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QUESTION BANK

B.SC. II SEM

Based On NEP 2020

THERMAL PHYSICS AND SEMICONDUCTOR DEVICES

- 400+ MCQs
- Brief and Intensive Notes

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Syllabus

Subject: **Physics**	
Year: First	Semester: **IInd**
Course Code: **B010201T**	Course Title: **Thermal Physics & Semiconductor Devices**

Unit	**Topics**
I	**0^{th} & 1^{st} Law of Thermodynamics** State functions and terminology of thermodynamics. Zeroth law and temperature. First law, internal energy, heat and work done. Work done in various thermodynamical processes. Enthalpy, relation between C_P and C_V. Carnot's engine, efficiency and Carnot's theorem. Efficiency of internal combustion engines (Otto and diesel).
II	**2^{nd} & 3^{rd} Law of Thermodynamics** Different statements of second law, Clausius inequality, entropy and its physical significance. Entropy changes in various thermodynamical processes. Third law of thermodynamics and unattainability of absolute zero. Thermodynamical potentials, Maxwell's relations, conditions for feasibility of a process and equilibrium of a system. Clausius- Clapeyron equation, Joule-Thompson effect.
III	**Kinetic Theory of Gases** Kinetic model and deduction of gas laws. Derivation of Maxwell's law of distribution of velocities and its experimental verification. Degrees of freedom, law of equipartition of energy (no derivation) and its application to specific heat of gases
IV	**Theory of Radiation** Blackbody radiation, spectral distribution, concept of energy density and pressure of radiation. Derivation of Planck's law, deduction of Wien's distribution law, Rayleigh-Jeans law, Stefan- Boltzmann law and Wien's displacement law from Planck's law.
V	**DC & AC Circuits** Growth and decay of currents in RL circuit. Charging and discharging of capacitor in RC, LC and RCL circuits. Network Analysis - Superposition, Reciprocity, Thevenin's and Norton's theorems. AC Bridges - measurement of inductance (Maxwell's, Owen's and Anderson's bridges) and measurement of capacitance (Schering's, Wein's and de Sauty's
VI	**Semiconductors & Diodes** P and N type semiconductors, qualitative idea of Fermi level. Formation of depletion layer in PN junction diode, field & potential at the depletion layer. Qualitative idea of current flow mechanism in forward & reverse biased diode. Diode fabrication. PN junction diode and its characteristics, static and dynamic resistance. Principle, structure, characteristics and applications of Zener, Tunnel, Light Emitting, Point Contact and Photo diodes. Half and Full wave rectifiers, calculation of ripple factor, rectification efficiency and voltage regulation. Basic
VII	**Transistors** Bipolar Junction PNP and NPN transistors. Study of CB, CE & CC configurations w.r.t. active, cutoff & saturation regions; characteristics; current, voltage & power gains; transistor currents & relations between them. Idea of base width modulation, base spreading resistance & transition time. DC Load Line analysis and Q-point stabilisation. Voltage Divider Bias circuit for CE amplifier. Qualitative discussion of RC coupled

VIII	**Electronic Instrumentation** Multimeter: Principles of measurement of dc voltage, dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance. Cathode Ray Oscilloscope: Block diagram of basic CRO. Construction of CRT, electron gun, electrostatic focusing and acceleration (no mathematical treatment). Front panel controls, special features of dual trace CRO, specifications of a CRO and their significance. Applications of CRO to study the waveform and measurement of voltage, current, frequency & phase difference.

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Unit - I

Unit I

(0th & 1st Law of Thermodynamics)

Introduction

Thermodynamics deals with the transformation of energy in the form of heat into other forms of energy and vice-versa. This subject evolved out of the need for an efficient engine during industrialisation of Europe. But today it finds wide applications in all facets of physical science and beyond. In thermodynamics deals with (directly observable) macroscopic properties of matter without any reference to their microscopic structure. Thermodynamics is based on empirical laws which is very exact and powerful. Each of these laws introduced a new concept (like temperature, internal energy, entropy) which gives a definite meaning to physically measurable quantities and provides useful correlation between observables properties of matter. The first law is essentially a statement about the conservation of energy for thermodynamical systems and recognition of heat as form of energy. It gives the relation between heat and mechanical work.

Summary/Information at a Glance:

System
The substance (or substances) involved in physical and/or chemical changes is known as the system. There are four types of system in thermodynamics.

1. **Open System**: In such a system, exchange of energy and matter occurs with its surroundings.

2. Closed System: In such a system, exchange of energy may occur but no transfer of matter occurs between the system and its surroundings.

3. Thermally Isolated System: No exchange of energy (in the form of heat) takes place.

4. Mechanically Isolated System: No work is done on the system or by the system.

Surroundings

Defined as the regions outside the boundaries of the system which may act on the system.

Process
The actual change that occurs in a system and the manner of its occurrence is known as the process. A process may be physical or chemical. Magnetising of iron bar → Physical process Rusting of iron→ Chemical process

1. Reversible Process: Process carried out very slowly so that system remains in temperature and pressure equilibrium with surroundings.

2 Irreversible Process: In such a process a property of the system differs by a finite amount from one instant to another and system cannot returns to its original state Such processes are real or natural processes.

3. Spontaneous Process: Takes place under a given set of conditions without application of any force.

4. Isothermal Process: Reversible process at a constant temperature.

5. Adiabatic Process: Thermally isolated so that no heat can enter or leave the system.

6. Isentropic Process: A reversible adiabatic process is called isentropic process

7. Isobaric Process: The process carried out at a constant pressure.

8. Isochoric Process: The process carried out at constant volume.

9. Cyclic Process: This process leads from a given state through a sequence of changes back to the original state.

State

The state of a system is described by specifying the values of all relevant macroscopic variables (volume, pressures and temperature), so that the system could be precisely duplicated from this information.

State Variables or Functions

The macroscopic quantities that are used to specify the state of a thermodynamic system are called state variables because their values depend only on the condition.

Volume, temperature, pressure and density are state variables but work and heat are not state variables.

Extensive Variables

Those variables that are proportional to the amount of matter are called extensive variables, e.g. volume V and heat capacity.

Intensive Variables

amount of matter are called intensive variables Those variables that are independent of the e.g. temperature T. pressure P and viscosity

Laws of Thermodynamics and their Consequences

- In thermodynamics we deal with the transformation of heat into mechanical work or vice versa.
- The state of a thermodynamical system is defined by the thermodynamic variables such as pressure P, volume V, temperature T
- Out of these three thermodynamic variables, only two are independent variables.
- The relation connecting these thermodynamic variables, is called the equation of state of the system.
- For example the equation of state for the gaseous system is $f(P,V,T)=0$

Thermal Equilibrium and Zeroth Law of Thermodynamics

Two systems in thermal equilibrium with a third one are in thermal equilibrium with each other. This statement is called the zeroth law of thermodynamics.

Internal Energy

The total internal energy of a system is the sum of internal kinetic energy (due to motion of molecules) and internal potential energy (due to intermolecular attractions).

The Difference Between the Two Specific Heats of a Perfect Gas
The specific heat of a system is defined as the amount of heat energy given to a unit mass of the system to raise its temperature by unity.

If dQ →Amount of heat energy given for a rise of temperature by an amount dT, then

Specific heat of system,

$$C = \left(\frac{dQ}{dT}\right)$$

When volume is kept constant, then

$$C_V = \left(\frac{dQ}{dT}\right)_V$$

When pressure is kept constant,

$$C_P = \left(\frac{dQ}{dT}\right)_P$$

The difference in specific heat at constant pressure to that at constant volume is given as

$$C_P - C_V = R$$

First Law of Thermodynamics

- The first law of thermodynamics is a law of conservation of energy.
- **Statement**: Whenever other forms of energy are converted into heat energy or vice versa there is a fixed ratio between that form ot energy and heat thus converted.

$$\frac{W}{H} = J \text{ (Mechanical equivalent of heat)}$$

- In mathematical form, we can state the law as

$$dQ = dU + dW$$

  Where dQ→ amount of heat given to system which which is used up in
  (i) raising the internal energy of the system by an amount dU
  (ii) doing work dW by the system.
- **Specific heat capacity**
  (i) at constant volume
  $$\Delta U = nC_V\Delta T$$
  (ii) at constant pressure
  $$\Delta H = nC_P\Delta T$$

Isothermal change of perfect gas:

$$PV = nRT$$

Adiabatic change of perfect gas:

PV^{γ} = constant

$TV^{\gamma-1}$ = constant

$TP^{(1-\gamma)/\gamma}$ = constant

Work done during **isothermal** expansion of an ideal gas:

$$W = 2.303nRT\log_{10}\left(\frac{V_f}{V_i}\right)$$

Work done during **adiabatic** expansion of an ideal gas:

$$W = \frac{1}{\gamma - 1}(P_iV_i - P_fV_f)$$

Joule's law for perfect gas:

$$\left(\frac{\partial U}{\partial V}\right)_T = 0$$

A **heat engine** is a mechanical device which converts heat into mechanical work. The system which undergoes such change is called working substance.
Heat engine are of two types: steam engine and internal combuston engine.

The efficiency of the heat engine

$$\eta = \frac{workoutput}{Heatinput}$$

$$\eta = \frac{W}{Q},$$

$W = Q_1 - Q_2$ (work done by the system)

Q_1 = amount of heat absorbed by the system

Q_2 = amount of heat rejected by it

$\eta = (Q_1 - Q_2)/Q_1$

$= 1 - Q_2/Q_1$

Carnot's Engine:

A simple type of engine working between two reservoirs at fixed temperature T_1 (source temperature) and T_2 (Temperature of sink)

The efficiency of Carnot Engine is given by :

$\eta = 1 - Q_2/Q_1 = 1 - T_2/T_1$

$Q_1/Q_2 = T_1/T_2$

Different process in Carnot's cycle:

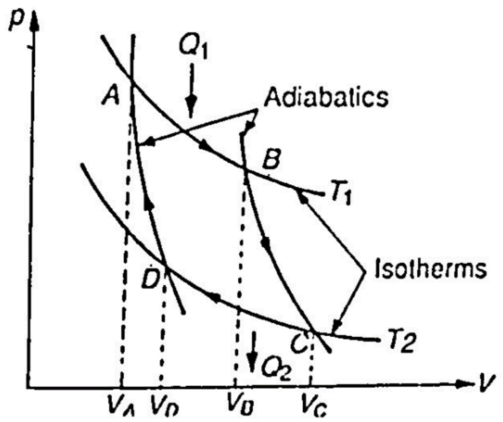


Fig. 1. Carnot Cycle on a P-V diagram

Step 1. Isothermal Expansion

$Q_1 = W_1$

$W_1 = nRT_1\ln(V_2/V_1)$

Step 2. Adiabatic Expansion

Heat absorbed by gas = 0

$W_2 = R(T_1 – T_2)/(\gamma-1)$

Step 3. Isothermal Compression

$Q_2 = W_3 = -RT_2\ln(V_3/V_4)$

Step 4. Adiabatic Compression

Heat absorbed by gas = 0

$W_4 = - R(T_1 – T_2)/(\gamma-1)$

Coefficient of performance for refrigerator,

k = (heat extracted from the cold reservoir)/(work input)

$= Q_2/W$

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

Relation between η and k:

$$\eta = \frac{1}{k+1}$$

In **Internal Combuston Engine**, heat is generated inside the cylinder itself. Two types of Internal combuston engine

1. **Otto engine** in which heat absorbed at constant volume.
2. **Diesel engine** in which heat is absorbed at constant pressure.

Multiple Choice Questions and Answers

1. Temperature and Energy related to which laws of thermodynamics respectively
   a) First law and Zeroth law
   b) Zeroth law and First law
   c) Ist law and IInd law
   d) None of these

Ans. b) Zeroth law and First law

2. Which of the following is reversible process?
   a) Diffusion
   b) Radiation
   c) Change of state
   d) Heat Conduction

   Ans. c) Change of state

3. In which process, the change in internal energy of the system is not zero?
   a) Cyclic
   b) Free expansion
   c) Adiabatic
   d) Isothermal

   Ans. c) Adiabatic

4. Which one is correct? (Symbols have their usual meaning)
   a) $dQ = dU + dW$
   b) $dQ = dU - dW$
   c) $dQ = dW - dU$
   d) $dQ = dW$

   Ans. a) $dQ = dU + dW$

5. A system which has constant temperature, pressure and chemical composition is called
   a) Thermal Equilibrium
   b) Chemical equilibrium
   c) Thermodynamic equilibrium
   d) Mechanical Equilibrium

   Ans. c) Thermodynamic equilibrium

6. Which of the following is reversible process
   a) Transfer of heat by radiation
   b) Transfer of heat from hot body to cold body
   c) Diffusion of gases
   d) Very slow isothermal expansion of a gas

   Ans. d) Very slow isothermal expansion of a gas

7. Which of the following is an example of Closed system
   a) Thermoflask
   b) Stream turbine
   c) Pressure Cooker
   d) All of the above

   Ans. c) Pressure Cooker

Hint: As exchange of energy with surrounding but not matter, thermoflask is isolated system

8. Two samples of ideal gas A and B having same composition and initially at the same temperature and pressure are compressed from V to V/3. (A → isothermally and B → adiabatically). Which one is correct?
   a) $P_A > P_B$
   b) $P_A < P_B$
   c) $P_A = P_B$
   d) $P_A = 3P_B$
   Ans. b) $P_A < P_B$

9. An ideal gas of three sample A, B and C expands to double its volume V to 2V. A → isobarically, B → Isothermally and C → adiabatically. Which of the following is correct for heat absorption?
   a) $Q_A > Q_B > Q_C$
   b) $Q_A = Q_B = Q_C$
   c) $Q_A < Q_B < Q_C$
   d) $Q_A > Q_B < Q_C$
   Ans. a) $Q_A > Q_B > Q_C$
   Hint: In the PV diagram, work done is calculated by area under the curve, therefore Isobaric has larger area than other. Similarly adiabatic case least work, heat absorbs is zero.

10. A gas expands by 0.25 m^3 at constant pressure of 10^3 N/m^2. If increase in internal energy of 50 J. The heat change of the system is
    a) +300 J
    b) –300 J
    c) 0
    d) None of these
    Ans. a) +300 J
    Hint: Use dQ = dU + PdV

11. A gas is compressed at a constant pressure of 100 N/m^2 from a volume of 10 m^3 to a volume of 5 m^3. Energy of 200 J is then added to the gas by heating. Its internal energy is
    a) Increased by 700 J
    b) Decreased by 700 J
    c) Increased by 300 J
    d) Increased by 300 J
    Ans. a) Increased by 700 J
    Hint: Q = 200 J, dV = 5 – 10 = -5m^3
    Use first law of thermodynamics, dU = dQ - W

12. In an adiabatic change between the system and surrounding
    a) There is a transfer of heat in such a way temperature remain constant.

b) There is no transfer of heat but the temperature may vary.
c) There is no transfer of heat hence the temperature remain constant.
d) There is free transfer of heat as well as variation in heat.
Ans. b) There is no transfer of heat but the temperature may vary.

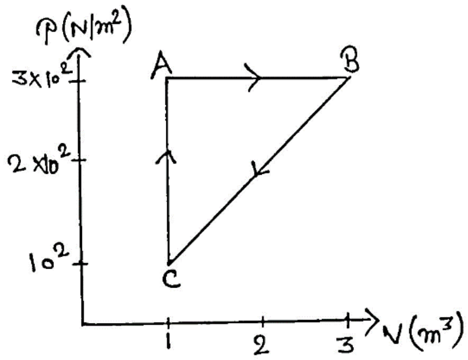
13. For one mole of an ideal gas in adiabatic process, work done is

a) $RT\ln\left(\frac{V_2}{V_1}\right)$
b) PV^{γ}
c) 0
d) $\frac{R(T_1 - T_2)}{\gamma - 1}$

Ans. d) $\frac{R(T_1 - T_2)}{\gamma - 1}$

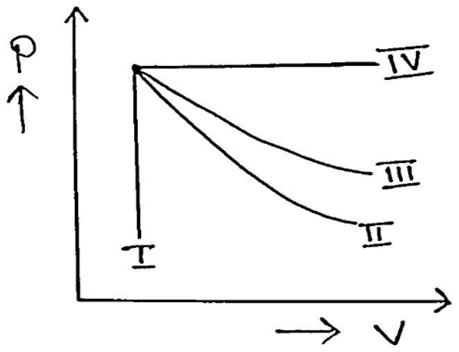
14. A system is taken from state A to state B along two different path 1 and 2. If the heat absorbed and work done by the system along these two paths are Q_1, Q_2 and W_1, W_2 respectively then
a) $Q_1 = Q_2$
b) $W_1 = W_2$
c) $Q_1 - W_1 = Q_2 - W_2$
d) $Q_1 + W_1 = Q_2 + W_2$
Ans. c) $Q_1 - W_1 = Q_2 - W_2$

15. For the given cycle as shown in fig. the work done during the isobaric process is



a) 200 J
b) 0
c) 400 J
d) 600 J
Ans. d) 600 J
Hint: W_{AB} = AB region of the curve(Isobaric), P = constant = 3×10^2 N/m^2
$W_{AB} = P(V_2 - V_1) = 3 \times 10^2 \times (3 - 1) = 600$

16. An ideal gas undergoes four different process from the same initial state as shown in figure below. Those process are adiabatic, isothermal, isobaric and isochoric. Which of the following correct?



a) I→ Isothermal, II→Isobaric, III→ Adiabatic, IV→Isochoric
b) I→Isochoric, II→ Adiabatic, III→ Isothermal, IV→Isobaric
c) I→Isobaric, II→ Adiabatic, III→ Isothermal, IV→Isochoric
d) I→ Adiabatic, II→Isobaric, III→Isochoric, IV→ Isothermal

Ans. b) I→Isochoric, II→ Adiabatic, III→ Isothermal, IV→Isobaric

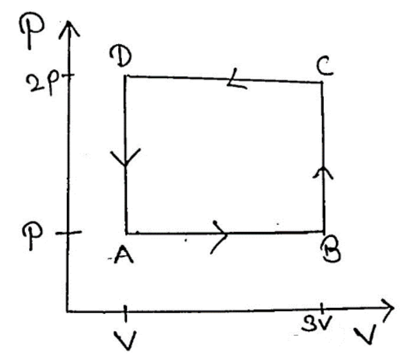
Hint: Thermodynamic process PV^n = constant

For n = 0, P = constant (Isobaric)

For n = 1, PV = constant (Isothermal)

For n = γ, PV^γ = constant (Adiabatic)

17. A thermodynamic system is taken through the cycle ABCD as shown in fig. Heat rejected by the gas during the cycle is



a) PV
b) 2PV
c) 0.5PV
d) 4PV

Ans. b) 2PV

Hint: For cyclic process, Internal energy is zero. Therefore heat is equal to the work done by the gas whch is area ABCD. $W = W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$W_{DA} = W_{BC} = 0$

W = 2PV – 4PV = -2PV = heat rejected

18. During an adiabatic process, the pressure of the gas is found to be proportional to the cube of its temperature. The ratio of C_p/C_v for the gas is

a) 5/3
b) 4/3
c) 3/2
d) 2
Ans. c) 3/2

Hint: Given P = kT^3 threfore $TP^{-1/3}$ compare this with adiabatic relation P and T

Use $TP^{(1-\gamma)/\gamma}$ = constant, Therfore $TP^{-1/3} = TP^{\left(\frac{1-\gamma}{\gamma}\right)}$

19. A monoatomic gas at a pressure P, having a volume V expands first isothermally to volume 2V and then adiabatically to a volume 16V. The final pressure of the gas is (take γ = 5/3)
a) 64P
b) 32P
c) 16P
d) P/64
Ans. d) P/64
Hint: For isothermal expansion, Use $P_2V_2 = P_1V_1$ and find P_2 after that adiabatic expansion use $P_2V_2^{\gamma} = P_1V_1^{\gamma}$

20. When one mole of monoatomic gas (γ = 5/3) is mixed with one mole of a diatomic gas (γ = 7/5). What is the value of γ for mixture?
a) 1.5
b) 1.4
c) 1.53
d) 3.07
Ans. a) 1.5

Hint: γ for mixture = $\frac{\gamma_1 n_1 + \gamma_2 n_2}{n_1 + n_2}$

21. Compressed air coming out from a tyre burst
a) Becomes hotter
b) Becomes cooler
c) Remains at same temperature
d) Attains atmospheric pressure
Ans. b) Becomes cooler
Hint: Adiabatic process

22. The difference between two specific heat C_p and C_v for a gas represents
a) Increase in potential energy of gas molecules
b) Increase in kinetic energy of gas molecules
c) External work done
d) Increase in volume
Ans. c) External work done

23. If a gas of volume 6000 cm^3 and pressure of 200 KPa is compressed quasistatically according to PV^2 = constant until the volume becomes 3000 cm^3. Determine the final pressure
    a) 600 KPa
    b) 800 KPa
    c) 900 KPa
    d) 400 KPa
    Ans. b) 800 KPa
    Hint: Use equation $P_1V_1^2 = P_2V_2^2$

24. PV graph for _________ process is parallel to X-axis.
    a) Adiabatic
    b) Isothermal
    c) Isobaric
    d) Isochoric
    Ans. c) Isobaric

25. For hydrogen gas $C_p - C_v = k_1$ and for Nitrogen gas $C_p - C_v = k_2$, relation between k_1 and k_2 can be given by (where C is molar heat capacity)
    a) $k_1 = 14k_2$
    b) $k_2 = 14k_1$
    c) $k_1 = 4k_2$
    d) $k_1 = k_2$
    Ans. d) $k_1 = k_2$

26. n moles of a gas are filled in a container at temperature T. If the gas slowly and isothermally compressed to half its initial volume, the work done by the atmosphere on the gas is
    a) –nRTln2
    b) nRTln2
    c) (nRT)/2
    d) -(nRT)/2
    Ans. b) nRTln2
    Hint: Work done by gas (W_g) = - Work done by atmosphere (W_a) on the gas
    $W_g = nRT\ln(V_2/V_1)$ and $V_2 = V_1/2$

27. A tyre is at 27°C temperature and at 2 atm pressure it burst suddenly then the resultant temperature will be ($\gamma = 1.4$, $2^{2/7} = 1.22$)
    a) -123°C
    b) 240°C
    c) -27°C
    d) 0°C
    Ans. c) -27°C
    Hint: As tyre burst its pressure becomes atmospheric pressure
    Therefore $P_2 = 1$ atm, $P_1 = 2$ atm

Adiabatic process, $TP^{(1-\gamma)/\gamma}$ = constant, use this for initial and final pressure and temperature T_2 = 246 K

28. The slope of Isothermal and adiabatic curves are related as
    a) Isothermal curve slope = adiabatic curve slope
    b) Isothermal curve slope = γ×adiabatic curve slope
    c) Adiabatic curve slope = γ×isothermal curve slope
    d) Isothermal slope = 1/2× adiabatic curve slope
    Ans. c) Adiabatic curve slope = γ×isothermal curve slope

29. For a particular ideal gas, the value of R is 0.280 KJ/KgK and the value of γ is 1.375. The value of C_p and C_v are respectively in KJ/KgK
    a) 1.25, 0.8
    b) 1.0267, 0.7467
    c) 1.111, 0.66
    d) 1.2, 0.7
    Ans. b) 1.0267, 0.7467
    Hint: $C_V = R/(\gamma-1)$ and $C_P = \gamma R/(\gamma-1)$

30. The efficiency of carnot engine is 50% and temperature of sink is 500 K. If temperature of source is kept constant and its efficiency raised to 60%, then the required temperature of sink will be
    a) 100 K
    b) 400 K
    c) 500 K
    d) 600 K
    Ans. b) 400 K
    Hint: use $\eta = 1 - \frac{T_2}{T_1}$

31. The difference between C_p and C_v is equal to the universal gas constant R, when
    a) one gram of gas is heated
    b) any amount of gas is heated
    c) one molecule of gas is heated
    d) one gram molecule of the gas is heated
    Ans. d) one gram molecule of the gas is heated

32. Which statement is false?
    a) Carnot cycle is reversible.
    b) A reversible cycle is more efficient than irreversible one.
    c) Carnot Cycle is the most efficient among all cycles.
    d) All reversible cycle has same efficiency.
    Ans. d) All reversible cycle has same efficiency.

33. If two engine E_1 and E_2 are working in the same temperature ranges. The E_1 is an reversible engine, where as E_2 is an irreversible engine. Which of the following is correct for the efficiency of the engines?
    a) $\eta(E_1) > \eta(E_2)$
    b) $\eta(E_1) < \eta(E_2)$
    c) $\eta(E_1) = \eta(E_2)$
    d) Insufficient data
    Ans. a) $\eta(E_1) > \eta(E_2)$
    Hint: Carnot Theorem

34. The first carnot engine work under temperature T_1, T_2 and the second carnot engine work under T_2 and T_3. Which of the following is true for above mentioned carnot engine for same work output?
    a) $T_2 = (T_1 - T_3)/2$
    b) $T_1 - T_2 = T_2 - T_3$
    c) $T_2 = \sqrt{T_1 \times T_3}$
    d) $T_2 = 2(T_1 - T_3)$
    Ans. b) $T_1 - T_2 = T_2 - T_3$
    Hint: Carnot engine in series, $W_1 = W_2$
    Therefore $T_2 = (T_1 + T_3)/2$

35. The heat engine operating between temperature 2000 K and T K and T K and 500 K respectively. What is the intermediate temperature, if the efficiency of both the cycle is same.
    a) 900 K
    b) 1000 K
    c) 1500 K
    d) 1600 K
    Ans. b) 1000 K

    Hint: use formula Carnot engine, $\eta = 1 - \frac{T}{T_1} = 1 - \frac{T_2}{T}$ therefore

    $T = (T_1 \times T_2)^{1/2}$

36. The coefficient of performance of refrigerator between 10^0C and 42^0C is
    a) 6.77
    b) 7.77
    c) 8.84
    d) 10.77
    Ans. c) 8.84

    Hint: use k = $\frac{T_2}{T_1 - T_2}$

37. If C_p and C_v are the molar heat capacities of an ideal gas at constant pressure and constant volume respectively. Which of the following is Universal constant?
    a) C_pC_v

b) C_p/C_v
c) $C_p - C_v$
d) $C_p + C_v$
Ans. c) $C_p - C_v$

38. The efficiency of a reversible engine is 100% if
a) temperature of source is 100^oC
b) temperature of sink is 0^oC
c) temperature of sink is 0 K
d) temperature of source is same as the temperature of the sink.
Ans. c) temperature of sink is 0 K

39. A carnot engine works between hot reservoir at temperature T_1 and a cold reservoir at temperature T_2. To increase its efficiency
a) T_1 and T_2 both should be decreased
b) T_1 and T_2 both should be increased
c) T_1 should be increased and T_2 decreased.
d) T_1 should be decreased and T_2 increased
Ans. c) T_1 should be increased and T_2 decreased.

40. A carnot engine with the sink temperature at 17^0C has 50% efficiency. By how much should its source temperature be changed to increase its efficiency to increase its efficiency to 60%?
a) Decreased by 145 K
b) Increased by 200 K
c) Increased by 145 K
d) Decreased by 200 K
Ans. c) Increased by 145 K
Hint: use Carnot efficiency
$\eta_{carnot} = (T_1 – T_2)/T_1$, $\eta_1 = 0.5$ find T_1
next use $\eta_2 = 0.6$ and calculate T_1 and fixed T_2 same. Take the difference of T_1 for both case.

41. An insulated box containing 0.5 Kg of a gas having $C_v = 0.98$ KJ/Kg-K falls from a balloon 4 Km above the earth's surface. The temperature rise of the gas when box hits the ground is
a) 0 K
b) 20 K
c) 40 K
d) 60 K
Ans. c) 40 K
Hint: As the box hit the ground, Potential energy = Internal energy of gas
$mgh = mc_v\Delta T$ therefore $\Delta T = (9.8\times4000)/0.98 = 40$ K

42. A heat engine is supplied 278 KW of heat at a constant fixed temperature of 283^0C and heat rejection takes place at 5^0C. The engine is reversible if the heat rejected, in KW is
a) 139
b) 208
c) 35
d) 70
Ans. a) 139 KW
Hint: engine is reversible, $\oint \frac{dQ}{T} = 0$, $Q_1/T_1 = Q_2/T_2$

43. If the heat rejected from the system is zero, then which of the following statement will hold true?
a) When net work is equal to the heat absorbed, work efficiency is 100%
b) Heat is exchanged from one heat reservoir only
c) It violates Kelvin-Planck statement
d) All options are correct
Ans. d) All options are correct

44. Carnot cycle is not practical because it
a) Demands that all process should be reversible
b) Piston movement is required very slow in isothermal process and very fast in adiabatic process, this variations practically not possible
c) Heat addition at constant temperature is not possible
d) All of the above
Ans. d) All of the above

45. A Carnot engine has the **same** efficiency between 800 K to 500 K and X to 600 K. The value of X is
a) 960 K
b) 846 K
c) 812 K
d) 754 K
Ans. a) 960 K
Hint: use Carnot efficiency $\eta_1 = \eta_2$

46. In a Carnot Cycle, heat is transferred at
a) Constant pressure
b) Constant volume
c) Constant temperature
d) Constant enthalpy
Ans. c) Constant temperature

47. A cyclic machine receives 325 KJ from a 1000 K energy reservoir. It rejects 125 KJ to a 400 K energy reservoir and the cycle produces 200 KJ of work as output. Is this cycle

a) Reversible
b) Irreversible
c) Impossible
d) None of these
Ans. c) impossible
Hint: $\eta_{actual} = 200/325 = 0.615$, $\eta_{carnot} = (T_1 - T_2)/T_1 = 0.6$
As $\eta_{actual} > \eta_{carnot}$ therefore impossible

48. A litre of an ideal gas at pressure of 72 cm of Hg column is compressed isothermally to a volume of 900 cc. The stress in terms of length of Hg column is
a) 80 cm
b) 64.8 cm
c) 8 cm
d) 7.2 cm
Ans. a) 80 cm
Hint: use $P_1V_1 = P_2V_2$

49. The absolute zero temperature is taken as
a) -273^0C
b) 273^0C
c) 0^0C
d) 273K
Ans. d) -273^0C

50. For same compression ratio and for same heat added which one is more efficient between Otto cycle and Diesel cycle?
a) Otto cycle
b) Diesel cycle
c) both are equal
d) depends on other factors
Ans. a) Otto cycle

Unit - II

Unit II

(2nd & 3rd Law of Thermodynamics)

Introduction

The first law of thermodynamics is a statement abount conservation of energy in thermal processes. However, it gives no information about the way thermodynamic system evolve or the direction of flow of heat. Can heat flow by itself from a colder to hotter body? Similarly, it is a common experience that one can achieve complete conversion of heat into work and the extent to which it can be done. Can we achieve 100% efficiency? The answer to these questions given by second law of thermodynamics. What determines the direction of a process? The answer to these given by Clausius when he introduced the concept of entropy. After familiar with the several properties of thermodynamic system like P, T, V, H, U and S. Of these U and S cannot measure in laboratory. So we would naturally like to know how one can relate them with measurable properties. To answer these question, we would require thermodynamic relations. After this, third law of thermodynamics to explain the nature of bodies in neighbourhood of absolute zero temperature. It allow the calculation of absolute value of entropy and the physical interpretation of thermodynamic properties such as Helmholtz and Gibbs free energies etc.

Second law of Thermodynamics

Kelvin-Planck statement – It is impossible to construct a device which when operates in a cycle, extracts heat from a source and converts whole of it into work.

Clausius statement – It is impossible to construct a device which when operates in a cycle, produces no effect other than to transfer heat from a colder body to hotter body.

Both the statements are equivalent to each other.

Entropy

Boltzman showed that entropy is a measure of disorder in molecular arrangement of a system and as such it is an abstract concept.

Clausius developed a general mathematical formulation of the second law and showed that only such process can occur for which entropy does not decrease.

Entropy change for an ideal gas

$$\Delta S = C_v \ln\left(\frac{T_f}{T_i}\right) + R\ln\left(\frac{V_f}{V_i}\right)$$

Entropy change in terms of T and P

$$\Delta S = C_p \ln\left(\frac{T_f}{T_i}\right) - R\ln\left(\frac{P_f}{P_i}\right)$$

Entropy change of ideal gas in terms of P and V

$$\Delta S = C_v \ln\left(\frac{P_f}{P_i}\right) + C_p \ln\left(\frac{V_f}{V_i}\right)$$

Entropy change Isothermal expansion

$$\Delta S = R\ln\left(\frac{V_f}{V_i}\right) = R\ln\left(\frac{P_f}{P_i}\right)$$

Entropy change in reversible change of state

$$\Delta S = \frac{dQ}{T} = \frac{mL}{T}$$

Wher L is the latent of substance

Entropy change in reversible process:

$$dQ = TdS$$

Carnot cycle as an example with corresponding T-S diagram

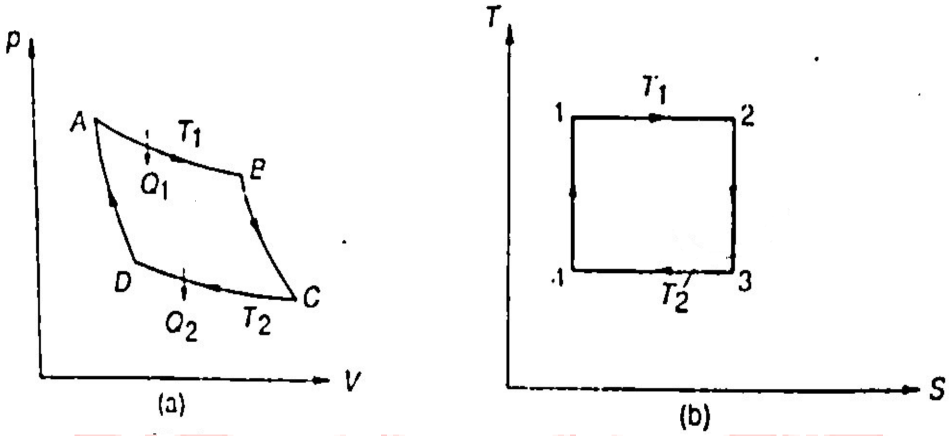


Fig. 1. Carnot cycle on (a) P-V diagram and (b) T-S diagram

Entropy change in irreversible change of state

$$\Delta S = \frac{dQ}{T} = \frac{mL_1}{T_1} + mc\ln\left(\frac{T_2}{T_1}\right) + \frac{mL_2}{T_2}$$

Clausius-Clapeyron equation:

By the second law of thermodynamics, the boiling point and melting point of substance change with pressure explain by Clausius – Clapeyron equation or **first latent heat equation**.

$$\frac{dp}{dT} = \frac{L}{T(V_2 - V_1)}$$

a) **Effect of change of pressure on the melting point**: When a solid is converted to liquid, there is change in the volume.

If $V_2 > V_1$, (dP/dT) is positive, so that the melting point of substance will increase in pressure and vice-versa.

If $V_2 < V_1$, (dP/dT) is negative quantity. In such case the melting point of the substance will decrease with increase in pressure and vice-versa. (e.g. for ice, $V_2 < V_1$, (dP/dT) is negative, hence ice will melt at a temperature lower than 0^0C at a pressure higher than the normal pressure)

b) **Effect of change of pressure on boiling point**: Here always $V_2 > V_1$, (dP/dT) is positive quantity. So with increasing pressure, the boiling point of a substance increases and vice-versa. The liquid will boil at lower temperature under reduced pressure.

The **second latent heat equation** of Clausius:

$$C_2 - C_1 = \left(\frac{dL}{dT} - \frac{L}{T}\right)$$

Thermodynamic Potential – Four thermodynamic potential which are the functions of the thermodynamic variables P, V, T and S.

(i) Internal Energy (U)

(ii) Helmholtz Free Energy (F)

F = U - TS

(iii) Enthalpy or total heat function (H)

H = U + PV

(iv) Gibb's potential/free energy (G)

G = U + PV – TS
= H – TS
= F + PV

Maxwell's Thermodynamic relationship:

i) $$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$ derive from dU = TdS - PdV

ii) $$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$ derive from dF = -PdV – SdT

iii) $$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$ derive from dH = TdS + VdP

iv) $$\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$$ derive from dG = VdP – SdT

Ratio of adiabatic and Isothermal elasticity:

i) Adiabatic elasticity E_S (entropy constant)

$$E_S = -V\left(\frac{\partial P}{\partial V}\right)_S$$

ii) Isothermal elasticity E_T (temperature constant)

$$E_T = -V\left(\frac{\partial P}{\partial V}\right)_T$$

Ratio $$\frac{E_S}{E_T} = \frac{C_P}{C_V} = \gamma$$

Joule Thomson Coefficient (μ):

Gas at constant high pressure forced through a porous plug to a region of constant low pressure, the temperature of the escaping gas changes called the Joule-Thomson effect.

$$\mu = \left(\frac{\partial T}{\partial P}\right)_H = \frac{1}{C_P}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right]$$

For perfect gas, $\mu = 0$

The *TdS* equation:

i) The entropy of pure substance can be regarded as a function of temperature and volume.

$$TdS = C_V dT + T\left(\frac{\partial P}{\partial T}\right)_V dV$$ (**Ist *TdS* equation**)

ii) The entropy of pure substance can be regarded as a function of temperature and pressure.

$$TdS = C_p dT - T\left(\frac{\partial V}{\partial T}\right)_P dP \quad (\textbf{IInd } \boldsymbol{TdS} \textbf{ equation})$$

Multiple Choice Questions and Answers

1. One gram mole of a perfect gas expands isothermally to 8 times its initial volume. Than the change in entropy in terms of R is
   a) 1.386R J/K
   b) 2.079R J/K
   c) 0.693R J/K
   d) 0
   Ans. b) 2.079R J/K
   Hint: use $\Delta S = R\ln\left(\frac{V_f}{V_i}\right)$, $V_f = 8\ V_i$

2. Which of the following statement is false about entropy?
   a) Entropy of universe always is decreasing
   b) Entropy change of the system is the degree of increase or decrease of its randomness.
   c) Entropy of substance with high degree of randomness is higher.
   d) Entropy of solid state is the least
   Ans. a) Entropy of universe always is decreasing

3. Change in entropy during constant pressure process is given by the relation
   a) $mc_p\ln(T_2/T_1)$
   b) $mc_p\ln(T_1/T_2)$
   c) $mc_v\ln(T_2/T_1)$
   d) $m(R/J)\ln(T_2/T_1)$
   Ans. a) $mc_p\ln(T_2/T_1)$

4. The entropy always increases for an isolated system and when the equilibrium is reached, it is
   a) Maximum
   b) Same as the initial state
   c) More than initial state
   d) Zero
   Ans. a) Maximum

5. The net entropy change of a system in Carnot's cycle is
   a) zero
   b) positive
   c) negative
   d) None of these
   Ans. a) zero

6. The change in entropy of a one mole of an ideal gas, when the gas undergoes free expansion is
   a) zero
   b) positive
   c) negative
   d) none of these
   Ans. b) positive

7. When water vapour condenses into water, its entropy
   a) increases
   b) remains unchanged
   c) decreases
   d) none of these
   Ans. c) decreases

8. Choose the correct option for <u>entropy</u> measurement
   a) solid > liquid > gas
   b) gas > liquid > solid
   c) solid = liquid = gas
   d) None of these
   Ans. b) gas > liquid > solid

9. The amount of heat required to raise the temperature of the unit mass of gas through one degree at constant volume is called
   a) Entropy
   b) c_v
   c) c_p
   d) Enthalpy
   Ans. b) c_v

10. Entropy change depends on
    a) Heat transfer
    b) Thermodynamic state
    c) Change of temperature
    d) mass transfer
    Ans. a) Heat transfer

11. If a piece of ice is added to water in a vessel than its
    a) increased
    b) decreased
    c) remains same
    d) none of these
    Ans. a) increased

12. 10 gm of water at 40^0C are mixed with 20 gm of water at 70^0C. What is the temperature of mixture? specific heat of water, c = 1cal/g-deg

a) 60^0C
b) 65^0C
c) 110^0C
d) 50^0C
Ans. a) 60^0C
Hint: use principle of calorimetry,
Heat absorb = heat lost
$m_1c(T - 40) = m_2c(70 - T)$

13. 10 gm of steam at 100^0C is converted into water at the same temperature. Latent heat of steam is 540 cal/gm. The change in entropy in cal/K is
a) 14.48
b) 1.448
c) -1.448
d) -14.48
Ans. d) -14.48
Hint: The change in Entropy for change of state, $\Delta S = \frac{dQ}{T} = \frac{mL}{T}$

14. A heat engine is supplied 278 KW of heat at a constant fixed temperature of 283^0C and heat rejection takes place at 5^0C. The engine is reversible if the heat rejected, in KW is
e) 139
f) 208
g) 35
h) 70
Ans. a) 139 KW
Hint: engine is reversible, $\oint \frac{dQ}{T} = 0$, $Q_1/T_1 = Q_2/T_2$

15. In the free expansion of an ideal gas from volume V_1 to V_2
a) The entropy of the gas remains while its temperature decreases
b) The entropy of the gas remains constant while its temperature decreases
c) The entropy and temperature both increases
d) None of the above
Ans. d) None of the above
Hint: dU = 0, dT = 0 (free expansion)
$\Delta S = nR\ln(V_2/V_1)$ as $V_2 > V_1$ therefore S increases and T constant.

16. At constant temperature, the work done by a gas is equal to
a) change in its internal energy
b) change in its Gibbs energy
c) change in its Helmholtz energy
d) change in its enthalpy
Ans. c) change in its Helmholtz energy
Hint: F = U – TS, dT and dU is zero

dF = -TdS = dQ = dW

17. Which one of the following is correct?
a) $-\Delta G = \Delta H - T\Delta S$
b) $\Delta H = \Delta G - T\Delta S$
c) $\Delta S = (1/T)[\Delta G - \Delta H]$
d) $\Delta S = (1/T)[\Delta H - \Delta G]$
Ans. d) $\Delta S = (1/T)[\Delta H - \Delta G]$
Hint: use G = H - TS

18. Joule Thomson Coefficient is given by the expression :
a) $\left(\frac{\partial T}{\partial P}\right)_H$
b) $\left(\frac{\partial T}{\partial V}\right)_H$
c) $\left(\frac{\partial E}{\partial P}\right)_V$
d) $\left(\frac{\partial S}{\partial T}\right)_P$
Ans. a) $\left(\frac{\partial T}{\partial P}\right)_H$

19. Gibb's Potential is defined as
a) G = U – PV + TS
b) G = U + PV + TS
c) G = U – PV - TS
d) G = U + PV – TS
Ans. d) G = U + PV – TS
Hint: Use G = H – TS and H = U + PV

20. Which of the following is not a Maxwell thermodynamical relation?
a) $\left(\frac{\partial T}{\partial V}\right)_S = \left(\frac{\partial P}{\partial S}\right)_V$
b) $\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$
c) $\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$
d) $\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$
Ans. a) $\left(\frac{\partial T}{\partial V}\right)_S = \left(\frac{\partial P}{\partial S}\right)_V$ as negative sign needed

21. The condition for an isolated system to be in equilibrium is
    a) Gibb's energy must be maximum.
    b) Helmholtz free energy must be maximum
    c) Internal energy must be maximum.
    d) Entropy must be maximum.
    Ans. d) Entropy must be maximum.

22. As entropy is related to probability of occurance of a state. Entropy increased during the irreversible process can be associated with a change of state from
    a) less probable to more probable
    b) more probable to less probable
    c) both are equally probable
    d) None of these
    Ans. a) less probable to more probable state

23. The Gibbs Helmholtz equation is written as:
    a) $U = F - T\left(\frac{\partial F}{\partial T}\right)_V$
    b) $F = U - T\left(\frac{\partial F}{\partial T}\right)_V$
    c) $U = F - T\left(\frac{\partial F}{\partial T}\right)_P$
    d) $F = U - T\left(\frac{\partial F}{\partial T}\right)_P$
    Ans. a) $U = F - T\left(\frac{\partial F}{\partial T}\right)_V$

24. If C_1 and C_2 represents the specific heat of a liquid and its saturated vapour. L is the latent heat then $C_2 - C_1$ is given by
    a) $\left(\frac{dL}{dT} - \frac{L}{T}\right)$
    b) $\left(\frac{dL}{dT} + \frac{L}{T}\right)$
    c) $\frac{dL}{dT} - \left(\frac{L}{T}\right)^2$
    d) $\frac{dL}{dT} + \left(\frac{L}{T}\right)^2$
    Ans. a) $\left(\frac{dL}{dT} - \frac{L}{T}\right)$

25. Mathematical form of the Second law of thermodynamics is
    a) dS = TdQ

b) dQ = TdS
c) dQ = dU + PdV
d) dS = dQ + PdV
Ans. b) dQ = TdS

26. According to Clausius theorem

a) $\oint \frac{dQ}{T} > 0$

b) $\oint \frac{dQ}{T} < 0$

c) $\oint \frac{dQ}{T} = 0$

d) $\oint \frac{dQ}{T} = cons\tan t$

Ans. b) $\oint \frac{dQ}{T} < 0$

27. Clausius Clapeyron heat equation is:

a) $\frac{dp}{dT} = \frac{L}{P(V_2 - V_1)}$

b) $\frac{dp}{dT} = \frac{L}{T(V_2 - V_1)}$

c) $\frac{dp}{dT} = \frac{L}{V(P_2 - P_1)}$

d) $\frac{dp}{dV} = \frac{L}{T(V_2 - V_1)}$

Ans. b) $\frac{dp}{dT} = \frac{L}{T(V_2 - V_1)}$

28. Thermodynamic Potentials are
a) P, V, T, U
b) H, U, T, S
c) U, H, F, G
d) S, H, U, F
Ans. c) U, H, F, G

29. On a T-S diagram the isothermals are
a) parallel to T-axis
b) parallel to S-axis
c) 45^0 to the plane
d) None of these
Ans. b) parallel to S-axis

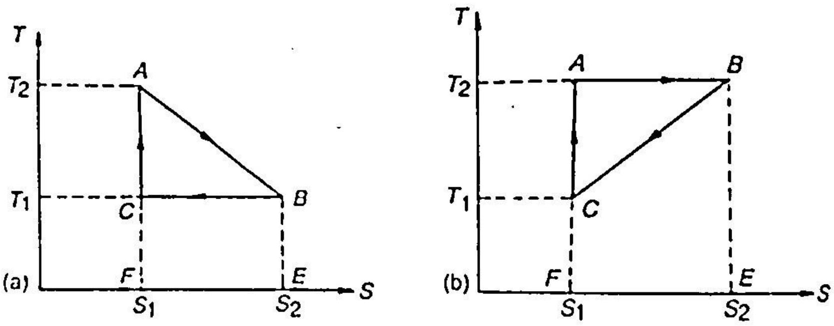
30. Pressure cooker, cook the food rapidly because

a) higher pressure available at 100^0C
b) the boiling point of water is raised by increased pressure inside the cooker
c) more steam available to cook the food at 100^0C
d) None of these
Ans. b) the boiling point of water is raised by increased pressure inside the cooker
Hint: use clausius clapeyron equation

31. Water boils at 100^0C at NTP. Under the deep down tunnel, water will boil at the temperature
a) less than 100^0C
b) greater than 100^0C
c) at 100^0C
d) None of these
Ans. b) greater than 100^0C

32. The volume expansion coefficient is given by
a) $\frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$
b) $V\left(\frac{\partial V}{\partial T}\right)_P$
c) $\frac{1}{P}\left(\frac{\partial P}{\partial T}\right)_V$
d) $P\left(\frac{\partial P}{\partial T}\right)_V$
Ans. a) $\frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$

33. T-S diagram of cycle ABCA shown in figure.



Which one of the figure have higher work?
a) Fig (a)
b) Fig (b)
c) both have equal work done
d) None of these
Ans. c) both have equal work done
Hint: As work done = area ABC, which is same in both case

$W = (1/2) \times (T_2 - T_1) \times (S_2 - S_1)$

34. In the above question in given figure, Find out the ratio of efficiency $\frac{\eta_a}{\eta_b}$

a) $\frac{2T_2}{T_1 + T_2}$
b) $\frac{2T_1}{T_1 + T_2}$
c) $\frac{2T_2}{T_1 - T_2}$
d) 0

Ans. a) $\frac{2T_2}{T_1 + T_2}$

Hint: Use $\eta = \frac{W}{Q}$, Q = heat absorbed by the system which is different for area (ABEFA) in fig. (a) and fig. (b). Calculate and put in efficiency equation.

35. A heat engine receives 100 kcal of heat from source at 1000 K. It rejects (I) 50 kcal or (II) 75 kcal of heat to the surroundings at 500 K. Identify the nature of change in each case?

a) I→ Reversible, II→ Irreversible
b) I→ Irreversible, II→ Reversible
c) both reversible
d) both irreversible
Ans. a) I→ Reversible, II→ Irreversible

36. Nernst's heat theorem also called as

a) First law of thermodynamics
b) IInd law of thermodynamics
c) IIIrd law of thermodynamics
d) None of these
Ans. c) IIIrd law of thermodynamics

37. IIIrd law of thermodynamics stated
a) total energy of universe is conserved
b) Entropy of all solids or liquid is zero at absolute zero
c) Entropy of the universe is increasing
d) None of these
Ans. b) Entropy of all solids or liquid is zero at absolute zero

38. In First *TdS* equation S is function of
a) T and V
b) T and P
c) P and V
d) constant

Ans. a) T and V

39. Which one is correct relation?

a) $\frac{E_S}{E_T} = \gamma$

b) $\frac{E_S}{E_T} = \frac{1}{\gamma}$

c) $\frac{E_T}{E_S} = \gamma$

d) $\frac{E_S}{E_T} = \gamma^2$

Ans. a) $\frac{E_S}{E_T} = \gamma$

40. Rice cooked take longer time
a) at sea level
b) at Higher altitude
c) at mines below sea level
d) None of these
Ans. c) at Higher altitude

41. Unit of entropy
a) $JK^{-1}mol^{-1}$
b) $JKmol^{-1}$
c) J
d) $K^{-1}mol^{-1}$
Ans. a) $JK^{-1}mol^{-1}$

42. Which of the following statement is not true?
a) The pressure of a saturated vapour is independent of its temperature
b) A liquid boils when its saturated vapour pressure is equal to the atmospheric pressure
c) The saturated vapour pressure is independent of its volume.
d) when saturated pressure is equal to the atmospheric pressure, abubble of vapour can form anywhere in the liquid.
Ans. a) The pressure of a saturated vapour is independent of its temperature

43. Adiabatic elasticity of an ideal gas ($\gamma = 1.4$) is 2×10^5 N/m^2. Its isothermal elasticity is given by
a) 2×10^5 N/m^2
b) 0
c) 10^5 N/m^2
d) 1.42×10^5 N/m^2
Ans. d) 1.42×10^5 N/m^2

Hint: use formula $\frac{E_S}{E_T} = \gamma$

44. For thermodynamic system under isothermal – isochoric process in stable equilibrium, the Helmholtz potential (F) becomes
a) Maximum
b) Minimum
c) neither max nor min.
d) none of these
Ans. b) Minimum

45. For real gas, the Joule-Thomson coefficient (μ) is
a) $\frac{1}{C_P}\left(\frac{2a}{RT} - b\right)$
b) 0
c) $\frac{2a}{RT}$
b) $\frac{1}{C_V}\left(\frac{2a}{RT} - b\right)$
Ans. a) $\frac{1}{C_P}\left(\frac{2a}{RT} - b\right)$

46. The temperature at which Joule-Thomson effect change its sign is called
a) Critical Temperature
a) Inversion Temperature
b) Ordinary temperature
d) None of the above
Ans. b) Inversion Temperature

47. If specific volume of liquid is much less than of its vapour. The vapour obey ideal gas equation, than Clausius-clapeyron equation leads to
a) $P = RTlnV$
b) $P = ke^{-L/RT}$
c) $T = ke^{-L/RT}$
d) $P = 0$
Ans. b) $P = ke^{-L/RT}$
Hint: Clausius Clapeyron equation is
$$\frac{dp}{dT} = \frac{L}{T(V_2 - V_1)}$$
Given $V_2 >>> V_1$ therefore $V_2 - V_1 = V_2 = V$
PV = RT, V = RT/P put in the equation we get the result.

48. At normal temperature, H and He gas shows
    a) Cooling
    b) Heating
    c) sometimes cooling and sometime heating effect
    d) None of these
    Ans. b) Heating effect

49. Specific heat of saturated water vapour at boiling point is
    a) 0
    b) positive
    c) negative
    d) None of these
    Ans. c) negative

50. During phase change of water to steam, if latent heat of water L = 800 – 0.705T Than the specific heat of water vapour at 100^0C using second latent heat equation of clausius is
    a) – 11.4
    b) 0
    c) – 1.14
    d) + 1.14
    Ans. c) - 1.14
    Hint: Second latent Heat equation is
    $C_2 = C_1 + \left(\frac{dL}{dT} - \frac{L}{T}\right)$, take $C_1 = 1$ (for water at liquid state)
    $T = 100^0C = 373K$ and $L = 800 - 0.705T$, calculated C_2

Unit - III

Unit III

(Kinetic Theory of Gases)

Summary

1. Kinetic Model of Gases

- According to this model the gas consists of a very large number of extremely tiny particles called the 'molecules'.
- All the molecules of a pure gas are identical and do not occupy space.
- Molecules do not exert attractive or repulsive force on each other.
- Due to its thermal state the molecules of a gas are in continuous thermal random motion.
- The molecules are widely separated and execute only linear motion in this space. In this process they frequently collide with each other and with the wall of the container. In these collisions the speed and direction of motion of molecule continuously changes.
- The gas exerts pressure on the walls of the container due to continuous collisions of the molecules. When a gas molecule collides with the wall of the container, there is a change in its momentum and according to Newton's law of motion an equal and opposite momentum is transferred to the wall of the container. The pressure on the wall is due to this rate of change of momentum transferred to its unit area.

2. Assumptions of Kinetic Theory of Gases

- The molecules of a gas behave as hard, smooth and perfectly elastic spheres of extremely small dimensions; there is no loss of kinetic energy in the collisions of a molecule with other molecules or the walls of the container.
- Due to thermal state of the gas its molecules are in a state of continuous random motion, colliding with one another and the walls of the container. They move with very high velocities in straight lines. Their velocity and direction changes in collision.
- The collisions are instantaneous, the time taken in collision is negligible compared to that taken in travelling the mean free path (the average distance travelled by a molecule between successive collisions).
- The molecules are point masses and do not occupy any space.
- The molecules of a gas do not exert any force on each other.

3. Pressure exerted by an Ideal Gas

- $\boldsymbol{P = \frac{mnC^2}{3V}}$; m is the mass of each molecule, n is the number of molecules in volume V and C is root mean square velocity, C^2 is the mean square velocity of the molecules.
- $\boldsymbol{P = \frac{\rho C^2}{3}}$; ρ is the density of the gas
- Pressure exerted by a gas is equal to two-third of the K.E of translation per unit volume i.e. $\boldsymbol{P = \frac{2E}{3}}$; E is the energy density of the gas = $\frac{\rho C^2}{2}$

4. Kinetic Interpretation of Temperature

- $\frac{mC^2}{2} = \frac{3kT}{2}$
- Average kinetic energy of translation of the molecules is directly proportional to the absolute temperature of the gas.
- Average kinetic energy of translation of the molecules can be regarded as a measure of temperature.
- Absolute zero is that temperature at which all molecular motion of a gas ceases.

5. Using Kinetic theory of gases, one can deduce and verify Boyle's law, Charle's law, Ideal gas equation, Graham's law of diffusion, Avogadro hypothesis and Dalton's law of Partial Pressure.

6. Root- mean-square-speed of molecules

- $C=\sqrt{\frac{3RT}{M}}$
- mN = M; N is Avogadro number and M is molecular weight; R = Nk where k is Boltzmann constant

  $C=\sqrt{\frac{3kT}{m}}$
- As $P = \frac{\rho C^2}{3}$ so $C = \sqrt{\frac{3P}{\rho}}$

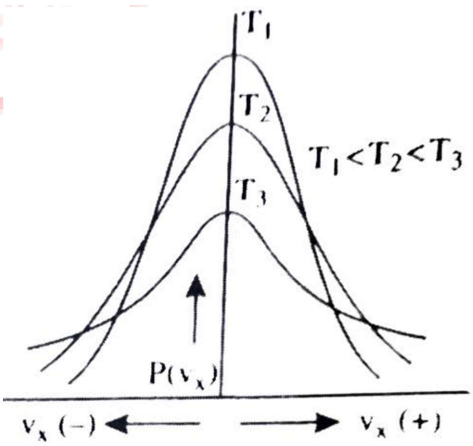
7. Maxwell's Distribution Law of Velocities

- According to Maxwell's distribution of velocities, the probability that a molecule will have x-component of velocity in the range v_x to $v_x + dv_x$ is

  $\mathbf{P(v_x)\, dv_x = (m/2\pi kT)^{1/2} \exp[-(mv_x^2/2kT)]\, dv_x}$
- In terms of x-component of momentum p_x

  $\mathbf{P(p_x)\, dp_x = (1/2\pi mkT)^{1/2} \exp[-(p_x^2/2mkT)]\, dp_x}$
- $P(v_x)$ is symmetrically distributed about $v_x = 0$.
- The maximum value of probability $P_{max}(v_x) = (m/2\pi k_B T)^{1/2}$ when $v_x = 0$
- Probability falls to (1/e) of its maximum value

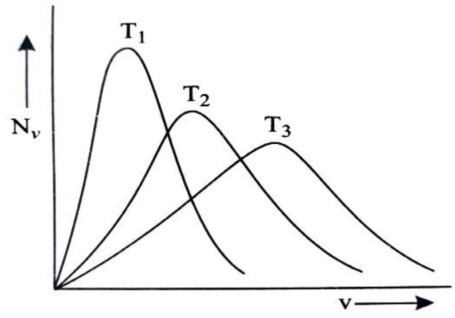
  $P_{max}(v_x)$ at $v_x=\sqrt{\frac{2kT}{m}}$
- As T increases, the peak at $v_x=0$ becomes lower and the distribution spreads out; the area under the curve is always unity.
- Maxwell-Boltzmann law of distribution of molecular velocities can be indirectly verified by study of the width of a spectral line.



- Stern experiment, Zartman and Ko experiment and Estermann, Simpson and Stern experiment gives direct experimental verification of Maxwell-Boltzmann law of distribution of molecular velocities.

8. Maxwell's Distribution Law of Speeds

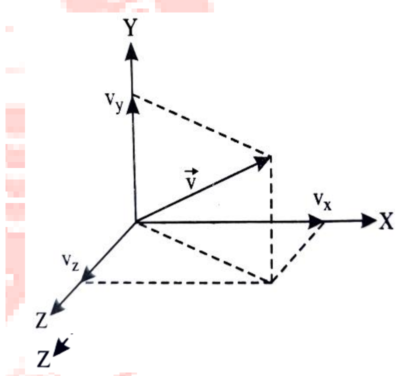
- The number of molecules having speed in the range v and v + dv is
  $N_v\, dv = 4\pi N\, (m/2\pi kT)^{3/2}\, v^2 \exp[-(mv^2/2kT)]\, dv$
- Most probable speed $v_{mp} = \sqrt{\frac{2kT}{m}}$
- Average speed $v_{avg} = \sqrt{\frac{8kT}{\pi m}}$
- Root-mean-square-speed $v_{rms} = \sqrt{\frac{3kT}{m}}$



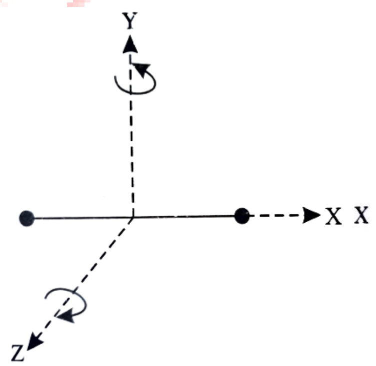
Distribution function at three different temperatures ($T_1 < T_2 < T_3$)

9. Degrees of Freedom

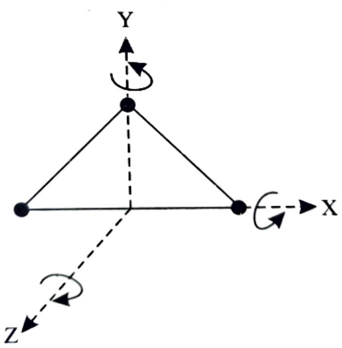
- The number of independent directions in which a particle can execute motion.
- For a molecule of a monoatomic gas; it contains only one atom which is a point mass. It can execute only translational motion and can move in any direction in the three dimensional space. Its motion can be resolved into three mutually perpendicular components along the X-, Y-and Z-axes in the Cartesian coordinate system. Thus, the particle may be regarded as executing motion in three independent directions. Therefore, it is said to possess 3-degrees of freedom **f=3**.



- The diatomic molecule (H_2, N_2, O_2) contains two atoms separated by a small distance. It is of the shape of a dumbell. Such a molecule, in addition to executing translatory motion in the 3-dimensional space can also execute rotatory motion about two axes perpendicular to the bond-length. Thus, a diatomic molecule possesses 5 degrees of freedom, 3 for translatory motion and 2 for rotatory motion **f=5**.



- The polyatomic molecule (O_3, H_2O, CH_4) in which all the atoms are not in the same line; such a molecule in addition to the translational motion in three dimensional space can also execute rotatory motion about three mutually perpendicular axes. Therefore, a polyatomic molecules possess six-degrees of freedom, 3 for the translatory motion and 3 for the rotational motion **f=6**.



- At high temperatures, the atoms of diatomic and polyatomic gas molecules vibrate with respect to each other and possess vibrational degrees of freedom also.

10. Law of Equipartition of Energy

- The total energy of a dynamical system consisting of a large number of particles is uniformly distributed over all the degrees of freedom of its particles.
- The average energy corresponding to each degree of freedom is kT/2.

11. Ratio of Specific heats

- For 1 mole of a perfect gas at absolute temperature T, if each molecule possess f degrees of freedom, the average total kinetic energy per molecule (Internal Energy) is **U = f RT/2**
- Molar specific heat at constant volume $\mathbf{C_v = dU/dT = f\ R/2}$
- As $C_p - C_v = R$ therefore Molar specific heat at constant pressure $\mathbf{C_p = [(f/2)+1]R}$
- $\mathbf{C_p / C_v = \gamma = 1 + (2/f)}$
- Monoatomic gas f=3, $\gamma = 5/3 = 1.67$
- Diatomic gas f=5, $\gamma = 7/5 = 1.40$
- Non-linear Triatomic or polyatomic gas f=6, $\gamma = 4/3 = 1.33$

Multiple Choice Questions and Answers

1. Which of the following statements is true according to the kinetic theory of gases?
a) Gas particles move in straight lines between collisions
b) Gas particles move in a predictable pattern
c) Gas particles occupy fixed positions
d) Gas particles have no kinetic energy
Ans. a) Gas particles move in straight lines between collisions

2. Which of the following is NOT an assumption of the kinetic theory of gases?
a) Gas particles are in constant random motion
b) Gas particles exert attractive forces on each other
c) Gas particles undergo elastic collisions
d) Gas particles occupy negligible volume

Ans. b) Gas particles exert attractive forces on each other

3. According to Kinetic theory, gas exerts pressure due to:
a) Total energy of the gas particles
b) Attraction between gas particles
c) Volume occupied by the gas particles
d) Change in momentum of gas particles on collisions with the container walls
Ans. d) change in momentum of gas particles on collisions with the container walls

4. The correct expression for pressure exerted by gas is (m is the mass of each molecule, n is the number of molecules in volume V and C is root mean square velocity):
a) $p = \frac{mnC^2}{3V}$
b) $p = \frac{2mnC^2}{3V}$
c) $p = \frac{2mnC^2}{V}$
d) $p = \frac{mnC^2}{V}$
Ans. a) $p = \frac{mnC^2}{3V}$

5. According to Kinetic theory of gases, relation between pressure p, density ρ and root mean square velocity C is:
a) $p = \frac{\rho C^2}{2}$
b) $p = \frac{\rho C^2}{3}$
c) $p = \frac{\rho C}{2}$
d) $p = \frac{\rho C}{3}$
Ans. b) $p = \frac{\rho C^2}{3}$

6. According to Kinetic theory of gases, root mean square velocity C is related to pressure p and density of the gas ρ as:
a) $C = \sqrt{\frac{3p}{\rho}}$
b) $C = \sqrt{\frac{2p}{\rho}}$
c) $C = \sqrt{\frac{p}{\rho}}$
d) $C = \sqrt{\frac{3\rho}{p}}$
Ans. a) $C = \sqrt{\frac{3p}{\rho}}$

7. The correct relation between pressure P and energy density u of an ideal gas is:

a) $p = \frac{u}{2}$
b) $p = \frac{2u}{3}$
c) $p = \frac{3u}{4}$
d) $p = u$
Ans. b) $p = \frac{2u}{3}$

8. Calculate the number of molecules in 1cc of oxygen at NTP given $\rho_{mercury}$ =13.6g/cm3, rms velocity of oxygen molecules at $0^oC=5x10^4$cm/s and mass of one molecule of oxygen is $50x10^{-24}$ g?
a) 1.22×10^{16}
b) 2.12×10^{18}
c) 2.43×10^{19}
d) 3.2×10^{20}
Ans. c) $2.43x10^{19}$
Hint: $n=3PV/mC^2$; P=76 x 13.6 x 980 dynes/cm^2; V=1cc

9. According to the kinetic theory of gases, the average kinetic energy of gas particles is directly proportional to:
a) Pressure
b) Volume
c) Temperature
d) Density
Answer: c) Temperature

10. The temperature of gas is held constant, while its volume is decreased. The pressure exerted by the gas on the wall of the container increases, because of its molecules:
a) Strike the walls with higher velocities
b) Strike the walls with large farce
c) Strike the walls more frequently
d) Are in contact with the walls for a shorter time
Ans. c) Strike the walls more frequently
Hint: When the volume is decreased, the gas molecules strike the walls more frequently.

11. Calculate the mean translational kinetic energy per molecule of a gas at 327^0C? given R=8.3 J/mole-K and Avogadro's number $N=6x10^{23}$
a) $1.24x10^{-20}$ Joule
b) $2.12x10^{-21}$ Joule
c) $2.44x10^{-22}$ Joule
d) $3.06x10\text{-}^{22}$ Joule
Ans. a) $1.24x10^{-20}$ Joule
Hint: Mean translational KE per molecule =3kT/2; $k=R/N=8.3/6x10^{23}$;T=327+273=600 K

12. According to law of equipartition of energy, the energy associated with each degree of freedom is:
a) (1/2) k_BT
b) k_BT
c) (3/2) k_BT
d) (5/2) k_BT
Ans. a) (1/2) k_BT

13. Equal volumes of two gases at the same temperature and pressure have the same:
a) No. of molecules
b) RMS velocity
c) No. of molecules with rms velocities
d) None of the above
Ans. a) No. of molecules

14. For a gas molecule with 6 degrees of freedom, the law of equipartition of energy gives the relation between molar specific heat C_v and gas constant R:
a) C_v =R/2
b) C_v =R
c) C_v =2R
d) C_v =3R
Ans. d) C_v =3R
Hint: γ=1+2/f=4/3, C_p-C_v=R and $C_p/C_v=\gamma$ therefore γC_v-C_v=R

15. A gas is formed of molecules, each molecule possess f degrees of freedom then C_p/C_v is:
a) 1- (2/f)
b) 1+ (2/f)
c) 1+ (f/2)
d) 1- (f/2)
Ans. b) 1+ (2/f)

16. Two gases A and B are kept at the same temperature, if the degree of freedom of the molecule of gas A is more than gas B, then which of the following is correct?
a) Energy of the molecule of gas A is more than gas B
b) Energy of the molecule of gas A is less than gas B
c) Energy of the molecule of gas A is equal to gas B
d) can't say
Ans. a) Energy of the molecule of gas A is more than gas B
Hint: Total energy=f x (1/2) k_BT; T constant then total energy α f

17. If the molecule of a monoatomic gas is free to move in a space, then its degree of freedom is:
a) 1
b) 2

c) 3
d) 4
Ans. c) 3

18. If the molecule of a gas can move in a free space and it can also rotate about two different axis, then the ratio of the energy of the molecule due to translational motion to the rotational motion is:
a) 1/2
b) 3/2
c) 1/3
d) 2/3
Ans. b) 3/2
Hint: E_{trans}=3 x (1/2) k_BT; E_{rot}=2 x (1/2) k_BT

19. According to the law of equipartition of energy, the energy of the molecule of a gas depends on the:
a) Degree of freedom
b) Degree of freedom and mass
c) Degree of freedom and temperature
d) Mass and temperature
Ans. c) Degree of freedom and temperature
Hint: Total energy = f x (1/2)k_BT

20. Which of the following experiment(s) verify the Maxwell's law of distribution of velocities?
a) Stern experiment
b) Zartman and Ko experiment
c) Estermann, Simpson and Stern experiment
d) All of the above
Ans. d) All of the above

21. According to Maxwell's law of distribution of molecular velocities, the no. of molecules having velocities between v and v+dv is:[a and b are some constants]
a) $dn_v=4\pi na^3\exp(-bv^2)vdv$
b) $dn_v=4\pi na^3\exp(-bv^2)v^2dv$
c) $dn_v=4\pi na^3v^2dv$
d))$dn_v=4\pi na^3\exp(-bv^2)dv$
Ans. b) $dn_v=4\pi na^3\exp(-bv^2)v^2dv$

22. According to Maxwell's distribution of velocities, the maximum probability that a molecule will have x-component of velocity in the range v_x to $v_x + dv_x$ is:
a) $(m/2\pi k_BT)^{1/2}$
b) $(m/2\pi k_BT)^{1/4}$
c) $m/2\pi k_BT$
d) $(m/2\pi k_BT)^2$

Ans. a) $(m/2\pi k_BT)^{1/2}$

Hint: According to Maxwell's distribution of velocities, the probability that a molecule will have x-component of velocity in the range v_x to $v_x + dv_x$ is $(m/2\pi k_BT)^{1/2} \exp[-(m v_x^2/2k_BT)] dv_x$ and maximum probability when $v_x = 0$

23. Which of the following statement is true about Maxwell's velocity distribution law:

a) The graph between Probability $P(v_x)$ and v_x is symmetrical about $v_x=0$

b) The maximum value of Probability is $(m/2\pi k_BT)^{1/2}$

c) Probability falls to (1/e) of its maximum value at $v_x=\sqrt{\frac{2kT}{m}}$

d) All of the above

Ans. d) All of the above

24. The no. of degrees of freedom for CO_2 (linear triatomic molecule) gas is:

a) 3

b) 4

c) 5

d) 6

Ans. c) 5

25. The no. of degrees of freedom for H_2S (non-linear triatomic molecule) gas is:

a) 3

b) 4

c) 5

d) 6

Ans. d) 6

26. At what temperature will O_2 molecules have the same root mean square velocity as that of H_2 at -100^0C ?

a) 1492^0C

b) 1798^0C

c) 2495^0C

d) 2865^0C

Ans. c) 2495^0C

Hint: $(1/2)mC^2=(3/2)k_BT$; $m_2/m_1=16:1$; $T_1=173$K; $C_1=C_2$; $T_2= (m_2 C_2^2 T_1)/ m_1 C_1^2$; C is rms velocity

27. γ for a gas is 5/3. The gas is:

a) Monoatomic

b) Diatomic

c) Linear triatomic

d) Non-linear triatomic

Ans. a) Monoatomic

28. The increase in internal energy of a gas per unit mass per unit rise in temperature is:
a) C_p
b) C_v
c) C_p+C_v
d) C_p-C_v
Ans. b) C_v

29. For hydrogen, c_p=3400cal/kg-K, c_v =2400cal/kg-K, R=8400 J/kmole-K. If the molecular weight of H_2 is 2, value of J is:
a) 4.1 J/cal
b) 4.18 J/cal
c) 4.2 J/cal
d) 4.3 J/cal
Ans. c) 4.2 J/cal

30. The difference between two principal specific heats of nitrogen is 300J/kg-K and ratio of the two specific heats is 1.4. c_p is:
a) 1050 J/kg-K
b) 750 J/kg-K
c) 650 J/kg-K
d) 150 J/kg-K
Ans. a) 1050 J/kg-K

31. The density of a gas is $6x10^{-2}$ kg/m^3 and rms velocity (C) of the gas molecule is 500m/s. The pressure exerted by the gas on the walls of the vessel is:
a) $5x10^3$ N/m^2
b) $0.83x10^{-4}$ N/m^2
c) $1.2x10^{-4}$ N/m^2
d) 30 N/m^2
Ans. a) $5x10^3$ N/m^2
Hint: $C = \sqrt{\frac{3p}{\rho}}$

32. If the pressure of the gas is doubled at constant volume and mass, the frequency of collision of the molecules with the walls of a container will:
a) Not change
b) Increase 4 times
c) Be doubled
d) Increase by $\sqrt{2}$ times
Ans. d) increase by $\sqrt{2}$ times
Hint: Collision frequency=v_{rms}/λ_{mean}; $v_{rms} \alpha \sqrt{P}$

33. 1 mole of a gas with $\gamma=7/5$ is mixed with 1 mole of a gas with $\gamma=5/3$, then the value of γ for the resulting mixture is:
a) 7/5
b) 2/5
c) 24/16
d) 12/7
Ans. c) 24/16
Hint: Gas A: $C_p = 7R/2$ $C_v = 5R/2$; Gas B: $C_p = 5R/2$ $C_v = 3R/2$; $C_p = \gamma R/\gamma-1$; $C_v = R/\gamma-1$
$C_{peff} = (C_{p1}+C_{p2})/2=12R/2$; $C_{veff} = (C_{v1}+C_{v2})/2=8R/2$; $\gamma_{new} = C_{peff}/C_{veff} = 24/16$

34. At what temperature is the rms velocity of a hydrogen molecule equal to that of an oxygen molecule at 47^0C?
a) 80K
b) -73K
c) 3K
d) 20K
Ans. d) 20K
Hint: $V_{rms}=\sqrt{\frac{3RT}{M}}$; $V_{rmsH2}=V_{rmsO2}$; $\sqrt{\frac{3RT}{2}} = \sqrt{\frac{3R(47+273)}{32}}$; T=2x320/32 K

35. One mole of ideal monoatomic gas ($\gamma=5/3$) is mixed with one mole of diatomic gas ($\gamma=7/5$). What is γ for the mixture? γ denotes the ratio of specific heat at constant pressure to that at constant volume.
a) 3/2
b) 23/15
c) 35/23
d) 4/3
Ans. a) 3/2
Hint: Monoatomic gas $C_v = 3R/2$, Diatomic gas $C_v = 5R/2$; $C_{vavg} = (3R/2+5R/2)/2=2R$; $C_{pavg} = C_{vavg} + R = 3R$;
$\gamma= C_{pavg} / C_{vavg} =3/2$

36. A gaseous mixture consists of 16g of He and 16g of O_2. The ratio C_p / C_v of the mixture is:
a) 1.4
b) 1.54
c) 1.59
d) 1.62
Ans. d) 1.62
Hint: $Cv = (n_1C_{v1}+n_2C_{v2})/(n_1+n_2)$
$=[(16/4)(R/\gamma_1-1)+(16/32)(R/\gamma_2-1)]/(16/4+16/32) =[4(3R/2)+(1/2)(5R/2)]/(4+1/2)=29R/18$
$C_v=29R/18=R/\gamma-1$ or $\gamma = (18/29)+1=1.62$ i.e. $C_p / C_v =1.62$

37. If c_p and c_v denotes the specific heats of nitrogen per unit mass at constant pressure and constant volume resp., then:
a) $c_p-c_v=28R$

b) $c_p-c_v=R/28$
c) $c_p-c_v=R/14$
d) $c_p-c_v=R$
Ans. b) $c_p-c_v=R/28$

38. One kg of a diatomic gas is at a pressure of 8 x10^4 N/m^2. The density of the gas is 4 kg/m^3. What is the energy of the gas due to its thermal motion?
a) 3 x10^4 J
b) 5 x10^4 J
c) 6 x10^4 J
d) 7 x10^4 J
Ans. b) 5 x10^4 J
Hint: For a diatomic molecular gas U/molecule= $5Nk_BT/2$; Also $PV=Nk_BT$. Therefore U=5PV/2; V=m/ρ

39. What will be the temperature when the root-mean-square velocity is double of that at 300 K?
a) 300 K
b) 600 K
c) 900 K
d) 1200 K
Ans. d) 1200 K
Hint: V_{rms} α $\sqrt{T}$

40. If Maxwell distribution is valid and V_p denotes the most probable speed, V the average speed and V_{rms} the root-mean-square speed, then:
a) $V < V_p < V_{rms}$
b) $V_p < V < V_{rms}$
c) $V < V_{rms} < V_p$
d) $V_p < V_{rms} < V$
Ans. b) $V_p < V < V_{rms}$

41. The root-mean-square (rms) speed of O_2 molecules at a certain absolute temperature is V. If the temperature is doubled and the O_2 gas dissociates into atomic oxygen, the rms speed would be:
a) V
b) $\sqrt{2}$ V
c) 2V
d) $2\sqrt{2}$ V
Ans. c) 2V

Hint: root-mean-square speed V α $\sqrt{\frac{T}{M}}$; M_{new} = M/2

42. The first excited state of hydrogen atom is 10.2 eV above its ground state. The temperature needed to excite hydrogen atoms to the first excited level is:
a) 6.22×10^4 K
b) 7.88×10^4 K
c) 9.04×10^4 K
d) 10^5 K
Ans. b) 7.88×10^4 K
Hint: Kinetic interpretation of temperature: $mv^2/2 = 10.2 \times 1.6 \times 10^{-19} = 3k_BT/2$

43. The temperature at which the root-mean-square speed of a gas will be half its value at 0 ^{0}C is (assume the pressure remains constant):
a) -86.4 ^{0}C
b) -68.4 ^{0}C
c) -104.75 ^{0}C
d) -204.75 ^{0}C
Ans. d) -204.75 ^{0}C
Hint: $V_{rms1}/(V_{rms1}/2) = \sqrt{\frac{273}{T_2}}$

44.The most probable speed of a gas molecule whose root-mean-square speed is 4.6×10^2 m/sec is:
a) 2.27×10^2 m/sec
b) 3.77×10^2 m/sec
c) 4.27×10^2 m/sec
d) 5.77×10^2 m/sec
Ans. b) 3.77×10^2 m/sec
Hint: $V_{mp} = \sqrt{\frac{2}{3}}\, v_{rms}$

45. The average kinetic energy of a gas molecule at 27^{0}C is 5.4×10^{-21} J. Its average kinetic energy at 227^{0}C is:
a) 7×10^{-21} J
b) 8×10^{-21} J
c) 9×10^{-21} J
d) 10^{-20} J
Ans. c) 9×10^{-21} J
Hint: Average kinetic energy = $(3/2)k_BT$

46. When an ideal diatomic gas is heated at constant pressure, the fraction of the heat energy supplied which increases the internal energy of the gas is:
a) 2/5
b) 3/5
c) 3/7
d) 5/7

Ans. d) 5/7

Hint: $f=\Delta U/\Delta Q=nC_v\Delta T$ / $nC_p\Delta T= C_v/ C_p=1/\gamma=5/7$

47. At room temperature ($T=27^0C$), the root-mean-square speed of the molecules of a certain diatomic gas is 1930 m/sec. The gas is:

a) H_2

b) F_2

c) O_2

d) Cl_2

Ans. a) H_2

Hint: $V_{rms}=\sqrt{\frac{3RT}{M}}$; T=300K; R=8.31 J/K-mol calculation gives M=2g

48. The temperature of an ideal gas is increase from 120 K to 480 K. If at 120 K root-mean-square velocity of the gas molecules is v, at 480 K it becomes:

a) v/2

b) v/4

c) 2v

d) 4v

Ans. c) 2v

Hint: V_{rms} α $\sqrt{T}$

49. The average translational kinetic energy of O_2 (molar mass 32) molecules at a particular temperature is 0.052 eV. The translational kinetic energy of N_2 (molar mass 28) molecules in eV at the same temperature is:

a) 0.0022

b) 0.003

c) 0.048 eV

d) 0.052 eV

Ans. d) 0.052 eV

Hint: average translational kinetic energy α T and T is same for both oxygen and nitrogen

50. One mole of a monoatomic gas is heated at a constant pressure of 1 atmosphere from 0 K to 100 K. If the gas constant R=8.31 J/K-mol, the change in internal energy of the gas is approx.:

a) 2.2 J

b) 34 J

c) 3.4×10^2 J

d) 12.5×10^2 J

Ans. d) 12.5×10^2 J

Hint: ΔU is always equal to the heat supplied at constant volume = $(\Delta Q)_v = nC_v\Delta T=1 \times (3R/2) \times (100-0)$

Unit - IV

Unit IV

(Theory of Radiation)

Summary

1. Thermal Radiation

- Maxwell defined radiation as the transfer of heat from a hot body to a cooler body without appreciable heating of the intervening medium or space.
- The propagation of heat by radiation consists merely in transference of energy which can take place even in empty space.
- Thermal radiations have the same nature as that of light with only difference that average wavelength of thermal radiation is greater than that of visible light. Therefore, **thermal radiation is called the infra-red radiation.**
- These radiations cannot be detected by naked eye or the photographic plate but can be detected by **bolometer or thermopile**.

2. Terms frequently used in Radiation

- **Total Energy Density (u):** At any point, it is the total radiant energy per unit volume around that point for all the wavelengths taken together.
- **Spectral Energy Density (u_λ):** For a particular wavelength, it is the energy per unit volume per unit wavelength range.
- **Total Emissive Power (E):** Radiant energy emitted per unit time per unit surface area of body for all the wavelengths taken together.
- **Spectral Emissive Power (E_λ):** For a particular wavelength, it is the radiant energy emitted per unit time per unit surface area of body within a unit wavelength range.
- **Absorptive Power (a_λ):** At a particular temperature and for a particular wavelength, it is the ratio of the radiant energy absorbed per unit surface area per unit time to the total energy incident on the same area of the body in unit time within a unit wavelength range.
- **Relative Emittance or Emissivity (ε):** It is the ratio of emittance of a surface to the emittance of a black body.
  $0 < \varepsilon < 1$
  For a perfectly black body $\varepsilon = 1$

3. Radiation in an Isothermal Enclosure

The energy density of radiation in a uniform temperature enclosure depends on its temperature and is entirely independent of the nature of its walls or on the bodies present inside it.

4. Black-Body Radiation

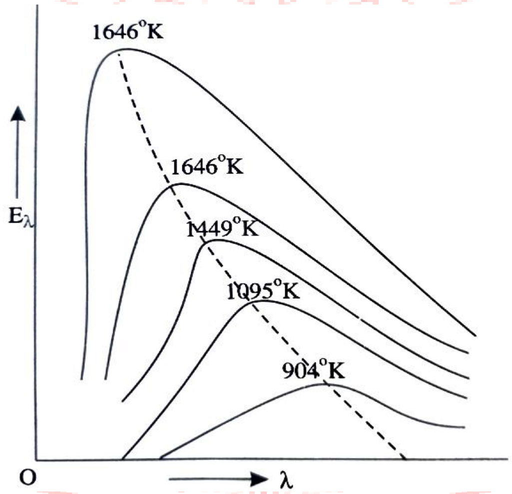
- A perfectly black body is one which absorbs all the heat radiations of whatever wavelengths incident on it.
- Heat radiations in an isothermal enclosure is black body radiation

- In practice, no substance is a perfect black body. Lamp-black, Platinum black are very near to be considered as a black body.
- Some constructed bodies showing close approximation to a perfectly black body are Ferry's black body and Wien's black body.

5. Pressure of Radiation (P)

- Radiation possess properties of light; it exerts a small but definite pressure on the surface on which it is incident.
- Expression for pressure of radiation could be obtained on the basis of Quantum theory.
- **P = E/c ;** E is the total energy incident on the surface per unt area per second and c is velocity of light.
- In terms of energy density u, **for normal incidence on a surface P = u**
- **For diffuse radiation P = u/3** (assuming all the radiations incident on the surface are absorbed)
- **The pressure exerted by diffuse radiations P on the perfectly reflecting surface P =2u/3**

6. Spectral Distribution of Black Body Radiation



- Lummer and Pringsheim investigated the distribution of energy among the radiations emitted by a black body at different temperatures.
- The curves are drawn for various temperatures between intensity and wavelength.
- The curves show:
  - Energy is not uniformly distributed in the spectrum of a black body
  - At a given temperature, intensity of radiation increases with wavelength and becomes maximum at a particular wavelength. On increasing wavelength further, intensity decreases.
  - An increase in temperature causes an increase in energy emission for all wavelengths.
  - An increase in temperature causes a decrease in λ_m where λ_m is the wavelength at which energy emitted is maximum.

$\lambda_m \alpha 1/T$ or $\lambda_m T$ = constant which is Wien's Displacement Law

- The area under each curve represents the total energy emitted by the body at a particular temperature for the range of wavelengths considered. This area increases with increase in temperature and directly proportional to T^4 which is Stefan's Law.

7. Stefan's Law

- Rate of emission of radiant energy by unit area of perfectly black body is directly proportional to the fourth power of its absolute temperature
  $E = \sigma T^4$; Stefan's constant $\sigma = 2\pi^5 k^4/15c^2h^3 = 5.67 \times 10^{-8}$ W/m²-K⁴
- This law refers to the emission only and not to the net loss of heat by body after exchange with the surroundings.

8. Stefan- Boltzmann Law

- A black body at absolute temperature T surrounded by another black body at absolute temperature T_0 , not only loses an amount of enery σT^4 but also gains σT_0^4 therefore amount of heat loss by the former per unit time is **$E = \sigma(T^4 - T_0^4)$**
- Power radiated from a surface at temperature T and surrounding temperature T_0^4 , having emissivity ε is **$P = \varepsilon \sigma A(T^4 - T_0^4)$**

9. Wien's Displacement Law

- The product of the wavelength corresponding to maximum energy λ_m and the absolute temperature T is constant; **$\lambda_m T$ = constant=b**
- Constant b is Wien's displacement constant = hc/4.965k = 0.2896×10^{-2} m- K
- $\lambda_m \alpha 1/T$

10. Wien's Distribution Law

- The energy-wavelength curves obtained by Lummer and Pringsheim shows that energy is not uniformly distributed in the radiation spectrum of a black body.
- The amount of energy contained in the spectral region from wavelength λ to λ + dλ emitted by a black body at temperature T is
  $E_\lambda d\lambda = A f(\lambda T) d\lambda / \lambda^5$
  or
  $E_\lambda d\lambda = A T^5 F(\lambda T) d\lambda$ where $F(\lambda T) = (\lambda T)^{-5} f(\lambda T)$
- Wien's distribution law of radiation is applicable to shorter wavelengths at lower temperatures.

11. Planck's Radiation Law

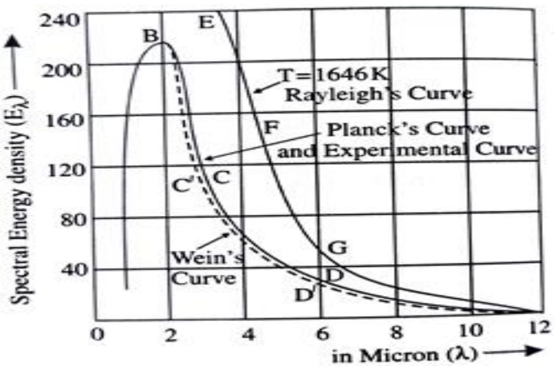
- Planck found an empirical formula to explain the experimentally observed distribution of energy in the spectrum of a black-body.
- Postulates:
  - 1. A black body radiation chamber is filled up not only with radiation, but also with simple harmonic oscillators or resonators of the molecular dimensions; which cannot have any value of energy but only energies given by E=nhν; ν is the frequency of the oscillator, h is the Planck's constant and n is a number that can take only integral values, i.e. n=0,1,2,3......
  - 2. The oscillators cannot radiate or absorb energy continuously; but an oscillator of frequency ν can only radiate or absorb energy in units or quanta of magnitude hν. The exchange of energy between radiation and matter cannot take place continuously; but is limited to discrete set of values 0, hν, 2hν…. i.e., in multiples of some small unit, called quantum.

The average energy of a Planck's oscillator $\bar{E} = h\nu / (e^{h\nu/kT} - 1)$

- Average energy of classical oscillator in thermal equilibrium at absolute temperature T is kT.
- For black body radiation, the number of modes of vibration per unit volume within frequency range ν and ν+dν is $8\pi\nu^2 d\nu / c^3$ or the number of modes of vibration per unit volume within wavelength range λ and λ +d λ is $8\pi\, d\lambda / \lambda^4$
- Each resonator entails one degree of freedom only so the number of resonators per unit volume in the frequency range ν and ν+dν = $8\pi\nu^2 d\nu / c^3$
- Energy density belonging to range dν:
  $E_\nu d\nu = 8\pi h\nu^3 d\nu / c^3 (e^{h\nu/kT} - 1)$ **Planck's Radiation Formula**
- Energy density belonging to range dλ
  $E_\lambda d\lambda = 8\pi hc\, d\lambda / \lambda^5 (e^{hc/\lambda kT} - 1)$ **Planck's Radiation Formula**

12. Rayleigh-Jean's Law

- Rayleigh and Jeans assumed that the law of equipartition of energy is applicable to radiation also i.e $\bar{E}$ =kT.
- Energy density belonging to range dν:
  $E_\nu d\nu = 8\pi\nu^2 d\nu\, kT/c^3$
- Energy density belonging to range dλ
  $E_\lambda d\lambda = 8\pi kT\, d\lambda / \lambda^4$
- Rayleigh-Jeans law of radiation applicable to longer wavelengths at higher temperatures.



Multiple Choice Questions and Answers

1. What is the fastest mode of heat transfer?
a) Conduction
b) Convection
c) Radiation
d) Both conduction and convection
Ans. c) Radiation

2. Thermal radiations are:
a) Infra-red radiations
b) Ultra-violet radiations
c) Visible radiations
d) Microwave radiations
Ans. a) Infra-red radiations

3. The rate of energy emission from unit surface area through unit solid angle, along a normal to the surface is known as:
a) Emissivity
b) Transmissivity
c) Reflectivity
d) Intensity of Radiation
Ans. d) Intensity of Radiation

4. A black body can absorb radiations of:
a) Higher wavelength only
b) Lower wavelength only
c) Intermediate wavelengths only
d) All wavelengths
Ans. d) All wavelengths

5. For a perfectly black body, the absorptive power is:
a) 1
b) 0.5
c) 0
d) ∞
Ans. a) 1

6. For an object other than a black body, it's emissivity ε is:
a) 1
b) Between 0 and 1
c) Greater than 1
d) 0
Ans. b) Between 0 and 1

7. An ideal black body is represented by:
a) A metal coated with a black dye
b) A glass surface coated with coal tar
c) A hollow enclosure blackened from inside and having a small hole
d) A lump of charcoal heated to a high temperature
Ans. c) A hollow enclosure blackened from inside and having a small hole

8. The temperature of a black body is gradually increased. The colour of the body will change from
a) White-green-red
b) Red-yellow-blue
c) Red-violet-yellow
d) Yellow-green-red
Ans. b) Red-yellow-blue

9. The black body emits:
a) A continuous spectrum
b) A band spectrum
c) A line spectrum
d) Line and band spectrum
Ans. a) A continuous spectrum

10. The emissive powers of a gold foil and the black body are 3.5 and 4.5 watts per square meter at 67^0C and 908 nm. The emissivity of the gold foil is:
a) 1
b) 0.67
c) 0.77
d) 0.87
Ans. c) 0.77

11. The relation between emissive power E of a black body and energy density u is:
a) E = u
b) E = uc
c) E = uc/4
d) E = u/c
Ans. b) E = uc

12. Pressure of radiation P is related to the total energy incident on the surface per unit area per second E as: [c is the velocity of light]
a) P = E/c
b) $P = E/c^2$
c) P = Ec
d) $P = Ec^2$

Ans. a) P = E/c

13. For normal incidence on a surface, the correct relation between pressure of radiation P and energy density u is:
a) P = uc
b) P = u/c
c) P = u
d) $P = uc^2$
Ans. c) P = u

14. The pressure exerted by diffuse radiations P on the perfectly reflecting surface is related to energy density u as:
a) P = 2u/3
b) P = u/3
c) P = u/2
d) P = u
Ans. a) P = 2u/3

15. The pressure exerted by diffuse radiations P on a surface is related to energy density u as:[assuming that all the radiations incident on the surface are absorbed]
a) P = 2u/3
b) P = u/3
c) P = u/2
d) P = u
Ans. b) P = u/3

16. The energy received from sun at earth's surface per unit area per second is 10^{-1} J/cm^2-s. The total force due to solar radiation on the earth (assumed perfectly absorbing) is: [earth's diameter = 10^{-7} m]
a) 10^9 N
b) 10^{10} N
c) 10^{11} N
d) 10^{12} N
Ans. a) 10^9 N
Hint: E = 10^{-1} J/cm^2-s = 10^3 J/m^2-s; Radiation pressure P = E/c; F = P x $4\pi r^2$

17. The amount of solar radiation energy on unit area of the surface of the earth in unit time is called:
a) Stefan's constant
b) Boltzmann constant
c) Solar constant
d) Radiation constant
Ans. c) Solar constant

18. Which of the following is not the characteristics of Planck's black body radiation distribution:
a) Spectral emissive power varies continuously with the change in wavelength
b) As temperature increases, the peak of the curve shift towards higher wavelength
c) At a given wavelength, as temperature increases, emissive power also increases
d) The energy is not uniformly distributed in the radiation spectrum
Ans. b) As temperature increases, the peak of the curve shift towards higher wavelength

19. The area under each curve of E_λ-λ graph showing the distribution of energy among the radiation emitted by a black body at different temperatures T is directly proportional to:
a) T
b) T^2
c) T^3
d) T^4
Ans. d) T^4
Hint: Stefan's Law

20. Wien's displacement law is: [λ_m wavelength corresponds to maximum emission in E_λ-λ curve]
a) λ_m/T = constant
b) λ_m/T^2 = constant
c) $\lambda_m T$ = constant
d) $\lambda_m T^2$ = constant
Ans. c) $\lambda_m T$ = constant

21. The value of constant in Wien's displacement law is:
a) 1.3×10^{-2} m-K
b) 2.9×10^{-2} m-K
c) 1.3×10^{-3} m-K
d) 2.9×10^{-3} m-K
Ans. d) 2.9×10^{-3} m-K

22. In terms of universal constants, the value of constant in Wien's displacement law is: [k is Boltzmann constant, c is velocity of light and h is Planck's constant]
a) hc/k
b) hc/4.965k
c) h/4.965k
d) hk/4.965c
Ans. b) hc/4.965k

23. If wavelength of maximum intensity of radiation emitted by sun and moon are 0.5×10^{-6} m and 10^{-4} m resp. the ratio of their temperature is:
a) 2000
b) 1000

c) 100
d) 200
Ans. d) 200
Hint: Wien's Displacement Law $\lambda_m T$ = constant

24. A black body radiates power P and maximum energy is radiated by it around a wavelength λ_0. The temperature of the black body is now changed such that it radiates maximum energy around the wavelength 3 $\lambda_0/4$. The power radiated by it now is:
a) 256P/18
b) 27P/64
c) 64P/27
d) 81P/256
Ans. a) 256P/18
Hint: Wien's Displacement law $\lambda_0 T_0 = \lambda T$; Stefan's law $P/P' = (T_0/T)^4$ hence $\lambda/\lambda_0 = (P/P')^{1/4}$ or $P' = (\lambda_0/\lambda)^4 P$

25. The power radiated by a black body is P_0 and the wavelength corresponding to maximum energy is λ_0. On changing the temperature of black body, power radiated becomes $256P_0/81$. The shift in wavelength corresponding to the maximum energy will be:
a) $\lambda_0/4$
b) $\lambda_0/2$
c) λ_0
d) $2\lambda_0$
Ans. a) $\lambda_0/4$
Hint: Wien's Displacement law $\lambda_0 T_0 = \lambda T$; Stefan's law $P_0/P = (T_0/T)^4$; it implies that $\lambda/\lambda_0 = (81/256)^{1/4} = 3/4$
Shift in wavelength $|\Delta\lambda| = |\lambda - \lambda_0| = |3\lambda_0/4 - \lambda_0|$

26. The maximum wavelength of radiations emitted at 900K is 4μm. What will be the maximum wavelength of radiations emitted at 1200K?
a) 0.3μm
b) 1μm
c) 3μm
d) 3.7μm
Ans. a) 0.3μm
Hint: Wien's Displacement Law $\lambda_m T$ = constant

27. If a black body at a temperature 7000 K emits 4800 Å with maximum energy, the temperature at which it will emit a wavelength of 1.4 x 10^{-5} m with maximum energy is:
a) 140 K
b) 240 K
c) 340 K
d) 440 K
Ans. b) 240 K

Hint: Wien's Displacement Law $\lambda_m T$ = constant

28. The maximum energy in thermal radiations from a black body occurs at wavelength 4000Å.The effective temperature of the source is:
a) 7240K
b) 80000K
c) 10^4K
d) 10^6K
Ans. a) 7240K

29. The intensity of radiation emitted by the Sun has its maximum value at a wavelength 510 nm and that emitted by the North Star has the maximum value at 350 nm. If these stars behave like black bodies, then the ratio of the surface temperature of the Sun and North Star is:
a) 1.46
b) 0.69
c) 1.21
d) 0.83
Ans. b) 0.69

30. A blackbody is at a temperature of 2880 K. The energy of radiation emitted by this object with wavelength between 499 nm and 500 nm is U_1, between 999 nm and 1000 nm is U_2 and between 1499 nm and 1500 nm is U_3.The Wien constant b=2.88x10^6 nm-K. Then:
a) U_1=0
b) U_3=0
c) U_1>U_2
d) U_2>U_1
Ans. d) U_2>U_1
Hint: $\lambda_m T$ = 2.9 x 10^{-3} m-K = 2.9 x 10^6 nm-K; λ_m ~ 1000 nm; given energy of radiation emitted by this object with wavelength between 999 nm and 1000 nm is U_2

31. The amount of heat lost by a black body at absolute temperature T surrounded by another black body at absolute temperature T_0 is
a) $E = \sigma (T - T_0)$
b) $E = \sigma (T + T_0)$
c) $E = \sigma (T^4 - T_0^4)$
d) $E = \sigma (T^4 + T_0^4)$
Ans. c) $E = \sigma (T^4 - T_0^4)$
Hint: Stefan-Boltzmann Law

32. The value of σ in Stefan's law $E = \sigma T^4$ is:
a) 5.67 x 10^{-7} W/m^2-K^4
b) 5.67 x 10^{-8} W/m^2-K^4
c) 5.67 x 10^{-7} W/m-K^4
d) 5.67 x 10^{-8} W/m^2-K

Ans. b) 5.67 x 10^{-8} W/m^2-K^4

33. The formula used to calculate the value of Stefan's constant is:[k is Boltzmann constant, c is velocity of light and h is Planck's constant]
a) $2\pi k^4/15c^2h^3$
b) $2\pi^5k^5/15c^2h^3$
c) $2\pi^5k^4/15c^2h^3$
d) $2\pi^4k^5/15c^3h^2$
Ans. c) $2\pi^5k^4/15c^2h^3$

34. If a blackbody radiates 10 cal/s at 227ºC, it will radiate at 727 ºC:
a) 10 cal/s
b) 80 cal/s
c) 160 cal/s
d) 320 cal/s
Ans. c) 160 cal/s
Hint: $E = \sigma T^4$

35. The temperature of body is increased from 27 ºC to 127 ºC .The radiation emitted by it increases by a factor of:
a) 3.16
b) 1.67
c) 0.8
d) 0.44
Ans. a) 3.16
Hint: $E = \sigma T^4$

36. A sphere has a surface area of 1.0m^2 and a temperature of 400K and the power radiated from it is 150W. Assuming the sphere is blackbody radiator the power in kW radiated when the area expands to 2.0m^2 and the temperature changes to 800K is:
a) 6.2
b) 9.6
c) 4.8
d) 16
Ans. c) 4.8
Hint: Stefan's law $E = \sigma T^4$ where E is the rate of emission of radiant energy per unit area or E = P/A where P is the power radiated; therefore $P = \sigma AT^4$ for a perfectly black body; $P_2/P_1 = (A_2/A_1)(T_2/T_1)^4$

37. The area of hole of a heat furnace is $10^{-4}m^2$. It radiates 1.58 x10^5 calorie of heat per hour. If the emissivity of the furnace is 0.80, then it's temperature is: [use $(40)^{1/4} = 2.5$]
a) 1500K
b) 2000K
c) 2500K

d) 3000K
Ans. c) 2500K
Hint: Stefan's law Power radiated from a surface having emissivity ε is $P = \varepsilon\sigma AT^4$

38. If the total surface area of human body is $1.2m^2$ and the temperature is 30 ºC, then the net rate of radiation from the body if surrounding temperature is 20 ºC would be: [Take emissivity of human body =1 and use $(303)^4 – (293)^4 = 1.05$]
a) 574W
b) 72W
c) 800W
d) 60W
Ans. b) 72W
Hint: Stefan Boltzmann law: Power radiated from a surface at temperature T and surrounding temperature T_0^4, having emissivity ε is $P = \varepsilon\sigma A(T^4 - T_0^4)$

39. A spherical blackbody with a radius of 12 cm radiates 450W power at 500K. If the radius halved and the temperature is doubled, the power radiated in W would be:
a) 225
b) 450
c) 900
d) 1800
Ans. d) 1800
Hint: $P = \varepsilon\sigma A(T^4 - T_0^4)$; $P_1/P_2 = (r_1^2 \times T_1^4) / (r_2^2 \times T_2^4)$

40. The energy radiated per minute from the filament of an incandescent lamp at 2000 K if the surface area is 5×10^{-5} m^2 and its relative emittance is 0.85:
a) 152 J
b) 1087 J
c) 2315 J
d) 3015 J
Ans. c) 2315 J
Hint: Stefan's law: Energy radiated per second i.e. power from a surface having emissivity ε is $P = \varepsilon\sigma AT^4$; in t seconds Energy radiated = $\varepsilon\sigma AT^4 \times t$; t = 60 sec

41. The absolute temperature of a perfectly black body is increased to twice its value. The rate of emission of energy per unit area will be:
a) 2 times
b) 4 times
c) 8 times
d) 16 times
Ans. d) 16 times
Hint: Stefan's law $E = \varepsilon\sigma T^4$ where E is the rate of emission of radiant energy per unit area; ε=1 for a perfectly black body.

42. An electric flat-plate square heater of sides 10 cm provides 100W power from each side. If the heater is assumed to be black, its temperature is approximately:
a) 648^0C
b) 648 K
c) 6480^0C
d) 6480 K
Ans. b) 648 K
Hint: $P = \varepsilon\sigma AT^4$

43. For black body radiation, the number of modes of vibration per unit volume within frequency range ν and ν+dν is:
a) $4\pi\nu^2 d\nu / c^3$
b) $8\pi\nu^2 d\nu / c^3$
c) $4\pi\nu d\nu / c^3$
d) $4\pi c^2\nu^2 d\nu$
Ans. b) $8\pi\nu^2 d\nu / c^3$

44. The number of modes of vibration in a black body chamber of volume 50 cc in the frequency range 4×10^{14} and 4.01×10^{14} sec^{-1} is:
a) 6.5×10^{10}
b) 6.5×10^{11}
c) 7.5×10^{12}
d) 7.5×10^{13}
Ans. c) 7.5×10^{12}
Hint: For black body radiation, the number of modes of vibration per unit volume within frequency range ν and ν+dν is $8\pi\nu^2 d\nu / c^3$

45. A black body has its cavity in the shape of a cube. The number of modes of vibration per unit volume in the wavelength region 4990Å to 5010Å is:
a) 7×10^{11}
b) 8×10^{11}
c) 7×10^{12}
d) 8×10^{12}
Ans. b) 8×10^{11}
Hint: For black body radiation, the number of modes of vibration per unit volume within frequency range ν and ν+dν is $8\pi\nu^2 d\nu / c^3 = 8\pi d\lambda / \lambda^4$

46. Planck's Radiation law is: [E_λ is energy density belonging to the range dλ; k is Boltzmann constant]
a) $E_\lambda\, d\lambda = (8\pi hc\, d\lambda) / [\lambda^5(e^{hc/\lambda kT} - 1)]$
b) $E_\lambda\, d\lambda = (8\pi hc\, d\lambda) / [\lambda^4(e^{hc/\lambda kT} - 1)]$
c) $E_\lambda\, d\lambda = (8\pi hc\, d\lambda) / [\lambda^5 e^{hc/\lambda kT}]$
d) $E_\lambda\, d\lambda = (8\pi hc\, d\lambda) / [\lambda^4 e^{hc/\lambda kT}]$
Ans. a) $E_\lambda\, d\lambda = (8\pi hc\, d\lambda) / [\lambda^5(e^{hc/\lambda kT} - 1)]$

47. The Rayleigh-Jeans law of radiation is expressed as:
a) $E_\lambda\, d\lambda = 8\pi kT\, d\lambda / \lambda^4$
b) $E_\lambda\, d\lambda = 8\pi kT\, d\lambda / \lambda^3$
c) $E_\lambda\, d\lambda = 8\pi kT\, d\lambda / \lambda^2$
d) $E_\lambda\, d\lambda = 8\pi kT\, d\lambda$
Ans. a) $E_\lambda\, d\lambda = 8\pi kT\, d\lambda / \lambda^4$

48. Rayleigh-Jeans law of radiation:
a) Applies to shorter wavelengths at lower temperatures
b) Applies to longer wavelengths at higher temperatures
c) Applies to all wavelengths
d) Does not apply to any wavelength
Ans. b) Applies to longer wavelengths at higher temperatures

49. Wien's distribution law of radiation:
a) Applies to shorter wavelengths at lower temperatures
b) Applies to longer wavelengths at higher temperatures
c) Applies to all wavelengths
d) Does not apply to any wavelength
Ans. a) Applies to shorter wavelengths at lower temperatures

50. The Wien's distribution law of radiation is expressed as:
a) $E_\lambda\, d\lambda = (8\pi hc\, d\lambda) / [\lambda^5(e^{hc/\lambda kT} - 1)]$
b) $E_\lambda\, d\lambda = (8\pi hc\, e^{hc/\lambda kT}\, d\lambda) / \lambda^5$
c) $E_\lambda\, d\lambda = (8\pi hc\, e^{-hc/\lambda kT}\, d\lambda) / \lambda^5$
d) $E_\lambda\, d\lambda = 8\pi hc\, e^{-hc/\lambda kT}\, d\lambda$
Ans. c) $E_\lambda\, d\lambda = (8\pi hc\, e^{-hc/\lambda kT}\, d\lambda) / \lambda^5$

Unit - V

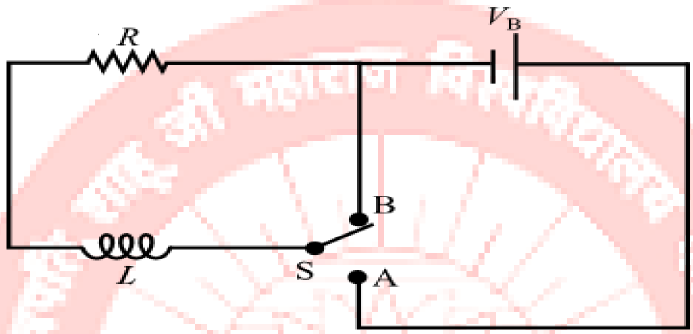
Unit V
DC & AC Circuits

Summary

LR Circuit: a serial arrangement of an inductor and a resistor. This circuit is connected with a voltage source, i.e., a battery E and a switch. Here, the wire of the coil of an inductor has a DC resistance, i.e., R

During the storage or decay the circuit is said to be in a transient state

When the capacitor or inductor has stored energy to its full value, the circuit voltage and current do not change with time, then the circuit is said to be in steady state.

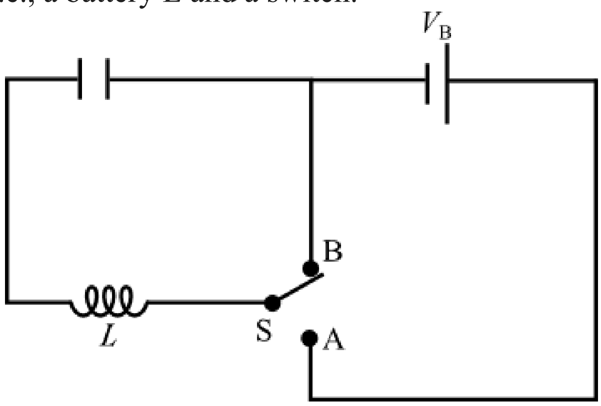


- the voltage across a resistor V_R = IR
- the voltage across an inductor $V_L = L\frac{di}{dt}$
- the voltage across the battery V_B = E
- the growth of current in L-R circuit is given by the following equation

  $$I = I_0\left[1 - e^{-\left(\frac{R}{L}\right)t}\right] \qquad I = I_0(0.632) = 63\%$$

- the rate of growth of current is given by $\frac{dI}{dt} = \frac{R}{L}(I_0 - I)$
- the decay of current is given by $I = I_0\, e^{-\left(\frac{R}{L}\right)t}$=$0.368I_0$=37%
- the rate of decay of current is given by $\frac{dI}{dt}$ = -$\left(\frac{R}{L}\right) I$
- the $\frac{L}{R}$ is known as time constant of LR circuit

CR Circuit: : a serial arrangement of a capacitor C and a resistor R. This circuit is connected with a voltage source, i.e., a battery E and a switch.



- the voltage across a resistor V_R = IR
- the voltage across an inductor $V_C = \frac{q}{c}$
- the voltage across the battery V_B = E
- The growth of charge in CR circuit is given by the following equation

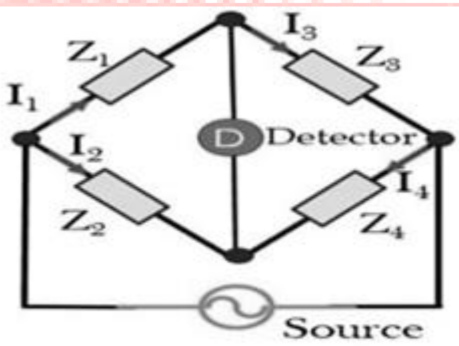
$$q = q_0 \left[1 - e^{-\frac{t}{CR}}\right]$$

$$q = q_0(0.632) = 63\%$$

- the rate of growth of charge is given by $\frac{dq}{dt} = \frac{1}{CR}(q_0 - q)$
- the decay of charge is given by $q = q_0\, e^{-\frac{t}{CR}} = 0.368 q_0 = 37\%$
- the rate of decay of charge is given by $\frac{dq}{dt} = -\frac{q}{CR}$
- the CR is known as time constant of CR circuit

LCR Circuit: An electronic LCR circuit contains a resistor of R ohms, a capacitor of C farad, and an inductor of L Henry, all connected in a series combination with each other. Since all the three elements of the LCR circuit are connected in series, the current passing through each of them is the same and is equivalent to the total current I passing through the circuit.

Balance condition of A.C. bridge: the principle of direct current Wheatstone bridge can also be applied to A.C network with the modification that here complex impedance and current are used instead of resistance. The null point determines with the help of an A.C. detector. at the balance point B and D are at the same potential and detector d, which is, in general a heat phone, gives a minimum sound. the balance condition for bridge is given by



Maxwells bridge: The maxwell LC bridge for measuring self-inductance in term of capacitance and resistance. $L = C_1R_2R_3$

Owen's bridge: it is sensitive bridge for the measurement of self- inductance in term of resistance and a fixed standard capacitance. $L = C_2R_1R_4$

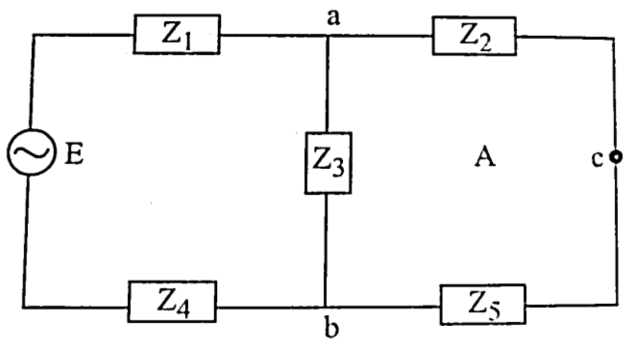
Wein's bridge: this bridge is a convenient method of measurement of capacitance as well as the power factor of the capacitance.

$$C = C_3\frac{R_4}{R_2} \text{ and Power factor } \cos\phi = \frac{R}{Z}$$

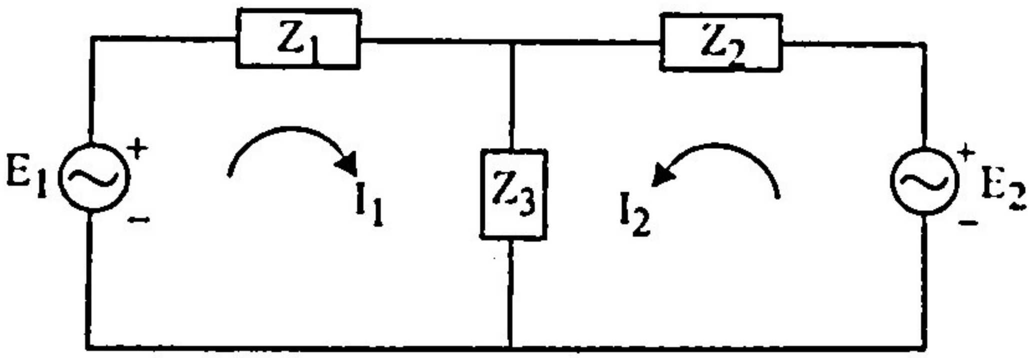
Schering bridge: Schering bridge the most accurate bridge for determining capacitance of a standard capacitor .it is particularly used for the of measurement of small capacitance.

Network theorem:

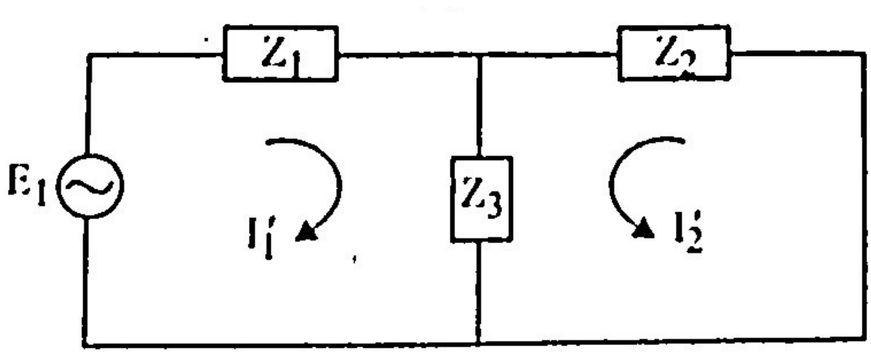
1. An electrical circuit containing element like resistance, inductance, capacitance and generator's is known as electric network.
   hus an electrical network is nothing but combination of circuit element and generators.
2. A network is said to be linear when the current in all branches is directly proportional to the driving circuit.
3. If relation between voltage and current in any branch of network is non-linear, the network is said to be non-linear.
4. If the network contains energy source as well as other circuit elements, it is called active network while a network containing circuit element without any energy source is known as passive network.
5. If the inductors, resisters and capacitors are electrically separated in a network, it is called a distributed network. In a lumped network on the other hand, physically separated inductors, resistors and capacitors are separated.



Superposition theorem: In a network containing linear impedance and energy source the current flowing at any point is the vector sum of the current which would exist. if each source of e.m.f. were consider separately, all the other sources being replaced at that time by their internal impedance.



(a)

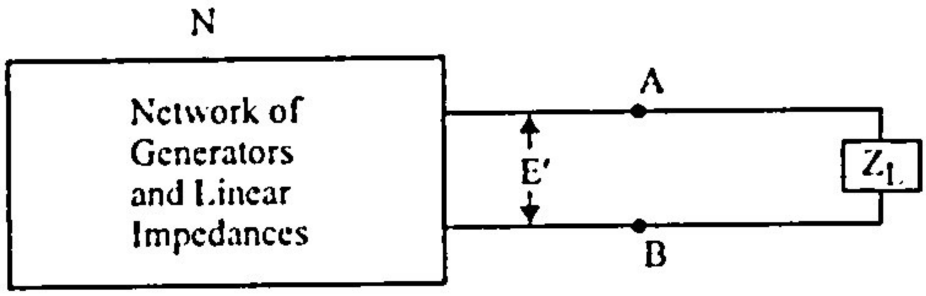


(b)

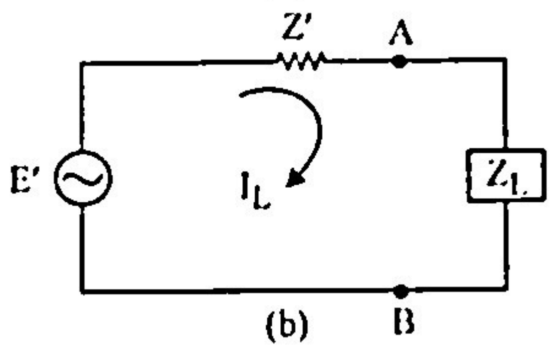
Therfore, $I_1 = I_1' + I_1''$,

$I_2 = I_2' + I_2''$

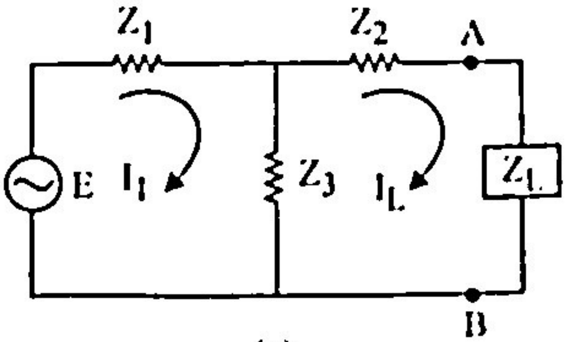
Thevenin's theorem: the current in load resistant connected to two terminals A and B of a network or generators and linear impedance is the same if this impedance were connected to single voltage generator whose e.m.f. is the open circuit (where there is no load) voltage measured across A and B and whose internal impedance is equal to the impedance of the network between the terminals A and B when all the generators in the network have been replaced by their internal impedance.



(a)



(b)



(c)

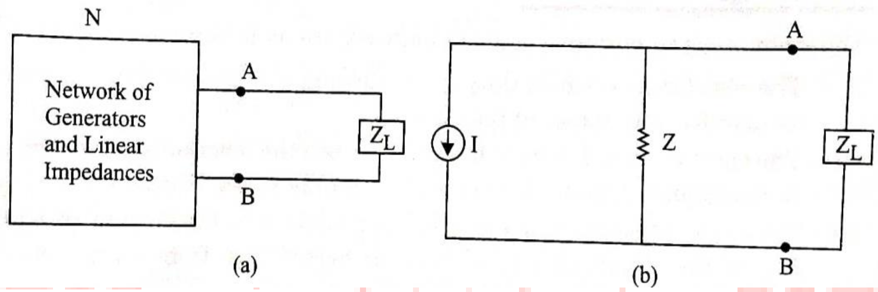
the impedance between terminals A and B after discounting the load Z_L is given by

$$Z' = Z_2 + \frac{Z_1 Z_3}{Z_1 + Z_3}.$$

The value of load current I_L is given by

$$I_L = \frac{E'}{Z' + Z_L}$$

Norton's theorem: the current in a load impedance connected to two terminals A and B of a network of generators and linear impedances is the same as if this impedance were connected to a constant current generator whose generated current is equal to the short circuit current at the terminal A, B and placed in parallel with an impedance equal to the impedance of the network between the terminals A and B when all the generators in the network have been replaced by their internal impedances



The current through Z_L is given by

$$I_L = \frac{E'}{Z' + Z_L}$$

Multiple Choice Questions and Answer

1. A varying current is that which
a) Varies in magnitude but not in direction
b) Varies in magnitude but direction both
c) Change its direction once in a cycle
d) Change its direction twice in a cycle
Ans. a) Varies in magnitude but not in direction

2. In L-R Circuit time constant is the time in which current increase from zero to
a) 37% of maximum value
b) equal to maximum value of current
c) 50% of maximum value
d) 63% of maximum value
Ans. d) 63% of maximum value

3. Which is not the dimension of time
a) L/R

b) CR
c) LC
d) R/L
Ans. d) R/L

4. The conjugate impedance is defined as
a) Z = Z - jX
b) Z = R + Jx
c) Z= $\frac{R}{jX}$
d) None of these
Ans. b) Z = R + Jx

5. In series LCR Circuit if $1/LC = R^2/4L^2$ the circuit is
a) Dead beat
b) Critically damped
c) Oscillatory
d) None of these
Ans. b) Critically damped

6. RC has the Unit of
a) Sec
b) 1/sec
c) H/sec
d) Sec/H
Ans. a) Sec

7. In LCR Circuit resonance occurs when
a) WL =1/WC
b) L = 1/C
c) L = C
d) WL= C
Ans. a) WL =1/WC

8. The dimension of RC is
a) Time
b) Inverse time
c) Square of time
d) Square of inverse time
Ans. a) Time

9. The time constant of LR circuit is
a) LR
b) L/R

c) R/L
d) C/L
Ans. b) L/R

10. The necessary condition for the oscillation of LCR circuit
a) R< 2L/C
b) R> 2L/C
c) R= 2L/C
d) R> L/C
Ans. a) R< 2L/C

11. In L-R circuit the current increase to three-fourth of its maximum value in 4 sec then time constant of the circuit
a) 2log2
b) 4/log2
c) 2/log2
d) 3/log2
Ans. c) 2/log2

12. In RC circuit the transient current is maximum
a) T= ∞
b) T= RC
c) T= RC/e
d) T= 0
Ans. d) T= 0

13. In L-R circuit the value of current I when t→∞ is given by
a) $I = I_0\left(1-e^{-(R/L)t}\right)$
b) $I = I_0\left(1-e^{-(L/R)t}\right)$
c) $I = I = I_0\left(e^{(R/L)t}\right)$
d) $I = I_0 e^{(L/R)t}$
Ans. a) $I = I_0\left(1-e^{-(R/L)t}\right)$

14. The rate of growth of current in LR circuit
a) (R/L)($I-I_0$)
b) (L/R)($I-I_0$)
c) (L/R) I_0
d) (LI)/R
Ans. a) (R/L)($I-I_0$)

15. In LR circuit the current decays exponentially is
a) $I = I_0 e^{-\left(\frac{R}{L}\right)t}$

b) $I = I_0 e^{-\left(\frac{L}{R}\right)t}$

c) $I = I_0 e^{\left(\frac{R}{L}\right)t}$

d) $I = I_0 e^{\left(\frac{L}{R}\right)t}$

Ans. a) $I = I_0 e^{-\left(\frac{R}{L}\right)t}$

16. In LR Circuit the rate of decay of current
a) dI/dt = -(R/L)I
b) dI/dt = (R/L)I
c) dI/dt = -(L/R)I
d) dI/dt = (L/R)I
Ans. a) dI/dt = -(R/L)I

17. The unit of inductance L
a) time
b) ohm
c) henry
d) none
Ans. c) henry

18. A capacitor is connected through register and dc source in series the expression of charge on capacitor at a time t is

a) $q = q_0 e^{-t/RC}$

b) $q = q_0 e^{CR}$

c) $q = q_0 (1 - e^{-t/RC})$

d) None of these

Ans. c) $q = q_0 e^{-t/RC}$

19. In RC circuit the capacitor discharge through the capacitor charge on the capacitor
a) Increase
b) Decrease
c) First increase then decrease
d) None of these
Ans. b) Decrease

20. The capacitor discharge through the resister, the rate discharge of the capacitor
a) dq/dt = q/CR

b) dq/dt = -q/CR
c) dq/dt = CR/q
d) none of these
Ans. b) dq/dt = -q/CR

21. A capacitor of capacity 0.5μF and resistance 10Ωm is charge to a potential difference of 10 volts find time constant
a) 2sec
b) 4 sec
c) 8 sec
d) 5 sec
Ans. d) 5 sec

22. The maximum charge stored by capacitor if c =10mΩ and E= 10 volts
a) 6μc
b) 5 μc
c) 3 μc
d) 2 μc
Ans. b) 5 μc

23. General condition of balance in ac bridge
a) $Z_4/Z_2 = Z_3/Z_1$
b) $Z_1/Z_2 = Z_3/Z_4$
c) $Z_2/Z_1 = Z_4/Z_3$
d) both b) and c)
Ans. d) both b) and c)

24. Maxwell bridge is used for the measurement of
a) Capacitance
b) Inductance
c) Both inductance and capacitance
d) Frequency of ac supply
Ans. b) Inductance

25. Value of self-Inductance in term of C and R is measure using
a) Maxwell bridge
b) Owens bridge
c) Both (a) and (b)
d) Weins bridge
Ans. a) Maxwell bridge

26. Owens bridge is used for measurement of
a) Capacitance
b) Resistance

c) Inductance
d) None
Ans. c) Inductance

27. The average power dissipation in pure inductance is
a) $Li^2/2$
b) Li^2
c) $2Li^2$
d) None of these
Ans. a) $Li^2/2$

28. A ballistic galvanometer is used to measure
a) Current
b) Capacitance
c) Charge
d) Potential difference
Ans. c) Charge

29. For measuring self-inductance over a wide range we used
a) Maxwell bridge
b) Owens bridge
c) Weins bridge
d) Anderson bridge
Ans. d) Anderson bridge

30. The modification of LC bridge is
a) Weins bridge
b) Schering bridge
c) Anderson bridge
d) Owens bridge
Ans. c) Anderson bridge

31. Convenient method for measurement of capacitance as well as the power factor of capacitor
a) Maxwell bridge
b) Weins bridge
c) Schering bridge
d) None of these
Ans. b) Weins bridge

32. The bridge used for the accurate measurement of small capacitance is
a) Schering bridge
b) De-sauty bridge
c) Anderson bridge

d) Maxwell bridge
Ans. a) Schering bridge

33. Weins bridge can be used for measuring
a) Frequency
b) Resistance
c) Distortion
d) None of these
Ans. a) Frequency

34. De-sauty bridge is
a) To determine unknown resistance
b) To determine unknown capacitance
c) To determine unknown inductance
d) None of these
Ans. b) To determine unknown capacitance

35. The value of time constant LR and RC circuit is respectively
a) R/L, RC
b) R/L, R/C
c) L/R, C/R
d) L/R, RC
Ans. d) L/R, RC

36. The Schering bridge is used to measure
a) Resistance
b) Inductance
c) Power
d) Capacity
Ans. d) Capacity

37. Network theorem can be applied network with
a) DC source only
b) AC source only
c) Both AC and DC source
d) None of these
Ans. c) Both AC and DC source

38. Superposition theorem can be applied to circuit have
a) resistive element
b) passive element
c) linear element
d) non linear element
Ans. c) linear element

39. A network containing circuit element without any energy source is
a) Active network
b) Negative network
c) Not a network
d) Passive network
Ans. d) Passive network

40. According to superposition theorem current following at any point is vector sum of
a) Voltage
b) Impedance
c) Current
d) Current and impedance
Ans. c) Current

41. The relation of current in superposition theorem
a) $I_1 = I_1' + I_1''$, $I_2 = I_2' + I_2''$
b) $I_1 = I_1' - I_1''$, $I_2 = I_2' - I_2''$
c) $I_1 = I_1' + I_1''$, $I_2 = I_2' - I_2'$
d) $I_1 = I_1' - I_1''$, $I_2 = I_2' - I_2''$
Ans. a) $I_1 = I_1' + I_1''$, $I_2 = I_2' + I_2''$

42. Thevenin's and Norton's circuit are equivalent at
a) resonant frequency
b) all frequency
c) only at frequency at which these are computed
d) no frequency
Ans. c) only at frequency at which these are computed

43. In superposition theorem while considering a source, all other voltage source are
a) Open circuit
b) Short circuit
c) Change its position
d) Removed from the circuit
Ans. b) Short circuit

44. To get the Norton current you have to
a) short the load resistor
b) open the load resistor
c) short the voltage source
d) open the voltage source
Ans. a) short the load resistor

45. When dc source is switch off then current voltage
a) decrease
b) increase
c) fall abruptly to zero
d) None of these
Ans. c) fall abruptly to zero

46. The form of energy in charge capacitor is
a) heat
b) magnetic
c) gravitational
d) electrostatic
Ans. d) electrostatic

47. At 0 k temperature a semiconductor like
a) conductor
b) insulator
c) semiconductor
d) none
Ans. b) insulator

48. In a semiconductor at room temperature there is
a) a partially field conduction band
b) a partially field valance band
c) a very narrow energy gap between then
d) all of these
Ans. d) all of these

49. The ratio of forward resistance and reverse resistance of a germanium Crystal diode
a) 1: 4000
b) 1: 100
c) 1: 10
d) 1: 1000
Ans. a) 1: 4000

50. Find the power factor if R = 50Ω and Z = 300Ω
a) $\frac{1}{6}$
b) 6
c) 1
d) 0
Ans. a) $\frac{1}{6}$
Hint: power factor = $\frac{R}{Z}$

Unit - VI

Unit VI
Semiconductor and Diodes

Introduction to Semiconductor

Classification of solids based on the conductivity is as follows:

Conductors: those substance whose atoms have their outermost orbits incomplete are called conductors. There is no forbidden gap between the valence band and conduction band which results in the overlapping of both the bands. **Semiconductors**: the conduction band is empty and the valence band is completely filled but the forbidden gap between the two bands is very small that is about 1eV. For Germanium, forbidden gap is 0.72eV and for Silicon, it is 1.1eV.

Insulators: These substances do not allow electricity to pass through them. They have high resistivity and very low conductivity. The energy gap in the insulator is very high up to 7eV.

Band Theory of Semiconductors

The Walter Heitler and Fritz London discovered the energy bands. We know that the electrons in an atom are present at different energy levels. When we try to assemble a lattice of a solid with N atoms, each level of an atom must split into N Levels in the solid.

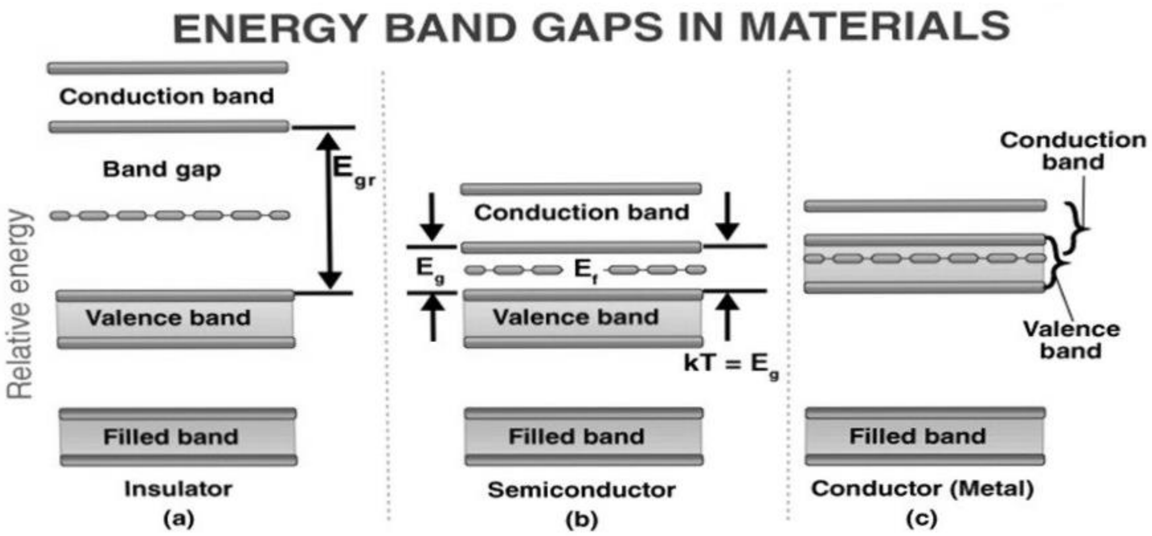


Fig. Energy Band Diagram for Semiconductors, Conductors and Insulators

Band Gap: The Gap between valence band and conduction band is called Band Gap. Band Gap are two types 1- Valence band 2- Conduction band.

Valence Band: The energy band involving the energy levels of valence electrons is known as the valence band. It is the highest occupied energy band.

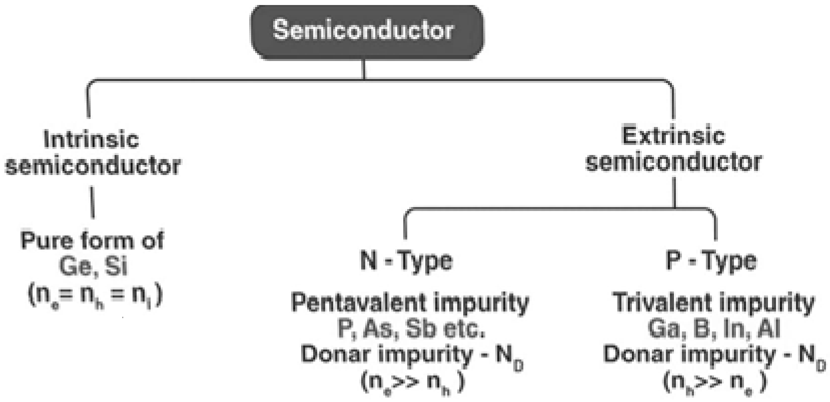
Conduction Band*:* It is the lowest, unoccupied band that includes the energy levels of positive (holes) or negative (free electrons) charge carriers. It has conducting electrons resulting in the flow of current.

Fermi Level in Semiconductors: The Fermi level (denoted by EF) is present between the valence and conduction bands. It is the highest occupied molecular orbital at absolute zero.

When the temperature rises above absolute zero, these charge carriers will begin to occupy states above the Fermi level.

In a **p-type semiconductor** the Fermi level lie top of valence band.

In an **n-type semiconductor** the Fermi level lie bottom of conduction band.



An **intrinsic semiconductor** is made up of very pure materials. Example: Ge and Si, they have four valence electrons (tetravalent). at absolute zero temperature intrinsic semiconductor behave as insulator. When the temperature rises due to collisions, few electrons are unbounded and become free to move through the lattice which are responsible for conduction of current, thus creating an absence in its original position (hole). These free electrons and holes contribute to the conduction of electricity in the semiconductor. The negative and positive charge carriers are equal in number.

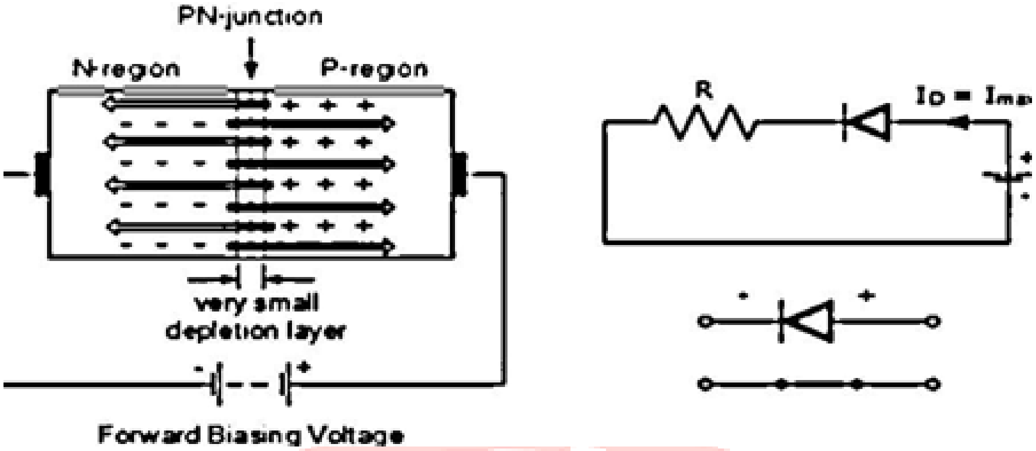
The total current is the sum of the electron current I_e and hole current I_h.

Total Current (I) = $I_e + I_h$

Extrinsic Semiconductor: The conductivity of semiconductors can be greatly improved by introducing a small number of suitable replacement atoms called Impurities. An extrinsic semiconductor can be further classified into types:

1. N-type Semiconductor
   - Mainly due to electrons
   - Entirely neutral
   - $n_e >> n_h$
   - Majority – Electrons and Minority – Holes
   - Donor impurity
2. P-type Semiconductor
   - Mainly due to holes
   - Entirely neutral
   - $n_h >> n_e$
   - Majority – Holes and Minority – Electrons
   - Acceptor impurity

A p-n junction diode is a basic semiconductor device that control the flow of electric current in a circuit. It has a positive (p) side and a negative (n) side.



There are two operating regions and three possible "biasing" conditions for the standard **Junction Diode** and these are:

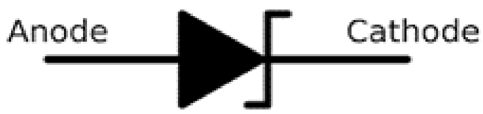
1. **Zero Bias** – No external voltage potential is applied to the PN junction diode.

2. **Reverse Bias** – The negative terminals of battery connected to the P-type material and positive terminals of battery connect to the N-type material, across the diode which **Increasing** the width of PN junction diode.

3. **Forward Bias** – The positive terminals of battery is connected to the P-type material and negative terminals of battery connected to the N-type material, across the diode which **Decreasing** the width of PN junction diode.

Zener Diode: is defined as the semiconductor which is heavily doped to operate in reverse direction or in breakdown region. The Zener diode behaves just like a normal general-purpose diode consisting of a silicon PN junction and when biased in the forward direction, that is Anode positive with respect to its cathode, it behaves just like a normal diode passing the current. However, unlike a conventional diode that blocks any flow of current through itself when reverse biased, that is the Cathode becomes more positive than the Anode, as soon as the reverse voltage reaches a predetermined value, the zener diode begins to conduct in the reverse direction.

Zener Diode Symbol:



Working of Zener Diode

The basic principle behind Zener diode working is based on the cause of breakdown when the diode is in the reverse biased condition. For a Zener diode there are two types of breakdown:

1. **Zener breakdown**
2. **Avalanche breakdown**

Application of Zener Diode

- Zener diode as voltage regulator
- Zener diode in over-voltage protection
- Zener diode in clipping circuits

Static or DC Resistance : It is defined as the ratio of the d.c voltage to the d.c current.

$$R_{dc} = V/I$$

Dynamic or AC Resistance: it is defined as ratio of change voltage to change in current

$$R_{ac}= dV/dI$$

Light Emitting Diode: A light-emitting diode (LED) is a semiconductor device that emits light when current flows through it. The lighting emitting diode is a p-n junction diode. It work in forward biased condition.

Photodiode: A photodiode is a PN-junction diode that consumes light energy to produce an electric current. They are also called a photo-detector, a light detector, and a photo-sensor. Photodiodes are designed to work in reverse bias condition.

Rectifier: A rectifier is an electronic device that converts an alternating current into a direct current by using one or more P-N junction diode. This process is known as rectification

The rectifiers are classified into two categories.

1. Half wave rectifier

2. Full wave rectifier

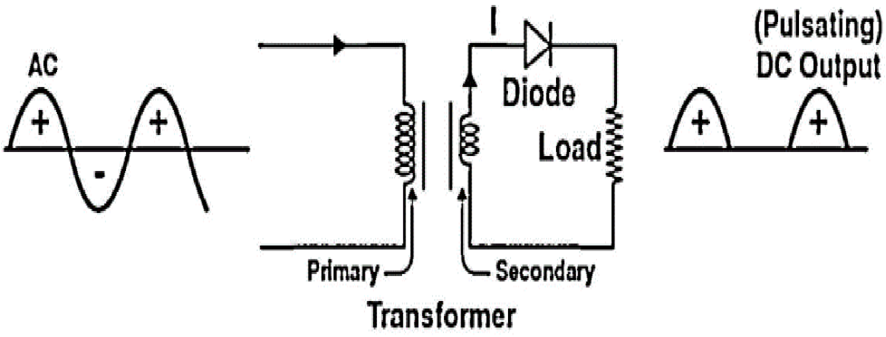
Half Wave Rectifier (HWR) : The half-wave rectifier converts the AC signal to a DC signal by passing the signal to either a negative or positive half-cycle of waveform while blocking the other half-cycle.

The half-wave rectifier is made of 3 components:-

1. Diode

2. Transformer

3. Resistive Load



Efficiency of HWR: The efficiency of HWR is defined as the ratio of output DC power to the input AC power.

$$\eta = \frac{P_{dc}}{P_{ac}} * 100\% = 40.6\%.$$

Peak Inverse Voltage of HWR: PIV= $\boldsymbol{V_m}$

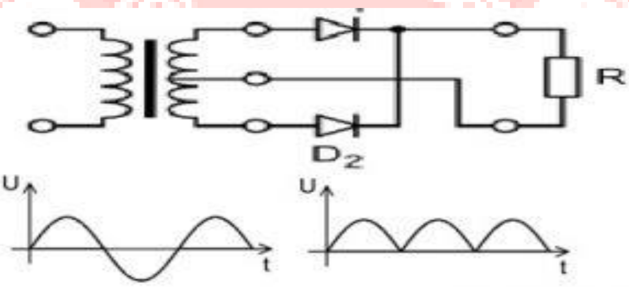
RMS Value of Load Current of HWR: $I_{rms} = \frac{I_m}{2}$

Average Value of Load Current of HWR: $I_{avg} = \frac{I_m}{\pi}$

Form Factor of HWR $= \frac{V_{rms}}{V_{avg}}$

Ripple Factor of HWR: r= $\sqrt{\left(\frac{I_{rms}^2}{I_{dc}^2}\right) - 1}$ **= 1.21**

Full wave rectifier: A rectifier that converts the complete cycle of alternating into pulsating DC.



Efficiency of FWR: The efficiency of FWR is defined as the ratio of output DC power to the input AC power.

$$\eta = \frac{P_{dc}}{P_{ac}} = 81.2$$

Peak Inverse Voltage of FWR PIV= **2Vm**

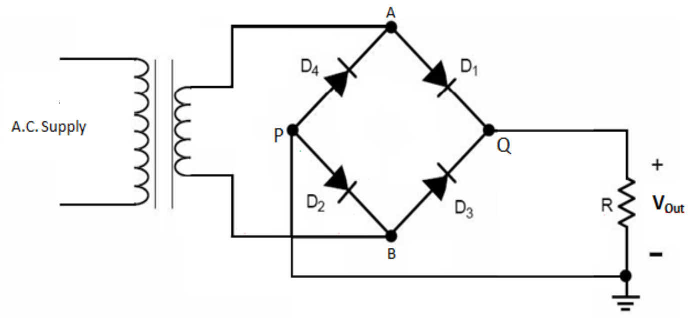
RMS Value of Load Current of FWR: $I_{rms} = \frac{I_m}{\sqrt{2}}$

Average Value of Load Current of FWR: $I_{dc} = \frac{2I_m}{\pi}$

Form Factor of FWR = $\frac{V_{rms}}{V_{vag}}$

Ripple Factor of FWR: r= $\sqrt{\left(\frac{I_{rms}^2}{I_{dc}^2}\right) - 1}$ **= 0.48**

Bridge Rectifier: Bridge Rectifier is a type of Full Wave Rectifier that uses four diodes to form a close-loop bridge. The diodes conduct in pairs through each positive and negative half cycle, leading to no wastage of power. bridge Rectifier does not require a centre tap over the secondary winding of the transformer.



Efficiency of bridge rectifier : $\eta = \frac{P_{dc}}{P_{ac}}$=81.2%

Peak Inverse Voltage of bridge rectifier: PIV= $\mathbf{V_m}$

Average Value of Load Current of bridge rectifier: $I_{dc} = \frac{2I_m}{\pi}$

RMS Value of Load Current of bridge rectifier: $I_{rms} = \frac{I_m}{\sqrt{2}}$

Ripple Factor of bridge rectifier: r = 0.48

Multiple Choice Questions and Answers

1. Which among the following is the most widely used semiconductor material?
a) Potassium
b) Phosphorous
c) Silicon
d) Arsenic
Ans. c) Silicon

2. The energy gap between the valence band and the conduction band in a semiconductor is
a) 5 eV
b) 10 eV
c) 15 eV
d) 1 eV
Ans. d) 1 eV

3. What is the sign of the temperature coefficient of resistance in a semiconductor?
a) Negative
b) Positive
c) Zero
d) None of the above
Ans. a) Negative

4. What does the addition of pentavalent impurity to semiconductors create?
a) Free Electrons
b) Holes
c) Valence electrons
d) Bound electrons
Ans. a) Free Electrons

5. How many valence electrons are there in a pentavalent impurity?
a) 3 Valence electrons
b) 6 Valence electrons
c) 4 Valence electrons
d) 5 Valence electrons
Ans. d) 5 Valence electrons

6. How many valence electrons are there in a trivalent impurity?
a) 3 Valence electrons
b) 5 valence electrons
c) 6 valence electrons
d) 4 valence electrons
Ans. a) 3 Valence electrons

7. What is the effect on the bulk resistance on a semiconductor by adding impurities?
a) Decreases
b) Remain the same
c) Increases
d) None of the above
Ans. a) Decreases.

8. In germanium and silicon the valance electron are
a) two
b) four
c) six
d) four
Ans. d) four

9. The charge carrier in intrinsic semiconductor is
a) electrons

b) hole
c) both electrons and hole
d) none
Ans. c) both electrons and hole

10. n- type semiconductor is
a) positively charged
b) negatively charged
c) electrically neutral
d) none
Ans. c) electrically neutral

11. On increasing the temperature of an intrinsic semiconductor
a) conductivity of semiconductor is decrease
b) resistance of semiconductor increase
c) hole are produce in conduction band
d) conductivity of semiconductor is increase
Ans. d) conductivity of semiconductor is increase

12 In p-type semiconductor the impurity is called
a) acceptor
b) donor
c) both donor and acceptor
d) none of these
Ans. a) acceptor

13. For intrinsic semiconductor fermi level is
a) $E_f = (E_C+E_V)/2$
b) $E_f = (E_C-E_V)/2$
c) $E_f = E_C \times E_V$
d) none of these
Ans. a) $E_f = (E_C+E_V)/2$

14. The band gap is
a) $E_g = E_c-E_v$
b) $E_g = E_c+E_v$
c) $E_g = E_c*E_v$
d) $E_g = E_c/E_v$
Ans. a) $E_g = E_c-E_v$

15. How many junctions in a diode consist?
a) 0
b) 1
c) 2
d) 3
Ans. b) 1

16. If the positive terminal of the battery is connected to the p-type of the diode, then it is known as
a) Forward biased
b) Reverse biased
c) Equilibrium
d) Schottky barrier
Ans. a) Forward biased

17. During reverse bias, a small current develops known as
a) Forward current
b) Reverse current
c) Reverse saturation current
d) Active current
Ans. b) Reverse current

18. Thickness of depletion layer is the order of
a) 10^{-9}
b) 10^{-6}
c) 10^{-10}
d) 10^{-8}
Ans. b) 10^{-6}

19. The barrier potential of silicon diode at room temperature is
a) 0.3V
b) 0.1V
c) 2mV
d) 0.7V
Ans. d) 0.7V

20. The potential barrier at a P-N Junction is due to
a)majority carrier
b) minority carrier
c) both majority and minority carrier
d) fixed donor and acceptor ions
Ans. d) fixed donor and acceptor ions

21. The depletion layer width of a P-N Junction has maximum value in
a) forward bias
b) reverse bias
c) zero bias
d) a.c. bias
Ans. b) reverse bias

22. A Zener diode is used for
a) modulation

b) detection
c) voltage regulation
d) rectification
Ans. c) voltage regulation

23. The mobility of charge carrier can be expressed in unit of
a) m^2/volt-sec
b) volt/ m^2-sec
c) volt-sec/m^2
d) m^2.sec/volt
Ans. a) m^2/volt-sec

24. When the current through Zener diode increase by a factor of 2, voltage across its terminals
a) halved
b) double
c) practically unchanged
d) zero
Ans. c) practically unchanged

25. Static or D.C resistance is
a) R_{dc}= I/V
b) R_{dc}=V/I
c) R_{dc}= IR
d) none
Ans. b) R_{dc}=V/I

26. Dynamic or AC resistance for Ge (η = 1) at room temperature is
a) R_{ac}=26/I
b) R_{ac}= I/26
c) R_{ac}= 26
d) R_{ac}= I
Ans. a) R_{ac}=26/I

27. Find static resistance of P-N Junction diode Ge diode temperature is 2 C and I =1µA for an applied forward bias of 0.2 volt.
a) 300kΩ
b) 250 kΩ
c) 200 kΩ
d) 100 kΩ
Ans. c) 200 kΩ

28. Zener Breakdown occurs
a) mostly in silicon diode
b) mostly in Ge diode
c) because of rupture of covalent bond
d) due to thermal generated carrier

Ans. c) because of rupture of covalent bond

29. Photo diode work in
a) forward biasing
b) reverse biasing
c) Zero biasing
d) none of these
Ans. b) reverse biasing

30. LED always work in
a) reverse bias
b) forward bias
c) both a and b
d) none of the above
Ans. b) forward bias

31. Bridge rectifier is an alternative for
a) Full wave rectifier
b) Peak rectifier
c) Half wave rectifier
d) None of the mentioned
Ans. a) Full wave rectifier

32. Which rectifier requires four diodes?
(a) half-wave rectifier
(b) full-wave rectifier
(c) bridge rectifier
(d) voltage quadrupler
Ans. c) bridge rectifier

33. The ripple factor of a bridge rectifier is
(a) 0.48
(b) 0.812
(c) 1.21
(d) 1.11
Ans. a) 0.48

34. The ripple factor of a half wave rectifier is
a) 0.48
b) 1
c) 1.21
d) 2.56
Ans. a) 1.21

35. In half wave rectifier rms value of output current is
a) $I_{rms} = I_0/\sqrt{2}$
b) $I_{rms} = I_0/2$

c) $I_{rms} = I_0$
d) $I_{rms} = I_0 + 2$
Ans. b) $I_{rms} = I_0 / 2$

36. The ripple factor r > 1, then rectifier is
a) Good device
b) Poor device
c) Both a and b
d) none of these
Ans. b) Poor device

37. Ripple factor of full wave rectifier is
a) 0.23
b) 0.121
c) 1.11
d) 0.482
Ans. d) 0.482

38. In bridge rectifier, the peak inverse voltage is
a) E_0
b) $2E_0$
c) $E_0 /2$
d) $3E_0$
Ans. a) E_0

39. A Zener diode is used as
a) an amplifier
b) a voltage regulator
c) a rectifier
d) a multi vibrator
Ans. b) a voltage regulator

40. Avalanche breakdown occurs at
a) zero reverse voltage
b) small reverse voltage
c) high reverse voltage
d) none of these.
Ans. c) high reverse voltage

41. The height of potential barrier is
a) qV_b
b) $q + V_b$
c) $V_b - q$
d) none of these
Ans. a) qV_b

42. Zener diode gives
a) sharp breakdown voltage
b) zero breakdown
c) undefined breakdown voltage
d) none of these
Ans. a) sharp breakdown voltage

43. For detection light intensity we use
a) LED in forward bias
b) LED in reverse bias
c) photodiode in forward bias
d) photodiode in bias
Ans. a) LED in forward bias

44. Avalanche breakdown is a
a) Addition process
b) cumulative
c) both Addition and cumulative
d) none of these
Ans. b) cumulative

45. π section filter consists of
a) inductor only
b) capacitor only
c) both inductor and capacitor
d) none of these
Ans. c) both inductor and capacitor

46. In a half - wave rectifier, the load current flows for
(a) Complete cycle of the input signal
(b) Less than half-cycle of the input signal,
(c) More than half-cycle but less than complete cycle of the input signal.
(d) Only for the positive half-cycle of the input signal.
Ans. d) Only for the positive half-cycle of the input signal.

47. The basic purpose of a filter is to
(a) Minimize variations in a.c. input signal.
(b) Suppress harmonics in rectified output.
(c) Remove ripples from the rectified output.
(d) Stabilize d.c. output voltage.
Ans. c) Remove ripples from the rectified output

48. The peak inverse voltage of full wave rectifiers is
a) $2E_0$
b) E_0
c) $3E_0$

d) $E_0/2$
Ans. a) $2E_0$

49. Maximum efficiency of half wave rectifier is
a) 100%
b) 40.6%
c) 81.2%
d) 43.6%
Ans. b) 40.6%

50. The maximum wavelength emitted by electron is 600 nm. The value of band gap energy (in eV) is
a) 2 eV
b) 1.875 eV
c) 18.75 eV
d) 0.2 eV
Ans. b) 1.875 eV

Unit – VII

Unit VII

(Transistors)

- A junction transistor is a sandwich made of two *pn* junctions either in *pnp* or *npn* form. In normal operation the base-emitter junction is always forward- biased and the base-collector junction is always reverse-biased. The collector current is proportional to the base current; and is much larger. The ratio of a small change in collector current brought about as a result of a small change in base current is known as the current gain.
- Transistors may be connected in the common-base, common-collector or common-emitter. The common-emitter configuration is the most common amplifier arrangement. Changes in collector current give rise to corresponding changes in voltage across a load resistor connected into the collector circuit.

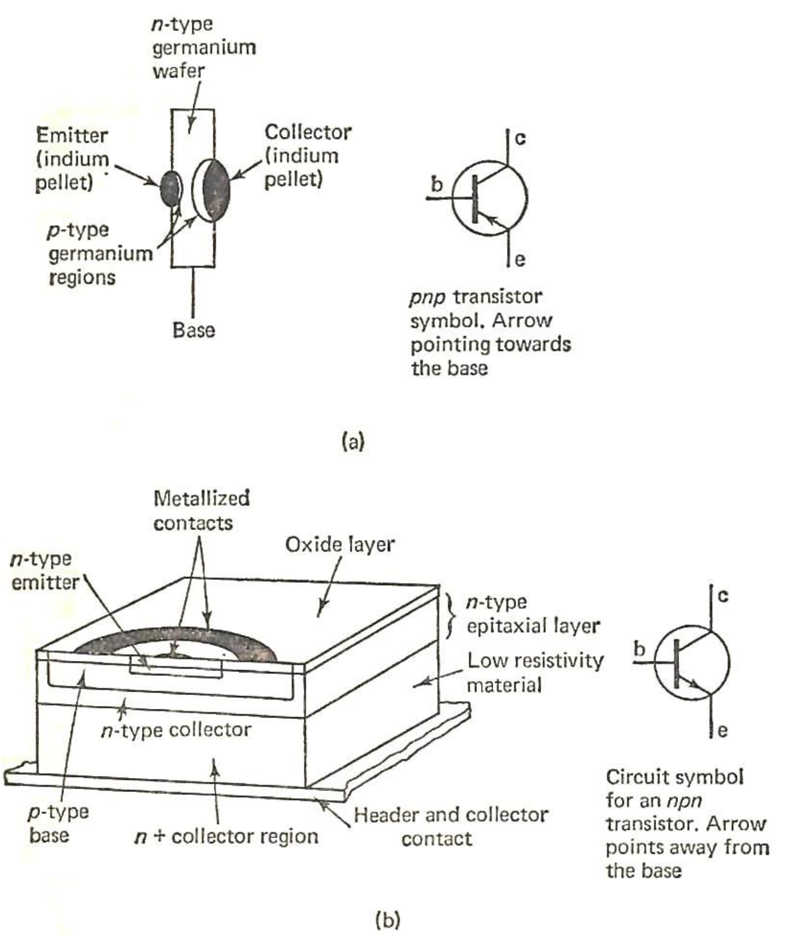


Fig. 1 Constructional features of different types of transistor. The planar epitaxial type is the standard type used now. (a) Alloy transistor; (b) planar epitaxial transistor.

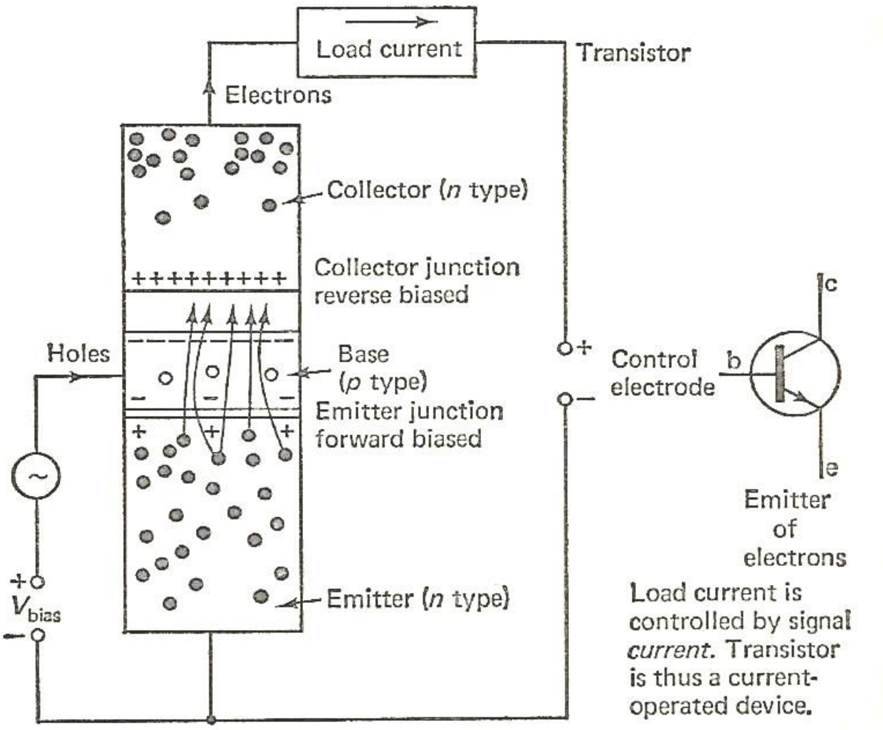
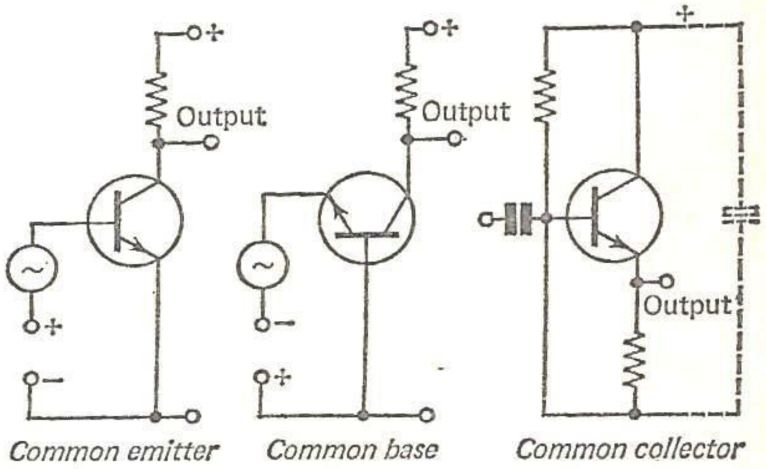


Fig. 2 . Diagrammatic representation of the amplifying action of a transistor.



	Common emitter	Common base	Common collector
Current gain	Large (50 – 250)	< 1 (about 0·99)	Large
Voltage gain	High	High	Less than 1
Input resistance	Medium (≈ 2 kΩ)	Low (≈ 50 Ω)	Very high (→ 1 MΩ)

Fig. 3 The three basic amplifier arrangements together with some of their properties. The figures are given only as a guide to the magnitudes involved.

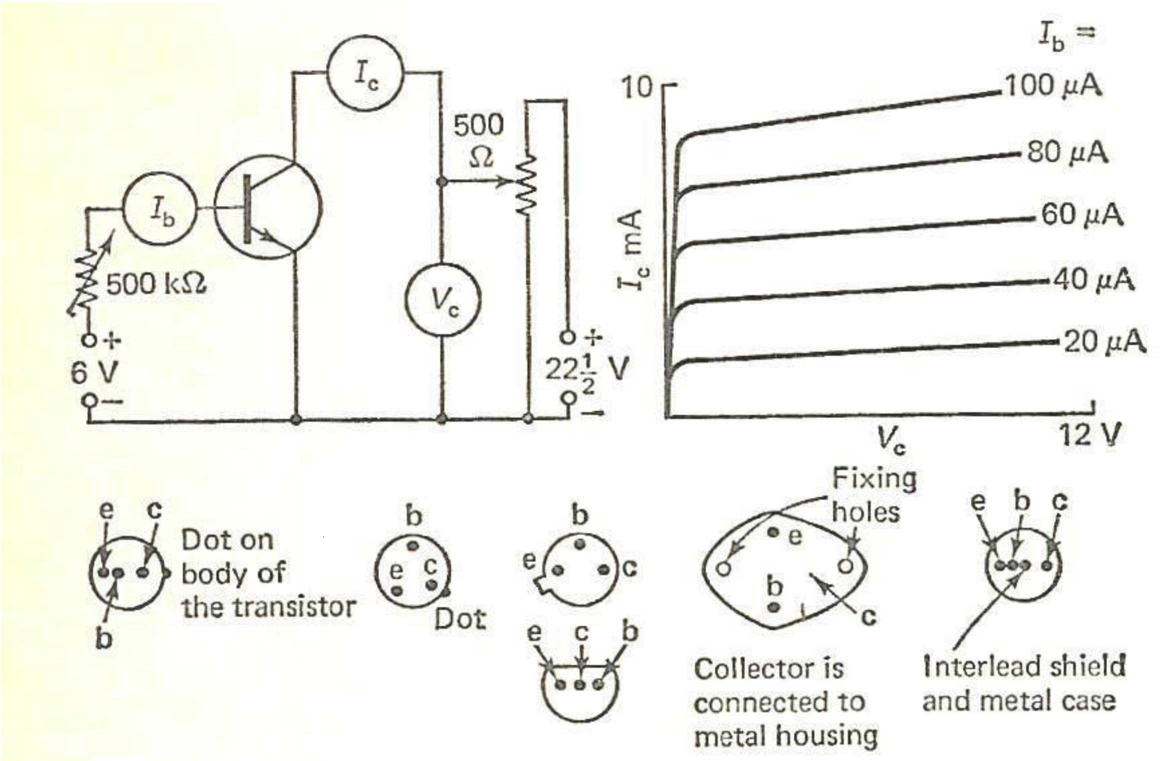


Fig. 4 Characteristics of a transistor in the common-emitter mode. Figures given are typical of a small low-power transistor. Modifications to the circuit will be required for other types (e.g. high-voltage or power transistors). Some connection diagrams are given for transistors in common use. In all cases the wires are pointing from the transistor to the viewer.

- Amplifiers are needed to increase the very small voltages produced by transducers to values suitable for driving power amplifiers. They may be classified according to the function they perform or their frequency of operation. Voltage amplifiers are designed to produce amplified versions of the input signal without introducing, as far as possible, any distortion or noise. The basic single-stage voltage amplifier uses a transistor as the active component. In order to avoid distortion and ensure satisfactory transistor operation, bias circuits must be used. Variations of base current are then superimposed on a steady bias current. This produces larger variations of collector current that are superimposed on a steady component known as the quiescent current. Bias circuits are designed not only to obtain satisfactory transistor operation, but also to compensate for variations of temperature and changes of component values.

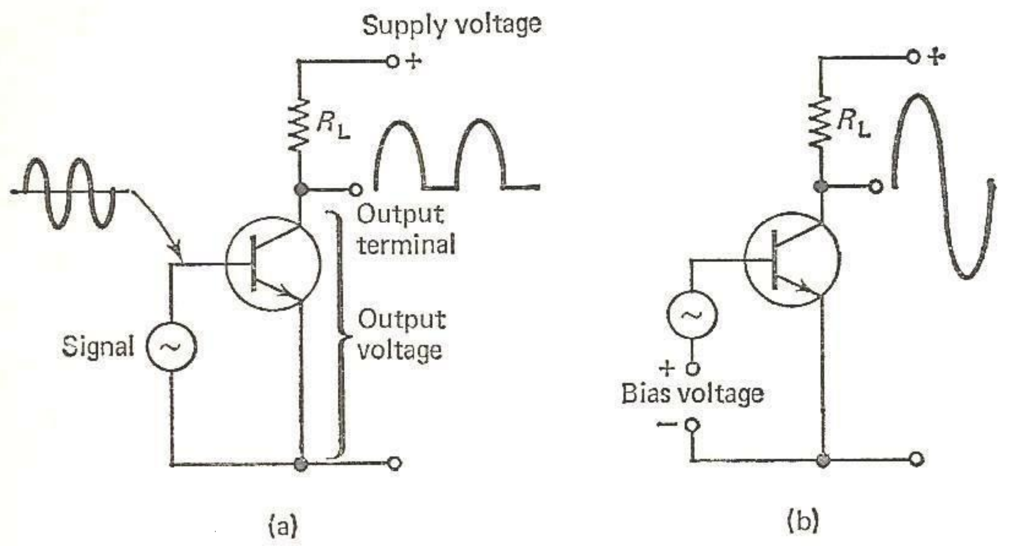


Fig. 5 . (a) Transistor amplifier without bias. (b) Amplifier with bias. (a) shows the production of an output voltage that is severely distorted. This distortion can be largely avoided by applying a bias voltage as shown in (b). Using a bias battery is not practical so the circuits of Fig. 6 have been devised.

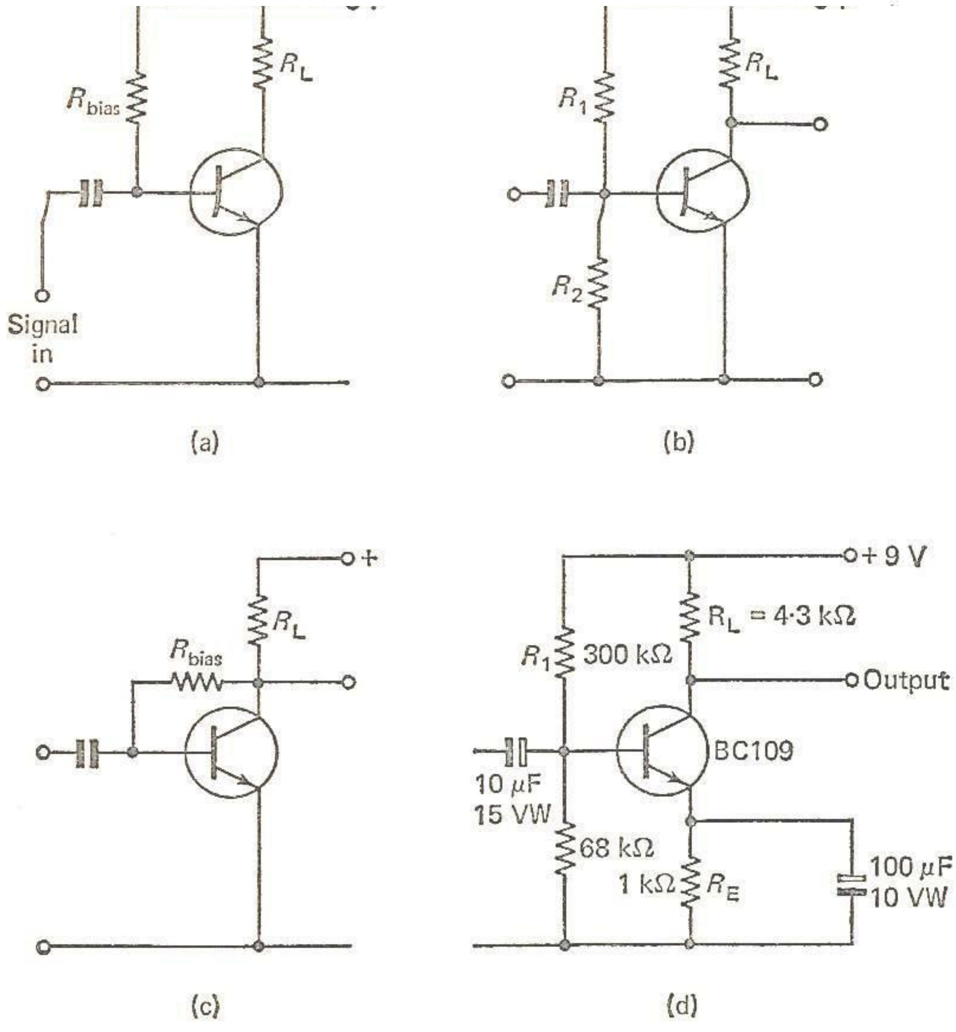


Fig. 6 . Biasing circuits for a common-emitter transistor amplifier stage.

- When we plot a graph showing how the collector current varies with the collector-emitting voltage for any fixed value of base current, the form of the graph is that shown in Fig. 7. Here several graphs of this type are drawn on one set of axes, each graph being for a different base current. The family of curves is known as a set of output characteristics. For any value of base current and collector voltage we could read off the corresponding value of collector current. Consider now the circuit diagram accompanying the set of output characteristics. Here we have a fixed supply voltage, V_{cc}, and a load resistor, R_L, in the collector circuit. For any particular value of collector current a voltage drop across R_L will be experienced which is equal to $I_c R_L$. The sum of this voltage and the collector voltage, V_{ce} is equal to the fixed supply voltage V_{cc}. Hence
$V_{cc} = V_{ce} + I_c R_L$

  Now the characteristic curves are plotted on axes which show I, as the y-axis and V_{ce} as the x-axis. We can transpose the above equation, using simple algebra, so that we have I_c on one side and everything else on the other side of the equation. This equation then becomes $I_c = (-1/R_L) V_{ce} + [V_{cc} / R_L]$

  which is in the form y = mx + c, where y is I_c and m (the slope) is $-1/R_L$ and the intercept on the y-axis is V_{cc}/R_L. This straight-line graph can be super- imposed on the set of output characteristics as shown; the straight line is known as the load line. From it we can make a more accurate estimate of the bias current needed as well as making many other deductions.

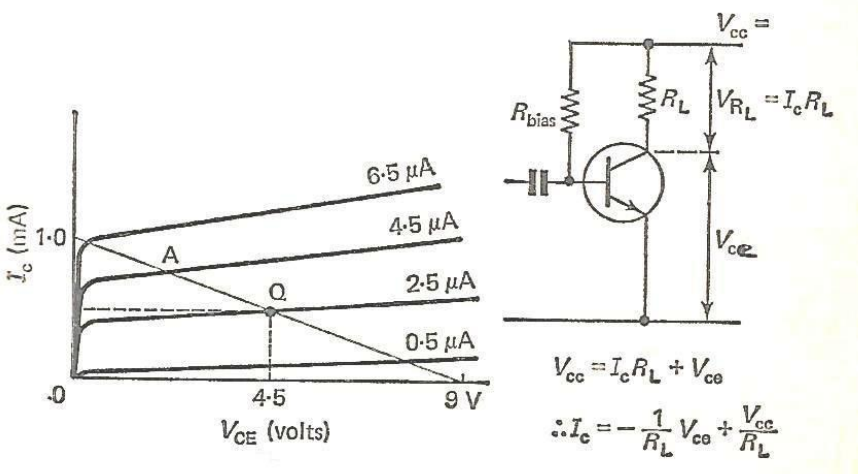


Fig. 7 . The simplest transistor amplifier.

- Important Relationships related to common-emitter, common-collector, common-base configurations:
$\beta = \alpha / (1- \alpha)$
$\gamma = 1 / (1 - \alpha)$
where α is current amplification factor for common-base configuration i.e. the ratio of change in collector current to change in emitter current when collector voltage is kept constant, β is current amplification factor for common-emitter configuration i.e.

the ratio of collector current to change in base current and γ is current amplification factor for common-collector configuration i.e. the ratio of change in emitter current to the change in base current.

Multiple Choice Questions and Answers

1. A transistor has ....
(a) one pn junction
(b) two pn junctions
(c) three pn junctions
(d) four pn junctions
Hint: Consider the basic structure of a transistor and the arrangement of pn junctions.
Ans: (b)

2. The number of depletion layers in a transistor is ....
a) four
b) three
c) one
d) two
Hint: Think about the formation of depletion layers in a transistor's structure.
Ans: d)

3. The base of a transistor is _____ doped.
(a) heavily
(b) moderately
(c) lightly
(d) none of the above
Hint: Consider the doping concentration required for the transistor's operation.
Ans: (c)

4. The element that has the biggest size in a transistor is ______
(a) collector
(b) base
(c) emitter
(d) collector-base junction
Hint: Think about the physical dimensions of the transistor's components.
Ans: (a)

5. In a pnp transistor, the current carriers are __________
(a) acceptor ions
(b) donor ions
(c) free electrons
(d) holes

Hint: Consider the type of charge carriers in a pnp transistor's operation.
Ans: (d)

6. The collector of a transistor is _______ doped.
(a) heavily
(b) moderately
(c) lightly
(d) none of the above
Hint: Think about the doping concentration needed for efficient charge carrier collection.
Ans: (b)

7. A transistor is a ___________ operated device.
(a) current
(b) voltage
(c) both voltage and current
(d) none of the above
Hint: Consider how a transistor responds to different types of input signals.
Ans: (a)

8. In an npn transistor ___________ are the minority carriers.
(a) free electrons
(b) holes
(c) donor ions
(d) acceptor ions
Hint: Think about the behavior of charge carriers in an npn transistor.
Ans: (b)

9. The emitter of a transistor is__________ doped.
(a) lightly
(b) heavily
(c) moderately
(d) none of the above
Hint: Consider the doping concentration required for efficient emitter injection.
Ans: (b)

10. In a transistor, the base current is about___________ of emitter current.
(a) 25%
(b) 20%
(c) 35%
(d) 5%
Hint: Consider the typical ratio between base current and emitter current in transistor operation.
Ans: (d)

11. At the base-emitter junction of a transistor, one finds ___________

(a) reverse bias
(b) a wide depletion layer
(c) low resistance
(d) none of the above
Hint: Consider the typical characteristics of the base-emitter junction in a transistor.
Ans: (c)

12. The input impedance of a transistor is ......
(a) high
(b) low
(c) very high
(d) almost zero
Hint: Think about the ease of input signal application to a transistor.
Ans: (b)

13. Most of the majority carriers from the emitter __________
(a) recombine in the base
(b) recombine in the emitter
(c) pass through the base region to the collector
(d) none of the above
Hint: Consider the behavior of majority carriers in a transistor's operation.
Ans: (c)

14. The current I_B is _________
(a) electron current
(b) hole current
(c) donor ion current
(d) acceptor ion current
Hint: Think about the type of charge carriers involved in the base current.
Ans: (a)

15. In a transistor ___________
(a)$I_C = I_E + I_B$
(b) $I_B = I_C + I_E$
(c) $I_E = I_C - I_B$
(d) $I_E = I_C + I_B$
Hint: Consider the relationship between collector, emitter, and base currents in a transistor.
Ans: (d)

16. The value of α of a transistor is___________
(a) more than 1
(b) less than 1
(c) 1
(d) none of the above

Hint: Recall the definition and typical range of the current gain parameter α for transistors.
Ans: (b)

17. $I_C = \alpha I_E +$ ___________
(a) I_B
(b) I_{CEO}
(c) I_{CBO}
(d) βI_B
Hint: Consider the relationship between collector current, emitter current, and base current in a transistor.
Ans: (c)

18. The output impedance of a transistor is ____________
(a) high
(b) zero
(c) low
(d) very low
Hint: Think about the impedance seen at the collector terminal of a transistor.
Ans: (a)

19. In a transistor, I_C = 100 mA and I_E = 100.5 mA. The value of β is__________
(a) 100
(b) 50
(c) about 1
(d) 200
Hint: Use the relationship between collector current, emitter current, and base current to calculate β.
Ans: (d)

20. In a transistor if β = 100 and collector current is 10 mA, then I_E is __________
(a) 100 mA
(b) 100.1 mA
(c) 110 mA
(d) none of the above
Hint: Apply the relationship between collector current, emitter current, and β to find IE.
Ans: (b)

21. The relation between α and β is __________
(a) β = 1/(1-α)
(b) β = (1-α)/α
(c) β = α/(1-α)
(d) β = α/(1+α)
Hint: Think about the relationship between the current gain parameters α and β.
Ans: (c)

22. The value of β for a transistor is generally _______________
(a) 1
(b) less than 1
(c) between 20 and 500
(d) above 500
Hint: Consider the typical range of β values for transistors.
Ans: (c)

23. The most commonly used transistor arrangement is___________ arrangement.
(a) common emitter
(b) common base
(c) common collector
(d) none of the above
Hint: Think about the transistor configuration commonly used in amplifier circuits.
Ans: (a)

24. The input impedance of a transistor connected in___________ arrangement is the highest.
(a) common emitter
(b) common base
(c) common collector
(d) none of the above
Hint: Consider the configuration that provides the highest input impedance.
Ans: (b)

25. The output impedance of a transistor connected in_________ arrangement is the highest.
(a) common emitter
(b) common collector
(c) common base
(d) none of the above
Hint: Think about the configuration that provides the highest output impedance.
Ans: (c)

26. The phase difference between the input and output voltages in a common base arrangement is _________
(a) 180°
(b) 90°
(c) 270°
(d) 0°
Hint: Consider the phase relationship between input and output signals in different transistor configurations.
Ans: (d)

27. The power gain of a transistor connected in ______________ arrangement is the highest.

(a) common emitter
(b) common base
(c) common collector
(d) none of the above
Hint: Think about the configuration that typically provides the highest power gain.
Ans: (a)

28. The phase difference between the input and output voltages of a transistor connected in common emitter arrangement is _______________
(a) 0^o
(b) 180^o
(c) 90^o
(d) 270^o
Hint: Consider the phase relationship between input and output signals in common emitter configuration.
Ans: (b)

29. The voltage gain of a transistor connected in arrangement is the highest.
(a) common base
(b) common collector
(c) common emitter
(d) none of the above
Hint: Think about the configuration that typically provides the highest voltage gain.
Ans: (c)

30. As the temperature of a transistor goes up, the base-emitter resistance ....
(a) decreases
(b) increases
(c) remains the same
(d) none of the above
Hint: Consider the effect of temperature on the semiconductor properties of the transistor.
Ans: (a)

31. The voltage gain of a transistor connected in common collector arrangement is ....
(a) equal to 1
(b) more than 10
(c) more than 100
(d) less than 1
Hint: Consider the typical voltage gain characteristics of a common collector configuration.
Ans: (d)

32. The phase difference between the input and output voltages of a transistor connected in common collector arrangement is ....
(a)180^o

(b) 0^o
(c) 90^o
(d) 270^o
Hint: Think about the phase relationship between input and output signals in a common collector configuration.
Ans: (b)

33. $I_C = \beta I_B$ + ...
(a) I_{CBO}
(b) I_C
(c) I_{CEO}
(d) αI_E
Hint: Consider the additional term related to the transistor's characteristics.
Ans: (c)

34. $I_C = \frac{\alpha}{1-\alpha} I_B$ + _______
(a) I_{CEO}
(b) I_{CBO}
(c) I_C
(d) $(1-\alpha) I_B$
Hint: Think about the relationship between collector and base currents in a transistor.
Ans: (a)

35. $I_C = \frac{\alpha}{1-\alpha} I_B + \frac{\_\_\_}{(1-\alpha)}$
(a) I_{CBO}
(b) I_{CEO}
(c) I_C
(d) I_E
Hint: Consider the additional term related to the transistor's characteristics.
Ans: (a)

36. BC 147 transistor indicates that it is made of ....
(a) germanium
(b) silicon
(c) carbon
(d) none of the above
Hint: Consider the common semiconductor materials used in transistor manufacturing.
Ans: (b)

37. I_{CEO} = (______) I_{CBO}
(a) β
(b) $1 + \alpha$
(c) $1 + \beta$

(d) none of the above

Hint: Think about the relationship between ICEO and ICBO in terms of transistor parameters.

Ans: (c)

38. A transistor is connected in CB mode. If it is now connected in CE mode with same bias voltages, the values of I_E, I_B and I_C will_______________

(a) remain the same
(b) increase
(c) decrease
(d) none of the above

Hint: Consider the differences in configurations and their effects on transistor parameters.

Ans: (a)

39. If the value of α is 0.9, then value of β is ....

(a) 9
(b) 0.9
(c) 900
(d) 90

Hint: Use the relationship between α and β to calculate the value of β.

Ans: (d)

40. In a transistor, signal is transferred from a _____________ circuit.

(a) high resistance to low resistance
(b) low resistance to high resistance
(c) high resistance to high resistance
(d) low resistance to low resistance

Hint: Consider the flow of signal through different parts of the transistor.

Ans: (b)

41. The arrow in the symbol of a transistor indicates the direction of ____________

(a) electron current in the emitter
(b) electron current in the collector
(c) hole current in the emitter
(d) donor ion current

Hint: Consider the conventional current flow direction in the transistor.

Ans: (c)

42. The leakage current in CE arrangement is ___________ that in CB arrangement.

(a) more than
(b) less than
(c) the same as
(d) none of the above

Hint: Compare the leakage characteristics of transistors in different configurations.

Ans: (a)

43. A heat sink is generally used with a transistor to _________
(a) increase the forward current
(b) decrease the forward current
(c) compensate for excessive doping
(d) prevent excessive temperature rise
Hint: Think about the purpose of a heat sink in electronic devices.
Ans: (d)

44. The most commonly used semiconductor in the manufacture of a transistor is _________
(a) germanium
(b) silicon
(c) carbon
(d) none of the above
Hint: Consider the semiconductor material commonly used in transistor fabrication.
Ans: (b)

45. The collector-base junction in a transistor has _____________
(a) forward bias at all times
(b) reverse bias at all times
(c) low resistance
(d) none of the above
Hint: Think about the biasing conditions and characteristics of the collector-base junction.
Ans: (b)

46. In a common emitter transistor configuration, the output voltage is taken across ___________
(a) base-emitter junction
(b) base-collector junction
(c) collector
(d) emitter
Hint: Consider the terminal where the output signal is usually measured in a common emitter setup.
Ans: (c)

47. The purpose of the base region in a transistor is to ___________
(a) amplify the input signal
(b) provide a path for majority carriers
(c) act as a barrier for majority carriers
(d) control the flow of majority carriers
Hint: Think about the role of the base region in transistor operation.
Ans: (d)

48. The common emitter configuration provides ___________.
(a) Highest voltage gain and current gain
(b) Highest voltage gain and lowest current gain
(c) Lowest voltage gain and highest current gain
(d) Lowest voltage gain and current gain
Hint: Consider the characteristics of different transistor configurations.
Ans: (a)

49. The primary purpose of biasing in transistor circuits is to ___________.
(a) Maintain the operating point stable
(b) Increase the voltage gain
(c) Decrease the collector current
(d) Prevent the transistor from overheating
Hint: Think about why biasing is necessary for proper transistor operation.
Ans: (a)

50. The primary function of the emitter in a transistor is to ___________.
(a) Provide a path for majority carriers
(b) Increase the breakdown voltage
(c) Increase the base current
(d) Decrease the collector current
Hint: Consider the role of the emitter region in transistor operation.
Ans: (a)

Unit – VIII

Unit VII

(Electronic Instrumentation)

Summary

- **A multimeter is an electrical measuring instrument used for measuring voltage, current, resistance, and other electrical parameters. It can measure “multiple” electrical quantities that depend on the type of multimeter.**
- To measure dc voltage, suitable range resistances are connected in series with galvanometer. Now switching to dc position with desired ranre selection, one measures the dc voltage from the galvanometer.
- To measure ac voltage, a bridge type full wave rectifier is used. It converts ac into dc and thus by switching to ac position with desired range selection, one measures the ac voltage.
- To measure dc current, low resistances are connected in parallel with galvanometer. Now switching to dc position with desired range selection, one measures the dc current.
- To measure ac current, once again a bridge type full wave rectifier is used. It converts the ac to be measured into dc which can be measured by the same galvanometer.
- To measure resistance, one chooses the proper range and galvanometer is taken which is calibrated directly in ohms. Before using the multimeter one should short the terminals in ohmmeter position and inbuilt small resistance is adjusted to get the reading zero ohm.
- **The cathode-ray oscilloscope is designed as a measuring instrument that displays signal information in the form of a graph or trace on the face of a cathode-ray tube.**
- The **cathode-ray tube** consists of an electron gun which produces and focuses a thin beam of electrons onto a fluorescent screen. The latter glows at the point of impact of the electrons.
- A deflection system deflects the electron beam electrostatically in accordance with the voltage waveform to be displayed. Deflections in the vertical direction are controlled by applying voltages to a pair of Y-plates. These voltage waveforms are those of the signal to be examined. Deflections in the horizontal direction are controlled by applying voltages to the X-plates. Usually, the horizontal deflections must be proportional to time because the phenomena usually studied are time-dependent. The necessary X-voltages are produced by a saw-tooth oscillator. Both X- and Y-amplifiers are re- quired to amplify the control signals before application to the X- and Y- plates.
- Double-beam tubes are available to enable two signals to be displayed simultaneously.
- Voltage and time measurements can be made by using the calibrated controls of the instrument. Alternatively, separate calibrated signals of known magnitude can be used. Frequency measurements can be made by observing Lissajous' patterns. For these the time base is made inoperative and the two signals whose frequencies are to

be compared are applied to the X- and Y- inputs respectively. Phase differences and waveform analyses can be made by a proper interpretation of the patterns or graphs produced on the screen.

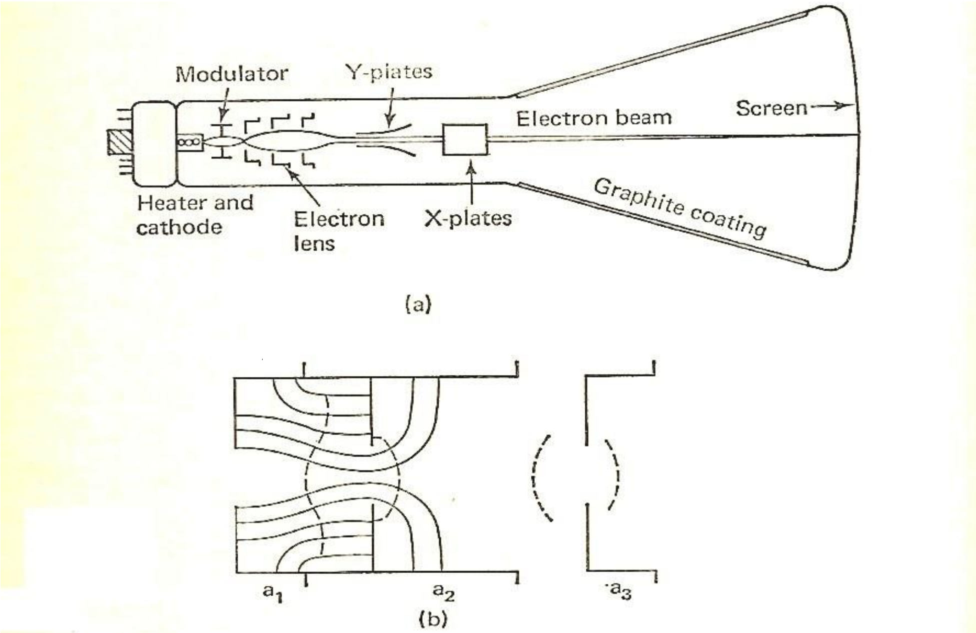


Fig. 1 . (a) Diagrammatic representation of a cathode-ray tube showing the main electrode features. (b) The electric field within the three-anode electron lens system. The solid lines show the shape of the electric field, and the broken lines show the position of the equipotential surfaces. The similarity between the shape of the equipotential lines and that of converging glass lenses should be noted.

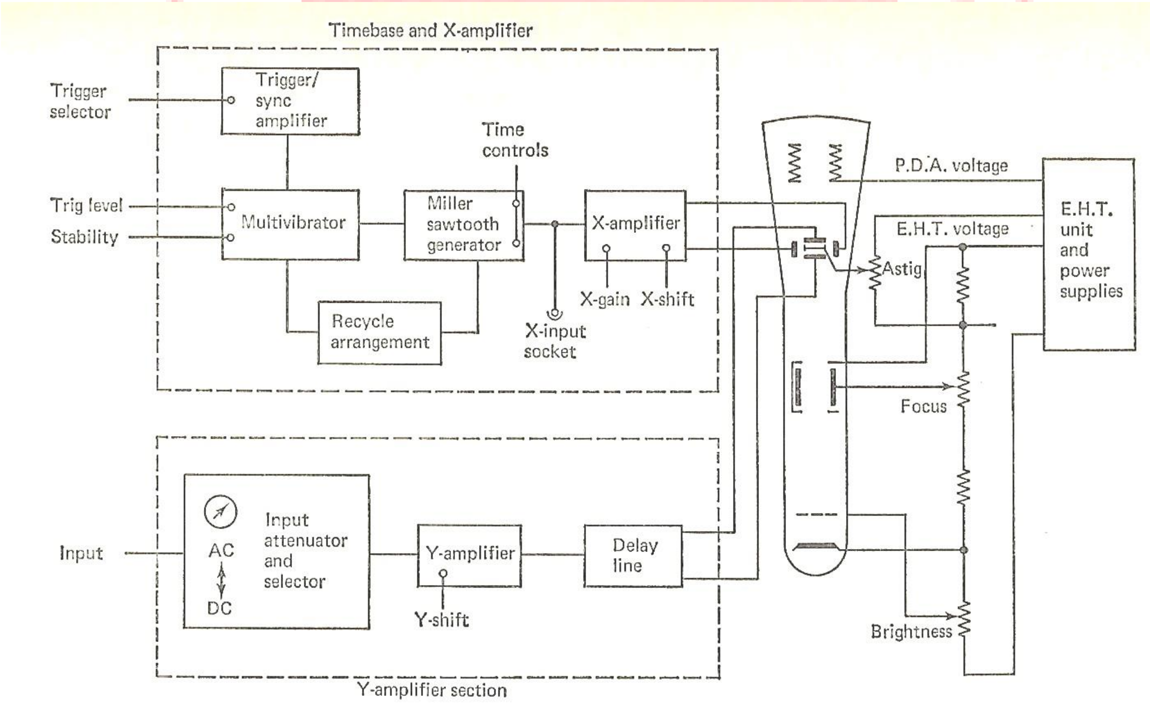


Fig. 2 . Block diagram showing the basic sections of a modern oscilloscope. Double-beam instruments have the Y-section duplicated and use a beam-switching circuit or a double-beam tube.

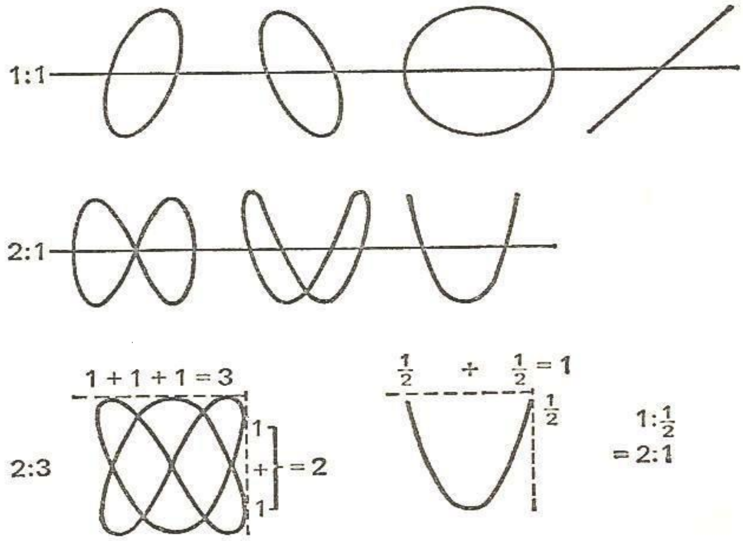


Fig. 4 . Typical Lissajous' patterns (for the significance of the figures and the estimation of the frequency ratios see text).

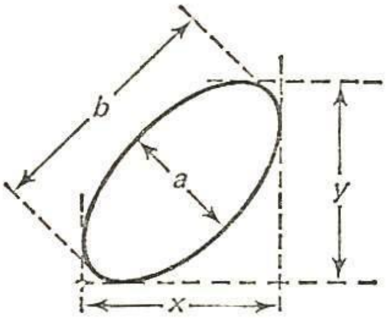


Fig. 5 . When the phase shift in a network or amplifier is required, the input and output voltages can be fed to the X and Y inputs to produce the 1:1 Lissajous figure. The gain settings must be such that the amplitudes of the voltages presented to the deflector plates produce a pattern in which $x = y$. The phase angle φ is then given by

$$\text{Tan}\,\frac{\varphi}{2} = \frac{a}{b}$$

where a and b are the minor and major axes of the ellipse and φ is the phase angle.

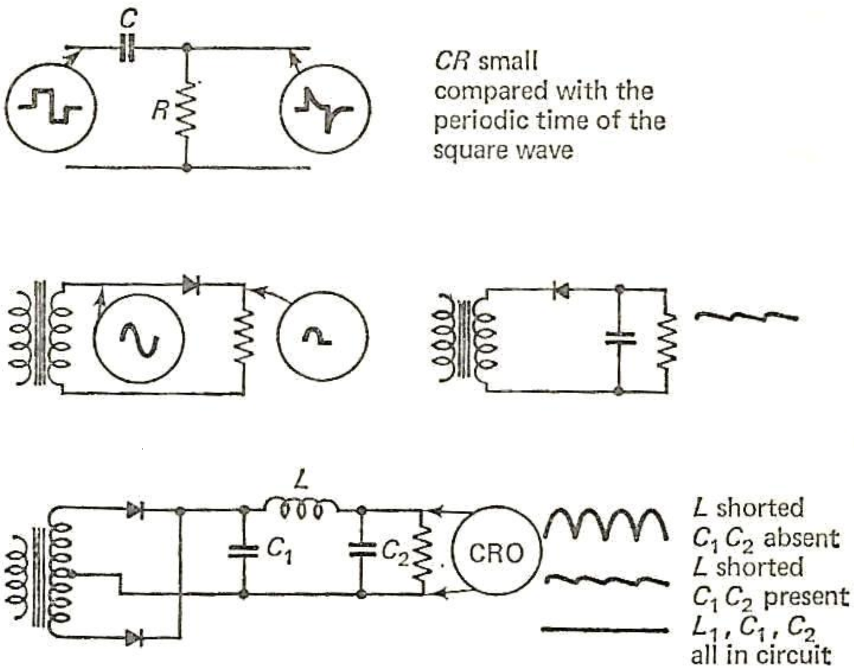


Fig. 6 . Typical traces to be expected when examining the above circuits with a cathode-ray oscilloscope.

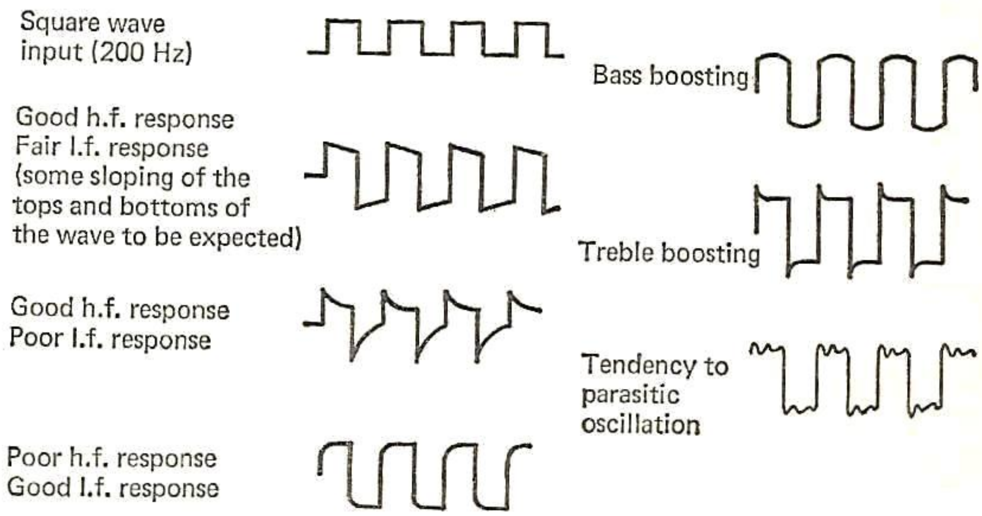


Fig. 7 . Square-wave testing of an audio amplifier.

Multiple Choice Questions and Answers

1. An ammeter is connected in _______ with the circuit element whose current we wish to measure.
   (a) series
   (b) parallel
   (c) series or parallel
   (d) none of the above

Hint: Think about where in the circuit you would place the ammeter to measure current flow.
Ans: (a)

2. A galvanometer in series with a high resistance is called _______________
(a) an ammeter
(b) a voltmeter
(c) a wattmeter
(d) none of the above
Hint: Consider the purpose and setup of a device used to measure voltage.
Ans: (b)

3. An ammeter should have__________ resistance.
(a) infinite
(b) very large
(c) very low
(d) none of the above
Hint: Think about how an ammeter should ideally affect the circuit it's measuring.
Ans: (c)

4. A voltmeter is connected in____________ with the circuit component across which potential difference is to be measured.
(a) parallel
(b) series
(c) series or parallel
(d) none of the above
Hint: Consider how a voltmeter is typically connected to measure voltage.
Ans: (a)

5. A voltmeter should have __________ resistance.
(a) zero
(b) very high
(c) very low
(d) none of the above
Hint: Think about what kind of resistance would be ideal for measuring voltage without affecting the circuit significantly.
Ans: (b)

6. The sensitivity of a multimeter is given in
(a) Λ
(b) amperes
(c) kΛ/V
(d) none of the above
Hint: Consider what unit would be used to express the sensitivity of a multimeter.

Ans: (c)

7. If the full-scale deflection current of a multimeter is 50 µA, its sensitivity is______________

(a) 10 k Λ /V
(b) 100 k Λ /V
(c) 50 k Λ /V
(d) 20 k Λ /V
Hint: Calculate the sensitivity based on the given full-scale deflection current.
Ans: (d)

8. If a multimeter has a sensitivity of 1000 Λ per volt and reads 50 V full scale, its internal resistance is_______________

(a) 20 k Λ
(b) 50 k Λ
(c) 10 k Λ
(d) none of the above
Hint: Use the sensitivity and full-scale voltage to calculate the internal resistance.
Ans: (b)

9. A VTVM has ___________ input resistance than that of a multimeter.

(a) more
(b) less
(c) same
(d) none of the above
Hint: Consider the differences between VTVM and a regular multimeter.
Ans: (a)

10. The input resistance of a VTVM is about ________________

(a) 1000 Λ
(b) 10 k Λ
(c) 20 k Λ
(d) 10 M Λ
Hint: Consider typical values for the input resistance of a VTVM.
Ans: (d)

11. If the negative potential on the control grid of CRT is increased, the intensity of spot __________

(a) is increased
(b) is decreased
(c) remains the same
(d) none of the above
Hint: Consider the effect of the control grid potential on the intensity of the spot on the CRT screen.

Ans: (b)

12. For display of signal pattern _________ voltage is applied to the horizontal plates of a CRO.

(a) sinusoidal
(b) rectangular
(c) sawtooth
(d) none of the above

Hint: Think about the type of signal pattern typically displayed on a CRO and what type of voltage would be needed to generate it.

Ans: (c)

13. Two multimeters A and B have sensitivities of 10 k Λ /V and 30 k Λ /V respectively. Then _______

(a) multimeter A is more sensitive
(b) multimeter B is more sensitive
(c) both are equally sensitive
(d) none of the above

Hint: Compare the sensitivities of the two multimeters to determine which one is more sensitive.

Ans: (b)

14. A galvanometer of resistance G is shunted by a very small resistance S. The resistance of the resulting ammeter is _________

(a) GS/(G+S)
(b) G + S
(c) G - S
(d) none of the above

Hint: Consider the effect of the shunt resistance on the overall resistance of the ammeter.

Ans: (a)

15. A VTVM is never used to measure ____________

(a) voltage
(b) current
(c) resistance
(d) none of the above

Hint: Consider the specific purpose of a VTVM and what quantities it is designed to measure.

Ans: (b)

16. The sensitivity of a voltmeter which uses a 100 μA meter movement is___________

(a) 1 k Λ /V
(b) 10 k Λ /V
(c) 5 k Λ /V

(d) data insufficient
Hint: Use the given meter movement current to calculate the sensitivity.
Ans: (b)

17. What is the total resistance of a voltmeter on the 10 V range when the meter movement is rated for 50 µA of full-scale current?
(a) 10 k Λ
(b) 20 k Λ
(c) 200 k Λ
(d) none of the above
Hint: Consider the formula for calculating the total resistance of a voltmeter.
Ans: (c)

18. The material used to coat inside face of CRT is ___________
(a) carbon
(b) sulphur
(c) silicon
(d) phosphorus
Hint: Think about the properties of materials suitable for coating the inside face of a CRT.
Ans: (d)

19. When an ammeter is inserted in the circuit, the circuit current will ___________
(a) increase
(b) decrease
(c) remain the same
(d) none of the above
Hint: Consider how adding an ammeter would affect the overall resistance in the circuit.
Ans: (b)

20. A series ohmmeter circuit uses a 3 V battery and a 1 mA meter movement. What is the half-scale resistance for this movement?
(a) 3 k Λ
(b) 1.5 k Λ
(c) 4.5 k Λ
(d) 6 k Λ
Hint: Use the given information to calculate the resistance.
Ans: (a)

21. The most accurate device for measuring voltage is _________
(a) voltmeter
(b) multimeter
(c) CRO
(d) VTVM
Hint: Consider the accuracy and capabilities of each device in measuring voltage.

Ans: (c)

22. The horizontal plates of a CRO are supplied with __________ to observe the waveform of a signal.
(a) sinusoidal wave
(b) cosine wave
(c) sawtooth wave
(d) none of the above
Hint: Think about the type of wave typically used to drive the horizontal plates for waveform observation.
Ans: (c)

23. A CRO is used to measure ....
(a) voltage
(b) frequency
(c) phase
(d) all of the above
Hint: Consider the various parameters a CRO can measure.
Ans: (d)

24. If 2 % of the main current is to be passed through a galvanometer of resistance G, then
(a) G/50
(b) G/49
(c) 49 G
(d) 50G
Hint: Use the formula for calculating the required shunt resistance.
Ans: (b)

25. Which of the following is likely to have the largest resistance?
(a) voltmeter of range 10 V
(b) moving coil galvanometer
(c) ammeter of range 1 A
(d) a copper wire of length 1 m and diameter 3 mm
Hint: Compare the typical resistances of each device.
Ans: (a)

26. An ideal ammeter has _________ resistance.
(a) low
(b) infinite
(c) zero
(d) high
Hint: Consider the ideal characteristics of an ammeter.
Ans: (c)

27. The resistance of an ideal voltmeter is __________
   (a) low
   (b) infinite
   (c) zero
   (d) high
   Hint: Consider the ideal characteristics of a voltmeter.
   Ans: (b)

28. To send 10% of the main current through a moving coil galvanometer of resistance 99 Λ, the shunt required is _________
   (a) 11 Λ
   (b) 9.9 Λ
   (c) 100 Λ
   (d) 9 Λ
   Hint: Use the formula for calculating the required shunt resistance.
   Ans: (a)

29. A voltmeter has a resistance of G ohms and range V volts. The value of resistance required in series to convert it into voltmeter of range nV is _____________
   (a) nG
   (b) G/n
   (c) G/(n-1)
   (d) (n-1)G
   Hint: Consider the total resistance required for the desired range.
   Ans: (d)

30. An ammeter has a resistance of G ohms and range of I amperes. The value of resistance required in parallel to convert it into an ammeter of range nI is ....
   (a) nG
   (b) (n-1) G
   (c) G/(n-1)
   (d) G/n
   Hint: Consider how the total resistance affects the range of the ammeter.
   Ans: (c)

31. Which one of the following meters cannot be used to test the transistors and diodes?
(a) Voltmeter
(b) Multi-meter
(c) Both a and b
(d) None of the above
Ans: (a)

32. In which one of the following meters the scope of application is vast?
(a) Multi-meter

(b) Voltmeter
(c) Both a and b
(d) None of the above
Ans: (a)

33. When measuring resistance with a multimeter, what should be the condition of the circuit?
(a) Open circuit
(b) Short circuit
(c) Powered on
(d) Powered off
Hint: Consider the impact of current flow on resistance measurement.
Answer: (d) Powered off

34. How does a multimeter typically display continuity?
(a) By emitting a sound
(b) By showing "OL" (Over Limit)
(c) By displaying "0.00" resistance
(d) By flashing a light
Hint: Think about how a multimeter indicates the presence of continuity in a circuit.
Answer: (a) By emitting a sound

35. What does the abbreviation "DMM" stand for in the context of multimeters?
(a) Digital Multimeter
(b) Direct Measurement Module
(c) Differential Mode Measurement
(d) Dynamic Measurement Method
Hint: Think about the type of multimeter commonly used in modern electrical work.
Answer: (a) Digital Multimeter

36. What feature allows a multimeter to automatically select the appropriate range for a measurement?
(a) Range selector knob
(b) Auto-ranging function
(c) Manual adjustment dial
(d) Backlight display
Hint: Consider the convenience of modern multimeter designs.
Answer: (b) Auto-ranging function

37. What should be the internal resistance of an ideal ammeter?
(a) Infinite
(b) Very low
(c) Very high
(d) Variable

Hint: Consider how the internal resistance of an ammeter affects the circuit it's measuring.
Answer: (b) Very low

38. Why is it essential for an ammeter to have low resistance?
(a) To ensure accurate measurement of voltage
(b) To minimize its effect on the circuit's current flow
(c) To protect the circuit from high voltage spikes
(d) To increase its sensitivity in detecting voltage variations
Hint: Think about the impact of resistance on current measurement.
Answer: (b) To minimize its effect on the circuit's current flow

39. What should you do before connecting an ammeter to a circuit?
(a) Set the range to maximum
(b) Set the range to minimum
(c) Turn off the circuit power
(d) Adjust the ammeter's internal resistance
Hint: Consider safety precautions when working with electrical circuits.
Answer: (c) Turn off the circuit power

40. What happens to the circuit current when an ammeter is inserted into the circuit?
(a) It increases
(b) It decreases
(c) It remains the same
(d) It fluctuates
Hint: Think about the impact of adding additional resistance to the circuit.
Answer: (b) It decreases

41. In an ammeter, what does the term "full-scale deflection" refer to?
(a) The maximum voltage it can measure
(b) The maximum current it can measure
(c) The maximum resistance it can handle
(d) The maximum frequency it can detect
Hint: Think about how the scale of an ammeter is calibrated.
Answer: (b) The maximum current it can measure

42. Which of the following materials is commonly used for the shunt resistor in an ammeter?
(a) Copper
(b) Aluminum
(c) Manganin
(d) Tungsten
Hint: Consider the properties required for a shunt resistor in an ammeter.
Answer: (c) Manganin

43. In what unit is the sensitivity of a galvanometer typically specified?

(a) Volts (V)
(b) Amperes per Volt (A/V)
(c) Ohms (Ω)
(d) Tesla (T)
Hint: Think about how sensitivity is quantified in terms of current and voltage.
Answer: (b) Amperes per Volt (A/V)

44. What happens if the current exceeds the full-scale deflection of a galvanometer?
(a) The galvanometer becomes damaged
(b) The needle gets stuck at maximum deflection
(c) The resistance of the galvanometer increases
(d) The galvanometer deflects beyond the scale limit
Hint: Think about the limitations of a galvanometer's scale.
Answer: (b) The needle gets stuck at maximum deflection

45. What is the primary purpose of shunting a galvanometer?
(a) To increase its sensitivity
(b) To decrease its sensitivity
(c) To protect it from overload
(d) To change its range
Hint: Consider how shunting affects the effective resistance of the galvanometer.
Answer: (c) To protect it from overload

46. Which parameter(s) can be measured using a CRT?
(a) Voltage only
(b) Frequency only
(c) Phase only
(d) Voltage, frequency, and phase
Hint: Think about the capabilities of a CRT in terms of measurement.
Answer: (d) Voltage, frequency, and phase

47. What is the purpose of the control grid in a CRT?
(a) To focus the electron beam
(b) To accelerate the electrons
(c) To control the intensity of the electron beam
(d) To deflect the electron beam
Hint: Think about how the control grid affects the behavior of the electron beam.
Answer: (c) To control the intensity of the electron beam

48. How does increasing the negative potential on the control grid affect the electron beam in a CRT?
(a) It increases the intensity of the beam
(b) It decreases the intensity of the beam
(c) It changes the color of the beam

(d) It has no effect on the beam
Hint: Consider the impact of control grid potential on the behavior of the electron beam.
Answer: (b) It decreases the intensity of the beam

49. What type of waveform voltage is typically applied to the horizontal plates of a CRT to observe signal patterns?
(a) Sinusoidal
(b) Rectangular
(c) Sawtooth
(d) Triangular
Hint: Consider the waveform necessary for displaying signal patterns accurately.
Answer: (c) Sawtooth

50. What is the purpose of the phosphor coating on the inside face of a CRT?
(a) To generate the electron beam
(b) To control the intensity of the electron beam
(c) To convert electron energy into visible light
(d) To amplify electrical signals
Hint: Think about the role of phosphor in producing visible images on a CRT screen.
Answer: (c) To convert electron energy into visible light

Model Question Paper (B010201T)
Thermal Physics and Semiconductor Devices

1. Which of the following is state function?
a) Temperature
b) Heat
c) Internal Energy
d) Work
Ans. c) Internal Energy

2. First law of thermodynamics is based upon
a) law of conservation of charge
b) law of conservation of energy
c) law of conservation of momentum
d) law of conservation of angular momentum
Ans. b) law of conservation of energy

3. Thermal radiation extends over the range of:
a) 0.01 μm to 0.1 μm
b) 0.1 μm to 100 μm
c) 100 μm to 250 μm
d) 250 μm to 1000 μm
Ans. b) 0.1 μm to 100 μm

4. Who studied the spectrum of black body radiation?
a) Ferry
b) Maxwell
c) Stefan
d) Pringsheim
Ans. d) Pringsheim

5. What type of particle forms the cathode rays in a CRT?
a) Electrons
b) Protons
c) Neutrons
d) Alpha particles
Hint: Consider the charged particle responsible for generating the electron beam in a CRT.
Answer: a) Electrons

6. Which of the following materials is commonly used for making the coil in a galvanometer?
(a) Copper
(b) Aluminum
(c) Nichrome
(d) Manganin
Hint: Consider the properties required for the coil material in a galvanometer.
Answer: (c) Nichrome

7. In a transistor, what region acts as a barrier to the flow of majority charge carriers?
(a) Base region
(b) Collector region
(c) Emitter region
(d) Depletion region
Hint: Think about the structure of a transistor and its regions' roles.
Answer: (d) Depletion region

8. What effect does increasing the current through an ammeter have on its resistance?
(a) Resistance decreases
(b) Resistance increases
(c) Resistance remains constant
(d) Resistance becomes negative
Hint: Think about how the design of an ammeter affects its resistance.
Answer: (a) Resistance decreases

9. Pressure of radiation P is related to the total energy incident on the surface per unit area per second E as: [c is the velocity of light]
a) P = Ec
b) $P = Ec^2$
c) P = E/c
d) $P = E/c^2$
Ans. c) P = E/c

10. As the wavelength of the radiation decreases, the intensity of the black body radiations:
a) Increases
b) Decreases
c) First increases and then decreases
d) First decreases and then increase
Ans. c) First increases and then decreases

11. Ideal gas in adiabatic process follow
a) $T^{\gamma}V^{-\gamma}$ = constant
b) $T\ V^{\gamma-1}$ = constant
c) $T\ V^{\gamma+1}$ = constant
d) $T^{\gamma-1}V$ = constant
Ans. b) $T\ V^{\gamma-1}$ = constant

12. Internal energy of a real gas depends upon
a) P
b) V
c) T
d) T and V

Ans. d) T and V

13. For one mole of ideal gas in Isothermal Process, work done is

a) $RTln\left(\frac{V_2}{V_1}\right)$

b) $\frac{R(T_1 - T_2)}{\gamma - 1}$

c) 0

d) PV^{γ}

Ans. a) $RTln\left(\frac{V_2}{V_1}\right)$

14. A perfect gas heat engine operate in carnot cycle between 227^{0}C and 127^{0}C. It absorbs 60000 cals of heat at higher temperature. Amount of heat converted to work is

a) 24000 cals

b) 60000 cals

c) 12000 cals

d) 48000 cals

Ans. c) 12000 cals

15. A refrigerator works between 4^{0}C and 30^{0}C. It is required to remove 600 cals of heat every second in order to keep inside the temperature to be constant. The power required is (Take 1 cal = 4.2 J)

a) 2.365 W

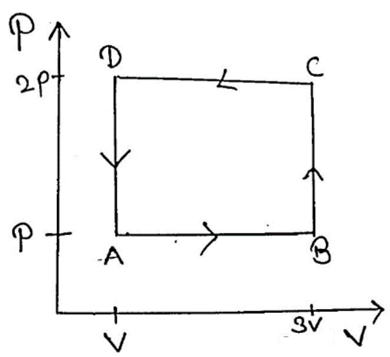
b) 23.65 W

c) 236.5 W

d) 2365 W

Ans. c) 236.5 W

16. A thermodynamic system is taken through the cycle ABCD as shown in fig. Change in internal energy of the gas during the cycle is



a) PV

b) 2PV

c) -2PV

d) 0
Ans. d) 0

17. What principle is utilized in the operation of a moving-coil galvanometer?
(a) Electromagnetic induction
(b) Coulomb's law
(c) Ohm's law
(d) Newton's laws of motion
Hint: Consider the interaction between magnetic fields and electric currents.
Answer: (a) Electromagnetic induction

18. What does the term "sensitivity" of a galvanometer refer to?
(a) Its ability to measure voltage
(b) Its ability to measure resistance
(c) Its ability to detect small currents
(d) Its ability to withstand high currents
Hint: Think about what characteristic allows a galvanometer to detect small currents.
Answer: (c) Its ability to detect small currents

19. What is the function of the emitter in a bipolar junction transistor (BJT)?
(a) To control the flow of current
(b) To provide majority charge carriers
(c) To amplify the input signal
(d) To collect the output signal
Hint: Consider the role of each region in a BJT's operation.
Ans. (b) To provide majority charge carriers

20. Which type of galvanometer is commonly used as the basis for a digital multimeter (DMM)?
(a) Moving-coil galvanometer
(b) Moving-magnet galvanometer
(c) Vibrating-reed galvanometer
(d) Electronic galvanometer
Hint: Consider the technology used in modern digital measurement devices.
Ans. (d) Electronic galvanometer

21. As per Wien's displacement law, the spectral distribution of the energy emitted at a given temperature has:
a) A definite minimum and this minimum shifts to longer wavelengths as the temperature increases
b) A definite minimum and this minimum shifts to shorter wavelengths as the temperature increases
c) A definite maximum and this maximum shifts to shorter wavelengths as the temperature decreases
d) A definite maximum and this maximum shifts to shorter wavelengths as the temperature increases

Ans. d) A definite maximum and this maximum shifts to shorter wavelengths as the temperature increases

22. If wavelength of maximum intensity of radiation emitted by sun and moon are 10^{-6} m and 10^{-4} m resp. the ratio of their temperature is:
a) 2000
b) 1000
c) 100
d) 20
Ans. c) 100

23. Stefan's law states that rate of emission of radiant energy by unit area of perfectly black-body is directly proportional to: [T is the absolute temperature]
a) T
b) T^2
c) T^3
d) T^4
Ans. d) T^4

24. The temperature at which a black body loses thermal energy at the rate of 1watt/cm^2 is: [$(5.672)^{-1/4} = 0.6480$; $\sigma = 5.672 \times 10^{-8}$ W/m^2-K^4]
a) 500 K
b) 648 K
c) 748 K
d) 820 K
Ans, b) 648 K

25. Out of the given options, which one is not a postulate of the kinetic theory of gases?
a) The molecules of a gas are always at rest position
b) The molecules of the gas are point masses
c) The molecules of a gas are perfectly elastic spheres
d) The molecules of a gas are identical
Ans. a) The molecules of a gas are always at rest position

26. The density of hydrogen at N.T.P. is 0.000089 g/cc. The rms velocity for hydrogen is:
a) 2.4×10^2 m/s
b) 11.2×10^2 m/s
c) 18.4×10^2 m/s
d) 38.1×10^2 m/s
Ans. c) 18.4×10^2 m/s

27. Calculate the number of molecules in 1cc of oxygen at NTP given $\rho_{mercury}$ =13.6 g/cm^3, the rms velocity of oxygen molecules at 0^{o}C=7 x10^4cm/s and mass of one molecule of oxygen=50 x10^{-24} g:
a) 1.24×10^{16}
b) 1.24×10^{17}

c) 1.24 x 10^{18}
d) 1.24 x 10^{19}
Ans. d) 1.24 x 10^{19}

28. What will be the temperature when the root-mean-square velocity is double of that at 600 K?
a) 600 K
b) 1200 K
c) 2400 K
d) 4800 K
Ans. c) 2400 K

29. What parameter does a cathode ray tube (CRT) primarily measure?
(a) Voltage
(b) Current
(c) Frequency
(d) Phase
Hint: Think about the role of a CRT in electronic measurement.
Answer: (a) Voltage

30. What is the resistance of a galvanometer used in conjunction with a shunt resistor?
(a) Equal to the shunt resistor
(b) Greater than the shunt resistor
(c) Smaller than the shunt resistor
(d) Equal to the total circuit resistance
Hint: Think about the combined resistance of the galvanometer and the shunt resistor.
Answer: (c) Smaller than the shunt resistor

31. What is the function of the electron gun in a CRT?
(a) To generate X-rays
(b) To produce the electron beam
(c) To amplify electrical signals
(d) To regulate voltage
Hint: Consider the role of the electron gun in the CRT's operation.
Answer: (b) To produce the electron beam

32. Which material is commonly used for coating the inside face of a CRT?
(a) Carbon
(b) Sulphur
(c) Silicon
(d) Phosphorus
Hint: Consider the properties of materials suitable for CRT coatings.
Answer: (d) Phosphorus

33. During compression of the spring, the work done is 10 KJ and 2 KJ of heat is escaped to the surrounding. The change in the internal energy is

a) -8
b) 12
c) 8
d) -12
Ans. c) 8

34. 5 moles of gas are filled in container at 27^0C. If the gas slowly and isothermally compressed to 1/4 of its volume, the work done by the gas is
a) -3000R*ln*2
b) 3000R*ln*2
c) 1500R*ln*2
d) -1500R*ln*2
Ans. a) -3000R*ln*2

35. The capacitance of a PN Junction under reverse bias
a) Increase as the reverse bias is increased
b) Increase as the reverse bias is decreased
c) Mostly depends on the reverse saturation current
d) Renders the junction more effective at higher frequencies
Ans. b) Increase as the reverse bias is decreased

36. The output of rectifier is
a) Unidirectional
b) Bidirectional
c) Both a) and b)
d) None of these
Ans. a) Unidirectional

37. The correct expression is
a) dU = TdS – PdV
b) dF = -PdV – SdT
c) dH = TdS + VdP
d) dG = -VdP – SdT
Ans. d) dG = -VdP – SdT

38. 20 g of water at 40^0C are mixed with 20 g of water at 80^0C. What is the temperature of the mixture.?
a) 60^0C
b) 120^0C
c) 50^0C
d) 0
Ans. a) 60^0C

39. Average energy of a Planck's oscillator is:
a) hν/kT
b) hν

c) hν / ($e^{h\nu/kT}$ – 1)
d) hν / $e^{h\nu/kT}$
Ans. c) hν / ($e^{h\nu/kT}$ – 1)

40. Rayleigh-Jeans law of radiation:
a) Applies to longer wavelengths at higher temperatures
b) Applies to shorter wavelengths at lower temperatures
c) Applies to all wavelengths
d) Does not apply to any wavelength
Ans. a) Applies to longer wavelengths at higher temperatures

41. Equation $P = ke^{-L/RT}$ derive from
a) Clausius-Clapeyron equation
b) Ideal gas equation
c) only from a)
d) both a) and b)
Ans. d) both a) and b)

42. Ist TdS equation is
a) $TdS = C_V dT + T\left(\frac{\partial P}{\partial T}\right)_V dV$
b) $TdS = C_V dT - T\left(\frac{\partial P}{\partial T}\right)_V dV$
c) $TdS = C_P dT + T\left(\frac{\partial P}{\partial T}\right)_P dP$
d) None of these
Ans. a) $TdS = C_V dT + T\left(\frac{\partial P}{\partial T}\right)_V dV$

43. Which terminal of a bipolar junction transistor (BJT) controls the flow of current between the other two terminals?
(a) Base
(b) Emitter
(c) Collector
(d) None of the above
Hint: Think about the role of each terminal in the operation of a BJT.
Answer: (a) Base

44. What type of charge carriers are injected into the base terminal of a bipolar junction transistor (BJT)?
(a) Majority carriers
(b) Minority carriers
(c) Holes
(d) Electrons

Hint: Consider the flow of charge carriers in a BJT and the role of the base terminal.
Answer: (b) Minority carriers

45. What type of material is commonly used for the filament in a cathode ray tube (CRT)?
(a) Copper
(b) Tungsten
(c) Aluminum
(d) Iron
Hint: Consider the properties required for the filament material.
Answer: (b) Tungsten

46. What is the primary function of a galvanometer?
(a) Measure voltage
(b) Measure resistance
(c) Measure current
(d) Measure magnetic field strength
Hint: Consider the principle of operation of a galvanometer.
Answer: (c) Measure current

47. Latent heat varies with temperature as L = 0.705T, specific heat of water at 127^0C is 1.02 cal/gm-^{0}C. The specific heat of vapour at 127^0C (in cal/gm-^{0}C) is
a) 0.98
b) -0.98
c) 0
d) 9.8
Ans. b) -0.98

48. Ice melt at the base but not at the top explain through the equation
a) Ideal gas equation
b) Clausius-Clapeyron equation
c) Ist TdS equation
d) None of these
Ans. b) Clausius-Clapeyron equation

49. "It is impossible to construct a device which when operates in a cycle, extracts heat from a source and converts whole of it into work."
a) Clausius statement
b) Zeroth law of thermodynamics
c) Ist law of thermodynamics
d) Kelvin-Planck statement
Ans. d)

50. According to Maxwell's distribution of velocities, the probability that a molecule will have x-component of velocity in the range v_x to $v_x + dv_x$ is:
a) $(m/2\pi k_BT) \exp[-(m v_x^2/2k_BT)] dv_x$
b) $(m/2\pi k_BT)^{1/2} \exp[-(m v_x^2/2k_BT)] dv_x$

c) $(m/2\pi k_BT)$ exp $[-(m\ v_x/2k_BT)]\ dv_x$
d) $(m/2\pi k_BT)^{1/2}$ exp $[-(m\ v_x/2k_BT)]\ dv_x$
Ans. b) $(m/2\pi k_BT)^{1/2}$ exp $[-(m\ v_x^2/2k_BT)]\ dv_x$

51. Diatomic gas molecule (O_2) has five degrees of freedom. The ratio of translational to rotational degrees of freedom is:
a) 1:4
b) 2:3
c) 3:2
d) 4:1
Ans. c) 3:2

52. The indirect verification of the Maxwell's law of distribution of molecular velocities comes from:
a) Study of the width of spectral line
b) Stern experiment
c) Zartman and Ko experiment
d) Estermann, Simpson and Stern experiment
Ans. a) Study of the width of spectral line

53. The value of Transition or space charge capacitance is
a) $C_T = \frac{\varepsilon A}{T}$
b) $C_T = \frac{\varepsilon A}{V}$
c) $C_T = \frac{\varepsilon A}{I}$
d) None of these
Ans. a)

54. In the manufactured of electronic device Si is preferred to Ge because
a) Si is cheaper than Ge
b) Si is more compact than Ge
c) The leakage current is less in Si than Ge
d) Silicon has better appearance than germanium
Ans. c) The leakage current is less in Si than Ge

55. When an ideal monoatomic gas is heated at constant pressure, the fraction of the heat energy supplied which increases the internal energy of the gas is:
a) 1/2
b) 2/5
c) 2/3
c) 3/7
Ans. c) 2/3

56. At high temperature (750 K), hydrogen molecule possess 7 degrees of freedom. The molar specific heat at constant volume (C_v) is:

a) 9R/2
b) 7R/2
c) 5R/2
d) 3R/2
Ans. b) 7R/2

57. The absolute zero temperature is that temperature at which the average K.E. of translation of each molecule of the gas is:
a) 0
b) kT
c) kT/2
d) 2kT
Ans. a) 0

58. In a CRT, what causes the electron beam to move horizontally across the screen?
(a) Anode voltage
(b) Filament heating
(c) Deflection coils
(d) Phosphor coating
Hint: Consider the component responsible for horizontal beam movement.
Answer: (c) Deflection coils

59. How is a galvanometer typically connected to convert it into an ammeter?
(a) In series with a high resistance
(b) In parallel with a high resistance
(c) In series with the load
(d) In parallel with the load
Answer: (a) In series with a high resistance.

60. Two or more branches in a circuit meet at a point is called
a) Antinode
b) Node
c) Mesh
d) None of these
Ans. b) Node

61. What is the purpose of the base terminal in a bipolar junction transistor (BJT)?
(a) To provide mechanical support
(b) To control the input signal
(c) To provide majority charge carriers
(d) To collect the output signal
Hint: Think about the function of each terminal in a BJT.
Answer: (b) To control the input signal

62. In a bipolar junction transistor (BJT), what happens when a small current flows into the base terminal?

(a) The transistor enters saturation mode
(b) The transistor enters cut-off mode
(c) The transistor undergoes amplification
(d) The transistor experiences breakdown
Hint: Consider the behaviour of a BJT based on the input current at the base terminal.
Answer: (c) The transistor undergoes amplification

63. The semiconductor which comes in the category of direct band gap
a) GaAs
b) Si
c) Ge
d) Si-Ge combination
Answer a) GaAs

64. The device which converts heat into mechanical work is
a) Motor
b) Generator
c) Energy converter
d) Heat engine
Ans. d) Heat engine

65. A silicon sample having intrinsic carrier concentration 1.5* $10^{13}/cm^3$ is doped by a trivalent impurity of $10^{18}/cm^3$ concentratio. After doping the number of electron in the sample will be about
a) $1.5 \times 10^{13}/cm^3$
b) $1.5 \times 10^{31}/cm^3$
c) $1.5 \times 10^{-5}/cm^3$
d) $1.5\times 10^{8}/cm^3$
Answer d) $1.5\times 10^{8}/cm^3$

66. At any temperature fermi energy is that energy
a) Above which all state are empty
b) Below which all state are occupied
c) At which average occupancy is half
d) At which average occupancy is maximum
Answer d) At which average occupancy is maximum

67. When pure germanium is doped with pentavalent impurity, the conduction is due to
a) Electron
b) Holes
c) Positron
d) Photons
Answer a) Electron

68. At absolute zero temperature the resistance of pure silicon is
a) Infinite

b) Zero
c) 10Ω
d) 1Ω
Answer a) Infinite

69. When the temperature of a semiconductor is increased, its resistance
a) Increased
b) Decrease
c) Remains unchanged
d) May increase or decrease
Answer b) Decrease

70. A carnot engine takes 1000 cals of heat at 927^{0}C and reject some part at 27^{0}C. The efficiency of engine is
a) 0.75
b) 0.66
c) 0.33
d) None of these
Ans. a) 0.75

71. The knee voltage in a semiconductor diode is
a) 0.3 for silicon and 0.7 for germanium
b) 0.7 for silicon and 0.3 for germanium
c) 0.7 for both silicon and germanium
d) 0.3 for both silicon and germanium
Answer b) 0.7 for silicon and 0.3 for germanium

72. If n_e and n_h be the number of conduction electron and holes respectively in an intrinsic semiconductor, then
a) $n_h > n_e$
b) $n_h < n_e$
c) $n_h = n_e$
d) $2n_h = n_e$
Answer c) $n_h = n_e$

73. For efficiency of engine to be unity, the temperature of sink must be
a) 0^{0}C
b) 0 K
c) -273^{0}C
d) both b) and c)
Ans. d) both b) and c)

74. If voltage across the Zener diode is 50V and load across the Zener diode is 10 kΩ find load current through load resistance

a) 5×10^{-3} amp
b) 6×10^{-4} amp
c) 1×10^{-5} amp
d) 2 amp
Answer a) 5×10^{-3} amp
Hint: $I_L = \frac{V_Z}{R_L}$

75. A Zener diode has a breakdown voltage 9.1volts with a maximum power dissipation of 364 milliwatts find maximum current diode
a) 40 mA
b) 50 mA
c) 60 mA
d) 55 mA
Answer a) 40 mA
Hint: P_{max} = VI

76. Find static resistance of PN Junction diode if forward voltage is 0.4 volts
a) 300 kΩ
b) 400 kΩ
c) 100 kΩ
d) 600 kΩ
Answer b)
Hint: $R_{AC} = \frac{V}{I}$

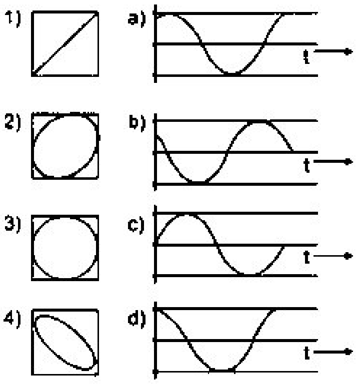
77. Find dynamic resistance of PN Junction diode if forward current is 2μA
a) 0.013 Ω
b) 0.026 Ω
c) 0.001 Ω
d) 0.023 Ω
Answer a) 0.013 Ω

78. Find efficiency of half wave rectifier if diode resistance is 0.2Ω and load resistance is15Ω
a) 39.94%
b) 40.44%
c) 23.44%
d) 44.23%
Answer a) 39.94%

79. P-type semiconductor materials is
a) Silicon doped with indium
b) Silicon
c) Silicon doped with arsenic
d) Germanium

Answer a) Silicon doped with indium

80. Match the following Lissajous figurers to their vertical deflection voltage graph.



a) 1-d, 2-b, 3-c, 4-a
b) 1-b, 2-d, 3-a, 4-c
c) 1-a, 2-d, 3-b, 4-c
d) 1-c, 2-a, 3-d, 4-b
Ans. d) 1-c, 2-a, 3-d, 4-b

81. A commercial power supply has a voltage regulation of
a) 1%
b) 5%
c) 20%
d) 50%
Answer a) 1%

82. If C = 2.0μF and R = 1.0mΩ find the value of time constant
a) 1 sec
b) 2 sec
c) 10 sec
d) 5 sec
Answer b) 2 sec
Hint: time constant = CR

83. A network circuit element without any energy source is
a) Negative network
b) Passive network
c) Active network
d) None of these
Answer b)

84. The average speed of molecule varies with temperature T as V_{av} α T^n then the value of n is
a) 1
b) 2

c) 0
d) 0.5
Ans. d) 0.5

85. In application of superposition theorem, one is required to solve as many circuits an there are
a) Nodes
b) Branches
c) Meshes
d) Sources
Answer d) Sources

86. A solenoid has an inductor of 50 H and resistance 30Ω, it connects to a 100volt battery. Time taken for the current to reach one half of its final equilibrium value
a) 2.15 sec
b) 1.15 sec
c) 4 sec
d) 3 sec
Answer b) 1.15 sec

87. Kirchoff's law is applicable for
a) AC network
b) DC network
c) AC as well as DC network
d) None of these
Ans. c) AC as well as DC network

88. In Norton's equivalent circuit the impedance is connected in
a) Series
b) Parallel
c) Either series or parallel
d) None of these
Answer b) Parallel

89. In the active region the emitter-base junction is --------biased and base-collector junction is---------biased?
a) Reversed biased, Forward biased
b) Forward biased, Forward biased
c) Reversed biased, Reversed biased
d) Forward biased, Reverse biased
Ans. d) Forward biased, Reverse biased

90. Due to forward biasing of emitter-base junction ----------are induced into the base?

a) Minority carriers
b) Majority carriers
c) All the charge carriers
d) Only electrons
Ans. b) Majority carriers

91. In irreversible process change in entropy is
a) Increase
b) Decrease
c) Unchanged
d) None of these
Ans. a) Increase

92. The heavily doped region of the transistor is
a) Emitter
b) Collector
c) Both emitter and collector
d) Only collector
Ans. a) Emitter

93. In the active region, collector current depends upon
a) Collector voltage.
b) Emitter voltage.
c) Emitter current.
d) None of the above.
Ans. d) None of the above.

94. Which one is correct? (Symbols have their usual meaning)
a) $\eta_I > \eta_R$
b) $\eta_I < \eta_R$
c) $\eta_I = \eta_R$
d) None of these
Ans. b) $\eta_I < \eta_R$

95. The width of the depletion region -------------with the magnitude of the reverse voltage?
a) Increases
b) Decreases
c) Remains constant
d) None of these
Ans. a) Increases

96. Under which of the following conditions a Wheatstone bridge is balanced?
a) When no current flows
b) When the temperature of the circuit is high

c) When power dissipation is high
d) When no voltage drop across the galvanometer
Ans. d) When no voltage drop across the galvanometer

97. A multiplier is __________
a) non-capacitive
b) capacitive
c) non-inductive
d) resistive
Ans. c) non-inductive

98. The expression for ripple factor is
a) r = $\sqrt{\frac{I_{rms}^2}{I_{dc}^2}} - 1$
b) r = $\sqrt{\left(\frac{I_{rms}^2}{I_{dc}^2}\right) - 1}$
c) r = $\sqrt{\left(\frac{I_{dc}^2}{I_{rms}^2}\right) - 1}$
d) none of these
Ans. b) r = $\sqrt{\left(\frac{I_{rms}^2}{I_{dc}^2}\right) - 1}$

99. 100 gm of ice at 0^0C converted into water at the same temperature. The latent heat of ice is 80 cal/gm. The change in entropy in calK^{-1}
a) 0.293
b) 2.93
c) 29.3
d) 293
Ans. c) 29.3

100. During Fusion, entropy of system
a) constant
b) decreases
c) increases
d) none of these
Ans. c) increases