



Thermodynamics

Marks: 30

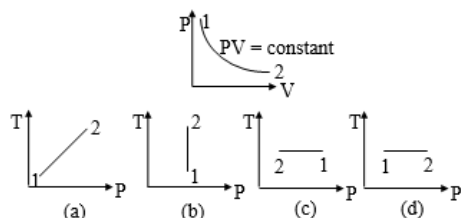
ANSWER KEY

Physics

Q.1 C	Q.2 B	Q.3 D	Q.4 D	Q.5 B	Q.6 A	Q.7 B	Q.8 C
Q.9 D	Q.10 C	Q.11 C	Q.12 A	Q.13 A	Q.14 B	Q.15 D	Q.16 B
Q.17 C	Q.18 D	Q.19 D	Q.20 C	Q.21 A	Q.22 B	Q.23 C	Q.24 A
Q.25 D	Q.26 A	Q.27 D	Q.28 A	Q.29 B	Q.30 B		

## Physics

**Q.1** Consider P – V diagram for an ideal gas shown in figure. Out of the following graphs which represents the T – P graph corresponding to P – V graph?



**Correct option: (C)**

As  $PV = \text{constant}$ , it is an isothermal process. As a result, the temperature remains constant.

Also from PV graph we know that, pressure is decreasing hence  $P_2 < P_1$  which is represented by graph (c).

**Q.2** A monoatomic ideal gas, initially at temperature  $T_1$ , is enclosed in a cylinder fitted with a frictionless piston. The gas is allowed to expand adiabatically to a temperature  $T_2$  by releasing the piston suddenly.  $L_1, L_2$  are lengths of gas columns before and after the expansion respectively. The value of  $\frac{T_1}{T_2}$  is

**Correct option: (B)**

For an adiabatic process

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$\therefore \frac{T_2}{T_1} = \left( \frac{V_1}{V_2} \right)^{\gamma-1}$$

For a monoatomic gas,  $\gamma = \frac{5}{3}$

$$\Rightarrow \gamma - 1 = \frac{5}{3} - 1 = \frac{2}{3}$$

$$V_1 = AL_1 \text{ and } V_2 = AL_2$$

$$\therefore \frac{T_2}{T_1} = \left[ \frac{AL_1}{AL_2} \right]^{2/3} = \left[ \frac{L_1}{L_2} \right]^{2/3}$$

For an adiabatic process,

$$\frac{T_2}{T_1} = \left( \frac{V_1}{V_2} \right)^{\gamma-1} = \left( \frac{V_1}{V_2} \right)^{\frac{2}{3}}$$

But  $V \propto L$

$$\therefore \frac{T_1}{T_2} = \left( \frac{L_2}{L_1} \right)^{\frac{3}{2}}$$

**Q.3** The efficiency of a Carnot engine which operates between the two temperatures  $T_1 = 600 \text{ K}$  and  $T_2 = 200 \text{ K}$  is

**Correct option: (D)**

$$\eta = \left[ 1 - \frac{T_C}{T_H} \right] \times 100 = \left[ 1 - \frac{200}{600} \right] \times 100 = 66.6\%$$

**Q.4** Consider an ideal gas. If 100 J of work is done in compressing it under adiabatic conditions, then its

**Correct option: (D) internal energy**

**increases by 100 joule and heat given out is zero.**

Self Explanatory

**Q.5** The first law of thermodynamics is a special case of

**Correct option: (B) the law of conservation of energy.**

Self Explanatory

**Q.6**  $1 \text{ mm}^3$  of a gas is compressed at 1 atmospheric pressure and temperature  $27^\circ\text{C}$  to  $327^\circ\text{C}$ . What is the final pressure under adiabatic condition ( $\gamma$  for the gas = 1.5)?

**Correct option: (A)**

$$T_1 = 27 + 273 = 300 \text{ K}$$

$$T_2 = 327 + 273 = 600 \text{ K}, \gamma = 1.5$$

For an adiabatic change,  $\frac{T^\gamma}{P^{\gamma-1}} = \text{constant}$

$$\therefore \left( \frac{P_2}{P_1} \right)^{1/2} = \left( \frac{T_2}{T_1} \right)^{3/2} \Rightarrow \left( \frac{P_2}{10^5} \right)^{1/2} = \left( \frac{600}{300} \right)^{3/2}$$

$$\therefore P_2 = 8 \times 10^5 \text{ N / m}^2$$

**Q.7** A Carnot engine has the same efficiency between  $800 \text{ K}$  to  $500 \text{ K}$  and  $x \text{ K}$  to  $620 \text{ K}$ .

**The value of x is**

**Correct option: (B)**

$$\text{Efficiency of a Carnot engine is, } \eta = 1 - \frac{T_C}{T_H}$$

For case (i),

$$T_C = 500 \text{ K and } T_H = 800 \text{ K}$$

$$\therefore \eta_1 = 1 - \frac{500}{800} = \frac{3}{8}$$

For case (ii),

$$T_C = 620 \text{ K and } T_H = x \text{ K}$$

$$\therefore \eta_2 = 1 - \frac{620}{x}$$

$$\text{Given } \eta_1 = \eta_2$$

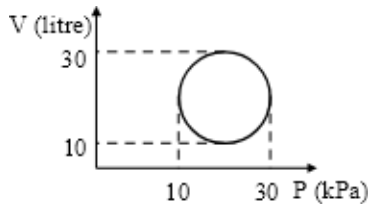
$$\therefore \frac{3}{8} = 1 - \frac{620}{x}$$

$$\frac{620}{x} = 1 - \frac{3}{8}$$

Solving for x, we get

$$x = 992 \text{ K}$$

**Q.8 Heat energy absorbed by a system in going through a cyclic process shown in figure is**



**Correct option: (C)  $10^2 \pi \text{ J}$**

For a cyclic process,  $\Delta U = 0$

$\therefore$  By 1<sup>st</sup> law of thermodynamics,

$$Q = \Delta U + W = 0 + W$$

= Area of closed curve

$$\therefore Q = \pi r^2 = \pi \left( \frac{20}{2} \right)^2 \text{ kPa} \times \text{litre}$$

$$= 100\pi \times 10^3 \times 10^{-3} \text{ J}$$

$$= 100 \pi \text{ J}$$

**Q.9 Among the amount of heat absorbed and the amount of work done by a system, Correct option: (D) both depend on the path.**

Self Explanatory

**Q.10 During adiabatic process, a perfect gas obeys**

$PV^{3/2} = \text{constant}$ . Initial temperature of the gas is T. When it is compressed to  $\left(\frac{1}{3}\right)^{\text{rd}}$  of

initial volume, the final temperature of the gas will be

**Correct option: (C)**

For adiabatic process,

$$PV^{3/2} = \text{constant} \quad \dots(i)$$

The ideal gas law states that

$$PV = NRT$$

$$\therefore P = \frac{NRT}{V}$$

Substituting this value of 'P' in equation (i),

$$\frac{NRT}{V} \times V^{3/2} = \text{Constant}$$

$$NRTV^{1/2} = \text{constant}$$

$\therefore$  N and R values will remain constant,

$$\therefore TV^{1/2} = \text{constant}$$

$$T = \frac{\text{constant}}{V^{1/2}}$$

$$T \propto \frac{1}{V^{1/2}}$$

If T is the initial temperature with initial volume V and  $T_f$  is the final temperature with final volume  $V_f$ , then,

$$\frac{T_f}{T} = \left( \frac{V}{V_f} \right)^{1/2}$$

$$V_f = \frac{V}{3} = \text{final volume}$$

$$\therefore \frac{T_f}{T} = \left( \frac{V}{V/3} \right)^{1/2} = \sqrt{3}$$

$$\therefore T_f = \sqrt{3}T$$

**Q.11 When heat energy of 1500 joules is supplied to a gas at constant pressure  $2.1 \times 10^5 \text{ N/m}^2$ , there is an increase in its volume equal to  $2.5 \times 10^{-3} \text{ m}^3$ . The increase in internal energy of the gas in joules is**

**Correct option: (C)**

By 1<sup>st</sup> law of thermodynamics,

$$Q = \Delta U + P(\Delta V)$$

$$\therefore \Delta U = Q - P(\Delta V)$$

$$= 1500 - (2.1 \times 10^5)(2.5 \times 10^{-3}) = 975 \text{ J}$$

**Q.12 If Q, E and W denote respectively the heat added, change in internal energy and the work done in a closed cycle process, then**

**Correct option: (A)**

In a closed cyclic process, the change in internal energy is always zero

$$\therefore E = 0$$

**Q.13** If Q, E and W denote the heat added, change in internal energy and the work done in a closed cycle process respectively, then

**Correct option: (A)**

In a closed cyclic process, the change in internal energy is always zero  $\Rightarrow E = 0$

**Q.14** A litre of dry air at S.T.P. expands adiabatically to a volume of 3.6 litres. If  $\gamma = 1.40$ , the work done by air is (3<sup>1.4</sup> = 4.6555) [Take air to be an ideal gas]

**Correct option: (B)**

In case of adiabatic process,  $\Delta Q = 0$

$$\therefore \Delta W = -\Delta U$$

Thus, work done by the air will be,

$$\therefore \Delta W = -\frac{P_2 V_2 - P_1 V_1}{\gamma - 1}$$

For an ideal gas at S.T.P.,

$$P_1 = 10^5 \text{ Pa}$$

For adiabatic process,  $PV^\gamma = \text{constant}$

$$\begin{aligned} \therefore P_2 &= P_1 \times \left(\frac{V_1}{V_2}\right)^\gamma \\ &= 10^5 \times \left(\frac{1}{3.6}\right)^{1.4} = \frac{10^5}{4.6555} \text{ Pa} \end{aligned}$$

$$V_1 = 1 \text{ L} = 1 \times 10^{-3} \text{ m}^3 \text{ and}$$

$$V_2 = 3.6 \text{ L} = 3.6 \times 10^{-3} \text{ m}^3$$

$$\begin{aligned} \therefore \Delta W &= -\frac{\left(\frac{10^5}{4.6555} \times 3.6 \times 10^{-3}\right) - (10^5 \times 1 \times 10^{-3})}{1.4 - 1} \\ &= -\frac{(0.7733 - 1) \times 10^2}{0.4} \\ &= -56.7 \text{ J} \end{aligned}$$

**Q.15** Air is expanded from 6 litre to 16 litre at 2 atmospheric pressure. The external work done is (1 atmosphere =  $10^5 \text{ N / m}^2$ )

**Correct option: (D)**

$$\begin{aligned} \text{Change in volume, } \Delta V &= 16 - 6 = 10 \text{ litre} \\ &= 0.01 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} W &= P\Delta V \\ &= 2 \times 10^5 \times 0.01 = 2000 \text{ J} \end{aligned}$$

**Q.16** Three samples X, Y, and Z of same gas have equal volumes and temperatures. The volume of each sample is doubled, the process being isothermal for X, adiabatic for Y and isobaric for Z. If the final pressures are equal for the

three samples, the ratio of the initial pressures is ( $\gamma = 3/2$ )

**Correct option: (B)**

$$\text{Given: } V_2 = 2V_1, \gamma = \frac{3}{2}$$

For gas Y subjected to adiabatic process,

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

$$\therefore \frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^\gamma = (2)^{\frac{3}{2}} = 2\sqrt{2}$$

$$\therefore P_1 = 2\sqrt{2}P_2$$

For gas Z subjected to isobaric process,

$$P_1 = P_2 \quad \text{or} \quad \frac{P_1}{P_2} = 1$$

For gas X subjected to isothermal process,

$$P_1 V_1 = P_2 V_2$$

$$\frac{P_1}{P_2} = \frac{V_2}{V_1} = 2 \text{ or } P_1 = 2P_2$$

$$\therefore \text{Ratio of initial pressures is } 2 : 2\sqrt{2} : 1$$

**Q.17** The gas law  $(PV/T) = \text{constant}$  is true for

**Correct option: (C)**

**Q.18** When an ideal diatomic gas is heated at constant pressure, the fraction of the heat energy supplied which increases the internal energy is

**Correct option: (D)**

The fraction of heat energy used to increase the internal energy of gas is,

$$\frac{\Delta U}{\Delta Q} = \frac{C_V}{C_P} = \frac{1}{\gamma}$$

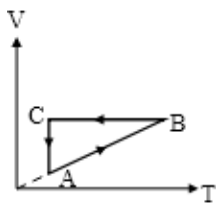
$$\text{For diatomic gas, } \gamma = \frac{7}{5}$$

$$\therefore \frac{\Delta U}{\Delta Q} = \frac{5}{7}$$

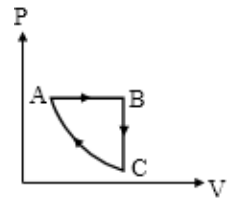
**Q.19** First law of thermodynamics states that **Correct option: (D)**

Heat always refers to energy in transit from one body to another because of temperature difference.

**Q.20** A cyclic process ABCA is shown in the V-T diagram. Process on the P-V diagram is



Correct option: (C)



From the given VT diagram,

For process AB,  $V \propto T \Rightarrow$  Pressure is constant

For process BC,  $V = \text{Constant}$  and for process CA,

$T = \text{constant}$

These processes are correctly represented on PV diagram by graph [C].

**Q.21** Which one of the following equations specifies an isochoric process?

[ $Q =$  heat supplied,  $\Delta p =$  change in pressure,  $\Delta V =$  change in volume,  $\Delta T =$  change in temperature]

Correct option: (A)

In an isochoric process, the volume remains constant.

$$\therefore \Delta V = 0$$

**Q.22** In an isothermal process, an ideal gas having volume ' $V_1$ ' undergoes an expansion. The final volume is ' $V_2$ '. The total work done by the gas is

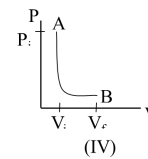
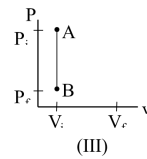
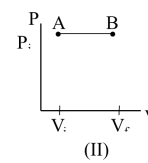
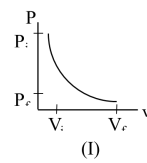
Correct option: (B)

The work done by the gas during an isothermal expansion is given by the area under the pressure-volume curve on a P-V diagram.

Hence, the work done during an isothermal expansion can be calculated using the

$$\text{integral: } \int_{V_1}^{V_2} PdV$$

**Q.23** Which one of the following P-V diagram is correct for an isothermal process?



Correct option: (C)

**Caution**

Graph (IV) though appears similar to (I), note that in (I), volume remains constant over a large drop in pressure. This is not the characteristic of isothermal process.

**Q.24** The relation between efficiency ( $\eta$ ) of Carnot engine and coefficient of performance ( $\eta_1$ ) of refrigerator is

Correct option: (A)

$$\eta = 1 - \frac{T_2}{T_1}$$

$$\eta_1 = \frac{T_2}{T_1 - T_2} = \frac{\frac{T_2}{T_1}}{\frac{T_1}{T_1} - \frac{T_2}{T_1}} = \frac{1 - \eta}{1 - (1 - \eta)} =$$

$$\frac{1}{\eta} - 1$$

$$\therefore \frac{1}{\eta} = \eta_1 + 1$$

$$\therefore \eta = \frac{1}{\eta_1 + 1}$$

**Q.25** The work of 146 kJ is performed in order to compress one kilo mole of a gas adiabatically and in this process the temperature of the gas increases by 7 °C.

The gas is

$$(R = 8.3 \text{ J mol}^{-1} \text{ K}^{-1})$$

Correct option: (D)

In adiabatic process,  $\Delta Q = 0$

$\therefore$  work is done on the system  $\Rightarrow$  internal energy of the system increases

$$\therefore \Delta U = \Delta W \Rightarrow n \times C_v \times \Delta T = \Delta W$$

$$\therefore n \times \left( \frac{R}{\gamma - 1} \right) \times 7 = 146 \times 10^3$$

$$\therefore 10^3 \times \frac{8.3}{(\gamma - 1)} \times 7 = 146 \times 10^3$$

$\therefore$  On solving we get,  $\gamma = 1.4$

$\therefore$  The gas is diatomic.

**Q.26** The number of repetitions of the operating cycles of an automobile engine is indicated by

**Correct option: (A)**

The number of repetitions of the operating cycles of an automobile engine is indicated by *revolutions per minute*. The engine's crankshaft rotates, completing a full circle with each revolution. The speed of the crankshaft rotation is measured in revolutions per minute (RPM).

**Q.27** During an adiabatic process the cube of the pressure of a gas is proportional to the fifth power of its volume. The ratio of specific heat  $C_P / C_V$  for that gas is

**Correct option: (D) 5/3**

$$P^3 = k V^5$$
$$\therefore P = k V^{\frac{5}{3}}$$

But, for adiabatic process,  $PV^\gamma = \text{constant}$

$$\therefore C_P / C_V = 5/3$$

**Q.28** Air in a cylinder is suddenly compressed by a piston, which is then maintained at the same position. With the passage of time

**Correct option: (A)**

Due to compression the temperature of the system increases to a very high value. This causes the flow of heat from system to the surroundings, thus

decreasing the temperature. The decrease in temperature results in decrease in pressure.

**Q.29** A lead bullet moving with velocity 'v' strikes a wall and stops. If 50% of its energy is converted into heat, then the increase in temperature is (s = specific heat of lead)

**Correct option: (B)**

Energy converted to heat = 50 % of K.E.

$$\therefore E = \frac{1}{2}mv^2 \times \left(\frac{50}{100}\right) = \frac{1}{4}mv^2$$

$$\text{Heat, } Q = ms\Delta T$$

$$J = \text{Mechanical equivalent of heat} = \frac{W}{Q}$$

$$\therefore J = \frac{\frac{1}{4}mv^2}{ms\Delta T}$$

$$\Delta T = \frac{v^2}{4Js}$$

**Q.30** A gas in a closed container is heated with 10 J of energy, causing the lid of the container to rise 2 m with 3 N of force. What is the total change in energy of the system?

**Correct option: (B)**

Given that,  $Q = 10 \text{ J}$

$$\begin{aligned} \text{Work done (W)} &= \text{Force} \times \text{displacement} \\ &= 3 \times 2 \\ &= 6 \text{ J} \end{aligned}$$

$\therefore$  From first law of thermodynamics,

$$\Delta U = |Q| - |W| = 10 - 6 = 4 \text{ J}$$