NCERT SOLUTIONS
CLASS-XI PHYSICS
CHAPTER-12
THERMDYNAMICS

Q.1: Water flowing at the rate of 4.0 litres/minute is heated from 28 °C to 76 °C by a gas burner, if its heat of combustion is 4.0×10^4 J/g. Find the rate of consumption of fuel.

Answer:

Given:

The rate of flow of water = **4.0 litres/min**

And, Heat of consumption = $\mathbf{4.0 \times 10^4}$ **J/g**

Since, the temperature of water is raised from 28 °C to 76 °C by the geyser

Therefore, the initial temperature, T_1 **= 28 °C**

And, the final temperature, T_2 **= 76 °C**

Hence, the rise in temperature, $\Delta T = T_2 - T_1$

Therefore, ΔT = 76 – 28 = **48 °C**

And, specific heat of water, **c = 4.2 J g^{-1} °C^{-1}**

Now, Mass of flowing water, **m = 4.0 litres/min**

i.e. **m = 4000 g/min** [Since, 1L = 1000 g]

Since, total heat used, $\Delta Q = m \times c \times \Delta T$

Therefore, ΔQ = 4000 × 4.2 × 48 = $\mathbf{8.064 \times 10^5}$ **J/min**

Therefore, the Rate of consumption of fuel = $\frac{8.064\times10^4}{4.0\times10^4} = \mathbf{2.016}$ g/min

Q.2: Find the amount of heat that must be provided to 1.8×10^{-2} kg of nitrogen at room temperature to increase its temperature at a constant pressure by 50 °C? (Molecular mass of N_2 = 28 and take R = 8.3 J mol^{-1} K^{-1})

Answer: Given:
The Molecular mass of Nitrogen, **M = 28**
Universal gas Constant, **R = 8.3 J mol^{-1} K^{-1}**

Mass of Nitrogen, **m =** 1.8×10^{-2} kg = **18 g**
Now, the number of moles, n = $\frac{mass\ of\ N_2}{Molicular\ mass\ of\ N_2} = \frac{m}{M} = \frac{18}{28}$

Therefore, **n = 0.643**

Now, for Nitrogen Molar specific heat at constant pressure $C_P = \frac{7}{2} \times R = \frac{7}{2} \times 8.3$

Therefore, C_P **= 29.05 J mol^{-1} K^{-1}**

Now, the total amount of heat that is to be supplied to increase its temperature by 50 °C:

$\Delta Q = n \times C_P \times \Delta T$
$\Rightarrow \Delta Q = 0.643 \times 29.05 \times 50 = 933.9575$J
Therefore, the total amount of heat that is to be supplied to raise the temperature of Nitrogen by 50 °C = 933.9575 J

Q.3: Explain the following statements:

(i). It is not necessary for two bodies having different temperatures say T_1 and T_2, when brought in thermal contact to settle for a mean temperature of $(T_1 + T_2)/2$

(ii). The coolant that is used in a chemical or nuclear power plant should have a high specific heat.

(iii). While driving a vehicle, the air pressure of the tyres increases.

(i). A harbour town has a more temperate climate than a desert town which is at the same latitude the

harbour town is.

Answer:

(i). When two bodies having different temperatures say, T1 and T_2 are brought in thermal contact with each other, there is a flow of heat from the body at the higher temperature to the body at the lower temperature till both the body reaches to an equilibrium position, i.e., both the bodies are having equal temperature. The equilibrium temperature is only equal to the mean temperature when the thermal capacities of both the bodies are equal.

(ii). The coolant used in a chemical or nuclear plant should always have a high specific heat. Because higher is the specific heat of the coolant, higher is its capacity to absorb heat and release heat. Therefore, a liquid with a high specific heat value is the best coolant to be used in a nuclear or chemical plant. This would prevent different parts of the plant from getting too hot.

(iii). When the driver is driving a vehicle then due to the motion of air molecules the air temperature inside the tyre increases. And according to the Charles' law, the temperature is directly proportional to pressure.

Therefore, when the temperature inside a tyre increases, then there is also an increase of air pressure.

(iv). The relative humidity in a harbour town is more than that of the relative humidity in a desert town.

Q.4: A cylinder having a movable piston has 4 moles of hydrogen at standard pressure and temperature. The cylinder is designed in such a way that the walls of cylinder are made up of a heat insulating substance, and for insulating the piston sand is piled on it. By how much does the pressure of gas increase if the gas is compressed to quarter of its original volume?

Answer:

The process described above is an **Adiabatic process**, as the cylinder is completely insulated from its surrounding and because of that there is no exchange of heat between the surroundings and the system.

Let, the **Initial Volume** inside the cylinder **= V_1**

And the **Final Volume** inside the cylinder **= V_2**

Let, the **Initial Pressure** inside the cylinder **= P_1**

And the **Final Pressure** inside the cylinder **= P_2**

Also, the **Ratio** of **specific heats**, **Υ = 1.4**

Now, for an **adiabatic process:**

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$......... **(1)**

Since, $V_2 = \frac{V_1}{4}$ **[Given]**

Now, from equation (1):

$$\Rightarrow P_1 V_1^{\gamma} = P_2 \left(\frac{V_1}{4}\right)^{\gamma}$$
$$\Rightarrow \frac{P_1}{P_2} = \frac{1}{4^{1.4}}$$
$$\Rightarrow \mathbf{\frac{P_2}{P_1} = 6.964}$$

Therefore, the pressure of gas should be increased by a factor of 6.964, if the gas is to be compressed to quarter of its original volume.

Q.5: The state of a gas is changed adiabatically from one equilibrium state 'P' to another equilibrium state 'Q' and for this change of state, work equal to 23.2 J is done on the system. If the gas is taken from state 'P' to state 'Q' by a process in which the total heat absorbed by the system is equal to 9.40 calories. Find the total work that is done by the system in the second case. Take 1 calorie = 4.19 J

Answer:

In first case, the **work done** on the system when the gas is brought from **state P to state Q is 23.2 J.**

Now, since this process is an **Adiabatic process**. Therefore, the **change in heat** will be **0.**

i.e. ΔQ = 0

And ΔW = -23.2 J, because the work is done by the system.

Now, according to the 1st law of thermodynamics:

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

i.e. $\Delta U = \Delta Q - \Delta W$= 0 – (-23.2)

Therefore, ΔU 23.2 J

For second case,

The net heat absorbed by the system when the gas changes its state from state P to state Q is:

ΔQ = 9.40 calories = 9.40 × 4.19 = 39.386 J

Since heat absorbed,$\Delta Q = \Delta U + \Delta W$

Therefore, $\Delta W = \Delta Q - \Delta U$

$\Rightarrow \Delta W = 39.386 - 23.2 = 16.186\ J$

Therefore, 16.186 J of work is done by the system.

Q.6: Two cylinders 'P' and 'Q' having the same capacity are joined with each other through a stopcock. Cylinder 'P' contains a gas at standard pressure and temperature whereas the cylinder Q is completely empty. This entire system is thermally insulated and the stopcock is opened suddenly.

Answer the following statements:

(a). What is the final pressure of the gas in cylinder P and cylinder Q?

(b). What are the changes in the internal energy of the gas?

(c). What are the changes in the temperature of the gas

(d). Do the intermediate states of the system (before settling to the final equilibrium state) lie on its Pressure – Volume – Temperature surface?

Answers:

(a). Now, as soon as the stop cock is opened the gas will start flowing from cylinder P to cylinder Q which is completely evacuated and thus the volume of the gas will be doubled because both the cylinders have equal capacity. And since the pressure is inversely proportional to volume, hence the pressure will get decreased to half of the original value.

Since, the initial pressure of the gas in cylinder P is 1 atm. **Therefore, the pressure in each of the cylinder will now be 0.5 atm.**

(b). Here in this case, the internal energy of the gas will not change i.e. $\Delta U = 0$**.** It is because the internal energy can change only when the work is done by the system or on the system. Since in this case, no work is done by the gas or on the gas.

Therefore, the internal energy of the gas will not change.

c) There will be no change in the temperature of gas. It is because during the expansion of gas there is no work being done by the gas.

Therefore, there will be no change in the temperature of the in this process.

d). The above case is the clear case of free expansion and free expansion is rapid and it 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 Pressure – Volume – Temperature surface of the system**

Q.7: The steam engine is delivering 5.8 × 10^8 J of work / minute and uses 3.5 × 10^9 J of heat / minute from its boiler. Calculate the efficiency of the engine and the amount of heat is wasted/minute.

Answer:

Given:

Work done by the steam engine, **W = 5.8 × 10^8 J per minute**

Heat supplied from the boiler, **H = 3.5 × 10^9 J per minute**

Since, **Efficiency** of the engine:

$\Rightarrow \frac{Output\ Energy}{Input\ Energy} = \frac{5.8\times10^8\ J}{3.5\times10^9\ J} = 0.1657$

Therefore, **percentage efficiency** of the engine is **16.57 %.**

Now, the amount of **heat wasted** = (3.5 × 10^9 – 5.8 × 10^8) = **2.92×10^9 J**.

Therefore the efficiency of steam engine is 16.57% and amount of heat that is wasted per minute is 2.92×10^9 J.

Q.8: There is an electric heater that provides heat to a system at the rate of 110W. If work done by the system is at the rate of 80 Jules per second. Find the rate at which the internal energy is increasing.

Answer:

Given:

Heat supplied to the system **= 110 J/sec** **[1 Watt = 1 J/sec]**

Work done by the system **= 80 J/sec**

Now, according to **the first law of thermodynamics**:

Q = U + W [U = internal inergy]

Therefore, **U = Q – W**

⇒ U = 110 – 80 = 30 J/sec

Therefore, the rate at which the internal energy of an electric heater is increasing = 30 W.

Q.9: The state of a thermodynamic system is changed from an original state to an intermediate state by a linear process as shown in the below figure and its volume is reduced to original value from B to C by an isobaric process. Calculate the net work done by the gas from A to E to F.

Answer:

From the above figure, the **Total work done** by the gas **from A to B to C = Area of triangle ABC.**

Now, Area of triangle ABC = $\frac{1}{2}$ × AC × BC

Where, **AC = Change in pressure** and **BC = Change in volume**

Now, **AC** = (800 – 400) N/m^2 **= 400 N/m^2**

And, **BC** = (7 – 3) m^3 **= 4 m^3**

Now, the **Area of triangle ABC** = $\frac{1}{2}$ × AC × BC

$\Rightarrow \frac{1}{2} \times 400 \times 4 = 800$J

Therefore, the Total work done by the gas from A to B to C is 800 J

Q.10: The temperature inside the refrigerator is to be maintained at 8°C. If the room of room is 35°C, Calculate the coefficient of performance.

Answer:

Given:

Room temperature, **T_2 =** 35°C = 35 + 273 **= 308 K**

Temperature inside the refrigerator, **T_1 =** 8°C **= 281 K**

Since, the Coefficient of performance = $\frac{T_1}{T_2 - T_1} = \frac{281}{308-281} = 10.41$

Therefore, the coefficient of performance of refrigerator is 10.41