



# POSTAL BOOK PACKAGE 2027

## MECHANICAL ENGINEERING

### OBJECTIVE PRACTICE SETS VOLUME - I

#### CONTENTS

#### ► Thermodynamics 1-87

1. Basic Concepts & Zeroth Law of Thermodynamics 2 - 8
2. Energy and Energy Interactions 9 - 18
3. First Law of Thermodynamics 19 - 29
4. Open System Analysis by First Law 30 - 37
5. Second Law of Thermodynamics 38 - 47
6. Entropy 48 - 67
7. Properties of Pure Substances 68 - 79
8. Thermodynamic Relations 80 - 87

#### ► Refrigeration and Air Conditioning 88-159

1. Introduction and Basic Concepts of Refrigerator, Heat Pump & Reversed Carnot Cycle 89 - 94
2. Vapour Compression Refrigeration System and Cascade Refrigeration 95 - 110
3. Vapour Absorption Refrigeration System 111 - 114
4. Air Refrigeration System 115 - 123

5. Refrigerants 124 - 128
6. Psychrometric processes, Air-conditioning, Thermal comfort and Cooling load calculations 129 - 147
7. Refrigeration equipments, Duct design and Method of Refrigerations 148 - 159

#### ► Internal Combustion Engine 160-224

1. Basics and Air Standard Cycles 161 - 182
2. Combustion in SI and CI engines 183 - 192
3. Fuels 193 - 200
4. Ignition, Engine friction, Lubrication and cooling 201 - 208
5. Supercharging, Engine Emission and their Control 209 - 224



# **THERMODYNAMICS**

## **OBJECTIVE PRACTICE SETS**

Page No. 1 - 87

# Basic Concepts & Zeroth Law of Thermodynamics

## MCQ and NAT Questions

- Q.1** A system and its environment put together constitute
- an adiabatic system
  - an isolated system
  - a segregated system
  - a homogeneous system
- Q.2** A closed system is a
- variable mass and variable energy system
  - fixed mass and variable energy system
  - fixed mass and fixed energy system
  - constant entropy system
- Q.3** A system is said to be in thermodynamic equilibrium if
- it is in mechanical, chemical and thermal equilibrium.
  - it is in thermal equilibrium
  - it is in electrical, chemical and mechanical equilibrium
  - volume is changing and pressure is constant
- Q.4** Diathermic wall means
- it would not allow the flow of heat
  - it would allow the flow of heat
  - there is no such thing as diathermic wall
  - it only allows the flow of mass
- Q.5** An adiabatic boundary is one which
- prevents heat transfer
  - permits heat transfer
  - prevents work transfer
  - permits work transfer
- Q.6** Which one of the following is NOT the correct statement about control volume?
- Matter flows continuously in and out
  - Heat and work flows across the control surface
  - Control volume must be stationary
  - Focusses a definite volume and volume is enclosed by control surface
- Q.7** Which of the following are intensive properties?
- Energy
  - Specific Energy
  - Pressure
  - Density
- (i) and (iii)
  - (i), (ii) and (iii)
  - (ii), (iii) and (iv)
  - (iii) and (iv)
- Q.8** A quasi-static process is
- a succession of equilibrium states that can be retraced back to initial condition
  - a succession of equilibrium states that cannot be retraced back to initial condition
  - infinitely slow
  - spontaneous
- Which of the above is/are correct?
- (i) and (iv)
  - (ii) and (iii)
  - (iv) only
  - (i) and (iii)
- Q.9** In macroscopic approach of thermodynamic analysis,
- a certain quantity of matter is considered, without the events occurring at the molecular level being taken into consideration.
  - a certain quantity of matter is considered, with events occurring at the molecular level being taken into consideration.
  - is completely independent of the assumptions regarding the nature of the matter.
  - nature of the matter has implication on the analysis.
- (i) and (iii) are correct
  - (i) and (iv) are correct
  - (ii) and (iii) are correct
  - only (iii) is correct
- Q.10** Consider the following statements:
- Thermodynamic properties are the macroscopic coordinates significant only for systems existing in states of thermodynamic equilibrium.
  - Engineering thermodynamic studies about rate of storage, transfer and transformation of energy.
  - Engineering thermodynamics studies about storage, transfer and transformation of energy.

Which of the above statements are correct?

- (a) 3 only                      (b) 1 and 3  
(c) 2 only                      (d) 1 and 2

**Q.11** For an isolated system executing a process

- no heat transfer takes place
- no work is done
- no mass crosses the boundary
- no chemical reaction takes place within the system

Which of the above statements are correct?

- (a) 1, 2 and 3                      (b) 1, 3 and 4  
(c) 2, 3 and 4                      (d) all of the above

**Q.12** Which of the following aspect is NOT true regarding microscopic properties of thermodynamic system?

- a knowledge of the structure of matter is essential.
- a limited number of variables/properties are needed to describe the state of matter.
- the values of these variables cannot be measured.
- statistical averaging is adopted to predict the behaviour of individual fluid particles.

**Q.13** The value of an extensive property is extensively dependent on

- mass or extent of the system
- interaction of the system with its surroundings
- path followed by the system in going from one state to another
- nature of boundaries, rigid or flexible

**Q.14** Which of the following statements regarding the concept of continuum are correct?

- Small number of molecules enable meaningful statistical averaging and assignment of property values
  - Mean free path of the molecules is order of magnitude much lower than system dimensions
  - Behaviour of individual molecules is disregarded
  - Mean free path of the molecules approaches the order of magnitude of the system dimensions
- (a) 1 and 3                      (b) 2 and 3  
(c) 3 and 4                      (d) 1 and 4

**Q.15** Consider the following statements regarding a pure substance.

- A pure substance is one that has a homogeneous and invariable chemical composition.
- It may exist in more than one phase, but the chemical composition is the same in all phases.
- A mixture of liquid air and gaseous air is a pure substance.
- A mixture of liquid water and water vapor (steam), and a mixture of ice and liquid water all represent pure substance.

Which of the following statements are correct?

- (a) 3, 2 and 1 only                      (b) 2, 3 and 4 only  
(c) 1 and 4 only                      (d) 4, 2 and 1 only

**Q.16** In a mixture there are 5 gases present. The degree of freedom of the mixture is

- (a) 4                                      (b) 5  
(c) 6                                      (d) 7

**Q.17** A system which is in thermodynamic equilibrium will

- deliver maximum reversible work.
- have maximum thermal efficiency
- deliver both maximum reversible work and have maximum thermal efficiency
- do not deliver anything

**Q.18** Consider the following statements and mark the correct answer.

- Cyclic integral of a property can be zero.
- Cyclic integral of a property is always greater than zero
- Cyclic integral of a property is always zero
- Cyclic integral of a property is less than zero

**Q.19** Consider the following:

- Temperature
  - Viscosity
  - Internal energy
  - Entropy
- Which of these are extensive properties?
- (a) 1, 2, 3 and 4                      (b) 2 and 4 only  
(c) 2 and 3 only                      (d) 3 and 4 only

**Q.20** Zeroth law of thermodynamics state that

- Two thermodynamic system are always in thermal equilibrium with each other.
- If two systems are in thermal equilibrium then the third system will also be in thermal equilibrium

- (c) Two systems not in thermal equilibrium with a third system will also not in thermal equilibrium with each other.
- (d) When two systems are in thermal equilibrium with a third system, they are in thermal equilibrium with each other.

**Q.21** Which one of the following correctly defines 1 K, as per the internationally accepted definition of temperature scale ?

- (a)  $1/100^{\text{th}}$  of the difference between normal boiling point and normal freezing point water
- (b)  $1/273.15^{\text{th}}$  of the normal freezing point of water
- (c) 100 times the difference between the triple point of water and the normal freezing point of water
- (d)  $1/273.15^{\text{th}}$  of the triple point of water

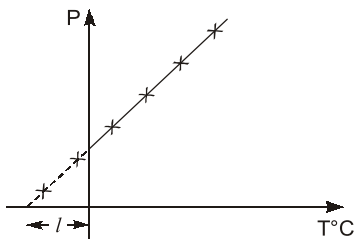
**Q.22** Thermocouple is based on

- (a) Joule's effect      (b) Peltier effect
- (c) Seebeck effect      (d) Boyle's Law

**Q.23** An apple loses 4.5 kJ of heat as it cools per  $^{\circ}\text{C}$  drop in its temperature. The amount of heat lost from the apple per  $^{\circ}\text{F}$  drop in its temperature is

- (a) 1.25 kJ      (b) 2.5 kJ
- (c) 5.0 kJ      (d) 8.1 kJ

**Q.24** Experimental data obtained from a constant-volume-gas thermometer is shown in the figure below. The value of  $l$  (in  $^{\circ}\text{C}$ ) is



- (a) 273.15      (b) 1.0
- (c) -100      (d) -273.15

**Q.25** A new temperature scale in degrees 'N' is to be defined. The boiling and freezing points on these scale are  $400^{\circ}\text{N}$  and  $100^{\circ}\text{N}$  respectively. What will be the reading on new scale corresponding to  $60^{\circ}\text{C}$ ?

- (a)  $120^{\circ}\text{N}$       (b)  $180^{\circ}\text{N}$
- (c)  $220^{\circ}\text{N}$       (d)  $280^{\circ}\text{N}$

**Q.26** The constant volume gas thermometer works on the principle that

- (a) at low pressure, the temperature of the gas is independent of its pressure at constant volume
- (b) at high pressure, the temperature of the gas is independent of its pressure at constant volume
- (c) at low pressure, the temperature of the gas is proportional to its pressure at constant volume
- (d) at high pressure, the temperature of the gas is proportional to its pressure at constant volume

**Q.27** Which of the following is used for measuring high temperature beyond  $1063^{\circ}\text{C}$ ?

- (a) Platinum-platinum/Rhodium thermocouple
- (b) Electrical resistance thermometer
- (c) Optical method using Planck's law of thermal radiation
- (d) Constant pressure gas thermometer

**Q.28** Match the column and select the correct answer using the codes given below:

Thermometric property	Thermometric property
<b>A.</b> Volume	<b>1.</b> Electric-resistance thermometer
<b>B.</b> Resistance	<b>2.</b> Thermocouple
<b>C.</b> Length	<b>3.</b> Mercury-in-glass thermometer
<b>D.</b> Thermal E.M.F.	<b>4.</b> Constant pressure gas thermometer

**Codes:**

	A	B	C	D
(a)	3	4	2	1
(b)	3	4	1	2
(c)	4	2	3	4
(d)	4	1	3	2

**Q.29** The resistance of the windings in a certain motor is found to be 80 ohms at room temperature ( $25^{\circ}\text{C}$ ). When operating at full load under steady state conditions, the motor is switched off and the resistance of the windings, immediately measured again, is found to be 93 ohms. The windings are made of copper whose resistance at temperature  $t^{\circ}\text{C}$  is given by

**Answers Basic Concepts & Zeroth Law of Thermodynamics**

1. (b)    2. (b)    3. (a)    4. (b)    5. (a)    6. (c)    7. (c)    8. (d)    9. (a)
10. (b)    11. (a)    12. (d)    13. (a)    14. (b)    15. (d)    16. (c)    17. (d)    18. (c)
19. (d)    20. (d)    21. (d)    22. (c)    23. (b)    24. (d)    25. (d)    26. (c)    27. (c)
28. (d)    29. (70.41)    30. (a)    31. (a)    32. (b)    33. (b)    34. (d)    35. (a, c)
36. (b, c)

**Explanations Basic Concepts & Zeroth Law of Thermodynamics****1. (b)**

An isolated system is one in which there is no interaction of system with the surrounding.

for isolated system

$$\delta Q = 0$$

$$\delta W = 0$$

The first law gives

$$\delta Q = \delta U + \delta W$$

$$\delta U = 0$$

$$U = \text{constant}$$

The energy of isolated system is constant.

**2. (b)**

A closed system is a system of fixed mass. There is no mass transfer across the system boundary. There may be energy transfer in or out of the system.

**3. (a)**

A system is said to be in thermodynamic equilibrium if it is in:

1. Thermal equilibrium (equality of temperature)
2. Mechanical equilibrium (equality of force/pressure)
3. Chemical equilibrium (equality of chemical potential)

**5. (a)**

An adiabatic boundary is one which prevents heat transfer.

**6. (c)**

Control volume is a volume which is surrounding the device to be analysed. From the boundary of control volume, both mass and energy (in the form of heat and work) can cross.

**7. (c)**

Intensive properties are independent of size or mass, external pressure, temperature, density, thermal conductivity, etc. All specific properties like specific volume, specific internal energy, specific enthalpy, specific entropy are intensive properties.

**8. (d)**

A quasi-static process is a succession of equilibrium states that can be retraced back to initial condition. It is carried out in infinitely slow manner so that every point passes through equilibrium states.

**9. (a)**

In macroscopic approach of thermodynamic analysis, individual molecular behaviour is not taken into consideration, but the average behaviour of molecules is taken into consideration. So (i) and (iii) statements are correct.

**10. (b)**

- Thermodynamic properties are the macroscopic coordinates significant only for systems existing in states of thermodynamic equilibrium.
- Engineering thermodynamics studies about storage transfer and transformation of energy, not the rate of all these.

**11. (a)**

The isolated system is one in which there is no interaction between the system and surrounding. It is of fixed mass and energy, and there is no mass or energy transfer across the system boundary. However there might be chemical reaction taking place within the system.

12. (d)

In microscopic approach, individual molecular behaviour is taken into consideration. So, the statement regarding microscopic properties of thermodynamic system that statistical averaging is adopted to predict the behaviour of individual fluid particles, is not true.

14. (b)

In the concept of continuum, even a very small quantity of a system is assumed to contain large number of molecules so that statistical averaging is meaningful and a property value can be assigned to it. Disregarding the behaviour of individual molecules, matter is here treated as continuous. The concept of continuum loses validity when the mean free path of the molecules approaches the order of magnitude of the dimensions of the system.

15. (d)

A pure substance is one that has a homogeneous and invariable chemical composition. It may exist in more than one phase, but the chemical composition is the same in all phases. Thus, liquid water, a mixture of liquid water and water vapor (steam), and a mixture of ice and liquid water are all pure substances; every phase has the same chemical composition. In contrast, a mixture of liquid air and gaseous air is not a pure substance because the composition of the liquid phase is different from that of the vapor phase.

16. (c)

According to Gibb's phase rule,

$$P + F = C + 2$$

if  $P = \text{No. of phases} = 1 \text{ (gas)}$

$C = \text{No. of components} = n$

$$1 + F = n + 2$$

$$F = n + 1$$

Here  $n = \text{No. of components} = 5$

$$F = 5 + 1 = 6$$

17. (d)

A system in thermodynamic equilibrium will have same properties as its surroundings so it won't deliver anything by interacting with its surroundings.

18. (c)

For a cyclic process, the initial and final states of the system are the same and hence, the change in any property is zero, i.e.

$$\oint dV = 0, \quad \oint dp = 0,$$

$$\oint dT = 0$$

where the symbol  $\oint$  denotes the cyclic integral for the closed path. Therefore, the cyclic integral of a property is always zero.

20. (d)

Zeroth law of thermodynamics state that when a body  $A$  is in thermal equilibrium with body  $B$  and body  $B$  is in thermal equilibrium with body  $C$  separately, then  $A$  and  $C$  are in thermal equilibrium.

21. (d)

1 K = 1/273.15<sup>th</sup> of the triple point of water

22. (c)

Thermocouple is based on principle of Seebeck effect. If two different metals are joined at two different junctions which are kept at different temperature then an emf is generated between the two junctions which is directly proportional to the temperature difference between them. According to Seebeck effect,

$$\text{EMF} \propto T_2 - T_1$$

23. (b)

$$Q \text{ per } ^\circ\text{C} = 4.5 \text{ kJ}$$

$$Q \text{ per } ^\circ\text{F} = \frac{Q \text{ per } ^\circ\text{C}}{1.8} = \frac{4.5}{1.8} = 2.5 \text{ kJ}$$

24. (d)

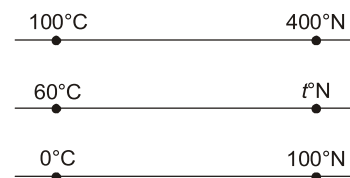
We know,  $K = ^\circ\text{C} + 273.15$

But Kelvin scale has minimum value zero,

$$^\circ\text{C} = -273.15$$

So, the value of  $l$  is  $-273.15 ^\circ\text{C}$

25. (d)



From figure it can written as,

# **REFRIGERATION AND AIR CONDITIONING**

**OBJECTIVE PRACTICE SETS**

Page No. 88 - 159

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

### MCQ and NAT Questions

- Q.1** 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.2** 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.3** 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.4** 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.5** 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.6** 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.7** 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.8** A Carnot refrigerator requires 70 kJ/min of work to produce one ton of refrigeration at  $-40^{\circ}\text{C}$ . The COP of this refrigerator is  
 (a) 4  
 (b) 3  
 (c) 5  
 (d) 6
- Q.9** A one ton capacity water cooler cools water steadily from  $35^{\circ}$  to  $20^{\circ}$ . 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.10** 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.11** 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.12** Two refrigerators 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.

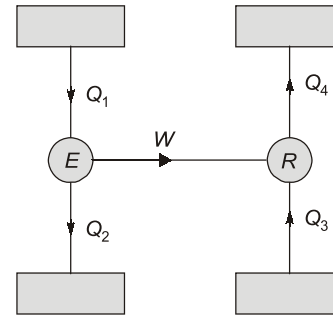
- Q.13** A reversed Carnot engine is used for heating a building. It supplies  $210 \times 10^3$  kJ/hr of heat to the building at  $20^\circ\text{C}$ . The outside air is at  $-5^\circ\text{C}$ . The heat taken from the outside will be nearly  
 (a)  $192 \times 10^3$  kJ/hr (b)  $188 \times 10^3$  kJ/hr  
 (c)  $184 \times 10^3$  kJ/hr (d)  $180 \times 10^3$  kJ/hr

- Q.14** A refrigerator storage is supplied with 3600 kg of fish at a temperature of  $27^\circ\text{C}$ . The fish has to be cooled to  $-23^\circ\text{C}$  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  $-3^\circ\text{C}$ . 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.15** Carnot refrigerator absorbs heat at  $-13^\circ\text{C}$  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,  $t = 37^\circ\text{C}$   
 (b) COP = 7.5,  $t = 27^\circ\text{C}$   
 (c) COP = 6.5,  $t = 30^\circ\text{C}$   
 (d) COP = 6.5,  $t = 27^\circ\text{C}$

- Q.16** 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  $20^\circ\text{C}$ . The heat transfer through the house walls is 7.9 kJ/s and outside temperature in winter is  $5^\circ\text{C}$ . 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.17** 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

- Q.18** 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.19** A water chilling plant has a capacity of 30 tons of refrigeration. If cools  $20 \text{ m}^3/\text{hr}$  of water entering at  $12^\circ\text{C}$ . The temperature (in  $^\circ\text{C}$ ) of water leaving the chiller is \_\_\_\_\_.

- Q.20** 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.

**Direction (Q.21 to Q.24):** The following items consists of two statements, one labelled as **Statement (I)** and the other labelled as **Statement (II)**. You have to examine these two statements carefully and select your answers to these items using the codes given below:

**Codes:**

- (a) Both Statement (I) and Statement (II) are true and Statement (II) is the correct explanation of Statement (I).  
 (b) Both Statement (I) and Statement (II) are true but Statement (II) is not a correct explanation of Statement (I).  
 (c) Statement (I) is true but Statement (II) is false.  
 (d) Statement (I) is false but Statement (II) is true.

- Q.21 Statement (I):** Heat pump used for heating is a definite advancement over the simple electric heater.

**Statement (II):** The heat pump is far more economical in operation than electric heater.

**Q.22 Statement (I):** COP of heat pump is more than the COP of its refrigerator version.

**Statement (II):** Pumping of heat requires less work relative to extraction of heat from the evaporator.

**Q.23 Statement (I):** An air-conditioner operating as a heat pump is superior to an electric resistance heater for winter heating.

**Statement (II):** A heat pump rejects more heat than the heat equivalent of the heat absorbed.

**Q.24 Statement (I):** The COP of an air conditioning plant is higher than the COP of a household refrigerator.

**Statement (II):** For the same condenser temperature, the suction pressure of the evaporator is higher in air conditioning plant than in household refrigerator.

**Multiple Select Questions (MSQ)**

**Q.25** 1.5 kW power is required for 1 tonne of refrigeration to maintain the temperature at  $-40^{\circ}\text{C}$  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  $60^{\circ}\text{C}$ .
- (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.26** A cold storage plant is required to store 20 tonnes of fish. The fish is supplied at a temperature of  $30^{\circ}\text{C}$ . The specific heat of fish above freezing point is  $2.93\text{ kJ/kgK}$ . The specific heat of fish below freezing point is  $1.26\text{ kJ/kgK}$ . The fish is stored in cold storage which is maintained at  $-8^{\circ}\text{C}$ . The freezing point of fish is  $-4^{\circ}\text{C}$ . The latent heat of fish is  $235\text{ kJ/kg}$ . The plant requires  $75\text{ kW}$  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  $6793.2\text{ MJ}$ .

**Q.27** 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. (b)  | 2. (c)  | 3. (a)  | 4. (b)        | 5. (b)           | 6. (b)           | 7. (b)  |
| 8. (b)  | 9. (d)  | 10. (a) | 11. (a)       | 12. (b)          | 13. (a)          | 14. (c) |
| 15. (d) | 16. (d) | 17. (d) | 18. (0.4)     | 19. (7.5)        | 20. (50)         | 21. (a) |
| 22. (c) | 23. (a) | 24. (a) | 25. (a, b, d) | 26. (a, b, c, d) | 27. (a, b, c, d) |         |

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

1. (b)  
Coefficient of performance of domestic refrigerator is more than 1.

2. (c)  
$$\text{COP} = \frac{T_L}{T_H - T_L} = \frac{200}{300 - 200} = 2$$

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

3. (a)

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

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

4. (b)

$$\eta_{\text{HE}} = 0.3$$

As we know,

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

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

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

5. (b)

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

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

6. (b)

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

where  $T_l$  is lower temperature $T_h$  is higher temperature

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

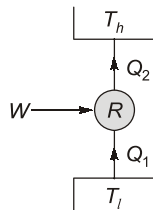
$$6T_h - 6T_l = T_l$$

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

7. (b)

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

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



8. (b)

$$\text{COP}_{\text{Ref}} = \frac{R.E}{W_{\text{in}}} = \frac{1 \text{ T.R}}{70 \text{ kJ/min}} \\ = \frac{3.5 \text{ kW}}{\frac{70 (\text{kJ})}{60 (\text{s})}} = 3$$

9. (d)

$$\frac{210}{60} = m \times 4.18 \times 150 \\ m = 0.056 \text{ kg/sec} \\ = 200.96 \text{ kg/hr} = 201 \text{ lit/hr}$$

10. (a)

$\text{COP}_{\text{Ref}}$  can be increased by increasing  $T_1$  and keeping  $T_2$  constant.

11. (a)

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

12. (b)

$$\downarrow \text{COP}_{\text{Ref}} = \left( \frac{T_L \downarrow}{(T_H - T_L) \downarrow} \right) \downarrow$$

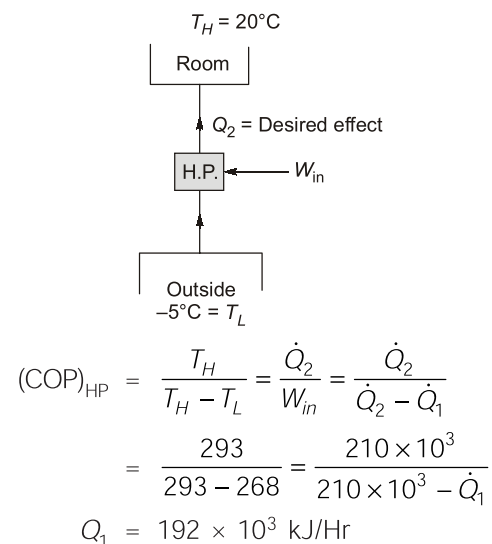
COP of refrigerator for ice making is lower because the lowest temperature required to maintain in ice making is lower than that of comfort cooling.

13. (a)

A heat supplied to room =  $210 \times 10^3$  kJ/Hr

$T_H = 20^\circ\text{C} = 293 \text{ K}$ ,  $T_L = -5^\circ\text{C} = 268 \text{ K}$

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



14. (c)

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

$$\text{Actual COP} = 0.5 \times 5 = 2.5$$

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,

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

# **INTERNAL COMBUSTION ENGINES**

**OBJECTIVE PRACTICE SETS**

Page No. 160 - 224

# Basic and Air Standard Cycles

## MCQ and NAT Questions

- Q.1** The function of piston rings in internal combustion engines is to
- dissipate heat to cylinder walls
  - seal the cylinder
  - prevent piston from wear
  - all of the above
- Q.2** Advantage of two stroke engine over a four stroke engine is
- more uniform turning moment on crankshaft
  - reduced friction loss
  - more power for same cylinder dimensions
  - all of the above
- Q.3** The power to weight ratio of diesel engine compared to petrol engine is
- high
  - low
  - same
  - high in some cases and low in other cases
- Q.4** An engine has four cylinders of 68 mm bore and 75 mm stroke. The cubic capacity of the engine is
- 1089.5 cm<sup>3</sup>
  - 1289.5 cm<sup>3</sup>
  - 1489.5 cm<sup>3</sup>
  - 1689.5 cm<sup>3</sup>
- Q.5** A certain engine produces 10 kW indicated power & mechanical efficiency is 80%. The friction power is
- 12 kW
  - 8 kW
  - 4 kW
  - 2 kW
- Q.6** Fuel consumption of a engine is 0.35 kg/kW-hr and heating value of fuel is 43000 kJ/kg. The brake thermal efficiency is
- 20.1%
  - 23.9%
  - 28.29%
  - 32.21%
- Q.7** The relative efficiency of a engine will be equal to if air standard efficiency & brake thermal efficiency of engine are 53.4% & 24.4%, respectively.
- 40.7%
  - 45.7%
  - 13.1%
  - 53.4%
- Q.8** In a SI engine very high compression ratio cannot be used because
- the engine efficiency would be unmanageable high
  - the power required for compression would be high
  - cylinders will required very thick walls
  - self-ignition may takes place before the spark occurs
- Q.9** In a four stroke IC engine cam shaft rotates at
- same speed as crankshaft
  - twice the speed of crankshaft
  - half the speed of crankshaft
  - none of the above
- Q.10** Thermal efficiency of CI engine is higher than that of SI engine due to
- fuel used
  - higher compression ratio
  - constant pressure heat addition
  - none of the above
- Q.11** If clearance volume is 10% of swept volume, the compression ratio will be equal to
- 9
  - 10
  - 11
  - 12
- Q.12** In an engine working on Otto cycle, the compression ratio is 5.5. The work output per cycle is  $23.625 \times 10^5 V_c$  joule where  $V_c$  is the clearance volume in m<sup>3</sup>, the mean effective pressure (in bar) is
- 3.25 bar
  - 5.25 bar
  - 7.25 bar
  - 9.25 bar
- Q.13** The order of values of thermal efficiency of Otto, diesel and Dual cycle, when they have equal compression ratio and heat rejection, is given by
- $\eta_{\text{Otto}} > \eta_{\text{diesel}} > \eta_{\text{dual}}$
  - $\eta_{\text{diesel}} > \eta_{\text{dual}} > \eta_{\text{Otto}}$

- (c)  $\eta_{\text{dual}} > \eta_{\text{diesel}} > \eta_{\text{Otto}}$   
 (d)  $\eta_{\text{Otto}} > \eta_{\text{dual}} > \eta_{\text{diesel}}$

**Q.14** Which of the following process is not a part of the dual cycle ?

- (a) Adiabatic compression  
 (b) Constant volume expansion  
 (c) Isothermal expansion  
 (d) Constant pressure expansion

**Q.15** Match **List-I** (details of the processes of the cycle) with **List-II** (name of the cycle) and select the correct answer using the codes given below the lists:

**List-I**

- A.** Two isothermals and two adiabatics  
**B.** Two isothermals and two constant volumes  
**C.** Two adiabatics and two constant volumes  
**D.** Two adiabatics and two constant pressure

**List-II**

1. Otto  
 2. Joule  
 3. Carnot  
 4. Stirling

**Codes:**

	A	B	C	D
(a)	4	3	1	2
(b)	4	3	2	1
(c)	3	4	1	2
(d)	3	4	2	1

**Q.16** For an engine working on air standard Otto cycle has a clearance volume of 10 percent of swept volume. The efficiency of engine will be

- (a) 56.4%                      (b) 61.6%  
 (c) 67.8%                      (d) data insufficient

**Q.17** The stroke and bore of a four stroke spark ignition engine are 250 mm and 200 mm respectively. The clearance volume is  $0.001 \text{ m}^3$ . If the specific heat ratio  $\gamma = 1.4$ , the air-standard cycle efficiency of the engine is

- (a) 46.40%                      (b) 56.10%  
 (c) 58.20%                      (d) 62.80%

**Q.18** A diesel engine is usually more efficient than a spark ignition engine because

- (a) diesel being a heavier hydrocarbon, releases more heat per kg than gasoline

(b) the air standard efficiency of diesel cycle is higher than the Otto cycle, at a fixed compression ratio

(c) the compression ratio of a diesel engine is higher than that of an SI engine

(d) self ignition temperature of diesel is higher than that of gasoline

**Q.19** In combustion process, the effect of dissociation is to

- (a) reduce the flame temperature  
 (b) separate the products of combustion  
 (c) reduce the proportion of carbon monoxide in gases  
 (d) reduce the use of excess air

**Q.20** The most perfect method of scavenging is

- (a) cross scavenging  
 (b) uniflow scavenging  
 (c) loop scavenging  
 (d) reverse flow scavenging

**Q.21** As compared to air standard cycle, in actual working the effect of variation in specific heats is to

- (a) increase maximum pressure and maximum temperature  
 (b) reduce maximum pressure and maximum temperature  
 (c) increase maximum pressure and decrease maximum temperature  
 (d) decrease maximum pressure and increase maximum temperature

**Q.22** For same power output and same compression ratio, as compared to two-stroke engines, four-stroke S.I. engines have

- (a) higher fuel consumption  
 (b) lower thermal efficiency  
 (c) higher exhaust temperatures  
 (d) higher thermal efficiency

**Q.23** Two stroke SI engines suffer from

- (a) fuel loss  
 (b) idling difficulty  
 (c) both (a) and (b)  
 (d) none of the above

**Q.24** With dissociation the exhaust gas temperature

- (a) decreases  
 (b) increases  
 (c) no effect  
 (d) increases upto certain air-fuel ratio and then decreases

- (c) The specific volume at the end of compression stroke is  $0.23 \text{ m}^3/\text{kg}$ .
- (d) The specific net work output of the cycle is  $663.7 \text{ kJ/kg}$ .
- Q.93** In a compression ignition engine, the inlet air pressure is 1 bar and the pressure at the end of isentropic compression is 32.42 bar. The expansion ratio is 8. The temperature at the end of compression stroke is 810 K. Which of the following statements is(are) correct?  
(For air  $\gamma = 1.4$ ,  $R = 0.287 \text{ kJ/kgK}$ )
- (a) The compression ratio of the cycle is 12.  
(b) Maximum temperature in the cycle is  $942.^\circ\text{C}$ .  
(c) Cut-off ratio of the cycle is 1.5.  
(d) Air standard efficiency of the above diesel cycle is 43.44%.
- Q.94** A diesel engine has a compression ratio of 17 and cut-off takes place at 10% of the stroke. The pressure and temperature at the beginning of the compression stroke are 1 bar and 300 K respectively. (Take  $\gamma = 1.4$  for air)
- (a) Maximum pressure in the cycle is 52.8 bar.  
(b) Maximum temperature in the cycle is 1490.8 K.  
(c) Cut-off ratio for the cycle is 2.6.  
(d) Air standard efficiency of diesel cycle is 43.44%.
- Q.95** The minimum and maximum temperature in air standard Otto cycle are 300 K and 1875 K respectively. Which of the following statements is(are) correct when net work output is maximum?  
(For air take,  $c_p = 1.005 \text{ kJ/kgK}$ ,  $c_v = 0.718 \text{ kJ/kgK}$ ,  $\gamma = 1.4$ )
- (a) Temperature after the compression process in 750 K.  
(b) Compression ratio of the cycle is 6.72.  
(c) Heat added in the cycle is 807.75 kJ/kg  
(d) Net work output from the cycle is 430.76 kJ/kg
- Q.96** Which of the following statements is(are) true for Dual cycle?
- (a) The heat addition at constant pressure is 2-3 times more than the heat addition at constant volume.  
(b) The dual cycle engine is more compact in size with respect to diesel cycle.  
(c) The sound pollution for dual cycle engine is higher than that of the diesel cycle engine.  
(d) The maintenance is easier and maintenance cost is less for dual cycle engine than that of the diesel cycle engine.



Answers Basic and Air Standard Cycles						
1. (d)	2. (d)	3. (b)	4. (a)	5. (d)	6. (b)	7. (b)
8. (d)	9. (c)	10. (b)	11. (c)	12. (b)	13. (d)	14. (c)
15. (c)	16. (b)	17. (c)	18. (c)	19. (a)	20. (b)	21. (b)
22. (d)	23. (c)	24. (a)	25. (c)	26. (b)	27. (c)	28. (b)
29. (b)	30. (c)	31. (d)	32. (b)	33. (d)	34. (a)	35. (b)
36. (b)	37. (c)	38. (c)	39. (c)	40. (a)	41. (b)	42. (d)
43. (a)	44. (a)	45. (d)	46. (c)	47. (c)	48. (a)	49. (d)
50. (d)	51. (d)	52. (c)	53. (d)	54. (a)	55. (d)	56. (d)
57. (d)	58. (b)	59. (a)	60. (c)	61. (c)	62. (a)	63. (b)
64. (b)	65. (6.075)	66. (75)	67. (168)	68. (0.34)	69. (25)	70. (264)
71. (5.328)	72. (2)	73. (1.78)	74. (53.9)	75. (45.45)	76. (5.34)	77. (535.96)
78. (1554.97)	79. (8.92)	80. (154.6)	81. (83.9)	82. (6.94)	83. (c)	
84. (c)	85. (b)	86. (a)	87. (a, c)	88. (a, d)	89. (b, d)	90. (a, d)
91. (a, b, c)	92. (a, d)	93. (a, b, c)	94. (a, c)	95. (a, c)	96. (a, b, d)	

**Explanations Basic and Air Standard Cycles**

1. (d)

Function of piston rings:

- (i) Improves heat transfer from the piston to the cylinder wall.
- (ii) Seals the combustion chamber so that there will be minimal loss of gases to the crank cases.
- (iii) Prevent piston from wear.
- (iv) Regulating oil consumption by scraping oil from the cylinder walls back to the sump.
- (v) Maintain proper oil quantity between piston and cylinder wall.

2. (d)

Advantages of 2-stroke over 4-stroke.

- For same power developed, 2-stroke engine is lighter, less bulky and occupy less floor area.
- More uniform turning moment so lighter weight of flywheel is required.
- More power for same cylinder dimension.
- The work required to overcome the friction and the exhaust strokes is saved.
- Little maintenance because of fewer parts.

3. (b)

The power of weight ratio of diesel is lower than petrol engine because of bulky and robust construction required for its higher compression ratio.

4. (a)

$$\begin{aligned} \text{Capacity of engine} &= 4 \times V_s \\ &= 4 \times \frac{\pi}{4} (6.8)^2 \times 7.5 = 1089.5 \text{ cm}^3 \end{aligned}$$

5. (d)

b.p.(brake power)

$$= \eta_m \times ip = 0.80 \times 10 = 8 \text{ kw}$$

$$\therefore f.p = ip - bp = 10 - 8 = 2 \text{ kw}$$

6. (b)

$$\begin{aligned} \eta_{bt} &= \frac{1kW - hr}{m_f/hr \times CV} \\ &= \frac{3600}{0.35 \times 43000} = 23.9\% \end{aligned}$$

7. (b)

Relative efficiency

$$= \frac{\text{Brake thermal efficiency}}{\text{Air thermal efficiency}} = \frac{24.4}{53.4} = 45.7\%$$

8. (d)

A very high compression ratio in SI engines is avoided because self ignition may occur before spark occurs.

9. (c)

In a four stroke IC engine cam shaft rotates at half the speed of crank shaft.

10. (b)

Thermal efficiency of CI is higher than SI engines because of its higher compression ratio (16 - 24).

11. (c)

$$r = \frac{V_1}{V_2} = \frac{V_s + V_c}{V_c} = \frac{V_s + 0.1V_s}{(0.1V_s)} = 11$$

12. (b)

Compression ratio

$$r = \frac{V_c + V_s}{V_c}$$

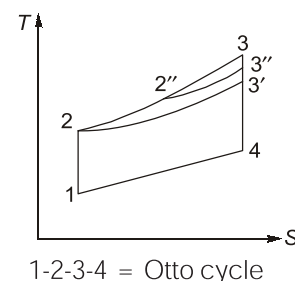
$$5.5 = 1 + \frac{V_c}{V_c} \Rightarrow \frac{V_s}{V_c} = 4.5 \text{ or,}$$

$$V_s = 4.5 V_c$$

$$\begin{aligned} \therefore P_m &= \frac{W_{net}}{V_s} = \frac{23.625 \times 10^5}{4.5 V_c} V_c \\ &= 5.25 \times 10^5 \text{ N/m}^2 = 5.25 \text{ bar} \end{aligned}$$

13. (d)

For same compression and heat rejection. Process 1-2 same compression ratio for all three cycles.



1-2-3-4 = Otto cycle

1-2-3'-4 = Diesel cycle

1-2-2''-3''-4 = Dual cycle

$$(Q_s)_{\text{otto}} > (Q_s)_{\text{dual}} > (Q_s)_{\text{diesel}}$$

$$\Rightarrow \eta_{\text{otto}} > \eta_{\text{dual}} > \eta_{\text{diesel}}$$

14. (c)

Isothermal expansion is not a part of the dual cycle.

16. (b)

Given

$$V_c = 10\% V_s$$

we know that

$$r = 1 + \frac{V_s}{V_c} = 1 + \frac{1}{0.1} = 11$$

$$\eta = 1 - \frac{1}{(r)^{\gamma-1}} = 1 - \frac{1}{(11)^{1.4-1}}$$

$$= 0.616 = 61.6\%$$

17. (c)

$$V_c = 0.001 \text{ m}^3$$

$$V_s = \frac{\pi}{4} \times 0.200^2 \times 0.250 \text{ m}^3$$

$$\therefore \eta = 1 - \left( \frac{V_c}{V_c + V_s} \right)^{r-1}$$

$$= 1 - \left( \frac{0.001}{0.001 + \frac{\pi}{4} \times 0.200^2 \times 0.250} \right)^{1.4-1}$$

$$= 58.2\%$$

18. (c)

For same compression ratio and the same heat supplied, Otto cycle is most efficient and Diesel cycle is least efficient.

In practice, however, the compression ratio of the Diesel engine ranges between 14 and 25, whereas that of the Otto engine between 6 and 12. Because of which its efficiency, is higher than that of the Otto engine.

19. (a)

The effect of dissociation is to reduce  $T_{\text{max}}$  and  $P_{\text{max}}$  of cycle and hence efficiency and work output of cycle reduces.

20. (b)

Uniflow is the most efficient scavenging system.

21. (b)

Except for monoatomic gases,  $C_p$  and  $C_v$  increase with increase in temperature and  $\gamma$  decrease. Thus  $P_{\text{max}}$  and  $T_{\text{max}}$  reduces.

22. (d)

Thermal efficiency is higher and part load efficiency is better for 4-stroke engine than 2-stroke engine.

23. (c)

2-stroke engines suffer from fuel loss and idling difficulty.

24. (a)

With dissociation the exhaust gas temperature decreases.

25. (c)

For same compression ratio, as mixture progresses from lean to rich, the mean effect pressure initially increases and then decreases.

26. (b)

When inlet valve closes before the BDC, the charge inhaled will reduce thereby reducing the volumetric efficiency.

27. (c)

Keeping other parameter constant, the brake power of CI engine can be increase by increasing the pressure of intake air.

28. (b)

Valve train controls the amount of air and fuel entering the combustion chamber at any point of time. It consists of valves, rocker arms, cam, cam shaft, push rods and lifters.

29. (b)

$$\eta_v \text{ (for SI engine at full throttle)} = 80 - 85\%$$

$$\eta_v \text{ (for CI engine at full throttle)} = 85 - 90\%$$

30. (c)

$$\text{Mean piston speed, } \bar{V}_p = \frac{2LN}{60} \text{ m/s}$$

31. (d)

$$Z = \frac{u}{\alpha} = \left( \frac{b}{D_i} \right)^2 \frac{V_p}{C_i \alpha}$$