 \times [0 - (-20)] \]

\[ = 25200 \text{ J}. \]

Heat required to melt ice at 0°C to water at 100°C

\[ Q_3 = ms_{w} \Delta T_2 \]
= 0.6 X 4186 X (100 – 0)
= 251160 J.

Heat required to convert water at 100°C to steam at 100°C

\[ Q_4 = m \cdot L_{\text{steam}} \]
\[ = 0.6 \times 2.256 \times 10^6. \]

Q4. A 10 kW drilling machine is used to drill a bore in a small aluminium block of mass 8 kg. how much is the rise in temperature of the block in 2.5 minutes assuming, 50% of power is used up in heating the machine itself or lost to the surroundings. Specific heat of aluminium = 0.91 J g⁻¹°C⁻¹.

Ans. Here, \( P = 10 \text{ kW} = 10^4 \text{ W} \)

- Mass, \( m = 8 \text{ kg} = 8 \times 10^3 \text{ g} \)
- Rise in temperature \( \Delta T = ? \)
- \( T = 2.5 \text{ min.} = 2.5 \times 60 = 150 \text{ s} \)

Specific heat, \( c = 0.91 \text{ J g}^{-1} \text{ °C}^{-1} \)

Total energy

\[ P \times t = 10^4 \times 150 = 15 \times 10^5 \text{ J.} \]

As 50% of energy is lost,

Therefore, energy available

As, \( \Delta Q = \frac{1}{2} \times 15 \times 10^5 = 7.5 \times 10^5 \text{ J} \)

As, \( \Delta Q = mc\Delta T \)

Therefore, \( \Delta T = \frac{\Delta Q}{mc} = \frac{7.5 \times 10^5}{(8 \times 10^3 \times 0.91)} \)

= 103°C.

Q.5 How many grams of ice at -14°C are needed to cool 200grs of water from 25°C to 10°C?

Take specific heat of ice = 0.5 cal g⁻¹°C⁻¹ and latent heat of ice = 80cal/g.

Ans. Heat extracted from water \( Q_1 = cm\Delta T \)

\[ = 1 \times 200 \times (25-10) = 3000 \text{ cal} \]

Heat absorbed by m gram of ice (at -14°C) to convert it to water at 10°C

\[ Q_2 = (cm\Delta T)_{\text{ice}} + mL + (cm\Delta T)_{\text{water}} \]
\[=0.5m \times 14 + m \times 80 + 1 \times m \times 10\]

\[Q_2 = 97 \text{ m cal}\]

As \(Q_2 = Q_1\)

Therefore, \[97m = 3000\]

\[m = 31 \text{ gram}\]

Q6. During India Pakistan war, a soldier discovered that his lead bullet just melted when stopped by an obstacle. Calculate the velocity of the bullet if its temp was 47.6\(^0\)C, given – melting point of lead = 327\(^0\)C, specific heat of lead = 0.03 cal gram\(^{-1}\) C\(^{-1}\) and \(J = 4.2 \times 10^7\) erg cal\(^{-1}\). Assume that no heat is lost.

Ans. Increase in temp,

\[\Theta = (327 - 47.6)^0\text{C} = 279.4^0\text{C}\]

Let \(m\) be the mass of the bullet.

Heat required,

\[Q = mS\Theta + mL\]

\[Q = m(S\Theta + L)\]

\[= m(0.03 \times 279.4 + 6)\]

\[= 14.38m \text{ cal}\]

Work done,

\[W = \frac{1}{2} mv^2\]

Where \(v\) is the velocity of the bullet

Now, \(W = IQ\)

\[1/2mv^2 = 4.2 \times 10^7 \times 14.38m\]

\[V^2 = 2 \times 4.2 \times 10^7 \times 14.38\]

\[V = 3.48 \times 10^4 \text{ cm s}^{-1}\]

Q7. A Carnot engine works between ice point and steam point. It is desired to increase the efficiency by 20% by (a) making temperature of the source as constant.

(b) Making temp. of the sink as constant. Calculate the change in temp in the two cases. Which one of these will you prefer and why?

Ans. \(\eta = 1 - T_2/T_1 = 1 - 273/373 = 100/373\)
Adding 20% i.e., (1/5) to the existing η

η = 100/3 + 3 +20% = 100/373 + 1/5 = 873/1865

(a) If the temp of the sink corresponding to η’
be T’2 (source at 373 K), then
thus, η’ = 1 - T’2/373
T’2/373 = 1 - η’ = 1 - 873/1865 = 992/1865
T’2 = 198.4 K
T’2 - T2 = 198.4 K - 273 K = - 74.6 K

(b) If the temp of the source corresponding to η’ to T’1 (sink at 273 K), then
η’ = 1 - T’2/T’1 or 873/1865 = 1 - 273/T’1
273/T’1 = 1 - 873/1865 = 992/1865
T’1 = 513 K
T’1 - T1 = 513 K - 273 K
= 149.25 K = 140°C

Q8. A copper block of mass 2.5 kg is heated in a furnace to a temperature of 500 °C and then placed on a large ice block. What is the maximum amount of ice that can be melted? (specific heat of copper = 0.39 J g⁻¹°C⁻¹; heat of fusion of water = 335 J g⁻¹).

Ans. m = 2.5 kg, S_c = 0.39 J/g°C, L_w = 335 J/g

Heat lost by copper block is used in the melting of ice

2.5 x 10^3 x 0.39 x 500 = M x L_w

M = 2.5 x 500 x 0.39 x 10^3/335

= 1455 g = 1.455 kg

Q9. 1 gram of water at 373 K is converted into steam at the same temp. The volume of 1 cm³ of water becomes 1671 cm³ on boiling. Calculate change in internal energy of the system, if heat of vaporization is 540 Cal g⁻¹. Given standard atmospheric pressure is 1.013 x 10⁵ N/m².

Ans. here mass of water,
m = 1 g

Initial vol. of water,
V_1 = 1 cm³

Volume of steam,
V_2 = 1671 cm³

Change in volume,
dV = V_2 - V_1
1671-1=1670 \text{cm}^3=1670 \times 10^{-6} \text{m}^3

Standard atmospheric pressure

P=1.013 \times 10^5 \text{Nm}^{-2}

As change of state is involved,

dQ=m \times L=1 \times 540 \times 4.18 \text{J}=2257 \text{J}

change in internal energy, dU is asked

dW=PdV

=1.013 \times 10^5 \times 1670 \times 10^{-6}

=169.17 \text{J}

From \ dQ=dU+dW

dU=dQ-dW=2257-169.17

dU=2087.83 \text{J}

Q10. there is a layer of ice 10 cm thick over the surface of a pond. Temp. above the surface is -5 °C. how long will it take the next 1 mm of ice to form? The thermal conductivity of ice is 0.008 CGS units and its latent heat is 80 cal/g. density of ice is 0.9g/cc.

Ans. thickness of layer =10 cm,

Temperature =-5^\circ \text{C}, K=0.008 \text{ CGS units}

L = 80 \text{ cal/g}, \rho=09 \text{ g/cc}

Suppose the area of the surface of ice to be 1sq. cm

Vol. of 1mm thickness of layer

=area x thickness=1 \times 0.1=0.1 \text{cm}^3

Mass of new layer formed

=vol. x density=0.1 \times 0.9 = 0.09 \text{g}

Amount of heat radiated by the water to freeze 0.09g of ice=0.09 \times 80=7.2 \text{cal}

We know that \ Q/t=KA \Delta t/\Delta x

Here Q=7.2 \text{cal}, K=0.008,

\Delta t=0-(-5)=5^\circ \text{C}, A=1 \text{ sq. cm}
\[ \Delta x = \frac{(10 + 10.1)}{2} = 10.05 \text{ cm} \]

Putting these values, we have

\[ \frac{7.2}{t} = 0.008 \times \frac{1 \times 5}{10.05} \]

\[ t = \frac{(7.2 \times 10.05)}{0.008 \times 5} = 30 \text{ min. 9 sec.} \]

**VALUE BASED QUESTIONS**

1. A group of four friends went to Taj Mahal from Yamuna expressway by car. They started by filling the tank and then they got air pressure in the tyres checked. Seeing the world class roads, Rajat’s friends boosted him to drive faster. He refused at first but after sometime increased the speed. Suddenly, one of the side tyre burst and the car went unbalanced and hit a tree on the roadside. Since all of them were wearing seat belts, they escaped with minor injuries. After such an experience, they vowed not to drive dangerously as more.

(i) What do you infer from the incident?

(ii) A tyre pumped to a pressure of 6 atmosphere suddenly bursts. Calculate the temperature of escaping air. (Given initial temperature is 15\(^0\) C and \(\gamma\) for air is 1.4)

(iii) What are the main cause of accidents?

Ans. (i) this incident infers that we should always follow the speed limits while driving.

(ii) Given, \( P_1 = 6 \text{ atm} \)

\[ P_2 = 1 \text{ atm} \]

\[ T_1 = 273 + 15 = 288 \text{ K} \]

\[ T_2 = ? \quad \text{and} \quad \gamma = 1.4 \]

From, \( P_2^{(1-\gamma)} \cdot T_2^\gamma = P_1^{(1-\gamma)} \cdot T_1^\gamma \)

\[ T_2 = \frac{T_1}{P_1/P_2}^{(1-\gamma)/\gamma} \]

\[ = 288 \times \left( \frac{6}{1} \right)^{(1-1.4)/1.4} \]

\[ = 288 \times 6^{27/7} = 172.6 \text{ K} \]

2. Manvi and her friends were enjoying the birthday party of one of their friends in her home. They all were enjoying themselves by playing various games and dancing. One of her friends became sweaty and was feeling very hot. As there was no air conditioner, she got an idea. She opened the door of the refrigerator thinking that this might relieve him from heat. On seeing this, Manvi immediately rushed towards him and made him understand that opening of the door of the refrigerator would increase
the temperature of the room. she told him to rest for some time, if he was feeling very hot. Her friend understood this and closed the door of refrigerator at once.

(i) What qualities of Manvi do you appreciate?
(ii) Temperature inside an ideal refrigerator is 275 K. how much heat is delivered to the room for every one joule of work done on working substance when room temperature is 315 K.
(iii) a room cannot be cooled by opening the door of refrigerator in a closed room. Why?

Ans. (i) Manvi is a sensible girl and she has scientific knowledge also.

(ii) $T_2 = 275 \, \text{K}, \quad T_1 = 315 \, \text{K}$

$Q_1=?$, $W = 1 \, \text{J}$, $\beta = ?$

$\beta = Q_2/W = T_2/(T_1-T_2) = 275/40 = 6.9$

$Q_2 = 6.9 \, \text{W} = 6.9 \, \text{J}$

$Q_1 = Q_2 + W = 6.9 + 1 = 7.9 \, \text{J}$.

(iii) When a refrigerator is working in a closed room with its door opened, it is rejecting heat from inside to the air in the room. So, temperature of room increases gradually.

3. While teaching thermodynamics to class XI, one day the Physics teacher called one of the best students, Ajay, to come near him. He told Ajay to whistle out air on to his palm holding close to his mouth. He asked Ajay how you feel. Ajay replied the air feels cold. The teacher then asked Anuj to blow out air from his mouth by keeping it wide open. He again asked Anuj how do you now feel. Anuj replied that the air now feels hot. The teacher then asked Anuj to explain the difference in the two cases. Anuj explained the reason quite satisfactorily. The teacher praised Anuj for his correct answer.

(a) What are the values displayed by Ajay?
(b) What is the reason behind feeling air cold and hot in the two cases in the above demonstration?

Ans. (a) Good observer, intelligent, good knowledge of Physics.

(b) During whistling, we blow out air through a small opening between the lips. This is an adiabatic expansion, so there is fall in temperature. But when we keep our mouth wide open, hot air of the mouth blows on to the palm which feels hot.

4. It was a hot summer day. Ramu and his mother were perspiring heavily. Feeling quite uneasy, Ramu’s mother opened the door of the working refrigerator kept in the room in the hope that it will cool the room also. But it brought no relief instead it further warmed the room. Ramu's mother was unable to understand why it is happening so.
Next day Ramu asked his Physics teacher why cannot we cool a room by leaving the door of the refrigerator open. The teacher explained the reason behind it.

(a) What are the values displayed by Ramu in his actions?
(b) Why can’t we cool the room by leaving the room of a working refrigerator open?

Ans. (a) Concern for his mother, quest for scientific knowledge.
(b) When the refrigerator is kept open, it extracts heat from the room. Work is done on it by the electric motor and the total energy is rejected to the same room. Thus the work done by the motor also gets added to the room, so it gets warmed.

5. Sita takes two containers of equal volume containing the same gas at pressure $P_1$ and $P_2$ and absolute temperatures $T_1$ and $T_2$, respectively. She joins the vessels, the gas reaches a common pressure $P$ and common temperature $T$.

(i) Find the ratio $P/T$.
(ii) What value of life do you learn from this question?
(iii) What is STP?
(iv) What qualities are displayed by Sita from her actions?

Ans. (i) Number of moles in first vessel, $\mu_1 = \frac{P_1}{RT_1}$ and number of moles in second vessel, $\mu_2 = \frac{P_2T}{RT_2}$.

If both vessels are joined together, then quantity of gas remains remain same, i.e. $\mu = \mu_1 + \mu_2$

$P(2V)/RT = \frac{P_1V}{RT_1} + \frac{P_2V}{RT_2}$

(ii) This law reminds us about equilibrium nature of universe. Every constituent of this universe wants to achieve equilibrium.

(iii) IUPAC established standard temperature and pressure (STP) as a temperature of 273.15 K and absolute pressure of exactly $10^5$ Pa.

(iv) Curiosity about law of nature and being practical.
Q1. The work of 146 J is performed in order to compress one kilo mole of gas adiabatically and in this process the temperature of the gas increases by 7°C. Identify the atomicity of the gas. Given R= 83 J/mol K.

Ans. By first law of thermodynamics, 
\[ \Delta Q = \Delta U + \Delta W \]
For an adiabatic process, \( \Delta Q = 0 \)
\[ \Delta U = \Delta W = -146 \text{ kJ} = +146 \text{ kJ} \]
\[ \Delta U = nC_v \Delta T \]
\[ C_v = \frac{\Delta U}{n\Delta T} = \frac{146 \times 10^3}{1 \times 10^3 \times 7} = 20.8 \text{ J/mol K} \]
For a diatomic gas, \( C_v = \frac{5}{2} R = \frac{5}{2} \times 8.3 = 20.8 \text{ J/mol K} \)
Hence the gas is diatomic.

Q2. In the given process on an ideal gas, \( dW = 0 \) and \( dQ < 0 \). What happens to the temperature of the gas?

Ans. As \( dQ = dU + dW \)
\( dW = 0 \) and \( dQ < 0 \), so \( dU < 0 \)
for an ideal gas, \( U \propto T \), so \( dT < 0 \) i.e., temperature of the gas decreases.