23 Electronics and Communication Systems

QUICK LOOK

Thermionic valves or vacuum tubes come in many forms including the diode, triode, tetrode, pentode, heptode and many more. These tubes have been manufactured by the millions in years gone by and even today the basic technology finds applications in today's electronics scene. It was the vacuum tube that first opened the way to what we know as electronics today, enabling first rectifiers and then active devices to be made and used. The simplest form of vacuum tube is the diode, was invented by Fleming while triode valve by Le-de Forst It consists of two electrodes: a cathode and anode held within an evacuated glass bulb, connections being made to them through the glass envelope. The direction of current in the valve is from plate to cathode. The plate resistance of a diode valve at saturation current is infinite. A diode value can be used as a rectifier, detector and modulator while it cannot be used as an amplifier. For an ideal diode, forward resistance is zero; while its reverse resistance is infinity-Potential barrier $V_B = 0$, forward resistance $R_f = 0$ and reverse resistance $R_f = \infty$

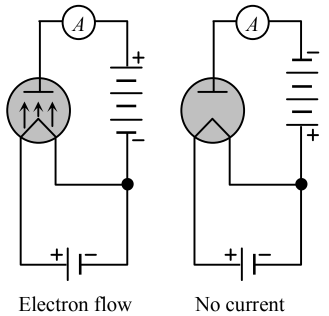


Figure: 23.1

- Richardson's formula for saturation current I_p in a diode value is $I_s = AT^2 e^{-W/RT}$
  where T = absolute temperature,
  W = work function and
  k = Boltzmann constant.
- Child's law for space charge limited current $I_p = kV_p^{3/2}$
  where k = constant

A triode valve can be used as an amplifier and oscillator. The phase difference between input and output voltage in a triode amplifier is π. Triode Valve constants:

- Amplification factor $\mu = -\left(\dfrac{\Delta V_p}{\Delta V_g}\right)_{I_p = \text{constant}}$
- Plate resistance, $R_p = \left(\dfrac{\Delta V_p}{\Delta I_p}\right)_{V_g \text{constant}}$
- Mutual conductance, $g_m = -\left(\dfrac{\Delta V_p}{\Delta V_g}\right)_{V_p = \text{constant}}$
- Relation betweenμ, R_p and g_m is $\mu = R_p \cdot g_m$
- Child's law for triode value is $I_p = K\left(V_p + \mu V_g\right)^{\frac{3}{2}}$

or $I_p = K'\left(\dfrac{V_p}{\mu} + V_g\right)^{\frac{3}{2}}$

- Minimum grid potential for plate current to be zero,
  $V_p = -\dfrac{V_p}{\mu}$
  Voltage gain in a triode amplifier
- $A_v = \dfrac{\text{voltage across load}}{e_g} = -\dfrac{\mu_{R_L}}{R_P + R_L}$
  Maximum Voltage gain, $(A_v)_{\max} = \mu$; for $R_L \to \infty$
  In practice $A_v < A$
  When several stages of amplifier are cascaded, then the net gain $A_v = A_1 \times A_2 \times A_2 \times \ldots$.

Band Theory of Solids: To visualize the difference between conductors, insulators and semiconductors is to plot the available energies for electrons in the materials. Instead of having discrete energies as in the case of free atoms, the available energy states form bands. An important parameter in the band theory is the Fermi level, the top of the available electron energy levels at low temperatures. The position of the Fermi level with the relation to the conduction band is a crucial factor in determining electrical properties.

Table 23.1: Band Theory of Insulator, Semiconductor and Conductor

Insulator	**Semiconductor**	**Conductor**
Energy of electrons Conduction Band Large energy gap between valence and conduction bands Valence Band	Energy of electrons Fermi level Conduction Band Valence Band	Energy of electrons Fermi level Conduction Band Valence Band Overlap region

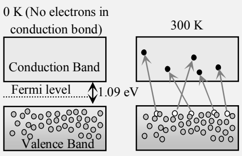
Most solid substances are insulators, and in terms of the band theory of solids this implies that there is a large forbidden gap between the energies of the valence electrons and the energy at which the electrons can move freely through the material (the conduction band).

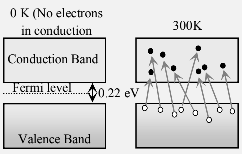
Glass is an insulating material which may be transparent to visible light for reasons closely correlated with its nature as an electrical insulator. The visible properties of glass can also give some insight into the effects of "doping" on the properties of solids. A very small percentage of impurity atoms in the glass can give it color by providing specific available energy levels which absorb certain colors of visible light. The ruby mineral (corundum) is aluminum oxide with a small amount (about 0.05%) of chromium which gives it its characteristic pink or red color by absorbing green and blue light.

For intrinsic semiconductors like silicon and germanium, the Fermi level is essentially halfway between the valence and conduction bands.
Although no conduction occurs at 0 K, at higher temperatures a finite number of electrons can reach the conduction band and provide some current. In doped semiconductors, extra energy levels are added. The doping of semiconductors has a much more dramatic effect on their electrical conductivity.

Silicon and Germanium Energy Bands: The bonding among electrons of germanium and silicon is covalent. Energy band gap in a semi-conductor is of the order of 1 eV.

At finite temperatures, the number of electrons which reach the conduction band and contribute to current can be modeled by the Fermi function. That current is small compared to that in doped semiconductors under the same conditions.





In terms of the band theory of solids, metals are unique as good conductors of electricity. This can be seen to be a result of their valence electrons being essentially free. In the band theory, this is depicted as an overlap of the valence band and the conduction band so that at least a fraction of the valence electrons can move through the material.

Types of Semiconductor (Intrinsic and Extrinsic Semiconductors)

Intrinsic (Pure) Semiconductors: These are the substances without any impurity. Their conductivity is lower than extrinsic semiconductors. They have 4 electrons in their outermost shell. These four electrons forms covalent bond with neighboring atoms. At high temperature some of the covalent bond are broken and electron-hole pairs are created. These electrons are known as free electrons. Free electrons and holes are always equal in number, therefore, semiconductor is always electrically neutral. These free electrons and holes are carriers of electricity in an intrinsic semiconductor.

Extrinsic Semiconductors: An extrinsic semiconductor is a semiconductor doped by a specific impurity which is able to deeply modify its electrical properties, making it suitable for electronic applications (diodes, transistors, etc.) or optoelectronic applications (light emitters and detectors).

- **P-type:** They are impure semiconductors with P-type (trivalent) of impurities doped in. They have majority of holes as charge carriers.
- **N-type:** When N-type (pentavalent) impurity is added to intrinsic semiconductor they become N-type extrinsic semiconductors. Majority carriers are electrons in N-type semiconductors.

Forbidden Energy Gap: The separation between conduction band and valence band on the energy level diagram is called

Forbidden energy gap (E_g). For a semiconductor E_g depends upon the temperature by following relationship.

Table 23.2: E_g at 0°K and room temperature (300°K)

	0°K	**300°K**
Ge	0.785 eV	072 eV
Si	1.21 eV	1.1 eV
	***T* is temperature in °K**	**300°K**
Ge	$E_g(T) = [0.785 - 2.23 \times 10^{-4} T] eV$	$2.5 \times 10^{13} / \mathrm{Cm}^3$
Si	$E_g(T) = [1.21 - 3.6 \times 10^{-4} T] eV$	$1.5 \times 10^{10} / \mathrm{Cm}^3$

Types of Dopings: If trivalent or pentavalent impurities are added to intrinsic semiconductor, extrinsic (impure) semiconductor is formed.

Trivalent Impurities → B, Al, Ga, In, Tl
Pentavalent Impurities → N, P, As, Sb, Bi
Doping can be donor type or acceptor type.

Effect of Doping on Properties of Semiconductor: The doping has following effects on semiconductor.

- Increased number of charge carries (holes or electrons).
- Conductivity (σ) increases ($\because$ $\sigma \propto$ number of charge carriers).
- Fermi levels shifts. It shifts towards valence band for P-type and towards conduction band for N-type semiconductors.
- Concentration of electrons in conduction band increases for N-type semiconductor.

- Concentration of holes in valence band increase for P-type semiconductor.
- For N-type semiconductor, concentration of holes (minority carries falls below the level of holes in intrinsic semiconductor. Since N type semiconductor have large number of electrons, therefore, rate of recombination increases and concentration of holes decreases. Although concentration of electrons also decreases due to recombination but percentage change is negligible, considering large concentration of electrons in N-type semiconductor.
- No. of free electrons fall below intrinsic level for P-type semiconductor in the same manner as explained above.
  From law of neutrality of semiconductor, we have
  Magnitude of positive charge concentration = Magnitude of negative charge concentration
  $\Rightarrow\ N_D + n_h = N_A + n_e$

N-type Semiconductor: N-type semiconducting material does not have acceptor impurities, therefore, $N_A = 0$

And concentration of electrons (n_e) much exceeds the concentration of holes (n_h) i.e., $n_e >> n_h$

Substituting in equation 1, we have $n_D > n_e$

According to mass action law

$$n_e \cdot n_h = n_i^2$$

$$\Rightarrow\ n_D \cdot n_h = n_i^2$$

Therefore, concentration of holes (or hole density), in an N-type semiconductor is

$$n_h = \frac{n_i^2}{N_D}$$

P-type Semiconductor: For a P-type semiconductor we have

$N_D = 0$ and $n_h >> n_e$

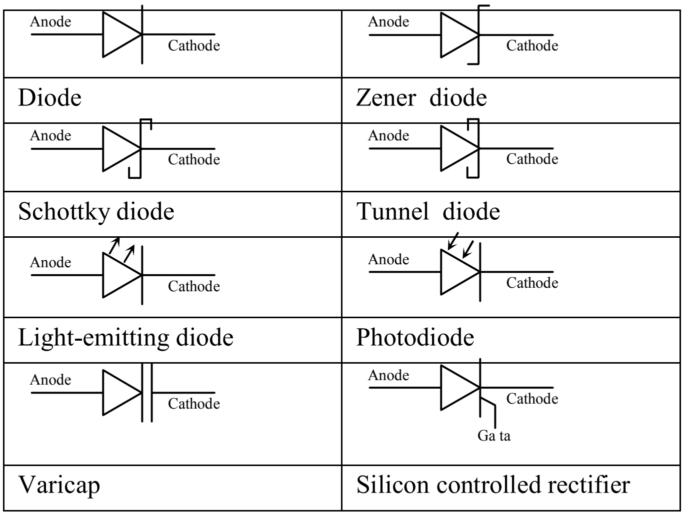
we have $n_h = N_A$

Using mass action law $n_e h_n = n_i^2$

$$N_A n_e = n_i^2$$

Therefore, concentration of electrons (electron density) in P-type semiconductor is $n_e = \dfrac{n_i^2}{N_A}$

PN Junction: The charge carriers in semi-conductors are electrons and holes. Penta-valent impurity mixed semi-conductor are N-type while trivalent impurity mixed semi-conductors are P-type. Types of semiconductor diode:



The charge carriers in P-type semiconductor are holes while those in N-type semi-conductor are electron. Penta-valent impurities are phosphorus, arsenic antimony. Trivalent impurities are aluminium, indium, boron, and gallium.

- Conductivity of an intrinsic semiconductor $\sigma = en_i(\mu_e + \mu_h)$
- Conductivity of an extrinsic semi-conductor $\sigma = e(n_e\mu_e + n_h\mu_h)$

p-n Junction or Diode: Current in biased *p–n* junction $I = I_0(e^{eV/\eta kT} - 1)$

Where I_0 = reverse saturation current

V = applied voltage positive for forward and negative for reverse biased,

η = 1for germanium diode

η = 2 for silicon diode,

T = absolute temperature.

At room temperature T = 300 K; $I = I_0(e^{39V/\eta} - 1)$

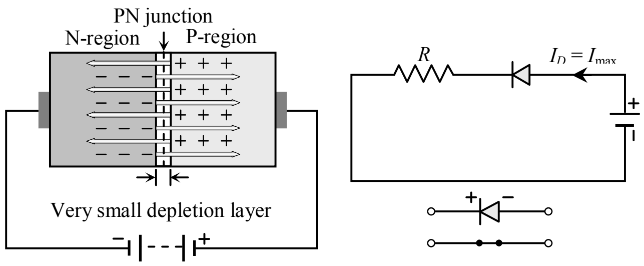


Figure: 23.2 (a)

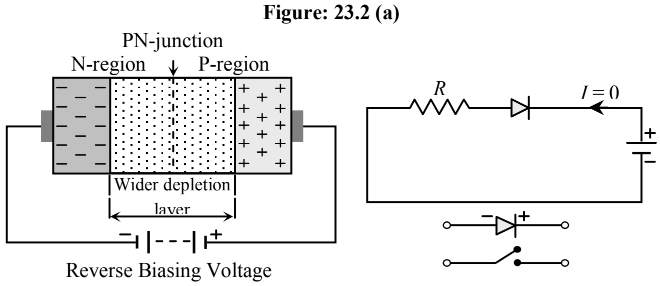


Figure: 23.2 (b)

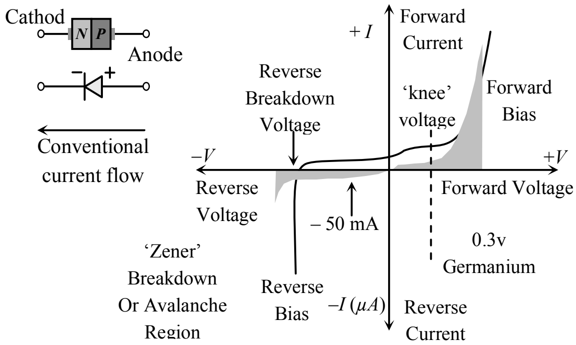


Figure: 23.2 (c)

Load Line Concept: Point or region of operation of devices (i.e., diode, transistor, FET etc.) is decided by applied load. Point of intersection of device characteristics with load line determine the point of operation of the system. The point of operation is usually called the quiescent point (or **Q point**).

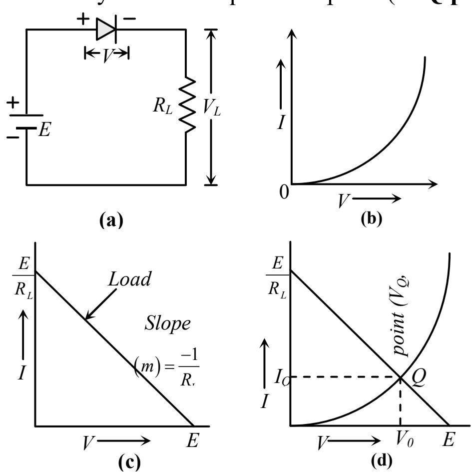


Figure: 23.3 (*a*)) Diode circuit, (*b*)) V-I characteristics in forward region, (*c*) load line and (*d*) combined curve

Diode as circuit element and R_L is load resistance

$$V = E - V_L = E - IR_L$$

$$\Rightarrow \quad I = -\frac{1}{R_L}V + \frac{E}{R_L}$$

Where, I and V represents current carried by diode and voltage drop across diode under forward bias. Equation resembles to that of a straight line (like $y = -mx + c$) and shown in figure 23.3 (c). Intercepts of load line with vertical axis can be found by putting $V = 0$ in the equation $I = \left.\frac{E}{R_L}\right|_{V=0}$

Intercept with horizontal axis is calculated by putting $I = 0$ in equation, therefore,

$$0 = -\frac{V}{R_L} + \frac{E}{R_L} \Rightarrow V = E$$

The slope of the line is dependent only upon load resistance R_L

$$\text{Slope}(m) = -\frac{1}{R_L}$$

Since vertical intercepts as well as slope of the line is dependent upon load R_L , therefore, this line is termed as load line.

Variation of Q-Point: Change of load resistance (R_L) and input voltage (E) changes the load line, therefore, point of intersection of two curves (i.e., Q point changes. Let us see how Q point is varied.

Resistance

- dc resistance of diode $r_{de} = \frac{V}{I}$
- The dynamic (or ac resistance) of diode is $r_{\propto} = \frac{dV}{dI} = \frac{26\eta}{I} k\,\Omega$ (for sufficiently forward biased)

Rectifier: A rectifier converts ac into dc. Junction diodes are used for rectification and detection. A half wave rectifier uses one diode, while full wave diode used two diodes. In a half wave rectifier $I_{\propto} > I_{dc}$ while for a full wave $I_{\propto} < I_{dc}$. Filter circuits are used to reduce/eliminate ripples (ac components), which are simple inductances and capacitance suitably arranged.

- **Half-wave rectifier**

  Currents $I_{dc} = \frac{I_0}{\pi}, I_{rms} = \frac{I_0}{2}$

  Power: DC power, $P_{dc} = I_{dc}^2 R_L$

  AC power $P_{ac} = I_{rms}^2 (R_L + R_F)$

  Efficiency of rectification $\eta_R = \frac{P_{dc}}{P_{ac}} \times 100\% = \frac{40.6}{\left(1 + \frac{R_F}{R_L}\right)}\%$

- **Full wave rectifier**

  Currents $I_{dc} = \frac{2I_0}{\pi}, I_{rms} = \frac{I_0}{\sqrt{2}}$

  Power: $P_{dc} = I_{dc}^2 R_L, P_{ac} = I_{rms}^2 (R_L + R_F)$

  Efficiency of rectification, $\eta_R = \frac{P_{dc}}{P_{ac}} \times 100\% = \frac{81.2}{\left(1 + \frac{R_F}{R_L}\right)}\%$

  Ripple factor, $\gamma = \frac{I_{ac}}{I_{dc}} = 0.482$ i.e., $I_{ac} < I_{dc}$

For transistor or Triode: $I_E = I_B + I_C$

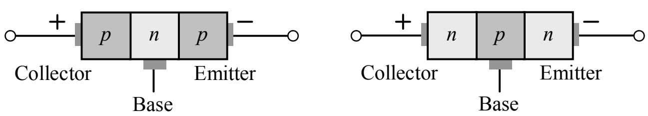


Figure: 23.4 (a)

(a) Construction

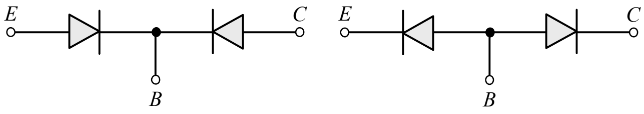


Figure: 23.4 (b)

(b) Two-diode Analogy

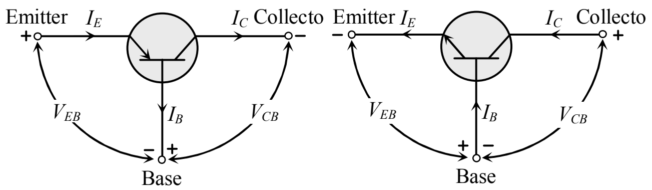
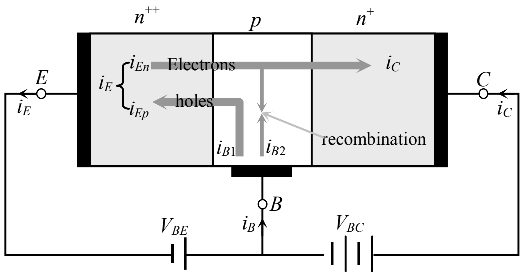


Figure: 23.4 (c)



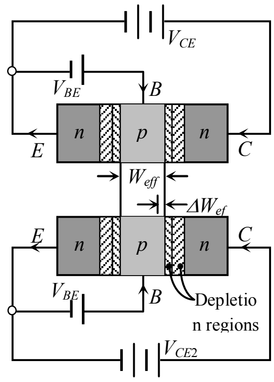


Figure: 23.4 (d)

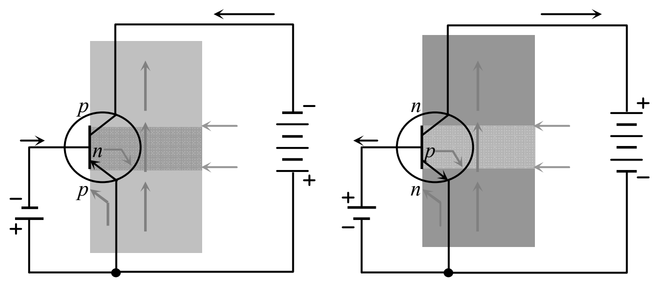


Figure: 23.4 (e)

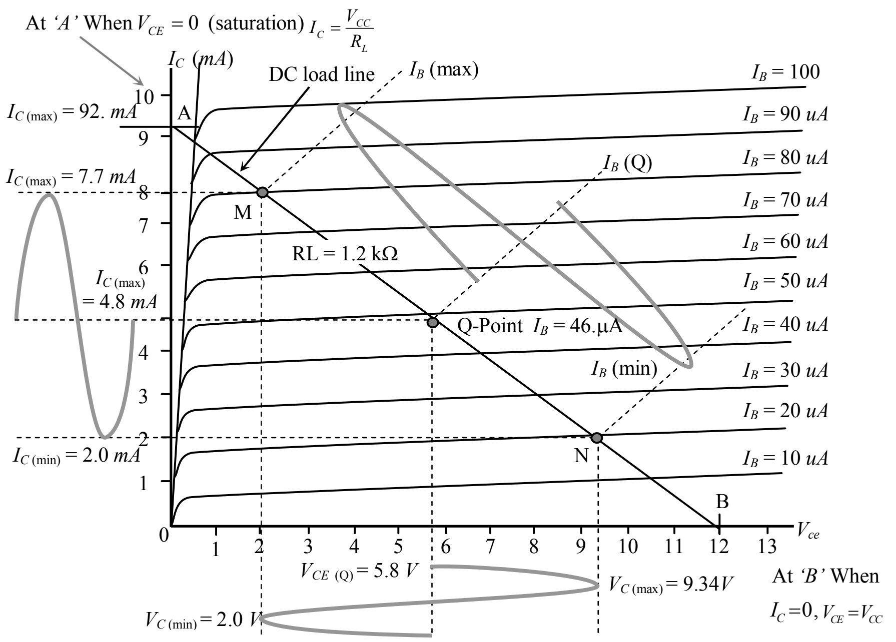


Figure 23.4 (f)

Amplifier: Negative feedback is used in amplifiers to reduce distortions, Voltage gain:

- Common base voltage gain: $A_V = \alpha \dfrac{R_2}{R_1}$
- Current gain of transistor: $\alpha = \left(\dfrac{\Delta I_C}{\Delta I_E}\right)_{V_{CB}} < 1$ (common base configuration)

Note: In common base arrangement there is no phase difference between input and output signals.

- Common emitter voltage gain: $A_V = \beta \dfrac{R_2}{R_1}$
- Current gain of transistor $\beta = \left(\dfrac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}} > 1$ common emitter configuration)

Note: In common emitter arrangement there is a phase difference of π between input and output signals.

- Relation in between β and α: $\beta = \dfrac{\alpha}{1-\alpha}$ or $\alpha = \dfrac{\beta}{\beta+1}$

Transistor as an Oscillator: An oscillator converts dc into ac. Positive feedback is used in oscillators.

Frequency of oscillation $f = \dfrac{1}{2\pi\sqrt{LC}}$

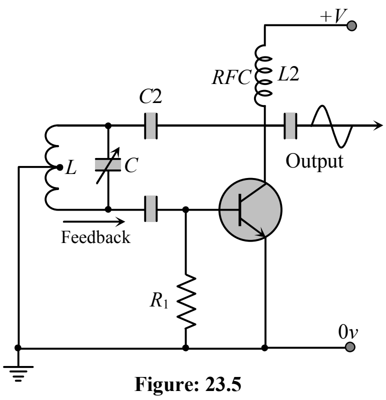


Figure: 23.5

Boolean Algebra and Digital Circuits

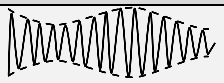
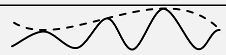
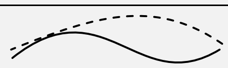
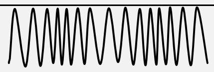
Table 23.3: Logic Gates

	AND	OR	NOT	NAND	NOR	EXCLUSIVE OR	
x	y	$x\cdot y$	$x+y$	$\bar{x}$	$\overline{x\cdot y}$	$\overline{x+y}$	$x\oplus y$
1	1	1	1	0	0	0	0
1	0	0	1	0	1	0	1
0	1	0	1	1	1	0	1
0	0	0	0	1	1	1	0

- **de Morgan's laws:** $\overline{x+y} = \bar{x}.\bar{y}$; $\overline{x\cdot y} = \bar{x}+\bar{y}$
- **Consensus:** $x\cdot y + \bar{x}\cdot z = x\cdot y + \bar{x}\cdot z + y\cdot z$

  $(x+y)\cdot(\bar{x}+z) = (x+y)\cdot(\bar{x}.z)\cdot(y+z)$
- **Absorption:** $x + x\cdot y = x$; $x\cdot(x+y) = x$

Table 23.4: Radio-Band Frequencies

Type	Wave	Frequency
Short wave (AM)		2.30–26, 100 kHz
Medium wave (AM)		525–1,700 kHz
Long wave (AM)		150–300 kHz
VHF (FM)		87–108 kHz

- Sky wave transmission of electromagnetic wave cannot be used for TV transmission why?

  TV transmission takes place at higher frequencies (approx 18 MHz to 200 MHz). Such higher frequencies do not return back to the earth.
- In digital communication, PCM (Pulse Code Modulation) is preferred than PAM (Pulse Amplitude Modulation). Why?

  PCM is free from noise in interfering signals. It is also coded electrical signal. It permits use of repeater for long distance transmission.
- In sending a binary data over an analog transmission line, what kind of device does the conversion?

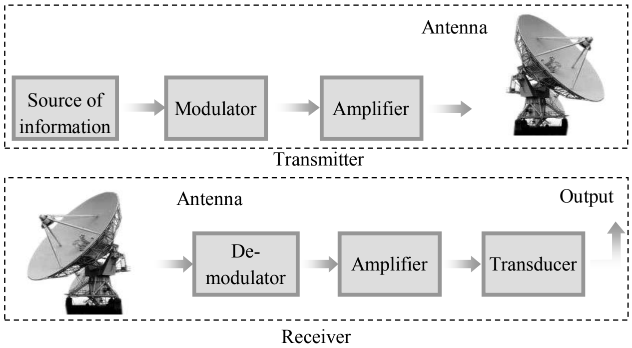


Figure: 23.6

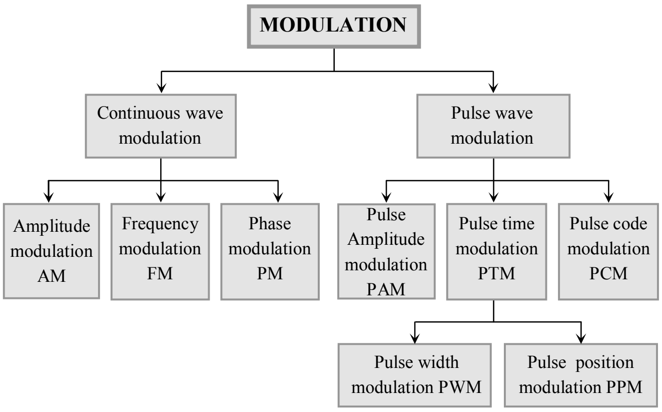
Table 23.5: Analog Communication System

System	Specification
Telegraphy	Message in the form of codes are sent.
Television broadcast	Both sound as well as pictures are sent.
Telephony	It sends voice signal from one place to another by means of wire.
Radar	It means radio detection and ranging. It is used for determining the distance and direction of objects using microwave.
Tele-printing	Message can be typed and telegraphed to distant receivers

Table 23.6: Digital Communication System

System	Specification
Facsimile transmission (FAX)	This involves exact reproduction of a document or picture which are static
Mobile phone	Such telephones are also called cellular phones, because they operate within a network of radio cells.
E-mail	the message sent via a computer network are called e-mail
Teleconferencing	It is a system in which persons sitting at coloured television screens. See and talk to each other via a computer communication network.
Communication satellite	Used to relay radio and television programmers.
Global positioning system (GPS)	It is a navigation system based on a network of earth orbiting satellites. The users can find their positions within an accuracy of 100 *m* by receiving.

The process of placement of a low frequency (LF) signal over the high frequency (HF) signal is known as modulation.



Amplitude Modulated Transmission: Radio waves having frequency less than or equal to 30 MHz form an amplitude modulation band (or AM band). The signals can be transmitted from one place to another place on earth's surface in two ways

- Ground wave propagation: The radio waves following the surface of the earth are called ground waves.
- Sky wave propagation: The amplitude modulated radio waves which are reflected back by the ionosphere are called sky waves.
  Voltage equation for AM wave is $e = E\sin\omega_c t = (E_c + e_m)\sin\omega_c t$
  $= (E_c + e_m \sin\omega_m t)\sin\omega_c t$
  $= E_c \sin\omega_c t + \frac{m_a E_c}{2}\cos(\omega_c - \omega_m)t - \frac{m_a E_c}{2}\cos(\omega_c + \omega_m)t$
- **Band width:** The two side bands lie on either side of the carrier frequency at equal frequency interval f_m. So, band width $= (f_c + f_m) - (f_c - f_m) = 2f_m$
- **Power in AM waves**: Power dissipated in any circuit $P = \frac{V_{rms}^2}{R}$. Carrier power $P_c = \frac{\left(\frac{E_c}{\sqrt{2}}\right)^2}{R} = \frac{E_c^2}{2R}$

  Total power of side bands $P_{sb} = \frac{\left(\frac{m_a E_c}{2\sqrt{2}}\right)^2}{R} + \frac{\left(\frac{m_a E_c}{2\sqrt{2}}\right)}{R}$

  $= \frac{m_a^2 E_c^2}{4R}$

  Total power of AM wave $P_{\text{Total}} = P_c + P_{sb} = \frac{E_c^2}{2R}\left(1 + \frac{m_a^2}{2}\right)$
- $\frac{P_t}{P_c} = \left(1 + \frac{m_a^2}{2}\right)$ and $\frac{P_{sb}}{P_t} = \frac{m_a^2/2}{\left(1 + \frac{m_a^2}{2}\right)}$
- Maximum power in the AM (without distortion) will occur when $m_a = 1$ *i.e.* $P_t = 1.5P = 3P_{sb}$
- If I_c = Unmodulated current and I_t = total or modulated current $\frac{P_t}{P_c} = \frac{I_t^2}{I_c^2} \Rightarrow \frac{I_t}{I_c} = \sqrt{\left(1 + \frac{m_a^2}{2}\right)}$

Frequency Modulation (FM): The process of changing the frequency of a carrier wave in accordance with the audio frequency signal is known as frequency modulation

- **Frequency deviation**

$\therefore\ \delta = (f_{\max} - f_c) = f_c - f_{\min} = k_f . \frac{E_m}{2\pi}$

k_f = Constant of proportionality. It determines the maximum variation in frequency of the modulated wave for a given modulating signal.

- **Carrier swing (CS):** The total variation in frequency from the lowest to the highest is called the carrier swing

i.e. $CS = 2 \times \Delta f$

- **Frequency modulation index (m_f):** The ratio of maximum frequency deviation to the modulating frequency is called modulation index.

  $m_f = \frac{\delta}{f_m} = \frac{f_{\max} - f_c}{f_m} = \frac{f_c - f_{\min}}{f_m} = \frac{k_f E_m}{f_m}$
- **Frequency spectrum:** FM side band modulated signal consist of infinite number of side bands whose frequencies are $(f_c \pm f_m), (f_c \pm 2f_m), (f_c \pm 3f_m)$.......

Pulse Modulation: A system of modulation in which pulses are altered and controlled in order to represent the message to be communicated.

- **Pulse amplitude modulation (PAM):** The amplitude of the pulse varies in accordance with the modulating signal.
- **Pulse width modulation (PWM):** The pulse duration varies in accordance with the modulating signal.
- **Pulse position modulation (PPM):** In PPM, the position of the pulses of the carrier wave train is varied in accordance with the instantaneous value of the modulating signal.

Demodulation: The process of extracting the audio signal from the modulated wave is known as demodulation or detection. The wireless signals consist of radio frequency (high frequency) carrier wave modulated by audio frequency (low frequency). The diaphragm of a telephone receiver or a loud speaker cannot vibrate with high frequency. So it is necessary to separate the audio frequencies from the radio frequency carrier wave.

Modem: In audio transmission: high-level transmission, the powers of the carrier and modulating signals are amplified before applying them to the modulator stage, in low-level modulation, the powers of the two input signals of the modulator stage are not amplified.

Fax (Facsimile Transmission): The electronic reproduction of a document at a distance place is known as facsimile transmission (FAX). The original written document is converted into transmittable codes at the sending end. These codes are converted back into a copy of the original document at the receiving end.

Optical Communication and Optical Fibre

- **Optical Communication:** The use of optical carrier waves for transmission of information from one place to another is called optical communication. The useful optical frequency range is 10^{12} Hz to 10^{16} Hz which is very high as compared to radio and microwave frequencies (10^6 Hz – 10^{11} Hz). The information carrying capacity $\propto$ bandwidth $\propto$ frequency of carrier wave. So optical communication is better than others. (because of high frequency). Light emitting diodes (LED) and diode lasers are preferred for optical source. LED's are used for small distance transmission while diode laser is used for very large distance transmission. In order to transmit information signal via an optical communication system, it is necessary to modulate light with the information signal. The optical signal reaching the receiving end has to be detected by a detector which converts light into electrical signals, So that the transmitted information may be decoded.
- **Optical Fibre:** The optical fibres are used to transmit light signals from one place to another without any practical loss in the intensity of light signal. Optical fibre is made of a thin glass core (diameter 10 to 100 μm) surrounded by a glass coating called cladding are protected by a jacket of plastic.

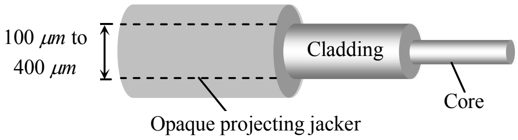


Figure 23.7: Optical Fibre

It works on the principle of total internal reflection. The refractive index of the glass used for making core ($\mu_1 \approx 1.7$) is a little more than the refractive index of the glass ($\mu_2 \approx 1.5$) used for making the cladding *i.e.* $\mu_1 > \mu_2$.

The core dimension is so small (≈ 10 μm) that the light entering will almost essentially be having incident angle (θ_i) more than the critical angle (θ_C) and will suffer total internal reflection at the core. Cladding boundary such successive total reflections at opposite boundaries will confine the light to the core as shown in figure.

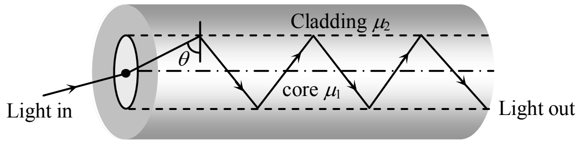


Figure 23.8: Working of Optical Fibre

Critical Angle (θ_c): At core-cladding interface if $\theta = \theta_c$

then $\cos\theta_c = \dfrac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_1} \Rightarrow \theta_c = \cos^{-1}\left(\dfrac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_1}\right)$

Acceptance Angle (θ_a): The value of maximum angle of incidence with the axis of fibre in air for which all the incident light is totally reflected is known as acceptance angle.

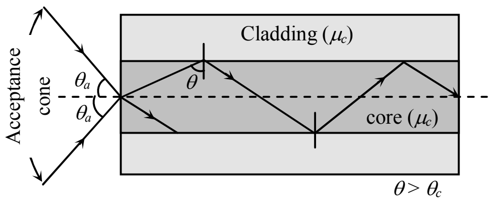
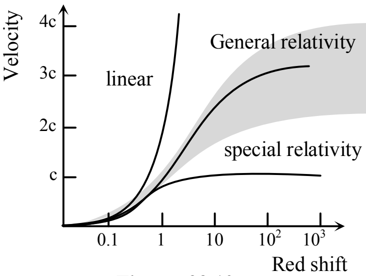


Figure 23.9

If θ_a = Acceptance angle then μ_1 = refractive index of core, μ_2 = refractive index of cladding. $\sin\theta_a = \dfrac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_0}$

$\Rightarrow \theta_a = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2}$ (for air $\mu_0 = 1$)

Hubble's Law: the law that the velocity of recession of distant galaxies from our own is proportional to their distance from us. $v = Hr$ Where, v = velocity and H = Hubble's constant.



Age of the universe

$T_0 < \dfrac{1}{H}$

Figure: 23.10

Hubble's generalized law $c_0 = Hr + \dfrac{H^2 r^2}{2c_0}(q-1)$

Red shift $z = \dfrac{\Delta\lambda}{\lambda}\sqrt{\dfrac{1+\dfrac{v}{c_0}}{1-\dfrac{v}{c_0}}} - 1$

MULTIPLE CHOICE QUESTIONS

Solids and Crystals

1. The nature of binding for a crystal with alternate and evenly spaced positive and negative ions is:
   a. Covalent **b.** Metallic
   c. Dipolar **d.** Ionic
2. In a triclinic crystal system:
   a. $a \neq b \neq c$, $\alpha \neq \beta \neq \gamma$ **b.** $a = b = c$, $\alpha \neq \beta \neq \gamma$
   c. $a \neq b \neq c$, $\alpha \neq \beta = \gamma$ **d.** $a = b \neq c$, $\alpha = \beta = \gamma$
3. The coordination number of Cu is:
   a. 1 **b.** 6
   c. 8 **d.** 12
4. The distance between the body centred atom and a corner atom in sodium (a = 4.225 Å) is:
   a. 3.66 Å **b.** 3.17 Å
   c. 2.99 Å **d.** 2.54 Å
5. The nearest distance between two atoms in case of a bcc lattice is equal to:
   a. $a\frac{\sqrt{2}}{3}$ **b.** $a\frac{\sqrt{3}}{2}$
   c. $q\sqrt{3}$ **d.** $\frac{a}{\sqrt{2}}$
6. Sodium has body centred packing. If the distance between two nearest atoms is 3.7 Å, then its lattice parameter is:
   a. 4.8 Å **b.** 4.3 Å
   c. 3.9 Å **d.** 3.3 Å

Semiconductors

7. The majority charge carriers in *P*-type semiconductor are:
   a. Electrons **b.** Protons
   c. Holes **d.** Neutrons
8. In *P*-type semiconductor, there is:
   a. An excess of one electron
   b. Absence of one electron
   c. A missing atom
   d. A donar level
9. A piece of copper and the other of germanium are cooled from the room temperature to 80 K, then which of the following would be a correct statement:
   a. Resistance of each increases
   b. Resistance of each decreases
   c. Resistance of copper increases while that of germanium decreases
   d. Resistance of copper decreases while that of germanium increases
10. A *N*-type semiconductor is:
    a. Negatively charged **b.** Positively charged
    c. Neutral **d.** None of these
11. The forbidden gap in the energy bands of germanium at room temperature is about:
    a. $1.1 eV$ **b.** $0.1 eV$
    c. $0.67 eV$ **d.** $6.7 eV$
12. The energy gap of silicon is 1.14 eV. The maximum wavelength at which silicon will begin absorbing energy is:
    a. 10888 Å **b.** 1088.8 Å
    c. 108.88 Å **d.** 10.888 Å

Semiconductor Diode

13. In a *PN*-junction diode:
    a. The current in the reverse biased condition is generally very small
    b. The current in the reverse biased condition is small but the forward biased current is independent of the bias voltage
    c. The reverse biased current is strongly dependent on the applied bias voltage
    d. The forward biased current is very small in comparison to reverse biased current
14. The reverse biasing in a *PN* junction diode:
    a. Decreases the potential barrier
    b. Increases the potential barrier
    c. Increases the number of minority charge carriers
    d. Increases the number of majority charge carriers
15. The *PN* junction diode is used as:
    a. An amplifier **b.** A rectifier
    c. An oscillator **d.** A modulator
16. The approximate ratio of resistances in the forward and reverse bias of the *PN-j*unction diode is:
    a. $10^2:1$ **b.** $10^{-2}:1$
    c. $1:10^{-4}$ **d.** $1:10^4$
17. A potential barrier of 0.50 V exists across a *P-N* junction. If the depletion region is $5.0 \times 10^{-7}\, m$ wide, the intensity of the electric field in this region is:
    a. $1.0 \times 10^6\, V/m$ **b.** $1.0 \times 10^5\, V/m$
    c. $2.0 \times 10^5\, V/m$ **d.** $2.0 \times 10^6\, V/m$

Communication

18. In short wave communication waves of which of the following frequencies will be reflected back by the ionospheric layer, having electron density 10^{11} per m^3?
a. 2 *MHz* **b.** 10 *MHz*
c. 12 *MHz* **d.** 18 *MHz*

19. Range of frequencies allotted for commercial FM radio broadcast is:
a. 88 to 108 *MHz* **b.** 88 to 108 *kHz*
c. 8 to 88 *MHz* **d.** 88 to 108 *GHz*

20. A step index fibre has a relative refractive index of 0.88%. What is the critical angle at the corecladding interface?
a. 60° **b.** 75°
c. 45° **d.** None of these

21. Through which mode of propagation, the radio waves can be sent from one place to another:
a. Ground wave propagation
b. Sky wave propagation
c. Space wave propagation
d. All of them

22. The carrier frequency generated by a tank circuit containing 1 *nF* capacitor and 10 μH inductor is:
a. 1592 *Hz* **b.** 1592 *MHz*
c. 1592 *kHz* **d.** 159.2 *Hz*

23. For television broadcasting, the frequency employed is normally:
a. 30-300 *MHz* **b.** 30-300 *GHz*
c. 30-300 *KHz* **d.** 30-300 *Hz*

24. Maximum useable frequency (MUF) in *F*-region layer is *x*, when the critical frequency is 60 *MHz* and the angle of incidence is 70°. Then *x* is:
a. 150 *MHz* **b.** 170 *MHz*
c. 175 *MHz* **d.** 190 *MHz*

25. The attenuation in optical fibre is mainly due to:
a. Absorption
b. Scattering
c. Neither absorption nor scattering
d. Both a and b

26. A laser beam is used for carrying out surgery because it:
a. Is highly monochromatic **b.** Is highly coherent
c. Is highly directional **d.** Can be sharply focussed

27. An oscillator is producing FM waves of frequency 2 *kHz* with a variation of 10 *kHz*. What is the modulating index?
a. 0.20 **b.** 5.0
c. 0.67 **d.** 1.5

28. Sinusoidal carrier voltage of frequency 1.5 *MHz* and amplitude 50 *V* is amplitude modulated by sinusoidal voltage of frequency 10 *kHz* producing 50% modulation. The lower and upper side-band frequencies in *kHz* are:
a. 1490, 1510 **b.** 1510, 1490
c. $\frac{1}{1490}, \frac{1}{1510}$ **d.** $\frac{1}{1510}, \frac{1}{1490}$

29. An AM wave has 1800 *watt* of total power content, For 100% modulation the carrier should have power content equal to:
a. 1000 *watt* **b.** 1200 *watt*
c. 1500 *watt* **d.** 1600 *watt*

30. An antenna is a device:
a. That converts electromagnetic energy into radio frequency signal
b. That converts radio frequency signal into electromagnetic energy
c. That converts guided electromagnetic waves into free space electromagnetic waves and vice-versa
d. None of these

31. Indicate which one of the following system is digital:
a. Pulse position modulation
b. Pulse code modulation
c. Pulse width modulation
d. Pulse amplitude modulation

32. In an FM system a 7 *kHz* signal modulates 108 *MHz* carrier so that frequency deviation is 50 *kHz*. The carrier swing is:
a. 7.143 **b.** 8
c. 0.71 **d.** 350

33. Advantage of optical fibre:
a. High bandwidth and EM interference
b. Low bandwidth and EM interference
c. High band width, low transmission capacity and no EM interference
d. High bandwidth, high data transmission capacity and no EM interference

34. Audio signal cannot be transmitted because:
a. The signal has more noise
b. The signal cannot be amplified for distance communication
c. The transmitting antenna length is very small to design
d. The transmitting antenna length is very large and impracticable

35. For sky wave propagation of a 10 *MHz* signal, what should be the minimum electron density in ionosphere?

a. ~ $1.2 \times 10^{12}\ m^{-3}$ **b.** ~ $10^{6}\ m^{-3}$
c. ~ $10^{14}\ m^{-3}$ **d.** ~ $10^{22}\ m^{-3}$

Junction Transistor

36. When *NPN* transistor is used as an amplifier:
a. Electrons move from base to collector
b. Holes move from emitter to base
c. Electrons move from collector to base
d. Holes move from base to emitter

37. In an *NPN* transistor the collector current is 24 *mA*. If 80% of electrons reach collector its base current in *mA* is:
a. 36 **b.** 26
c. 16 **d.** 6

38. In the case of constants α and β of a transistor:
a. $\alpha = \beta$ **b.** $\beta < 1 \quad \alpha > 1$
c. $\alpha\beta = 1$ **d.** $\beta > 1 \quad \alpha < 1$

39. For a common base configuration of *PNP* transistor $\frac{l_C}{l_E} = 0.98$ then maximum current gain in common emitter configuration will be:
a. 12 **b.** 24
c. 6 **d.** 5

40. A common emitter amplifier is designed with *NPN* transistor (α = 0.99). The input impedance is 1 $K\Omega$ and load is 10 $K\Omega$. The voltage gain will be:
a. 9.9 **b.** 99
c. 990 **d.** 9900

Digital Electronics

41. The following truth table corresponds to the logic gate:

A	0	0	1	1
B	0	1	0	1
X	0	1	1	1

a. NAND **b.** OR
c. AND **d.** XOR

42. A truth table is given below. Which of the following has this type of truth table?

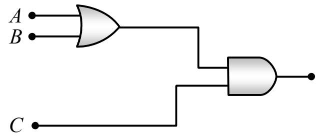
A	0	1	0	1
B	0	0	1	1
y	1	0	0	0

a. XOR gate **b.** NOR gate
c. AND gate **d.** OR gate

43. The logic behind 'NOR' gate is that it gives
a. High output when both the inputs are low
b. Low output when both the inputs are low
c. High output when both the inputs are high
d. None of these

44. How many NAND gates are used to form an AND gate:
a. 1 **b.** 2
c. 3 **d.** 4

45. To get an output 1 from the circuit shown in the figure, the input must be:



a. $A = 0,\ B = 1,\ C = 0$
b. $A = 1,\ B = 0,\ C = 0$
c. $A = 1,\ B = 0,\ C = 1$
d. $A = 1,\ B = 1,\ C = 0$

Valve Electronics (Diode and Triode)

46. Thermionic emission from a heated filament varies with its temperature T as:
a. T^{-1} **b.** T
c. T^{2} **d.** $T^{3/2}$

47. Due to S.C.R in vacuum tube:
a. $I_p \rightarrow$ Decrease **b.** I_p – Increase
c. V_p = Increase **d.** V_g = Increase

48. The grid voltage of any triode valve is changed from –1 volt to – 3 *volt* and the mutual conductance is 3×10^{-4} *mho*. The change in plate circuit current will be:
a. 0.8 *mA* **b.** 0.6 *mA*
c. 0.4 *mA* **d.** 1 *mA*

49. In a triode, $g_m = 2 \times 10^{-3} ohm^{-1}; \mu = 42$, resistance load, $R = 50$ kilo ohm. The voltage amplification obtained from this triode will be:
a. 30.42 **b.** 29.57
c. 28.18 **d.** 27.15

50. For a given plate-voltage, the plate current in a triode is maximum when the potential of:
a. The grid is positive and plate is negative
b. The grid is positive and plate is positive
c. The grid is zero and plate is positive
d. The grid is negative and plate is positive

NCERT EXEMPLAR PROBLEMS

More than One Answer

51. In *N*-type semiconductor, there are:
a. no majority carries
b. electrons as majority carriers
c. immobile negative ions
d. immobile positive ions

52. Which of the following statement/(s) is/are correct for a junction transistor?
a. the base region is very thin
b. emitter is more heavily doped as compared to collector
c. emitter and collector can be interchanged
d. the surface area of collector is quite large

53. If I_B, I_C and I_B represent the emitter current, collector current and base current respectively in a transistor, then:
a. i_C is slightly smaller than i_E
b. i_C is slightly greater than i_E
c. i_B is much smaller than i_E
d. i_B is much greater than i_E

54. In a *p-n* junction:
a. new holes and conduction electrons are produced continuously throughout the material except in the depletion region
b. new holes and conduction electrons are produced continuously throughout the material except in the depletion region
c. holes and conduction electrons recombine continuously throughout the material
d. holes and conduction electrons recombine continuously throughout the material except in the depletion region

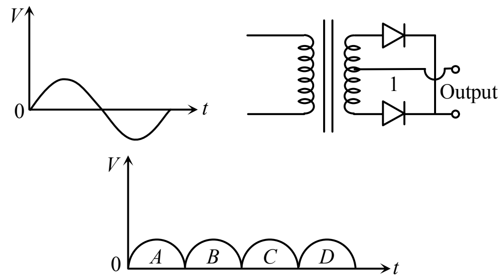
55. When a potential difference is applied across, the current passing through:
a. an insulator at 0 *K* is zero
b. a semiconductor at 0 *K* is zero
c. a metal at 0 *K* is finite
d. a *p-n* diode at 300 *K* is finite, if is reverse biased

56. Germanium semi-conductor is to be made so that it conducts electrons. The doping elements for this purpose are:
a. Aluminium
b. Antimony
c. Arsenic
d. Phosphorous

57. The impurity atoms with which pure silicon should be doped to make a *p*-type semiconductor are those of:
a. phosphorus **b.** boron
c. antimony **d.** aluminium

58. In an *n-p* transistor circuit, the collector current is 10 mA. If 90% of the electrons emitted reach the collector:
a. the emitter current will be 9 mA
b. the emitter current will be 11 mA
c. the base current will be 1 mA
d. the base current will be -1 mA

59. A full wave rectifier circuit along with the output is shown in figure. The contribution (s) from the diode 1 is (are)



a. *C* **b.** *A, C*
c. *B, D* **d.** *A, B, C, D*

60. A transistor is used in common emitter mode as an amplifier, then:
a. the base emitter junction is forward biased
b. the base emitter junction is reverse biased
c. the input signal is connected in series with the voltage applied to bias the base emitter junction
d. the input signal is connected in series with the voltage applied to bias the base collector junction

61. Space communication refers to:
a. Ground or surface wave propagation
b. Space or tropospheric wave propagation
c. sky or ionospheric wave propagation
d. satellite communication

62. In ground or surface wave propagation, the loss of power in a signal wave is due to:
a. induced charges in earth which travel in ground along with the wave, resulting the alternating currents in the earth's surface
b. interference of waves
c. diffraction of waves
d. high frequency of signal wave.

63. Long distance radio broadcasts use short wave bands because these waves are
a. of wavelength less than 200m
b. of frequency greater than 1.5 MHz
c. absorbed by the earth easily
d. reflected from ionosphere

64. Which mode of communication is/are not employed for the transmission of T.V. signals?
a. Ground wave propagation
b. sky wave propagation
c. space wave propagation
d. none of the above

65. Which of the following statements is/are correct?
a. A diode valve can be used as a rectifier
b. A triode valve can be used as a rectifier
c. A diode valve can be used as an amplifier
d. A triode value can be used as an amplifier

Assertion and Reason

Note: Read the Assertion (A) and Reason (R**)** carefully to mark the correct option out of the options given below:

a. If both assertion and reason are true and the reason is the correct explanation of the assertion.
b. If both assertion and reason are true but reason is not the correct explanation of the assertion.
c. If assertion is true but reason is false.
d. If the assertion and reason both are false.
e. If assertion is false but reason is true.

66. **Assertion:** In a transistor, the base current is very small compared to the collector current.
Reason: A very large number of electrons recombine with holes and hence do not pass through the base.

67. **Assertion:** In a transistor amplifier, the power dissipated at the base-collector junction is much smaller than that dissipated at the emitter-base junction.
Reason: The resistance of the base-collector junction is much higher than that of the emitter-base junction.

68. **Assertion:** In a transistor amplifier, the output voltage is always out of phase with the input voltage.
Reason: The emitter-base junction is reverse biased and the base-collector junction is forward biased.

69. **Assertion:** Short wave band are used for transmission of radiowaves to large distance.
Reason: Short waves are reflected from ionosphere.

70. **Assertion:** The refractive index of the ionosphere increases as we go from the lower to upper layers in the iono-sphere.
Reason: The degree of ionization is higher at the upper layers than at the lower layers of the ionosphere.

71. **Assertion:** The electrical conductivity of earth's atmosphere decreases with altitude.
Reason: The high energy particles (*i.e.* γ-rays and cosmic rays) coming from outer space and entering our earth's atmosphere cause ionisation of the atoms of the gases present there and the pressure of gases decreases with increase in altitude.

72. **Assertion:** In high latitude one sees colourful curtains of light hanging down from high altitudes.
Reason: The high energy charged particles from the sun are deflected to polar regions by the magnetic field of the eart

73. **Assertion:** Short wave bands are used for transmission of radio waves to a large distance.
Reason: Short waves are reflected by ionosphere

Comprehension Based

Paragraph –I

When pure semiconductor material is mixed with small amounts of certain specific impurities with valency different from that of the parent material, the number of mobile electrons/holes drastically changes.P/*N*-type semiconductor is electrically neutral (not positively /negatively charged); Impurity is called Donor impurity because one impurity atom generates one electron. Impurity is called Acceptor impurity and majority charge carriers-holes. When a *P*-type semiconductor is suitably joined to an *N*-type semiconductor, then resulting arrangement is called *P-N* junction.

74. The majority charge carriers in *P*-type semiconductor are:
a. Electrons **b.** Protons
c. Holes **d.** Neutrons

75. A *N*-type semiconductor is:
a. Negatively charged
b. Positively charged
c. Neutral
d. None of these

76. Which statement is correct?

a. *N*-type germanium is negatively charged and *P*-type germanium is positively charged

b. Both *N*-type and *P*-type germanium are neutral

c. *N*-type germanium is positively charged and *P*-type germanium is negatively charged

d. Both *N*-type and *P*-type germanium are negatively charged

77. Holes are charge carriers in:

a. Intrinsic semiconductors

b. Ionic solids

c. *P*-type semiconductors

d. Metals

78. In *P*-type semiconductor the majority and minority charge carriers are respectively:

a. Protons and electrons

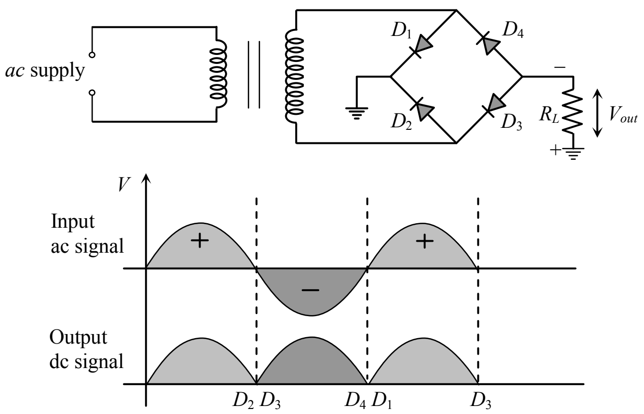
b. Electrons and protons

c. Electrons and holes

d. Holes and electrons

Paragraph –II

Rectifier is a circuit which converts *ac* to unidirectional pulsating output. In figure: During positive half cycle D_1 and D_3 are forward biased and D_2 and D_4 are reverse biased; during negative half cycle D_2 and D_4 are forward biased and D_1 and D_3 are reverse biased. Output voltage is obtained across the load resistance R_L. It is not constant but pulsating (mixture of *ac* and *dc*) in nature



79. Select the correct statement:

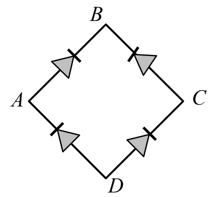
a. In a full wave rectifier, two diodes work alternately

b. In a full wave rectifier, two diodes work simultaneously

c. The efficiency of full wave and half wave rectifiers is same

d. The full wave rectifier is bi-directional

80. In the diagram, the input is across the terminals *A* and *C* and the output is across the terminals *B* and *D*, then the output is:



a. Zero | **b.** Same as input

c. Full wave rectifier | **d.** Half wave rectifier

81. In a full wave rectifiers, input *ac* current has a frequency 'ν'. The output frequency of current is:

a. $\nu/2$ | **b.** ν

c. 2ν | **d.** None of the

Paragraph –III

There is a transmitter at a height *h* (= 400 m) from the ground at place *A*, from which the radiowaves can be transmitted. There is a receiver at station *B* on earth at a distance *d* (= 125 km), which can receive the signal from station *A*. The radiowaves can reach the station B, either through earth's atmosphere or through satellite. There are four main layers in earth's atmosphere named *D*, *E*, F_1 and F_2 which play effective role in radio communication. The electron density of these layers is 4×10^8; $2\times10^{11}, 5\times10^{11}$ and $8\times10^{11}\,m^{-3}$. The radius of the earth is 6.4×10^6 m.

82. The ratio of critical frequency for reflection of radiowaves from *E*, F_1 and F_2 layers in ionosphere of earth's atmosphere is:

a. 2 : 3 : 8

b. 1/2 : 1/3 : 1/8

c. 1/4 : 1/9 : 1/64

d. $\sqrt{2}:\sqrt{3}:\sqrt{8}$

83. On a particular day, the maximum frequency reflected from the ionosphere is 9 MHz. On another day, it was found to increase by 1 MHz. The ratio of maximum electron density of the ionosphere on the two days is:

a. 10/9

b. $\sqrt{10}/3$

c. 100/81

d. none of the above

84. The value of radio frequency at which the electromagnetic wave must be propagated for the D-layer of atmosphere to have a refractive index of 0.5 is:

a. 52 kHz **b.** 104 kHz
c. 208 kHz **d.** 78 kHz

85. If the frequency of the transmitting station is 5 MHz, and maximum number density of electrons in the ionosphere is $10^{-12}\,\text{m}^{-3}$; state whether it is coming via:

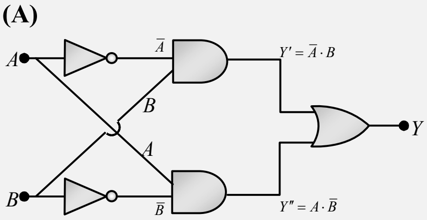
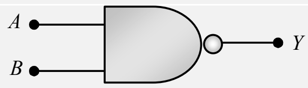
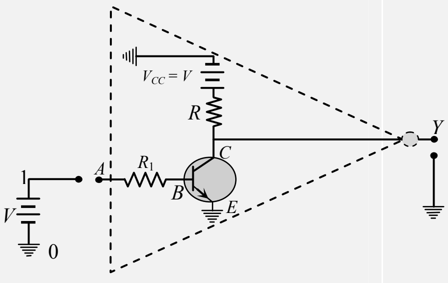
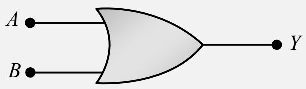
a. Ground waves propagation
b. Space wave propagation
c. sky wave propagation
d. satellite communication

86. If the station A sends the T.V. signals, then the maximum area on earth upto which T.V. transmission can be received on earth is: (average population density around the tower is 1000 km^{-2})

a. 1.6×10^{5} **b.** 1.6×10^{6}
c. 1.6×10^{7} **d.** 1.6×10^{8}

Match the Column

87. Match the statement of Column with those in Column II:

Column I	Column II
(A) 	**1.** NOT
(B) 	**2.** XOR
(C) 	**3.** NAD
(D) 	**4.** OR

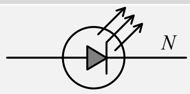
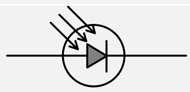
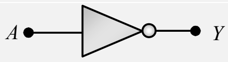
a. A→2; B→3; C→1; D→4 **b.** A→2; B→4; C→3; D→1
c. A→1; B→3; C→2; D→4 **d.** A→4; B→1; C-3; D→2

88. Match the statement of Column with those in Column II:

Column I	Column II
(A) Conductivity of semiconductor	**1.** $\sigma = e[n_e\mu_e + n_h\mu_h]$
(B) Forbidden energy gap	**2.** $\Delta E_g = (C.B.)_{\min} - (V.B.)_{\max}$
(C) trivalent impurity to a pure sample of semiconductor	**3.** P-Type semiconductor
(D) pentavalent impurity to a pure sample of semiconductor	**4.** N- Type Semiconductor

a. A→4; B→3; C→2; D→1
b. A→1; B→2; C→3; D→4
c. A→3, B→4; C→1; D→2
d. A→2; B→3; C→4; D→1

89. Match the statement of Column with those in Column II:

Column I	Column II
(A) Zener diode	**1.** 
(B) NOT - Gate	**2.** 
(C) Photo diode	**3.** 
(D) LED	**4.** 

a. A→4; B→3; C→2; D→1 **b.** A→3; B→2; C→1; D→4
c. A→2; B→1; C-4; D→3 **d.** A→1; B→2; C→3; D→4

90. In each of the following questions, match column I and column II, and select the correct match out of four given choices:

Column I	Column II
(A) Transducer	**1.** Range of frequencies over which communication system works
(B) Attenuation	**2.** A device that has input in electrical form or provides output in electrical form
(C) Range	**3.** Loss of strength of a signal during propagation.
(D) Band width	**4.** Largest distance between transmitter and receiver.

a. A→2; B→4; C→1; D→3 **b.** A→4; B→3; C→1; D→2
c. A→1; B→2; C→3; D→4 **d.** A→2; B→3, C→4; D→1

91. Match the quantities of column I with the relation of column II.

Column I	**Column II**
(A) Critical frequency (ν_c)	**1.** $9\sqrt{N}$, where N is the electron density of the layer of ionosphere.
(B) Skip distance (D_{skip})	**2.** $2h\sqrt{\left(\frac{\nu_{max}}{\nu_c}\right)^2-1}$
(C) Refractive index of the layer of atmosphere (μ)	**3.** $1-\frac{81.45\,\text{N}}{\nu^2}$
(D) Dielectric constant of the layer of atmosphere (K)	**4.** $\sqrt{1-\frac{81.45\,\text{N}}{\nu^2}}$

a. A→2; B→1; C→4; D→3
b. A→1; B→2; C→4; D→3
c. A→3; B→2; C→4; D→1
d. A→4; B→2; C→1; D→3

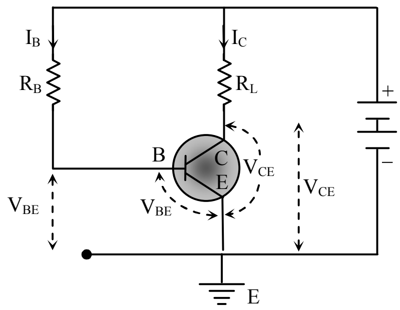
92. Match the quantities of column I with the relation of column II.

Column I	**Column II**
(A) Modulating wave	**1.** short wavelength
(B) Modulated wave	**2.** low frequency waves
(C) Ground wave propagation	**3.** high frequency waves
(D) Sky wave propagation	**4.** long wavelength

a. A→2,4; B→1,3; C→2,4; D→1,3
b. A→2,4; B→1,3; C→2,4; D→3,1
c. A→1,3; B→2; C→2,4; D→1,3
d. A→2,4; B→1,3; C→4,2; D→1,3

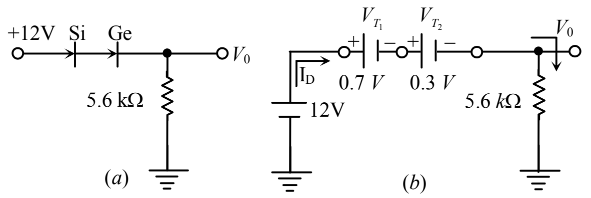
Integer

93. An *N-P-N* transistor in a common emitter mode is used as a simple voltage amplifier with a collector current of 4 mA. The terminal of an $8V$ battery is connected to the collector through a load resistance R_L and to the base through a resistance R_B. The collector-emitter voltage $V_{CE} = 4V$, base-emitter voltage $V_{BE} = 0.6V$ and base current amplification factor $\beta_{DC} = 10$. Calculate the values of R_L and R_B.



94. A *pn* junction diode can withstand currents upto 10 mA. When it is forward biased, the potential drop across it is 1.0 V. Assuming that this potential drop is independent of the current, find the maximum voltage of the battery used to forward bias the diode when a resistance of is connected in series with the diode.

95. In the network shown in figure (a) and (b), determine V_0.



96. If the maximum values of signal and carrier waves are 4 V and 5 V respectively, the percentage of amplitude modulation is $a\times 10\%$. What is the value of a ?

97. A signal wave of frequency 4.5 kHz is modulated with a carrier wave of frequency 3.45 MHz. The band width of FM wave is KHz is

98. What is the maximum usuable frequency (in MHz) for E-layer of atmosphere having critical frequency 4 MHz, when the angle of incidence is 60^o?

99. A T.V. Tower has a height 100 m. In order to triple its coverage range, the height of tower to be increased is $a\times 10^2$ m. What is the integer value of a?

100. A microwave telephone link operating at the central frequency of 10 GHz has been established. If 2% of this is available for microwave communication channel and each telephone is allotted a band width of 8 kHz, the number of telephone channels which can be simultaneously granted is 2.5×10^a. What is the integer value of a ?

ANSWER

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
d	a	d	a	b	b	c	b	d	c
11.	**12.**	**13.**	**14.**	**15.**	**16.**	**17.**	**18.**	**19.**	**20.**
c	a	a	b	b	d	a	a	a	d
21.	**22.**	**23.**	**24.**	**25.**	**26.**	**27.**	**28.**	**29.**	**30.**
d	c	a	c	d	d	b	a	b	c
31.	**32.**	**33.**	**34.**	**35.**	**36.**	**37.**	**38.**	**39.**	**40.**
b	a	d	d	a	a	d	d	b	c
41.	**42.**	**43.**	**44.**	**45.**	**46.**	**47.**	**48.**	**49.**	**50.**
b	b	a	b	c	c	a	b	b	b
51.	**52.**	**53.**	**54.**	**55.**	**56.**	**57.**	**58.**	**59.**	**60.**
b,d	All	a,c	b,d	a,b,d	b,c,d	b,d	b,c	b,c	a,d
61.	**62.**	**63.**	**64.**	**65.**	**66.**	**67.**	**68.**	**69.**	**70.**
a,c	a,c	All	a,b	a,b,d	c	a	c	a	d
71.	**72.**	**73.**	**74.**	**75.**	**76.**	**77.**	**78.**	**79.**	**80.**
e	a	a	c	c	b	a,c	d	a	c
81.	**82.**	**83.**	**84.**	**85.**	**86.**	**87.**	**88.**	**89.**	**90.**
c	d	c	c	c	c	a	b	a	d
91.	**92.**	**93.**	**94.**	**95.**	**96.**	**97.**	**98.**	**99.**	**100.**
b	a	185	2	12	8	9	8	8	4

SOLUTION

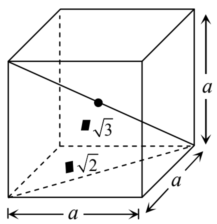
Multiple Choice Questions

1. **(d)** Ionic bonds cone into being when atoms that have low ionization energies, and hence lose electrons rapidly, interact with other atoms that and to acquire excess electrons. The former atoms give up electrons to the latter and they there upon become positive and negative ions respectively.

2. **(a)** In a triclinic crystal $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90°$

3. **(d)** *Cu* has *fcc* structure, for *fcc* structure co-ordination number = 12

4. **(a)** Sodium has *bcc* structure. The distance between body centre and a corner $= \frac{\sqrt{3}\,a}{2} = \frac{\sqrt{3}\times 4.225}{2} = 3.66\,\mathring{A}$



5. **(b)** The nearest distance between two atoms in a *bcc* lattice = 2 (atomic radius) $= 2\times\left(\frac{\sqrt{3}\,a}{4}\right) = \frac{\sqrt{3}a}{2}$

6. **(b)** For *bcc* packing, distance between two nearest atoms $d = 2r = 2\left(\frac{\sqrt{3}\,a}{4}\right)$

$\Rightarrow$ Lattice constant $a = \frac{2d}{\sqrt{3}} = \frac{2\times 3.7}{\sqrt{3}} = 4.3\mathring{A}$

7. **(c)** In *P*-type semiconductors, holes are the majority charge carriers

8. **(b)** Absence of one electron, creates the positive charge of magnitude equal to that of electronic charge.

9. **(d)** Resistance of conductors (*Cu*) decreases with decrease in temperature while that of semi-conductors (*Ge*) increases with decrease in temperature.

10. **(c)** *N*-type semiconductors are neutral because neutral atoms are added during doping.

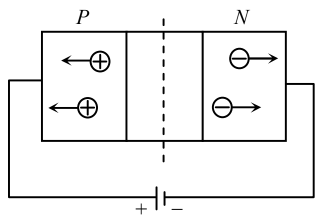
11. **(c)** $\Delta E_{g(\text{Germanium})} = 0.67\ eV$

12. **(a)** $\lambda_{\max} = \frac{hc}{E} = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.14\times1.6\times10^{-19}} = 10888\mathring{A}$

13. **(a)** In forward biased *PN*-junction, external voltage decreases the potential barrier, so current is maximum. While in reversed biased *PN*-junction, external voltage increases the potential barrier, so the current is very small.

14. **(b)** In reverse biasing, width of depletion layer increases.

15. **(b)** It is used to convert *ac* into *dc* (rectifier)



16. **(d)** Resistance in forward biasing $R_{fr} \approx 10\Omega$ and resistance in reverse biasing $R_{Rw} \approx 10^{5}\Omega$

$\Rightarrow$ $\frac{R_{fr}}{R_{Rw}} = \frac{1}{10^{4}}$

17. **(a)** $E = \frac{V}{d} = \frac{0.5}{5\times10^{-7}} = 10^{6}\ V/m$.

18. **(a)** By using $f_c \approx 9(N_{\max})^{1/2}$

$\Rightarrow$ $f_c \approx 2\,MHz$

19. **(a)** A maximum frequency deviation of 75 *kHz* is permitted for commercial FM broadcast stations in the 88 to 108 *MHz VHF* band.

20. **(d)** Here $\frac{n_1 - n_2}{n_1} = \frac{0.88}{100} \Rightarrow \frac{n_2}{n_1} = 0.9912$

$\therefore$ Critical angle $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}(0.9912) = 84°24'$

21. **(d)** Radio waves can be transmitted from one place to another as grand wave or sky wave or space wave propagation.

22. **(c)** $\nu = \frac{1}{2\pi\sqrt{LC}}$

$= \frac{1}{2\times 3.14\sqrt{10\times 10^{-6}\times 1\times 10^{-9}}}$ = 1592 kHz

23. **(a)** VHF (Very High Frequency) band having frequency range 30 MHz to 300 MHz is typically used for TV and radar transmission.

24. **(c)** $MUF = \frac{f_c}{\cos\theta} = \frac{60}{\cos 70°} = 175\, MHz$

25. **(d)** A very small part of light energy is lost from an optical fibre due to absorption or due to light leaving the fibre as a result of scattering of light sideways by impurities in the glass fibre.

26. **(d)** Surgery needs sharply focused beam of light and laser can be sharply focused.

27. **(b)** The formula for modulating index is given by

$$m_f = \frac{\delta}{\nu_m} = \frac{\text{Frequency variation}}{\text{Modulating frequency}} = \frac{10\times 10^3}{2\times 10^3} = 5$$

28. **(a)** Here, $f_c = 1.5\, MHz = 1500\, kHz,\ f_m = 10\, kHz$

$\therefore$ Low side band frequency

$= f_c - f_m = 1500\, kHz - 10\, kHz = 1490\, kHz$

Upper side band frequency

$= f_c + f_m = 1500\, kHz + 10\, kHz = 1510\, kHz$

29. **(b)** $P_t = P_c\left(1 + \frac{m_a^2}{2}\right)$; Here $m_a = 1$

$\Rightarrow\ 1800 = P_c\left(1 + \frac{(1)^2}{2}\right) \Rightarrow P_c = 1200W$

30. **(c)** An antenna is a metallic structure used to radiate or receive EM waves.

31. **(b)** Pulse code modulation is a digital system.

32. **(a)** Carrier swing $= \frac{\text{Frequency deviation}}{\text{Modulating frequency}} = \frac{50}{7} = 7.143$

33. **(d)** Few advantages of optical fibres are that the number of signals carried by optical fibres is much more than that carried by the Cu wire or radio waves. Optical fibres are practically free from electromagnetic interference and problem of cross talks whereas ordinary cables and microwave links suffer a lot from it.

34. **(d)** Following are the problems which are faced while transmitting audio signals directly.

(a) These signals are relatively of short range.

(b) If every body started transmitting these low frequency signals directly, mutual interference will render all of them ineffective.

(c) Size of antenna required for their efficient radiation would be larger *i.e.* about 75 *km*.

35. **(a)** The critical frequency of a sky wave for reflection from a layer of atmosphere is given by $f_c = 9(N_{\max})^{1/2}$

$\Rightarrow\ 10\times 10^6 = 9(N_{\max})^{1/2}$

$\Rightarrow\ N_{\max} = \left(\frac{10\times 10^6}{9}\right)^2 \simeq 1.2\times 10^{12}\, m^{-3}$

36. **(a)** When NPN transistor is used as an amplifier, majority charge carrier electrons of N-type emitter move from emitter to base and than base to collector.

37. **(d)** Given $i_c = \frac{80}{100}\times i_e$

$\Rightarrow\ 24 = \frac{80}{100}\times i_e$

$\Rightarrow\ i_e = 30\, mA$

By using $i_e = i_b + i_c \Rightarrow i_b = 30 - 24 = 6\, mA$.

38. **(d)** α is the ratio of collector current and emitter current while β is the ratio of collector current and base current.

39. **(b)** $\beta = \frac{\alpha}{1-\alpha} = \frac{0.96}{1-0.96}$ =24.

40. **(c)** Voltage gain = $\beta\times$ Resistance gain

$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{(1-0.99)} = 99$

Resistance gain $= \frac{10\times 10^3}{10^3} = 10$

$\Rightarrow$ Voltage gain = 99 × 10 = 990.

41. **(b)** For 'OR' gate $X = A + B$

i.e. $0+0=0$,

$0+1=1,\ 1+0=1$

$1+1=1$

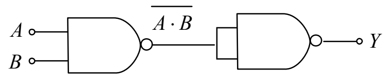
42. (b) In 'NOR' gate $Y=\overline{A+B}$

i.e. $\overline{0+0}=\overline{0}=1$, $\overline{1+0}=\overline{1}=0$; $\overline{0+1}=\overline{1}=0$, $\overline{1+1}=\overline{1}=0$

43. (a) The Boolean expression for 'NOR' gate is $Y=\overline{A+B}$

i.e. if $A=B=0$ (Low), $Y=\overline{0+0}=\overline{0}=1$ (High)

44. (b) Two 'NAND' gates are required as follows



$Y=\overline{\overline{AB}.\overline{AB}}=AB$

45. (c) The Boolean expression for the given combination is output $Y=(A+B).C$ The truth table is

A	*B*	*C*	*Y =(A+B).C*
0	0	0	0
1	0	0	0
0	1	0	0
0	0	1	0
1	1	0	0
0	1	1	1
1	0	1	1
1	1	1	1

Hence $A=1$, $B=0$, $C=1$

46. (c) According to Richardson-Dushman equation, number of thermions emitted per sec per unit area $J=AT^2e^{-W_0/kT}$

$\Rightarrow$ $J\propto T^2$

47. (a) In SCR (Space charge region) electrons collect around the plate, this cloud decreases the emission of electrons from the cathode, hence plate current decreases

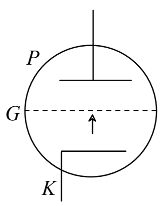
48. (b) By using $g_m=\dfrac{\Delta i_p}{\Delta v_g}\Rightarrow 3\times10^{-4}=\dfrac{\Delta i_p}{-1-(-3)}$

$\Rightarrow$ $\Delta i_p=6\times10^{-4}A=0.6\,mA$

49. (b) Voltage gain $A_v=\dfrac{\mu}{1+(r_p/R_L)}$ and $\mu=r_p\times g_m$

$\Rightarrow$ $r_p=\dfrac{42}{2\times10^{-3}}=21000\,\Omega\Rightarrow A_v=\dfrac{42}{1+\dfrac{21000}{50\times10^3}}=29.57$

50. (b) When grid is given positive potential more electrons will cross the grid to reach the positive plate *P*. Hence current increases.



NCERT Exemplar Problems

More than One Answer

51. (b,d) Antimony , Aluminium

52. (a,b,c,d) the base region is very thin, emitter is more heavily doped as compared to collector, emitter and collector can be interchanged, the surface area of collector is quite large.

53. (a,c) i_C is slightly smaller than i_E , i_B is much smaller than i_E .

54. (b,d) new holes and conduction electrons are produced continuously throughout the material except in the depletion region, holes and conduction electrons recombine continuously throughout the material except in the depletion region.

55. (a,b,d) an insulator at 0 *K* is zero, a semiconductor at 0 *K* is zero, a *p-n* diode at 300 *K* is finite, if is reverse biased

56. (b,c,d) Antimony , Arsenic, Phosphorous

57. (b,d) To make a *p*-type semiconductor, a trivalent impurity should be added to pure tetravalent compounds.

58. (b,c) Given: $i_c=10\,\text{mA}=(0.9)i_e$

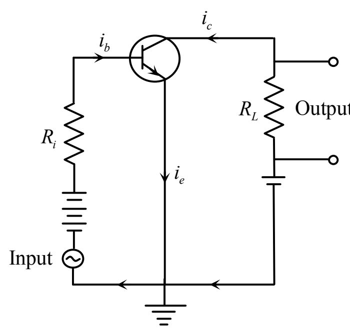
[Given that i_c is 90% of i_e]

$\therefore$ $i_e=\dfrac{10}{0.9}\text{mA}\approx11\text{mA}$

and $i_b=i_e-i_c=(11-10)\text{mA}=1\text{mA}$

59. (b,c) For half cycle diode 1 is forward biased and for the rest half it is reverse biased. Therefore, it will conduct only for one half cycle.

60. (a,d) The circuit of a common emitter amplifier is an shown below:



$V_{\text{base}}>V_{\text{emitter}}$

This has been shown an *n-p-n* transistor. Therefore, base emitter are forward biased and input signal is connected between base and emitter.

61. **(a,c)** In ground or surface wave propagation, the loss of power in a signal wave is due to attenuation, i.e., the absorption of energy by the earth which in turn is due to induced charges in earth which travel in ground along with the wave resulting in the alternating currents in the earth's surface, as well as due to tilting effect, i.e., diffraction of waves.

62. **(a,c)** induced charges in earth which travel in ground along with the wave, resulting the alternating currents in the earth's surface, diffraction of waves

63. **(a,b,c,d)** of wavelength less than 200m, of frequency greater than 1.5 MHz, absorbed by the earth easily, reflected from ionosphere

64. **(a,b)** The mode of communication used for T.V. signals transmission is either space wave propagation, i.e., line of sight propagation or satellite communication.

65. **(a,b,d)** A diode valve can be used as a rectifier, A triode valve can be used as a rectifier, A triode value can be used as an amplifier

Assertion and Reason

66. **(c)** The base current is about 1/100 of collector current. About 99% of electrons pass through the base without recombining with holes.

67. **(a)** The power dissipated in the base-collector junction is much higher than that dissipated at the emitter-base junction.

68. **(c)** The base emitter junction is forward biased and the base collector junction is reverse biased.

69. **(a)** Both Assertion-1 and Reason-2 are correct. Here the Reason-2 is correct explanation of Reason-1.

70. **(d)** The refractive index decreases as we go from the lower to upper layers in the ionosphere.

71. **(e)** The electrical conductivity of earth's atmosphere increases with height so assertion is false.
When high energy particles enters in earth's atmosphere. They ionises the gases present in atmosphere. Also as we go up, the air thins out gradually and air pressure decreases.

72. **(a)** Microwave communication is preferred over optical communication because microwaves provide large number of channels and wider band width compared to optical signals as information carrying capacity is directly proportional to band width. So, wider the band width, greater the information carrying capacity.

73. **(a)** Having the range of wavelength from 30 *km* to 30 *cm* are known as short wave. These waves are used for radio transmission and for general communication purpose to a longer distance from ionosphere. Ionosphere is the outermost region of atmosphere extending from height of 80 *km* to 400 *km* approximately, above the surface of earth. Therefore, both the assertion and reason are true and reason is the correct explanation of assertion.

Comprehension Based

74. **(c)** Holes

75. **(c)** Neutral

76. **(b)** Both *N*-type and *P*-type germanium are neutral

77. **(a,c)** Intrinsic semiconductors**,** *P*-type semiconductors

78. **(d)** Holes and electrons

79. **(a)** In a full wave rectifier, two diodes work alternately

80. **(c)** Full wave rectifier

81. **(c)** 2ν

82. **(d)** Critical frequency $\nu_C = 9(N_{\max})^{1/2}$

i.e., $\nu_C \propto N_{\max}^{1/2}$

$\therefore \quad \nu_{CF} : \nu_{CF_1} : \nu_{CF_2}$

$= (2\times10^{11})^{1/2} : (3\times10^{11})^{12} : (8\times10^{11})^{12}$

$= \sqrt{2} : \sqrt{3} : \sqrt{8}$

83. **(c)** $\frac{N'_{\max}}{N_{\max}} = \left(\frac{\nu'_C}{\nu_C}\right)^2$

$= \left(\frac{9+1}{9}\right)^2 = \frac{100}{81}$

84. **(c)** Refractive index,

$\mu = \mu_0\sqrt{1 - \frac{81.45\,N}{\nu^2}}$

$\therefore \quad 0.5 = 1\sqrt{1 - \frac{81.45\times4\times10^8}{\nu^2}}$

on solving, we get $\nu = 208.42$ kHz 205 $\approx$ kHz.

85. **(c)** Maximum distance covered by space wave communication is

$d = \sqrt{2Rh} = \sqrt{2\times64\times10^6\times400}$

$= 71.55\times10^3\,m \approx 72$ km

Since the distance between Transmitter and receiver is 125 km., hence for the given frequency signals of 5 MHz, the propagation is not possible via space propagation.

For sky wave propagation: the critical frequency

$\nu_C = 9(N_{\max})^{1/2} = 9(10^{12})^{1/2}$

$= 9 \times 10^6\, Hz = 9\,\text{MHz}$

Since 5 MHz < 9 MHz, so the propagation of signal of frequency 5 MHz is possible via sky waves.

86. **(c)** Population covered $= \rho\pi d^2 = \rho\pi(2\text{hR})$

$= (100\times10^{-6})\times\dfrac{22}{7}\times(2\times400\times6.4\times10^6)$

$= 1.61\times10^7$

Match the Column

87. **(a)** A→2; B→3; C→1; D→4

88. **(b)** A→1; B→2; C→3; D→4

89. **(a)** A→4; B→3; C→2; D→1

90. **(d)** A→2; B→3, C→4; D→1

A transducer is a device that has input in electrical form or provides output in electrical form. Attenuation is loss of strength of a signal during propagation. Range is largest distance between transmitter and receiver. Band width is range of frequencies over which communication system works.

91. **(b)** A→1; B→2; C→4; D→3

As is known from the knowledge of theory,

critical frequency, $\nu_c = 9\sqrt{\text{N}}$

skip distance, $D_{skip} = 2h\sqrt{\left(\dfrac{\nu_{\max}}{\nu_c}\right)^2 - 1}$

refractive index, $\mu = \sqrt{1 - \dfrac{81.45\,\text{N}}{\nu^2}}$

dielectric constant, $K = \dfrac{81.45N}{\nu^2}$

92. **(a)** A→2,4; B→1,3; C→2,4; D→1,3

Modulating wave is low frequency/long wavelength wave. Modulated wave is high frequency/short wavelength wave.

Ground wave propagation is suited for low frequency/ long wavelength; and sky wave propagation is suited for short wavelength/high frequency waves.

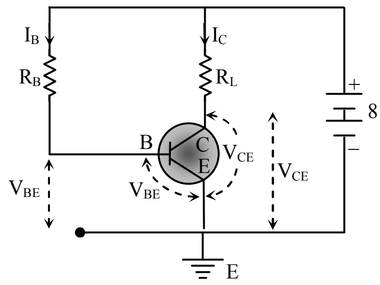
Integer

93. **(185)** Potential difference across

$R_L = 8 - V_{CE} = 8 - 4 = 4V$

Now $I_C R_L = 4V$

$R_L = \dfrac{4}{4\times10^{-3}} = 10^3\,\Omega = 1k\Omega$



Further, for base-emitter equation, $V_{CC} = I_B R_B + V_{BE}$

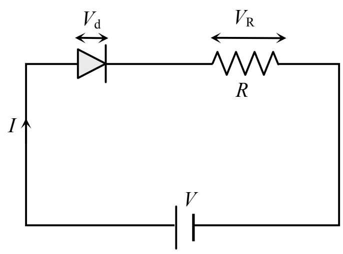
or $I_B R_B$ = Potential difference across R_B

$= V_{CC} - V_{BE} = 8 - 0.6 = 7.4V$

Again, $I_B = \dfrac{I_C}{\beta} = \dfrac{4\times10^{-3}}{100} = 4\times10^{-5}\,A$

$\therefore\quad R_B = \dfrac{7.4}{4\times10^{-5}} = 1.85\times1^5\,\Omega = 185k\Omega$

94. **(2)**



Voltage drop across diode is $V_d = 1.0V$

Voltage drop across R is $V_R = RI$

$= 100\times10\times10^{-3} = 1.0V$

$\therefore\quad V_{\max} = V_d + V_R = 1.0 + 1.0 = 2.0V$

95. **(12)** Direction of current I_D is in the same direction as arrow in the diode symbol. Both the diodes are in "on" state' hence voltage drops across their terminals V_{T_1} and V_{T_2} 0.7 V and 0.3 V respectively.

The network functions because

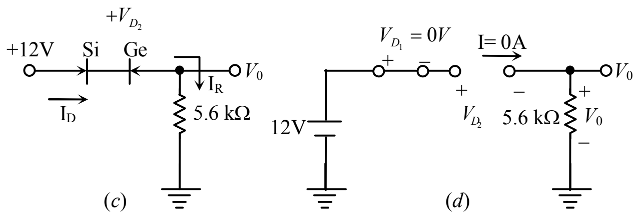
$E = 12V > (0.7V + 0.3V)$.

The circuit is redrawn as in figure (b)

$V_0 = E - V_{T_1} - V_{T_2} = 12 - 0.7 - 0.3 = 11V$

And $I_D = I_R = \dfrac{V_R}{R} = \dfrac{V_0}{R} = \dfrac{11}{5.6} \simeq 1.96mA$

Note: If germanium diode is reversed, direction of current is same



as arrow head of silicon diode but opposite to germanium. Hence silicon diode is in short circuit and germanium in open circuit. The combination of a short circuit with open circuit results in open circuit.

Hence $I_D = 0A, V_D = 0V$

$V_D = I_R \times R = I_D \times R = 0V$

$V_{D_2} = V_{open circuit} = E = 12V$

Applying Kirchhoff's voltage law to equivalent circuit shown below, $E - V_{D_1} - V_{D_2} - V_0 = 0$

and $V_{D_2} = E - V_{D_1} - V_0 = 12 - 0 - 0$ with $V_0 = 0V$

96. **(8)** Here, $A_m = 4$ V$A_c = 5$ V

Percentage of modulation,

$$\mu = \frac{A_m}{A_c} \times 100 = \frac{4}{5} \times 100 = 80\% = a \times 10\%.$$

$\Rightarrow$ $a = 8$

97. **(9)** Here, $v_s = 4.5\,\text{kHz}; v_c = 3.45\,\text{MHz} = 3450\,\text{kHz}$

Band width $= 2v_s = 2 \times 4.5 = 9.0\,\text{kHz}.$

98. **(8)** Here, $v_c = 4\,\text{MHz}, i = 90°$

Maximum usuable frequency = v_c sec i

$= 4 \times \sec 60° = 4 \times 2 = 8\,\text{MHz}$

99. **(8)** $d' = \sqrt{2h'R} = 3d = 3\sqrt{2hR}$

or $h' = 9h = 9 \times 100 = 900\,m$

Increase in height of tower

= 900 – 100 = 800 = $a \times 10^2$

$\Rightarrow$ $a = 8$

100. **(4)** Microwave frequency used in telephone link

= 10 GHz

= 10×10^9 Hz = 10^{10} Hz

Frequency available for microwave communication

= 2% of 10 GHz

$$= \frac{2}{100} \times 10^{10} = 2 \times 10^8\,Hz$$

Band width of each telephone channel = 8 kHz

= 8×10^3 Hz

Number of microwave telephone channels

$$= \frac{2 \times 10^8}{8 \times 10^3} = 2.5 \times 10^4 = 2.5 \times 10^a$$

$\therefore$ $a = 4$

* * *