

Grade 12 physics Unit 5



Competency Based Short Note

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Grade 12 Unit 5: Introduction To Electronics

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5.1 Semiconductors

Competency

- *Describe the difference between conductor, insulator and semiconductor.*
- *Give example of semiconductor elements.*
- *Distinguish between intrinsic and extrinsic semiconductors.*
- *Distinguish between N- type and P-type semiconductors.*
- *Explain how doping supports current flow in a semiconductor material*

5.2 Diodes and their Functions

Competency

- *Describe what a junction diode is and how it is made.*
- *Draw and label the schematic symbol for a diode.*
- *Explain Biasing of P-N junction diode*
- *Explain the difference between forward bias and reverse bias of a diode.*
- *Describe the I-V characteristics of a diode.*
- *Describe the function of diodes, including rectification.*

5.3 Rectification

Competency

- *Describe the working principle of half-wave and full-wave rectification.*
- *Describe the function of capacitor in the case of full-wave rectification.*
- *Describe some practical uses of diode.*

5.4 Transistors and their application

Competency

- *Describe how a transistor is constructed and its different configurations.*
- *Draw and label the schematic symbol for an NPN and a PNP transistor.*
- *Describe basic Transistor Operation of NPN and PNP Transistor.*
- *Describe the function of a transistor as an amplifier.*
- *Describe the difference between emitter, base and collector in terms of dopant concentration.*
- *Calculate the gain (amplification) of a transistor.*

5.5 Integrated Circuits

Competency

- *Explain the importance of integrated circuits.*
- *Identify the major components of an integrated circuit*
- *Identify advantages and disadvantages of integrated circuits.*

5.6 Logic gates and logic circuits

Competency

- *Identify digital and analog signals.*
- *Explain basics of logic gates.*
- *Identify and explain the function of the basic logic gates.*
- *Draw the symbols and analog switch circuit for the basic logic gates.*
- *Develop truth tables for the basic logic gates.*

1.7 Application of electronics

Competency

- *List some applications of Electronics*

5.1 Semiconductors

➤ Describe the difference between conductor, insulator and semiconductor.

A. Conductor

- Conductors are materials which allow electricity to flow through them.
- Metals are good conductors of electricity.
- Conductors have free electrons that allow the easy flow of electric current.

B. Insulator

- Some materials do not allow electricity to pass through them, these materials are known as insulators.
- Insulators do not have free electrons; every electron in them is tightly bound to the parent atom.
- Plastic, wood, glass and rubber are good electrical insulators.
- That is why they are used to cover materials that carry electricity.

C. Semiconductor

- Semiconductors are materials which have a conductivity between conductors and insulators.
- Semiconductors can be pure elements, such as silicon or germanium, or compounds such as gallium arsenide or cadmium selenide.
- Semiconductors act as insulators at absolute zero temperature (zero kelvin) and conductors at higher temperatures.
- Conduction occurs at higher temperature because electrons break away from covalent bonds and move freely.

UEE sample Question:

1. We usually use plastic materials to cover metallic wires that carry electricity to protect living things from danger. Which of the following statement correctly describes the nature of the plastic to use for this purpose? **[UEE 2017]**
 - A. Since every electron in plastic is slightly bound to the parent atom, it becomes poor conductor.
 - B. Since every electron in plastic is tightly bound to the parent atom, it becomes poor conductor.
 - C. Since it has free electrons, it facilitates the easy flow of electric current in the metallic wires.
 - D. Since it has no free electrons, it directs the electrons in the wire to flow in the same direction.

➤ **Give example of semiconductor elements.**

- Silicon
- Germanium

→ Semiconductors can be pure elements, such as silicon or germanium, or compounds such as gallium arsenide or cadmium selenide.

➤ **Distinguish between intrinsic and extrinsic semiconductors.**

- Semiconductors are divided into two categories: Intrinsic semiconductor and extrinsic semiconductor.

A. Intrinsic Semiconductor

- Intrinsic semiconductors are composed of only one kind of material.
- Silicon and germanium are examples of intrinsic semiconductors.
- These are semiconductor materials which have not had impurities added to them in order to change the carrier concentrations.
- Intrinsic semiconductors are also called undoped semiconductors.

B. Extrinsic Semiconductor

- Extrinsic semiconductors have impurities added to their lattice structure.
- The addition of small amounts of impurities improves conductivity.
- The process of adding impurity to a pure semiconductor is called doping.
- Sometimes the impurity is called a dopant.
- Extrinsic semiconductors are classified as N-type and P-type semiconductors.

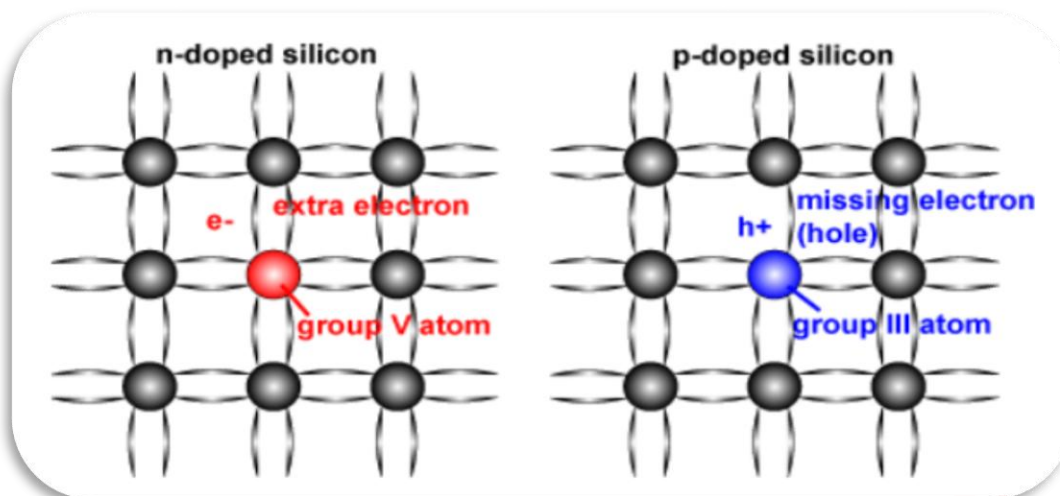
➤ Distinguish between N- type and P-type semiconductors.

A. N-type Semiconductor

- N-type semiconductor is formed by adding Group V elements to a pure semiconductor.
- Pure semiconductor materials doped with Group V elements such as phosphorus (P), arsenic (As), or antimony (Sb) as an impurity are called N-type semiconductors.
- Group V elements have five valence electrons.
- Examples include *antimony*, *arsenic*, *bismuth*, and *phosphorus*.
- Conduction mainly occurs by *electron flow*.
- The majority carriers in N-type semiconductors are electrons and holes are minority carriers.
- Since N-type dopants donate their free electrons to the semiconductor, they are known as donor atoms

B. P-type Semiconductor

- P-type semiconductor is formed by adding Group III elements to a pure semiconductor.
- Pure semiconductor materials doped with Group III elements such as boron (B) or indium (In) are called P-type semiconductors
- Examples include aluminum, boron, gallium, and indium.
- The absence of an electron creates a hole.
- Holes act as positive charge carriers.
- The majority carriers in P-type semiconductors are holes and electrons are minority carriers
- These impurities are called acceptor atoms.



Sample UEE Questions:

1. What will happen on a pure semiconductor when it is doped by group III element? [UEE 2017]
 - A. It becomes P-type semiconductor.
 - B. It gets extra free electrons.
 - C. It becomes intrinsic semiconductor.
 - D. It becomes N-type semiconductor.
2. Which one of the following statements is correct about conduction in semiconductors? [UEE 2015]
 - A. The majority charge carriers in N-type semiconductors are electrons due to doping.
 - B. When atoms with half-filled electrons are doped with atoms of five valence electrons, the majority charge carriers are holes.
 - C. N-type semiconductor is made from half-filled shell atoms doped with acceptor atoms.
 - D. P-type semiconductors have holes as minority charge carriers in the crystal lattice of the material.
3. Which of the following is true about types of semiconductors? A semiconductor [Matric 2009]
 - A. Doped with acceptor impurity atoms is called a p-type
 - B. Doped with donor impurity atoms is called p-type
 - C. In which the majority carries are holes due to doping in an n-type
 - D. Doped with acceptor impurity atoms is called an n-type

➤ Explain how doping supports current flow in a semiconductor material

- Doping is the process of adding impurities to a pure semiconductor material.
- The addition of small amounts of impurities causes large changes in conductivity.
- The main aim of doping is to create either too many electrons or too few electrons.
- When extra electrons are added, conduction occurs by movement of electrons.
- When holes are created, conduction occurs by movement of holes.
- These electrons and holes act as charge carriers and allow electric current to flow easily.
- **Remember:** Semiconductor materials are doped with Group III or V elements to increase their conductivity.

Discussion question 5.1

1. What are the current carriers in semiconductors and conductors?

Answer:

- In conductor free electrons are the carriers.
- In Semiconductors the current carriers are holes or electrons

2. A germanium (Ge) crystal is doped with boron. What type of semiconductor is this?

Answer:

- Boron is group III element. When it is doped with germanium excess holes are created and the type of semiconductor is P –type.

3. Would the following elements make good P-type dopants or good N-type dopants?

- a) Phosphorus
- b) Gallium
- c) Arsenic
- d) Indium

Answer:

- A) Phosphorus: N-tpe,
- B) Gallium: P-type
- C) Arsenic: N-type dopant
- D) Indium: P-type dopant

Review question 5.1:

1. Why a semiconductor conducts better when it is hot? Explain your answer.

Answer:

- Conduction occurs at higher temperature because the electrons surrounding the semiconductor atoms can break away from their covalent bond and move freely about the lattice.

2. Which of the following impurities could be used to convert intrinsic silicon to extrinsic P-type silicon?

- (A) aluminum.
- (B) germanium.
- (C) arsenic.
- (D) zinc.

Answer:

- (A) Aluminum → Group III → ✓
- (B) Germanium → Group IV → ✗
- (C) Arsenic → Group V → ✗ (n-type)
- (D) Zinc → Group II → ✗

3. What type of impurities are chosen for doping to form N-type semiconductor?

- (A) trivalent (B) tetravalent (C) pentavalent (D) both a and c

Answer:

- (A) Trivalent → creates holes → ✗
- (B) Tetravalent → no effect → ✗
- (C) Pentavalent → extra electrons ✓
- (D) Both A and C → incorrect → ✗

4. Electrons are the minority carriers in

- (A) extrinsic semiconductors
- (B) P-type semiconductors
- (C) intrinsic semiconductors
- (D) N-type semiconductors

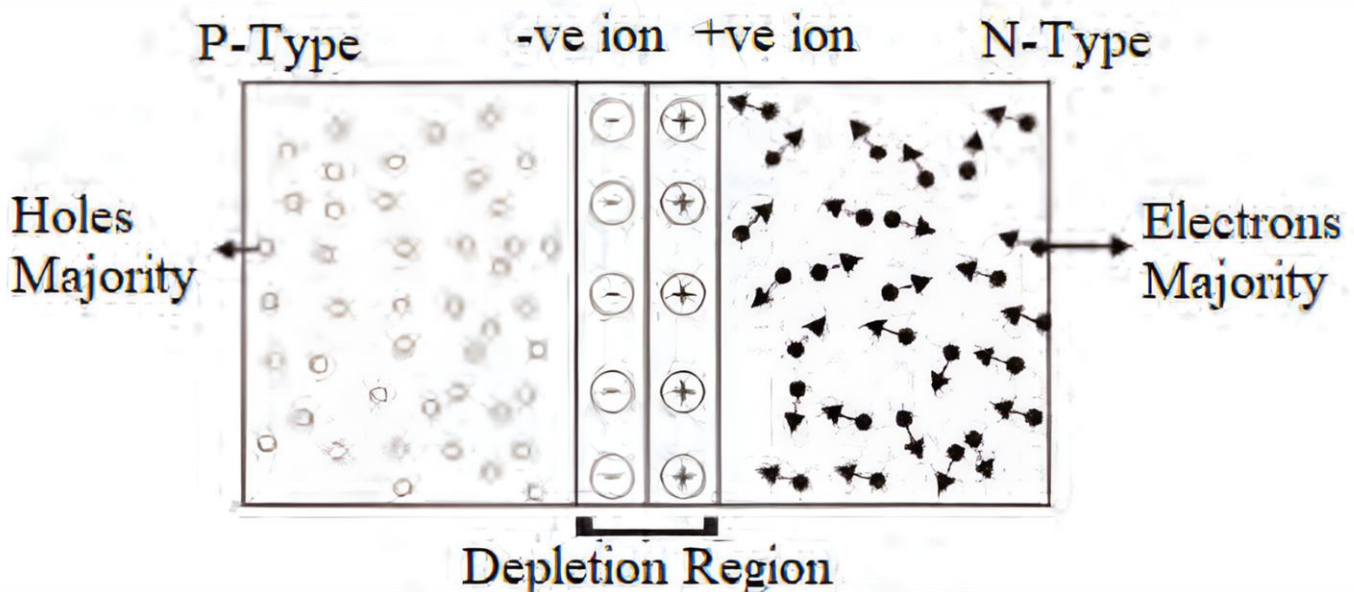
Answer:

- (A) Extrinsic → can be either type ✗
- (B) P-type → holes majority → electrons minority ✓
- (C) Intrinsic → equal electrons and holes → ✗
- (D) N-type → electrons majority → ✗

5.2 Diodes and their Functions

➤ Describe what a junction diode is and how it is made.

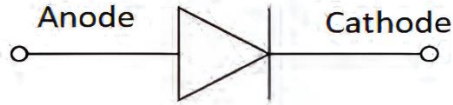
- A diode is a two-terminal electronic component that only conducts current in one direction and blocks current in the reverse direction.
- Diodes are made from materials such as silicon, germanium and gallium arsenide.
- A P-N junction diode is formed when an N-type semiconductor is joined with a P-type semiconductor.
- When a P-N junction is formed, some of the electrons in the N-region diffuse across the junction and combine with holes to form negative ions on the P-side
- This creates a narrow region near the junction called the depletion region.
- The depletion region forms a barrier that prevents further movement of charge carriers.



Sample UEE Question:

1. A diode is an electronic component that [UEE 2014/15]
 - A. allows the flow of current when its p-type region is connected to the negative terminal of a cell.
 - B. Is useful to convert a DC voltage to AC voltage.
 - C. allows electric current to pass through it in one direction.
 - D. allows current to pass through it either from cathode to anode or from anode to cathode.

➤ **Draw and label the schematic symbol for a diode.**



a) The P-N junction diode b) P-N junction symbol.

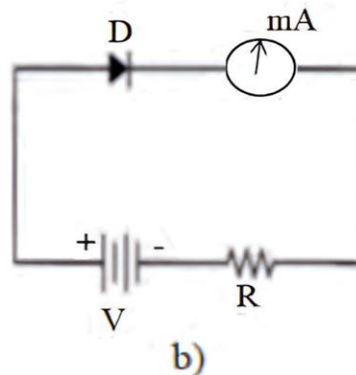
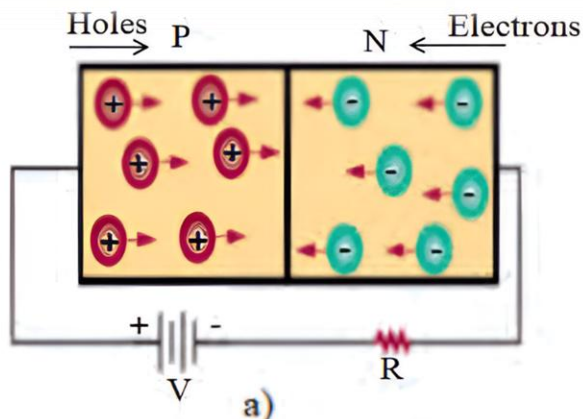
➤ **Explain Biasing of P-N junction diode**

- Applying a suitable DC voltage to a diode is known as **biasing**.
- It can be done in two ways: **forward** and **reverse biasing**.
- Diodes in both forward and reverse bias are useful for computer chips, solar cells, and other electronic devices.
- Zero biasing condition is when no external voltage is applied to the P-N junction diode.

➤ **Explain the difference between forward bias and reverse bias of a diode.**

A. Forward Bias

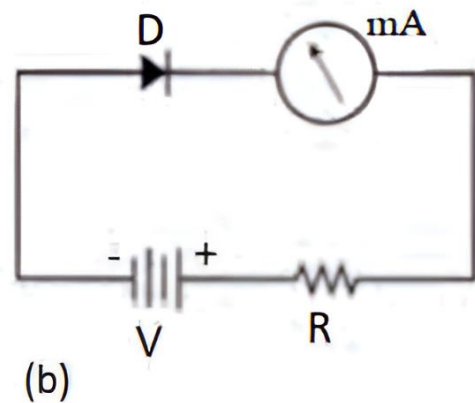
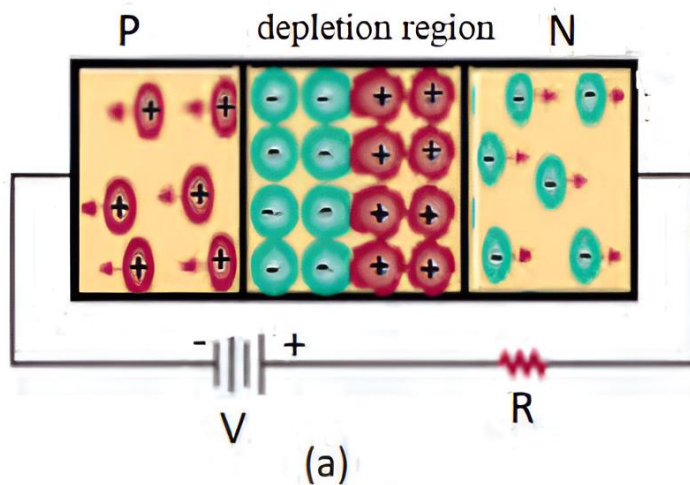
- When the positive terminal of the battery is connected to the P-type semiconductor and the negative terminal to the N-type semiconductor, **the diode is forward biased**.
- Electrons and holes move toward the junction.
- The depletion region becomes thin and narrow.
- This creates a low resistance path and large current flows through the diode.



(a) Forward biased P-N junction (b) Forward biased circuit diagram.

B. Reverse Bias

- When the negative terminal of the battery is connected to the P-type semiconductor and the positive terminal to the N-type semiconductor, the diode is **reverse biased**.
- Electrons and holes move away from the junction.
- The depletion region becomes wider.
- This creates a high resistance path.
- Almost no current flows through the diode.



(a) Reverse biased P-N junction (b) reverse biased circuit diagram.

Review question 5.2:

1. Under forward bias, the resistance is low and the current is high.

A. True **B.** False.

CONCEPT

Forward bias

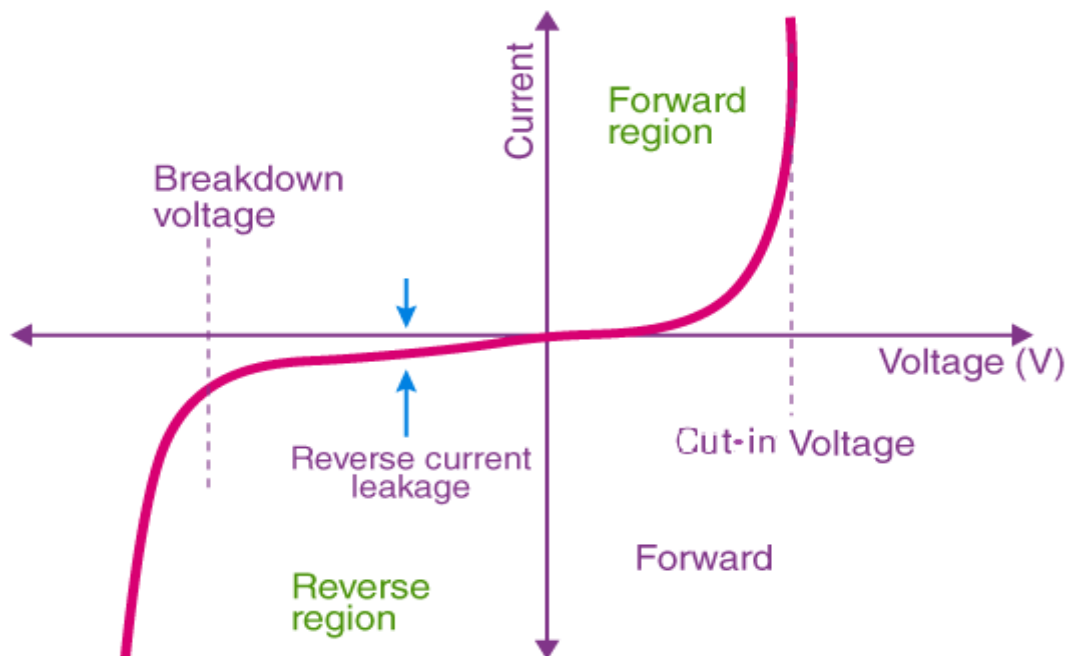
- reduces barrier potential and allows easy flow of charge carriers
- Resistance becomes low → ✓
- Current becomes high → ✓

2. Depletion layer is caused by

- (A) doping
- (B) recombination**
- (C) barrier potential
- (D) ions

➤ **Describe the I-V characteristics of a diode.**

- The I-V characteristic curve shows the relationship between current and voltage in a diode.
- The current is very low when the forward voltage is lower than the cut-in voltage.
- The cut-in voltage is the voltage at which the forward diode current starts increasing rapidly.
- Once the forward bias exceeds the cut-in voltage (0.3 V for germanium diode and 0.7 V for silicon diode), the current increases dramatically.
- **In forward bias**, the diode conducts large current and behaves like a short circuit.
- **In reverse bias**, a very small current called reverse bias current or leakage current flows.
- When the reverse voltage becomes very high, breakdown occurs and the current increases rapidly.



Sample UEE Question:

1. Which one of the following statements is correct about the current-voltage (I-V) characteristics of a typical semiconductor diode? **[UEE 2017]**
 - A. The region of the I-V curve that rises very rapidly after the voltage exceeds the cut-in voltage forward bias region.
 - B. The region of the I-V curve that increases very rapidly after the bias voltage exceeds the breakdown voltage is in the forward bias region.
 - C. The current due to the minority charge carriers is represented in the forward bias region of the I-V curve.
 - D. The current due to the majority charge carriers is represented in the reverse bias region of the I-V curve

➤ **Describe the function of diodes, including rectification.**

- A P-N junction diode conducts electricity when it is forward biased and does not conduct electricity when it is reverse biased.
- Hence, it is used to rectify an alternating current (AC) voltage supply.
- The process in which an AC voltage supply is converted into a unidirectional (DC) voltage is known as rectification, the electric circuit used for the conversion is called a rectifier.
- When AC input is applied to a junction diode, it becomes forward biased during the positive half cycle and reverse biased during the negative half cycle.
- Rectification is the main function of diodes.

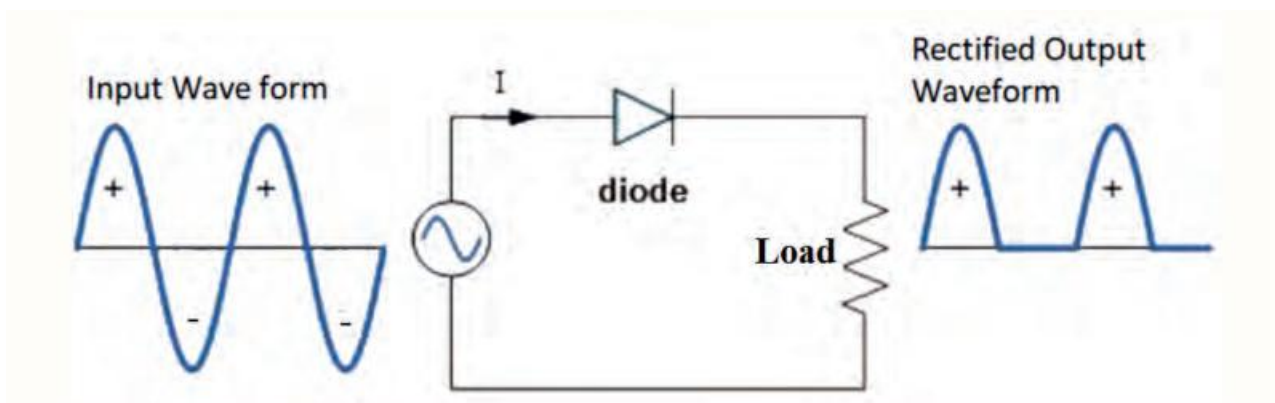
5.3 Rectification

- There are two basic types of rectifier circuit used with power supplies: half-wave rectifiers and full-wave rectifiers.

➤ **Describe the working principle of half-wave and full-wave rectification.**

A. Half-Wave Rectification

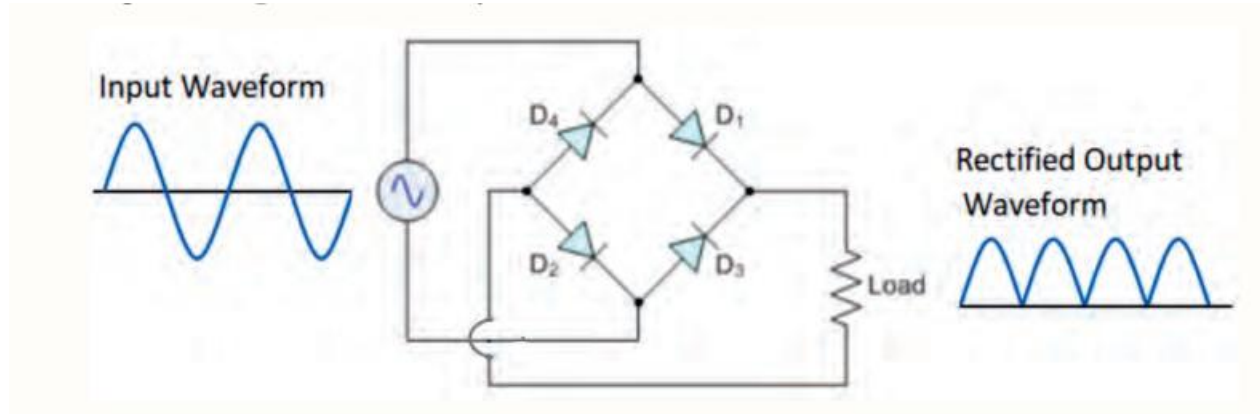
- A half-wave rectifier allows only one half-cycle of an AC voltage waveform and blocks the other half-cycle.
- During the positive half-cycle, the diode is forward biased and current flows through the load resistor.
- A voltage is developed across the load resistor.
- During the negative half-cycle, the diode is reverse biased and does not conduct.
- No current flows through the load resistor during the negative half-cycle.
- Thus, AC input signal is converted into a pulsating DC output signal.



- A half-wave rectifier consists of a diode and a load resistor connected in series to the cathode end of the diode.

B. Full-Wave Rectification

- A full-wave rectifier uses four diodes arranged in a bridge circuit.



- During the positive half-cycle, two diodes D₁ and D₂ conduct while the other two are reverse biased.
- Current flows through the load resistor in one direction.
- During the negative half-cycle, the other two diodes D₄ and D₃ conduct while the first two become reverse biased.
- Current again flows through the load resistor in the same direction.
- Thus, both half-cycles of AC are converted into DC output.

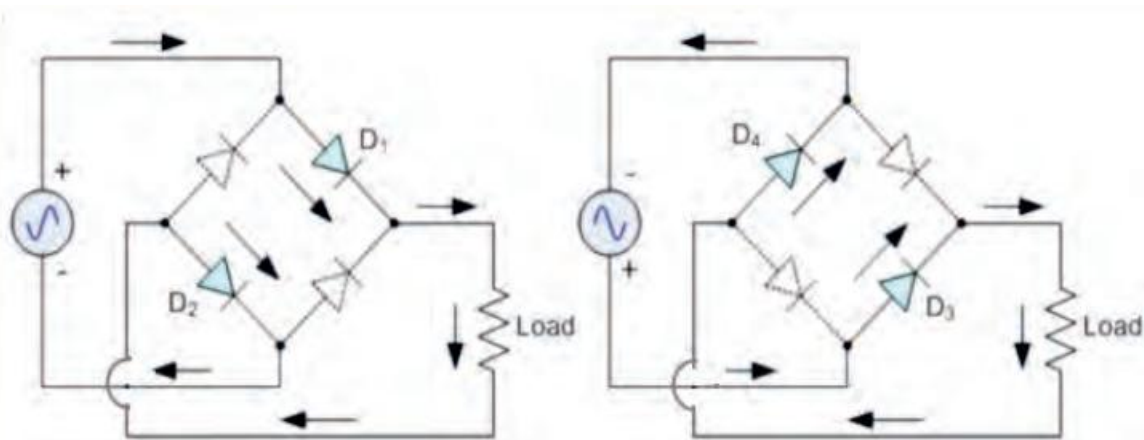
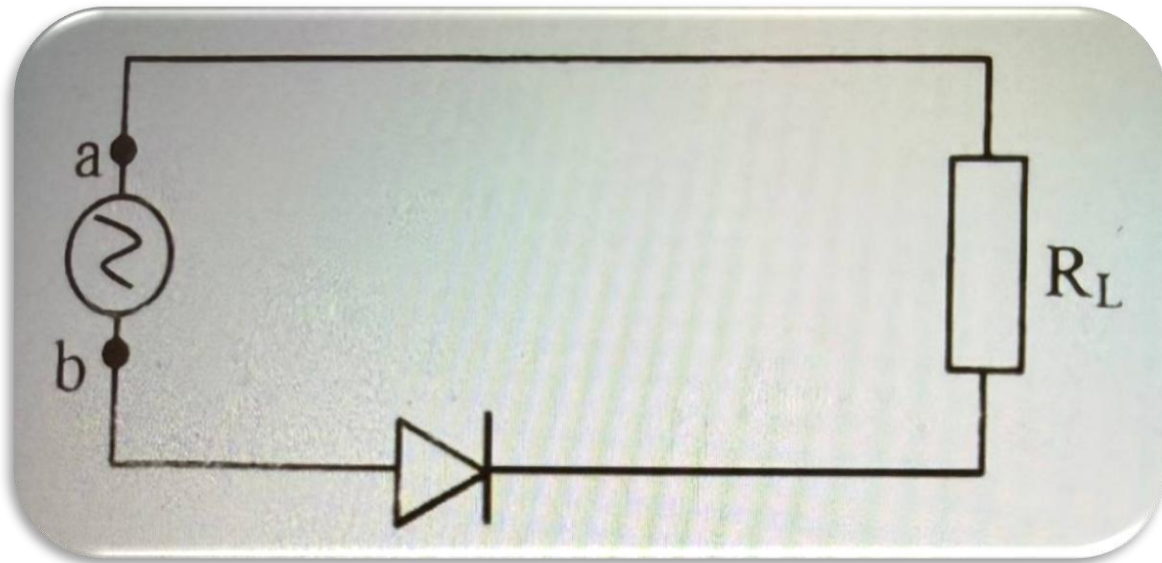


Figure 5.11 *a)* positive half cycle *b)* Negative half cycle.

Sample UEE Questions:

1. Consider a circuit containing diode and load resistor (R_L) are connected to an AC voltage as shown in the figure below.

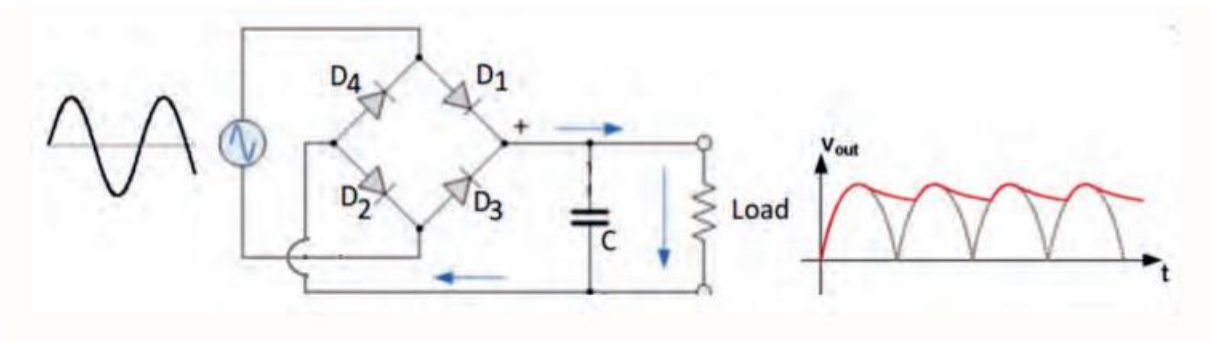


If initially polarity of 'a' is positive while 'b' is negative, [UEE 2017]

- A. During the first half-cycle, the diode is reverse biased and voltage is developed across the load resistor.
 - B. During the second half-cycle, the diode is forward biased and current flows in the load resistor.
 - C. During the second half-cycle, the diode is reverse biased and no current flow in the load resistor.
 - D. During the first half-cycle, the diode is forward biased and voltage is developed across the load resistor.
2. A diode is used in a half-wave rectification ac circuit, because it [Matric 2010]
- A. Allows current to flow in one direction only.
 - B. Generates only half of the current in a circuit.
 - C. Absorbs the current in the second half of the ac cycle.
 - D. Reduces the current in a circuit by half.

➤ **Describe the function of capacitor in the case of full-wave rectification.**

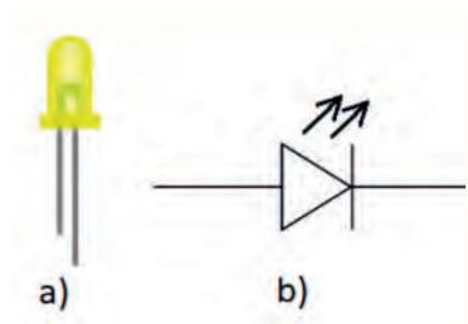
- **A capacitor** is used in rectifier circuits to smooth the fluctuations of the output voltage.
- A capacitor stores charge and releases it later.
- The capacitor is connected across the output terminals.
- During the positive quarter-cycle of the output voltage, the capacitor is charged to the peak voltage.
- As the rectifier voltage falls, the capacitor discharges and provides current to the load resistor.
- This charging and discharging process smooths out the waveform and produces a steady DC output.



➤ **Describe some practical uses of diode.**

A. Light emitting diodes (LED)

- A light emitting diode(LED) is a P-N junction diode which can emit light when an electrical current flows through it.
- It uses a special kind of doping so that when an electron crosses the P-N junction, a photon is emitted, which creates light.
- The frequency(color) of the light emitted is determined by the type of semiconductor material used in construction of the diode.
- LED allows the current to flow in the forward direction and blocks the current in the reverse direction.
- LEDs are very efficient producers of light.



B. Over-voltage protection

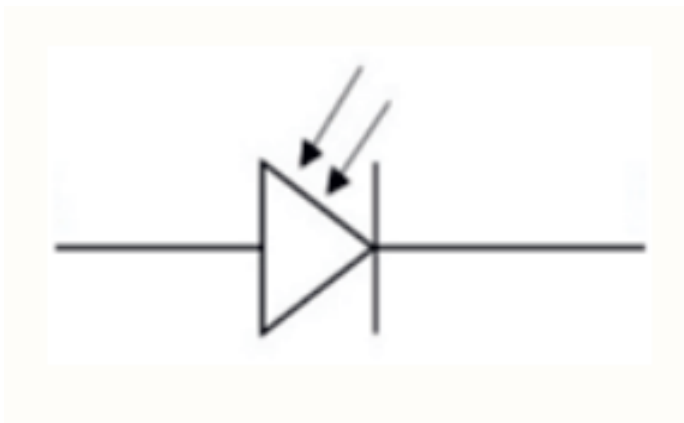
- Excess voltage can damage electronic devices.
- Sensitive electronic devices need protection from voltage fluctuations.
- A diode can be used for over-voltage protection.
- The diode works by shutting down the switch after detecting an over-voltage condition, preventing damage to the device.

C. Logic gates

- Diodes and resistors can be combined with other components to construct AND and OR logic gates.
- This is referred to as diode resistor logic. These are discussed in detail in section 5.5.

D. Photodiode

- A photodiode is a semiconductor device with a P-N junction that converts photons (or light) into electrical current.
- Photons absorbed in the depletion region (or near it) create electron-hole pairs.
- The electric field in the depletion region moves electrons toward the positive potential on the cathode and holes toward the negative potential on the anode.
- The movement of these charge carriers forms the photocurrent in the photodiode.
- It is used in devices where light needs to be detected and converted into electrical signals.



Discussion Question 5.3:

1. If we use half-wave rectifier, what percentage of the input AC power will be converted to DC power?

→ In half wave rectifier only 50% AC power passes through the diode.

3. The dc current through each forward-biased diode in a full-wave rectifier equals:

- | | |
|-------------------------------|-------------------------------------|
| (A) the load current | (B) half the dc load current |
| (C) twice the dc load current | (D) one-fourth the dc load current. |

Answer:

- The correct answer is (B) half the dc load current.
 - In a full-wave rectifier (either center-tapped or bridge), the load current is the sum of the currents provided by the diodes during their respective half-cycles.
 - Since each diode conducts for only one-half of the input cycle, it carries the full load current during its conduction period but zero current during the other half.
 - Therefore, on average, the DC current through an individual diode is exactly half of the total DC load current.
3. The basic reason why a full-wave rectifier has a twice the efficiency of a half-wave rectifier is that:
- (A) it makes use of transformer
 - (B) the heating loss is much less
 - (C) it utilizes both half-cycles of the input
 - (D) its output frequency is double the line frequency

Answer:

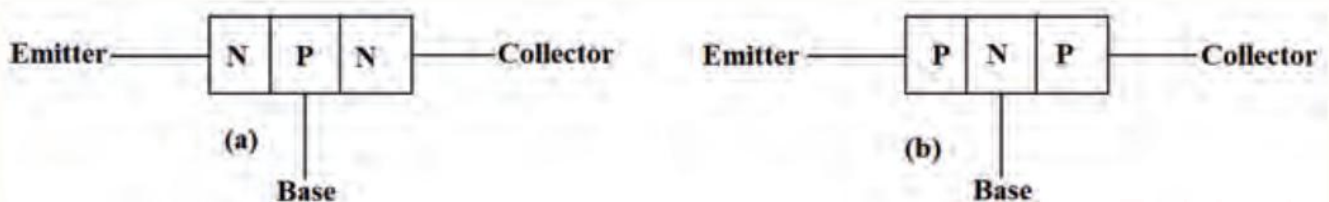
- The correct answer is (C) it utilizes both half-cycles of the input.
- In a half-wave rectifier, one half-cycle of the AC input is completely blocked, meaning half the potential energy is wasted.
- A full-wave rectifier converts both the positive and negative halves of the AC cycle into a unidirectional DC output.

5.4 Transistors and their application

➤ Describe how a transistor is constructed and its different configurations.

A. Construction of Transistor

- A transistor is a semiconductor device used to amplify or switch electronic signals.
- It is an essential component in an electronic circuit.
- Transistors are classified into two types: **bipolar junction transistors (BJT)** and **field effect transistors (FET)**.
- In this section, you will learn about BJTs.
- When a third layer is added to a semiconductor diode, a BJT is produced. The term, transistor, will now be used for a BJT.
- A transistor is a three-terminal, two-junction device used to control electron flow.
- A transistor consists of three alternately doped regions.
- By varying the amount of voltage applied to the three terminals, the amount of current can be controlled.
- This is how transistors can be used for amplification or switching.
- The three regions are arranged as **NPN** or **PNP** transistor.
- In an NPN transistor, P-type material is sandwiched between two N-type materials.
- In a PNP transistor, N-type material is sandwiched between two P-type materials.
- The **three regions** are called emitter, base and collector.
- In both types of transistor, the middle region is called the **base** and the outer regions are called the emitter and collector.
- The emitter is the section that supplies charge carriers (electrons or holes) and heavily doped compared to the base and collector.
- The base is the middle section between emitter and collector and lightly doped and very thin.
- The collector is the section that collects the charge carriers and moderately doped and slightly larger in size than emitter and base.
- The emitter, base, and collector are identified by the letters E, B, and C, respectively.

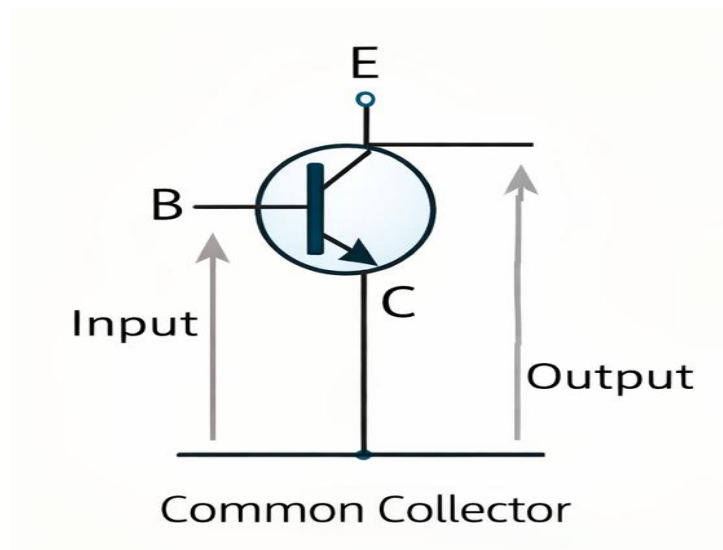


B. Transistor Configurations

- There are three possible ways to connect a transistor in an electronic circuit with one terminal being common to both the input and output signal.
- These configurations are:
 1. Common-emitter (CE)
 2. Common-collector (CC)
 3. Common-base (CB)
- Each method of connection responds differently to the input signal because the characteristics of the transistor vary with each circuit arrangement.

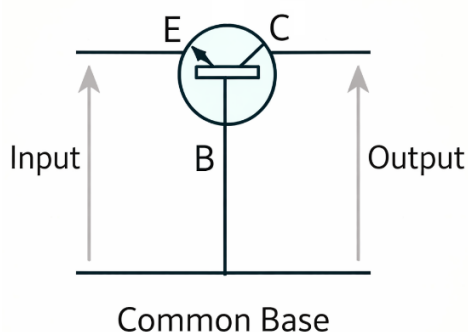
1. Common-Collector (CC)

- The input signal is applied between the base and collector terminal.
- The output is taken between the emitter and collector terminal.
- It provides good current gain but no voltage gains.



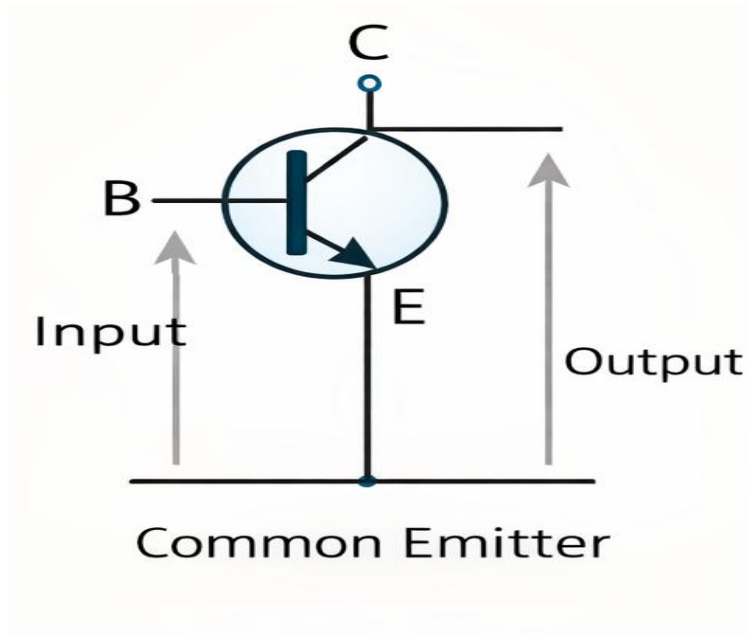
2. Common-Base (CB)

- The input signal is applied between the emitter and base terminal.
- The output signal is taken from collector and base terminal.
- The base is common to both emitter and collector.
- The circuit has voltage gain but no current gain.



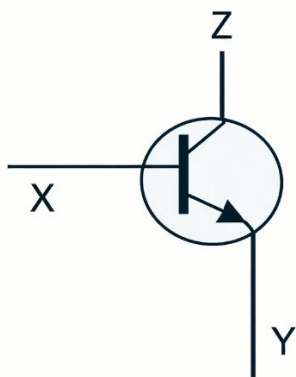
3. Common-Emitter (CE)

- The input signal is applied between the base and emitter terminal.
- The output is taken between the collector and emitter terminal.
- The circuit has both current and voltage gain.
- This configuration is commonly used because it has high gain.



Sample UEE Questions:

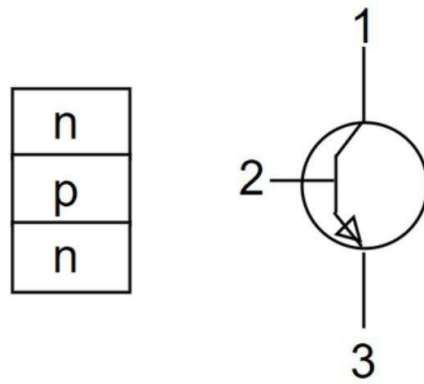
1. The following symbol is an n-p-n transistor.



What do the letter X, Y, Z represent respectively? **[Matric 2010]**

- A. Emitter, Collector, Base
- B. Collector, Base, Emitter
- C. Base, emitter, Collector
- D. Base, Collector, Emitter

2. The following figures show the symbol and nomenclature for n-p-n transistor.

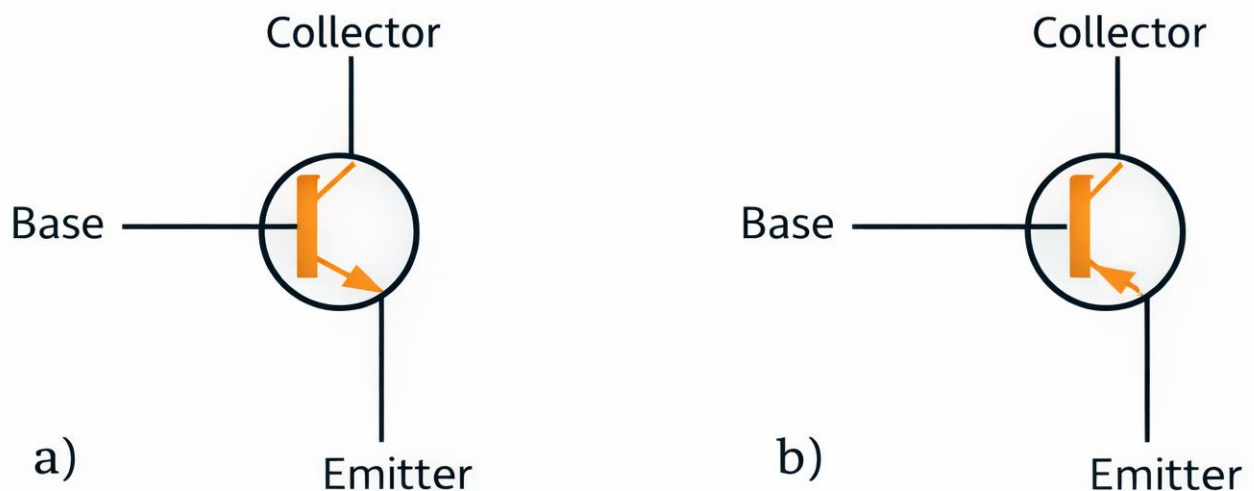


Which numbers represent emitter and base respectively? [Matric 2009]

- A. 2 and 3 C. 3 and 1
B. 3 and 2 D. 1 and 3

➤ **Draw and label the schematic symbol for an NPN and a PNP transistor.**

- In the symbolic representation for a transistor, the arrow mark is placed on the emitter in the direction of conventional current flow.

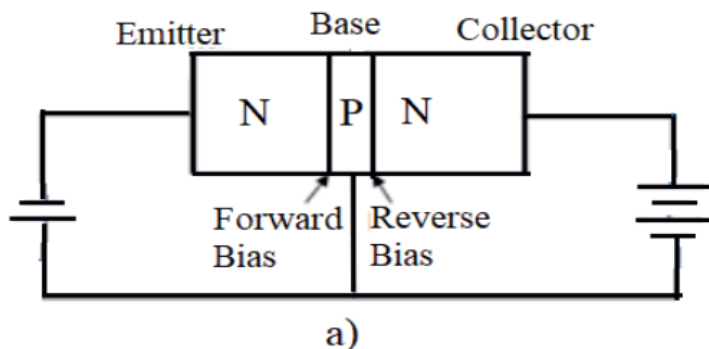


Schematic symbols for (a) NPN transistor (b) PNP transistor.

➤ Describe the Basic Transistor operation of NPN and PNP Transistor

A. NPN Transistor

- A transistor must be biased by external voltages so that the emitter, base, and collector regions interact properly.
- In a properly biased transistor, the emitter junction is forward biased and the collector junction is reverse biased.
- The emitter in NPN transistor is connected to the negative terminal while the base is connected to the positive terminal.
- Since the second P-N junction is required to be reverse biased for proper transistor operation, the collector must be connected to an opposite polarity voltage (positive), as shown in Figure



- **In the forward biased circuit:**
 - ✓ Electrons leave the negative terminal and enter the emitter forming emitter current.
 - ✓ Electrons pass through the emitter and cross the junction into the base region.
 - ✓ Since the base is lightly doped and thin, only a few electrons combine with holes forming base current.
 - ✓ Most electrons move toward the collector and form collector current.
 - ✓ The emitter current is the sum of base current and collector current.
 - ✓ $I_E = I_B + I_C$

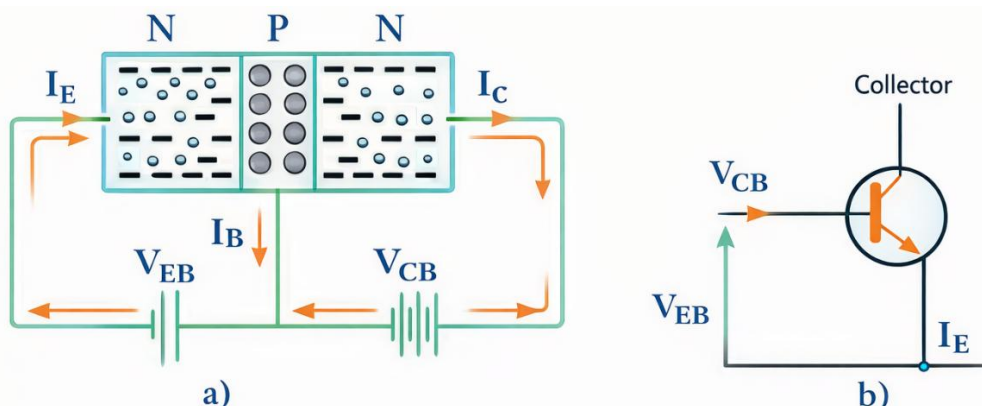
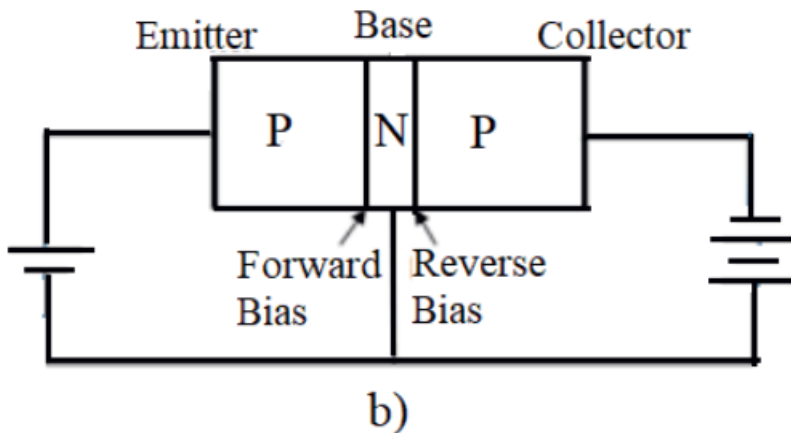


Figure 5.18 Electron current flow in NPN transistor (a) Block diagram NPN transistor (b) Schematic diagram of NPN transistor.

B. PNP Transistor

- The PNP transistor works in the same way as the NPN transistor but the majority carriers are holes.
- The bias batteries are reversed in PNP transistor.
- The positive terminal is connected to the emitter and the negative terminal to the base.
- The emitter-base junction is forward biased and collector-base junction is reverse biased.



- Since the base-collector junction is always reverse biased, a negative voltage is applied to the collector (V_{CB}), as shown in Figure 5.19.
- When the emitter-base junction is forward biased, the emitter current is created and the emitter pushes holes into the base region.
- When the holes move into the base, they combine with the electrons.
- The base is lightly doped and is comparatively thin. Hence only a few holes are combined with the electrons and the remaining are moved towards the collector.

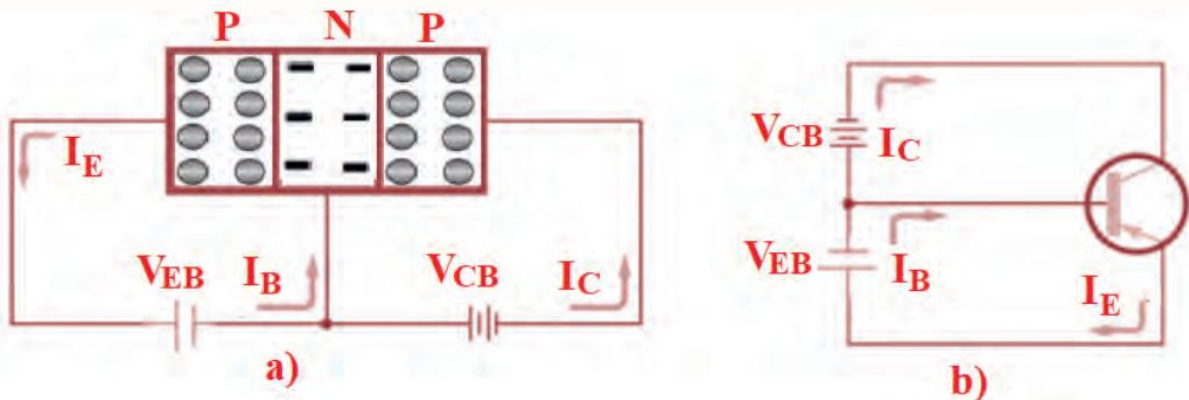


Figure 5.19 Electron current flow in PNP transistor. (a) Block diagram of a biased PNP transistor (b) Schematic diagram of a biased PNP transistor.

➤ **Describe the function of a transistor as an amplifier.**

- A transistor can amplify electronic signals.
- A weak signal applied in the input circuit appears in amplified form in the output circuit.
- Amplification is the property of a transistor to increase the strength of a weak signal.
- The ratio of collector current to base current is called the amplification factor or current gain (β).
- A small change in base current produces a large change in collector current.

➤ **Describe the difference between emitter, base and collector in terms of dopant concentration.**

- A transistor consists of three regions: emitter, base and collector.
- The emitter is heavily doped so that it can supply a large number of charge carriers.
- The base is lightly doped and very thin.
- The collector is moderately doped and slightly larger in size than emitter and base.

Sample UEE Question

1. Which one of the following statements differentiates emitter, collector and base of a transistor? **[UEE 2016]**
- A. The collector region is heavily doped as compared with emitter and base.
 - B. The emitter region is heavily doped as compared with base and collector.
 - C. The three parts; emitter, base and collector are equally doped.
 - D. The base region is heavily doped as compared with base and collector.

➤ **Calculate the gain (amplification) of a transistor.**

- The ratio of collector current to base current is called the amplification factor or current gain β .
- **Amplification** is the property of a transistor to raise the strength of a weak signal. It is calculated using the equation:

$$\beta = I_C / I_B$$

- The emitter current (I_E) is the sum of the collector current and the base current:

$$I_E = I_C + I_B$$

- Using these, the amplification factor can be calculated if I_C and I_B are known.
- Example: If $I_C = 10 \text{ mA}$ and $I_B = 0.2 \text{ mA}$, then
- $\beta = I_C / I_B = 10 \text{ mA} / 0.2 \text{ mA} = 50$
- This means the transistor amplifies the base current 50 times in the collector circuit.
- A transistor has a current gain of 250 and a base current $20 \mu\text{A}$. What is the collector current?

Solution: From the relation, $\beta = I_C / I_B$, $I_C = \beta \times I_B = 250 \times 20 \mu\text{A} = 5 \text{ mA}$

5.5 Integrated Circuits

➤ **Explain the importance of integrated circuits.**

- An integrated circuit (IC) (also referred to as a chip, or a microchip) is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material, usually silicon.
- Integrated circuits (ICs) combine a large number of electronic components, such as diode, transistors, resistors, and capacitors, on a single small chip.
- ICs reduce the size and weight of electronic devices.
- They increase reliability because components are fabricated together and connections are fixed.
- ICs reduce cost of manufacturing circuits compared to discrete components.
- They consume less power than circuits made of separate components.
- ICs are widely used in computers, calculators, mobile phones, and other electronic devices.

➤ **Identify the major components of an integrated circuit**

- **Transistors** – act as amplifiers and switches.
- **Resistors** – control current flow and voltage levels.
- **Capacitors** – store and release electrical energy, filter signals.
- **Diodes** – allow current to flow in one direction and provide rectification.
- **Interconnections (metallic paths)** – connect the components within the IC.
- **Substrate (semiconductor base)** – usually silicon, on which all components are fabricated.

➤ **Identify advantages and disadvantages of integrated circuits.**

Advantages

- Reduce the size and weight of electronic devices.
- Increase reliability because components are fabricated together.
- Reduce manufacturing cost compared to using discrete components.
- Consume less power than separate-component circuits.
- Allow high-speed operation in electronic devices.

Disadvantages

- Difficult to repair if one component fails.
- Heat dissipation can be a problem in high-power ICs.
- Limited current-carrying capacity compared to discrete components.
- Special equipment is required for fabrication.

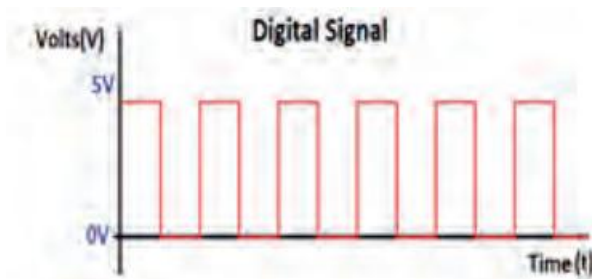
5.6 Logic gates and logic circuits

- In electronics and telecommunications, "signal" refers to any time-varying voltage, current, or electromagnetic wave that carries information.
- Two main types of signals encountered in practice are analog and digital.

➤ Identify digital and analog signals.

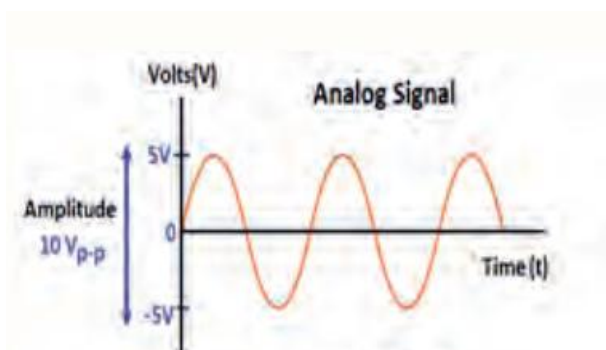
A. Digital Signals

- Represents data as a sequence of discrete values.
- At any time, it can take only one of a finite number of values.
- In most digital circuits, the digital signal can have two possible valid values; this is called a binary signal or logic signal.
- Represented by two voltage bands: near ground (0 V) or near supply voltage.
- The low voltage level is written as 0, while the high voltage level is written as 1
- They are used in digital circuits and computers.
- Computers convert information (pictures, music, text, etc.) into patterns of 0s and 1s.



B. Analog Signals

- An analog signal is any continuous signal representing some time-varying quantity.
- The voltage signals which vary continuously with time are called continuous or analog voltage signals.
- They are used in analog devices and circuits.
- Example: sound waves, temperature variations, voltage from a microphone.



➤ Explain basics of logic gates.

- An integrated circuit is a collection of logic gates. The logic gates are building blocks of digital electronics.
- Digital electronics deals with digital signals and devices that use or produce them.
- Logic gates are the simplest digital circuits. They change input voltage levels into output voltage levels according to a logical relationship.
- Each logic gate may have one or more inputs but only one output.
- Logical relationships followed by logic gates are expressed as Boolean expressions.
- Basic logic gates: AND, OR, NOT
- Universal logic gates: NAND, NOR (any logic gate can be built using these).
- Each gate performs a different logical operation based on its Boolean expression.
- Logic gates are made from microscopic transistors connected on a silicon chip.
- Boolean expressions describe the logical operations of logic gates.

➔ **OR operation uses +**

$$y = A + B \rightarrow \text{"A OR B"}$$

➔ **AND operation uses .**

$$y = A \cdot B \rightarrow \text{"A AND B"}$$

➔ **NOT operation uses bar**

$$y = \bar{A} \rightarrow \text{"NOT A"}$$

➤ Identify, explain, draw symbols, analog switch circuits, and functions of basic logic gates

2. AND Gate

- Has two or more inputs and one output.
- Output is 1 only if all inputs are 1; otherwise, output is 0.
- Boolean expression: $Y = A \cdot B$
- Application: Can be used to light a display only if multiple conditions are met.
- Lamp "ON" is equal to 1 and lamp "OFF" is equal to 0.

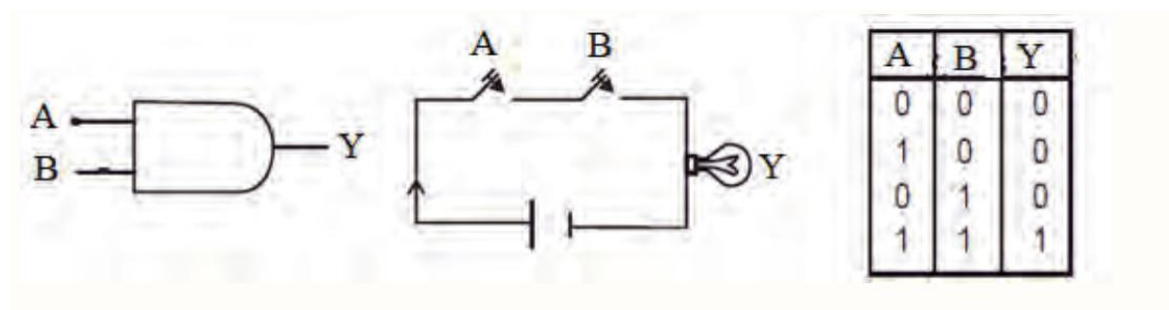


Figure 5.26 The AND gate symbol, switch circuit and truth table.

3. OR Gate

- Has two or more inputs and one output.
- Output is 1 if any one of the inputs is 1.
- Boolean expression: $Y = A + B$
- Application: Can be used for switching lights from two locations.

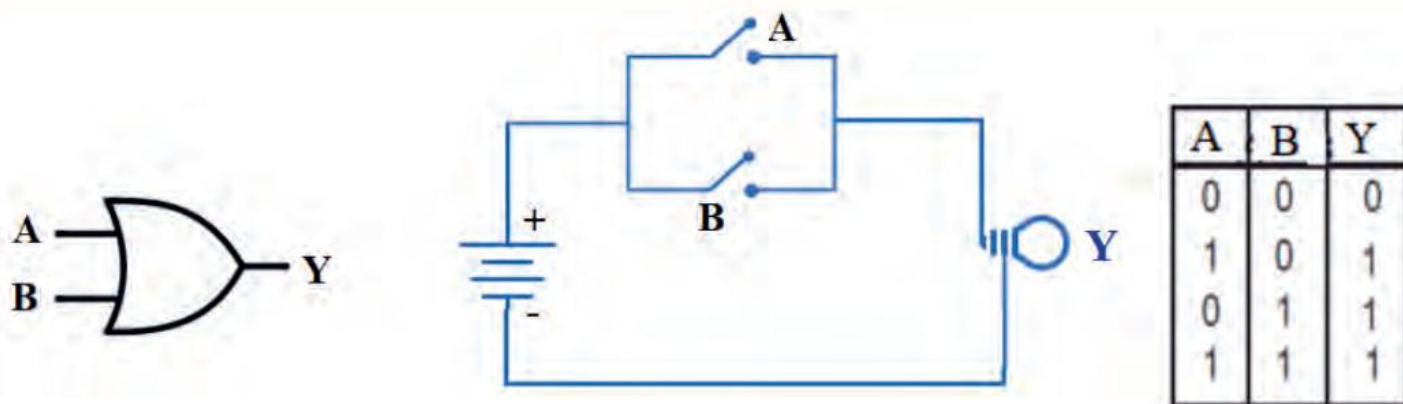


Figure 5.25 The OR gate symbol, switch circuit and truth table.

4. NOT Gate

- Has one input and one output.
- Output is the inverse of the input.
- Boolean expression: $Y = \bar{A}$
- Also called an inverter.
- Application: Can control devices automatically by inverting signals, e.g., turning a water pipe ON when the soil is dry.

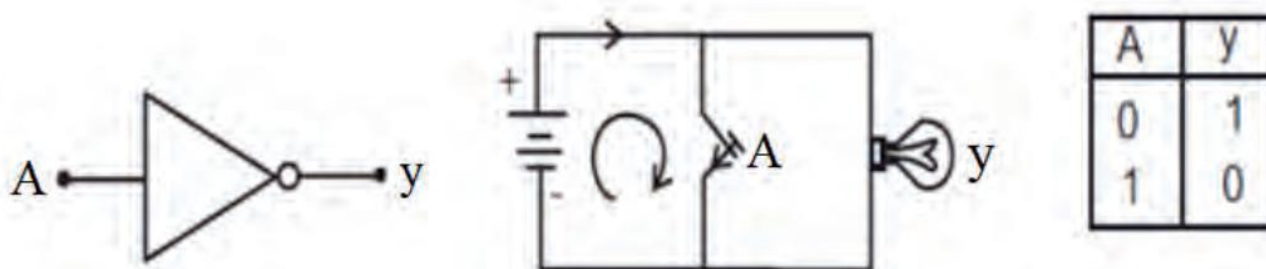


Figure 5.27 The NOT gate symbol, switch circuit and truth table.

5. NAND Gate

- Combination of AND and NOT gates.
- Output is 1 unless all inputs are 1.
- Boolean expression: $Y = \overline{A \cdot B}$

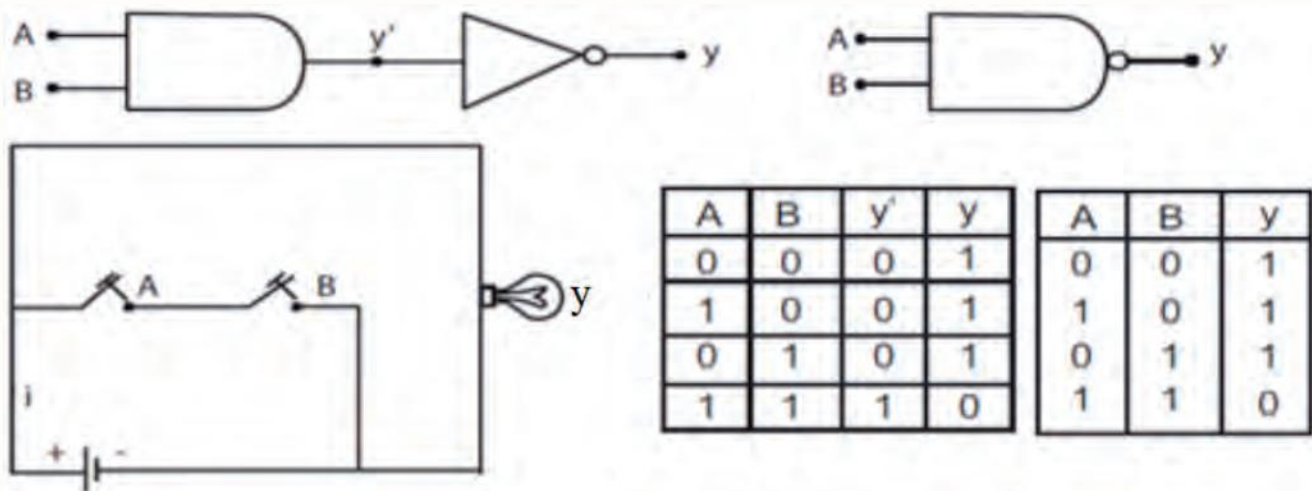


Figure 5.30 The NAND gate symbol, switch circuit and truth table.

6. NOR Gate

- Combination of OR and NOT gates.
- Output is 1 only when all inputs are 0.
- Boolean expression: $Y = \overline{A + B}$

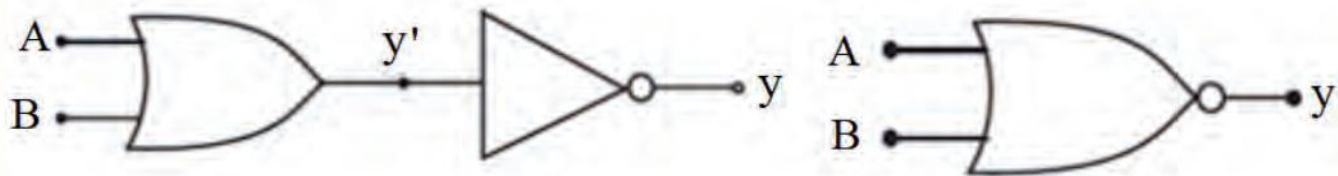


Figure 5.28 The NOR gate symbol.

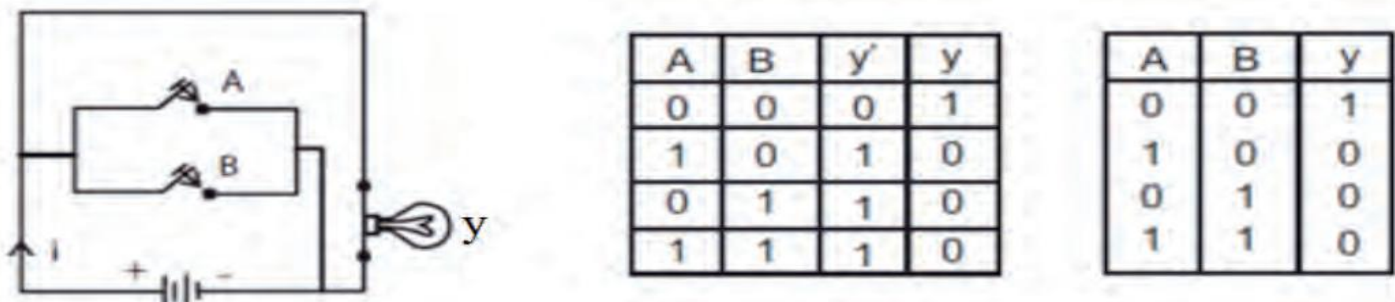


Figure 5.29 The NOR gate switch circuit and truth table.

➤ **Develop truth tables for the basic logic gates.**

1. Figure 5.31 shows a logic circuit and its incomplete truth table. Complete the truth table.

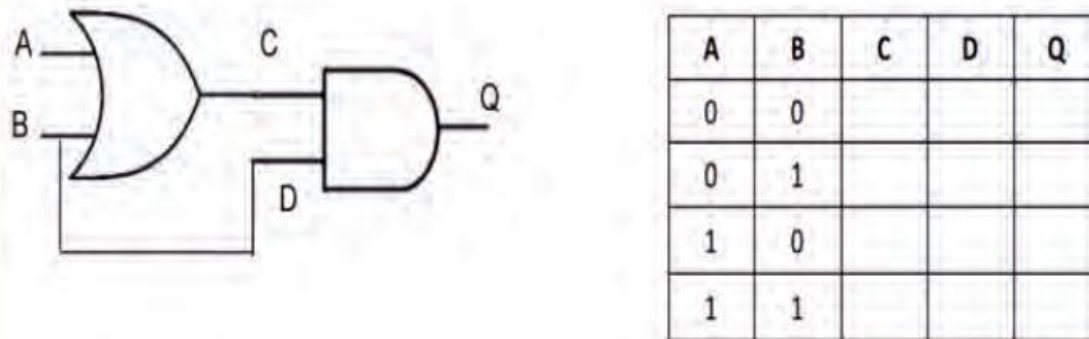


Figure 5.31 A logic circuit and its incomplete truth table

Answer:

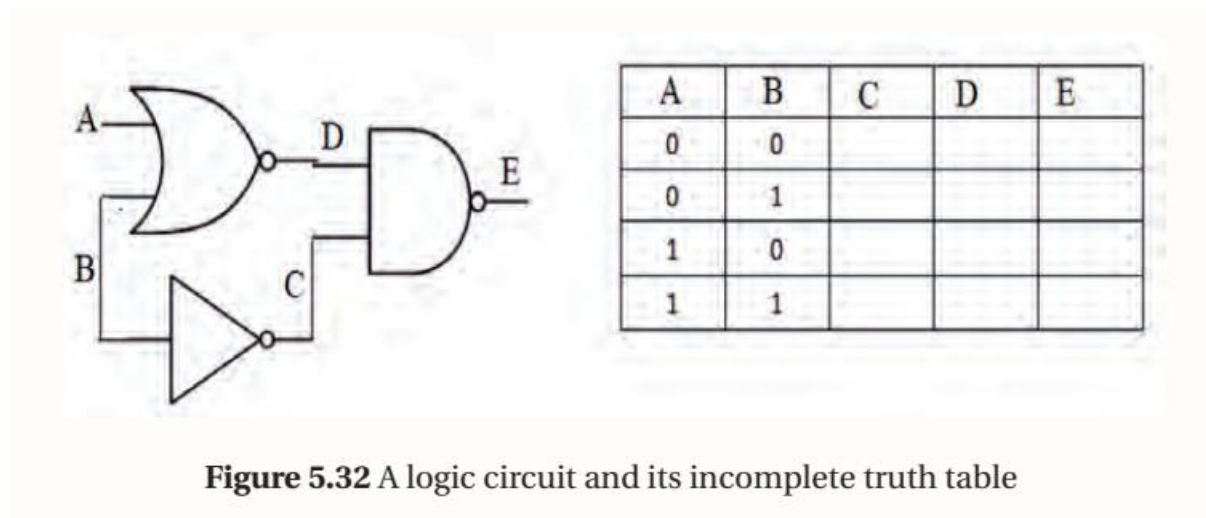
$$C = A + B$$

$$D = B$$

$$Q = C \cdot D$$

A	B	C	D	Q
0	0	0	0	0
0	1	1	1	1
1	0	1	0	0
1	1	1	1	1

2. Figure 5.32 shows a logic circuit and its incomplete truth table. Complete the truth table.



Answer:

$$C = \bar{B}$$

$$D = \overline{A + B}$$

$$E = \overline{D \cdot C}$$

A	B	C	D	E
0	0	1	1	0
0	1	0	0	1
1	0	1	0	1
1	1	0	0	1

3. The truth table of a logic circuit is given in Figure 5.33 (a) and (b). Name the logic circuit.

A	B	C
0	0	1
0	1	1
1	1	1
1	1	0

a)

A	B	C
0	0	1
0	1	1
1	0	1
1	1	0

b)

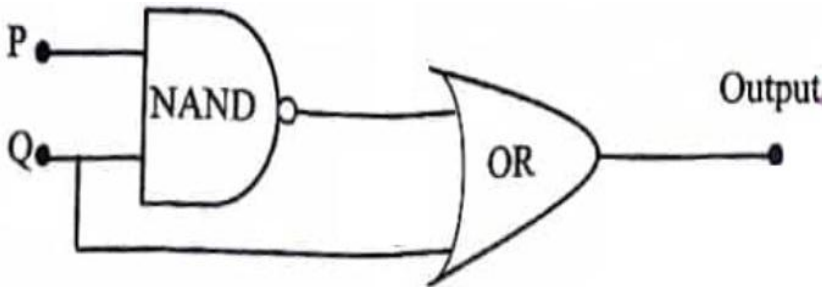
Figure 5.33 Truth tables of a logic circuit

Answer:

- A. It doesn't represent any logical gates.
- B. NAND

Sample UEE Questions:

1. A combination of logic Gate is constructed from an NAND Gate and an OR gate, as shown in the diagram below.



The Truth Table for the logic circuit shown above is [UEE 2016]

A.

P	Q	Output
0	0	0
0	1	0
1	0	0
1	1	0

B.

P	Q	Output
0	0	0
0	1	1
1	0	1
1	1	0

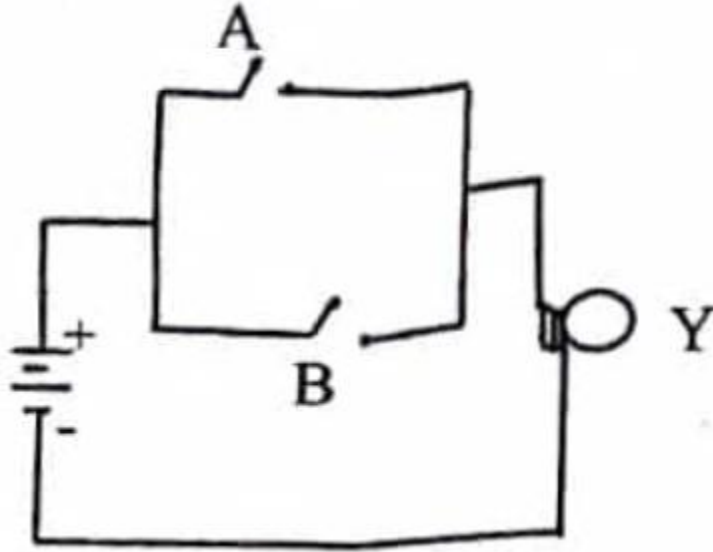
C.

P	Q	Output
0	0	1
0	1	0
1	0	0
1	1	1

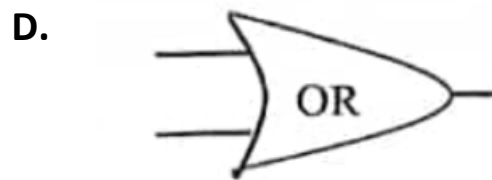
D.

P	Q	Output
0	0	1
0	1	1
1	0	1
1	1	1

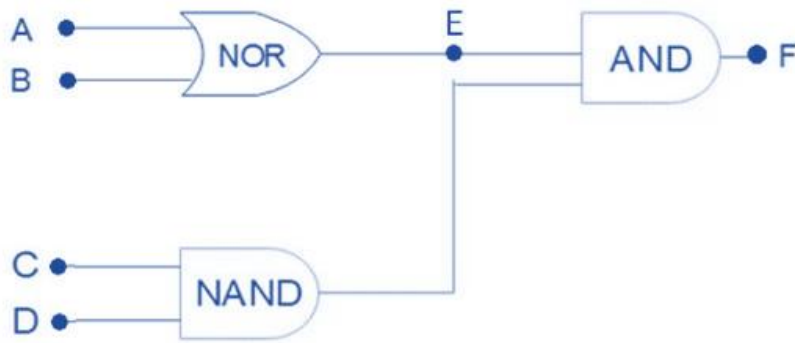
2. The following figure shows a switch of circuit consisting of a battery source, two switches represented by letter A and B, and a light bulb Y



Which one of the following logic gate can be represented by equivalent Switch circuit? [UEE 2016]



3. The following diagram shows the logic gates



If the inputs at points A, B, C are all 0 and at point D are 1, what will be the outputs at points E and F respectively? **UEE**

- A. 1,1 B. 0,1 C. 1,0 D. 0,0

5.7 Application of electronics

➤ List some applications of Electronics

1. Aerospace Industry

- Electronics is widely used in aerospace such as space shuttle, satellite power supplies and aircraft power management.
- Instruments are used to measure temperature, pressure, elevation and other physical factors.

2. Medical

- Electronics and computers help doctors examine patients.
- Medical machines such as X-ray, MRI and CT scan are built using electronics.
- Recent innovations include robotic check-ups, needle-free diabetes care and electronic aspirin.

3. Automobile

- Electronics are used in road vehicles such as carputers, telematics and in-car entertainment systems.
- Electronics control engine, transmission, chassis, safety, driver assistance and passenger comfort systems.

4. Agriculture

- Electronic devices are used to monitor crops.
- Sensors measure moisture level, nutrition level and salinity of soil.
- These systems help improve crop quality and growth.

5. Communication

- Electronic devices and systems are used for processing, storage, display, analysis and transfer of information.

6. Residential

- Electronic equipment such as air conditioner, cooking appliances, dryer and personal computers make life easier.
- Mobile phones are commonly used in daily life.

7. Military

- Electronics are widely used in military equipment.
- Drones and unmanned aerial vehicles are used for monitoring and attack.
- Night vision devices, people sniffer, infrared detector and night vision cameras are examples of military electronics.

Thank You!!!