PHYSICS CLASS XI
CHAPTER – 12 THERMODYNAMICS

Q.1. If a refrigerator's door is kept open, will the room become cool or hot? Explain.

Ans. Here, heat removed is less than the heat supplied and hence the room become hotter.

Q.2. A room can be cooled by opening the door of a refrigerator. Is it true or false?

Ans. Heat rejected by refrigerator remains in the room itself and so, temperature of room increases. Hence, it is false.

Q.3. On what factors, the efficiency of a Carnot engine depends?

Ans. On the temperature of source of heat and the sink.

Q.4. If the temperature of the sink is increased, what will happen to the efficiency of Carnot engine?

Ans. Efficiency $\eta = 1 - \frac{T_2}{T_1}$

By increasing (T_2), the efficiency of the Carnot engine will decrease.

Q.5. The coefficient of performance of a refrigerator depends on which factor?

Ans. The coefficient of performance of a refrigerator depends on the temperature of source and sink.

Q.6. Find the efficiency of the Carnot engine working between boiling point and freezing of water.

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Ans. Efficiency of Carnot engine $\eta = 1 - \frac{T_2}{T_1}$

$$= 1 - \frac{273K}{373K} = \frac{100}{373} = 0.268 = 26.8\%$$

Q.7. Which thermodynamic law put restrictions on the complete conversion of heat into work?

Ans. According to second law of thermodynamics, heat energy cannot converted into work completely.

Q.8. Can a ship could be moved with the energy of the sea water?

Ans. No, a ship cannot be moved in a sea by the use of the energy of sea water because refrigerator is against the second law of thermodynamics.

Q.9. Can we design a reversible Carnot engine in practice?

Ans. No, we cannot design an ideal Carnot engine in practice.

Q.10. What type of process is a Carnot cycle?

Ans. Carnot cycle is a reversible cyclic process through which heat is converted into mechanical work.

Q.11. Is reversible process is possible in nature?

Ans. A reversible process is never possible in nature because of dissipative forces and condition for a quassi-static process is not practically possible.

Q.12. What are the forces which make any process irreversible?

Ans. All sorts of dissipative forces e.g., force of friction, viscous drag, electrical resistance , non – elasticity, thermal radiation, convention etc., make a real process irreversible.

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Q.13. In a refrigerator, one removes heat from a lower temperature and deposits to the surroundings at a higher temperature. In this process, mechanical work has to be done, which is provided by an electric motor. If the motor is of 1 kW power and heat is transferred from - 3°C to 27°C, find the heat taken out of the refrigerator per second assuming its efficiency is 50% refrigerator per second assuming its efficiency is 50% of a perfect engine.

Ans. T_1 = -3°C = -3 + 273 = 270

T_2 = 27°C = 27 + 273 = 300 k

Efficiency, $\eta = 1 - \frac{T_1}{T_2} = 1 - \frac{270}{300} = \frac{1}{10}$ %

or $\frac{W}{Q} = 0.5\,\eta = \frac{1}{20}$

or Q = 20 W = 20 kJ

Q.14. A steam engine delivers 5.4 × 10^8 J of work per min and services 3.6 × 10^9 J of heat per min from its boiler.

(i) What is efficiency of the engine?

(ii) How much heat is wasted per minute?

Ans. (i) Work done by the engine per min

$$\Delta W = 5.4 \times 10^8 \text{ J} = 0.54 \times 10^9 \text{ J/min}$$

Heat absorbed by engine per min

$$\Delta Q_1 = 3.6 \times 10^9 J/\text{min}$$

So, engine efficiency, $\eta = \frac{Work\ done}{Heat\ delivered}$

$$= \frac{0.54\times10^9}{3.6\times10^9} = 0.15 = 15\%$$

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(ii) Heat wasted per min = heat absorbed – work done

$= 3.6 \times 10^9 - 0.54 \times 10^9$

$= 3.06 \times 10^9$ J/min

Q.15. A refrigerator is to maintain eatables kept inside at 9°C. If room temperature is 36°C. Calculate the coefficient of performance.

Ans. T_2 = 9°C = 9 + 273 = 282 K

T_1 = 36°C = 36 + 273 = 309 k

Coefficient of performance = $\frac{T_2}{T_1 - T_2} = \frac{282}{309-282} = 10.4$

Q.16. Under what condition, an ideal Carnot engine has 100% efficiency?

Ans. Efficiency of a Carnot engine is given by $\eta = \left(1 - \frac{T_2}{T_1}\right)$

where, T_2 = temperature of sink

and T_1 = temperature of sink source.

So for η = 1 or 100%, T_2 = 0 K or heat is rejected into a sink at 0 K temperature.

Q.16. A Carnot engine is operating between 600 K and 200 k. Consider that the actual energy produced is 2 kJ per kilocalorie of heat absorbed. Compare the real efficiency with the efficiency of Carnot engine.

Ans. Efficiency of Carnot engine, $\eta = \frac{T_1 - T_2}{T_1} = \frac{600-200}{600}$

$= \frac{400}{600} = \frac{2}{3} = 66\%$

Real efficiency = $\frac{Energy\ output}{Energy\ input}$

$= \frac{2}{1 \times 4.2} = 0.47 = 47\%$

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$$\frac{Carnot\ engine\ efficiency}{Real\ frequency} = 0.71$$

Q.17. Explain what do you understand by the efficiency of a heat engine?

Ans. The efficiency of a heat engine is stated as the ratio of the net work done by the heat engine and heat absorbed by the working substance.

Suppose a heat engine absorbs Q_1 heat from the hot reservoir and gives Q_2 heat to the colder reservoir. So, the work done by the working substance is

$$W = Q_1 - Q_2$$

So, efficiency of heat engine

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

Q.18. What is a heat engine? What is the best way to increase efficiency of a heat engine?

Is it possible to design a thermal engine that has 100% efficiency?

Ans. A heat engine is a device (or a combination) which converts heat into work.

Its efficiency $\eta = \frac{Work\ output}{Heat\ input}$

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

where, T_2 = temperature of sink

T_1 = temperature of source.

From above expression, we can see that for 100% efficiency, $T_1 = \infty$

⇒ temperature of source is very large compared to that of sink.

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Q.19. An ideal refrigerator is working between the temperature of ice and temperature of atmosphere at 300 K. Find the energy which has been supplied to it to freeze 4 kg of water at 0°C. Given that latent heat of ice 3.33 × 10^5J/kg.

Ans. Here, T_1 = 300 K, T_2 = 0°C = 273 K

Heat extracted, $Q_2 = mL_1$ **=** 2 kg × 3.33 × 10^5 J/kg

= 666 ×10^5 J

As, $\alpha = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$

∴ $W = \frac{Q_2(T_1 - T_2)}{T_2} = \frac{666 \times 10^5 \times (300 - 273)}{273}$

= 65868 J ≃ 6.5 × 10^4 J

Q.20. Temperature of the hot and cold reservoirs of a Carnot engine is raised by equal amounts. How the efficiency of the Carnot engine affected?

Ans. Let the initial temperatures of hot and cold reservoirs were T_1 and T_2 . The efficiency of the Carnot engine is given by

So, initially

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

As given the temperatures of both the reservoirs is raised by equal amount t, so $T_1' = T_1$ + t and $T_2' = T_2$ + t . The final efficiency of the Carnot engine will be

$\eta' = \frac{T_1' - T_2'}{T_1'} = \frac{(T_1 + t) - (T_2 + t)}{(T_1 + t)}$

$= \frac{T_1 - T_2}{(T_1 + t)}$

Dividing Eq. (ii) by Eq. (i), we have

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$\frac{\eta'}{\eta} = \frac{\left(\frac{T_1 - T_2}{T_1 + t}\right)}{\left(\frac{T_1 - T_2}{T_1}\right)} = \frac{T_1}{T_1 + t}$ .....(iii)

As $\eta' < \eta$ i.e., the efficiency of Carnot engine decreases.

Q.27. A refrigerator transfers 250 J heat per second from - 23°C to 25°C. Find the power consumed, assuming no loss of energy.

Ans. Here, $Q_2 = 250\ Js^{-1}$

T_2 = - 20°C = - 23 + 273 = 250 K

T_1 = 25°C = 25 + 273 = 298 k

Power = Work per second

We know $\beta = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$

∴ $W = \frac{Q_2(T_1 - T_2)}{T_2}$

$W = \frac{250(298 - 250)}{250}$

$= \frac{250 \times 48}{250}$

$W = 48\ Js^{-1}$

Q.28. Find out whether these phenomena are reversible or not.

(i) Waterfall and (ii) Rusting of iron

Ans. (i) Waterfall The falling of water cannot be reversible process. During the water fall, its potential energy convert into kinetic energy of the water. On striking the ground, some part of potential energy converts into heat and sound not possible that head and the sound. In nature, it is automatically convert the

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kinetic energy and potential energy so that the water will rise back so waterfall is not a reversible process.

(ii) Rusting of iron In rusting of iron, the iron become oxidised with the oxygen of the air as it is a chemical reaction, it cannot be reversed.

Q.29. The efficiency of a Carnot engine is ½. If the sink temperature is reduced by 100°C, then engine efficiency becomes 2/3. Find

(i) source temperature

(ii) sink temperature

(iii) Explain why a Carnot engine cannot have 100% efficiency?

Ans. (i) Efficiency, $\eta = 1 - \frac{T_2}{T_1}$

where, T_2 = sink temperature

T_1 = source temperature

$$1 - \frac{T_2}{T_1} = \frac{1}{2}$$

$$1 - \left(\frac{T_2 - 100}{T_1}\right) = \frac{2}{3}$$

From Eq. (i), $\frac{T_2}{T_1} = \frac{1}{2}$ and Eq. (ii) $\frac{T_2 - 100}{T_1} = \frac{1}{3}$

On dividing, we get

$$\frac{T_2}{T_2 - 100} = \frac{3}{2} \Longrightarrow T_2 = 300 \text{ K}$$

(ii) Substituting in Eq. (i), T_1 = 600 K

(iii) As efficiency $\eta_2 \Rightarrow 1 - \frac{T_2}{T_1}$

∴ It equals to 1 only when $\frac{T_2}{T_1} = 0$ or $T_2 = 0$ K

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But absolute zero is not possible

Q.30. An ideal refrigerator runs between - 23°C and 27°C

(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.

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

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

Given $T_1 = 273 + 27 = 300$ K

$T_2 = 273 - 23 = 250$ K

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

$\Longrightarrow$ $x = 6$ J

$\Longrightarrow$ $Q_1 = 6$ J, $Q_2 = 5$ J and $W = 1$ J

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