NCERT Solution For Class 11 Physics Chapter 12 Thermodynamics

Q.1: 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 × 10^4 J/g ?

Answer:

Given:

The rate of flow of water = **3.0 litres/min**

And, Heat of consumption = 3.0 × **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 = 27 °C**

And, the final temperature, **T_2 = 77 °C**

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

Therefore, ΔT = 77 – 27 = 50 °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, **ΔQ = m × c × ΔT**

Therefore, ΔQ = 4000 × 4.2 × 48 = **8.064 × 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: 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 ? (Molecular mass of N2 = 28; 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 why
(a) Two bodies at different temperatures T1 and T2 if brought in thermal contact do not necessarily settle to the mean temperature (T1 + T2)/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) Air 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.
(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 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 ?

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**, **Y = 1.4**

Now, for an **adiabatic process:**

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

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

Now, from equation (1):

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

$$\Rightarrow \frac{P_1}{P_2} = \frac{1}{4^{1.4}}$$

$$\Rightarrow \frac{P_2}{P_1} = 6.964$$

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: In changing the state of a gas adiabatically from an equilibrium state A to another equilibrium state B, an amount of work equal to 22.3 J is done on the system. If the gas is taken from state A to B via a 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 cal = 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 A and B of equal capacity are connected to each other via a stopcock. A contains a gas at standard temperature and pressure. 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 the temperature of the gas ?
(d) Do the intermediate states of the system (before settling to the final equilibrium state) lie on its P-V-T surface ? wers:

(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: 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?

Answer:

Given:

Work done by the steam engine, **W = 5.4×10^8 J per minute**

Heat supplied from the boiler, **H = 3.6×10^9 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** = $(3.5 \times 10^9 - 5.8 \times 10^8)$ = **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: An electric heater supplies heat to a system at a rate of 100W. If the system performs work at a rate of 75 joules per second. At what rate is the internal energy 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**

$\Rightarrow$ U = 110 – 80 = 30 J/sec

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

Q.9: A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in the figure.

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: A refrigerator is to maintain eatables kept inside at 90C. If room temperature is 360C, 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