CBSE Test Paper 03
Chapter 12 Thermodynamics

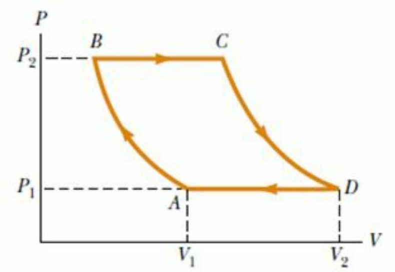
1. A geyser heats water flowing at the rate of 3.0 liters per minute from 27 $^\circ$C to 77 $^\circ$C. If the geyser operates on a gas burner, what is the rate of consumption of the fuel if its heat of combustion is 4.0 $\times$ 10^4 J/g? **1**

   a. 16 g per min
   b. 18 g per min
   c. 14 g per min
   d. 12 g per min

2. If ΔQ is the energy supplied to the system ΔU the change in internal energy, and ΔW the work done on the environment, First Law of Thermodynamics states that. **1**

   a. ΔU + ΔW = 0
   b. ΔQ = ΔU - ΔW
   c. ΔQ = ΔU + ΔW
   d. ΔQ = ΔU $\times$ ΔW

3. An ideal gas is carried through a thermodynamic cycle consisting of two isobaric and two isothermal processes, as shown in Figure. network done in the entire cycle is given by the equation. **1**



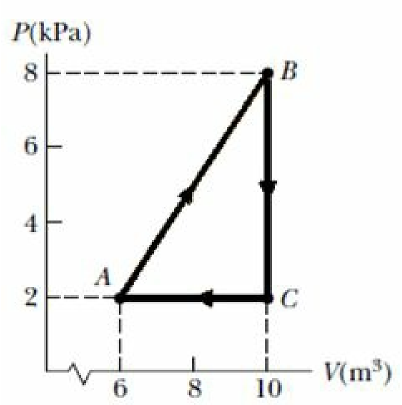
   a. $W_{net} = P_1 (V_2 + V_1) \ln \frac{P_2}{P_1}$
   b. $W_{net} = RP_1 (V_2 - V_1) \ln \frac{P_2}{P_1}$
   c. $W_{net} = P_1 (V_2 - V_1) \ln \frac{P_2}{P_1}$
   d. $W_{net} = P_1 (V_2 - V_1)$

4. A thermodynamic system undergoes a process in which its internal energy decreases

by 500 J. If, at the same time, 220 J of work is done on the system, what is the energy transferred to or from it by heat? **1**

a. Q = -700 J
b. Q = -740 J
c. Q = -730 J
d. Q = -720 J

5. Consider the cyclic process depicted in Figure if ΔE_{int} is negative for the process CA, what are the signs of Q and W are associated with CA? **1**



a. -, 0
b. -, -
c. -, +
d. +, 0

6. Which has a higher specific heat; water or sand? **1**

7. Animals in the forest find shelter from cold in holes in the snow. Why? **1**

8. Show the variation of specific heat at constant pressure with temperature. **1**

9. A steam engine intake steam at 200°C and after doing work exhausts it directly in the air at 100°C. Calculate the percentage of heat used for doing work. Assume the engine to be an ideal engine. **2**

10. What is an adiabatic process? Also give essential conditions for an adiabatic process to take place. **2**

11. State the Second law of thermodynamics and write 2 applications of it? **2**

12. The ends of the two rods of different materials with their thermal conductivities, radii of cross-section and lengths, in the ratio 1:2 are maintained at the same temperature difference. If the rate of flow of heat through the larger rod is 4 cal/s, what is the rate of flow through the shorter rod? **3**

13. Two rods A and B are of equal length. Each rod has its ends at temperatures T_1 and T_2. What is the condition that will ensure equal rates of flow of heat through the rods A and B? **3**

14. An ideal refrigerator runs between -23°C and 27°C. **3**

    i. Find the heat rejected to atmosphere for every joule of work input.
    ii. Also, find heat extracted from cold body.
    iii. Find coefficient of performance of the refrigerator.

15. Derive an expression for the work done during isothermal expansion. **5**

Answer

1. a. 16 g per min
   Explanation: $Q = ms\Delta T = 3000 \times 4.2 \times 50$
   m = mass of water
   s = specific heat of water
   heat of combustion is 4.0 $\times\ 10^4$ J/g
   rate of consumption of the fuel = Q / Heat of combustion
   $= \frac{3000\times4.2\times50}{4\times10^4} = 16gm/\min$

2. c. ΔQ = ΔU + ΔW
   Explanation: Heat given to a system is equal to the sum of increase in its internal energy and the work done by the system against the surroundings.

3. c. $W_{net} = P_1(V_2 - V_1)\ln\frac{P_2}{P_1}$
   Explanation: W = W_{AB} + W_{BC} + W_{CD} + W_{DA}
   W = $\int_A^B P\cdot dV + \int_B^C P.dV + \int_C^D P.dV + \int_D^A P.dV$
   W = $nRT_1\int_A^B\left(\frac{dV}{V}\right) + P_2\int_B^C dV + nRT_2\int_C^D\left(\frac{dV}{V}\right) + P_1\int_D dV$
   W = $nRT_1\log_e(\frac{V_B}{V_1}) + P_2(V_C - V_B) + nRT_2\log_e(\frac{V_2}{V_C}) + P_1(V_A - V_D)$
   $P_1V_A = P_2V_B$
   $P_2V_C = P_1V_D$
   $\frac{V_B}{V_1} = \frac{P_1}{P_2}$
   $\frac{V_2}{V_c} = \frac{P_2}{P_1}$
   W = $P_1(V_2 - V_1)\log_e(\frac{P_2}{P_1})$

4. d. Q = -720 J
   Explanation: $\Delta Q = \Delta U + W$ = (-500) + (-220) = -720 J

5. b. -, -
   Explanation: $\mathrm{W} = P\Delta V = -\mathrm{ve}(\mathrm{inCompression}\Delta\mathrm{V} = -ve)$

$Q = \triangle E_{int} + W$

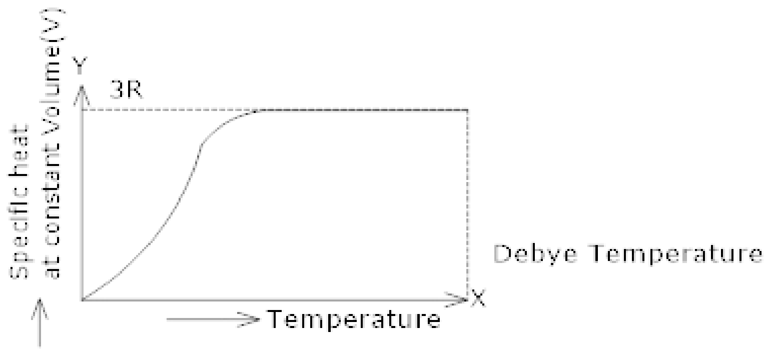
$\triangle E_{int}$ = -ve

W = -ve

So that $\triangle Q$ = -ve

6. Water has higher specific heat than sand as
   $\Delta T = \frac{Q}{mc}$, where T = Temperature, Q = Heat, m = Mass,
   C = Specific heat;
   Since for water temperature increases less slowly than sand hence, it results higher specific heat of sand.

7. Animals in the forest find shelter from cold in holes in the snow because snow has trapped air (as in ice there is no air) so, it acts as a heat insulator. Therefore, the snow prevents the transmission of heat from the body of the animal to the outside.

8. 

9. T_1 = 200 °C = 473 K

   T_2 = 100 °C = 373 K

   $\eta = \frac{W}{Q_1} = \frac{T_1 - T_2}{T_1} = \frac{473-373}{473}$
   $= \frac{100}{473} = 0.21$

10. An adiabatic process is a thermodynamic process in which the system is thermally insulated from the surroundings and the heat released or absorbed by the system is zero.
    Two essential conditions needed for an adiabatic process to take place are :

    i. The system walls must be adiabatic walls which do not allow the flow of energy from the system to the surroundings or vice-versa.

ii. The thermodynamic process should be a sudden process so that there is no opportunity for the system to exchange heat with the surroundings.

11. According to second law of thermodynamics, when a cold body and a hot body are brought into contact with each other, heat always transferred from hot Body to the cold body. Also, that no heat engine that works in cycle completely converts heat into work. Second law of thermodynamics is used in working of heat engine and refrigerator.

12. K_1 = thermal conductivity of first rod

K_2 = thermal conductivity of second rod

r_1 = radius of cross-section of first rod

r_2 = radius of cross-section of second rod

l_1 = length of first rod

l_2 = length of second rod

θ_1 = heat flow through first rod

θ_2 = heat flow through second rod

Now, $\frac{K_1}{K_2} = \frac{1}{2}$ (given)

Also, $\frac{r_1}{r_2} = \frac{1}{2}$ and $\frac{l_1}{l_2} = \frac{1}{2}$(Given)

and $\frac{\theta_2}{t}$ = rate of flow of heat through the second rod

$\frac{\theta_2}{t} = 4\ cal/sec$(given)

$\theta_1 - \theta_2$ = Same.

Now, we know, $\frac{\theta}{t} = \frac{KA(\theta_1 - \theta_2)}{x}$ (from the defination of thermal conductivity of a material)

$\frac{\theta}{t} = \frac{K\pi r^2(\theta_1 - \theta_2)}{r}$ ...(i) (cross-sectional area, A = πr^2)

So, Let

$\theta_1 = T_1$ and $\theta_2 = T_2$

$\therefore \frac{\theta_1}{t_1} = \frac{K_1 \pi r_1^2 (T_1 - T_2)}{l_1}$....(i)

And $\frac{\theta_2}{t_2} = \frac{K_2 \pi r_2^2 (T_1 - T_2)}{l_2}$ ...(ii)

Now, Dividing eqation (i) by equation (ii), we get

$$\frac{\theta_1}{t_1} \times \frac{t_2}{\theta_2} = \frac{K_1 (\pi r_1^2)(\theta_1 - \theta_2)}{K_2 (\pi r_2^2)(\theta_1 - \theta_2)} \times \frac{l_2}{l_1}$$

Since

$\frac{\theta_2}{t_2} = 4, \frac{t_2}{\theta_2} = \frac{1}{4}; \ and \ \frac{r_1}{r_2} = \frac{1}{2}, \therefore \left(\frac{r_1}{r_2}\right)^2 = \frac{1}{4}$

Again $\frac{l_1}{l_2} = \frac{1}{2}; \frac{l_2}{l_1} = \frac{2}{1}$

Now putting all the above values we get, $\frac{\theta_1}{t_1} \times \frac{1}{4} = \frac{1}{2} \times \left(\frac{1}{2}\right)^2 \times \left(\frac{1}{2}\right)$

$\Rightarrow \frac{\theta_1}{t_1} \times \frac{1}{4} = \frac{1}{2} \times \frac{1}{4} \times 2$

$\therefore \frac{\theta_1}{t_1} = 1 \ cal/sec$

13. By the formula of conduction of heat

$$Q = \frac{\mathrm{KA}(\theta_1 - \theta_2)t}{x}$$

Q = heat flow

K = co-efficient of thermal conductivity of substance

A = area of cross-sectional of body

θ_1 = Temperature of hot surface of body

θ_2 = Temperature of cold surface of body

X = distance between hot and cold surfaces

t = time for transfer of heat

For rod A :

$\frac{Q_A}{t} = \frac{K_A(T_1 - T_2)A_A}{x}$ .... (1)

And $\frac{Q_B}{t} = \frac{K_A(T_1 - T_2)A_B}{x}$ .... (2)

For equal rates of flow, $\frac{\theta_A}{t} = \frac{\theta_B}{t}$

So $K_A A_A = K_B A_B$

14. Let heat rejected $Q_1 = x$ and $W = 1J$

Now, $Q_2 = Q_1 - W = x - 1$

Given, T_1 = 273 + 27 = 300 K, T_2 = 273 - 23 = 250 K

i. For an ideal process, $\frac{Q_2}{Q_1} = \frac{T_2}{T_1} \Rightarrow \frac{x-1}{x} = \frac{250}{300}$

   $Q_1 = x = 6J$

ii. $Q_2 = 5J$

iii. Coefficient of performance

   $\beta = \frac{T_2}{T_1 - T_2} = \frac{250}{300-250} = 5$

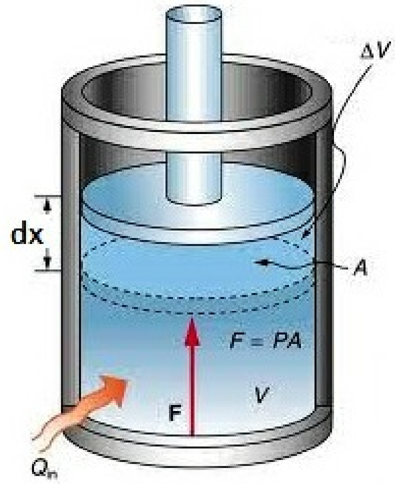
15. Consider that 1 mole (n = 1) of a perfect gas is taken in a cylinder provided with a

piston, having perfectly conducting walls and bottom.

Let the cylinder be placed on a source of heat at temperature T. If the piston is now moved slowly outwards, the gas expands, does some work and tends to cooldown but if it absorbs required amount of heat from source to keep it at same temperature, then expansion is thus isothermal.

Consider gas has initially with pressure, volume and temperature as P, V, T.

Let the gas expand to a volume V_2, when pressure reduces to P_2 and at the same temperature T



If A = Area of cross-section of piston

Force = Pressure $\times$ Area

F = P $\times$ A

If we assume that piston moves a displacement dx,

then work done : dW = F dx

dW = P $\times$ A $\times$ dx

$(\because dV = Adx)$

dW = P $\times$ dv

Total work done in increasing the volume from V_1 to V_2

$$\int_0^W dW = \int_{V_1}^{V_2} PdV$$

Since, PV = nRT (from ideal gas equation)

$$P = \frac{RT}{V} \ (\because n = 1)$$

$$W = \int_{V_1}^{V_2} \frac{RT}{V} dV$$

$$W = RT \int_{V_1}^{V_2} \frac{dV}{V}$$

$(\because \int \frac{dx}{x} = \text{Log}_e x)$

$W = R\,T\,\text{Log}_e V\Big|_{V_1}^{V_2}$

$W = R\,T\,[\text{Log}_e V_2 - \text{Log}_e V_1]$

$\left(\because Log\,\mathrm{m} - Log\,\mathrm{n} = Log\frac{m}{n}\right)$

$W = R\,T\,\text{Log}_e \frac{V_2}{V_1}$

$(\because \text{Log}_e a = 2.303 \text{Log}_{10} a)$

$W = 2.303 RT \text{Log}_{10} \left(\frac{V_2}{V_1}\right)$

As $P_1\,V_1 = P_2\,V_2$

$\frac{P_1}{P_2} = \frac{V_2}{V_1}$

So $W = 2.303\,R\,T\,\text{Log}_{10} \left(\frac{P_1}{P_2}\right)$