NCERT Solutions for Class 11 Physics Chapter 12 Thermodynamics

Q12.1 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 $4.0 \times 10^4\ J/g$?

Answer:

The volumetric flow of water is

$$\frac{dV}{dt} = 3\ litres\ minute^{-1}$$

Density of water = 1000 g/litre

The mass flow rate of water is

$$\frac{dm}{dt} = \rho\frac{dV}{dt}$$
$$\frac{dm}{dt} = 3000\ g\ min^{-1}$$

Specific heat of water, c = 4.2 J g^{-1} $^{o}C^{-1}$

The rise in temperature is $\Delta T = 77 - 27 = 50\ ^oC$

Rate of energy consumption will be

The heat of combustion of fuel $= 4.0 \times 10^4 J/g$

Rate of consumption of fuel is

$$\frac{6.3 \times 10^5}{4 \times 10^4}$$
$$= 15.75\ g\ min^{-1}$$

Q12.2 What amount of heat must be supplied to $2.0 \times 10^{-2}\ kg$ of nitrogen (at room temperature) to raise its temperature by 45 °C at constant pressure? (Molecular mass of $N = 28;\ R = 8.3\ J\ mol^{-1} K^{-1}$.)

Answer:

Mass of nitrogen, $m = 2.0 \times 10^{-2} kg = 20g$

Molar Mass of nitrogen, $M_N = 28$ g

Number of moles is n

$$n = \frac{m}{M_N}$$
$$n = \frac{20}{28}$$
$$n = 0.714$$

As nitrogen is a diatomic gas it's molar specific heat at constant pressure C_P is as follows

$$C_P = \frac{7R}{2}$$
$$C_P = \frac{7 \times 8.3}{2}$$
$$C_P = 29.05\ J\ mol^{-1}\ {}^oC^{-1}$$

Rise in temperature, $\Delta T = 45^o C^{-1}$

Amount of heat Q that must be supplied is

$$Q = nC_P \Delta T$$
$$Q = 0.714 \times 29.05 \times 45$$
$$Q = 933.38\ J$$

Q12.3 (a) 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 $(T_1 + T_2)/2$.

Answer:

As we know the heat will flow from the hotter body to the colder body till their temperatures become equal. That temperature will be equal to the mean of the initial temperatures of the bodies **only if the two thermal capacities of the two bodies are equal.**

Q12.3 (b) Explain why

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.

Answer:

The coolant should have high specific heat so that it can absorb large amounts of heat without itself getting too hot and its temperature lies in the permissible region. Higher is the specific heat more will be the heat absorbed by the same amount of the material for a given increase in temperature.

Q12.3(c) Explain why

Air pressure in a car tyre increases during driving.

Answer:

As the car is driven the air inside the tyre heats due to frictional forces. Thus the temperature of the air inside the tyre increases and this, in turn, increases the pressure inside the tyre.

Q12.3 (d) Explain why

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

Answer:

The climate of a harbour town is more temperate than that of a town in a desert at the same latitude because of the formation of sea breezes.

Q12.4 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:

As the walls of the cylinder and the piston is insulated the process will be adiabatic.
i.e. PV^{γ} would be constant.

Hydrogen is a diatomic gas and therefore $\gamma = 1.4$

Let the initial and final pressure be P_1 and P_2 respectively.

Let the initial and final volume be T_1 and T_2 respectively.

The pressure thus increases by a factor 2.639

Q12.5 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 $1cal = 4.19J$)

Answer:

In the first case, the process is adiabatic i.e. $\Delta Q = 0$

22.3 J work is done on the system i.e. $\Delta w = -22.3\ J$

$$\Delta Q = \Delta u + \Delta w$$
$$0 = \Delta u - 22.3$$
$$\Delta u = 22.3\ J$$

Since in the latter process as well the initial and final states are the same as those in the former process Δu will remain the same for the latter case.

In the latter case net heat absorbed by the system is 9.35 cal

$$\Delta Q = 9.35 \times 4.2$$
$$\Delta Q = 39.3\ J$$

$$\Delta w = \Delta Q - \Delta u$$
$$\Delta w = 39.3 - 22.3$$
$$\Delta w = 17.0\ J$$

The network done by the system in the latter case is 17.0 J

Q12.6 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?

Answer:

As the entire system is thermally insulated and as free expansion will be taking place the temperature of the gas remains the same. Therefore PV is constant.

Initial Pressure $P_1 = 1$ atm

Initial Volume, $V_1 = V$

Final Volume, $V_2 = 2V$

Final Pressure P_2 will be

$$P_2 = \frac{P_1 V_1}{V_2}$$
$$P_2 = \frac{P_1}{2}$$
$$P_2 = 0.5\ atm$$

The final pressure of the gas in *A* and *B is 0.5 atm.*

b) Since the temperature of the gas does not change its internal energy would also remain the same.

c) As the entire system is thermally insulated and as free expansion will be taking place the temperature of the gas remains the same.

d) The intermediate states of the system do not lie on its *P-V-T* surface as the process is a free expansion, it is rapid and the intermediate states are non-equilibrium states.

Q12.7 A steam engine delivers $5.4 \times 10^8\ J$ of work per minute and services $3.6 \times 10^9\ J$ of heat per minute from its boiler. What is the efficiency of the engine? How much heat is wasted per minute?

Answer:

Output = $5.4 \times 10^8\ J$

Input = $3.6 \times 10^9\ J$

Efficiency is η

$$\eta = \frac{output}{input}$$
$$\eta = \frac{5.4 \times 10^8}{3.6 \times 10^9}$$
$$\eta = 0.15$$

The efficiency of the engine is 0.15.

The percentage efficiency of the engine is 15%.

Heat wasted per minute = Heat produced per minute - useful work done per minute

$$= 3.6 \times 10^9 - 5.4 \times 10^8$$
$$= 3.06 \times 10^9\ J\ min^{-1}$$

Q12.8 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?

Answer:

The rate at which heat is supplied $\Delta Q = 100\ W$

The rate at which work is done $\Delta W = 75\ Js^{-1}$

Rate of change of internal energy is Δu

$$\Delta u = \Delta Q - \Delta w$$
$$\Delta u = 100 - 75$$
$$\Delta u = 25\ J\ s^{-1}$$

The internal energy of the system is increasing at a rate of 25 J s^{-1}

Q12.9 A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in Fig. (12.13)

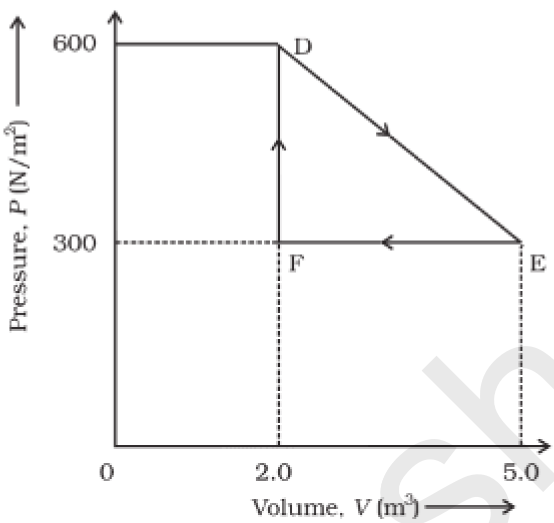

Fig. 12.13

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

Answer:

The work done by the gas as it goes from state D to E to F is equal to the area of triangle DEF

DF is change in pressure = 300 N m^{-2}

FE is change in Volume = 3 m^{3}

$$area(DEF) = \frac{1}{2} \times DF \times FE$$
$$area(DEF) = \frac{1}{2} \times 300 \times 3$$
$$area(DEF) = 450\ J$$

Work done is therefore 450 J.

Q12.10 A refrigerator is to maintain eatables kept inside at 9 °C. If room temperature is 36 °C, calculate the coefficient of performance.

Answer:

Room Temperature, T_1 = 36 °C = 309 K

The temperature which has to be maintained inside the fridge, T_2 = 9 °C = 282 K

Coefficient of performance is E

$$E = \frac{T_2}{T_1 - T_2}$$
$$E = \frac{282}{309 - 282}$$
$$E = \frac{282}{27}$$
$$E = 10.4$$