POSTAL
BOOK PACKAGE
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MECHANICAL ENGINEERING

Objective Practice Sets

Refrigeration and Air-conditioning

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1 CHAPTER

Introduction and Basic Concepts of Refrigerator, Heat Pump & Reversed Carnot Cycle

MCQ and NAT Questions

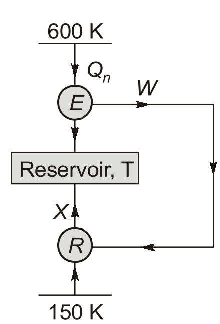
Q.1 The domestic refrigerator has a refrigeration load of the order of
(a) less than 0.25 ton (b) between 0.5 & 1 ton
(c) more than 1 ton (d) more than 5 ton

Q.2 The coefficient of performance of a domestic refrigerator is
(a) less than 1
(b) more than 1
(c) equal to 1
(d) dependent upon the mass of the refrigerant

Q.3 A refrigerating machine working on reversed Carnot cycle takes out 2 kW of heat from the system while between temperature limits of 300 K and 200 K. COP and power consumed by the cycle will be respectively.
(a) 1 and 1 kW (b) 1 and 2 kW
(c) 2 and 1 kW (d) 2 and 2 kW

Q.4 A machine working on a Carnot cycle operates between temperature 300 k and 260 K. The COP of the refrigerating machine and heat pump are respectively
(a) 6.5 and 7.5 (b) 7.5 and 6.5
(c) 6 and 7 (d) 7 and 6

Q.5 In the system shown in figure, the temperature T = 300 K. When is the thermodynamic efficiency η_E of Engine E equal to the reciprocal of the COP of R?



(a) When R acts as a heat pump
(b) When R acts as a refrigerator
(c) When R acts both as a heat pump and a refrigerator
(d) When R acts as neither a heat pump nor a refrigerator

Q.6 Thermal efficiency of heat engine is 30%, the COP of refrigerator will be equal to
(a) 1.33 (b) 2.33
(c) 3.33 (d) 4.33

Q.7 A refrigerator and a heat pump operate between the same temperature limits. If COP of the refrigerator is 5, the COP of the heat pump would be
(a) 5 (b) 6
(c) 4 (d) 7

Q.8 A Carnot refrigerator has a COP of 6. What is the ratio of lower to the higher absolute temperature?
(a) 1/6 (b) 6/7
(c) 1/7 (d) 7/8

Q.9 A condenser of a refrigeration system rejects heat at a rate of 120 kW, while its compressor consumes a power of 30 kW. The COP of the system would be
(a) 2 (b) 3
(c) 4 (d) 5

Q.10 A Carnot refrigerator requires 70 kJ/min of work to produce one ton of refrigeration at –40°C. The COP of this refrigerator is
(a) 4 (b) 3
(c) 5 (d) 6

Q.11 The COP of a heat pump can be increased either by decreasing T_H by ΔT or by increasing T_L by ΔT. The new COP of the heat pump is
(a) same in both the cases
(b) highest if T_H is decreased
(c) highest if T_L in increased
(d) independent of change in T_H and T_L

Q.12 A refrigerator works on reversed Carnot cycle producing a temperature of –40°C. Work done per TR is 700 kJ per ten minutes. What is the value of its COP?
(a) 3 (b) 4.5
(c) 5.8 (d) 7.0

Q.13 A one ton capacity water cooler cools water steadily from 35° to 20°. The water flow rate will be (if specific heat of water is 4.18 kJ/kg-k)
(a) 51 lit/hr (b) 101 lit/hr
(c) 151 lit/hr (d) 201 lit/hr

Q.14 The power (kW) required per ton of refrigeration is *N*/COP, where COP is the coefficient of performance, then *N* is equal to
(a) 2.75 (b) 3.50
(c) 4.75 (d) 5.25

Q.15 To increase the COP of reversed Carnot engine the temperature of heat rejection should be __________ and the temperature of heat absorption should be __________.
(a) decreased; increased
(b) increased; decreased
(c) decreased; decreased
(d) None of these

Q.16 COP of a Reversed Carnot cycle refrigerator working between higher temperatures T_2 and lower temperature T_1
(a) will increase with increase in T_1 keeping T_2 fixed
(b) will decrease with increase in T_1 keeping T_2 fixed
(c) will first increase with increase in T_1 and then decrease with increase in T_1 keeping T_2 fixed
(d) None of the above

Q.17 A reversible refrigerator working between two fixed temperatures
(a) has the same COP whatever the working substance
(b) has its COP increased for working substance with high enthalpy of evaporation
(c) has its COP increased for working substance with higher specific heats
(d) None of the above

Q.18 Two refrigerator are employed, one for ice-making and other for comfort cooling
(a) the COP of refrigerator for ice making is higher than that for the other
(b) the COP of refrigerator for ice making is lower than that for the other
(c) the COP of refrigerator for ice making is same as that for the other
(d) the COP of Carnot refrigerator will depend on refrigerant used.

Q.19 A Carnot refrigerator operates between 300.3 K and 273 K. The fraction of cooling effect to the work input is
(a) 20%
(b) 10%
(c) 50%
(d) not possible to find with the data

Q.20 A reversed Carnot engine is used for heating a building. It supplies 210×10^3 kJ/hr of heat to the building at 20 °C. The outside air is at –5°C. The heat taken from the outside will be nearly
(a) 192×10^3 kJ/hr (b) 188×10^3 kJ/hr
(c) 184×10^3 kJ/hr d) 180×10^3 kJ/hr

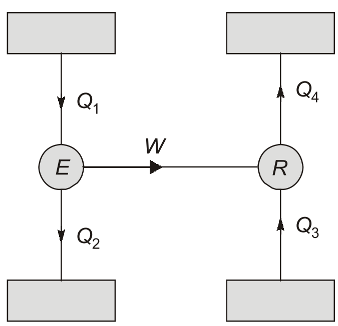
Q.21 A refrigerator storage is supplied with 3600 kg of fish at a temperature of 27°C. The fish has to be cooled to –23°C for preserving it for a long period without deterioration. The cooling takes place in 10 hours. The specific heat of fish is 2.0 kJ/kg K above freezing point of fish and 0.5 kJ/kg-K below freezing point of fish, which is –3°C. The latent heat of freezing is 230 kJ/kg. What is the power required to drive the plant if the actual COP is half that of the ideal COP ?
(a) 30 kW (b) 15 kW
(c) 12 kW (d) 6 kW

Q.22 Carnot refrigerator absorbs heat at –13°C and requires 1 kW for each 6.5 kW of heat absorbed, the COP and temperature of heat rejection respectively are
(a) COP = 7.5, t = 37°C
(b) COP = 7.5, t = 27°C
(c) COP = 6.5, t = 30°C
(d) COP = 6.5, t = 27°C

Q.23 A heat pump is used to heat a house in the winter then reversed to cool the house in the summer. The inside temperature of the house is to be maintained at 20°C. The heat transfer through the house walls is 7.9 kJ/s and outside temperature in winter is 5°C. The minimum power required to drive the heat pump to maintain the room temperature constant is

(a) 314 W (b) 336 W
(c) 361 W (d) 404 W

Q.24 In the given figure *E* is a heat engine with efficiency of 0.4 and *R* is a refrigerator given that $Q_2 + Q_4 = 3Q_1$, the COP of the refrigerator is



(a) 2.5 (b) 3.0
(c) 4.0 (d) 5.0

Direction (Q.25 to Q.28): The following questions consist of two statements, one labelled as '**Assertion (A)**' and the other labelled as '**Reason (R)**'. You are to examine these two statements carefully and select the answers to these items using the codes given below.

Codes:

(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true

Q.25 **Assertion (A):** Heat pump used for heating is a definite advancement over the simple electric heater.
Reason (R): The heat pump is far more economical in operation than electric heater.

Q.26 **Assertion (A):** COP of heat pump is more than the COP of its refrigerator version.
Reason (R): Pumping of heat requires less work relative to extraction of heat from the evaporator.

Q.27 **Assertion (A) :** An air-conditioner operating as a heat pump is superior to an electric resistance heater for winter heating.
Reason (R) : A heat pump rejects more heat than the heat equivalent of the heat absorbed.

Q.28 **Assertion (A):** The COP of an air conditioning plant is higher than the COP of a household refrigerator.
Reason (R): For the same condenser temperature, the suction pressure of the evaporator is higher in air conditioning plant than in household refrigerator.

Q.29 COP of a Carnot heat pump operating between –3°C and 27°C is ________.

Q.30 If COP of a refrigerator is 5 and efficiency of a heat engine of the same temperature limit is 50%. The ratio of heat supplied to the engine to heat absorbed by the refrigerator from the space is ________.

Q.31 A water chilling plant has a capacity of 30 tons of refrigeration. If cools 20 m^3/hr of water entering at 12°C. The temperature (in °C) of water leaving the chiller is ________.

Q.32 A Carnot refrigerator requires 1.5 kW/ton of refrigeration to maintain a region at a temperature of –30°C. The COP of the Carnot refrigerator is________.

Q.33 A refrigerator working on reversed Carnot cycle absorbs 10 kW of power and has a COP = 4. If it works as a heat pump, the quantity of heat delivered to a building is ________ kW.

Multiple Select Questions (MSQ)

Q.34 1.5 kW power is required for 1 tonne of refrigeration to maintain the temperature at –40°C in the refrigerator. If the refrigeration cycle works on Carnot cycle, then which of the following statements is/are correct?

(a) COP of the cycle is 2.33.
(b) Temperature of the sink is 60°C.
(c) Heat rejected to the sink per TR is 2 kW.
(d) COP if the cycle is used as heat pump is 3.33.

Q.35 A cold storage plant is required to store 20 tonnes of fish. The fish is supplied at a temperature of 30°C. The specific heat of fish above freezing point is 2.93 kJ/kgK. The specific heat of fish below

freezing point is 1.26 kJ/kgK. The fish is stored in cold storage which is maintained at –8°C. The freezing point of fish is –4°C. The latent heat of fish is 235 kJ/kg. The plant requires 75 kW to drive it. Which of the following statements is/are correct, if actual COP of the plant is 30% of the Carnot COP?
(a) The capacity of the plant is 44.83 TR.
(b) Actual COP of the plant is 2.092.
(c) Time taken to achieve cooling is 722 minutes approximately.
(d) Total heat removed by the plant is 6793.2 MJ.

Q.36 Which of the following statements is/are correct?
(a) Temperature appearing in the expression of reverse Carnot cycle COP are the temperature of working fluid.
(b) 1 Tonne of refrigeration represents heat removal rate.
(c) Rate of heat removal from lower temperature space is called refrigeration capacity.
(d) Refrigeration is a process of maintaining space at a lower temperature as compared to surrounding.

Answers — Introduction and Basic Concepts of Refrigerator, Heat Pump & Reversed Carnot Cycle

1. (a)	2. (b)	3. (c)	4. (a)	5. (a)	6. (b)	7. (b)
8. (b)	9. (b)	10. (b)	11. (c)	12. (a)	13. (d)	14. (b)
15. (a)	16. (a)	17. (a)	18. (b)	19. (b)	20. (a)	21. (c)
22. (d)	23. (d)	24. (d)	25. (a)	26. (c)	27. (a)	28. (a)
29. (10)	30. (0.4)	31. (7.5)	32. (2.33)	33. (50)	34. (a, b, d)	35. (a, b, c, d)
36. (a, b, c, d)						

Explanations — Introduction and Basic Concepts of Refrigerator, Heat Pump & Reversed Carnot Cycle

1. (a)

In domestic refrigerator, the refrigerating effect is less than 0.9 kW or 0.25 Ton.

2. (b)

COP of domestic refrigerator is more than 1.

3. (c)

$$\text{COP} = \frac{T_L}{T_H - T_L} = \frac{200}{300-200} = 2$$

$$\text{Power} = \frac{\text{RE}}{\text{COP}} = \frac{2}{2} = 1\text{ kW}$$

4. (a)

$$\text{COP}_{\text{ref}} = \frac{T_L}{T_H - T_L} = \frac{260}{300-260} = 6.5$$

$$\text{COP}_{\text{HP}} = \frac{T_H}{T_H - T_L} = \frac{300}{300-260} = 7.5$$

5. (a)

When heat engine is reversed it acts as heat pump.

and $(\text{COP})_{\text{H.P.}} = \dfrac{1}{\eta_{\text{H.E}}}$

6. (b)

$$\eta_{HE} = 0.3$$

As we know,

$$\eta_{HE} \times \text{COP}_{HP} = 1$$

$$\Rightarrow \quad \text{COP}_{HP} = \frac{1}{\eta_{HE}} = \frac{1}{0.3} = \frac{10}{3} = 3.33$$

Also, $\text{COP}_{\text{Ref}} = \text{COP}_{\text{HP}} - 1 = 3.33 - 1 = 2.33$

7. (b)

$$(\text{COP})_{\text{H.P.}} = (\text{COP})_{\text{refrigerator}} + 1$$

$$\therefore \quad (\text{COP})_{\text{H.P.}} = 5 + 1 = 6$$

8. (b)

$$COP = \frac{T_l}{T_h - T_l}$$

where T_l is lower temperature
T_h is higher temperature

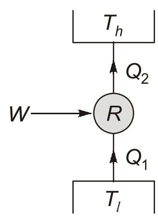
$$6 = \frac{T_l}{T_h - T_l}$$

$$6T_h - 6T_l = T_l$$

$$\Rightarrow \quad \frac{T_l}{T_h} = \frac{6}{7}$$

9. (b)

$$Q_1 = 120 - 30 = 90 \text{ kW}$$



$$COP = \frac{Q_1}{W} = \frac{90}{30} = 3$$

10. (b)

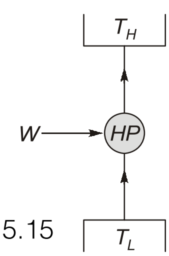
$$COP_{Ref} = \frac{R.E}{W_{in}} = \frac{1\text{T.R}}{70 \text{ kJ/min}}$$

$$= \frac{3.5 \text{ kW}}{\frac{70}{60}\left(\frac{\text{kJ}}{\text{s}}\right)} = 3$$

11. (c)

Assuming initially

$$T_H = 30°C$$
$$T_L = 10°C$$



$$(COP)_{HP} = \frac{T_H}{T_H - T_L} = \frac{30 + 273}{20} = 15.15$$

If Higher temperature is decreased by 5°C.
New conditions

$$T_H = 25°C$$
$$T_L = 10°C$$

Then the COP of heat pump is

$$(COP)_{HP} = \frac{25 + 273}{15} = 19.86$$

If Lower temperature is increased by 5°C.
New conditions

$$T_H = 30°C$$
$$T_L = 15°C$$

Then the COP of heat pump is

$$(COP)_{HP} = \frac{30 + 273}{15} = 20.2$$

Hence COP will be highest when lower temperature is increased rather than decreasing higher temperature by same amount.

12. (a)

$$W = 700 \text{ kJ/ten minutes}$$

$$= \frac{700}{10 \times 60} \text{kJ/sec}$$

Now, $$(COP)_R = \frac{RE}{W} = \frac{3.5}{700(10 \times 60)}$$

$$= \frac{3.5 \times 10 \times 60}{700}$$

$$COP = 3$$

13. (d)

$$\frac{210}{60} = m \times 4.18 \times 150$$

$$m = 0.056 \text{ kg/sec}$$

$$= 200.96 \text{ kg/hr} = 201 \text{ lit/hr}$$

14. (b)

$$COP = \frac{1\text{ TR}}{W} = \frac{Q_A}{W}$$

$$W = \frac{1\text{ TR}}{COP} = \frac{N}{COP}$$

$$N = 1 \text{ TR} = 3.50 \text{ kW}$$

15. (a)

$$COP_{HP} = \frac{T_H}{T_H - T_L} = \frac{1}{1 - \frac{T_L}{T_H}}$$

$$\uparrow COP_{HP} = \frac{1}{\left[\left(1 - \frac{T_L \uparrow}{T_H \downarrow}\right)\uparrow\right]\downarrow}$$

16. (a)

COP_{Ref} can be increased by increasing T_1 and keeping T_2 constant.

17. (a)

All the reversible refrigerator working two fixed temperature will have same COP, whatever will be working substance.

18. (b)

$$\downarrow COP_{Ref} = \left(\frac{T_L \downarrow}{(T_H - T_L \downarrow)\uparrow}\right)\downarrow$$

COP of refrigerator for ice making is lower because the lowest temperature required to maintain in ice making is lower than that of comfort cooling.

19. (b)

$$COP_{ref} = \frac{T_L}{T_H - T_L} = \frac{R.E}{W_{in}}$$

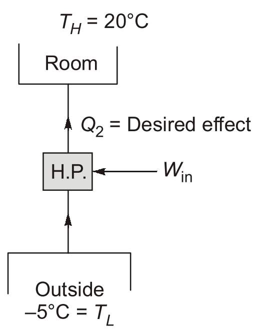
$$\frac{R.E}{W_{in}} = \frac{273}{300.3 - 273} = 10$$

20. (a)

A heat supplied to room = 210×10^3 kJ/Hr

T_H = 20°C = 293 K, T_L = –5°C = 268 K

Heat taken from outside = $\dot{Q}_1$ = ?

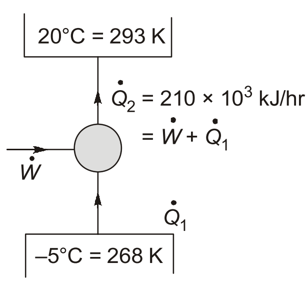


$$(COP)_{HP} = \frac{T_H}{T_H - T_L} = \frac{\dot{Q}_2}{W_{in}} = \frac{\dot{Q}_2}{\dot{Q}_2 - \dot{Q}_1}$$

$$= \frac{293}{293 - 268} = \frac{210 \times 10^3}{210 \times 10^3 - \dot{Q}_1}$$

$$Q_1 = 192 \times 10^3 \text{ kJ/Hr}$$

Alternate solution:



$$\oint_{rev} \frac{\delta Q}{T} = 0$$

$$\frac{\dot{Q}_1}{T_1} + \frac{\dot{Q}_2}{T_2} = 0$$

$$\frac{\dot{Q}_1}{268} + \frac{(-210 \times 10^3)}{293} = 0$$

$$\dot{Q}_1 = 192.081 \times 10^3 \text{ kJ/hr}$$

21. (c)

$$\text{Carnot COP} = \frac{273 - 23}{27 + 23} = \frac{250}{50} = 5$$

Actual COP = 0.5 × 5 = 2.5

Heat removed from the fish above freezing point,

$$Q_1 = mC_{AF}(T_2 - T_3)$$
$$= 3600 \times 2(27 + 3)$$
$$= 3600 \times 2 \times 30 = 2.16 \times 10^5 \text{ kJ}$$

Heat removed from the fish below freezing point,

$$Q_2 = 3600 \times 0.5(-3 + 23)$$
$$= 3600 \times 20 \times 0.5 = 0.36 \times 10^5 \text{ kJ}$$

Total latent heat of fish

$$Q_3 = mh_{fg} = 3600 \times 230 = 8.28 \times 10^5 \text{ kJ}$$

Total heat abstracted,

$$Q_A = Q_1 + Q_2 + Q_3$$
$$= (2.16 + 0.36 + 8.28) \times 10^5 \text{ kJ}$$
$$= 10.8 \times 10^5 \text{ kJ}$$

$$COP = \frac{Q_A}{W}$$

$$W = \frac{10.8 \times 10^5}{10 \times 3600 \times 2.5} = 12 \text{ kW}$$

22. (d)

Given: T_L = –13°C = 260 K

W_{in} = 1 kW

R.E = 6.5 kW

$$COP_{Ref} = \frac{T_L}{T_H - T_L} = \frac{R.E}{W_{in}} = \frac{6.5}{1} = 6.5$$

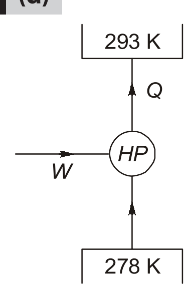
$$\frac{T_L}{T_H - T_L} = 6.5$$

$$\Rightarrow \frac{260}{T_H - 260} = 6.5$$

$$\Rightarrow T_H = 300 \text{ K}$$

$$T_H = 27°C$$

23. (d)



Q = 7.9 kJ/s

T_1 = 273 + 20 = 293 K

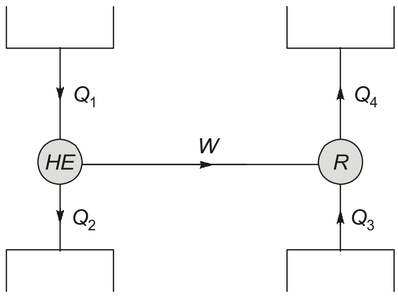
T_2 = 273 + 5 = 278 K

$$W = \left(\frac{T_1 - T_2}{T_1}\right) \times Q_1$$

$$= \frac{(293-278)}{293} \times 7.9 \times 10^3$$

$$= 404 \text{ W}$$

24. (d)



$$\eta = \frac{W}{Q_1} = 0.4$$

$$W = 0.4\,Q_1$$

$$\text{COP} = \frac{Q_3}{W} \Rightarrow \frac{Q_3}{0.4Q_1}$$

$$W = Q_1 - Q_2 = Q_4 - Q_3$$

$$Q_2 + Q_4 = Q_3 + Q_1$$

$$3Q_1 = Q_3 + Q_1$$

$$Q_3 = 2Q_1$$

$$\text{COP} = \frac{2Q_1}{0.4Q_1} = 5$$

25. (a)

At steady state, the electrical energy W supplied to an electrical heater is dissipated as heat to the space but when supplied to a heat pump dissipates Q_H which is greater than W.

26. (c)

$$(\text{COP})_{\text{HP}} = (\text{COP})_{\text{R}} + 1$$

The refrigerator can work as heat pump if the desired effect is altered. The work gets changed if the temperature difference gets changed, not the device.

If same device is used as HP and refrigerator, then W_{in} will be same.

27. (a)

Reason is correct for given assertion.

In case of electric resistance, the amount of heating obtained is equal to work done. Whereas in case heat pump, amount of heating obtained is more than work input.

28. (a)

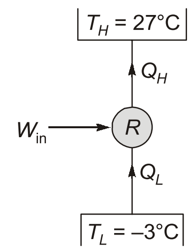
The evaporator temperature maintained in refrigerator is lower then that the evaporator temperature in air-conditioning. This is obtained by keeping lower evaporator pressure in refrigerator.

29. (10)

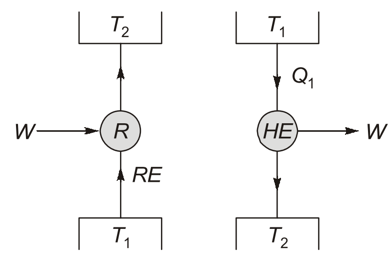
$$\text{COP} = \frac{T_H}{T_H - T_L}$$

$$= \frac{(27+273)}{27-(-3)}$$

$$= \frac{300}{30} = 10$$



30. (0.4)



$$(\text{COP})_R = 5,\ \eta_{\text{HE}} = 0.50$$

$$\frac{T_1}{T_2 - T_1} = 5 = \frac{\text{RE}}{W_{\text{in}}}$$

$$\Rightarrow \quad W_{\text{in}} = \frac{\text{RE}}{5}$$

$$\frac{T_1 - T_2}{T_1} = 0.5 = \frac{W}{Q_1}$$

$$\Rightarrow \quad W = 0.5Q_1$$

By equating, we get

$$\frac{\text{RE}}{5} = \frac{Q_1}{2}$$

$$\frac{Q_1}{\text{RE}} = \frac{2}{5} = 0.4$$

31. (7.5)

$$Q = \text{RE} = mc\,\Delta T$$

$$30 \times 210 = \left(1000 \times \frac{20}{60}\right) \times 4.2 \times \Delta T$$

$$\Delta T = 4.5$$

$$\Delta T = T_i - T_e = 4.5$$

$$\Rightarrow \quad T_e = 12 - 4.5$$

$$T_e = 7.5°\text{C}$$