Two mark questions and answers
UNIT II
SECOND LAW

1. Define Clausius statement.
It is impossible for a self-acting machine working in a cyclic process, to transfer heat from a body at lower temperature to a body at a higher temperature without the aid of an external agency.

2. What is Perpetual motion machine of the second kind?
A heat engine, which converts whole of the heat energy into mechanical work, is known as Perpetual motion machine of the second kind.

3. Define Kelvin Planck Statement. **Nov / Dec 2009**
It is impossible for a heat engine to produce network in a complete cycle if it exchanges heat only with bodies at a single fixed temperature.

4. Define Heat pump.
A heat pump is a device, which is working in a cycle and transfers heat from lower temperature to higher temperature.

5. Define Heat engine. **Nov / Dec. 2011**
Heat engine is a machine, which is used to convert the heat energy into mechanical work in a cyclic process.

6. What are the assumptions made on heat engine?
1. The source and sink are maintained at constant temperature.
2. The source and sink has infinite heat capacity.

7. State Carnot theorem. **April / May 2011**
It states that no heat engine operating in a cycle between two constant temperature heat reservoirs can be more efficient than a reversible engine operating between the same reservoirs.

8. What is meant by reversible process?
A reversible process is one, which is performed in such a way that at the conclusion of process, both system and surroundings may be restored to their initial state, without producing any changes in rest of the universe.

9. What is meant by irreversible process?
The mixing of two substances and combustion also leads to irreversibility. All spontaneous process is irreversible.

10. Explain entropy? **Nov / Dec 2011**
It is an important thermodynamic property of the substance. It is the measure of molecular disorder. It is denoted by S. The measurement of change in entropy for reversible process is obtained by the quantity of heat received or rejected to absolute temperature.

11. What is absolute entropy?
The entropy measured for all perfect crystalline solids at absolute zero temperature is known as absolute entropy.

12. Define availability. **May / June 2009**
The maximum useful work obtained during a process in which the final condition of the system is the same as that of the surrounding is called availability of the system.

13. Define available energy and unavailable energy. **May / June 2012**
Available energy is the maximum thermal useful work under ideal condition. The remaining part, which cannot be converted into work, is known as unavailable energy.

14. Explain the term source and sink.

Source is a thermal reservoir, which supplies heat to the system and sink is a thermal reservoir, which takes the heat from the system.

15. What do you understand by the entropy principle?

The entropy of an isolated system can never decrease. It always increases and remains constant only when the process is reversible. This is known as principle of increase in entropy or entropy principle.

16. What are the important characteristics of entropy?

1. If the heat is supplied to the system then the entropy will increase.
2. If the heat is rejected to the system then the entropy will decrease.
3. The entropy is constant for all adiabatic frictionless process.
4. The entropy increases if temperature of heat is lowered without work being done as in throttling process.
5. If the entropy is maximum, then there is a minimum availability for conversion in to work.
6. If the entropy is minimum, then there is a maximum availability for conversion into work.

17. What is reversed carnot heat engine? What are the limitations of carnot cycle?

1. No friction is considered for moving parts of the engine.
2. There should not be any heat loss.

18. Define an isentropic process.

Isentropic process is also called as reversible adiabatic process. It is a process which follows the law of pVy = C is known as isentropic process. During this process entropy remains constant and no heat enters or leaves the gas.

19. Explain the throttling process.

When a gas or vapour expands and flows through an aperture of small size, the process is called as throttling process.

20. What are the Corollaries of Carnot theorem? April / May 2011

(i) In the entire reversible engine operating between the two given thermal reservoirs with fixed temperature, have the same efficiency.

(ii) The efficiency of any reversible heat engine operating between two reservoirs is independent of the nature of the working fluid and depends only on the temperature of the reservoirs.

21. Define – PMM of second kind.

Perpetual motion machine of second kind draws heat continuously from single reservoir and converts it into equivalent amount of work. Thus it gives 100% efficiency.

22. What is the difference between a heat pump and a refrigerator?

May / June 2012, Nov / Dec 2010

Heat pump is a device which operating in cyclic process, maintains the temperature of a hot body at a temperature higher than the temperature of surroundings.

A refrigerator is a device which operating in a cyclic process, maintains the temperature of a cold body at a temperature lower than the temperature of the surroundings.

23. Define the term COP?

Co-efficient of performance is defined as the ratio of heat extracted or rejected to work input.

$$COP = \frac{\text{Heat extracted or rejected}}{\text{Work input}}$$

24. Write the expression for COP of a heat pump and a refrigerator?

COP of heat pump

$$COP\ HP = \frac{\text{Heat Supplied}}{\text{Work input}} = \frac{T2}{T2-T1}$$

COP of Refrigerator

$$COP\ Ref = \frac{\text{Heat extracted}}{\text{Work input}} = \frac{T1}{T2-T1}$$

25. Why Carnot cycle cannot be realized in practical?

(i) In a Carnot cycle all the four processes are reversible but in actual practice there is no process is reversible.

(ii) There are two processes to be carried out during compression and expansion. For isothermal process the piston moves very slowly and for adiabatic process the piston moves as fast as possible. This speed variation during the same stroke of the piston is not possible.

(iii) It is not possible to avoid friction moving parts completely.

26. Why a heat engine cannot have 100% efficiency?

For all the heat engines there will be a heat loss between system and surroundings. Therefore we can’t convert all the heat input into useful work.

27. What are the processes involved in Carnot cycle.

Carnot cycle consist of

i) Reversible isothermal compression
ii) Isentropic compression
iii) Reversible isothermal expansion
iv) Isentropic expansion

28. What do you mean by entropy generation? **Nov / Dec 2011**

The General Entropy Generation Equation can also be written on a rate basis:

$$\dot{S}_{gen} = \frac{d}{dt}(m_{stored}s_{stored})_{CV} - (\dot{m}_{in}s_{in} - \dot{m}_{out}s_{out}) - \frac{\dot{Q}_{net}}{T_{CV}}$$

For steady flow and steady state conditions (SFSS):

$$\frac{d}{dt}(m_{stored}s_{stored}) = 0 \quad \text{and} \quad \dot{m}_{in} = \dot{m}_{out} = \dot{m}$$

Thus, the **Entropy Generation Equation for an Open System with SFSS** is:

$$\dot{S}_{gen} = \dot{m}(s_{out} - s_{in}) - \frac{\dot{Q}_{net}}{T_{CV}}$$

29. List out the general types of irreversibilities. **April / May 2011**

(a) Internal irreversibility

(b) External irreversibility

30. What do you understand by dissipative effects? When work is said to be dissipated?
April / May 2010

A dissipative process is a process in which energy (internal, bulk flow kinetic or system potential) is transformed from some initial form to some final form; the capacity of the final form to do mechanical work is less than that of the initial form. For example, transfer of energy as heat is dissipative because it is a transfer of internal energy from a hotter body to a colder one.

31. Isentropic process need not be necessarily an adiabatic process – Justify.

April / May 2010

(ANSWER IS IN PAGE NO 199 – P.K. NAG)

32. Why is the second law, called a directional law of nature? **Nov / Dec 2009, 2007**

The transfer processes can never spontaneously occur from a lower to a higher potential. This directional law puts a limitation on energy transformation other than that imposed by first law.

33. Give the criteria of reversibility, irreversibility and impossibility of a thermodynamic cycle. **May / June 2009**

$\oint \frac{dQ}{T} = 0$, the cycle is reversible.

$\oint \frac{dQ}{T} < 0$, the cycle is irreversible and possible.

$\oint \frac{dQ}{T} > 0$, the cycle is impossible, since it violates the second law.

34. What is the relation between COP_{HP} and COP_{ref}?

$COP_{HP} = COP_{ref} + 1$

Unit – II
Question Bank

1. A heat engine operating between two reservoirs at 100 K and 300 K is used to drive heat pump which extracts heat from the reservoir at 300 K at a rate twice that at which engine rejects heat to it. If the efficiency of the engine is 40% of the maximum possible and the co-efficient of performance of the heat pump is 50% of the maximum possible, make calculations for the temperature of the reservoir to which the heat pump rejects heat. Also work out the rate of heat rejection from the heat pump if the rate of supply of heat to the engine is 50 kW. **(16)**

(NOVDEC 2006)

2. One kg of ail' is contained in a piston cylinder assembly at 10 bar pressure and 500 K temperature. The piston moves outwards and the air expands to 2 bar pressure and 350 K temperature. Determine the maximum work obtainable. Assume the environmental conditions to be 1 bar and 290 K. Also make calculations for the availability in the initial and final states. **(16)**

(NOVDEC 2006)

3. The interior lighting of refrigerators is provided by incandescent lamps whose switches are actuated by the opening of the refrigerator door. Consider a refrigerator whose 40W light bulb remains on continuously as a result of a malfunction of the switch. If the refrigerator has a coefficient of performance of 1.3 and the cost of electricity is Rs. 8 per kWh, determine the increase in the energy consumption of the refrigerator and its cost per year if the switch is not fixed. **(16)**

NOV/DEC 2009

4. A Carnot heat engine receives 650 kJ of heat from a source of unknown temperature and rejects 250 kJ of it to a sink at 297 K. Determine the temperature of the source and the thermal efficiency of the heat engine. **(6)**

NOV/DEC 2009

5. A Carnot heat engine receives heat from a reservoir at 1173 K at a rate of 800kJ/min and rejects the waste heat to the ambient air at 300 K. The entire work output of the heat engine is used to drive a refrigerator that removes heat from the refrigerated space at 268 K and transfers it to the same ambient air at 300 K. Determine the maximum rate of heat removal from the refrigerated space and the total rate of heat rejection to the ambient air.

(10)

NOV/DEC 2009

6. Air is compressed by an adiabatic compressor from 100 kPa and 12 °C to a pressure of 800 kPa at a steady rate of 0.2 kg/s. If the isentropic efficiency of the compressor is 80 percent, determine the exit temperature of air and the required power input to the compressor. **(16)**

NOV/DEC 2010

7. A 200 m^3 rigid tank initially contains atmospheric air at 100 kPa and 300 K and is to be used as storage vessel for compressed air at 1 Mpa and 300 K. Compressed air is to be supplied by a compressor that takes in atmospheric air at P_0 = 100 kPa and T_0 = 300 K. Determine the minimum work required for this process. **(16)**

NOV/DEC 2010

8. A reversible heat engine operates between two reservoirs at 827 ^oC and 27 ^oC. Engine drives a Carnot refrigerator maintaining - 13 ^oC and rejecting heat to reservoir at 27 ^oC.

Heat input to the engine is 2000 kJ and the net work available is 300 kJ. How much heat is transferred to refrigerant and total heat rejected to reservoir at 27 ^{o}C ? if the efficiency of the heat engine and COP of the refrigerator are each 40% of their maximum values, determine heat transfer to the refrigerator and also heat rejected to the reservoir at 27^{o}C. **(16)**

APRIL/MAY 2011

9. Determine the rate of power loss due to irreversibility in a heat engine operating between temperatures of 1800 K and 300 K. Engine delivers 2 MW of power when heat is added at the rate of 5 MW. **(12)**

APRIL/MAY 2011

10. An engine is supplied with 1120 kJ/s of heat. The source and sink temperature are maintained at 560◦K and 280◦K. Determine whether the following cases represent the reversible, irreversible or impossible heat engines.

(1) 900 kW of heat rejected
(2) 560 kW of heat rejected
(3) 108 kW of heat rejected **(8)**

NOV./DEC. 2011

11. A heat pump working on the Carnot cycle takes in heat from a reservoir at 5^{o}C and delivers heat to a reservoir at 60^{o}C. A heat engine is driven by a source at 840^{o}C and rejects heat to a reservoir at 60^{o}C. The reversible heat engine, in addition to driving the heat pump, also drives a machine that absorbs 30 kW. If the heat pump extracts 17 kJ/s from the 5^{o}C reservoir, determine (1) the rate of heat supply from the 840◦C source, and (2) the rate of heat rejection to the 60^{o}C sink. **(8)**

NOV./DEC. 2011

12. 2 kg of water at 90^{o}C is mixed with 3 kg of water at 10^{o}C in an isolated system. Calculate the change of entropy due to the mixing process. **(8)**

NOV./DEC. 2011

13. A heat exchanger circulates 5000 kg/hr of water to cool oil from 150^{o}C to 50^{o}C. The rate of flow of oil is 2500 kg/hr. The average specific heat of oil is 2.5 kJ/kgK. The water enters the heat exchanger at 21^{o}C. Determine the net change in the entropy due to heat exchange process, and the amount of work obtained if cooling of oil is done by using the heat to run a Carnot engine with sink temperature of 21^{o}C. **(12)**

May/June2007

14. An ideal gas of 0.12 m^3 is allowed to expand isentropically from 300kPa and 120^{o}C to 100 kPa. 5 kJ of heat is then transferred to the gas at constant pressure. Calculate the change in entropy for each process. Assume γ = 1.4 and Cp=1.0035 kJ/kg.K. If these two processes are replaced by a reversible polytropic expansion, find the index of expansion between original and final states. What will be the total changes in entropy? **(10)**

May/June2007

15. A house hold refrigerator is maintained at a temperature of 275 K. Every time the door is opened, warm material is placed inside, introducing an average of 420 kJ, but making only a small change in the temperature of the refrigerator. The door is opened 20 times a day, and the refrigerator operates at 15% of the ideal COP. The cost of work is Rs 2.50 per kWhr. What is the bill for the month of April for this refrigerator? The atmospheric is at 303 K. **(13)**

Nov/Dec 2007

16. A heat pump working on the Carnot cycle takes in heat from a reservoir at 5°C and delivers heat to a reservoir at 60°C. The heat pump is driven by a reversible heat engine which takes heat from reservoir at 840°C and rejects heat to a reservoir at 60°C. The reversible heat engine also drives a machine that absorbs 30 kW. If the heat pump extracts 17 kJ / s from the reservoir at 5°C, determine (1) the rate of heat supply from 840°C source, and (2) the rate of heat rejection to 60°C sink. **(8)**

April/May 2010

17. An aluminium block (Cp = 400 J / kgK) with a mass of 5 kg is initially at 40°C in room air at 20°C. It is cooled reversibly by transferring heat to a completely reversible cyclic heat engine until the block reaches 20°C. The 20°C room air serves as a constant temperature sink for the engine. Compute

(1) The change in entropy for the block,
(2) The change in entropy for the room air,
(3) The work done by the engine. **(8)**

April/May 2010

18. In a Carnot cycle the maximum pressure and temperature are limited to 18 bars and 410°C. The volume ratio of isentropic compression is 6 and isothermal expansion is 1.5. Assume the volume of the air at the beginning of isothermal expansion as $0.18 m^3$. Show the cycle on p-V and T-s diagrams and determine

(1) The pressure and temperature at main points
(2) Thermal efficiency of the cycle. **(10)**

Nov / Dec 2012

19. A metal block with m = 5 kg, c = 0.4 kJ / kg.K at 40°C is kept in a room at 20°C. It is cooled in the following two days:

(1) Using a Carnot engine (executing integral number of cycles) with the room itself as the cold reservoir;
(2) Naturally.

In each case, calculate the changes in entropy of the block, of the air of the room and of the universe, Assume that the metal block has constant specific heat. **(10)**

Nov / Dec 2012

20. An irreversible heat engine with 66% efficiency of the maximum possible is operating between 1000 K and 300 K. If it delivers 3 kW of work, determine the heat extracted from the high temperature reservoir and heat rejected to low temperature reservoir. **(10)**

May / June 2013

21. Helium enters an actual turbine at 300 kPa, 300°C and expands to 100 kPa, 150°C. Heat transfer to atmosphere at 101.325 kPa, 25°C amounts to 7 kJ / kg. Calculate the entering stream availability, leaving stream availability and maximum work. For helium, Cp = 5.2 kJ / kg and molecular weight = 4.003 kg /kg- mol. **(10)**

May / June 2013

22. Two Carnot engines A and B are operated in series. The first one receives heat at 870°K and rejects to a reservoir at T. B receives heat rejected by the first engine and it turns rejects to a sink at 300°K. Find the temperature T for

(1) Equal work outputs of both engines
(2) Same efficiencies **(12)**

Nov / Dec 2013

23. 3 kg of air at 500 kPa, 90^{o}C expands adiabatically in a closed system until its volume is doubled and its temperature becomes equal to that of the surroundings at 100 kPa and 10^{o}C. Find the maximum work, change in availability and irreversibility. **(12)**

Nov / Dec 2013

24. A reversible heat pump is used to maintain a temperature of 0^{o}C in a refrigerator when it rejects the heat to the surroundings at 25^{o}C. If the heat removal rate from the refrigerator is 1440 kJ / min, determine the C.O.P. of the machine and work input required. **(8)**

May / June 2014

25. If the required input to run the pump is developed by a reversible engine which receives heat at 380^{o}C and rejects heat to atmosphere, then determine the overall C.O. P. of the system. **(8)**

May / June 2014

26. 5 m^3 of air at 2 bar, 27^{o}C is compressed up to 6 bar pressure following $pv^{1.3}$ = constant. It is subsequently expanded adiabatically to 2 bar. Considering the two processes to be reversible, determine the network, net heat transfer, and change in entropy. Also plot the processes on T-S and P-V diagrams. **(16)**

May / June 2014

27. An refrigerator operating between two identical bodies cools one of the bodies to a temperature T_2. Initially both bodies are at temperature T_1. Deduce the expression for the minimum specific work input, taking their specific heat as c. **(8)**

May / June 2008

28. 1 kg of ice at -10^{o}C is exposed to atmosphere at 30^{o}C. After some time, the ice melts to water and water temperature becomes 30^{o}C. Determine the entropy increase of the universe. Take Cp ice = 2.093 kJ / kgK and the latent heat of ice =333.3 kJ/Kg. **(8)**

May / June 2008

29. In a closed system air is at a pressure of 1 bar, temperature of 300 K and volume of 0.025 m^3. The system executes the following processes during the completion of thermodynamic cycle: 1-2; constant volume heat addition till pressure reaches 3.8 bar, 2-3; constant pressure cooling of air, 3-1; isothermal heating to initial state. Determine the change in entropy in each process. Take Cv = 0.718 kJ / kg K, R=287 J/kgK. **(8)**

Nov / Dec 2008

30. An inventor claims to have developed an engine which receives 1000 kJ at a temperature of 160^{o}C. It rejects heat at a temperature of 5^{o}C and delivers 0.12 kWh of mechanical work. In this a valid claim? Justify your answer through clausius inequality. **(8)**

May / June 2008

31. 5 kg of air expands isothermally from 1 m^3 to 5 m^3. Assuming air to be ideal gas with constant specific heats, compute the change in entropy of air during the process. **(8)**

May / June 2004

32. In a Carnot heat engine 50g of air acts as the working substance. The peak cycle temperature is 930 K and the maximum pressure is 8.4x 10^3 kPa. The heat addition per cycle is 4.2 kJ. Determine the maximum cylinder volume if the minimum temperature during the cycle is 315 K. **(8)**

Nov / Dec 2004

33. One kg of ice at -5^{o}C is exposed to atmosphere which is at 20^{o}C. The ice melts and comes into contact into thermal equilibrium with the atmosphere. (i) Determine the entropy increase of the universe. (ii) What is the minimum amount of work necessary to convert the water back into ice at -5°C? Cp of ice is 2.093 kJ / kg K and the latent heat of fusion of ice is 333. kJ / kg. **(16)**

Nov / Dec 2003

Theory questions

1. How do you differentiate the Exergy (Availability) and energy based upon their characteristics? **(4)**
   APRIL/MAY 2011
2. Derive an expression for the change in entropy of a perfect gas during polytropic process in terms of *T*1 and *T*2. **(8)**
   NOV./DEC. 2011
3. What are the conditions for irreversibility? Explain. **(4)**
   May/June2007
4. Deduce Clausius in equality and interpret it. **(6)**
   May/June2007
5. Give the Clausius statement of second law. **(3)**
   Nov/Dec 2007
6. What is a thermal energy reservoir? **(3)**
   Nov/Dec 2007
7. Establish the inequality of Clausius. **(13)**
   Nov/Dec 2007
8. Show that the efficiency of a reversible engine operating between two given constant temperatures is the maximum. **(8)**
   April/May 2010
9. Determine the maximum work obtainable by using one finite body at temperature T and a thermal energy reservoir at temperature To, T > To. **(8)**
   April/May 2010
10. Define the terms 'Irreversible process' and 'Reversible process'. Give an example of each. **(4)**
    Nov / Dec 2012
11. State and prove Clausius inequality. **(6)**
    Nov / Dec 2012
12. Prove that increase in entropy in a Polytropic process is
    $$\Delta s = mc_v \frac{\gamma - n}{n} \ln\left(\frac{p_1}{p_2}\right).$$
    (6)
    May / June 2013
13. List out and explain various causes of irreversibility. **(6)**
    May / June 2013
14. Mention the Clausius in equality for open, closed and isolated systems. **(4)**
    Nov / Dec 2013
15. Briefly discuss about the concept of entropy. **(4)**
    Nov / Dec 2013