Electronics Devices & Circuits

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Previous Year Question Papers Solutions

Complete Bilingual Solutions (English & Gujarati)

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Contents

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Q.1 (a) List various types of filter circuits used with rectifier.

A rectifier circuit converts an alternating current (AC) into a direct current (DC). However, the output of a rectifier is not pure DC but contains pulsating AC components known as ripples. To smooth out these ripples and obtain a steady DC voltage, filter circuits are employed at the output of the rectifier.

The various types of filter circuits commonly used with rectifiers are listed below:

- **Capacitor Filter (C Filter):** Uses a capacitor connected in parallel with the load resistor to bypass AC ripples to the ground.
- **Inductor Filter (L Filter):** Uses an inductor connected in series with the load to block AC ripples while allowing DC to pass.
- **Choke Input Filter (LC Filter):** A combination of a series inductor (choke) and a parallel capacitor, offering better filtering than a single component.
- **Capacitor Input Filter (π Filter):** Consists of a capacitor in parallel, followed by a series inductor, and another parallel capacitor. It provides excellent ripple reduction and high DC output voltage.

Q.1 (b) Write various applications of P-N Junction Diode.

A P-N junction diode is a fundamental semiconductor device that allows current to flow in only one direction. Due to its unidirectional conduction property, it is widely utilized in various electronic circuits.

- **Rectifiers:** Diodes are extensively used in half-wave, full-wave, and bridge rectifiers to convert alternating current (AC) into direct current (DC) for power supplies.
- **Clipping Circuits:** Used to clip off or remove a specific portion (positive or negative half) of an input signal without distorting the remaining waveform.
- **Clamping Circuits:** Employed to shift the entire AC waveform to a different DC level (either positive or negative) without changing the shape of the signal.
- **Voltage Multipliers:** Diodes are used in cascade with capacitors to step up the input AC voltage by a factor of two (doubler), three (tripler), or more.
- **Logic Gates:** P-N junction diodes can be configured to construct basic digital logic gates like AND and OR gates (Diode Logic).
- **Protection Circuits:** They are used as freewheeling diodes to protect sensitive components from high voltage spikes produced by inductive loads, and for reverse polarity protection.

Q.1 (c) Explain the working of NPN Transistor.

An NPN transistor consists of a very thin and lightly doped P-type semiconductor layer sandwiched between two heavily doped N-type semiconductor layers. The three terminals are the Emitter, Base, and Collector.

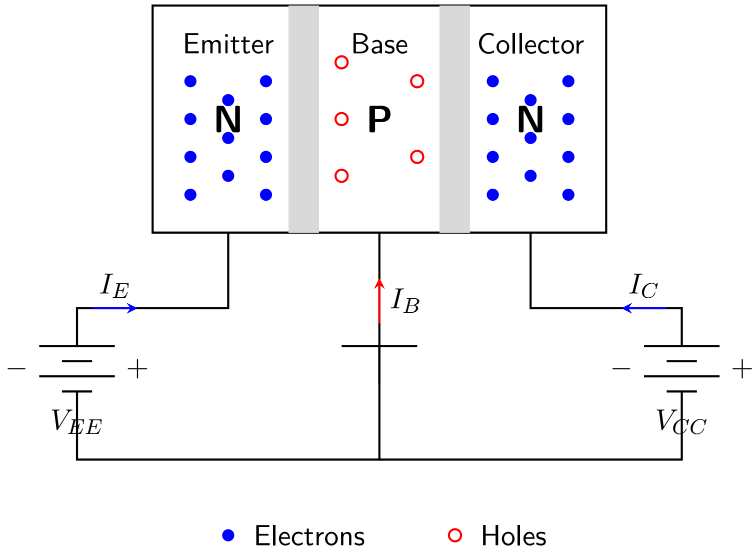


Figure 1: Working Mechanism of NPN Transistor

For normal operation in the active region, the Emitter-Base (EB) junction is forward-biased, and the Collector-Base (CB) junction is reverse-biased. The forward bias at the EB junction is provided by the voltage source V_{EE}, and the reverse bias at the CB junction is maintained by V_{CC}.

Working Mechanism:

1. **Emitter Injection:** Due to the forward bias at the EB junction, the majority charge carriers in the emitter (electrons) are repelled by the negative terminal of V_{EE} and pushed towards the base region. This movement of electrons constitutes the **Emitter Current (I_E)**.

2. **Base Recombination:** The base is a P-type material containing holes as majority carriers. Because the base is very thin and lightly doped, only a small fraction (about 5%) of the injected electrons recombine with the holes in the base. This small recombination current leaves the base terminal, forming the **Base Current (I_B)**.

3. **Collector Collection:** The remaining 95% of the electrons diffuse across the base and reach the depletion region of the CB junction. Since the CB junction is reverse-biased, its built-in electric field sweeps these electrons into the collector region, where they are attracted by the positive terminal of V_{CC}. This flow of electrons constitutes the **Collector Current (I_C)**.

Applying Kirchhoff's Current Law (KCL) to the transistor, the total emitter current is the sum of the base current and the collector current:

$$I_E = I_B + I_C$$

Q.1 (c) OR Explain the working of PNP Transistor.

A PNP transistor consists of a very thin and lightly doped N-type semiconductor layer sandwiched between two heavily doped P-type semiconductor layers. The three terminals are the Emitter, Base, and Collector.

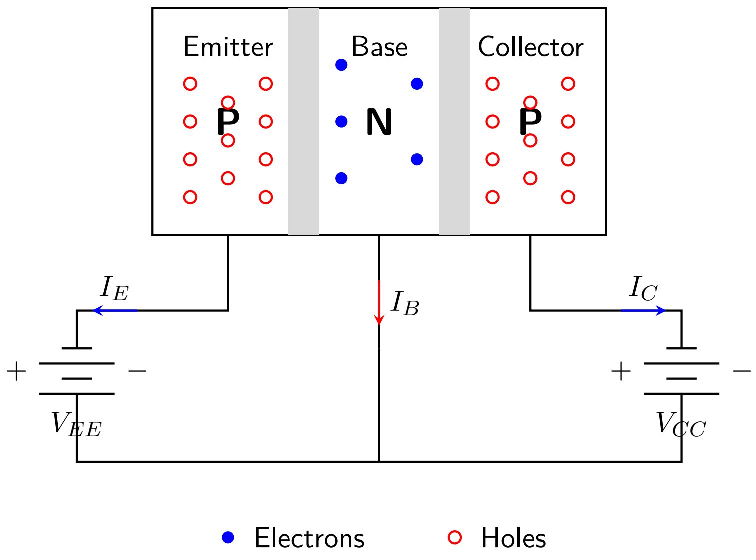


Figure 2: Working Mechanism of PNP Transistor

For operation in the active region, the Emitter-Base (EB) junction is forward-biased, while the Collector-Base (CB) junction is reverse-biased. The voltage source V_{EE} provides the forward bias at the EB junction, and V_{CC} maintains the reverse bias at the CB junction.

Working Mechanism:

1. **Emitter Injection:** Due to the forward bias at the EB junction, the majority charge carriers in the emitter (holes) are repelled by the positive terminal of V_{EE} and injected into the base region. This movement of holes constitutes the **Emitter Current** (I_E).

2. **Base Recombination:** The base is an N-type material where electrons are the majority carriers. Since the base is very narrow and lightly doped, only a small percentage (around 5%) of the injected holes recombine with the electrons. This small flow of charge creates the **Base Current** (I_B).

3. **Collector Collection:** The majority of the holes (about 95%) bypass the base and reach the depletion region of the CB junction. Because the CB junction is reverse-biased, the electric field sweeps these holes into the collector region, where they are attracted by the negative terminal of V_{CC}. This movement forms the **Collector Current** (I_C).

By applying Kirchhoff's Current Law (KCL), the relationship between the currents in the transistor is given by:

$$I_E = I_B + I_C$$

In a PNP transistor, conduction is primarily due to holes, whereas in an NPN transistor, it is due to electrons.

Q.2 (a) Draw symbol with proper nomenclature 1) Diode 2) Transistor 3) Zener Diode.

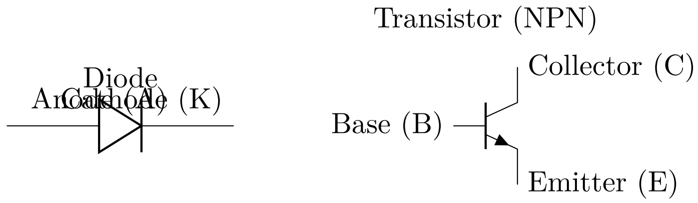


Figure 3: Symbols of Diode, Transistor, and Zener Diode

- **Diode**: A two-terminal device (Anode and Cathode) that allows current to flow primarily in one direction.
- **Transistor (NPN)**: A three-terminal device (Base, Collector, Emitter) used for amplification or switching.
- **Zener Diode**: A specialized diode designed to reliably allow current to flow backwards when a certain set reverse voltage is reached.

Q.2 (b) Draw a neat circuit of P-N Junction Diode in forward Biased conduction mode.

When the positive terminal of the battery is connected to the P-region and the negative terminal to the N-region, the P-N junction is said to be in forward bias.

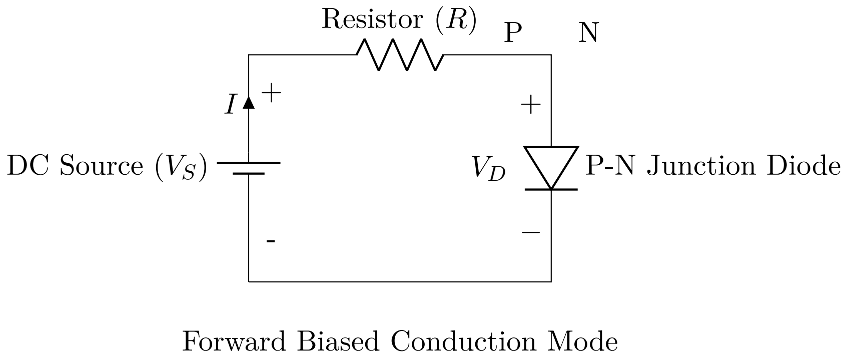


Figure 4: P-N Junction Diode in Forward Biased Conduction Mode

- In forward bias, the applied voltage opposes the built-in potential barrier.
- The depletion region width decreases, making it easier for majority charge carriers to cross the junction.
- A significant amount of forward current flows through the diode once the applied voltage exceeds the cut-in voltage (0.7 V for Silicon).

Q.2 (c) Explain the working of Half Wave Rectifier with proper waveforms.

A Half Wave Rectifier is a circuit that converts alternating current (AC) into pulsating direct current (DC) by passing only one half of the input AC cycle and blocking the other.

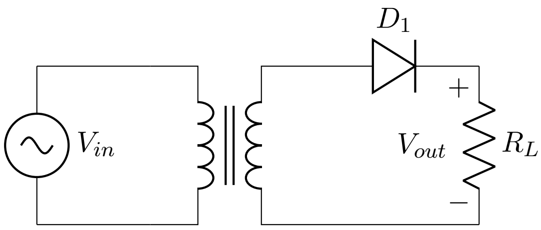


Figure 5: Circuit Diagram of Half Wave Rectifier

Working Principle:

- **Positive Half Cycle:** During the positive half cycle of the AC input, the anode of the diode D_1 becomes positive with respect to the cathode. The diode is forward-biased and conducts current through the load resistor R_L, producing an output voltage.
- **Negative Half Cycle:** During the negative half cycle, the anode becomes negative with respect to the cathode. The diode is reverse-biased and acts as an open switch. No current flows through R_L, and the output voltage is zero.

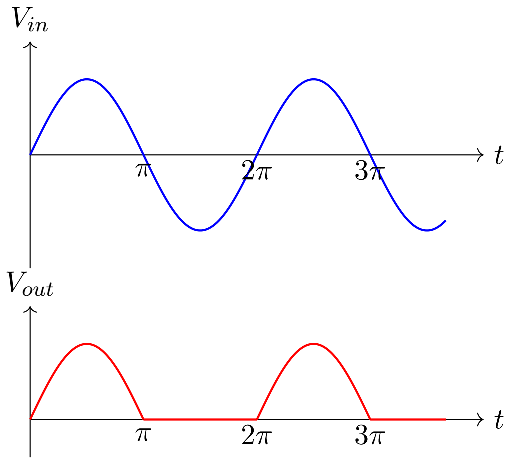


Figure 6: Input and Output Waveforms of Half Wave Rectifier

- **Efficiency:** The maximum rectification efficiency is 40.6%.
- **Ripple Factor:** It has a high ripple factor of 1.21, meaning the output contains a significant amount of AC components.

Q.2 (a) OR Explain intrinsic semi-conductors using at least 02 examples.

An **intrinsic semiconductor** is a pure semiconductor without any significant dopant species present.

- In an intrinsic semiconductor, the number of excited electrons in the conduction band (n) is exactly equal to the number of holes in the valence band (p).
- This is mathematically expressed as $n = p = n_i$, where n_i is the intrinsic carrier concentration.

- At absolute zero temperature (0 K), an intrinsic semiconductor behaves as a perfect insulator. As temperature increases, thermal energy excites some electrons across the bandgap, creating electron-hole pairs and allowing weak conduction.

Examples:

1. **Silicon (Si):** The most widely used semiconductor material due to its abundance and stable thermal properties. It has a bandgap of approximately 1.1 eV at room temperature.
2. **Germanium (Ge):** Widely used in early electronics, Germanium has a smaller bandgap of about 0.67 eV, making it more highly conductive at room temperature compared to Silicon, but also more sensitive to temperature variations.

Q.2 (b) OR Draw a neat circuit of P-N Junction Diode in Reverse Biased mode.

When the negative terminal of the battery is connected to the P-region and the positive terminal to the N-region, the P-N junction is said to be in reverse bias.

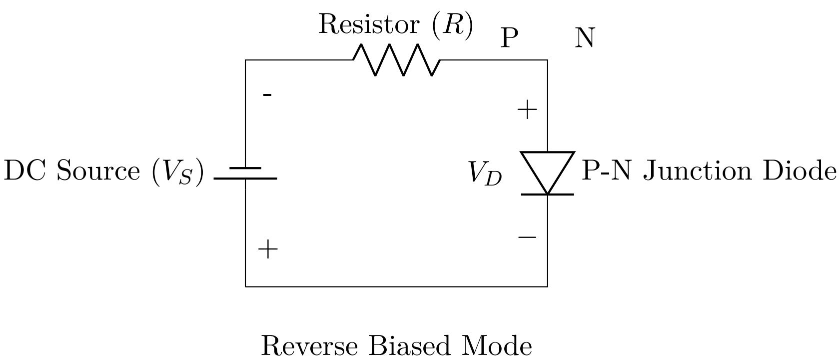


Figure 7: P-N Junction Diode in Reverse Biased Mode

- In reverse bias, the applied voltage adds to the built-in potential barrier, making it much harder for majority carriers to cross the junction.
- The depletion region widens as electrons and holes are pulled away from the junction by the battery terminals.
- Only a very small leakage current (due to minority carriers) flows through the diode until the breakdown voltage is reached.

Q.2 (c) OR Explain the working of Full Wave Bridge Rectifier with proper waveforms.

A Full Wave Bridge Rectifier uses four diodes arranged in a bridge configuration to convert both halves of an AC input cycle into pulsating DC, eliminating the need for a bulky center-tapped transformer.

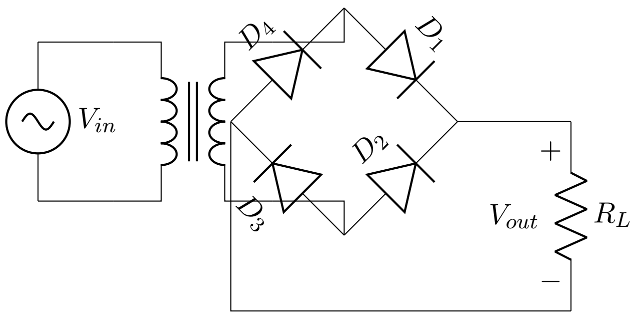


Figure 8: Circuit Diagram of Full Wave Bridge Rectifier

Working Principle:

- **Positive Half Cycle:** The top terminal of the secondary winding is positive, and the bottom is negative. Diodes D_1 and D_3 are forward-biased and conduct, while D_2 and D_4 are reverse-biased. Current flows from the top terminal, through D_1, down through the load resistor R_L, through D_3, and back to the bottom terminal.
- **Negative Half Cycle:** The bottom terminal is positive, and the top is negative. Diodes D_2 and D_4 are forward-biased, while D_1 and D_3 are reverse-biased. Current flows from the bottom terminal, through D_2, down through R_L (in the same direction as before), through D_4, and back to the top terminal.

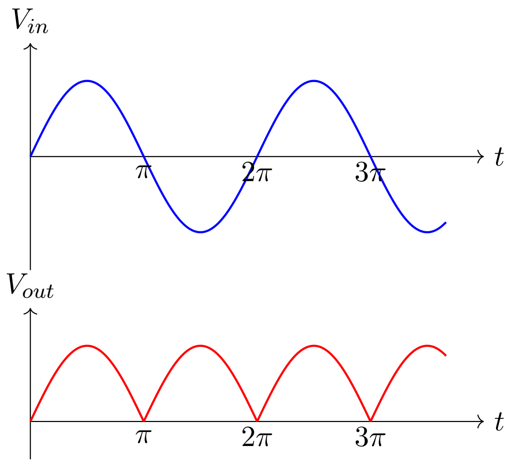


Figure 9: Input and Output Waveforms of Full Wave Bridge Rectifier

- **Efficiency:** The maximum rectification efficiency is 81.2%, which is double that of a half-wave rectifier.
- **Ripple Factor:** It has a much lower ripple factor of 0.48, providing a smoother DC output.

Q.3 (a) Explain extrinsic semi-conductors along with its types.

Extrinsic Semiconductor

An extrinsic semiconductor is a pure (intrinsic) semiconductor that has been intentionally doped with a small amount of specific impurities to enhance its electrical conductivity.

- The process of adding impurities to a pure semiconductor is called **doping**.

- It significantly increases the number of charge carriers (electrons or holes) at room temperature.
- There are two main types of extrinsic semiconductors based on the impurity added:
  1. **N-Type Semiconductor**: Formed by doping a pure semiconductor (like Silicon or Germanium) with a **pentavalent impurity** (having 5 valence electrons, e.g., Phosphorus, Arsenic, Antimony). Here, **electrons** are the majority charge carriers, and holes are the minority charge carriers.
  2. **P-Type Semiconductor**: Formed by doping a pure semiconductor with a **trivalent impurity** (having 3 valence electrons, e.g., Boron, Gallium, Indium). Here, **holes** are the majority charge carriers, and electrons are the minority charge carriers.

Q.3 (b) List various operating modes of transistor along with their configuration.

A Bipolar Junction Transistor (BJT) consists of two PN junctions: the Emitter-Base (EB) junction and the Collector-Base (CB) junction. Depending on the biasing (forward or reverse) of these two junctions, a transistor operates in four distinct modes.

Operating Modes of Transistor:

- **Active Mode**: The EB junction is forward-biased, and the CB junction is reverse-biased. This is the primary mode used for amplification purposes.
- **Saturation Mode**: Both the EB and CB junctions are forward-biased. The transistor acts like a closed switch (fully ON), allowing maximum current to flow.
- **Cut-off Mode**: Both the EB and CB junctions are reverse-biased. The transistor acts like an open switch (fully OFF), preventing current flow.
- **Reverse Active (Inverted) Mode**: The EB junction is reverse-biased, and the CB junction is forward-biased. It provides very poor amplification and is rarely used in practice.

Table 1: Summary of Operating Modes and Biasing Configurations

Operating Mode	Emitter-Base Junction	Collector-Base Junction	Application
Active	Forward Biased	Reverse Biased	Amplifier
Saturation	Forward Biased	Forward Biased	Closed Switch (ON)
Cut-off	Reverse Biased	Reverse Biased	Open Switch (OFF)
Reverse Active	Reverse Biased	Forward Biased	Attenuator

Note: Transistors are also configured in three basic ways based on the common terminal: Common Base (CB), Common Emitter (CE), and Common Collector (CC).

Q.3 (c) Explain the working of Center tap Full Wave Rectifier with proper waveforms.

A center-tap full-wave rectifier uses a center-tapped transformer and two diodes to convert the complete AC input cycle (both positive and negative half-cycles) into pulsating DC output.

Circuit Construction:

- It consists of an AC source, a center-tapped step-down transformer, two diodes (D_1 and D_2), and a load resistor (R_L).
- The secondary winding of the transformer is divided into two equal halves by a center tap, which acts as the common return path (ground).

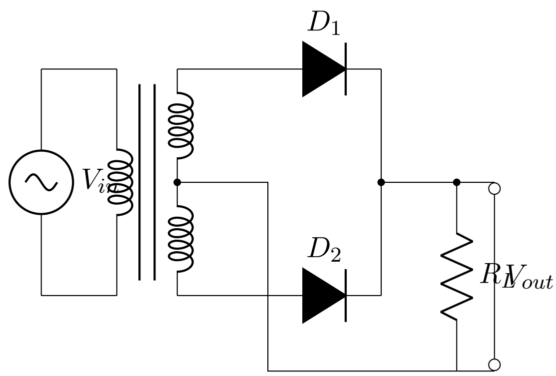


Figure 10: Circuit Diagram of Center Tap Full Wave Rectifier

Working Principle:

- **During Positive Half-Cycle**: The upper terminal of the secondary winding becomes positive, and the lower terminal becomes negative with respect to the center tap. Diode D_1 is forward-biased (conducts), and D_2 is reverse-biased (does not conduct). Current flows through D_1, R_L, and back to the center tap.
- **During Negative Half-Cycle**: The lower terminal becomes positive, and the upper terminal becomes negative. Diode D_2 is forward-biased, and D_1 is reverse-biased. Current flows through D_2, R_L, and back to the center tap.
- In both half-cycles, the current flows through the load resistor R_L in the same direction, producing a unidirectional (DC) output voltage.

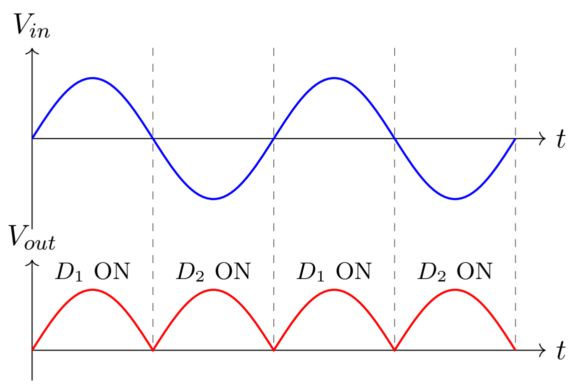


Figure 11: Input and Output Waveforms

Q.3 (a) OR Explain P Type semi-conductors using at least 03 examples.

P-Type Semiconductor

A P-type semiconductor is an extrinsic semiconductor created by doping a pure (intrinsic) semiconductor crystal with atoms of a trivalent impurity.

- **Mechanism**: A trivalent impurity atom has 3 valence electrons. When it replaces a Silicon (or Germanium) atom in the crystal lattice, it forms three covalent bonds with neighboring atoms. The fourth bond is left incomplete, creating a vacancy called a **hole**.
- **Charge Carriers**: In a P-type semiconductor, **holes** are the majority charge carriers, while **electrons** (generated thermally) are the minority charge carriers.
- **Acceptor Impurities**: Trivalent impurities are known as ”acceptor impurities” because the holes they create can accept electrons from neighboring atoms.
- **Examples of Trivalent Impurities**:
  1. **Boron (B)**: Widely used for doping Silicon.
  2. **Gallium (Ga)**: Used in specialized high-frequency semiconductor devices.
  3. **Indium (In)**: Often used in manufacturing specific types of diodes and transistors.

Q.3 (b) OR Explain the working of Optical Fibre cable.

An optical fiber cable transmits data in the form of light pulses. It works on the principle of **Total Internal Reflection (TIR)**.

Basic Construction:

- **Core**: The central thin glass or plastic medium through which light travels.
- **Cladding**: The outer optical material surrounding the core. It has a **lower refractive index** than the core.
- **Coating/Jacket**: The outermost plastic layer that protects the fiber from physical damage and moisture.

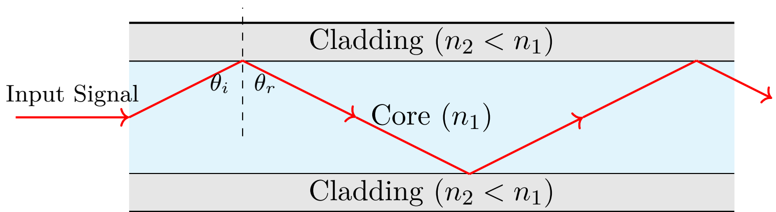


Figure 12: Total Internal Reflection in Optical Fiber

Working Principle:

- When a light ray enters the core at an angle greater than the **critical angle**, it strikes the core-cladding boundary.
- Because the refractive index of the core (n_1) is greater than the refractive index of the cladding (n_2), the light ray is completely reflected back into the core instead of refracting out.

- This continuous bouncing (Total Internal Reflection) allows the light signal to travel over long distances along the fiber with minimal energy loss.
- The optical signals are generated by light sources (LEDs or Lasers) at the transmitter and converted back to electrical signals by photodiodes at the receiver.

Q.3 (c) OR Explain V-I Characteristics of P-N junction diode.

The Voltage-Current (V-I) characteristics of a P-N junction diode represent the relationship between the applied voltage across the diode and the current flowing through it.

1. **Forward Bias Characteristics:**

- When the positive terminal of the battery is connected to the P-region and the negative terminal to the N-region, the diode is forward-biased.
- Initially, for low voltages, the forward current is almost zero because the applied voltage is less than the barrier potential.
- **Knee Voltage**: Once the applied forward voltage exceeds the barrier potential (approx. 0.7 V for Silicon and 0.3 V for Germanium), the depletion layer collapses.
- Beyond the knee voltage, the forward current increases exponentially with a small increase in voltage.

2. **Reverse Bias Characteristics:**

- When the positive terminal of the battery is connected to the N-region and the negative terminal to the P-region, the diode is reverse-biased.
- The depletion layer widens, and ideally, no current should flow. However, a very small **Reverse Saturation Current** (in microamperes) flows due to minority charge carriers.
- **Breakdown Voltage**: If the reverse voltage is increased excessively, it reaches a point called the breakdown voltage (V_{BR}). At this point, covalent bonds break, causing a sharp increase in reverse current, which can permanently damage the diode.

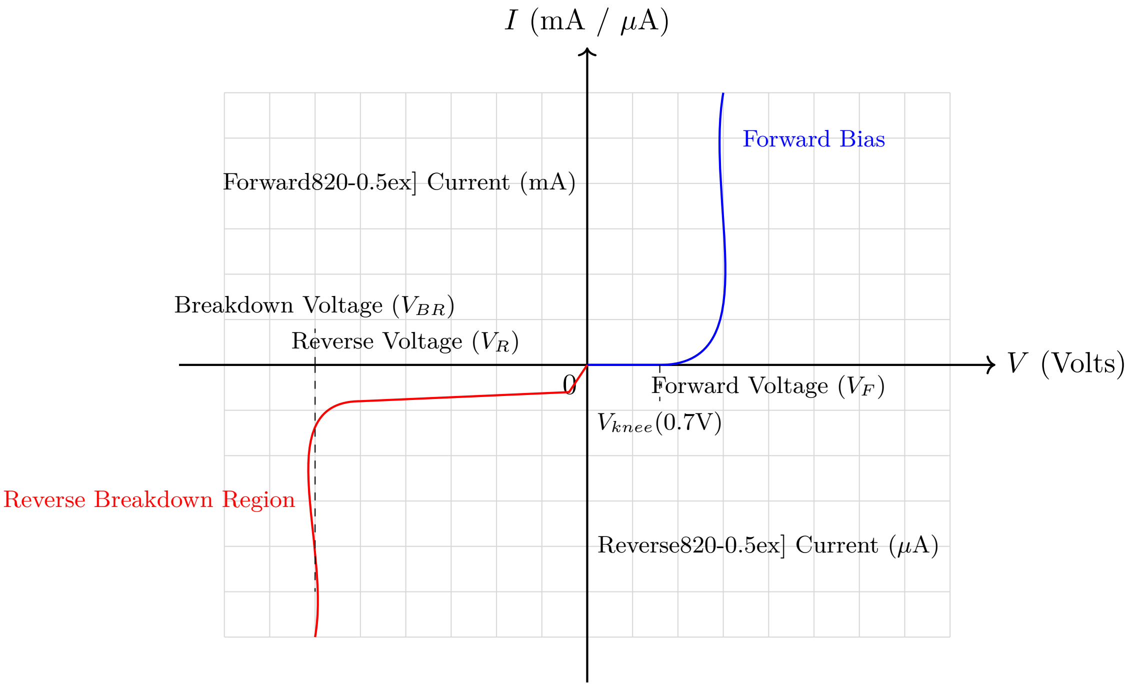


Figure 13: V-I Characteristics of P-N Junction Diode

Q.4 (a) Explain N-Type semi-conductors using at least 03 examples.

N-Type Semiconductor

An N-type semiconductor is created by adding pentavalent impurities (doping) to a pure (intrinsic) semiconductor like Silicon (Si) or Germanium (Ge).

- **Doping Process:** Pentavalent atoms have five valence electrons. When added, four electrons form covalent bonds with the neighboring semiconductor atoms, while the fifth electron remains loosely bound and becomes a free electron.
- **Charge Carriers:** Because of the extra free electrons, the majority charge carriers are electrons, and the minority charge carriers are holes.
- **Nomenclature:** The term 'N-type' stands for 'Negative' type due to the abundance of negatively charged free electrons.

Examples of Pentavalent Impurities:

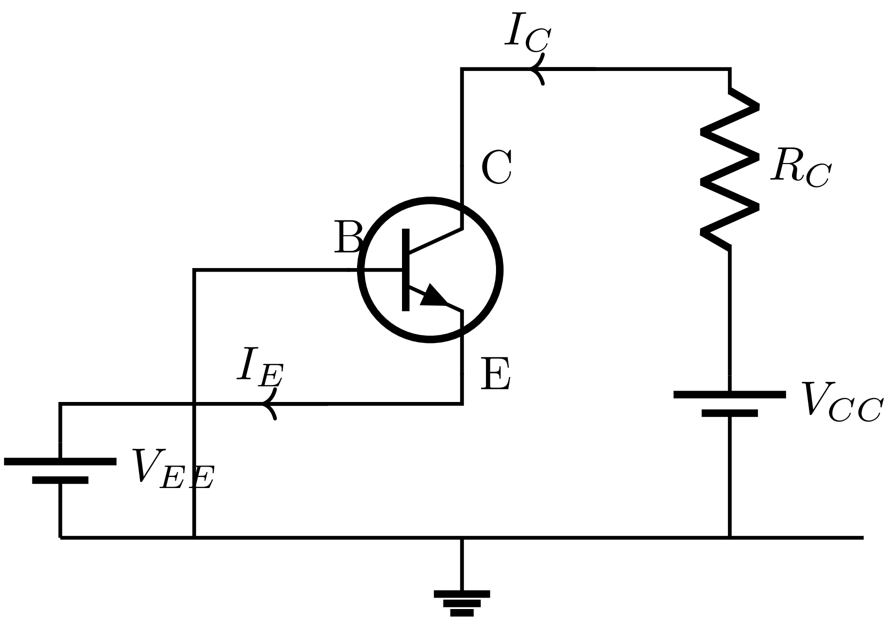
1. Phosphorus (P)
2. Arsenic (As)
3. Antimony (Sb)
4. Bismuth (Bi)

Q.4 (b) Compare CB, CE and CC configurations of transistor (At least 6 points).

Table: Comparison of CB, CE, and CC Transistor Configurations

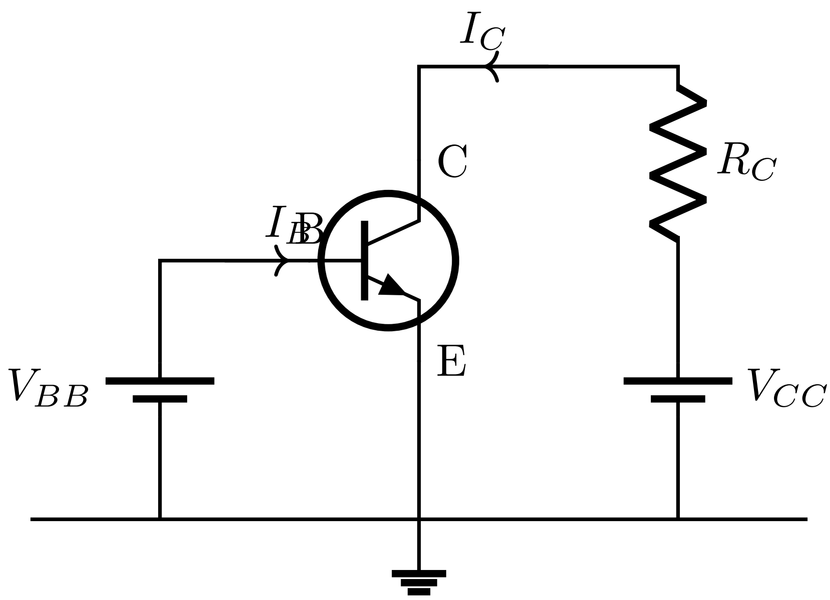
Sr. No.	Parameter	Common Base (CB)	Common Emitter (CE)	Common Collector (CC)
1	**Input Terminal**	Emitter	Base	Base
2	**Output Terminal**	Collector	Collector	Emitter
3	**Common Terminal**	Base	Emitter	Collector
4	**Current Gain**	Less than unity ($\alpha < 1$)	High (β)	Very High (γ)
5	**Voltage Gain**	High	High	Less than unity (≈ 1)
6	**Input Resistance**	Very Low ($\approx 100\,\Omega$)	Low/Moderate ($\approx 1\,\text{k}\Omega$)	Very High ($\approx 100\,\text{k}\Omega$)
7	**Output Resistance**	Very High ($\approx 1\,\text{M}\Omega$)	High/Moderate ($\approx 40\,\text{k}\Omega$)	Very Low ($\approx 50\,\Omega$)
8	**Phase Shift**	0° (In-phase)	180° (Out-of-phase)	0° (In-phase)
9	**Applications**	High-frequency circuits	Audio/General purpose amplifiers	Impedance matching

Q.4 (c) Draw CB(Common Base) & CE(Common Emitter) configuration of transistor with proper nomenclature.



Common Base (CB) Configuration

Figure 14: Common Base (CB) Configuration



Common Emitter (CE) Configuration

Figure 15: Common Emitter (CE) Configuration

- **Common Base (CB):** The base terminal is common to both the input and output circuits. The input is applied at the emitter, and the output is taken from the collector.

- **Common Emitter (CE):** The emitter terminal is common to both the input and output circuits. The input is applied at the base, and the output is taken from the collector.

— OR —

Q.4 (a) OR Draw symbol with proper nomenclature 1) UJT 2) SCR 3) LDR

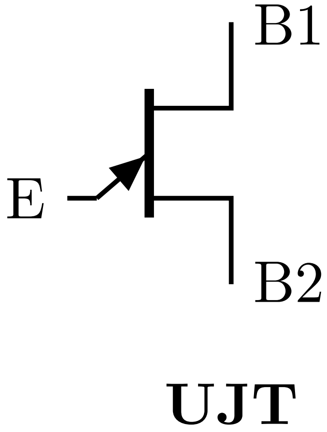


Figure 16: UJT Symbol

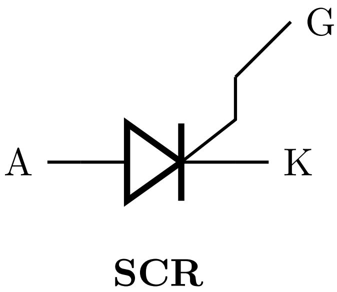


Figure 17: SCR Symbol

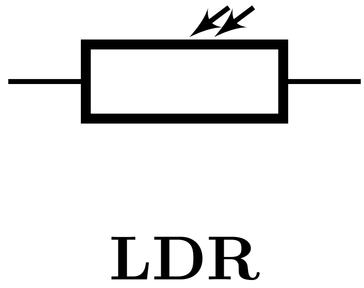


Figure 18: LDR Symbol

Q.4 (b) OR Explain working of Zener Diode as Voltage Regulator.

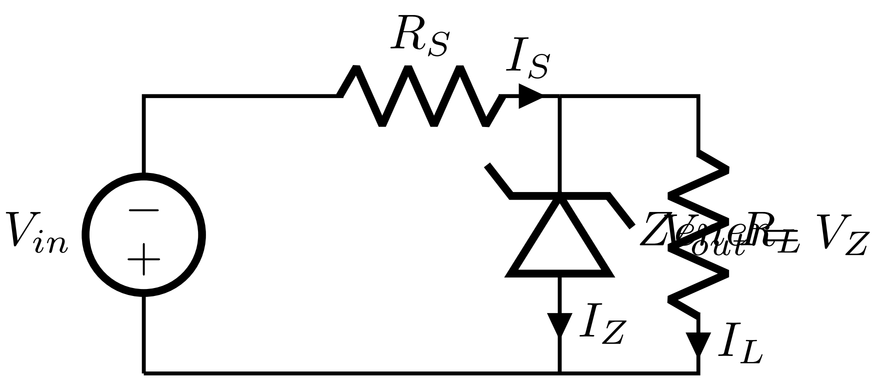


Figure 19: Zener Diode as a Voltage Regulator

- A Zener diode operates in the reverse breakdown region to regulate voltage.
- When the reverse-biased voltage across the diode exceeds the Zener breakdown voltage (V_Z), the voltage across it remains constant, even if the current through it changes significantly.

- As shown in the circuit, the Zener diode is connected in parallel with the load resistor (R_L), and a series resistor (R_S) is used to limit the current.
- **Varying Input Voltage:** If the input voltage (V_{in}) increases, the total current increases. The Zener diode absorbs the extra current, keeping the voltage across the load ($V_L = V_Z$) constant. The extra voltage drop occurs across R_S.
- **Varying Load Current:** If the load resistance decreases, load current (I_L) increases. The Zener diode compensates by drawing less current (I_Z), keeping the total current (I_S) and the output voltage constant.

Q.4 (c) OR Derive relation $\beta = \alpha/(1-\alpha)$ for transistors.

- For a Bipolar Junction Transistor (BJT), the total emitter current (I_E) is the sum of the base current (I_B) and the collector current (I_C):
$$I_E = I_B + I_C$$
- The **Common Base current gain (α)** is defined as the ratio of collector current to emitter current:
$$\alpha = \frac{I_C}{I_E} \quad \Rightarrow \quad I_E = \frac{I_C}{\alpha}$$
- The **Common Emitter current gain (β)** is defined as the ratio of collector current to base current:
$$\beta = \frac{I_C}{I_B} \quad \Rightarrow \quad I_B = \frac{I_C}{\beta}$$
- Substituting the values of I_E and I_B into the fundamental current equation:
$$\frac{I_C}{\alpha} = \frac{I_C}{\beta} + I_C$$
- Dividing the entire equation by I_C:
$$\frac{1}{\alpha} = \frac{1}{\beta} + 1$$
- Rearranging to solve for β:
$$\frac{1}{\beta} = \frac{1}{\alpha} - 1$$
$$\frac{1}{\beta} = \frac{1-\alpha}{\alpha}$$
- Inverting both sides yields the final relationship:
$$\beta = \frac{\alpha}{1-\alpha}$$

Q.5 (a) List various biasing methods used for transistors.

Transistor Biasing

Transistor biasing is the process of setting a transistor's DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified properly by the transistor.

The various biasing methods used for BJT (Bipolar Junction Transistor) are as follows:

1. **Base Resistor Bias (Fixed Bias):**
   - In this method, a single resistor is connected from the base to the supply voltage.
   - It is the simplest method but suffers from poor thermal stability.
2. **Collector-to-Base Bias (Collector Feedback Bias):**
   - A resistor is connected between the collector and the base.
   - It provides negative feedback, which improves thermal stability compared to fixed bias.
3. **Voltage Divider Bias (Self Bias):**
   - Two resistors form a voltage divider across the supply voltage to set the base voltage.
   - This is the most widely used biasing method because it provides excellent stabilization of the operating point, independent of β.
4. **Emitter Bias:**
   - Uses both a positive and a negative supply voltage.
   - It provides very good stability but requires a dual-polarity power supply.

Q.5 (b) Explain working of transistor as an Amplifier.

Transistor as an Amplifier

An amplifier is an electronic circuit that increases the amplitude of a weak input signal (voltage, current, or power) without changing its shape or frequency. A transistor can act as an amplifier when operated in its active region.

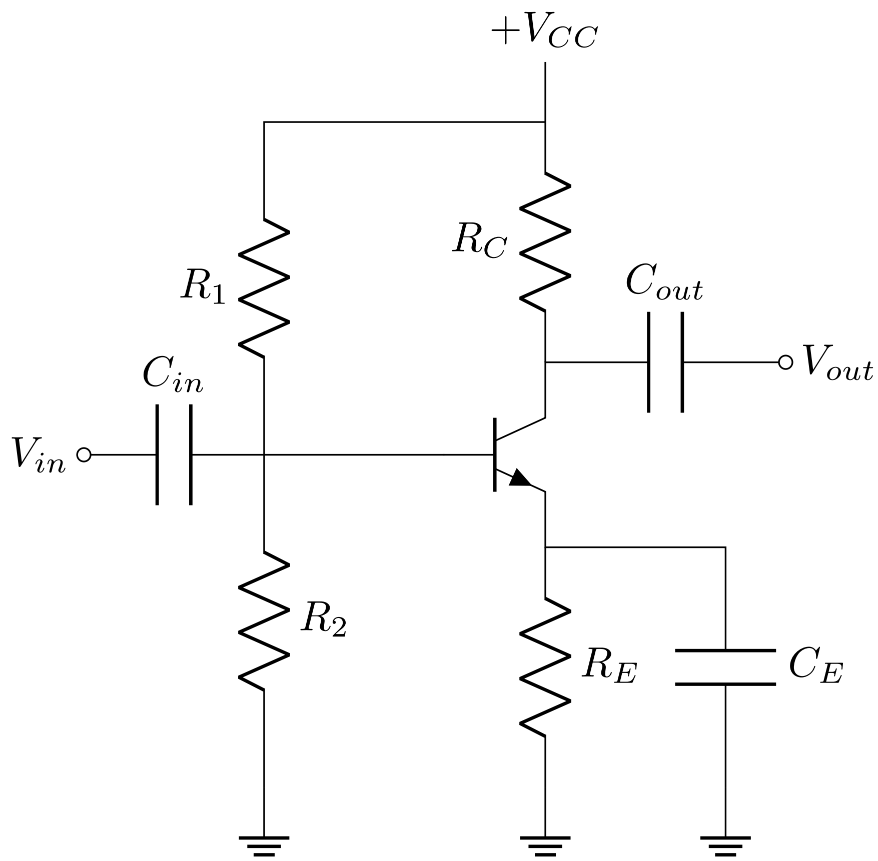


Figure 20: Transistor as a CE Amplifier

The working of a transistor as an amplifier in the Common Emitter (CE) configuration can be explained as follows:

- **Biasing Condition:** To function as an amplifier, the transistor's emitter-base junction is forward-biased, and the collector-base junction is reverse-biased (Active Region).
- **Input Signal:** A weak AC input signal V_{in} is applied across the base-emitter terminals using a coupling capacitor C_{in}.
- **Positive Half Cycle:**
  - During the positive half cycle of the input AC signal, the forward bias across the base-emitter junction increases.
  - This results in an increase in the base current I_B.
  - Since collector current $I_C = \beta I_B$, a small increase in I_B causes a large increase in I_C.
  - The increased I_C causes a larger voltage drop across the collector resistor R_C, which decreases the output voltage V_{out} (Phase reversal of 180°).
- **Negative Half Cycle:**
  - During the negative half cycle, the forward bias decreases, reducing I_B and consequently I_C.
  - The voltage drop across R_C decreases, causing the output voltage V_{out} to increase.
- **Overall Amplification:** A small change in input base current produces a proportionally large change in the collector current, leading to a magnified voltage signal at the output.

Q.5 (c) Draw a neat detailed sketch of construction of Optical Fibre Cable with proper nomenclature.

An optical fibre cable is a cylindrical dielectric waveguide that transmits light along its axis by the process of total internal reflection.

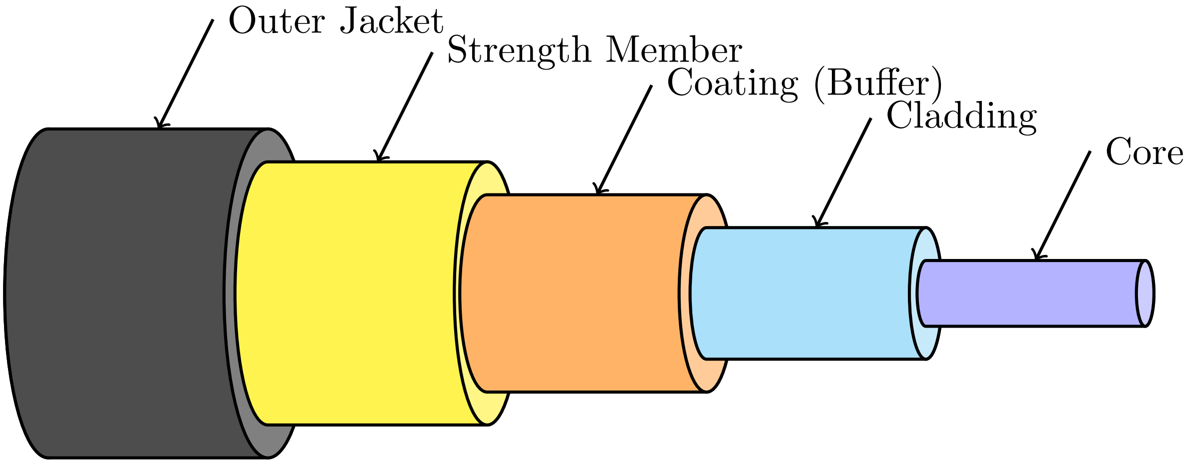


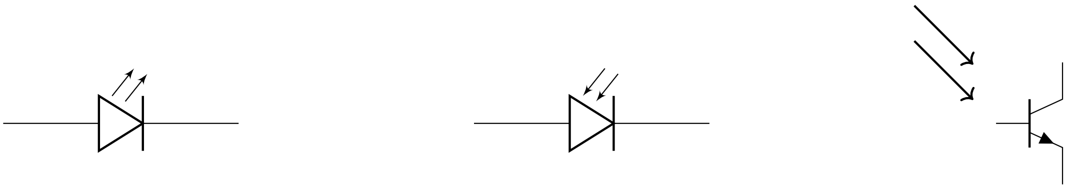
Figure 21: Construction of Optical Fibre Cable

The basic structural components of an optical fibre cable include:

1. **Core:**
   - The innermost part of the optical fibre where the light propagates.
   - Made of high-purity glass (silica) or plastic.
   - It has a higher refractive index (n_1) to allow total internal reflection.
2. **Cladding:**
   - The layer surrounding the core.
   - Also made of glass or plastic but with a slightly lower refractive index ($n_2 < n_1$).
   - It traps the light inside the core by reflecting it back towards the centre.
3. **Buffer Coating:**
   - A protective plastic layer applied over the cladding.
   - It shields the fibre from physical damage, moisture, and micro-bending losses.
4. **Strength Member:**
   - Materials like aramid yarn (Kevlar) or steel wire surrounding the buffer coating.
   - Provides high tensile strength to prevent the cable from breaking during installation and pulling.
5. **Outer Jacket:**
   - The outermost protective sheath typically made of PVC or polyurethane.
   - Protects the inner components from environmental factors such as moisture, abrasion, and chemical damage.

Q.5 (a) OR Draw symbol with proper nomenclature 1) LED Diode 2) Photo Diode 3) Photo Transistor

The standard electronic symbols for the given optoelectronic devices are shown below:



(1) LED (2) Photo Diode (3) Photo Transistor

Figure 22: Symbols of LED, Photo Diode, and Photo Transistor

- **LED (Light Emitting Diode):** A PN junction diode that emits light when forward-biased. The arrows point outwards to indicate the emission of light.
- **Photo Diode:** A semiconductor diode that generates a current when exposed to light. It is operated in reverse bias. The arrows point inwards to indicate the reception of light.
- **Photo Transistor:** A bipolar junction transistor whose base region is exposed to light. The light controls the base current, which in turn controls the larger collector current. The arrows point towards the base region.

Q.5 (b) OR Explain working of transistor as an Switch.

Transistor as a Switch

A transistor can be used as a solid-state switch to turn a load ON or OFF. When used as a switch, the transistor operates entirely in the cut-off region (OFF state) or the saturation region (ON state), avoiding the active region.

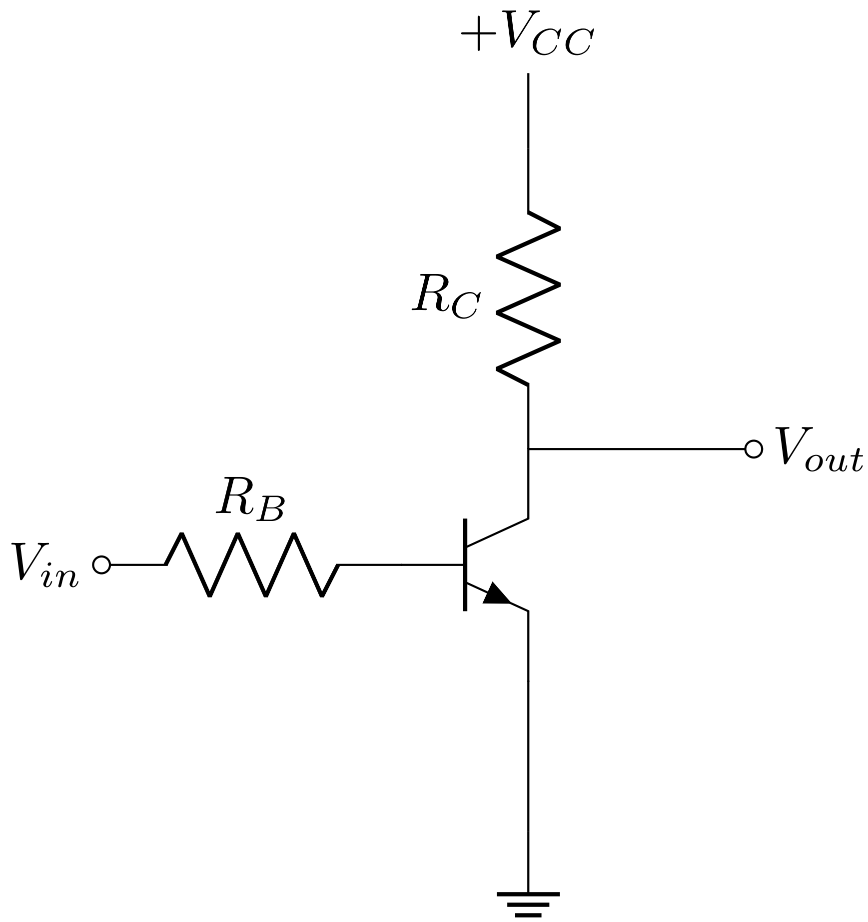


Figure 23: Transistor as a Switch

The operation of the transistor as a switch can be understood in two states:

1. **OFF State (Cut-off Region):**
   - When the input voltage V_{in} is zero or less than the cut-in voltage (e.g., 0.7 V for Silicon), the base-emitter junction is not forward-biased.
   - The base current $I_B = 0$, which results in zero collector current ($I_C = 0$).
   - Since there is no current flowing through the collector resistor R_C, there is no voltage drop across it.
   - Therefore, the output voltage $V_{out} \approx V_{CC}$. The transistor behaves like an open switch.
2. **ON State (Saturation Region):**
   - When a sufficient positive input voltage V_{in} is applied, a large base current I_B flows.
   - This forces the transistor to conduct heavily, driving it into the saturation region.
   - The collector current I_C reaches its maximum limit, limited only by R_C.
   - The voltage drop across the transistor ($V_{CE(sat)}$) becomes almost zero (typically 0.2 V).
   - As a result, the output voltage drops to nearly zero ($V_{out} \approx 0$ V). The transistor acts like a closed switch.

Q.5 (c) OR Derive relation $\alpha = \beta/1 + \beta$ for transistors.

The current gains for a transistor in different configurations are defined as α (Common Base) and β (Common Emitter).

Definitions of Current Gains

- **Alpha (α):** It is the ratio of collector current (I_C) to emitter current (I_E).

$$\alpha = \frac{I_C}{I_E}$$

- **Beta (β):** It is the ratio of collector current (I_C) to base current (I_B).

$$\beta = \frac{I_C}{I_B}$$

The fundamental current equation for any Bipolar Junction Transistor (BJT) is given by:

$$I_E = I_B + I_C \quad \text{— (Equation 1)}$$

Where:

- I_E = Emitter Current
- I_B = Base Current
- I_C = Collector Current

Dividing both sides of Equation 1 by the collector current I_C, we get:

$$\frac{I_E}{I_C} = \frac{I_B}{I_C} + \frac{I_C}{I_C}$$

$$\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$$

From the definitions of α and β, we know that:

$$\frac{I_E}{I_C} = \frac{1}{\alpha} \quad \text{and} \quad \frac{I_B}{I_C} = \frac{1}{\beta}$$

Substituting these values into the above equation:

$$\frac{1}{\alpha} = \frac{1}{\beta} + 1$$

Taking the least common multiple (LCM) on the right hand side:

$$\frac{1}{\alpha} = \frac{1+\beta}{\beta}$$

Taking the reciprocal of both sides to solve for α:

$$\alpha = \frac{\beta}{1+\beta}$$

This is the required relationship between the current amplification factors α and β.

Summer 2025

Q.1 (a) Explain the V-I characteristics of PN junction diode.

The V-I characteristic of a PN junction diode is a curve showing the relationship between the applied voltage across the diode and the current flowing through it.

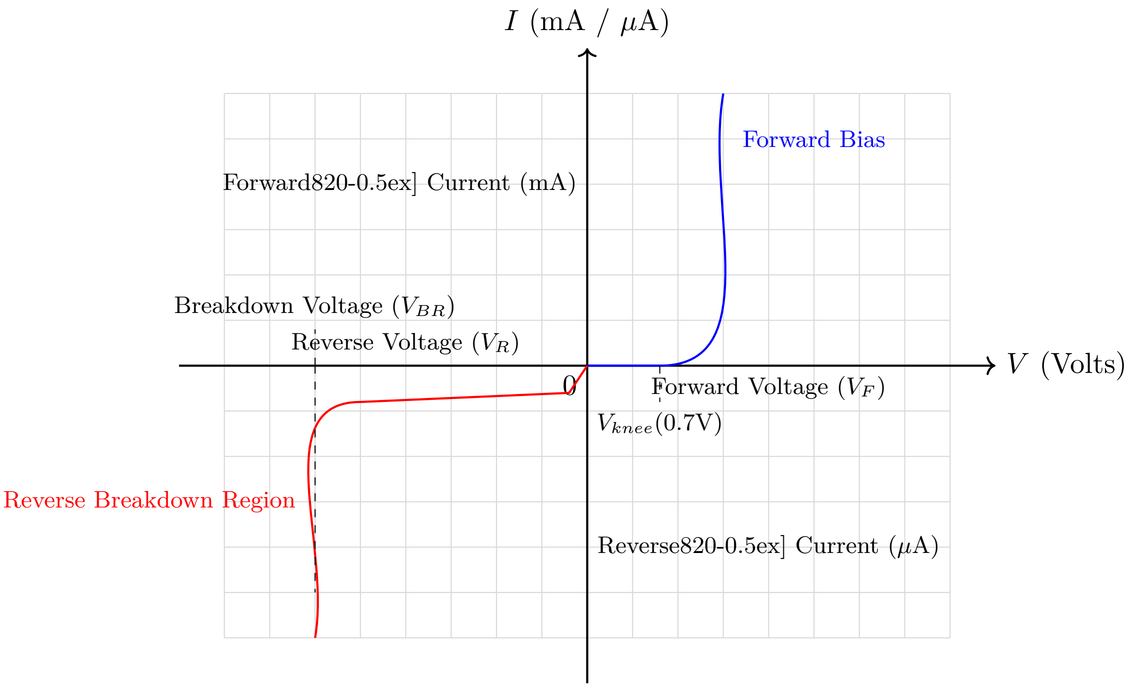


Figure 24: V-I Characteristics of PN Junction Diode

- **Forward Bias Region:** When the positive terminal of the battery is connected to the P-type and the negative terminal to the N-type, the diode is forward biased. The current is initially zero until the applied voltage overcomes the barrier potential (approx. 0.7 V for Silicon and 0.3 V for Germanium). This voltage is called the **Knee Voltage**. After this, the current increases exponentially.
- **Reverse Bias Region:** When the battery polarity is reversed, the diode is reverse biased. Only a very small reverse leakage current (in μA) flows due to minority charge carriers. If the reverse voltage is increased beyond a certain limit called the **Breakdown Voltage**, the covalent bonds break, and a large reverse current flows, which can damage the diode.

Q.1 (b) Compare Half wave rectifier and full wave center tap rectifier.

Table 3: Comparison of Half Wave and Full Wave Center Tap Rectifier

Sr. No.	Half Wave Rectifier	Full Wave Center Tap Rectifier
1	Uses only 1 diode.	Uses 2 diodes.
2	Maximum rectifier efficiency is 40.6%.	Maximum rectifier efficiency is 81.2%.

Sr. No.	Half Wave Rectifier	Full Wave Center Tap Rectifier
3	Ripple factor is high (1.21).	Ripple factor is low (0.48).
4	Center tap transformer is not required.	Center tap transformer is strictly required.
5	Peak Inverse Voltage (PIV) is V_m.	Peak Inverse Voltage (PIV) is $2V_m$.
6	Fundamental ripple frequency is equal to the input frequency (f_{in}).	Fundamental ripple frequency is twice the input frequency ($2f_{in}$).

Q.1 (c) Draw and Explain full wave rectifier circuit with its advantage and disadvantage.

A full wave rectifier converts the whole of the input AC voltage into pulsating DC voltage. The center-tap full wave rectifier uses two diodes and a center-tapped transformer.

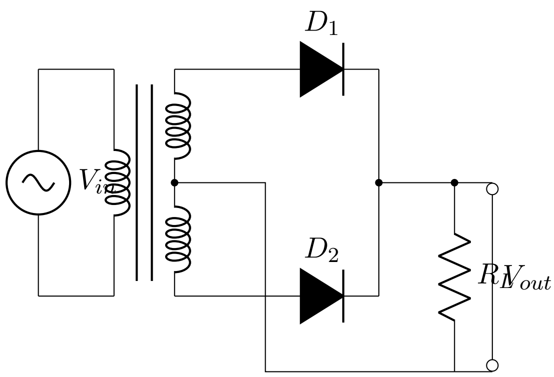


Figure 25: Full Wave Center Tap Rectifier Circuit

Working Principle:

- **Positive Half Cycle:** During the positive half cycle of the input AC supply, the upper end of the secondary winding becomes positive and the lower end becomes negative with respect to the center tap. This makes diode D_1 forward-biased and D_2 reverse-biased. Current flows through D_1 and the load resistor R_L.
- **Negative Half Cycle:** During the negative half cycle, the lower end of the secondary winding becomes positive and the upper end becomes negative. This makes diode D_2 forward-biased and D_1 reverse-biased. Current flows through D_2 and the load resistor R_L.
- In both half cycles, the current flows through the load resistor R_L in the same direction, providing a full-wave rectified output.

Advantages:

- Efficiency (81.2%) is double that of a half-wave rectifier.
- Ripple factor (0.48) is lower, making the output smoother.
- High DC output voltage and power.

Disadvantages:

- Requires a bulky and expensive center-tapped transformer.
- The Peak Inverse Voltage (PIV) of the diodes is high ($2V_m$), requiring diodes with a high PIV rating.

Q.1 (c) OR State types of filter circuit and explain any one.

A filter circuit is used to remove the AC components (ripples) from the pulsating DC output of a rectifier and provide a steady, smooth DC output voltage.

Types of Filter Circuits:

1. Capacitor Filter (C-Filter)
2. Inductor Filter (L-Filter)
3. Choke Input Filter (LC-Filter / L-Section Filter)
4. Capacitor Input Filter (π-Filter / CLC-Filter)

Explanation of Capacitor Filter:

The capacitor filter is the simplest and most widely used filter circuit. It consists of a capacitor C connected in parallel across the load resistor R_L.

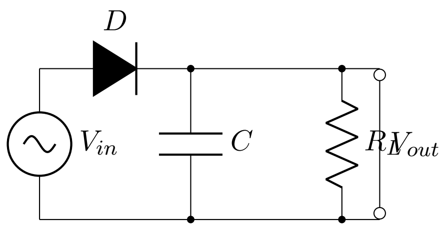


Figure 26: Capacitor Filter Circuit

Working:

- **Charging:** When the rectifier output voltage is increasing during a half cycle, the capacitor C charges up rapidly to the peak value of the input voltage (V_m).
- **Discharging:** When the rectifier output voltage starts decreasing from its peak value, the diode becomes reverse-biased. The capacitor then discharges through the load resistor R_L, supplying current to the load.
- Since the capacitor opposes any change in voltage, it does not allow the voltage across the load to fall rapidly. By the time the capacitor discharges slightly, the next peak of the rectified wave arrives and recharges the capacitor.
- This continuous charging and slow discharging process significantly reduces the ripples, resulting in a much smoother DC output voltage.

Q.2 (a) State Application of Transistor.

Transistors are fundamental building blocks of modern electronic devices. Their primary applications include:

- **Amplification:** Transistors are widely used to amplify weak audio, radio, or power signals in amplifiers. They increase the amplitude of the input signal.
- **Switching:** In digital logic circuits, computers, and microprocessors, transistors act as ultra-fast electronic switches to turn current ON or OFF.
- **Oscillators:** They are used in oscillator circuits to generate continuous AC waveforms (like sine waves or square waves) from a DC power supply.
- **Voltage Regulation:** Transistors help in maintaining a constant output voltage in regulated power supply circuits despite variations in input voltage or load current.
- **Modulation and Demodulation:** Used in communication systems for transmitting and receiving radio signals.

Q.2 (b) Explain DC load line and define Operating point.

DC Load Line

A DC load line is a straight line drawn on the output characteristics of a transistor which represents all the possible operating points for a given load resistance (R_C) and supply voltage (V_{CC}) under zero signal condition.

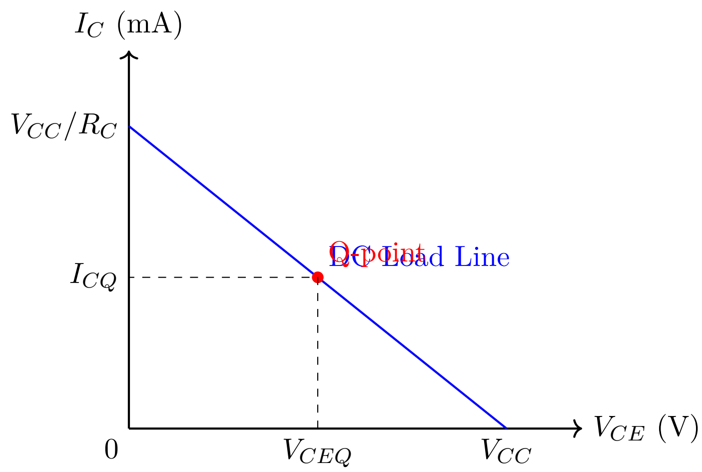


Figure 27: DC Load Line and Q-point

- The DC load line connects the maximum collector current point ($I_C = V_{CC}/R_C$ when $V_{CE} = 0$) on the Y-axis to the maximum collector-emitter voltage point ($V_{CE} = V_{CC}$ when $I_C = 0$) on the X-axis.
- It depends only on the DC supply voltage and external load resistance, independent of the transistor's parameters.

Operating Point (Q-Point)

The operating point, or Quiescent point (Q-point), is a specific point on the DC load line that represents the steady-state DC voltage (V_{CEQ}) and DC current (I_{CQ}) of a transistor when no AC input signal is applied.

For faithful amplification, the Q-point should be located approximately at the center of the active region on the DC load line.

Q.2 (c) Derive relationship between α_{dc} and β_{dc}.

In a bipolar junction transistor, the emitter current (I_E) is the sum of the base current (I_B) and the collector current (I_C).

$$I_E = I_B + I_C$$

Dividing the entire equation by I_C, we get:

$$\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$$

We know the definitions of current gains α_{dc} (Common Base) and β_{dc} (Common Emitter):

- $\alpha_{dc} = \frac{I_C}{I_E} \implies \frac{I_E}{I_C} = \frac{1}{\alpha_{dc}}$
- $\beta_{dc} = \frac{I_C}{I_B} \implies \frac{I_B}{I_C} = \frac{1}{\beta_{dc}}$

Substituting these into the equation:

$$\frac{1}{\alpha_{dc}} = \frac{1}{\beta_{dc}} + 1$$

$$\frac{1}{\alpha_{dc}} = \frac{1 + \beta_{dc}}{\beta_{dc}}$$

Taking the reciprocal on both sides, we get the relationship for α_{dc} in terms of β_{dc}:

Key Concept

$\alpha_{dc} = \frac{\beta_{dc}}{1+\beta_{dc}}$

Now, to find β_{dc} in terms of α_{dc}, we rearrange the equation $\frac{1}{\alpha_{dc}} = \frac{1}{\beta_{dc}} + 1$:

$$\frac{1}{\beta_{dc}} = \frac{1}{\alpha_{dc}} - 1$$

$$\frac{1}{\beta_{dc}} = \frac{1 - \alpha_{dc}}{\alpha_{dc}}$$

Taking the reciprocal, we obtain the relationship for β_{dc} in terms of α_{dc}:

Key Concept

$\beta_{dc} = \frac{\alpha_{dc}}{1-\alpha_{dc}}$

Q.2 (a) OR β for Transistor is 50 and the base current is 20 micro ampere. Find emitter current and α.

Given Data:

- Current gain (β) = 50
- Base current (I_B) = $20\mu\text{A} = 20 \times 10^{-6}$ A

Step 1: Calculate Collector Current (I_C) We know that $\beta = \frac{I_C}{I_B}$.

$$I_C = \beta \times I_B$$

$$I_C = 50 \times 20\mu\text{A}$$

$$I_C = 1000\mu\text{A} = 1 \text{ mA}$$

Step 2: Calculate Emitter Current (I_E) The total emitter current is the sum of base and collector currents:

$$I_E = I_B + I_C$$

$$I_E = 20\mu\text{A} + 1000\mu\text{A}$$

$$I_E = 1020\mu\text{A} = 1.02 \text{ mA}$$

Step 3: Calculate α We know the relationship between α and β:

$$\alpha = \frac{\beta}{1+\beta}$$

$$\alpha = \frac{50}{1+50} = \frac{50}{51}$$
$$\alpha \approx 0.9804$$

Answers:

- Emitter Current (I_E) = 1.02 mA
- Current gain (α) = 0.9804

Q.2 (b) OR Compare the three configuration of transistor.

A bipolar junction transistor can be connected in three primary configurations. Their comparison is given below:

Table 4: Comparison of Transistor Configurations

Parameter	Common Base (CB)	Common Emitter (CE)	Common Collector (CC)
Input Terminal	Emitter	Base	Base
Output Terminal	Collector	Collector	Emitter
Common Terminal	Base	Emitter	Collector
Input Resistance	Very Low ($\approx 50\ \Omega$)	Medium ($\approx 1\ \text{k}\Omega$)	Very High ($\approx 100\ \text{k}\Omega$)
Output Resistance	Very High ($\approx 1\ \text{M}\Omega$)	Medium ($\approx 40\ \text{k}\Omega$)	Very Low ($\approx 50\ \Omega$)
Current Gain	Less than 1 (α)	High (β)	High (γ)

Voltage Gain	High	High	Less than 1
Phase Shift	0° (In-phase)	180° (Out of phase)	0° (In-phase)
Applications	High frequency applications	Audio and power amplifiers	Impedance matching

Q.2 (c) OR Explain working of NPN transistor with diagram.

An NPN transistor consists of a thin P-type layer (Base) sandwiched between two N-type layers (Emitter and Collector).

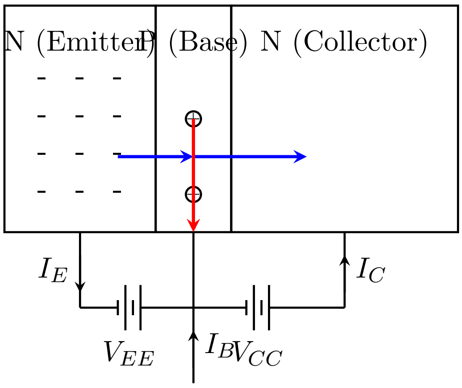


Figure 28: Working of NPN Transistor

Biasing: For normal active operation, the transistor is biased as follows:

- The Emitter-Base (EB) junction is forward-biased by battery V_{EE}.
- The Collector-Base (CB) junction is reverse-biased by battery V_{CC}.

Working Mechanism:

1. **Injection of Electrons:** The forward bias on the EB junction repels the majority charge carriers (electrons) in the N-type emitter towards the P-type base. This constitutes the emitter current (I_E).
2. **Base Recombination:** As the electrons enter the P-type base, they tend to recombine with the holes. However, because the base is very thin and lightly doped, only a small percentage (about 5%) of electrons recombine. This small recombination creates a weak base current (I_B).
3. **Collection of Electrons:** The remaining 95% of electrons cross the base region and reach the reverse-biased CB junction. The positive potential of V_{CC} strongly attracts these electrons into the collector region, forming the collector current (I_C).

Current Equation: From Kirchhoff's Current Law, the total emitter current entering the transistor is equal to the sum of the base and collector currents leaving it.

Key Concept

$I_E = I_B + I_C$

Q.3 (a) State the Advantages and disadvantages of Photo Diode. [3 marks]

- **Advantages of Photo Diode:**
  - **Fast Response:** They have a very rapid response time, making them suitable for high-frequency operations.
  - **Linearity:** The reverse current is highly linear with respect to the incident light intensity.
  - **Compact Size:** They are small in size and lightweight, allowing easy integration into various optical devices.
  - **Low Cost:** They are generally inexpensive to manufacture.
- **Disadvantages of Photo Diode:**
  - **Small Active Area:** The area sensitive to light is relatively small, requiring precise alignment with the light source.
  - **Temperature Sensitivity:** The dark current (current flowing without light) is highly dependent on temperature.
  - **Low Sensitivity:** Compared to devices like photomultiplier tubes, they have poorer sensitivity to very low light levels.
  - **Bias Requirement:** They typically require an external reverse bias voltage for optimal operation.

Q.3 (b) Compare FET with BJT [4 marks]

The comparison between Field Effect Transistor (FET) and Bipolar Junction Transistor (BJT) is shown below:

Table 6: Comparison between FET and BJT

Sr. No.	FET (Field Effect Transistor)	BJT (Bipolar Junction Transistor)
1	It is a unipolar device (current conduction is due to either electrons or holes).	It is a bipolar device (current conduction is due to both electrons and holes).
2	It is a voltage-controlled device.	It is a current-controlled device.
3	Input impedance is very high (approx $10^9\,\Omega$ to $10^{12}\,\Omega$).	Input impedance is low (approx $1\,\text{k}\Omega$ to $100\,\text{k}\Omega$).
4	It generates less noise, making it ideal for low-level signal amplification.	It generates more noise compared to FET.
5	It is less sensitive to temperature variations (higher thermal stability).	It is more sensitive to temperature variations (can suffer from thermal runaway).

6	The physical size is smaller.	The physical size is comparatively larger.
7	Voltage gain is relatively lower.	Voltage gain is higher.

Q.3 (c) Explain the construction and working of photovoltaic cell. [7 marks]

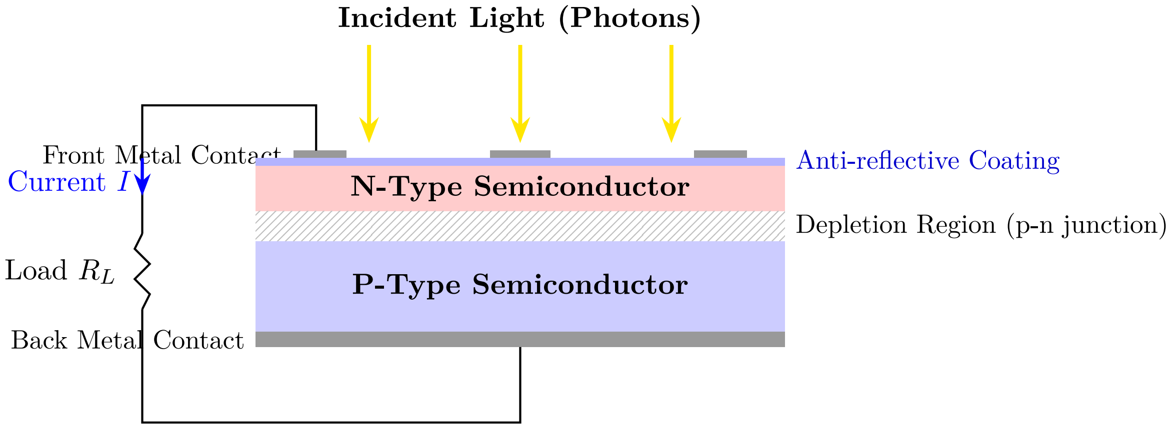


Figure 29: Construction of a Photovoltaic Cell

- **Construction:**
  - A photovoltaic (solar) cell is essentially a large-area p-n junction diode made from semiconductor materials like Silicon (Si) or Gallium Arsenide (GaAs).
  - It consists of a very thin layer of N-type semiconductor grown over a thicker P-type semiconductor layer. The top N-layer is kept very thin so that light can easily penetrate it to reach the p-n junction.
  - A metal grid forms the top electrical contact (front contact), allowing maximum light to pass through the spaces between the grid lines.
  - An anti-reflective coating is applied to the top surface to minimize the reflection of incident light, maximizing absorption.
  - The bottom surface is completely covered with a metal contact (back contact).
- **Working Principle:**
  - **Light Absorption:** When sunlight (photons) strikes the cell, photons with energy greater than the bandgap energy ($E > E_g$) pass through the thin N-layer and are absorbed near the depletion region.
  - **Electron-Hole Pair Generation:** The absorbed photon energy excites electrons from the valence band to the conduction band, generating electron-hole pairs.
  - **Charge Separation:** The built-in electric field at the p-n junction pushes the excited electrons toward the N-region and the holes toward the P-region.
  - **Voltage Generation:** The accumulation of electrons in the N-region and holes in the P-region creates a potential difference across the junction. This is known as photo-voltage.

– **Current Flow:** When an external load (R_L) is connected across the front and back contacts, a current I flows through the circuit. Thus, the cell converts light energy directly into electrical energy.

OR

Q.3 (a) State the Application of FET. [3 marks]

Field Effect Transistors (FETs) are widely used in various electronic circuits. Key applications include:

- **Voltage Variable Resistor (VVR):** Used in operational amplifiers and tone control circuits since the drain-source resistance can be controlled by the gate voltage.
- **Low-Noise Amplifiers:** Used in communication receivers and audio equipment because FETs generate significantly less noise than BJTs.
- **Buffer Amplifiers:** Due to its extremely high input impedance and low output impedance, it is ideal for buffer stages to prevent loading effects.
- **Digital Circuits:** Widely used in logic gates and memory devices, especially in CMOS technology, due to low power consumption.
- **Analog Switches and Multiplexers:** Used for switching signals on and off with high precision.
- **Oscillators and Current Limiters:** Employed in radio-frequency oscillators and constant-current sources.

Q.3 (b) Explain the Working principal of Fiber Optic Cable. [4 marks]

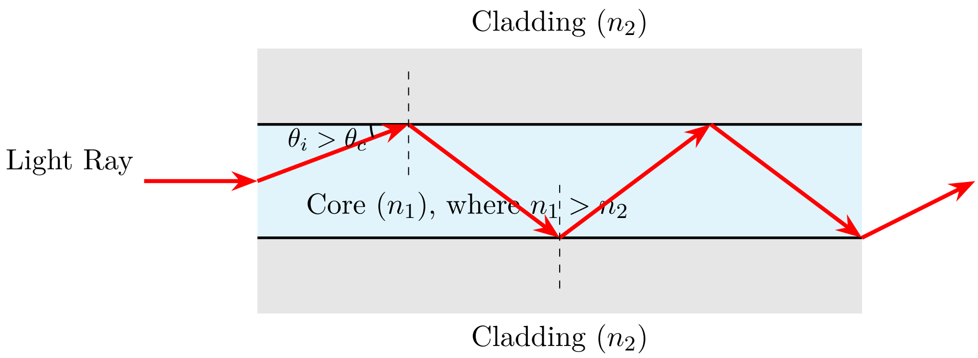


Figure 30: Total Internal Reflection in Fiber Optic Cable

The working principle of a fiber optic cable is based on **Total Internal Reflection (TIR)**.

- **Structure:** An optical fiber consists of a central transparent strand called the **core** (with refractive index n_1), surrounded by an outer layer called the **cladding** (with refractive index n_2). For TIR to occur, the core must have a slightly higher refractive index than the cladding ($n_1 > n_2$).

- **Total Internal Reflection:** When a light ray traveling inside the denser core strikes the boundary of the rarer cladding at an angle of incidence (θ_i) greater than the critical angle (θ_c), it is not refracted out. Instead, it is completely reflected back into the core.
- **Critical Angle:** The critical angle is defined as $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$.
- **Light Propagation:** Light entering the fiber within a specific "acceptance cone" experiences continuous multiple total internal reflections off the core-cladding interface. This allows the light signal to be guided along the entire length of the fiber optic cable with minimal attenuation or loss, even if the cable is bent.

Q.3 (c) Draw and explain optocouplers in detail. [7 marks]

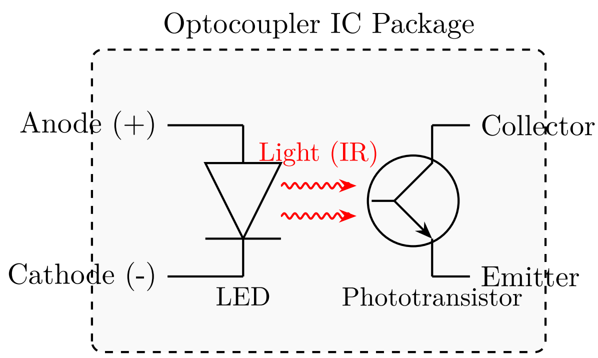


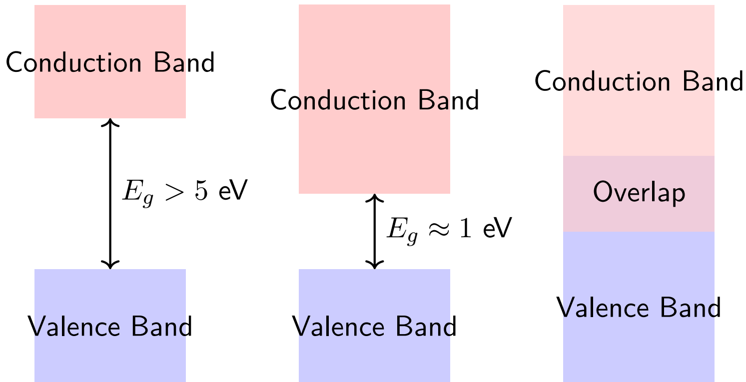
Figure 31: Internal diagram of an Optocoupler

- **Introduction:** An optocoupler (also known as an optoisolator) is a semiconductor device that transfers electrical signals between two isolated circuits using light. It prevents high voltages from affecting the system receiving the signal.
- **Construction:**
  - An optocoupler essentially consists of two main elements housed within a single opaque package to block external light.
  - **Light Emitter:** Located on the input side, typically a Gallium Arsenide (GaAs) Light Emitting Diode (LED) that emits infrared (IR) light.
  - **Light Detector:** Located on the output side, which can be a photodiode, phototransistor, photo-SCR, or photo-TRIAC. A phototransistor is most commonly used.
  - There is a transparent insulating gap (such as glass, air, or clear plastic) between the emitter and detector to provide electrical isolation.
- **Working Principle:**
  - When an electrical signal (current) is applied to the input terminals, it flows through the LED, causing it to emit infrared light.
  - The intensity of this emitted light is directly proportional to the input current.
  - The emitted light travels across the transparent gap and strikes the photosensitive area of the photodetector (e.g., the base of the phototransistor).

  - The incident light energy generates electron-hole pairs in the detector, creating a base current. This turns the transistor ON, allowing current to flow in the output circuit.
  - Thus, the input signal is coupled to the output purely through light, with no direct electrical connection.

- **Advantages & Applications:** Optocouplers offer excellent electrical isolation, immunity to electromagnetic interference (EMI), and eliminate ground loops. They are widely used in microprocessor I/O switching, solid-state relays, switch-mode power supplies (SMPS) feedback circuits, and protecting low-voltage control circuits from high-voltage surges.

Q.4 (a) Draw and compare energy band diagram of conductor, semiconductor and insulator material.



(a) Insulator **(b) Semiconductor** **(c) Conductor**

Figure 32: Energy Band Diagrams of Insulator, Semiconductor, and Conductor

The energy band theory describes the electrical conductivity of materials based on three main bands: the **Valence Band** (containing valence electrons), the **Conduction Band** (containing free electrons), and the **Forbidden Energy Gap** (E_g) between them.

Table 8: Comparison of Conductor, Semiconductor, and Insulator

Parameter	Conductor	Semiconductor	Insulator
Energy Gap (E_g)	Zero (Bands overlap)	Small (≈ 1 eV)	Large (> 5 eV)
Conductivity	Very High	Moderate	Very Low (Zero at 0 K)
Valence Band	Partially or completely filled	Completely filled at 0 K	Completely filled
Conduction Band	Partially filled	Empty at 0 K, partially filled at room temp	Completely empty
Examples	Copper, Aluminum, Silver	Silicon (Si), Germanium (Ge)	Wood, Glass, Rubber

Q.4 (b) Explain any one method of transistor biasing.

Transistor biasing is the process of setting a fixed DC operating voltage and current (the Q-point) for the proper operation of a transistor. One of the simplest methods is the **Fixed Bias (Base Bias) Method**.

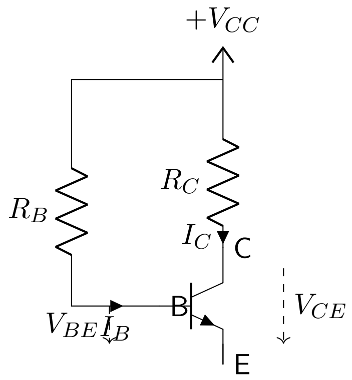


Figure 33: Fixed Bias Circuit

In this method, a single DC power supply ($+V_{CC}$) is used for both the base and collector circuits. A base resistor (R_B) is connected between V_{CC} and the base terminal.

Circuit Analysis:

- Applying Kirchhoff's Voltage Law (KVL) to the base-emitter loop:

$$V_{CC} - I_B R_B - V_{BE} = 0$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

  Since V_{CC}, V_{BE}, and R_B are constant, the base current I_B is fixed.

- The collector current is given by:

$$I_C = \beta I_B$$

- Applying KVL to the collector-emitter loop:

$$V_{CC} - I_C R_C - V_{CE} = 0$$

$$V_{CE} = V_{CC} - I_C R_C$$

Advantages and Disadvantages

Advantages: It is very simple and requires very few components. The operating point can be easily shifted by changing R_B.

Disadvantages: It provides very poor stabilization. The Q-point is highly unstable against changes in temperature or transistor replacement (variation in β), which can lead to thermal runaway.

Q.4 (c) Explain P type and N Type Semiconductor.

Extrinsic semiconductors are formed by adding specific impurities (doping) to pure intrinsic semiconductors to increase their conductivity. Depending on the type of impurity added, they are classified into **N-Type** and **P-Type** semiconductors.

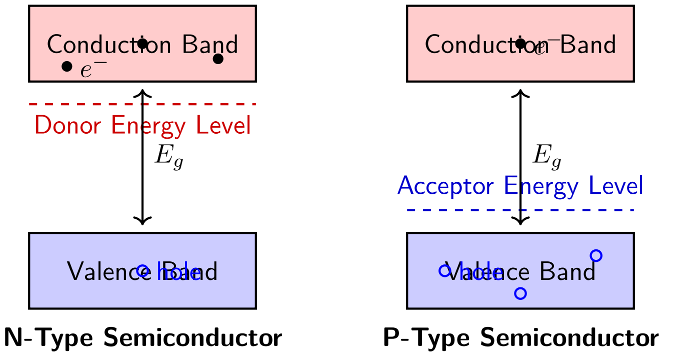


Figure 34: Energy Band Diagrams of N-Type and P-Type Semiconductors

- **N-Type Semiconductor:** It is formed when a pentavalent impurity (having 5 valence electrons, like Phosphorus, Arsenic, Antimony) is added to a pure semiconductor (Silicon or Germanium). Four of the five valence electrons form covalent bonds with adjacent Si/Ge atoms, while the fifth electron remains loosely bound and becomes a free electron. These impurities are called **donor** impurities because they donate free electrons. Here, electrons are the majority charge carriers and holes are the minority charge carriers.
- **P-Type Semiconductor:** It is formed when a trivalent impurity (having 3 valence electrons, like Boron, Gallium, Indium) is added to a pure semiconductor. The three valence electrons form covalent bonds with adjacent Si/Ge atoms, leaving a deficiency of one electron in the fourth bond, which creates a "hole". These impurities are called **acceptor** impurities because the holes can accept electrons. Here, holes are the majority charge carriers and electrons are the minority charge carriers.

Table 9: Difference between N-Type and P-Type Semiconductors

Basis	N-Type Semiconductor	P-Type Semiconductor
Doping	Doped with Pentavalent impurities.	Doped with Trivalent impurities.
Majority Carriers	Electrons	Holes
Minority Carriers	Holes	Electrons
Impurity Type	Donor impurities	Acceptor impurities
Energy Level	Donor level is just below the conduction band.	Acceptor level is just above the valence band.

Q.4 (a) OR Explain Zener diode as a voltage regulator

A Zener diode is a heavily doped PN junction diode designed to operate in the reverse breakdown region. Its most common application is as a **voltage regulator**, which maintains a constant output voltage across a load despite variations in input voltage or load current.

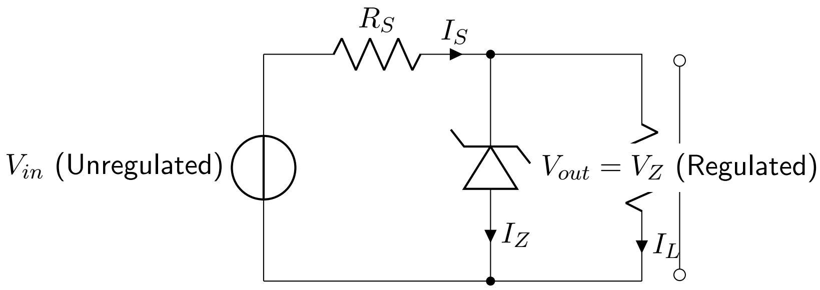


Figure 35: Zener Diode as a Voltage Regulator

Working Principle:

- The Zener diode is connected in reverse bias across the load R_L, in parallel. A series resistor R_S is connected to limit the current flowing through the circuit.
- When the input voltage (V_{in}) exceeds the Zener breakdown voltage (V_Z), the diode enters the breakdown region.
- In this region, the voltage across the Zener diode remains remarkably constant at V_Z, even if the current (I_Z) passing through it changes significantly.
- Therefore, the voltage across the parallel load R_L also remains constant ($V_{out} = V_Z$).
- From Kirchhoff's laws: $I_S = I_Z + I_L$ and $V_{in} = I_S R_S + V_Z$. If V_{in} increases, I_S and I_Z increase, but V_Z (and thus V_{out}) remains constant. The excess voltage is dropped across R_S.

Q.4 (b) OR Explain the intrinsic and extrinsic semiconductors.

Semiconductors are materials with electrical conductivity between that of a conductor and an insulator. They are classified into intrinsic and extrinsic types based on their purity.

Intrinsic Semiconductor:

- It is a semiconductor in its extremely pure form, free from any significant impurities. Examples include pure Silicon (Si) and Germanium (Ge).
- At absolute zero (0 K), the valence band is completely full and the conduction band is empty, making it behave like a perfect insulator.
- At room temperature, thermal energy breaks some covalent bonds, creating free electrons in the conduction band and an equal number of holes in the valence band. Thus, the number of electrons (n) equals the number of holes (p).

Extrinsic Semiconductor:

- The conductivity of intrinsic semiconductors is too low for practical applications. To increase conductivity, a small, controlled amount of impurity is added through a process called **doping**.
- The resulting impure semiconductor is called an extrinsic semiconductor.
- Depending on the type of impurity added, it is classified into two types: **N-type** (pentavalent impurity) and **P-type** (trivalent impurity).

Table 10: Comparison of Intrinsic and Extrinsic Semiconductors

Feature	Intrinsic Semiconductor	Extrinsic Semiconductor
Purity	Extremely pure material.	Impure (doped) material.
Charge Carriers	Number of electrons equals number of holes ($n = p$).	One type of carrier is majority, the other is minority ($n \neq p$).
Conductivity	Very low conductivity.	High conductivity, adjustable by doping level.
Operating Temperature	Conductivity depends only on temperature.	Conductivity depends on both temperature and doping concentration.

Q.4 (c) OR Explain Forward and Reverse characteristic of PN junction diode.

The V-I (Voltage-Current) characteristics of a PN junction diode describe its behavior under forward and reverse bias conditions.

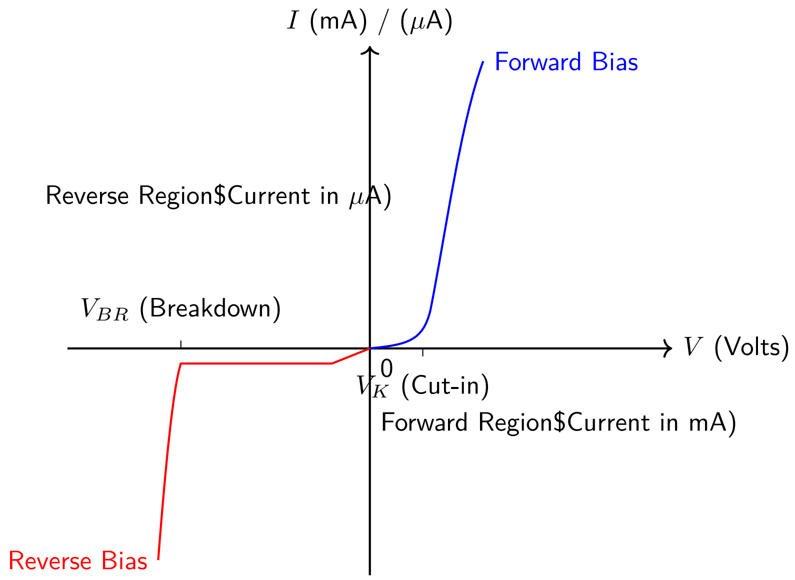


Figure 36: V-I Characteristics of a PN Junction Diode

Forward Bias Characteristics:

- A diode is forward-biased when its P-region is connected to the positive terminal and N-region to the negative terminal of a battery.
- This bias reduces the width of the depletion layer and the potential barrier.
- Initially, as the forward voltage increases, the current is very small. Once the applied voltage exceeds the barrier potential (**Cut-in or Knee voltage**, approx. 0.7 V for Si and 0.3 V for Ge), the current increases exponentially.
- The forward current is large (in milliamperes, mA) and is primarily due to the flow of majority charge carriers.

Reverse Bias Characteristics:

- A diode is reverse-biased when its P-region is connected to the negative terminal and N-region to the positive terminal.
- This bias widens the depletion layer and increases the potential barrier, blocking the flow of majority carriers.
- A very small current, called **reverse saturation current** or leakage current (in microamperes, μA), flows due to the minority charge carriers generated by thermal energy.
- If the reverse voltage is increased significantly, it eventually reaches the **Breakdown voltage** (V_{BR}). At this point, the covalent bonds break, releasing a massive number of electrons and causing a sharp increase in reverse current. This can destroy the diode if the current is not limited.

Q.5 (a) Compare LCD with LED

Table 11: Comparison between LCD and LED

Sr. No.	LCD (Liquid Crystal Display)	LED (Light Emitting Diode)
1.	It does not emit light of its own; it requires an external light source (backlight).	It emits its own light when forward-biased.
2.	Power consumption is very low (in microwatts).	Power consumption is higher compared to LCD (in milliwatts).
3.	Switching time or response time is slow.	Switching time or response time is very fast.
4.	Viewing angle is limited.	Viewing angle is wider.
5.	Life span is generally shorter.	Life span is much longer.
6.	Used in calculators, digital watches, and liquid crystal displays.	Used in indicator lamps, optocouplers, and LED displays.

Q.5 (b) Explain construction and working of Photo transistor.

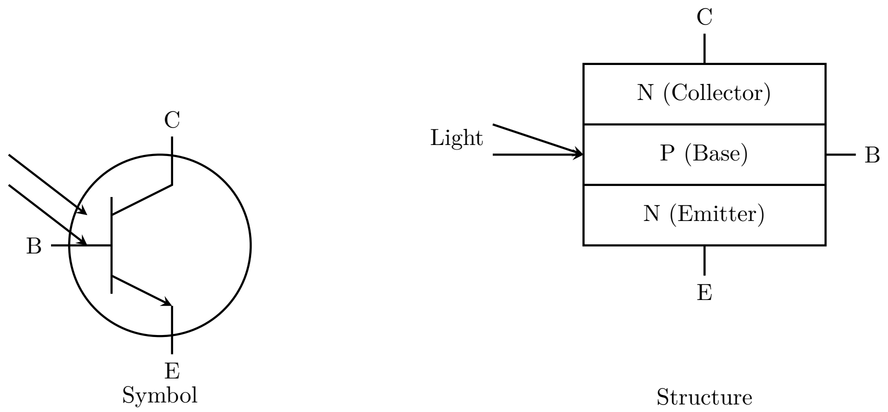


Figure 37: Construction and Symbol of Phototransistor

Construction:

- A phototransistor is similar to an ordinary bipolar junction transistor (BJT) except that its base region is exposed to light.
- It is typically packaged with a transparent window or lens to allow light to strike the base-collector junction.
- Usually, the base terminal is left open (unconnected), and only the collector and emitter terminals are used in the circuit.

Working:

- The phototransistor is operated in the active region with the collector-base junction reverse-biased and the base-emitter junction forward-biased.
- When no light is incident on the base, a very small dark current flows due to thermally generated minority carriers.
- When light (photons) falls on the base-collector junction, electron-hole pairs are generated.
- The electric field of the reverse-biased junction separates these carriers, creating a base current proportional to the light intensity.
- Due to transistor action, this small photo-generated base current is multiplied by the current gain (β) of the transistor, resulting in a much larger collector current.
- Thus, the phototransistor provides both light detection and internal amplification, making it more sensitive than a photodiode.

Q.5 (c) Draw and explain transistor as a switch.

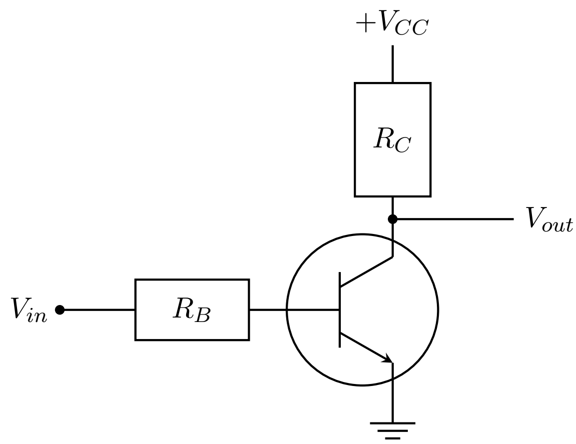


Figure 38: Transistor as a Switch Circuit

A transistor can be operated as an electronic switch by driving it between two extreme operating regions: the cut-off region and the saturation region.

Working of Transistor as a Switch:

1. **OFF State (Cut-off Region):**
   - When the input voltage V_{in} is zero or very low (less than the cut-in voltage, typically 0.7V for silicon), the base-emitter junction is not forward-biased.
   - As a result, the base current I_B is zero, which makes the collector current I_C zero.
   - The transistor acts like an open switch between the collector and emitter.
   - The output voltage V_{out} is equal to the supply voltage V_{CC} since there is no voltage drop across the collector resistor R_C.
2. **ON State (Saturation Region):**
   - When a high input voltage V_{in} is applied, a large base current I_B flows, forward-biasing the base-emitter junction heavily.
   - This causes a maximum collector current I_C to flow, which is limited only by the collector resistor R_C.
   - Both the base-emitter and collector-base junctions become forward-biased, driving the transistor into saturation.
   - The transistor acts like a closed switch, and the voltage drop across the collector-emitter terminal ($V_{CE(sat)}$) becomes almost zero (typically 0.1V to 0.2V).
   - Consequently, the output voltage V_{out} drops to nearly zero.

Key Concept

A transistor acts as an open switch (OFF) in the cut-off region and as a closed switch (ON) in the saturation region.

Q.5 (a) OR Explain the need of biasing of transistor and state the methods of biasing.

Need of Biasing:

- **To establish an operating point (Q-point):** Biasing sets the proper DC voltages and currents in the transistor to ensure it operates in the desired region (e.g., active region for amplification).
- **Faithful Amplification:** Proper biasing ensures that the input AC signal is amplified without any distortion by keeping the Q-point in the center of the active region.
- **Thermal Stability:** The operating point tends to shift due to temperature variations. Biasing circuits are needed to stabilize the Q-point against changes in temperature and transistor parameters like β.

Methods of Transistor Biasing:

1. Fixed Bias (Base Resistor Bias)
2. Collector-to-Base Bias
3. Voltage Divider Bias (Self Bias)
4. Emitter Bias

Q.5 (b) OR Explain working of PNP transistor.

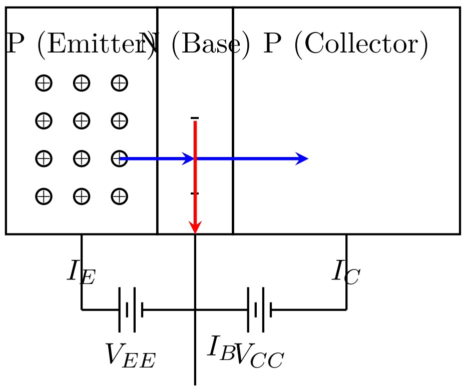


Figure 39: Working of PNP Transistor

Working of PNP Transistor:

- In a normally biased PNP transistor, the emitter-base junction is forward-biased using a voltage supply V_{EE}, and the collector-base junction is reverse-biased using V_{CC}.
- Due to the forward bias at the emitter-base junction, the majority charge carriers in the emitter (which are holes) are pushed towards the base region.
- This movement of holes constitutes the emitter current I_E.
- The base is an N-type material, making it very thin and lightly doped. Hence, only a small fraction (about 2% to 5%) of the holes recombine with electrons in the base region.

- The recombination of holes and electrons in the base generates a small base current I_B.
- The remaining holes (about 95% to 98%) cross the thin base and are swept into the collector region due to the strong attractive force of the negative terminal of the reverse-biased collector-base junction.
- This constitutes the collector current I_C.
- The total current relationship is given by the equation:

$$I_E = I_B + I_C$$

- In a PNP transistor, the direction of conventional current is into the emitter and out of the base and collector terminals.

Q.5 (c) OR Explain the construction and working of N-channel JEFT.

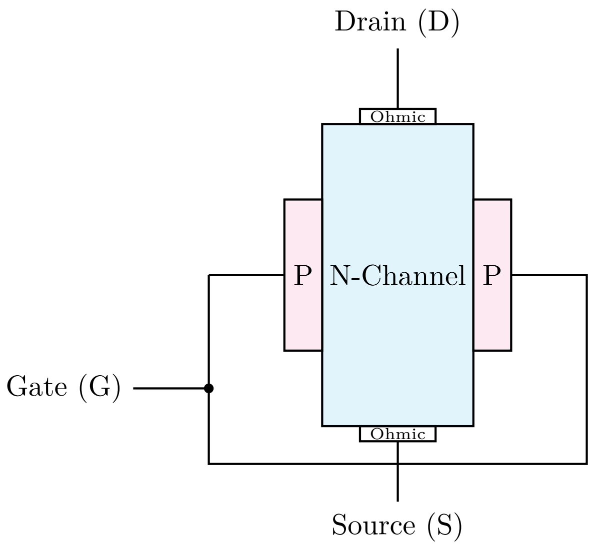


Figure 40: Construction and Working of N-channel JFET

Construction:

- An N-channel Junction Field Effect Transistor (JFET) consists of a bar of N-type semiconductor material.
- The two ends of this bar are connected to metallic contacts to form the **Source (S)** and **Drain (D)** terminals.
- On opposite sides of the N-type bar, two P-type regions are heavily doped.
- These two P-type regions are internally connected together to form a single **Gate (G)** terminal.
- The region between the two P-type gates through which the majority carriers (electrons) flow is called the **Channel**.

Working:

- The working of an N-channel JFET involves the control of current flowing from Source to Drain by varying the voltage applied at the Gate terminal.

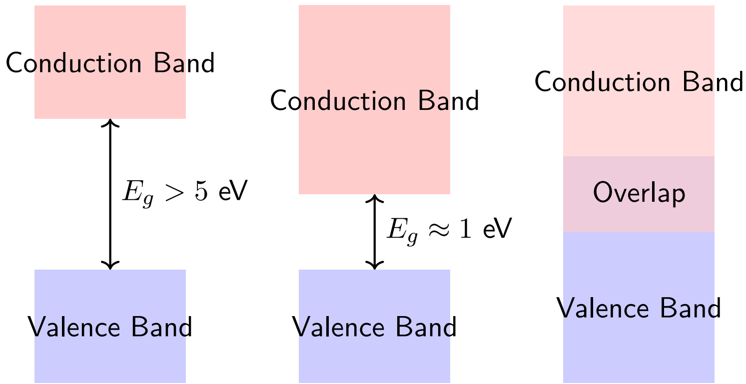
- **When** $V_{GS} = 0$ **and** $V_{DS} > 0$**:** A positive voltage is applied to the Drain with respect to the Source, and the Gate is shorted to the Source. Electrons flow from Source to Drain through the channel, establishing a drain current I_D.
- As V_{DS} increases, the drain current I_D increases proportionally. However, the reverse bias across the P-N junctions near the drain increases, widening the depletion region.
- At a certain voltage called the **Pinch-off Voltage (**V_P**)**, the depletion regions almost touch each other, restricting further increase in current. The current becomes constant (saturation).
- **When** $V_{GS} < 0$ **(Negative Gate Voltage):** If a negative voltage is applied to the Gate with respect to the Source, the P-N junctions become more reverse-biased.
- The depletion regions penetrate deeper into the N-channel, decreasing the channel width.
- This increases the channel resistance and decreases the drain current I_D.
- If the negative gate voltage is increased further, the depletion regions eventually touch each other (cut-off), and the drain current I_D drops to zero.

Key Concept

In a JFET, the flow of majority carriers in the channel is controlled by the reverse-biasing voltage applied to the gate, making it a voltage-controlled device.

Winter 2025

Q.1 (a) Draw and compare energy band diagram of conductor, semiconductor and insulator material.



(a) Insulator **(b) Semiconductor** **(c) Conductor**

Figure 41: Energy Band Diagrams of Insulator, Semiconductor, and Conductor

The comparison between conductor, semiconductor, and insulator based on energy band diagrams is given below:

Table 12: Comparison of Materials Based on Energy Bands

Property	**Conductor**	**Semiconductor**	**Insulator**
Energy Band	Valence and conduction bands overlap.	Small energy gap exists between bands.	Large energy gap exists between bands.
Forbidden Gap (E_g)	Zero ($E_g = 0$).	Approximately 1 eV.	Greater than 5 eV.
Conductivity	Very high.	Moderate (lies between conductor and insulator).	Very low (almost zero).
Effect of Temperature	Resistance increases with temperature (Positive Temperature Coefficient).	Resistance decreases with temperature (Negative Temperature Coefficient).	Remains an insulator, but may break down at extremely high temperatures.
Examples	Copper, Aluminum, Silver	Silicon (Si), Germanium (Ge)	Wood, Glass, Rubber

Q.1 (b) Explain why filters are needed? and explain π filter.

Need for Filters

The output of a rectifier circuit is not pure DC; it is a pulsating DC containing both DC components and unwanted AC components (called ripples). A filter circuit is required to remove or minimize these AC ripple components and provide a smooth, steady pure DC output to the load.

Operation of π (Pi) Filter: A π-filter (or capacitor-input filter) consists of a filter capacitor (C_1) connected in parallel with the rectifier output, an inductor (L) in series, and another capacitor (C_2) in parallel with the load. Its shape resembles the Greek letter π.

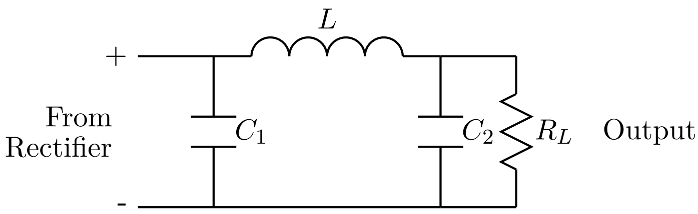


Figure 42: Circuit Diagram of π Filter

- **First Capacitor (C_1):** It offers low reactance to the AC ripples and blocks DC. Most of the AC components from the rectifier are bypassed to ground, making the output somewhat smooth.
- **Series Inductor (L):** The inductor opposes any change in current. It offers high impedance to the remaining AC components and low impedance to DC, thereby blocking the ripples and allowing DC to pass.
- **Second Capacitor (C_2):** It acts as a final bypass for any residual AC ripples that managed to pass through the inductor, ensuring a highly smooth DC voltage across the load resistor (R_L).

Due to the use of two capacitors and an inductor, the π-filter provides excellent filtering action and very low ripple factor compared to simple capacitor or inductor filters.

Q.1 (c) Draw & explain the V-I characteristics of PN junction diode.

The Voltage-Current (V-I) characteristics of a PN junction diode show the relationship between the applied voltage across the diode and the current flowing through it.

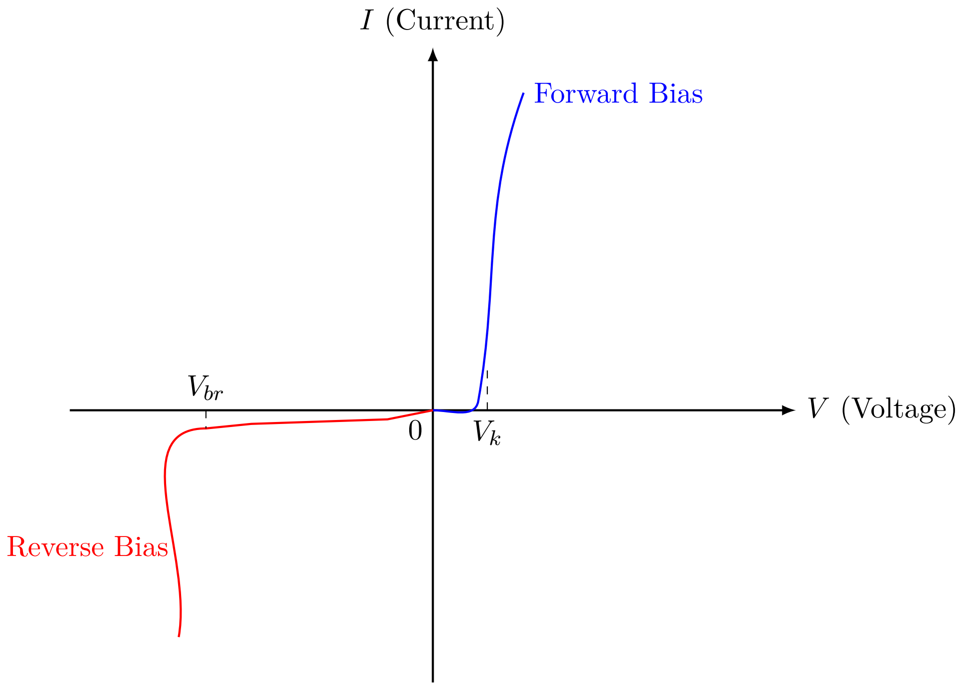


Figure 43: V-I Characteristics of PN Junction Diode

The V-I characteristic curve is divided into two operating regions:

1. Forward Bias Characteristics:

- When the positive terminal of the battery is connected to the P-region and the negative terminal to the N-region, the diode is forward biased.
- Initially, for small applied voltages, the forward current is practically zero because the external voltage is insufficient to overcome the potential barrier.
- Once the applied voltage exceeds the barrier potential (called **Knee Voltage** or **Cut-in Voltage**, $V_k \approx 0.7$ V for Silicon and 0.3 V for Germanium), the current increases exponentially.
- In this region, the diode offers very low forward resistance and acts like a closed switch.

2. Reverse Bias Characteristics:

- When the negative terminal is connected to the P-region and the positive terminal to the N-region, the diode is reverse biased.
- The depletion region widens, and majority carriers are pulled away from the junction. Thus, there is almost zero forward current.
- However, a very small current (in microamperes) flows due to minority charge carriers, known as **Reverse Saturation Current**.
- If the reverse voltage is increased continuously, at a certain high voltage called the **Breakdown Voltage** (V_{br}), the junction breaks down. This causes a sudden, massive flow of current, which can permanently damage a normal diode.

Q.1 (c) OR Explain rectifier circuit? And Explain any one full wave rectifier giving necessary waveforms.

Rectifier Circuit

A **Rectifier** is an electronic circuit that converts alternating current (AC), which periodically reverses direction, into direct current (DC), which flows in only one direction. This process is known as rectification, and it is widely used in power supplies for electronic devices.

Center-Tapped Full Wave Rectifier: A center-tapped full wave rectifier uses a center-tapped transformer and two diodes to rectify both the positive and negative half-cycles of the AC input.

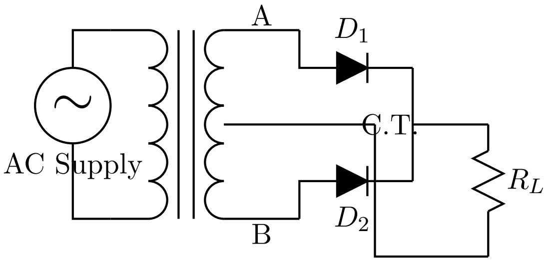
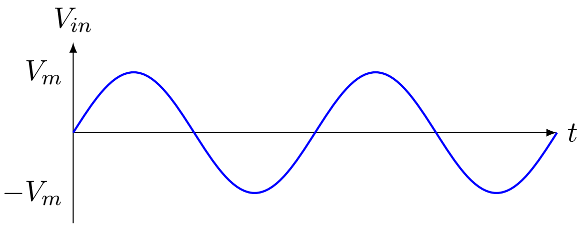


Figure 44: Circuit Diagram of Center-Tapped Full Wave Rectifier

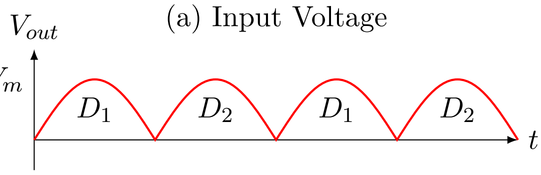
Working Principle:

- **Positive Half-Cycle:** During the positive half-cycle of the AC input, terminal A of the secondary winding becomes positive and terminal B becomes negative with respect to the center tap. Diode D_1 is forward biased and conducts current, while diode D_2 is reverse biased and remains off. Current flows through the load resistor R_L via D_1.
- **Negative Half-Cycle:** During the negative half-cycle, terminal A becomes negative and terminal B becomes positive. Now, diode D_1 is reverse biased (off) and diode D_2 is forward biased (on). Current again flows through the load resistor R_L via D_2, in the exact same direction as before.

Since current flows through the load in the same direction during both half-cycles, full-wave rectification is achieved.



(a) Input Voltage



(b) Output Voltage

Figure 45: Input and Output Waveforms

Key Parameters:

- The efficiency of a full wave rectifier is 81.2%, which is double that of a half-wave rectifier.
- The ripple factor is 0.48, indicating a smoother output compared to a half-wave rectifier.
- Output DC voltage is given by $V_{dc} = \frac{2V_m}{\pi}$.

Q.2 (a) Explain the difference between Avalanche and Zener breakdown. [3 marks]

Table 13: Difference between Avalanche and Zener Breakdown

Sr. No.	Avalanche Breakdown	Zener Breakdown
1.	It occurs due to the collision of high-velocity minority carriers with atoms, breaking covalent bonds.	It occurs due to the rupture of covalent bonds by a very strong electric field across the junction.
2.	It is typically observed in lightly doped PN junctions.	It is typically observed in heavily doped PN junctions.
3.	The depletion region is wider.	The depletion region is narrow.
4.	Breakdown usually occurs at higher voltages ($>$ 6V).	Breakdown usually occurs at lower voltages ($<$ 6V).
5.	It has a positive temperature coefficient (breakdown voltage increases with temperature).	It has a negative temperature coefficient (breakdown voltage decreases with temperature).

Q.2 (b) Define Majority and Minority charge carriers. [4 marks]

Majority and Minority Charge Carriers

In a semiconductor material, the electrical conductivity is determined by two types of charge carriers: electrons and holes. Depending on the doping, one type is present in abundance while the other is sparse.

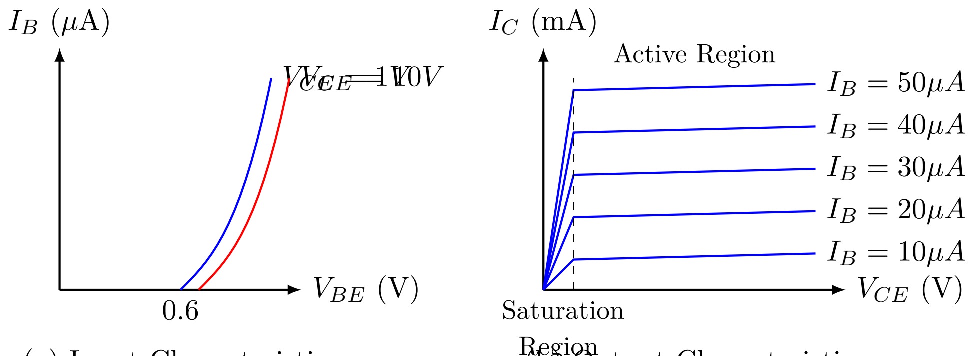
- **Majority Charge Carriers:**
  - **Definition:** The charge carriers that are present in larger numbers in a semiconductor are known as majority charge carriers.
  - **Role:** They are responsible for the primary current flow through the material and carry most of the electric charge.
  - **Examples:** In an N-type semiconductor, free electrons are the majority carriers. In a P-type semiconductor, holes are the majority carriers.
- **Minority Charge Carriers:**

– **Definition:** The charge carriers that are present in smaller numbers in a semiconductor are known as minority charge carriers.

– **Role:** They contribute very little to the overall current and are primarily generated due to thermal agitation (breaking of covalent bonds by heat energy).

– **Examples:** In an N-type semiconductor, holes are the minority carriers. In a P-type semiconductor, free electrons are the minority carriers.

Q.2 (c) Draw the input and output characteristic of transistor in CE configuration and explain. [7 marks]



(a) Input Characteristics (b) Output Characteristics

Figure 46: Input and Output Characteristics of CE Configuration

The Common Emitter (CE) configuration characteristics describe the behavior of the transistor when the emitter terminal is common to both input and output circuits.

- **Input Characteristics:**
  – It is the plot of input current I_B versus input voltage V_{BE} while keeping the output voltage V_{CE} constant.
  – Since the base-emitter junction is forward biased, the characteristic curve closely resembles the forward characteristics of an ordinary PN junction diode.
  – The base current I_B remains zero until the base-emitter voltage V_{BE} reaches the cut-in voltage (approximately 0.7V for Silicon). Beyond this point, I_B increases exponentially.
  – As V_{CE} increases, the effective base width decreases due to the Early effect, shifting the curve slightly to the right.
- **Output Characteristics:**
  – It is the plot of output current I_C versus output voltage V_{CE} while keeping the input current I_B constant.
  – **Active Region:** The base-emitter junction is forward biased and collector-base junction is reverse biased. I_C is nearly independent of V_{CE} and depends primarily on I_B ($I_C = \beta I_B$). The transistor is used as an amplifier here.
  – **Saturation Region:** Both junctions are forward biased. V_{CE} is very small (< 0.2V) and I_C increases rapidly. The transistor acts as a closed switch.

- **Cut-off Region:** Both junctions are reverse biased. $I_B = 0$ and only a very small leakage current flows. The transistor acts as an open switch.

OR

Q.2 (a) Explain Half wave rectifier giving necessary waveforms. [3 marks]

A Half-Wave Rectifier is an electronic circuit that converts an alternating current (AC) into pulsating direct current (DC) by allowing only one half-cycle of the input AC waveform to pass while blocking the other.

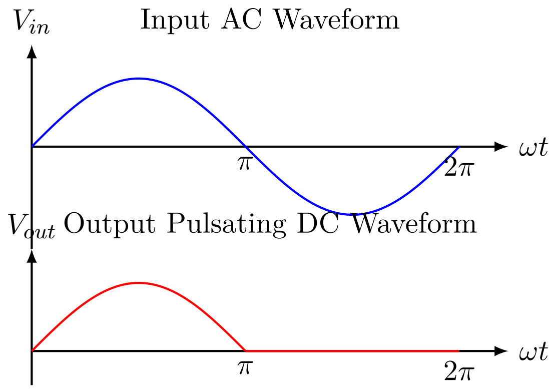


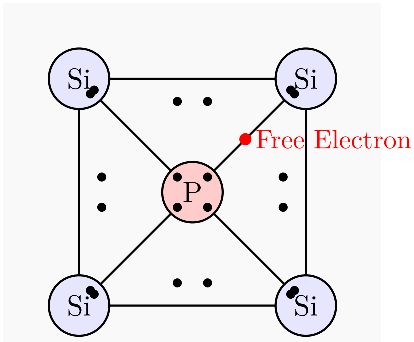
Figure 47: Input and Output Waveforms of Half-Wave Rectifier

Working Operation:

- **Positive Half-Cycle:** During the positive half-cycle of the input AC supply, the diode becomes forward-biased. It acts as a closed switch and conducts current to the load. A positive voltage appears across the load resistor.
- **Negative Half-Cycle:** During the negative half-cycle, the diode becomes reverse-biased. It acts as an open switch, blocking the current flow. The output voltage across the load drops to zero.

The output is a pulsating DC containing high ripple content. The maximum theoretical efficiency of a half-wave rectifier is 40.6%.

Q.2 (b) Explain N-type semiconductor. [4 marks]



N-Type Semiconductor Lattice

Figure 48: Crystal Structure of N-Type Semiconductor

An N-type semiconductor is an extrinsic semiconductor formed by adding a small amount of pentavalent impurity to a pure (intrinsic) semiconductor.

- **Doping Process:** When an intrinsic semiconductor like Silicon (Si) or Germanium (Ge) is doped with pentavalent atoms (atoms having 5 valence electrons) such as Phosphorus (P), Arsenic (As), or Antimony (Sb), it forms an N-type material.
- **Conduction Mechanism:** Four out of the five valence electrons of the impurity atom form covalent bonds with four neighboring silicon atoms. The fifth electron remains loosely bound to the parent atom and requires very little energy to become a free electron for conduction.
- **Donor Impurity:** Because each pentavalent atom donates one free electron to the crystal, these impurities are known as donor impurities.
- **Charge Carriers:** In an N-type semiconductor, the number of free electrons is much greater than the number of holes (which are generated only by thermal energy). Thus, **electrons are the majority charge carriers** and **holes are the minority charge carriers**. Despite having excess electrons, the material remains electrically neutral overall.

Q.2 (c) Draw and explain transistor as a switch. [7 marks]

A transistor can be operated as an electronic switch by driving it back and forth between two extreme operating regions: the cut-off region and the saturation region.

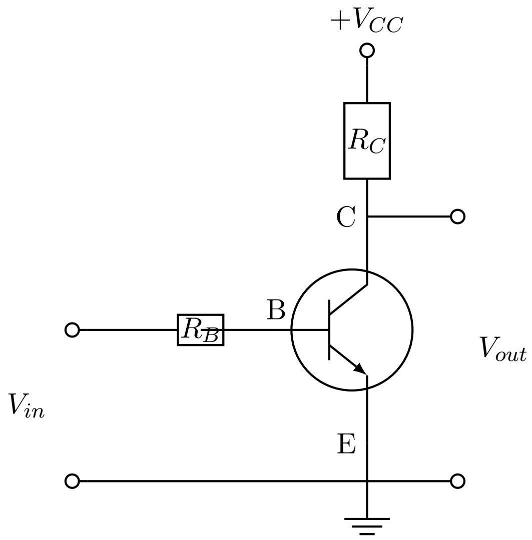


Figure 49: Circuit Diagram of Transistor as a Switch

- **OFF State (Cut-off Region):**
  - When the input voltage V_{in} is zero or very low (less than 0.7V), the base-emitter junction is not forward-biased.
  - As a result, the base current is zero ($I_B = 0$), which forces the collector current to be zero ($I_C = 0$).
  - With no current flowing through the collector resistor R_C, there is no voltage drop across it.
  - The entire supply voltage appears across the collector-emitter terminals, meaning $V_{out} = V_{CE} = V_{CC}$.
  - In this condition, the transistor acts as an **Open Switch** (OFF state).
- **ON State (Saturation Region):**
  - When a high input voltage V_{in} is applied, a large base current I_B flows, which is sufficient to drive the transistor into the saturation region.
  - In saturation, both the base-emitter and collector-base junctions are forward-biased.
  - A maximum collector current $I_C = V_{CC}/R_C$ flows through the circuit.
  - The voltage drop across the transistor V_{CE} becomes almost zero (ideally zero, practically around 0.2V).
  - The output voltage drops to nearly zero ($V_{out} \approx 0$V). The transistor acts as a **Closed Switch** (ON state).

Advantages of Transistor Switch

Unlike mechanical switches, a transistor switch has no moving parts, resulting in no wear and tear. It operates at extremely high speeds, is highly reliable, and can be easily controlled by low-voltage logic signals.

Q.3 (a) Draw the biasing Circuit for NPN and PNP transistor.

Biasing of Transistors

Transistor biasing is the process of providing appropriate DC voltages to the emitter-base and collector-base junctions to operate the transistor in the desired region (usually the active region for amplification). In the active region, the emitter-base junction is forward-biased, and the collector-base junction is reverse-biased.

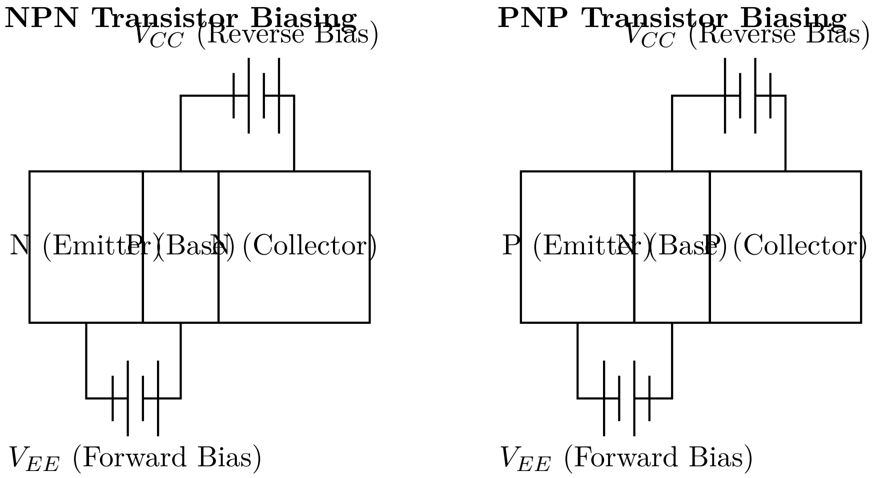


Figure 50: Biasing of NPN and PNP Transistors in Active Region

- **NPN Transistor Biasing:** The emitter (N-type) is connected to the negative terminal of V_{EE}, and the base (P-type) is connected to the positive terminal. For the collector (N-type), it is connected to the positive terminal of V_{CC} to make it reverse-biased.
- **PNP Transistor Biasing:** The emitter (P-type) is connected to the positive terminal of V_{EE}, and the base (N-type) is connected to the negative terminal. For the collector (P-type), it is connected to the negative terminal of V_{CC} to make it reverse-biased.

Q.3 (b) Define α and β for transistor. Derive relation between α and β.

Current Amplification Factors (α and β)

- **Alpha (α):** In a Common Base (CB) configuration, α is defined as the ratio of the change in collector current (ΔI_C) to the change in emitter current (ΔI_E) at a constant collector-base voltage.
  Formula: $\alpha = \frac{\Delta I_C}{\Delta I_E}$
- **Beta (β):** In a Common Emitter (CE) configuration, β is defined as the ratio of the change in collector current (ΔI_C) to the change in base current (ΔI_B) at a constant collector-emitter voltage.
  Formula: $\beta = \frac{\Delta I_C}{\Delta I_B}$

Derivation of the Relation Between α and β:

We know the fundamental current equation of a transistor is: $I_E = I_B + I_C$ For small changes in current, this equation can be written as: $\Delta I_E = \Delta I_B + \Delta I_C$ Dividing the entire equation by ΔI_C, we get: $\frac{\Delta I_E}{\Delta I_C} = \frac{\Delta I_B}{\Delta I_C} + \frac{\Delta I_C}{\Delta I_C}$ We know that $\frac{\Delta I_E}{\Delta I_C} = \frac{1}{\alpha}$ and $\frac{\Delta I_B}{\Delta I_C} = \frac{1}{\beta}$. Substituting these values: $\frac{1}{\alpha} = \frac{1}{\beta} + 1$ $\frac{1}{\alpha} = \frac{1+\beta}{\beta}$ $\alpha = \frac{\beta}{1+\beta}$

Alternatively, to find β in terms of α: $\frac{1}{\beta} = \frac{1}{\alpha} - 1$ $\frac{1}{\beta} = \frac{1-\alpha}{\alpha}$ $\beta = \frac{\alpha}{1-\alpha}$

Q.3 (c) Explain working of PNP transistor.

Working Principle of PNP Transistor

In a PNP transistor, the emitter and collector are P-type materials, and the base is an N-type material. The current conduction is primarily due to holes. For normal operation (active region), the emitter-base junction is forward-biased, and the collector-base junction is reverse-biased.

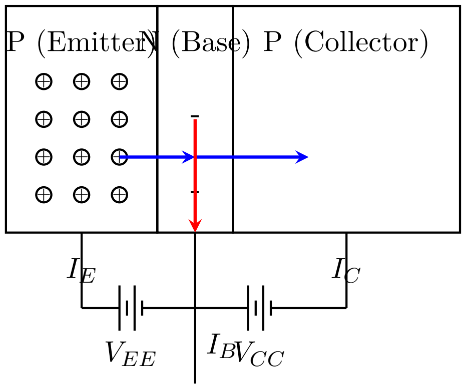


Figure 51: Working Mechanism of PNP Transistor

Working Mechanism:

1. **Forward Biasing of Emitter-Base Junction:** The battery V_{EE} forward-biases the emitter-base junction. The positive terminal repels the holes in the emitter, forcing them to cross the junction into the base region. This movement constitutes the emitter current (I_E).

2. **Recombination in Base Region:** The base is N-type, thin, and lightly doped. It contains a very small number of electrons. When the large number of holes enter the base, about 2% to 5% of them recombine with the electrons. This small recombination creates the base current (I_B).

3. **Reverse Biasing of Collector-Base Junction:** The remaining 95% to 98% of the holes do not recombine in the base. Instead, they are swept across the collector-base junction because it is reverse-biased by V_{CC}. The negative terminal of V_{CC} strongly attracts these holes into the collector region, creating the collector current (I_C).

4. **Current Equation:** The total emitter current is the sum of the base current and the collector current: $I_E = I_B + I_C$

5. **Role of Electrons:** While holes are the majority charge carriers driving the main current, the complete circuit is closed by the flow of electrons through the external wires from the negative terminal of the batteries to the positive terminal.

OR

Q.3 (a) Compare Common Base and Common Emitter Configuration of transistor.

Table 14: Comparison of CB and CE Configurations

Parameter	Common Base (CB)	Common Emitter (CE)
Common Terminal	Base is common to input and output.	Emitter is common to input and output.
Input Terminal	Emitter	Base
Output Terminal	Collector	Collector
Current Gain	α (Less than 1, approx. 0.98)	β (High, approx. 20 to 500)
Voltage Gain	Medium to High	High
Input Resistance	Very Low (approx. 20 Ω to 100 Ω)	Medium (approx. 1 kΩ to 2 kΩ)
Output Resistance	Very High (approx. 1 MΩ)	High (approx. 40 kΩ to 50 kΩ)
Phase Shift	0° (Input and Output are in phase)	180° (Output is out of phase with input)

Q.3 (b) Explain input and output characteristics of common base transistor configuration.

Common Base Characteristics

In a Common Base (CB) configuration, the base terminal is shared between the input (emitter-base) and output (collector-base) circuits. The characteristic curves define the relationship between currents and voltages in these circuits.

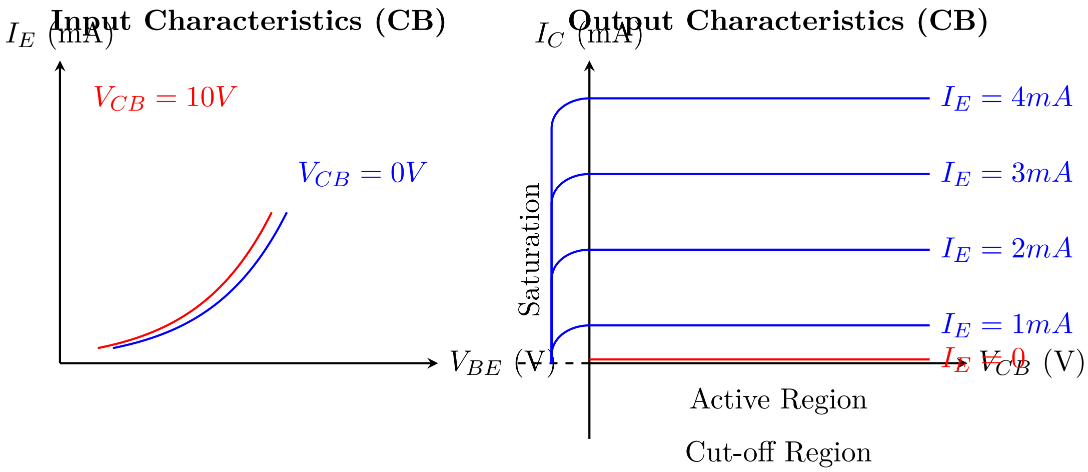


Figure 52: Input and Output Characteristics of CB Configuration

1. Input Characteristics:

- It is the curve between emitter current (I_E) and emitter-base voltage (V_{BE}) at a constant collector-base voltage (V_{CB}).

- The curve resembles the forward characteristics of a P-N junction diode.
- The emitter current (I_E) increases rapidly with a small increase in V_{BE} after the cut-in voltage is reached.
- The input resistance ($r_i = \frac{\Delta V_{BE}}{\Delta I_E}$) is very low.

2. Output Characteristics:

- It is the curve between collector current (I_C) and collector-base voltage (V_{CB}) at a constant emitter current (I_E).
- **Active Region:** For $V_{CB} > 0$ (reverse biased), I_C is almost independent of V_{CB} and depends only on I_E. Here, $I_C \approx I_E$.
- **Saturation Region:** For $V_{CB} < 0$ (forward biased), I_C drops sharply to zero.
- **Cut-off Region:** When $I_E = 0$, a very small reverse leakage current flows, making $I_C \approx 0$.
- The output resistance ($r_o = \frac{\Delta V_{CB}}{\Delta I_C}$) is very high because a large change in V_{CB} causes almost no change in I_C.

Q.3 (c) Explain working of NPN transistor.

Working Principle of NPN Transistor

In an NPN transistor, the emitter and collector are N-type materials, and the base is a P-type material. The current conduction is primarily due to electrons. For normal operation, the emitter-base junction is forward-biased, and the collector-base junction is reverse-biased.

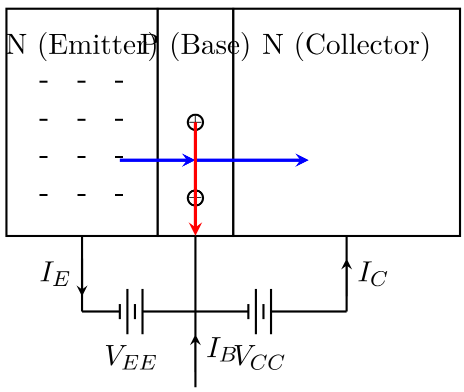


Figure 53: Working Mechanism of NPN Transistor

Working Mechanism:

1. **Forward Biasing of Emitter-Base Junction:** The battery V_{EE} forward-biases the emitter-base junction. The negative terminal repels the majority carriers (electrons) in the emitter, forcing them into the base region. This constitutes the emitter current (I_E).
2. **Recombination in Base Region:** The base is P-type and lightly doped, meaning it has very few holes. When electrons from the emitter enter the base, about 2% to 5% of them recombine with these holes. This recombination causes a small base current (I_B) to flow.

3. **Reverse Biasing of Collector-Base Junction:** The remaining 95% to 98% of the electrons do not recombine in the base. Since the collector-base junction is strongly reverse-biased by V_{CC}, the positive terminal of V_{CC} exerts a strong attractive force on these electrons, sweeping them into the collector region. This flow forms the collector current (I_C).

4. **Current Equation:** By Kirchhoff's Current Law, the total emitter current is the sum of the base current and the collector current: $I_E = I_B + I_C$

5. **External Circuit:** In the external wiring, the current is completely carried by electrons flowing from the negative terminal of the batteries, through the transistor, and back to the positive terminals. However, conventional current direction is marked opposite to the flow of electrons.

Q.4 (a) Define Biasing Of transistor and explain requirement of Biasing Circuit

Transistor Biasing

Transistor biasing is the process of applying appropriate external DC voltages and currents to the terminals of a transistor to establish a specific, stable operating point (Q-point) in the desired region (typically the active region) for proper functioning without applied AC signals.

Requirements of Biasing Circuit:

- **Operating Point Establishment:** To establish the operating point (Q-point) near the center of the active region on the output characteristics so that the transistor operates linearly and the amplified output signal does not clip during the positive or negative half-cycles.
- **Thermal Stability:** To stabilize the collector current against temperature variations. An increase in temperature increases leakage current, which can shift the Q-point and lead to thermal runaway.
- **Parameter Independence:** To make the operating point independent of transistor parameters like current gain (β), which varies significantly among transistors of the same type or due to aging.
- **Junction Conditions:** To ensure that the emitter-base junction always remains forward-biased and the collector-base junction remains reverse-biased under all instantaneous values of the input AC signal.

Q.4 (b) Explain the working principle of optical fiber.

Working Principle

An optical fiber works on the principle of **Total Internal Reflection (TIR)**. It guides light waves along its length by repeatedly reflecting them off the boundary between the core and the cladding.

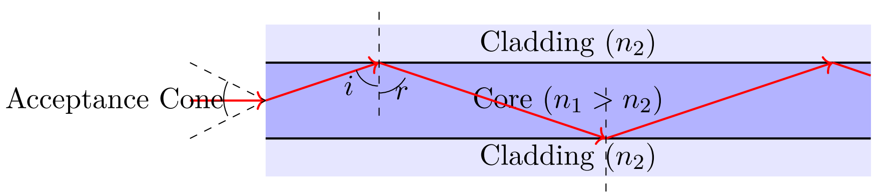


Figure 54: Total Internal Reflection in Optical Fiber

Mechanism of Light Propagation:

- **Structure:** An optical fiber consists of a central, denser transparent **core** (refractive index n_1) surrounded by a rarer transparent **cladding** (refractive index n_2), where $n_1 > n_2$.
- **Total Internal Reflection:** When a light ray traveling inside the denser core strikes the core-cladding boundary at an angle of incidence (i) greater than the **critical angle** (θ_c), it cannot refract into the cladding.
- Instead, the light is entirely reflected back into the core. This continuous multiple reflection allows light to travel long distances with minimal loss.
- **Acceptance Angle:** For TIR to occur, the light must enter the fiber core within a specific cone of angles called the **acceptance cone**. The maximum angle at which light can enter the fiber and still propagate is the acceptance angle.

Q.4 (c) Explain construction and characteristics of SCR.

The Silicon Controlled Rectifier (SCR) is a four-layer, three-junction, three-terminal unidirectional semiconductor switching device.
Construction of SCR:

- The SCR is made up of four alternating semiconductor layers: P-N-P-N.
- These four layers form three PN junctions: J_1, J_2, and J_3.
- It has three terminals:
  - **Anode (A):** Connected to the outer P-layer.
  - **Cathode (K):** Connected to the outer N-layer.
  - **Gate (G):** Connected to the inner P-layer (acting as the control terminal).

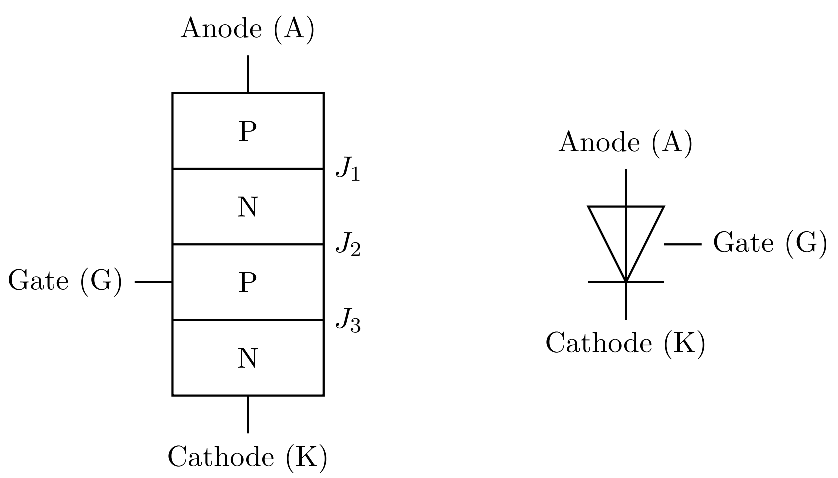


Figure 55: SCR Construction and Symbol

V-I Characteristics of SCR:

The V-I characteristic curve is plotted between Anode-Cathode Voltage (V_{AK}) and Anode Current (I_A) and operates in three distinct regions.

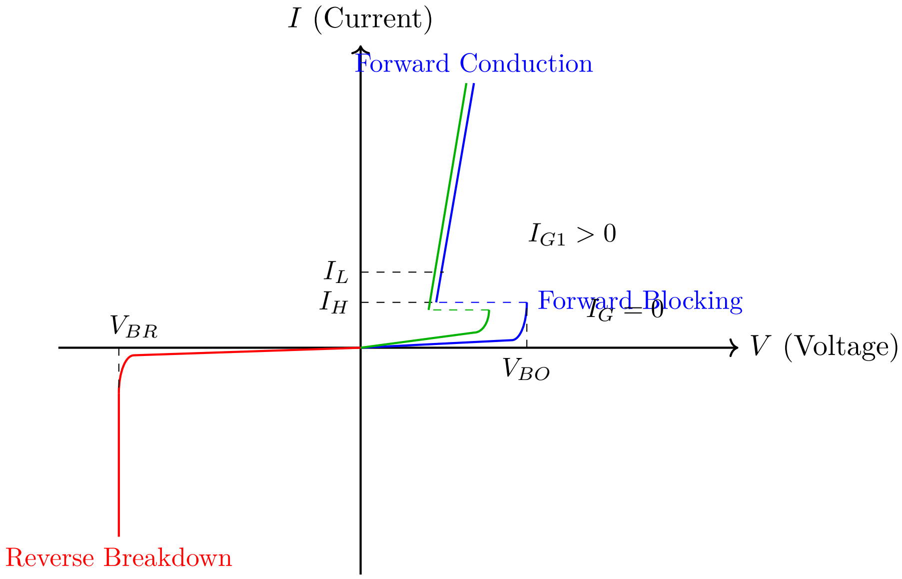


Figure 56: V-I Characteristics of SCR

1. **Reverse Blocking Mode ($V_A < V_K$):**
   - Anode is negative with respect to Cathode.
   - Junctions J_1 and J_3 are reverse-biased, while J_2 is forward-biased.
   - Only a small reverse leakage current flows until the reverse breakdown voltage (V_{BR}) is reached.
2. **Forward Blocking Mode ($V_A > V_K$, $I_G = 0$):**
   - Anode is positive with respect to Cathode, but no gate signal is applied.
   - Junctions J_1 and J_3 are forward-biased, but J_2 is reverse-biased, blocking the current flow. A very small forward leakage current flows.
3. **Forward Conduction Mode:**
   - When V_{AK} is increased beyond the forward breakover voltage (V_{BO}), or a positive pulse is applied to the Gate terminal, junction J_2 breaks down.
   - The SCR turns ON, acting as a closed switch, and a large forward current flows, limited only by the external load resistance.
   - A larger gate current (I_G) allows the SCR to turn ON at a lower forward voltage.

OR

Q.4 (a) State the applications of transistor.

Transistors are fundamental components in modern electronics with a wide range of applications:

- **Amplifiers:** Used to amplify weak audio, radio frequency (RF), and voltage signals in audio systems, radios, and communication devices.
- **Switches:** Act as electronic switches in digital logic circuits, microprocessors, and computer memory, forming the basis of binary operations (ON/OFF).
- **Oscillators:** Employed in oscillator circuits to generate continuous periodic waveforms (sine, square, triangular waves) for timing and signal generation.
- **Voltage Regulators:** Used in power supply circuits to maintain a constant output DC voltage despite variations in input voltage or load current.
- **Modulators and Demodulators:** Used in telecommunication systems for modulating signals onto carrier waves for transmission and recovering them at the receiver.
- **Multivibrators:** Form the core of astable, monostable, and bistable multivibrator circuits used for pulse generation and timing applications.

Q.4 (b) Explain the working principle of LDR.

Working Principle

A Light Dependent Resistor (LDR) operates on the principle of **Photoconductivity**. Its electrical resistance decreases significantly when light falls upon it.

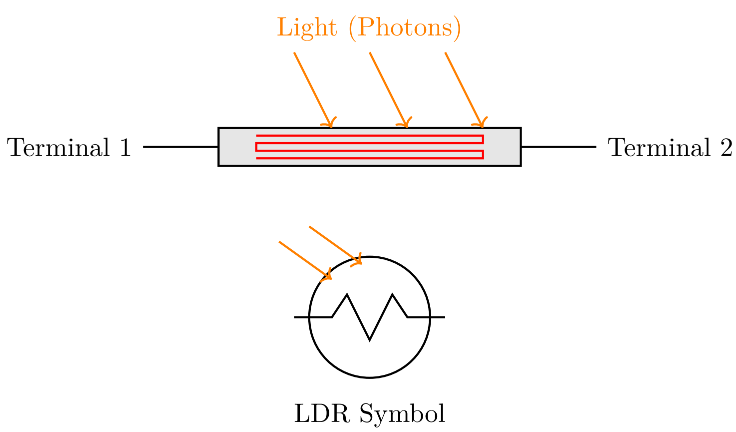


Figure 57: LDR Construction and Symbol

Working Mechanism:

- An LDR is made from a high-resistance semiconductor material, typically Cadmium Sulfide (CdS).
- **In Darkness (Dark Resistance):** When no light is present, the semiconductor has very few free charge carriers (electrons and holes). Thus, its resistance is extremely high (often in mega-ohms).
- **Under Illumination:** When light photons with sufficient energy (greater than the bandgap energy of the material) strike the LDR, they are absorbed by the semiconductor atoms.

- This absorbed energy excites electrons from the valence band to the conduction band, creating numerous electron-hole pairs.
- **Increased Conductivity:** The sudden increase in free charge carriers drastically increases the conductivity of the material, causing the overall electrical resistance to drop dramatically (down to a few hundred ohms).

Q.4 (c) Explain seven segment LED display.

A **Seven-Segment Display** is an electronic display device used to display decimal numerals (0-9) and certain alphabetic characters. It is widely used in digital clocks, electronic meters, basic calculators, and household appliances.

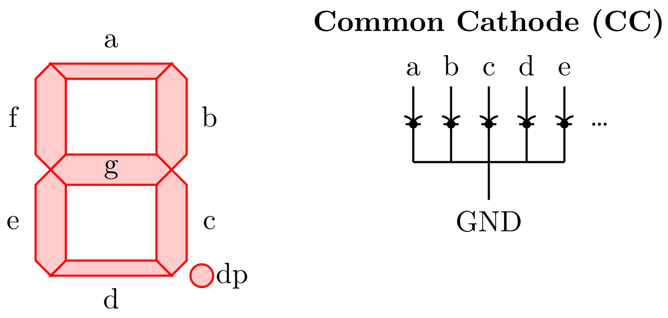


Figure 58: Seven Segment Display Layout and Common Cathode Configuration

Construction:

- It consists of seven individual Light Emitting Diodes (LEDs) arranged in a rectangular 'figure 8' pattern.
- Each of the seven LEDs is called a "segment" and is labeled with a lowercase letter from **a** to **g**.
- An optional eighth LED is often included to display a decimal point (**dp**).
- By illuminating specific combinations of these segments, different numbers can be displayed. For example, to display the number '1', segments **b** and **c** are turned ON. To display '8', all segments (**a** through **g**) are turned ON.

Types of Configurations: Seven-segment displays come in two primary electrical configurations:

1. **Common Cathode (CC) Display:**
   - In this configuration, all the cathode terminals of the eight LEDs are joined together and connected to the common Ground (0V).
   - The individual anode terminals (a-g) are connected to the control circuitry.
   - To turn ON a specific segment, a **Logic HIGH** (positive voltage, usually +5V) must be applied to its corresponding anode pin.
2. **Common Anode (CA) Display:**
   - Here, all the anode terminals of the eight LEDs are tied together and connected to the common positive supply voltage (V_{cc}).

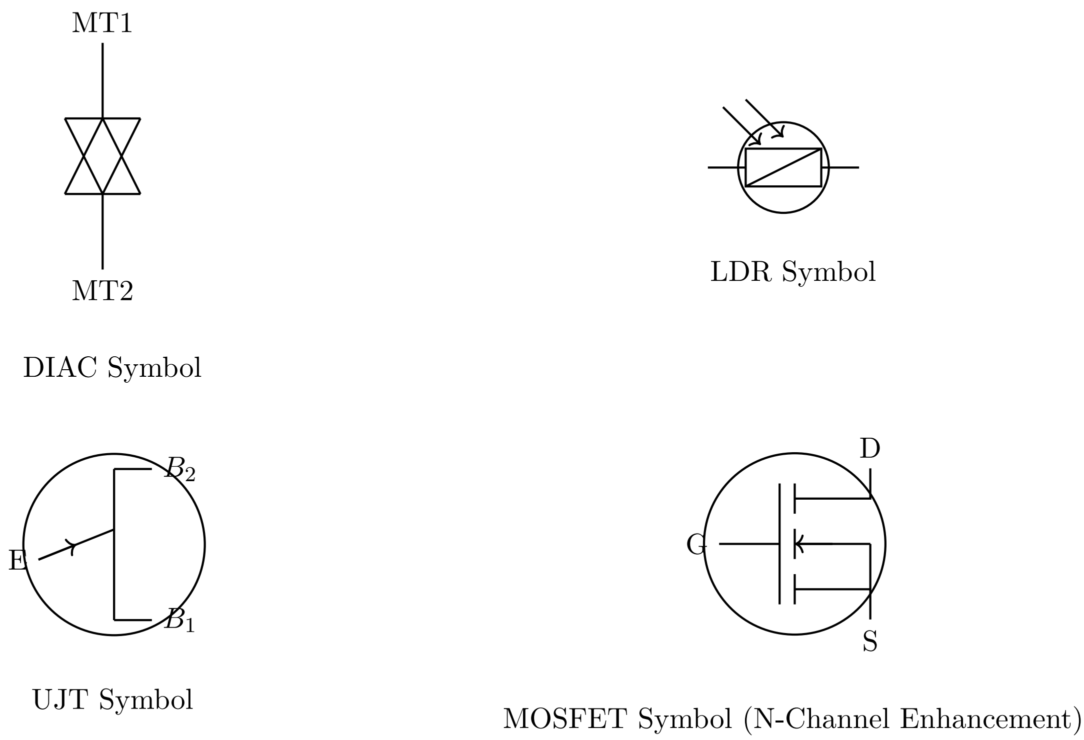
- The individual cathode terminals are connected to the control pins.
- To turn ON a specific segment, a **Logic LOW** (Ground or 0V) must be applied to its corresponding cathode pin.

Q.5 (a) State the application of FET

Field Effect Transistors (FET) are widely used in various electronic applications due to their high input impedance, low power consumption, and compact size. Some common applications include:

- **Amplifiers:** Used in low-noise amplifiers, buffer amplifiers, and operational amplifiers due to their extremely high input impedance, which prevents loading of the preceding stages.
- **Switching Circuits:** Widely used in digital logic circuits (especially MOSFETs) as electronic switches due to their fast switching speed and very low on-state resistance.
- **Voltage Variable Resistors (VVR):** JFETs can act as voltage-controlled resistors in their ohmic region, which is highly useful in automatic gain control (AGC) circuits.
- **Oscillators:** Employed in high-frequency oscillators and mixers in communication receivers.
- **Analog Switches:** Used in multiplexers, sample-and-hold circuits, and chopper circuits.
- **Current Sources:** JFETs can be configured to provide a reliable constant current source.

Q.5 (b) Draw the symbols of (i) DIAC (ii) LDR (iii) UJT (iv) MOSFET



DIAC Symbol

LDR Symbol

UJT Symbol

MOSFET Symbol (N-Channel Enhancement)

Figure 59: Symbols of various electronic components

Q.5 (c) Explain the construction and working of N-channel JFET.

Construction of N-Channel JFET

It consists of an N-type silicon bar that acts as a conducting channel. Two heavily doped P-type regions are formed on opposite sides of the N-type bar to create P-N junctions. The two P-type regions are internally connected together, and a single terminal called Gate (G) is brought out. Ohmic contacts are made at the two ends of the N-type bar. One end is called Source (S), through which majority carriers (electrons) enter, and the other is called Drain (D), through which they leave.

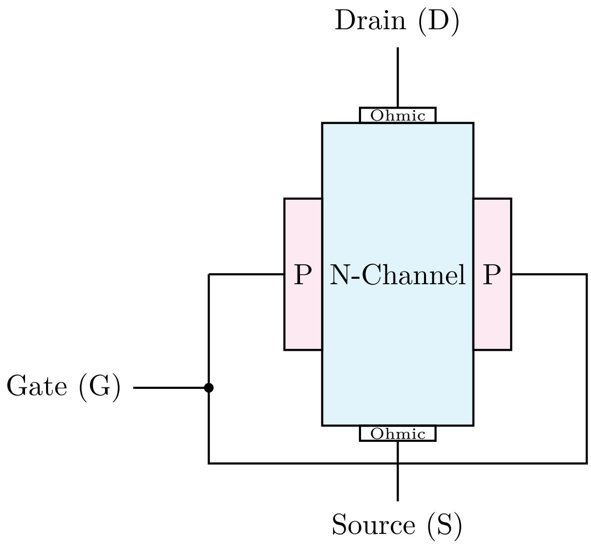


Figure 60: Construction of N-Channel JFET

Working of N-Channel JFET:

The operation of a JFET is based on varying the width of the conducting channel using a reverse-biased P-N junction.

- **When $V_{GS} = 0$ and V_{DS} is applied:** If a positive voltage is applied to the drain with respect to the source, electrons flow from source to drain through the N-channel, constituting the drain current I_D. The depletion regions around the P-N junctions are wider near the drain end because the reverse bias is highest at the drain end.
- **When $V_{GS} < 0$ and V_{DS} is applied:** When a negative voltage is applied to the gate, the reverse bias across the P-N junctions increases. This increases the width of the depletion regions, reducing the effective channel width available for conduction. Consequently, the channel resistance increases, and the drain current I_D decreases.
- **Pinch-off Voltage:** As the negative gate-to-source voltage (V_{GS}) is further increased, the depletion regions eventually touch each other, completely blocking the channel. The voltage at which I_D becomes practically zero is called the pinch-off voltage.

Thus, JFET is a voltage-controlled device where the gate-source voltage controls the drain current.

Q.5 (a) OR State the applications of SCR.

The Silicon Controlled Rectifier (SCR) is a versatile solid-state electronic switching device widely used in power control applications. Important applications include:

- **Phase Control:** Extensively used in AC phase control circuits for dimming lights, heater temperature control, and motor speed control.
- **Controlled Rectification:** Employed in controlled rectifiers to convert fixed AC into variable DC for industrial DC motor drives.
- **Switching:** Used as a static switch in solid-state relays and contactors due to its fast switching speed, reliability, and absence of moving parts.
- **Protection Circuits:** Used in over-voltage protection (such as crowbar circuits) and over-current protection systems to safeguard sensitive electronic equipment.
- **Inverters and Cycloconverters:** Widely used in power electronic circuits for DC to AC conversion (inverters) and for changing AC frequency (cycloconverters).
- **Battery Charging:** Utilized in regulated battery chargers to precisely control the charging current.

Q.5 (b) OR Draw the symbols of (i) TRIAC (ii) Photo Transistor (iii) SCR (iv) LED

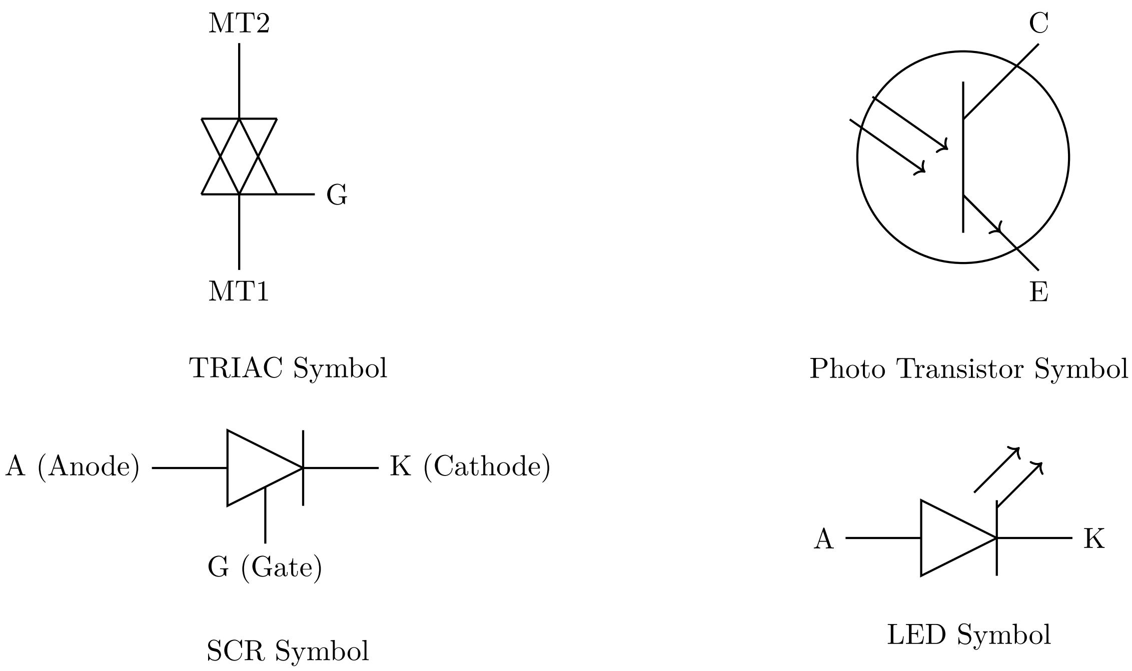


Figure 61: Symbols of Optoelectronic and Power Devices

Q.5 (c) OR Explain the construction and working of Photo Diode.

Construction of Photo Diode

A Photo Diode is a special type of P-N junction diode designed to operate in reverse bias mode and is highly sensitive to light illumination. It is typically fabricated from semiconductor materials like Silicon (Si) or Germanium (Ge). The P-N junction is packaged in a plastic or metal casing with a transparent window (glass or plastic lens) to allow incident light to fall directly on the junction. The P-region is kept extremely thin so that light can easily penetrate and reach the depletion region where it is absorbed.

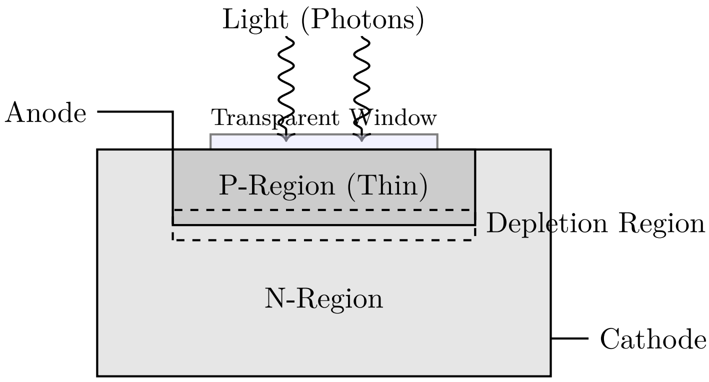


Figure 62: Construction of Photo Diode

Working of Photo Diode:

- **Dark Current:** When the photo diode is reverse biased and no light is incident on it (kept in darkness), a very small reverse leakage current flows due to thermally generated minority carriers. This minute current is called the dark current.
- **Effect of Illumination:** When light (consisting of photons) falls on the P-N junction, if the energy of the photons is greater than the bandgap energy of the semiconductor material, it excites electrons from the valence band to the conduction band.
- **Carrier Generation:** This excitation process generates new electron-hole pairs predominantly in and around the depletion region.
- **Photocurrent:** Due to the strong internal electric field of the reverse-biased junction, these newly generated electrons are rapidly swept towards the N-region, and holes are swept towards the P-region.
- **Linear Response:** This movement of charge carriers results in a reverse current flowing through the external circuit. This photocurrent is directly proportional to the intensity of the incident light. As the light intensity increases, the reverse current increases linearly.