Chapter 4 Second Law of Thermodynamics

One Mark Questions

01. A condenser of a refrigeration system rejects heat at a rate of 120 kW, while its compressor consumes a power of 30 kW. The coefficient of performance of the system would be (GATE-ME-92)
(a) 1/4 (b) 4 (c) 1/3 (d) 3

02. A reversible heat transfer demands:(GATE-ME-93)
(a) The temperature difference causing heat transfer tends to zero
(b) The system receiving heat must be at a constant temperature.
(c) The system transferring out heat must be at a constant temperature.
(d) Both interacting systems must be at constant temperatures

03. Any thermodynamic cycle operating between two temperature limits is reversible if the product of the efficiency when operating as a heat engine and the COP when operating as a refrigerator is equal to 1. (GATE-ME-94)

04. Consider a refrigerator and a heat pump working on the reversed Carnot cycle between the same temperature limits. Which of the following is correct? (GATE-ME-95)
(a) COP of refrigerator = COP of heat pump
(b) COP of refrigerator = COP of heat pump + 1
(c) COP of refrigerator = COP of heat pump – 1
(d) COP of refrigerator = inverse of the COP of heat pump

05. In the case of a refrigeration system undergoing an irreversible cycle, $\oint \frac{\delta Q}{T}$ is_______(<0/ = 0/>0) (GATE-ME-95)

06. An industrial heat pump operates between the temperatures of 27°C and –13°C. The rates of heat addition and heat rejection are 750 W and 1000 W, respectively. The COP for the heat pump is (GATE-ME-03)
(a) 7.5 (b) 6.5 (c) 4.0 (d) 3.0

07. The following four figures have been drawn to represent a fictitious thermodynamic cycle, on the P-v and T-S planes. (GATE-ME-05)

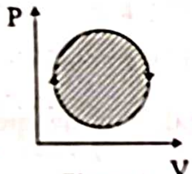


Figure 1

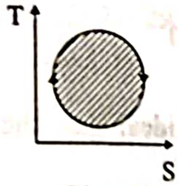


Figure 2

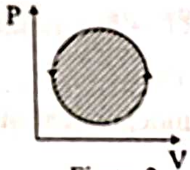


Figure 3

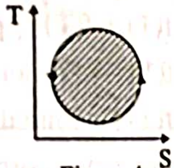


Figure 4

According to the first law of thermodynamics, equal areas are enclosed by
(a) figures 1 and 2 (b) figures 1 and 3
(c) figures 1 and 4 (d) figures 2 and 3

08. A reversed Carnot cycle refrigerator maintains a temperature of –5°C. The ambient air temperature is 35°C. The heat gained by the refrigerator at a continuous rate is 2.5 kJ/s. The power (in watt) required to pump this heat out continuously is _______ (GATE-ME-14-SET-4)

09. A Carnot engine (CE-1) works between two temperature reservoirs A and B, where $T_A = 900$ K and $T_B = 500$ K. A second Carnot engine (CE-2) works between temperature reservoirs B and C, where $T_c = 300$ K. In each cycle of CE-1 and CE-2, all the heat rejected by CE-1 to reservoir B is used by CE-2. For one cycle operation, if the net Q

absorbed by CE-1 from reservoir A is 150 MJ, the net heat rejected to reservoir C by CE-2 (in MJ) is (GATE –15 –Set 1)

______

The COP of a Carnot heat pump operating between 6°C and 37°C is ____ (GATE –15 –Set 2)

The heat removal rate from a refrigerated space and the power input to the compressor are 7.2 kW and 1.8 kW, respectively. The coefficient of performance (COP) of the refrigerator is __(GATE–16–SET–2)

A heat pump absorbs 10 kW of heat from outside environment at 250 K while absorbing 15 kW of work. It delivers the heat to a room that must be kept warm at 300 K. The Coefficient of performance (COP) of the heat pump is ___(GATE–17–SET–1)

13. A heat pump is to supply heat at the rate of 10 kW to a building to be maintained at 22°C. The outside temperature is 2°C. The minimum power (in kW) required to run the heat pump is ______ (round off to 2 decimal places) (GATE – 19_PI)

14. If a reversed Carnot cycle operates between the temperature limits of 27°C and –3°C, then the ratio of the COP of a refrigerator to that of a heat pump (COP of refrigerator/ COP of heat pump) based on the cycle is ______(round off to 2 decimal places). (GATE–20–SET–2)

15. A Carnot heat engine receives 600 kJ of heat per cycle from a source of 627°C and rejects heat to a sink at 27°C. The amount of heat rejected to the sink per cycle (rounded off to the nearest integer) in kJ is (GATE-PI-20)
(a) 574 (b) 200 (c) 26 (d) 400

16. Consider an ideal vapour compression refrigeration cycle working on R-134a refrigerant. The COP of the cycle is 10 and the refrigeration capacity is 150 kJ/kg. The heat rejected by the refrigerant in the condenser is ____ kJ/kg (round off to the nearest integer). (GATE–21_SET–2)

17. Heat is being removed from a refrigerator at a rate of 300 kJ/min to maintain its inside temperature at 2°C. If the input power to the refrigerator is 2 kW, the coefficient of performance of the refrigerator is ______[round off to one decimal place] (GATE_PI–21)

18. A heat engine extracts heat (Q_H) from a thermal reservoir at a temperature of 1000 K and rejects heat (Q_L) to a thermal reservoir at a temperature of 100 K, while producing work (W). Which one of the combinations of [Q_H, Q_L and W] given is allowed? (GATE_ME-23)
(a) $Q_H = 2000$ J, $Q_L = 500$ J, W = 1000 J
(b) $Q_H = 2000$ J, $Q_L = 750$ J, W = 1250 J
(c) $Q_H = 6000$ J, $Q_L = 500$ J, W = 5500 J
(d) $Q_H = 6000$ J, $Q_L = 600$ J, W = 5500 J

Two Marks Questions

01. Round the clock cooling of an apartment having a load of 300 MJ/day requires and air-conditioning plant of capacity about (GATE-ME-93)
(a) 1 ton (b) 5 tons (c) 10 tons (d) 100 tons

02. A solar energy based heat engine which receives 80 kJ of heat at 100°C and rejects 70 kJ of heat to the ambient at 30°C is to be designed. The thermal efficiency of the heat engine is (GATE-ME-96)
(a) 70% (b) 18.8% (c) 12.5% (d) Indeterminate

03. For two cycles coupled in series, the topping cycle has an efficiency of 30% and the bottoming cycle has an efficiency of 20%. The overall combined cycle efficiency is (GATE-ME-96)
(a) 50% (b) 44% (c) 38% (d) 55%

04. A cyclic heat engine does 50 kJ of work per cycle. If the efficiency of the heat engine is 75%, then heat rejected per cycle is **(GATE-ME-01)**

(a) $16\frac{2}{3}$ kJ (b) $33\frac{1}{3}$ kJ
(c) $37\frac{1}{2}$ kJ (d) $66\frac{2}{3}$ kJ

05. A Carnot cycle is having an efficiency of 0.75. If the temperature of the high temperature reservoir is 727°C, what is the temperature of low temperature reservoir? **(GATE-ME -02)**

(a) 23°C (b) – 23°C (c) 0°C (d) 250°C

06. A heat engine having an efficiency of 70% is used to drive a refrigerator having a coefficient of performance of 5. The energy absorbed from low temperature reservoir by the refrigerator for each kJ of energy absorbed from high temperature source by the engine is **(GATE-ME -04)**

(a) 0.14 kJ (b) 0.71 kJ (c) 3.5 kJ (d) 7.1 kJ

07. A solar collector receiving solar radiation at the rate of 0.6 kW/m² transforms it to the internal energy of a fluid at an overall efficiency of 50%. The fluid heated to 350 K is used to run a heat engine which rejects heat at 313 K. If the heat engine is to deliver 2.5 kW power, then minimum area of the solar collector required would be **(GATE-ME -04)**

(a) 8.33 m² (b) 16.66 m²
(c) 39.68 m² (d) 79.36 m²

08. A heat transformer is a device that transfers a part of the heat, supplied to it at an intermediate temperature, to a high temperature reservoir while rejecting the remaining part to a low temperature heat sink. In such a heat transformer, 100 kJ of heat is supplied at 350 K. The maximum amount of heat in kJ that can be transferred to 400 K, when the rest is rejected to a heat sink at 300 K is

(GATE-ME-07)

(a) 12.50 (b) 14.29 (c) 33.33 (d) 57.14

09. An irreversible heat engine extracts heat from a high temperature source at a rate of 100 kW and rejects heat to a sink at a rate of 50 kW. The entire work output of the heat engine is used to drive a reversible heat pump operating between a set of independent isothermal heat reservoirs at 17°C and 75°C. The rate (in kW) at which the heat pump delivers heat to its high temperature sink is

(GATE-ME-09)

(a) 50 (b) 250 (c) 300 (d) 360

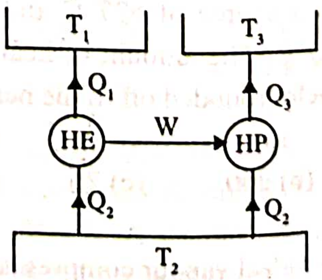
10. A reversible heat engine receives 2 kJ of heat from a reservoir at 1000 K and a certain amount of heat from a reservoir at 800 K. It rejects 1 kJ of heat to a reservoir at 400 K. The net work output (in kJ) of the cycle is **(GATE-ME-14-SET-1)**

(a) 0.8 (b) 1.0 (c) 1.4 (d) 2.0

11. A reversible cycle receives 40 kJ of heat from one heat source at a temperature of 127°C and 37 kJ from another heat source at 97°C. The heat rejected (in kJ) to the heat sink at 47°C is ______

(GATE–16–SET-2)

12. The figure shows a heat engine (HE) working between two reservoirs. The amount of heat (Q_2) rejected by the heat engine is drawn by a heat pump (HP). The heat pump receives the entire work output (W) of the heat engine. If temperatures, $T_1 > T_3 > T_2$, then the relation between the efficiency (η) of the heat engine and the coefficient of performance (COP) of the heat pump is **(GATE–19–SET-2)**



(a) $COP = \eta$ (b) $COP = \eta^{-1} - 1$
(c) $COP = \eta^{-1}$ (d) $COP = 1 + \eta$