CHAPTER 2: APPLY BASIC ELECTRONICS

2.1 Introduction

This unit specifies the competencies required to demonstrate basic skills of electronics. It involves identification of electric circuits, electronic components, understand semi-conductor theory, identify and classify memories, apply number systems and identify emerging trends in electronics.

2.2 Performance Standard

o Identified electrical components, quantities and their units of measurement (EMF in volts, Current in Amperes, Power in Watts, Energy in Joules, Resistance in Ohms)
o Constructed a simple circuit for direct current and alternate current
o Identified types of transistors (PNP and NPN) and their operations (forward biasing and reverse biasing)
o Categorized the memories according to their levels, types and hierarchy such as – semi-conductor, magnetic, optical
o Identified the number systems, binary codes and their operations

2.3 Learning Outcome

2.3.1 List of the Learning Outcomes

These are the key learning outcomes, which make up workplace function:
o Identify electric circuits
o Identify Electronic components
o Understand Semi-conductor theory
o Identify and classify memory
o Apply Number Systems
o Emerging trends in Electronics

2.3.2 Learning Outcome 1: Identify electric circuits

2.3.2.1 Learning Activities
The following are the performance criteria:
o Electrical circuits are identified
o Electrical quantities and their units are identified
o Types of electrical circuits are identified

Trainees to demonstrate knowledge in relation to:
o Definition of electrical circuit
o Basic electrical quantities and their units: EMF in volts, Current in Amperes, Power in Watts, Energy in Joules, Resistance in Ohms
o Types of electrical circuits: Simple AC circuits, Simple DC circuits

2.3.2.2 Information Sheet

An electric circuit is a path in which electrons from a voltage or current source flow. The point where those electrons enter an electrical circuit is called the "source" of electrons. The point where the electrons leave an electrical circuit is called the "return" or "earth ground". The exit point is called the "return" because electrons always end up at the source when they complete the path of an electrical circuit. The part of an electrical circuit that is between the electrons' starting point and the point where they return to the source is called an electrical circuit's "load". A load of an electrical circuit may be as simple as those that power home appliances like refrigerators, televisions, or lamps or more complicated, such as the load on the output of a hydroelectric power generating station. A simple, well-designed circuit, has a cell providing current along a path (wire), to a load (resistor) and back to the other end of the cell as shown in diagram.
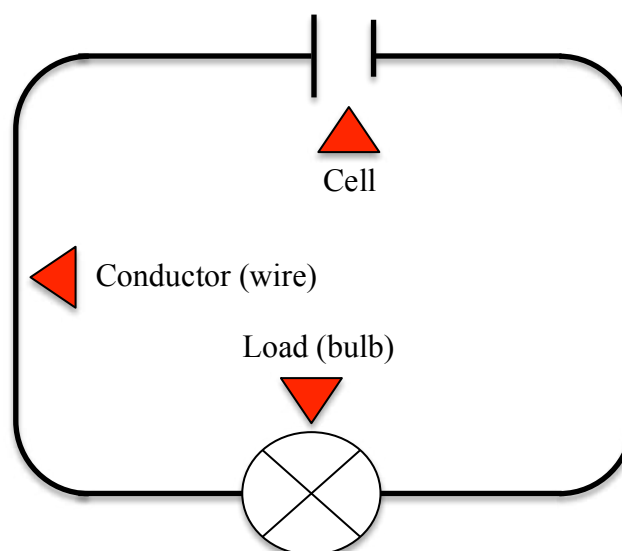

Figure 1: Electrical circuit depicting - load, conductor, cell

An electrical circuit is a path or line through which an electrical current flows. The path may be closed (joined at both ends), making it a loop. A closed circuit makes electrical current flow possible. It may also be an open circuit where the electron flow is cut short because the path is broken. An open circuit does not allow electrical current to flow.

Below is a basic set of symbols that you may find on circuit diagrams:
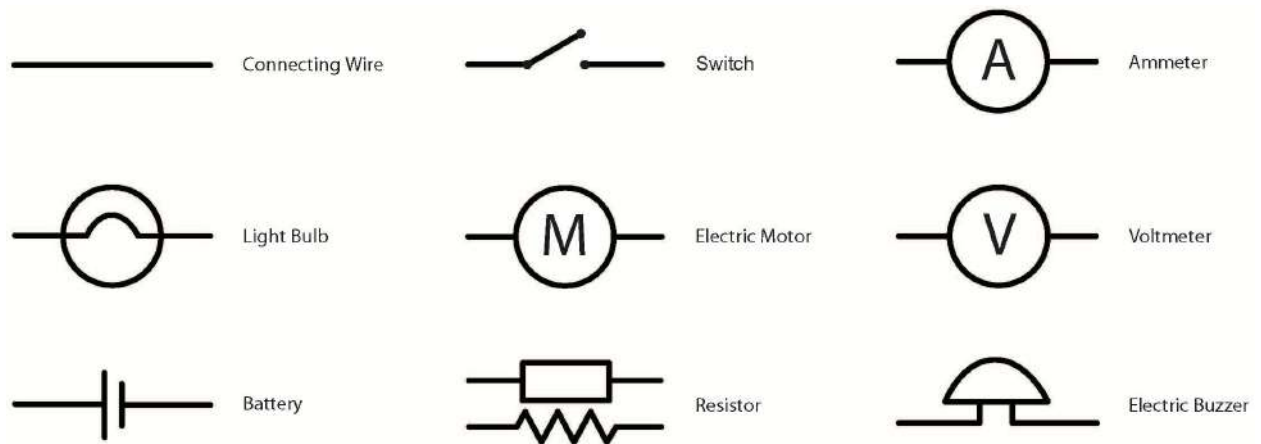
Source: http://victorysportstraining.com
Figure 2: Symbols of circuit diagrams

It is very important to know the basic parts of a simple circuit and the symbols that relate to them. A simple circuit has conductors, a switch, a load and a power source.

Here are the functions of each part:

Conductors:
These are usually copper wires with no insulation. They make the path through which the electricity flows. One piece of the wire connects the current from the power source (cell) to the load. The other piece connects the load back to the power source.

Switch:
The switch is simply a small gap in the conductor where you can close or open the circuit. When the switch is closed, the circuit is closed and electricity flows.
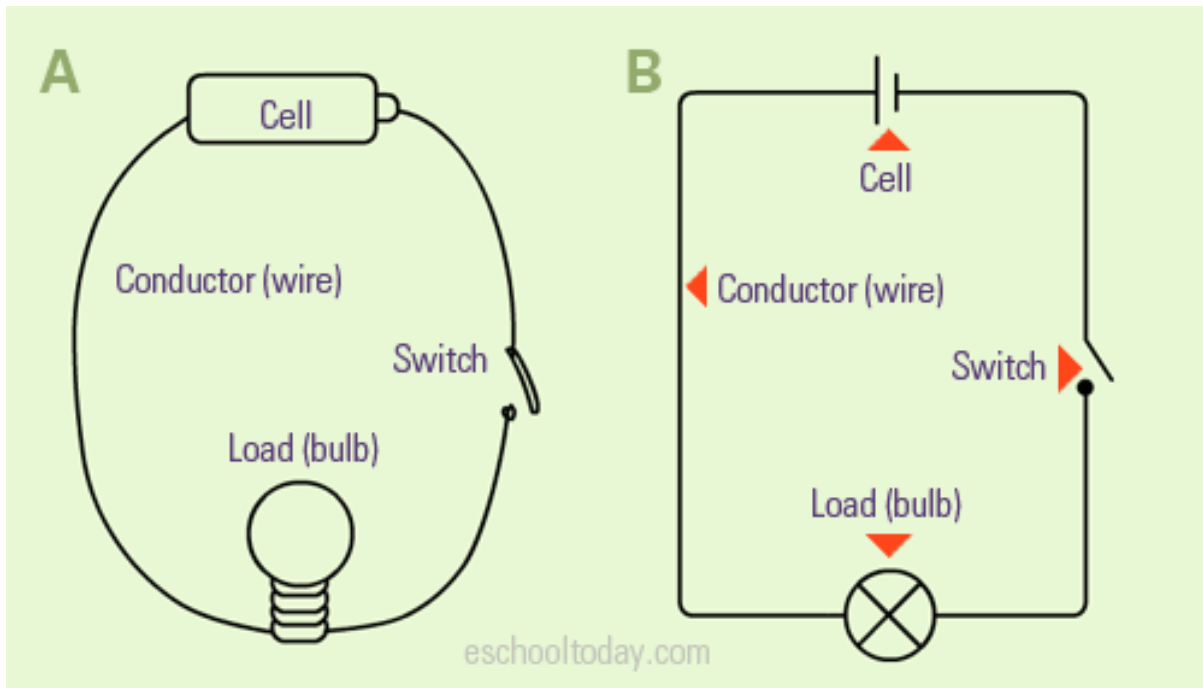
The Load:
The load is a small light bulb or buzzer that lights when the circuit is turned on. The load is also known as a resistor.

Cell:
The power source is a cell. (Note that more than one cell put together is known as a battery).

The diagram below shows how a basic circuit looks like.

Source: eschooltoday.com
Figure 3: Basic circuit

It is important to draw circuits with clean straight lines, as shown in diagram B. Avoid realistic sketches. It is important to know that a circuit can have more than the basic components in the diagram. It can have two or more batteries or two or more bulbs.

**A circuit or wiring diagram is a visual display of an electrical circuit.**

Electrical and electronic circuits can be complicated. Making a drawing of the connections to all the component parts in the circuit's load makes it easier to understand how circuit components are connected. Drawings for electronic circuits are called "**circuit diagrams**". Drawings for electrical circuits are called "**wiring diagrams**". A schematic is a diagram of an electrical circuit. Schematics are graphical representations of the essential connections in a circuit, but they are not life-like depictions of a circuit. Schematics use symbols to represent components in the circuit. Conventions are used in a schematic to represent the way electricity flows. The common convention we use is from the positive to the negative terminal. The realistic way electricity flows is from the negative to the positive terminal.

Circuit diagrams utilise special symbols recognised by everyone who uses the drawings. The symbols on the drawings show how components like resistors, capacitors, insulators, motors, outlet boxes, lights, switches, and other electrical and electronic components are connected together. The diagrams are a big help when workers try to find out why a circuit does not work correctly.

flow to the other end of the cell. When this happens the high voltage causes the wires to heat up and catch fire.
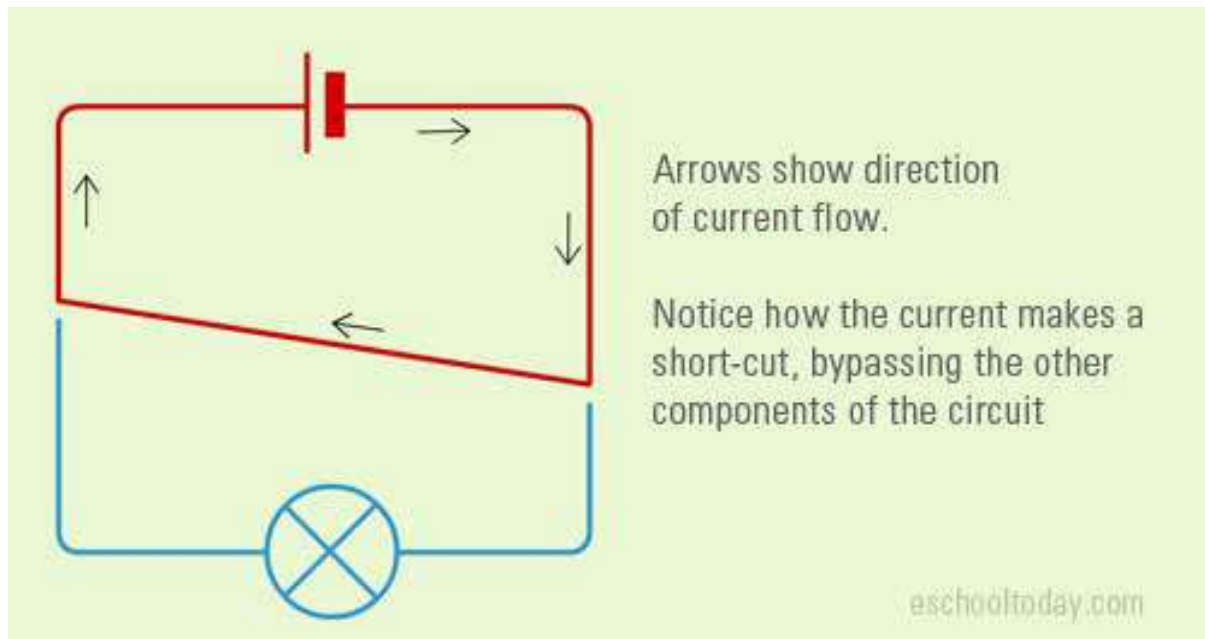
Source: eschooltoday.com
Figure 6: Short circuit

A fuse is simply a strip of alloy wire (made of bismuth and tin), which is connected to the circuit. The fuse is usually designed to take specific volumes of electricity (voltage). For example is a 3amp fuse is fixed into a circuit it cannot take any more than 3amps of electricity. If for any reason, there is a surge or increase in the voltage, the fuse will melt immediately and break. This will stop the flow of high voltage and prevent any potential damage to the circuit or device.

Electromotive force, also called **EMF** (and measured in volts), refers to voltage generated by a battery or by the magnetic force according to **Faraday's Law**, which states that a time varying magnetic field will induce an electric current.

Ampere or Amp (symbol: A) is the unit of electrical current. The Ampere unit is named after Andre-Marie Ampere from France. One Ampere is defined as the current that flows with electric charge of one Coulomb per second. 1 A = 1 C/s

The electric Power, P is equal to the energy consumption E divided by the consumption time t:

$$P = \frac{E}{t}$$

P is the electric power in Watt (W).
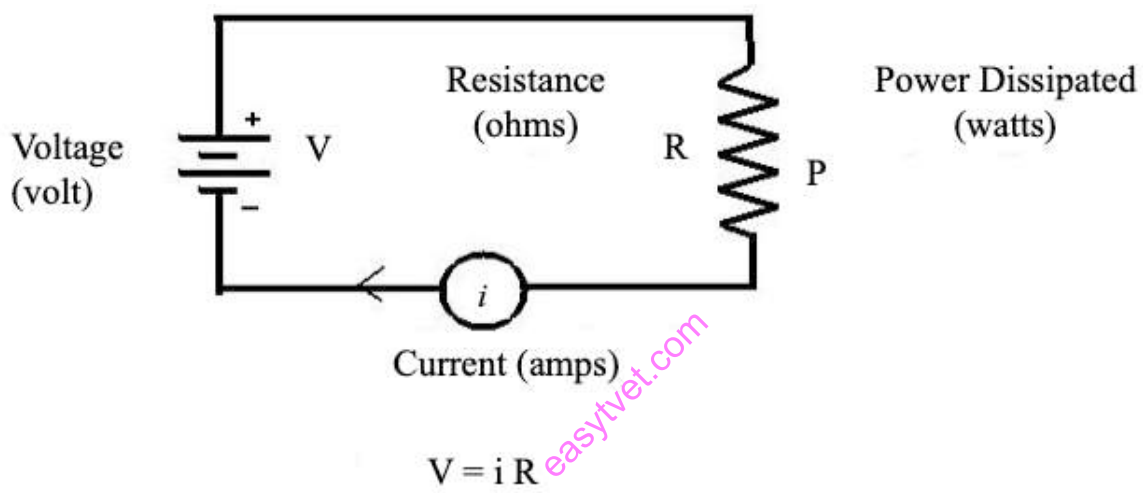E is the energy consumption in Joule (J).
t is the time in seconds (s).

Joule, unit of work or energy in the International System of Units (SI), is equal to the work done by a force of one newton acting through one metre.

Resistance is a measure of the opposition to current flow in an electrical circuit. Resistance is measured in Ohms, symbolized by the Greek letter Omega **(Ω).**

Ohm's Law is V = IR, where V = voltage, I = current, and R = resistance.

Ohm's Law allows you to determine characteristics of a circuit, such as how much current is flowing through it, if you know the voltage of the battery in the circuit and how much resistance is in the circuit.

Source: https://www.online-sciences.com
Figure 7: Ohm's Law

Watch: Ohms Law, Resistance, and its applications:
https://www.toppr.com/guides/physics/electricity/ohms-law-and-resistance/
https://learn.sparkfun.com/tutorials/voltage-current-resistance-and-ohms-law/all

In a **Direct Current** (DC) the electrons flow in one direction. Batteries create a direct current because the electrons always flow from the 'negative' side to the 'positive' side. A DC Circuit uses steady current components like resistors and resistor combinations; transient components like inductors and capacitors; indicating meters like moving coil voltmeters and ammeters; power supply battery sources, and so on. For analyzing these circuits, different tools like ohms law, voltage and current laws like KCL, KVL, and network theorems like Thevinens, Nortons, Mesh analysis, etc. are used.

In a simple DC circuit, a resistive load as a bulb is connected between the positive and negative terminals of the battery. The battery supplies the required power to the bulb and allows a user to place a switch to turn on or off according to the requirement.

Resistive loads represent the lighting loads that are connected in various configurations to analyze the DC circuits. The way of connecting loads certainly changes the circuit characteristics.
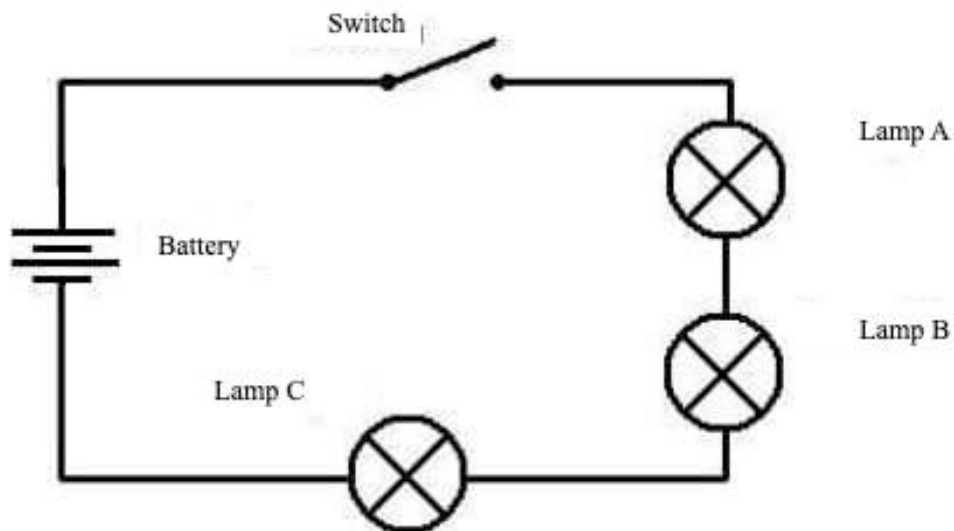
Figure 8: DC circuit

Alternating Current (AC) pushes the electrons back and forth, changing the direction of the flow several times per second. Unlike DC current, AC voltage or current changes its direction periodically as it increases from zero to maximum, and decreases back to zero, then negatively continue to maximum, and then again back to zero.
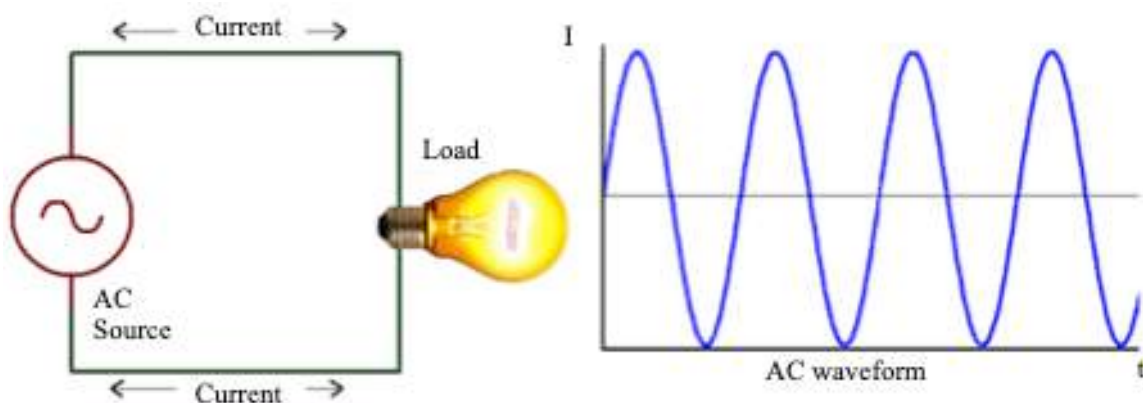
Figure 9: AC Circuit

Watch: Introduction to circuits and Ohm's Law:
https://www.khanacademy.org/science/ap-physics-1/ap-circuits-topic/current-ap/v/circuits-part-1

Watch: Understand electric circuits:
https://youtu.be/VnnpLaKsqGU
https://youtu.be/8RJ6Kdk8KDo

Read: Fundamental relationship between voltage, current and resistance in an electrical or electronic circuit is called Ohm's Law: https://www.electronics-tutorials.ws/dccircuits/dcp_1.html

Watch: Electrical measuring instruments:
https://www.youtube.com/watch?v=T_gCVuEPYPE
https://www.youtube.com/watch?v=cxIrBT-UJwc
https://www.youtube.com/watch?v=BTd4x1UFMLY

Table 3: Formula for electrical circuits

Quantity	Formula	Notations
Electric current	$I = \dfrac{Q}{t}$	• I is the current • Q is the charge flowing • t is the time period
Resistance	$R = \rho \cdot \dfrac{L}{A}$	• R is the resistance • ρ is the resistive value of the wire • L is the length of the wire • A is the cross-sectional area
Voltage	$\Delta V = I \cdot R$	• ΔV is the electric potential difference
Power	$P = \dfrac{\Delta E}{t}$	• P is the power • ΔE is the energy gain or loss • t is the time period
Series circuit	$R_{eq} = R_1 + R_2 + R_3 + \dots$	• R_{eq} is the total resistance of the resistors places in series • $R_1, R_2 \dots$ are the resistors places in series
Parallel circuit	$R_{eq} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \cdots$	• R_{eq} is the total resistance of the resistors places in parallel • $R_1, R_2 \dots$ are the resistors places in parallel

2.3.2.3 Self-Assessment

i.   What is electric circuit?
ii.   What is Ohm?
iii.   What is the difference between Ampere and Ohm?
iv.   Current is:
   A. The flow of charged particles through a conducting medium
   B. The flow of a conductor through charged particles
   C. The random movement of electrons from atom to atom

    D. Only present when there is no voltage

    E. Faster than the speed of light

v.   The two types of current are:

    A. Direct and Alternating

    B. Indirect and Alternating

    C. Direct and Attenuating

    D. None of the above

vi.   Prepare a circuit using 2 bulbs and 2 AA batteries.

vii.   Identify different equipment in the workshop or classroom and categorize if they are AC or DC devices.

viii.   True or False: An electric circuit is a closed loop or pathway that allows electric charges to flow.

ix.   If additional resistor is connected in an existing parallel circuit, the total resistance

    A. Remains the same

    B. Decreases by the value of the added resistor

    C. Increases by the value of the added resistor

    D. Decreases (Answer)

x.   Calculate resistance of an electrical circuit with 10 Volts and current of 5mA.

xi.   A 4 Ω and a 6 Ω resistor are connected in series, the current is measured to be 4 A.

    A. Draw a diagram of this circuit.

    B. What is the voltage drop across the 4 Ω resistor?

    C. What is the voltage drop across the 6 Ω resistor?

    D. What is the total voltage of the power source?

    E. What is the total power dissipated by the circuit?

xii.   In the circuit shown, what is the current through the 2-ohm resistor?

Source: https://www.nutsvolts.com
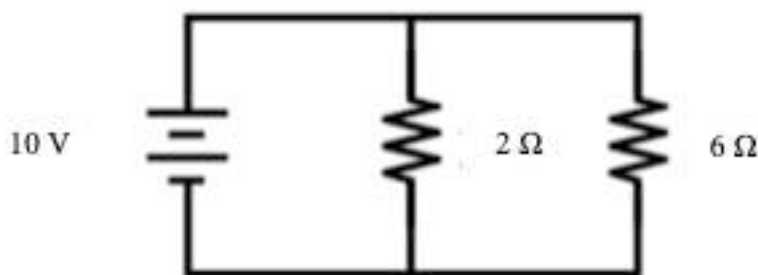
xiii. Which Power Condition Occurs When The Voltage Level Drops Below 120 Volts And Stays Below For An Extended Period Of Time?

2.3.2.4 Tools, Equipment, Supplies and Materials

Bulb, battery, soldering wire, soldering iron, printed circuit board, ammeter, volt meter, connecting wires, wire stripper, pliers, wire cutter, screw driver, driller, clamps, vise

2.3.2.5 References

- https://www.eolss.net/Sample-Chapters/C05/E6-08-29.pdf
- https://study.com/academy/lesson/what-is-electric-current-definition-unit-types.html

- https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_University_Physics_(OpenStax)/Map%3A_University_Physics_II_-_Thermodynamics%2C_Electricity%2C_and_Magnetism_(OpenStax)/15%3A_Alternating-Current_Circuits/15.2%3A_Simple_AC_Circuits
- https://www.rapidtables.com/electric/electric_power.html
- https://eschooltoday.com/science/electricity
- Digital Electronics authored by Roger L. Tokheim published by McGraw-Hill Education – Europe
- Basic Digital Electronics: Explains digital systems functions and how digital circuits are used to build them, authored by Alvis J. Evans, published by Master Publishing (1996)

2.3.3 Learning Outcome 2: Identify electronic components

2.3.3.1 Learning Activities
The following are the performance criteria:
o Identification of electrical components is done as per the standards procedures
o Characteristic of electronic components are identified
o Applications of electronic components are identified
o Characteristics of integrated circuit are identified

Trainees to demonstrate knowledge in relation to:
o Identification of electronic components: Resistor, Capacitor, Diode, Inductor
o Characteristic of electronic components
o Application of electronic components

2.3.3.2 Information Sheet

Resistor: The resistor is an inevitable part of a circuit. It is meant for reducing the current and voltage in the circuit parts. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat, may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors as discrete components can be composed of various compounds and forms. Resistors are also implemented within integrated circuits.

Resistors are identified using the standard colour code chart.
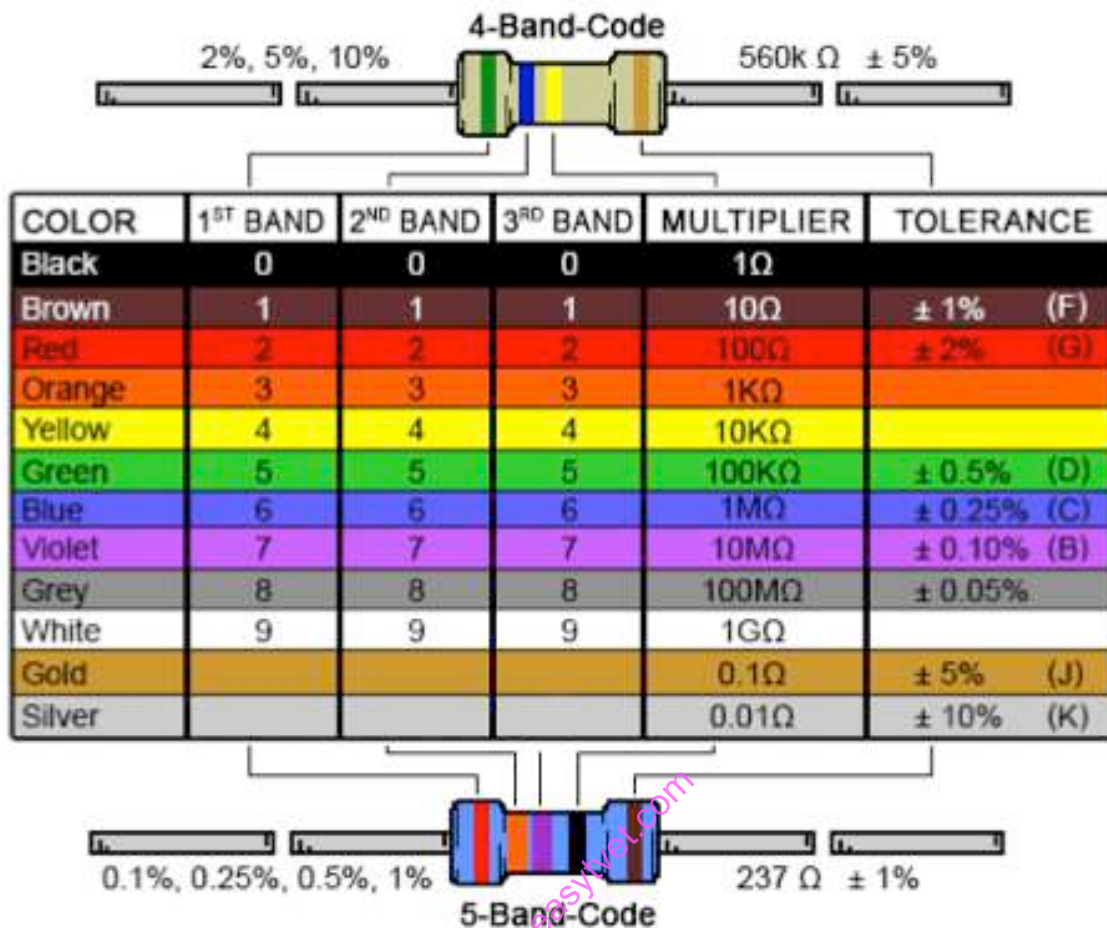
Source: http://nye6b4.holzdingens.de

Figure 10: Resistors standard colour code chart

A capacitor is a body that can store an electrical charge. It consists of two conducting plates facing each other and separated by an insulating material. This insulating material is also called dielectric material. When a charge is stored in one plate, an equal and opposite charge is inducted on the other plate and thus a potential difference is set up between the plates.

The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit. The capacitor was originally known as a condenser or condensator.

The unit of measurement for capacitance is Farad but this unit is much too large for practical work. It is usually measured in microfarads (uF) or picofarads (pF). The formula of calculating capacitance is

$C = [(0.224\ KA)(n-1)]/d$ where

C = capacitance in pF

K = dielectric constant of material between plates
A = area of one side of the plates square inches
d = separation of plate in inches
n = number of plates

The potential difference V developed when a charge Q is stored depends directly on the value of Q and inversely with the capacitance C of the cap.
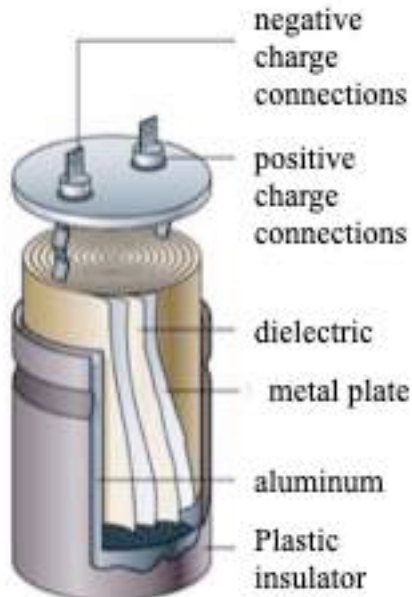
$$V = Q/C$$

They are used in timing circuits as it takes time for a cap. to be charged up. They are used to smooth varying DC power supplies by acting as a reservoir of charge. They are also used in filter circuits because they easily pass AC signals but they block DC signals.

Source: https://honestversion.com
Figure 11: Capacitors

Figure 12: Parts of a capacitor

There are many different types of cap. that are used for different types of applications. They are electrolytic cap, ceramic cap., tantalum cap., polyester cap., polystyrene cap. and safety cap.

Read: Introduction to capacitor: https://www.electronics-project-design.com/Capacitors.html

Watch: Introduction to capacitor: https://youtu.be/4Hg7SLhetXM

Watch: How to prepare a capacitor: https://youtu.be/tktrzx3r_WY

Diode in small signal application of which the current requirement is less than 100mA; 1N4148 is a typical choice. It has a forward voltage drop of 0.7V and is made from Silicon type.
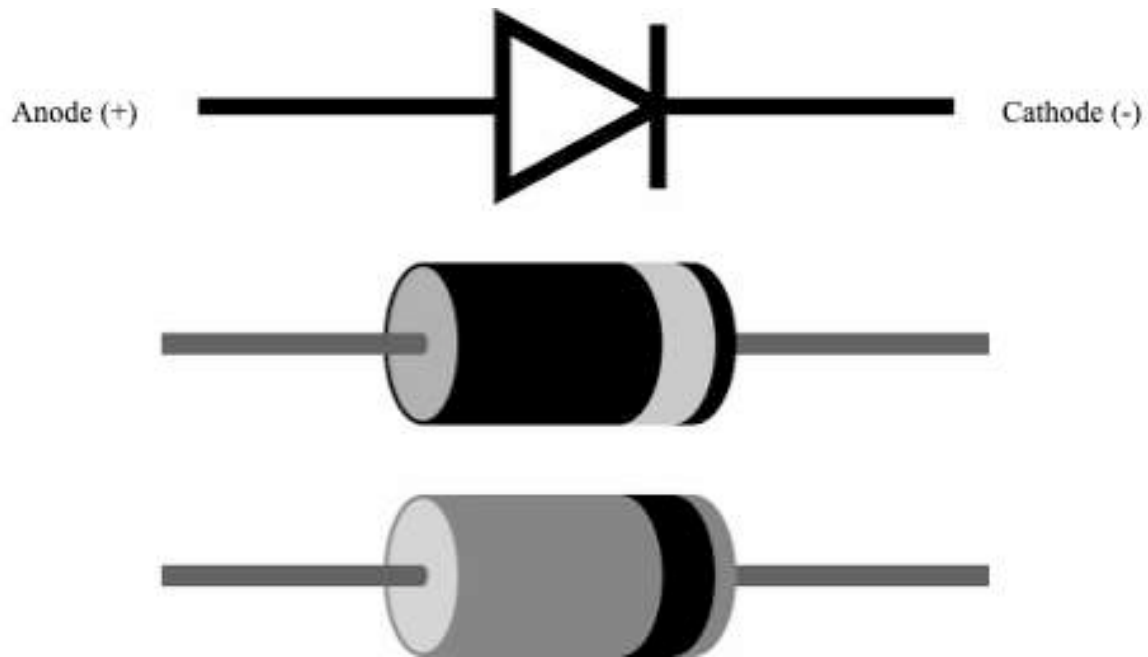
Figure 13: Diode

An inductor: Like capacitors, inductors also store energy in one part of AC cycle and return it during the next part of the cycle.

Figure 14: Inductor

Read: Electronic components:
https://www.electroschematics.com/8247/electronic-components-an-easy-to-use-guide/

Passive electronic components are those that do not have gain or directionality. They are also called Electrical elements or electrical components. Examples include resistors, capacitors, diodes, and inductors.

Active components are those that have gain or directionality. Examples include transistors,

integrated circuits or ICs, logic gates.
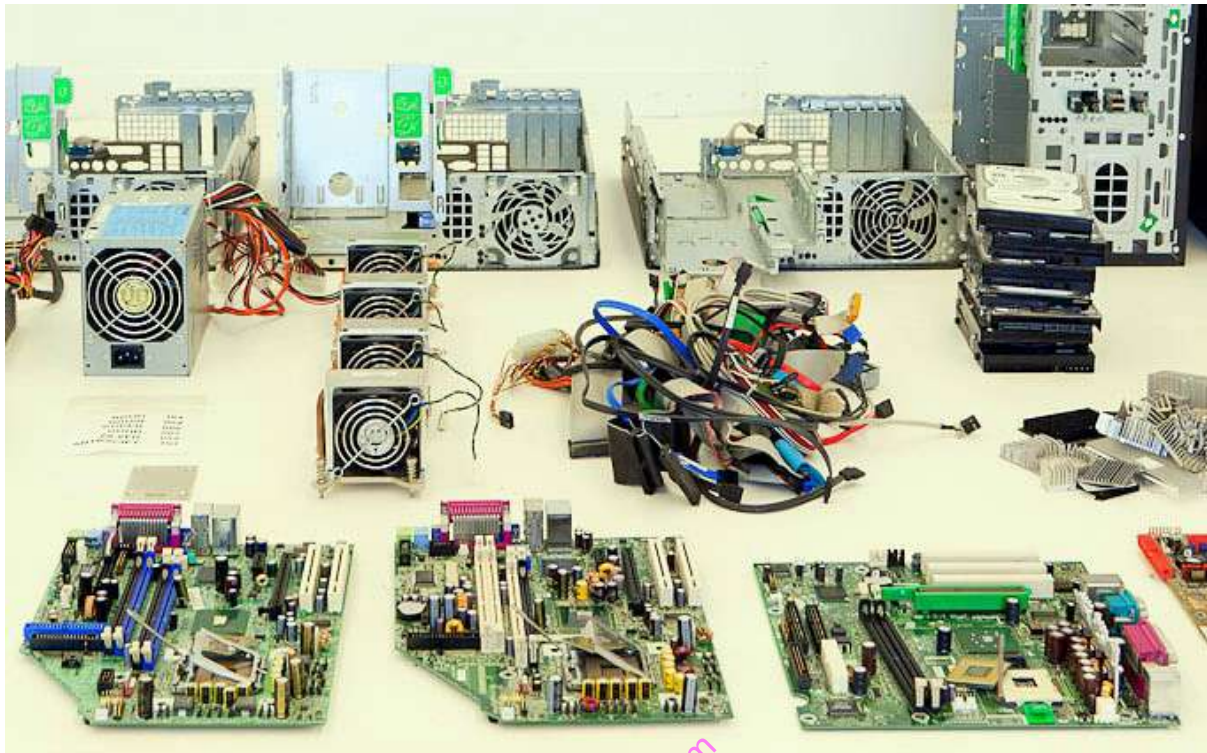
Figure 15: Electrical components in computers

Watch: The electronic components on a motherboard: https://youtu.be/OEL5laB3hfU
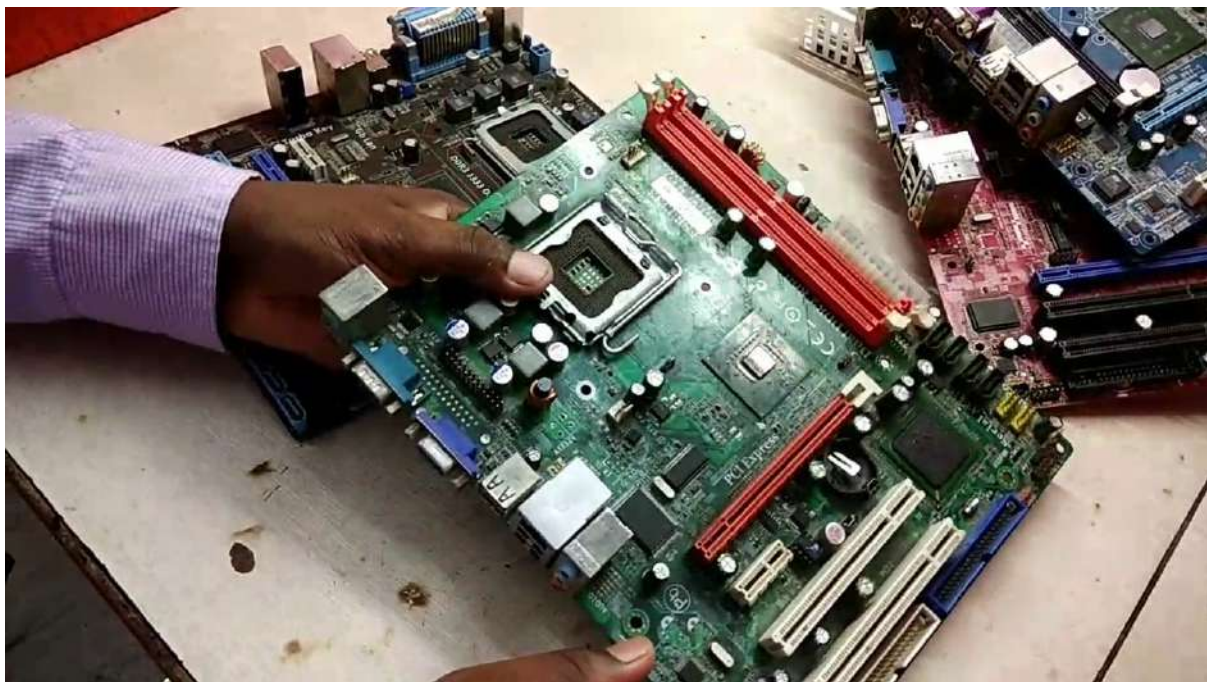
Figure 16 : Motherboard of a desktop

2.3.3.3 Self-Assessment

i.   What are electronic components and their application in a computer?
ii. Explain briefly electronic components.
iii. Capacitors are electronic components capable of storing and delivering electrical charges. They are classified accordingly to the material used on their manufacturing process. From the options below, which one ISN'T a type of capacitor:
   A. Electrolytic
   B. Tantalum
   C. Polyester
   D. Ceramic
   E. None of the above
iv. A 50 000 μF capacitor is charged by a constant current of 100 mA to a potential difference of 12 volts.
   o What is the charge on the capacitor?
   o How long did it take to charge up the capacitor?
   o What is the energy in the capacitor?
   o What is the energy supplied by the source?
   o How does this compare with the energy held by the capacitor?
vi. What are the electronic components found in a motherboard of a desktop? Identify them and list their use.
vii. Take a desktop motherboard and identify the various components and label the parts such as capacitor, resistors etc.
viii. Made from a variety of materials, such as carbon, this inhibits the flow of current.
   A. Resistor
   B. Capacitor
   C. Inductor
   D. Choke
ix. This is a type of semiconductor that only allows current to flow in one direction. It is usually used to rectify AC signals (conversion to DC).
   A. Univac
   B. Diode
   C. Transformer
   D. Inductor
x.   The capacitor capacitance is measured thru a unit called:
   A. Ohm
   B. Farad
   C. Hertz
   D. Watt
   E. None of the above

2.3.3.4 Tools, Equipment, Supplies and Materials

Motherboard, capacitor, diode, inductor, conductors e.g. copper, gold, silver

2.3.3.5 References

- https://www.electroschematics.com/8247/electronic-components-an-easy-to-use-guide/
- http://www.rajswasthya.nic.in/RHSDP%20Training%20Modules/CSIO%20Modules/Radiographers/ELCTRONIC%20COMPONENTS.pdf
- http://www.electronicsandyou.com/blog/electronic-components-parts-and-their-function.html
- https://www.electronics-project-design.com/Capacitors.html
- Digital Electronics authored by Roger L. Tokheim published by McGraw-Hill Education – Europe
- Electronics, Principles and Applications, authored by Charles A Schuler, published by McGraw-Hill/Glencoe

2.3.4 Learning Outcome 3: Understand semi-conductor theory

2.3.4.1 Learning Activities

The following are the performance criteria:
o Explanation of semiconductor theory is done
o Structure of matter is described
o Electrons in conductors and semiconductors are explained
o Types of semiconductor materials are identified
o P-type and N-type materials are explained
o Description of P-N junction diodes operations is done
o Types and operations of transistors are identified

Trainees to demonstrate knowledge in relation to:
o Definition of semiconductor and related terms: Atom, Atomic structure
o Description of the structure of matter
o Explanation of electrons in conductors and semiconductors
o Types of semiconductors materials: Silicon, Germanium
o Explanation of P-type and N-types materials
o Description of P-N junction diodes operations: Forward biasing, Reverse biasing
o Operations of transistors: PNP type, NPN type

2.3.4.2 Information Sheet

A semiconductor is a physical substance that is designed to manage and control the flow of current in electronic devices and equipment. It neither allows freely flowing electric current nor repels it completely. A semiconductor is in between a conductor and insulator and is commonly used in the development of electronic chips, computing components and devices. It is generally created using silicon, germanium or other pure elements.

Atoms are composed of subatomic particles among which are the charged particles known as electrons and protons.
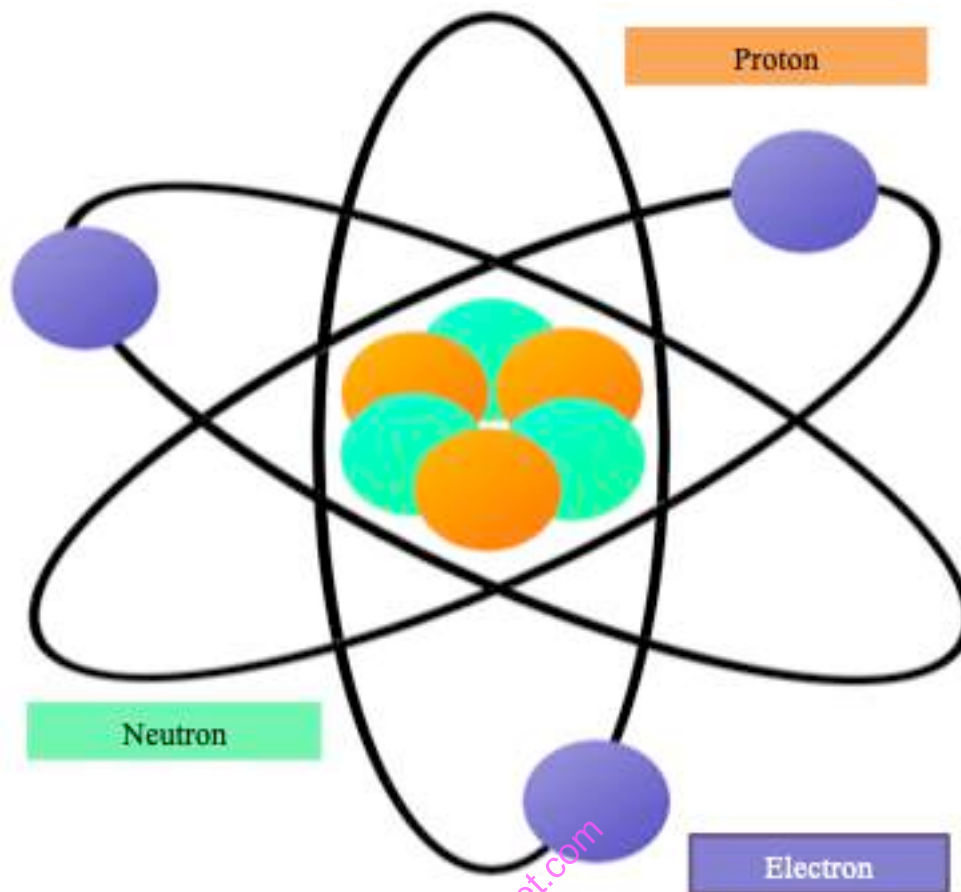
Figure 17: Parts of an atom

Watch: Atomic structure: https://youtu.be/EMDrb2LqL7E

Read: Structure of the atom: https://courses.lumenlearning.com/boundless-chemistry/chapter/the-structure-of-the-atom/

Matter can be defined as physical substance that has mass; occupies space; is composed of atoms; and is ultimately convertible to energy. A significant conversion of matter to energy, however, occurs only at speeds approaching that of the speed of light, a fact encompassed in the famous statement formulated by Albert Einstein (1879-1955), $E = mc^2$.
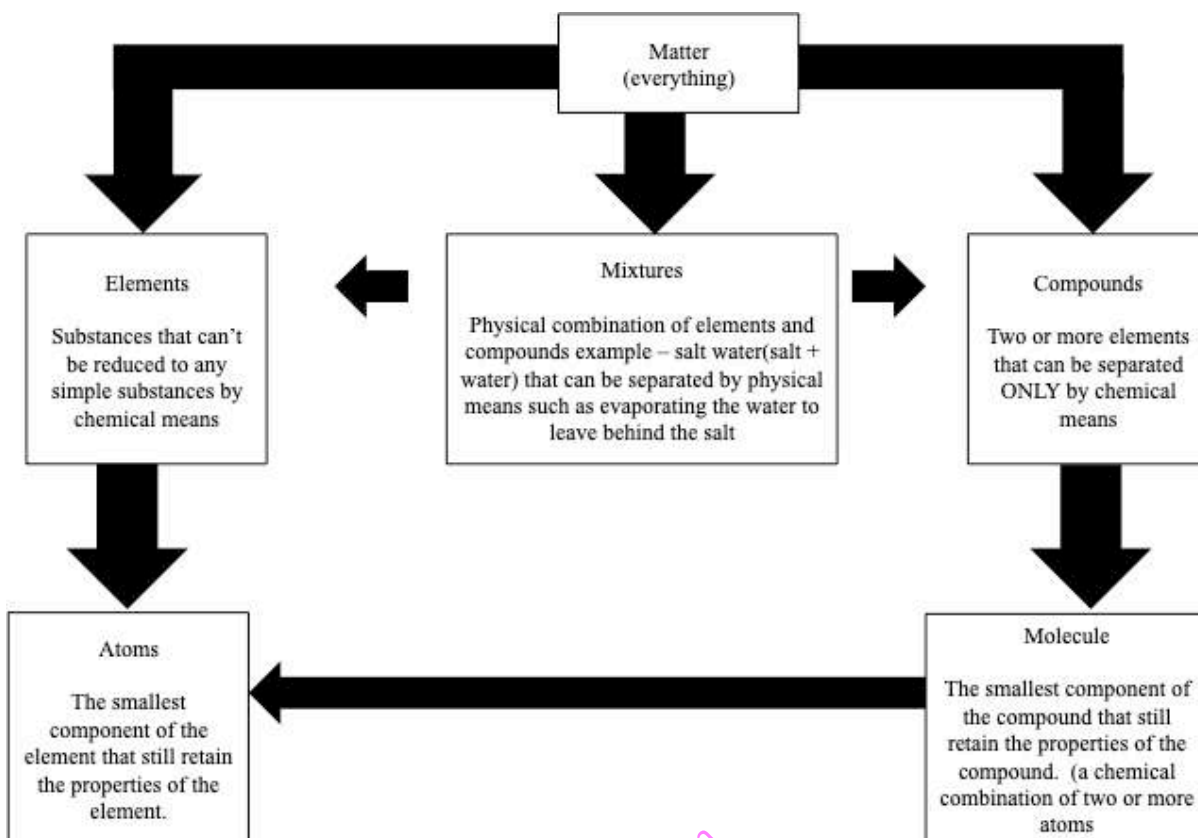
Figure 18: Classification of matter

Read: Structure of matter:
https://www.physicsclassroom.com/class/estatics/Lesson-1/The-Structure-of-Matter
https://www.encyclopedia.com/science/news-wires-white-papers-and-books/structure-matter

Metals such as copper typify conductors, while most non-metallic solids are said to be good insulators, having extremely high resistance to the flow of charge through them. "**Conductor**" implies that the outer **electrons** of the atoms are loosely bound and free to move through the material.

The Semiconductors, such as Germanium, Silicon, Carbon, Selenium, etc. are the materials, which are neither conductors nor insulators. Their conductivity lies in between or middle of the conductivity of conductors and insulators. Semiconductors have some useful properties and are being extensively used for the preparation of solid-state devices like the diode, transistor, etc. **Silicon and Germanium,** which belong to the fourth group element, behave like a semiconductor. Each atom of silicon and germanium share an electron with their neighbours. A Silicon atom and its neighbours share a pair of electrons in covalent bonding. Whenever a covalent bond breaks, an electron-hole pair is formed. To remove the valence electrons from the outer shells, a semiconductor atom needs the energy of the other.

Germanium was discovered in 1886. It is an earth element recovered from the ash of certain coaks or from the flue dust of zinc smelters. The recovered germanium is in the form of Germanium dioxide powder. It is then converted into pure Germanium.

The atomic structure of Germanium is shown below:
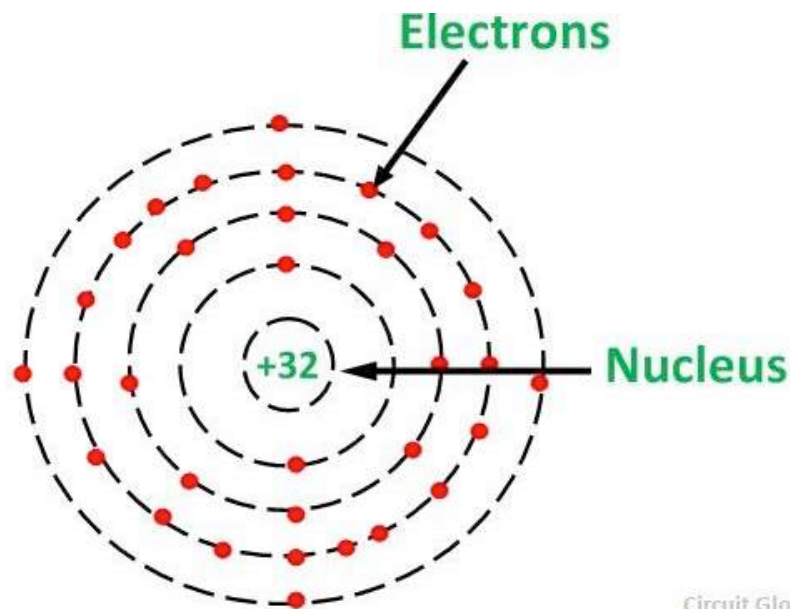
Figure 19: Atomic structure of Germanium

Its atomic number is 32. It has 32 protons in the nucleus and 32 electrons distributed in the four orbits around the nucleus. The number of electrons in the first, second, third and fourth orbit are 2, 8, 18 and 4 respectively. It is clear that the Germanium has four valence electrons. The various Germanium atoms are held together through covalent bonds as shown in the figure below.
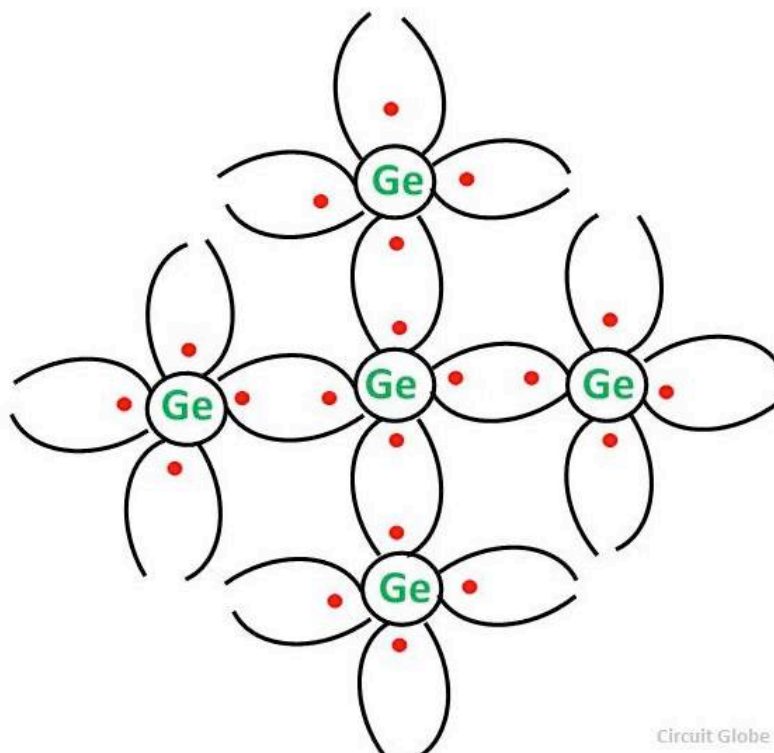
Figure 20: Germanium atomic bond

The energy band diagram of Germanium is shown below.
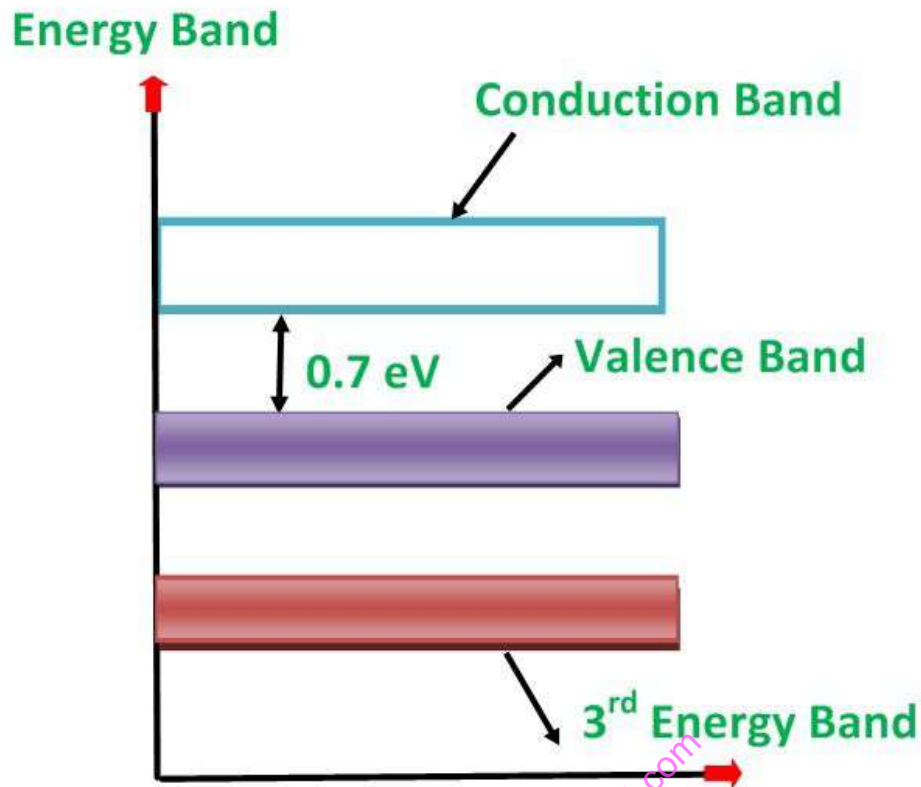
Figure 21: Energy bond for Germanium

The forbidden energy gap (i.e. Gap between the valence band and conduction band) in this material is very small. Hence, a very small energy is sufficient to lift the electrons from the valence band to the conduction band.

Silicon is the element available in most of the common rocks. Actually, sand is silicon dioxide. It is treated chemically and reduced to pure silicon, which can be used for the preparation   of   electronic   devices.

The figure below shows the atomic structure of silicon.
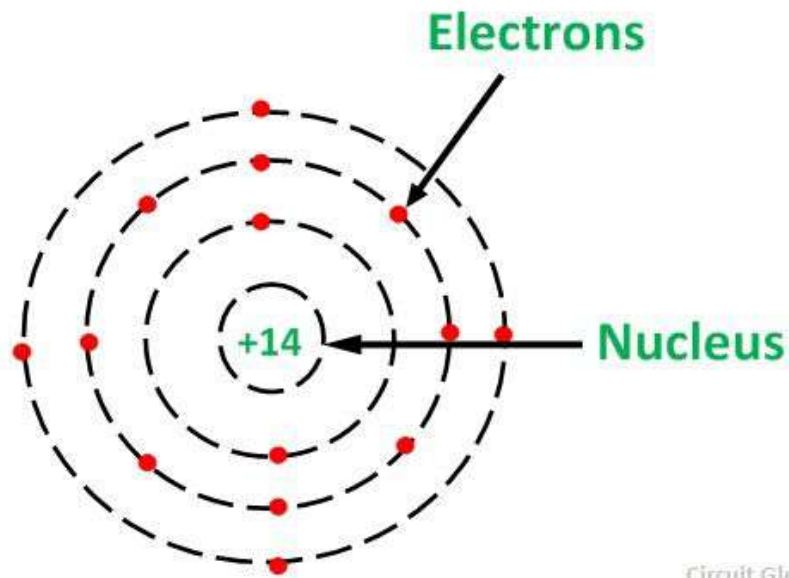
**Figure 22: Atomic structure of Silicon**

Its atomic number is 14. Therefore, it has 14 protons in the nucleus and 14 electrons distributed in the three orbits around the nucleus. The number of electrons in the first, second and third orbit are 2, 8 and 4 respectively. The various silicon atoms are held together through covalent bonds as shown in the figure below.

Figure 23: Silicon atomic bond

28

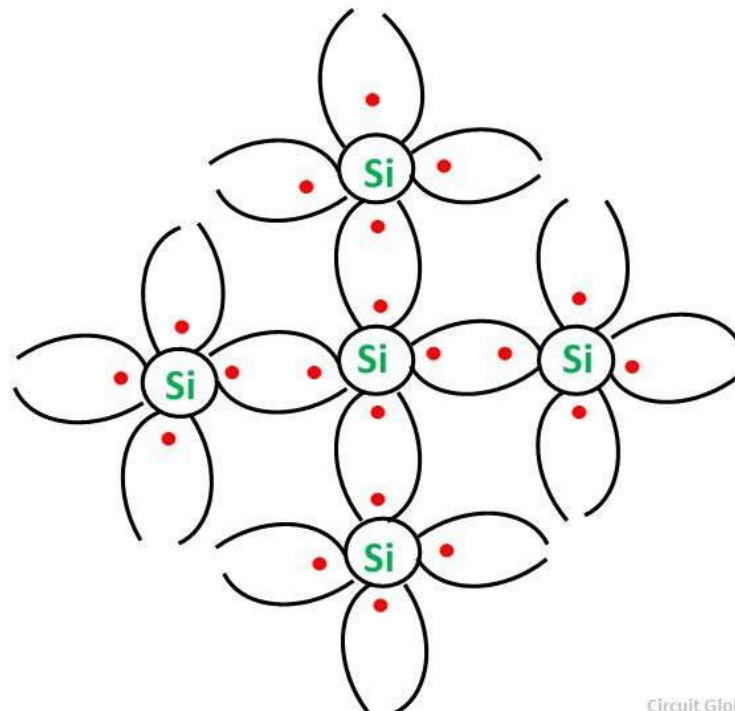The **energy band diagram** of the silicon material is shown below.
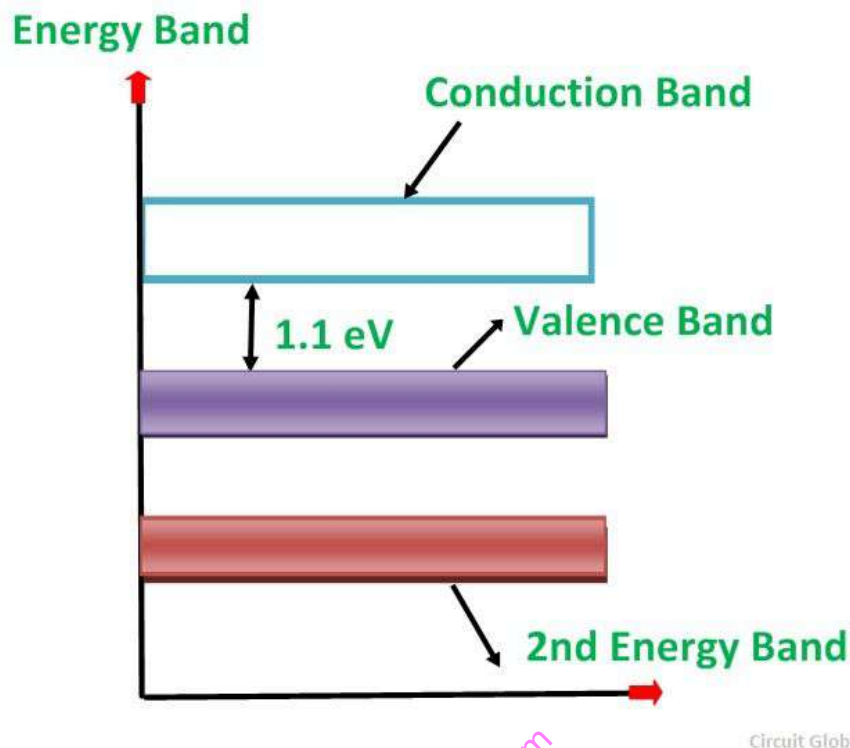
Figure 24: Energy bond of Silicon

The forbidden energy gap in this material is quite small. It also needs a small energy to lift the electrons from the valence band to the conduction band.

Therefore, even at room temperature, a minute quantity of valence electrons is lifted to the conduction band and constitute current conduction if a high electric field is applied. However, at room temperature, the number of electrons lifted to the conduction band in the case of silicon is quite less than germanium.

This is the reason why silicon semiconductor devices are preferred over germanium devices.

An extrinsic semiconductor is one that has been doped; during manufacture of the semiconductor crystal a trace element or chemical called a doping agent has been incorporated chemically into the crystal, for the purpose of giving it different electrical properties than the pure semiconductor crystal, which is called an intrinsic semiconductor. In an extrinsic semiconductor it is these foreign dopant atoms in the crystal lattice that mainly provide the charge carriers which carry electric current through the crystal. The doping agents used are of two types, resulting in two types of extrinsic semiconductor. An electron donor dopant is an atom which, when incorporated in the crystal, releases a mobile conduction electron into the crystal lattice. An extrinsic semiconductor which has been doped with electron donor atoms is called an n-type semiconductor, because the majority of charge carriers in the crystal are negative electrons. An electron acceptor dopant is an atom which

accepts an electron from the lattice, creating a vacancy where an electron should be called a hole which can move through the crystal like a positively charged particle. An extrinsic semiconductor which has been doped with electron acceptor atoms is called a p-type semiconductor, because the majority of charge carriers in the crystal are positive holes.
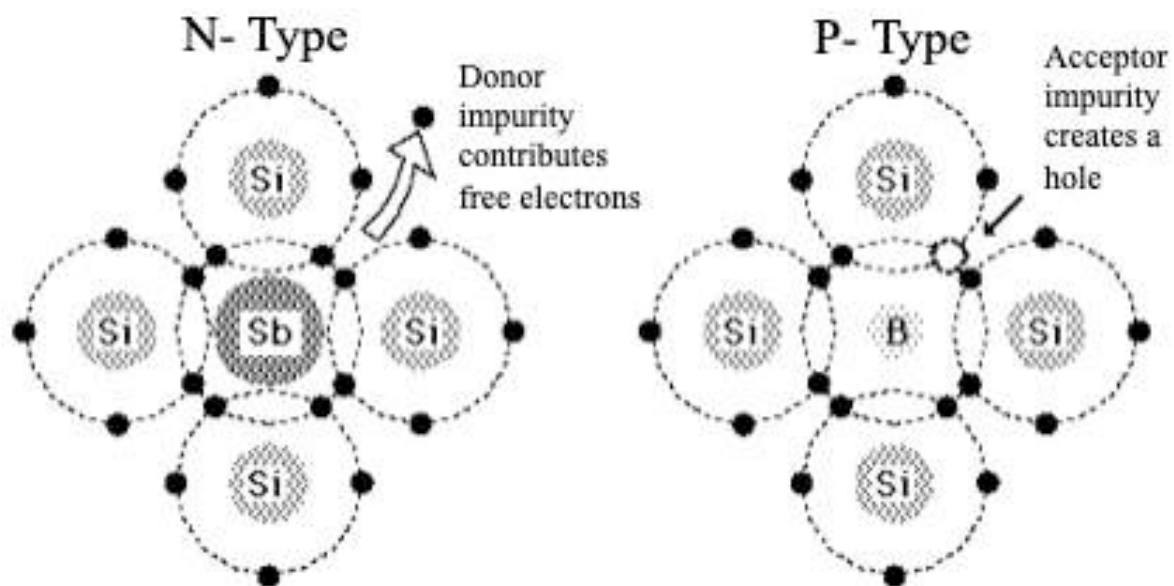
Figure 25: N-type and C-type semiconductors

The **N-type** semiconductor has a large number of electrons in the conduction band and less number of holes in the valence band, so electrons are called majority carriers and holes are called minority carriers.

The **P-type** semiconductor has a large number of holes in the conduction band and less number of electrons in the valence band, so holes are called majority carriers and electrons are called minority carriers.

Doping is the key to the extraordinarily wide range of electrical behavior that semiconductors can exhibit, and extrinsic semiconductors are used to make semiconductor electronic devices such as diodes, transistors, integrated circuits, semiconductor lasers, LEDs, and photovoltaic cells. Sophisticated semiconductor fabrication processes like photolithography can implant different dopant elements in different regions of the same semiconductor crystal wafer, creating semiconductor devices on the wafer's surface. For example a common type of transistor, the n-p-n bipolar transistor, consists of an extrinsic semiconductor crystal with two regions of n-type semiconductor, separated by a region of p-type semiconductor, with metal contacts attached to each part.

Table 4: Table for semiconductor - donor and acceptor atoms

	Intrinsic semiconductor	Donor atoms	Acceptor atoms
Group IV semiconductors	Silicon, Germanium	Phosphorus, Arsenic, Antimony	Boron, Aluminum, Gallium
Group III-V semiconductors	Aluminum phosphide, Aluminum arsenide, Gallium arsenide, Gallium nitride	Selenium, Tellurium, Silicon, Germanium	Beryllium, Zinc, Cadmium, Silicon, Germanium

Watch: Introduction to N-type and P-type semi conductors:
https://youtu.be/CM0C7gWMcyw

A **PN-junction diode** is formed when a P-type semiconductor is fused to an N-type semiconductor creating a potential barrier voltage across the diode junction.
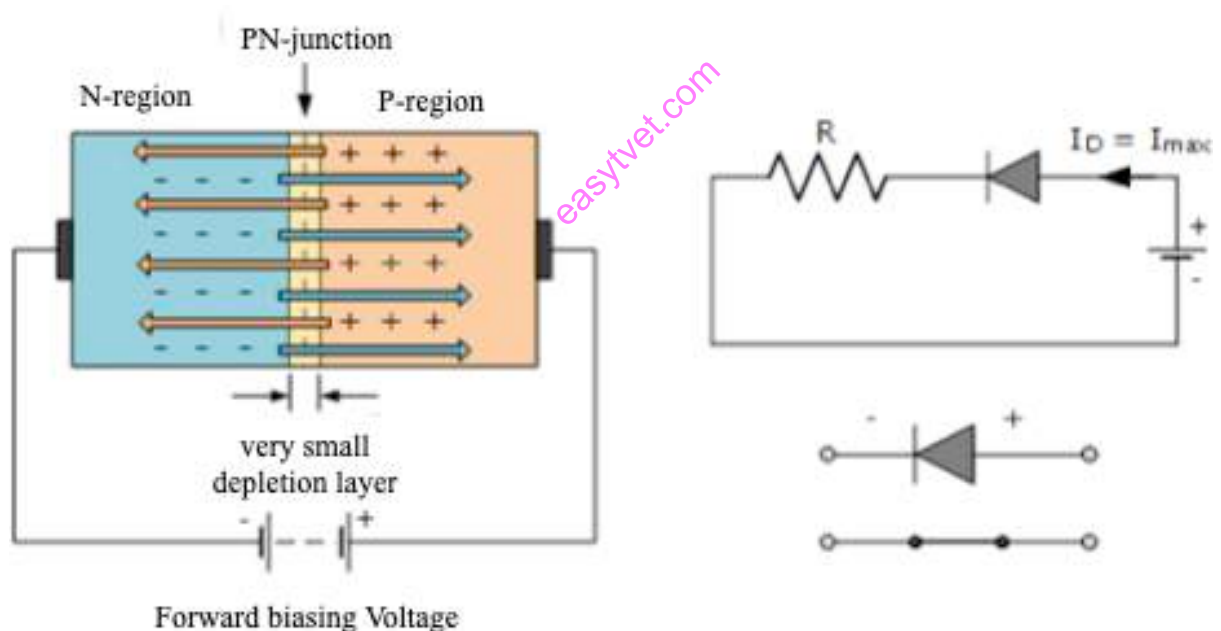
Source: https://www.electronics-tutorials.ws/diode/diode_3.html
Figure 26: PN-junction diode

Forward Bias: The voltage potential is connected positive (+ve) to the P-type material and negative (-ve) to the N-type material across the diode that has the effect of **decreasing** the PN junction diode's width.

Reverse Bias: The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode that has the effect of **increasing** the PN junction diode's width.

> **Why does computers use semi-conductors?**
>
> Computer chips, both for CPU and memory, are composed of semiconductor materials. Semiconductors make it possible to miniaturize electronic components, such as transistors. Not only does miniaturization mean that the components take up less space, it also means that they are faster and require less energy.

Examples of components and devices that utilize semiconductors and semiconductor materials include the following:
- o Integrated circuit
- o Keyboard and mouse
- o Monitor
- o Processor
- o Memory chip
- o Transistor

Silicon is used in most semiconductors for computer and electronic components, as is it considered to be the best semiconductor material.

Watch: Introduction to semi-conductor: https://youtu.be/gUmDVe6C-BU

Watch: How semi-conductors are manufactured: https://youtu.be/R0nlBJ_IVc4

Watch: Understand why silicon is used in computer chips: https://youtu.be/8W9CA1QENqg

Read: Understand the use of semi-conductors: https://ethw.org/Semiconductors

2.3.4.3 Self-Assessment
i.   Differentiate between forward bias and reverse bias.
ii.   Define PN-junction diode.
iii. A semiconductor is formed by _____ bonds.
      A. Covalent
      B. Electrovalent
      C. Co-ordinate
      D. None of the above
iv.   Differentiate between P-type and N-type semiconductors.
v.   Identify the use of semi-conductors in computer.
vi.   What are the alternatives for silicon semi-conductor in electronic devices like computers?
vii. Demonstrate the difference between conductor, semi-conductors and insulator using appropriate workshop equipment.
viii. A semiconductor has _____ temperature coefficient of resistance.
      A. Positive

32

B. Zero

C. Negative

D. None of the above

ix. The most commonly used semiconductor is.

A. Germanium

B. Silicon

C. Carbon

D. Sulphur

x. When a pure semiconductor is heated, its resistance.

A. Goes up

B. Goes down

C. Remains the same

D. Can't say

2.3.4.4 Tools, Equipment, Supplies and Materials

Silicon, Germanium, diode, semiconductor materials, pliers, rubber, copper wire, gold wire, glass

2.3.4.5 References

- https://www.encyclopedia.com/science/news-wires-white-papers-and-books/structure-matter
- https://byjus.com/physics/semiconductors-and-insulators/
- https://www.electronics-tutorials.ws/diode/diode_3.html
- https://circuitglobe.com/semiconductors.html
- Semiconductor Devices: Physics and Technology 3rd Edition authored by by Simon M. Sze , Ming-Kwei Lee, published by Wiley; 3 edition 2012
- Circuit Engineering: The Beginner's Guide to Electronic Circuits, Semi-Conductors, Circuit Boards, and Basic Electronics, authored by Solis Tech published by Solis Tech 2016

2.3.5 Learning Outcome 4: Identify and classify memory activities

2.3.5.1 Learning Activities
The following are the performance criteria:
o   Types of memories are identified
o   Memory hierarchy is identified
o   Levels of memory storage are identified
o   Classification of memories is done

Trainees to demonstrate knowledge in relation to:
o   Definition of memory: Classification of memories RAM, ROM, DAM
o   Types of memories: Semiconductor memories, Magnetic memories

2.3.5.2 Information Sheet

In computing, **memory** refers to the computer hardware integrated circuits that store information for immediate use in a computer; it is synonymous with the term "primary storage."

Read: The history of computer (memory and storage)
https://www.computerhistory.org/timeline/memory-storage/

Watch: How to computer memory works? Volatile and non- volatile memory:
https://youtu.be/TQCr9RV7twk

In computer architecture, the memory hierarchy separates computer storage into a hierarchy based on response time. Since response time, complexity, and capacity are related, the levels may also be distinguished by their performance and controlling technologies. Memory hierarchy affects performance in computer architectural design, algorithm predictions, and lower level programming constructs involving locality of reference.

Designing for high performance requires considering the restrictions of the memory hierarchy, i.e. the size and capabilities of each component. Each of the various components can be viewed as part of a hierarchy of memories (m1,m2,...,mn) in which each member mi is typically smaller and faster than the next highest member mi+1 of the hierarchy. To limit waiting by higher levels, a lower level will respond by filling a buffer and then signaling for activating the transfer.

There are four major storage levels.
o   Internal – Processor registers and cache.
o   Main – the system RAM and controller cards.
o   On-line mass storage – Secondary storage.
o   Off-line bulk storage – Tertiary and Off-line storage.

Computer memory or storage can be classified in three ways: primary, secondary an offline:
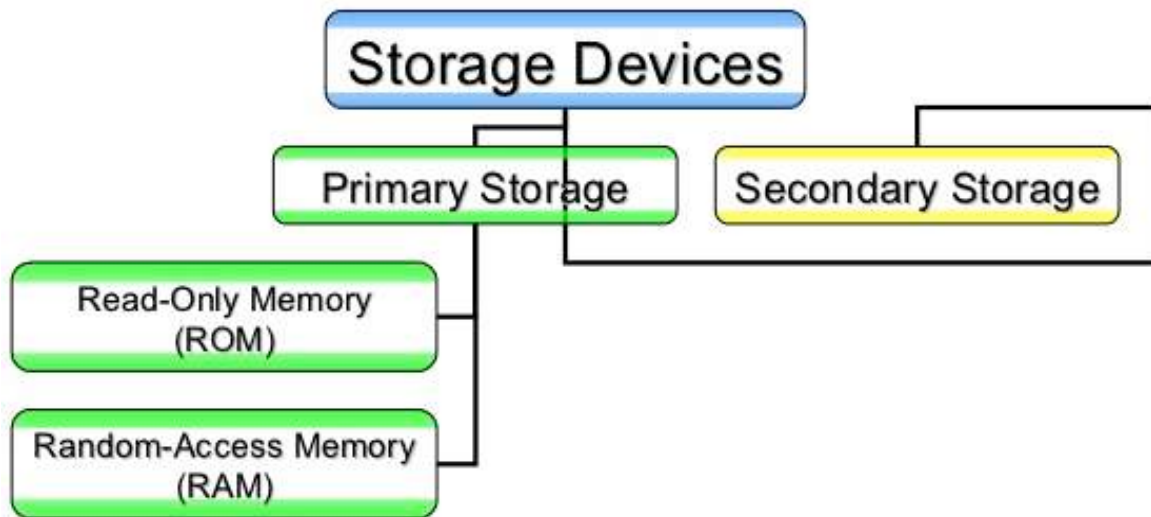
Source: https://www.slideshare.net
Figure 27: Classification of computer memory storage

Primary memory is the computer's main memory, which is directly accessible by the CPU and often much faster than secondary storage. RAM will hold the loaded operating system, plus all running applications and files. Examples of primary memory / storage:
o   Random Access Memory (RAM) – solid state
o   Read Only Memory (ROM) – solid state

Secondary storage is a non-volatile medium that holds data until it is deleted or overwritten. It is sometimes referred to as external memory and auxiliary storage. Secondary storage is where programs and data are kept on a long-term basis. Examples of secondary memory / storage:
o   Hard Disk Drive (HDD) – magnetic storage
o   Solid State Drive (SSD) – solid state

Off-line refers to non-volatile storage that can be easily removed from the computer. This is often used to transport data and keep backups for protection. Examples of off-line memory / storage:
o   CD, DVD, Blu-ray – optical storage
o   USB Flash Drive – solid state
o   Removable HDD / SSD

RAM is an acronym for Random Access Memory, a type of computer memory that can be accessed randomly; that is, any byte of memory can be accessed without touching the preceding bytes.
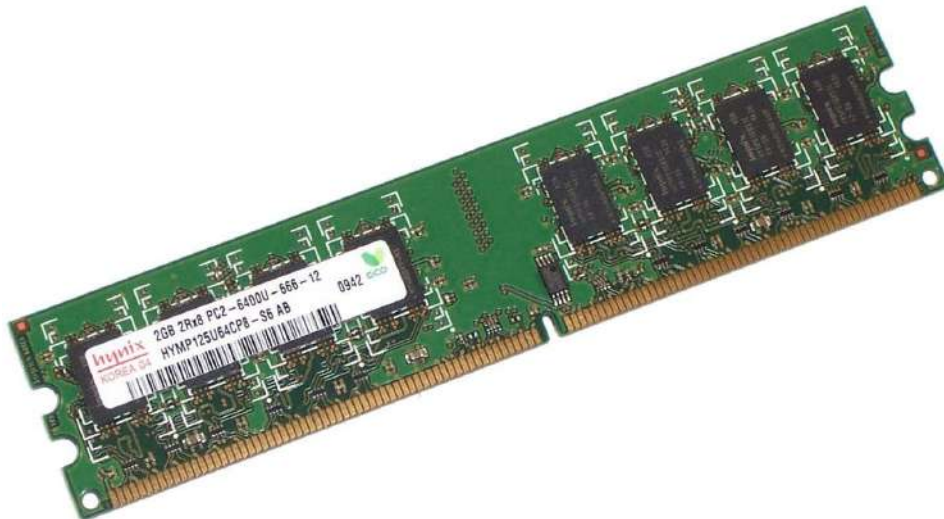
Source: https://www.archmemory.com
Figure 28: Random Access Memory (RAM)

The larger the RAM size of a computer, the faster it runs since it is faster to carry out orders and operations. In reality the RAM never runs out of memory, but it gets slower and slower when too much memory is stored until the computer freezes or restart (restarting your computer means that the data stored in the RAM will disappear).

There are 2 types of RAM, the dynamic RAM (DRAM) and the static RAM (SRAM).

Dynamic RAM: Dynamic RAM chips consist of a number of transistors and capacitors, which have different functions:
o Transistor- this acts like a switch, it allows the chip to control circuitry to read the capacitor or change the capacitor's value.
o Capacitors- this holds the bits of the information.

This type of RAM has to be refreshed continuously every (approximate) 15 microseconds otherwise it will lose its value.

Static RAM: This type of RAM doesn't need to be constantly refreshed. SRAM is faster than DRAM when it comes to data access. Static RAM costs more than DRAM, consumes more power than DRAM, lower storage capacity than DRAM.

Table 5: Difference between SRAM and DRAM

SRAM	DRAM
• SRAM has lower access time, so it is faster compared to DRAM.	• DRAM has higher access time, so it is slower than SRAM.
• SRAM is costlier than DRAM.	• DRAM cost less compared to SRAM.
• SRAM requires constant power supply, which means this type of memory	• DRAM offers reduced power consumption, due to the fact that the

consumes more power.	information is stored in the capacitor.
• Due to complex internal circuitry, less storage capacity is available compared to the same physical size as DRAM memory chip.	• Dues to the small internal circuitry in the one-bit memory cell of DRAM, the storage capacity is available.
• SRAM has low packaging density.	• DRAM has high packaging density.

Short for Read Only Memory, ROM is a storage medium that is used with computers and other electronic devices. As the name indicates, data stored in **ROM may only be read.**

Figure 29: Read Only Memory (ROM)

Watch: Understand the difference between RAM and ROM memory:
https://youtu.be/CPOcSGgSxiQ

Table 6: Difference between RAM and ROM

RAM	ROM
• Used in the computer's regular operations, after loading the OS.	• Used mostly in a computer's start-up process.
• With RAM, writing data is a fast process.	• Writing data to ROM is very slow.
• RAM is a type of volatile memory, meaning the stored data is lost when powering off.	• ROM is a type of non-volatile memory, meaning that the data will not be lost when power is removed.
• A RAM chip can store quite a lot of data, up to 16 GB.	• ROM chips usually store only a few megabytes of information, around 4 MB per

	chip.
• There are two main types of RAM: dynamic (DRAM) and static (SRAM).	• ROM types include EPROM, EEPROM, PROM and Mask ROM.

Digital Asset Management (DAM) is a business process for organizing, storing and retrieving rich media and managing digital rights and permissions. Rich media assets include photos, music, videos, animations, podcasts and other multimedia content.

Semiconductor memory is a type of semiconductor device tasked with storing data.

Magnetic storage or magnetic recording is the storage of data on a magnetized medium. Magnetic storage uses different patterns of magnetization in a magnetizable material to store data and is a form of non-volatile memory. The information is accessed using one or more read/write heads.

Read: Memory Storage: https://anatcomputerscience.wordpress.com/chapter-6/

2.3.5.3 Self-Assessment

i.   Define semiconductor memory.
ii.   What is DAM?
iii.   Differentiate between ROM and RAM.
iv.   Review a RAM and identify its components
v.   Review a ROM and identify its components
vi.   In your workshop, differentiate between – CD, DVD and a blue – ray memory device for offline storage.
vii.   Why is a hard drive and pen drive known as 'secondary storage'?
viii.   What does the word 'volatile' mean when used in computing?
ix.   All of following are non-volatile memory except
        A. ROM
        B. PROM
        C. Flash memory
        D. RAM
x.   Computer memory is measured in terms of:
        A. Bits
        B. Bytes
        C. Cells
        D. Units
xi.   Identify the RAM and the ROM component of a CPU.
xii.   Review the market on the various sizes of RAM and ROM available for desktop computers. Evaluate their advantages and disadvantages.
xiii.   You are an IT Technician, a user's computer turns on but there is no display. How will you fix the issue?
xiv.   Storage, which stores or retains data after power off is called-

       A. Volatile storage

       B. Non-volatile storage

       C. Sequential storage

       D. Direct storage

       E. None of these

xv.   Which of the following memories must be refreshed many times per second?

       A. EPROM

       B. ROM

       C. Static RAM

       D. Dynamic RAM

2.3.5.4 Tools, Equipment, Supplies and Materials

Semiconductor, RAM, Computer, Memory, screw driver

2.3.5.5 References

- https://searchcontentmanagement.techtarget.com/definition/What-is-digital-asset-management
- Computer Fundamentals, authored by Anita Goel published by Pearson 2010
- Computer System Architecture 3rd Edition, Authored by M. Morris Mano, published Pearson 2007

2.3.6 Learning Outcome 5: Apply Number Systems

2.3.6.1 Learning Activities

The following are the performance criteria:

o Types of number systems are identified

o Base conversion is done as per the standard procedures

o Binary arithmetic operations are done

o Binary codes are identified

o Representation of decimals in BCD is done

o BCD arithmetic is performed

Trainees to demonstrate knowledge in relation to:

o Definition of number system and binary code

o Types of number systems: Decimal, Binary, Octal, Hexadecimal

o Base conversion

o Binary arithmetic: Addition, Subtraction, Multiplication, Division

o Binary codes: 8421 BCD, Excess-3

o Represent decimal numbers in BCD

o BCD arithmetic: Addition, Subtraction, Multiplication, Division

2.3.6.2 Information Sheet

Number systems are the technique to represent numbers in the computer system architecture;

every value that you are saving or getting into/from computer memory has a defined number system. Computer architecture supports following number systems: The types are:

1. Decimal System
2. Binary System
3. The Octal System
4. The Hexadecimal System.

In **decimal system** the base (or radix) is 10, since any position can contain one of ten digits. The system therefore has a carrying factor of 10 and each digit indicates a value, which depends on the position it occupies, for example;

In 6421 the digit 6 signifies 6 x 1000
In 4621 the digit 6 signifies 6 x 100
In 4261 the digit 6 signifies 6 x 10 and in 4216 the digit 6 signifies 6

The decimal system uses ten digits to record the number. The ten digits are 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 and any number (used) is based upon power of 10.

For example 5281 is made up of:
$(5 \times 10^3) + (2 \times 10^2) + (8 \times 10^1) + (1 \times 10^0)$
$= 5000 + 200 + 80 + 1 = 5281$.

Whereas decimal system uses ten digits to record the number, the binary system uses only two digits (for recording the number) that is 0 and 1, and its base is 2 (whereas that of decimal system is 10). Although in everyday life, people generally use the decimal number system for counting, it is more convenient to use the binary number system in a computer because electronic components are usually in one of two states, which can be used to represent 0 and 1, the two digits used in the binary system.

The computer does not have a large number of symbols for representing data. It has only **two, 0 and 1 (called binary digits or bits).** These correspond to the two electronic or magnetic states used in computer circuits and storage.

For example if a punched paper tape is used in the computer, a hole in a tape may allow electrical contact to be made (ON) and the absence of a hole in the tape does not allow electrical contact to be made (OFF). Therefore a hole can represent 1 and no hole can represent 0. Binary system is more compact than the decimal system of coding as the latter will need large size of the storage medium and relative complexity of the reading device.

Given below is the table of construction of Binary numbers:

Table 7: Binary numbers

Binary Numbers				Equivalent Decimal Number	Explanation
2^3	2^2	2^1	2^0		
			1	1	$2^0 = 1$
		1	0	2	$2^1 + 0 = 2$
		1	1	3	$2^1 + 2^0 = 3$
	1	0	0	4	$2^2 + 0 + 0 = 4$
	1	0	1	5	$2^2 + 0 + 2^2 = 5$
	1	1	0	6	$2^2 + 2^1 + 0 = 6$
	1	1	1	7	$2^2 + 2^1 + 2^0 = 7$
1	0	0	0	8	$2^3 + 0 + 0 + 0 = 8$
1	0	0	1	9	$2^3 + 0 + 0 + 2^2 = 9$

Source: http://www.businessmanagementideas.com

Convert 10110111 to decimals

1	0	1	1	0	1	1	1		
128	64	32	16	8	4	2	1		
								$1*1 =$	1
								$1*2 =$	2
								$1*4 =$	4
								$0*8 =$	0
								$1*16 =$	16
								$1*32 =$	32
								$0*64 =$	0
								$1*128 =$	128
								Add	183
10110111 = 183 decimal									

Source: https://owlcation.com

Let the decimal number be 217.

(a) To find the binary equivalent proceed as follows:

		Remainder
2	217	
2	108	1
2	54	0
2	27	0
2	13	1
2	6	1
2	3	0
2	1	1
	0	1

Source: http://www.businessmanagementideas.com

Start binary number with last digit. Therefore the binary equivalent of 217 is 11011001.

(b) Convert .8125 into binary number.

1	.8125
	X2
1	.6250
	X2
0	.2500
	X2
1	.5000
	X2
	.0000

 Decimal .8125 = .1101 in binary

Convert decimal number 217.8125 into binary number
From (a) and (b) above =

Decimal number	Binary Number
$(217.8125)_{10}$	$(11011001.1101)_2$

The octal system (base 8) and hexadecimal system (base 16) are of importance because they can be used as shorthand for binary numbers. This is because three binary digits can be represented by the numbers 0 to 7 i.e., the octal range, while four binary digits can be represented by the numbers 0 to 9 and A to F.

Octal	761			365			6437101						
Binary	111	110	001	011	110	101	110	100	011	111	001	000	001

 To illustrate:

Binary number $111 = 2^2 + 2^1 + 2^0 = 4 + 2 + 1 = 7$

Binary number $110 = 2^2 + 2^1 + 0 = 4 + 2 + 0 = 6$ and so on.

That is,

111	110	001

 Binary cab be represented by only 761 in the octal system, therefore, octal system can be used as shorthand for binary numbers.

Table 8: Octal binary conversion table

Octal	Binary
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Source: http://www.businessmanagementideas.com

Read: On octal conversion: http://www.businessmanagementideas.com

The hexadecimal system has a base 16 and the digits 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and letters A, B, C, D, E, F are used. The letters A, B, C, D, E and F represent the decimal numbers 10, 11, 12, 13, 14 and 15 respectively.

When hexadecimal is used to represent a binary number, the individual hexadecimal digits represent successive groups of four binary digits starting at the point. This is similar to the conversion from binary to octal, in which each set of three bits is translated to an octal digit.

Table 9: Binary conversion table

Decimal	Hexadecimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

Source: http://www.businessmanagementideas.com

Read: Types of number systems: http://www.businessmanagementideas.com/information-technology/computers/4-main-types-of-number-system-computer/10285
Watch: Base conversion: https://youtu.be/Fpm-E5v6ddc
Read: Base conversion:
https://www.tutorialspoint.com/computer_logical_organization/number_system_conversion.htm

Binary arithmetic operation starts from the least significant bit.

Watch: Binary Arithmetic: https://youtu.be/-1gffkPjwXg

A binary code represents text, computer processor instructions, or any other data using a two-symbol system. The two-symbol system used is "0" and "1" from the binary number system.

8421 code: A weighted code in which each decimal digit 0 through 9 is represented by a four-bit codeword. The bit positions in each codeword are assigned weights, from left to right, of 8, 4, 2, and 1.

Excess-3 code: An 8421 code for which the weighted sum of the four bits in each codeword is three greater than the decimal digit represented by that codeword. For example, 9 is represented by 1100, the weighted sum of which is $8 \times 1 + 4 \times 1 + 2 \times 0 + 1 \times 0 = 12$

To represent the sign of a number in **binary-coded decimal (BCD)**, the number 0000 is used to represent a positive number, and 1001 is used to represent a negative number. The remaining 14 combinations are invalid signs.

In computing and electronic systems, **binary-coded decimal (BCD)** is a class of binary encodings of decimal numbers where each decimal digit is represented by a fixed number of bits, usually four or eight. Special bit patterns are sometimes used for a sign or for other indications.

Watch: BCD arithmetic: https://youtu.be/yPu57aSj9kA

2.3.6.3 Self-Assessment
i.   What is BCD? Explain.
ii.   What is the difference between binary and BCD?
iii.   Why is BCD called 8421 code?
iv.   What is binary code?
v.   Convert the binary number 1011010 to hexadecimal.
        A. 5C
        B. 5A
        C. 5F
        D. 5B

vi.   What is the result when a decimal 5238 is converted to base 16?
- A. 1388
- B. 1476
- C. 327.375
- D. 12166

vii.   An Excess-3 code to BCD (Binary-coded decimal) code converter is a device which converts an exceess-3 code input, represented by a, b, c and d

A. Follow the same rule and create a truth table for "excess-3" code to BCD

B. Derive each input a, b, c, and d as a function of the inputs w, x, y and z (see following truth table)

C. Model the converter circuit at gate level in structural style.

w	x	y	z	a	b	c	d
0	0	1	1	0	0	0	0
0	1	0	0	0	0	0	1
0	1	0	1	0	0	1	0
0	1	1	0	0	0	1	1
0	1	1	1	0	1	0	0
1	0	0	0	0	1	0	1
1	0	0	1	0	1	1	0
1	0	1	0	0	1	1	1
1	0	1	1	1	0	0	0
1	1	0	0	1	0	0	1

viii.   The binary equivalent of the decimal number 10 is _____
- A. 0010
- B. 10
- C. 1010
- D. 010

ix.   A computer language that is written in binary codes only is _____
- A. Machine language
- B. C
- C. C#
- D. Pascal

1.3.6.4 Tools, Equipment, Supplies and Materials
Computer, LCR meter

2.3.6.5 References
- https://www.encyclopedia.com/computing/dictionaries-thesauruses-pictures-and-press-releases/excess-3-code
- Electronics, Principles and Applications, authored by Charles A Schuler, published by McGraw-Hill/Glencoe

- Computer System Architecture 3rd Edition, Authored by M. Morris Mano, published Pearson

2.3.7 Learning Outcome 6: Emerging trends in electronics

2.3.7.1 Learning Activities
The following are the performance criteria:
o Description of emerging trends is done
o Challenges of emerging trends are explained
o Explanation on coping with the emerging trends is done

Trainees to demonstrate knowledge in relation to:
o Description of emerging trends
o Explanation of challenges of emerging trends
o Coping with the emerging trends

2.3.7.2 Information Sheet
The era of electronics began with the invention of the transistor in 1947 and silicon-based semiconductor technology. Seven decades later, we are surrounded by electronic devices and, much as we try to deny it, we rely on them in our everyday lives.

The performance of silicon-based devices has improved rapidly in the past few decades, mostly due to novel processing and patterning technologies, while nanotechnology has allowed for miniaturization and cost reduction.

For many years silicon remained the only option in electronics. But recent developments in materials-engineering and nanotechnology have introduced new pathways for electronics. While traditional silicon electronics will remain the main focus, alternative trends are emerging. These include:

2-D electronics: Interest in the field started with the discovery of graphene, a structural variant of carbon. Carbon atoms in graphene form a hexagonal two-dimensional lattice, and this atom-thick layer has attracted attention due to its high electrical and thermal conductivity, mechanical flexibility and very high tensile strength. Graphene is the strongest material ever tested.

In 2010, the Royal Swedish Academy of Sciences decided to award the Nobel Prize in Physics to Andre Geim and Konstantin Novoselov for their "groundbreaking experiments" in graphene research.

Graphnene may have started this 2D revolution in electronics, but silicene, phosphorene and stanene, atom-thick allotropes of silicon, phosphorus and tin, respectively, have a similar honeycomb structure with different properties, resulting in different applications.

All four have the potential to change electronics as we know it, allowing for miniaturization, higher performance and cost reduction. Several companies around the globe, including Samsung and Apple, are developing applications based on grapheme.

Organic electronics: The development of conducting polymers and their applications resulted in another Nobel prize in 2000, this time in chemistry. Alan J. Heeger, Alan G. MacDiarmid and Hideki Shirakawa proved that plastic can conduct electricity.

Unlike conventional inorganic conductors and semiconductors, organic electronic materials are constructed from organic (carbon-based) molecules or polymers using chemical synthesis. Organic electronics is not limited to conducting polymers, but includes other organic materials that might be of use in electronics. These include a variety of dyes, organic charge-transfer complexes, and many other organic molecules.

In terms of performance and industrial development, organic molecules and polymers cannot yet compete with their inorganic counterparts. However, organic electronics have some advantages over conventional electronic materials. Low material and production costs, mechanical flexibility, adaptability of synthesis processes and biocompatibility make organic electronics a desirable choice for certain applications.

Commercially available high-tech products relying on organic semiconductors, such as curved television screens, displays for smartphones, coloured light sources and portable solar cells, demonstrate the industrial maturity of organic electronics. In fact, several high-tech companies, including LG Electronics and Samsung, have invested in cheap and high-performance organic-electronic devices. It is expected that the organic electronics market will grow rapidly in the coming years.

Memristors: In 1971 Leon Chua reasoned from symmetry arguments that there should be a fourth fundamental electronic circuit-board element (in addition to the resistor, capacitor and inductor), which he called memristor, a portmanteau of the words memory and resistor. Although Chua showed that memristors have many interesting and valuable properties, it wasn't until 2007 that a group of researchers from Hewlett Packard Labs found that the memristance effect can be present in nanoscale systems under certain conditions. Many researchers believe that memristors could end electronics as we know it and begin a new era of "ionics".

While commonly available transistor functions use a flow of electrons, the memristor couples the electrons with ions, or electrically charged atoms. In transistors, once the flow of electrons is interrupted (for example by switching off the power) all information is lost. Memristors "memorize" and store information about the amount of charge that has flowed through them, even when the power is off.

The discovery of memristors paves the way to better information storage, making novel memory devices faster, safer and more efficient. There will be no information loss, even if

the power is off. Memristor-based circuits will allow us to switch computers on and off instantly, and start work straight away.

For the past several years, Hewlett Packard has been working on a new type of computer based on memristor technology. HP plans to launch the product by 2020.

Spintronics: Spintronics, a portmanteau word meaning "spin transport electronics", is the use of a fundamental property of particles known as "electron spin" for information processing. Electron spin can be detected as a magnetic field with one of two orientations: up and down. This provides an additional two binary states to the conventional low and high logic values, which are represented by simple currents. Carrying information in both the charge and spin of an electron potentially offers devices with a greater diversity of functionality.

So far, spintronic technology has been tested in information-storage devices, such as hard drives and spin-based transistors. Spintronics technology also shows promise for digital electronics in general. The ability to manipulate four, rather than only two, defined logic states may result in greater information-processing power, higher data transfer speed, and higher information-storage capacity.

It is expected that spin transport electronic devices will be smaller, more versatile and more robust compared with their silicon counterparts. So far this technology is in the early development stage and, irrespective of intense research, we have to wait a couple of years to see the first commercial spin-based electronic chip.

Molecular electronics: The ultimate goal of electrical circuits is miniaturization. Also known as single molecule electronics, this is a branch of nanotechnology that uses single molecules or collections of single molecules as electronic building blocks.

Molecular electronics and the organic electronics described above have a lot in common, and these two fields overlap each other in some aspects. To clarify, organic electronics refers to bulk applications, while molecular-scale electronics refers to nano-scale, single-molecule applications.

Conventional electronics are traditionally made from bulk materials. However, the trend of miniaturization in electronics has forced the feature sizes of the electronic components to shrink accordingly. In single-molecule electronics, the bulk material is replaced by single molecules. The smaller size of the electronic components decreases power consumption while increasing the sensitivity (and sometimes performance) of the device. Another advantage of some molecular systems is their tendency to self-assemble into functional blocks. Self-assembly is a phenomenon in which the components of a system come together spontaneously, due to an interaction or environmental factors, to form a larger functional unit.

Several molecular electronic solutions have been developed, including molecular wires, single-molecule transistors and rectifiers. However, molecular electronics is still in the early research phase, and none of these devices has left the laboratory.

The world is quickly and constantly transforming as new technologies continue to enter the market. This rapid pace of change is perhaps felt most heavily in the electronics industry which brings in the biggest and newest innovations every year. Following, we'll look at the five foremost challenges electronic companies must look forward to:

Brief Product Life Cycles: Technology isn't evolving for its own sake. It's responding to the wants and needs of consumers hungry for products that perfectly suit their day-to-day lives. Thus, companies in Electronics Manufacturing Services and contract manufacturers are required to have quality processes in place for new product introduction. To make sure product launches hit set goals on quality, volume and release, it's important to use closed-loop communication concepts between engineering, sales and manufacturing.

Intricate International Supply-Chain: It is obvious now that we live in a global economy. Those who are positioned best to deal with the complexities of international sales are those best positioned to succeed in the long run. Now, it is common for components to skate across multiple continents—sometimes more than three—before arriving at their end point. Companies must be prepared to deal with varying international standards along with the twin issues of compliance and traceability that are prone to raise operational problems.

Demand: The worst of the global economic crisis is fortunately in the rear view mirror, so it is expected that the demand for electronics should continue to rise. While cyclical fluctuations and economic dips are responsible for large shifts in demand, on a smaller level technology is highly susceptible to changing local conditions because tech is now so heavily tied to consumer demand. Consumer demand is an uncertain thing, determined by the vagueness of perceived value and swiftly fleeting tastes. For that reason, production capabilities must remain lean and able to shift quickly with uncertain demand.

Environmental Issues: This is no longer a world where companies' margins are freely raised above the concerns of the environment. New standards and regulations are pushing electronic manufacturers to consider their 'social responsibility' when making decisions both small and large. A manufacturing consultant says some Electrical Engineering Master's programs are now including sustainable engineering strategies in their curriculum to accommodate the growing trend of environmental awareness. The entire life cycle of a product must be considered; from manufacturing, with the use of harmful chemicals and human exposure; to consumer use, with the consumption of energy; to the end of its life, with waste disposal and complex disassembly.

Tighter Margins: Consumers have benefited from a global marketplace that has emphasized competition to bring in the latest and greatest innovations and lower prices. On the supply side, however, this has to lead to shrinking margins. Gains in efficiency and organization

have slowed and there is not enough differentiation between products to stave off this growing trend of commoditization. Electronic manufacturers must deal with this downward pressure on operating margins as lights continue to turn on across the world.

2.3.7.3 Self-Assessment

i. Describe emerging trends in the electronics from a consumer perspective.

ii. Discuss the challenges of implementing emerging trends in Kenya digital space.

iii. Keeping in mind the changing dynamics in the electronic sector, what are the changes you envisage in computer hardware? Prepare a report, basis research on the latest trend of using electronic components in computer desktops

iv. Select latest Internet generation technology
   A. Edge
   B. 3G
   C. 5G
   D. 4G LTE
   E. 3.75G

v. IIoT stands for _____
   A. Industrial Internet of Things
   B. Internet Internet of Things
   C. Intelligence Internet of Things
   D. Internal Internet of Things

vi. Which possibility automatically communicates with other vehicles?
   A. Transportation and logistics
   B. Energy and utilities
   C. Automotive
   D. Connected supply chain

vii. Which possibility is the highest contributor to cost overhead for manufacturing facilities?
   A. Transportation and logistics
   B. Energy and utilities
   C. Plant control flow operation
   D. Energy management and resource optimization

2.3.7.4 Tools, Equipment, Supplies and Materials
Computer, Internet

2.3.7.5 References
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