NCERT SOLUTIONS
PHYSICS XI CLASS
CHAPTER - 12
THERMODYNAMICS

12.1 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 ?

Sol. Here, m = mass of water flowing per unit time = 3000g /min.

$\Delta t = 77 - 27 = 50°C$

Heat of combustion = 4×10^4 J/g

Heat required to heat the water, $Q = ms\,\Delta t = \frac{3000g}{mm} \times \frac{4.2\text{ J}}{°Cg} \times 50°C = 63 \times 10^4$ J/min.

$\therefore$ Rate of consumption of the fuel = $\frac{\text{fuel required per min}}{\text{Heat of combustion}} = \frac{63 \times 10^4}{4 \times 10^4} = 15.675\text{ g / min}$.

12.2 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 $N_2 = 28$; R = 8.3 J mol^{-1} K^{-1})

Sol. Here mass of gas = 2.0×10^{-2} kg = 20g

Rise in temperature $\Delta t = 45°C$, Molecular mass M = 28

Number of moles, $n = \frac{m}{M} = \frac{20}{28} = 0.714$

For a diatomic gas $C_p = \frac{7}{2}R = \frac{7}{3} \times\ 8.3\text{ J mol}^{-1}\text{ K}^{-1}$

and $\Delta Q = nC_p\,\Delta T = 0.714 \times \frac{7}{3} \times 8.3 \times 4.5 = 933.4\text{ J}$

12.3 Explain why

(a) Two bodies at different temperatures T_1 and T_2 if brought in thermal contact do not necessarily settle to the mean temperature $(T_1 + T_2)/2$. Explain.

(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. Explain.

(c) Air pressure in a car tyre increases during driving. Explain.

(d) The climate of a harbour town is more temperate than that of a town in a desert at the same latitude. Explain.

Sol. (a) In thermal contact, heat flows from the body at higher temperature to the body at lower temperature till temperature becomes equal. The final temperature can be the mean temperature $(T_1 + T_2)/2$ only when thermal capacities of the two bodies are equal.

(b) We know the quantity of specific heat taken $Q = ms\,\Delta t$ i.e., $Q \propto s$
Larger the value of specific heat of the coolant more is the heat absorbed by it.

(c) During driving the temperature of the air, inside tyres increases due to friction force between road and tyres. As volume of air in the tyre is constant according to Charle's law.

$(P \propto T)_V$

pressure increases with increase in temperature.

(d) The climate of a harbour town is more temperate because of the large amount of water vapours present in the air due to its proximity with sea.

12.4 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?

Sol. The process in adiabatic

$\therefore \quad P_1V_1^{\gamma} = P_2V_2^{\gamma}$

Given, $\dfrac{V_1}{V_2} = \dfrac{2}{1}$ and $\gamma = \dfrac{7}{5}$ (for diatomic gas)

$\therefore \quad \dfrac{P_2}{P_1} = (2)^{7/5}$ i.e., $P_2 = (2)^{7/5}P_1$

12.5 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)

Sol. The system is going from A to B and then back to A, it is undergoing a cyclic change.
Change in internal energy is cyclic change, $\Delta U = 0$
Using first law of thermodynamics, $\Delta Q = \Delta U + \Delta W = \Delta W$
Heat absorbed by the system = (9.35 × 4.19 – 22.3) = 16.87 J
Net work done by the system = 16.87 J

12.6 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?

Sol. (a) The gas would pass from A to B. The change in pressure and volume will take place under adiabatic conditions. The final pressure in the two cylinders would be 0.5 atm.
(b) The change in internal energy of the gas is zero.
(c) The change in temperature will be zero.
(d) The process is rapid, the intermediate states are non-equilibrium states and hence do not satisfy the gas equation. The intermediate states do not lie on the P-V-T surface.

12.7 A steam engine delivers 5.4×10^8J of work per minute and services 3.6×10^9J of heat per minute from its boiler. What is the efficiency of the engine? How much heat is wasted per minute?

Sol. Output i.e. useful work done per min = 5.4×10^8 J
Input i.e. heat absorbed per min = 3.6×10^9 J

Efficiency = $\dfrac{\text{output}}{\text{input}} = \dfrac{5.4\times10^8}{3.6\times10^9} = 0.15 = 0.15 \times 100\% = 15\%$

Heat energy wasted per minute = Heat absorbed per minute – useful work done per minute
$= 3.6 \times 10^9 - 5.4 \times 10^8 = 10^9\,(3.6 - 0.54) = 3.06 \times 10^9$ J

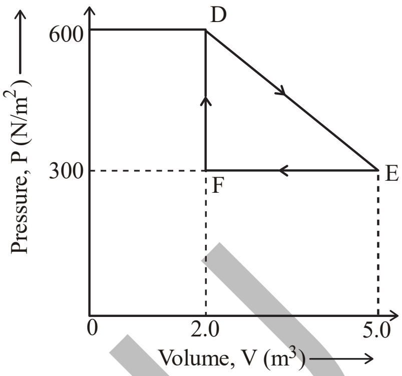
12.8 An electric heater supplies heat to a system at a rate of 100W. If system performs work at a rate of 75 joules per second. At what rate is the internal energy increasing?

Sol. Heat supplied, ΔQ = 100 W = 100 J/s
Useful work done, ΔW = 75 J/s
Increase in internal energy per sec, ΔU = ?

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

$\therefore \quad \Delta U = \Delta Q - \Delta W = 100 - 75 = 25$ J/S

12.9 A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in figure. Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the total work done by the gas from D to E to F.



Sol. As shown in the figure,

Change in pressure = 300 Nm^{-2}.

Change in volume = $3m^3$.

Work done by the gas from D to E to F = area of Δ DEF

$$W = \frac{1}{2} \times DF \times EF = \frac{1}{2} \times 300 \times 3 = 450 \text{ J}$$

12.10 A refrigerator is to maintain eatables kept inside at 9°C. If room temperature is 36°C, calculate the coefficient of performance.

Sol. Here, $T_1 = 36°C = 36 + 273 = 309$ K,

$T_2 = 10°C = 10 + 273 = 283$ K

$$COP = \frac{T_2}{T_1 - T_2} = \frac{283}{309 - 283} = \frac{283}{26} = 10.9$$