SS3 FIRST TERM SCHEME OF WORK

WEEK	TOPIC	CONTENT
1	SIMPLE A.C CIRCUITS	- Nomenclature in A.C circuits - Peak/R.M.S values - Calculations on peak/R.M.S values
2	SIMPLE A.C CIRCUITS	- Resistance , capacitance and inductance in A.C circuits - Reactance , impedance and power in A.C circuits
3	NUCLEUS	- Radioactivity - Radioactive elements - Half life
4	NUCLEUS	- Nuclear reaction - Nuclear fission/fusion - Nuclear energy
5	ENERGY QUANTIZATION	- Energy levels in atoms - Excited state - Emission of light energy in return to ground state
6	ENERGY QUANTIZATION	- photoelectric effect - Einstein's photoelectric equation and its explanation - X- ray production, characteristics and uses
7	DUALITY OF MATTER	- Wave nature of matter - Particle nature of matter - The uncertainty principle

8	SEMI- CONDUCTORS	- Concept of semi – conductors - Types of semi - conductors(intrinsic and extrinsic) - Semi – conductor devices - Applications of semi- conductors
9	OPTICAL FIBRES	- Concept of optical fibres - Types of optical fibres - Uses of optical fibres
10	LASERS	- Meaning of LASERS - Types of LASERS - Uses of LASERS
11-13	Revision/Examination	

WEEK1

TOPIC: SIMPLE A. C CIRCUITS

A current that flows in one direction during one part of a cycle and in opposite direction during the rest part of the cycle is called an alternating current.

These alternating currents are being produced by alternating voltage source. These voltages are like a sine curve with constant amplitude and frequency such that

$$\boxed{V = V_o \sin \dot{\omega} t}$$

V_o = peak, maximum or amplitude voltage

$\dot{\omega} = 2\pi f$

The current produced as a result of a voltage source connected in circuit is given by

$I = I_o \sin (\dot{\omega} t + \phi)$

Where I=instantaneous current

I_o= peak, maximum or amplitude current

t= time of current flow

ϕ= phase angle

Example (j) The peak value of an A.C circuit is 240v. The instantaneous p.d at 1/8th of a cycle is

Solution

$V_0 = 240V$, $V = ?$, $\theta = \omega t = 1/8 \times 360 = 45^0$

$V = V_o \sin \omega t$

$V = 240 \sin 45^0 = 120\sqrt{2}\ V$

USES OF ALTERNATING CURRENT

1. Power technology
2. Power transmission
3. Power processing
4. Power distribution e.g. radio television satellite etc.

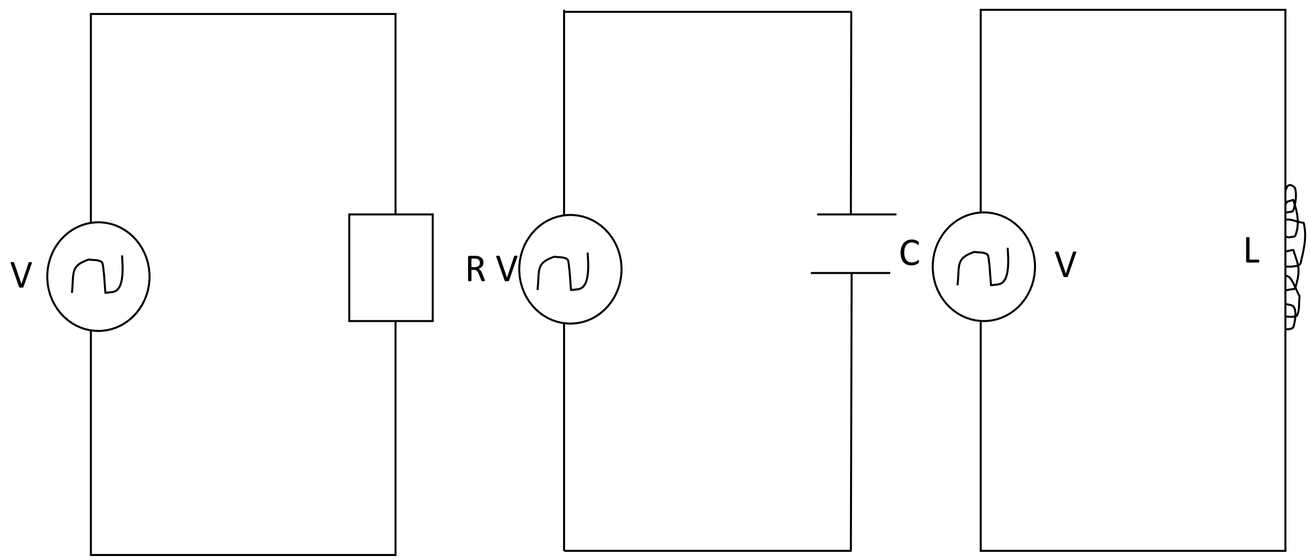
EFFECTIVE VALUE OR ROOT MEAN SQUARE (R.M.S)

This is the practical value being taken due to the continuous changing of the alternating currents and voltages. It is also the value of a steady direct current that would produce the same heating effect as the alternating current.

In relating to the above we have

$$\boxed{\begin{aligned} I_{eff} &= I_o/\sqrt{2} = 0.7071\ I_o \\ V_{r.m.s} &= v_o/\sqrt{2} = V_{eff} \\ I_{r.m.s} &= I_o/\sqrt{2} = I_{eff} \end{aligned}}$$

ALTERNATING CURRENT IN RESISTORS , CAPACITORS AND INDUCTORS



Resistive circuit

Capacitive circuit

Inductive circuit

In this resistive circuit, the current is in phase or step with the voltage. This means that both voltage and current attain their maximum, minimum, and zero values at the same time.

In the capacitive circuit, the current leads the voltage by 90^0 $(\pi/_2)$

$$Xc = \frac{V_o}{I_o} = \frac{1}{2\pi fc} = \frac{1}{wc}$$

Where

Xc = capacitive reactance in ohm (Ω) Which is the opposition posed by the capacitor to the flow of an alternating current.

V_o = Peak, maximum or amplitude voltage.

I_o = Peak, maximum or amplitude current.

C = capacitance in farad (F)

W = angular velocity = $2\pi f$. (rad/sec)

f = frequency in Hertz (Hz)

In the inductance circuit, the current lags the voltage by 90^0 ($\pi/2$)

$$X_L = \frac{V_o}{I_o} = \omega L = 2\pi f L$$

Where

X_L = inductive reactance in ohm (Ω) is the opposition posed by the inductor to the flow of alternating current.

L = inductance in Henry (H)

Also

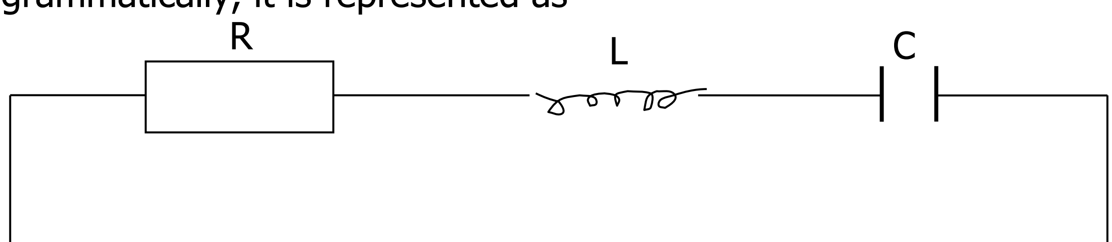
$$V = IR$$
$$V = I X_L$$
$$V = IX_C$$
$$V = IZ$$

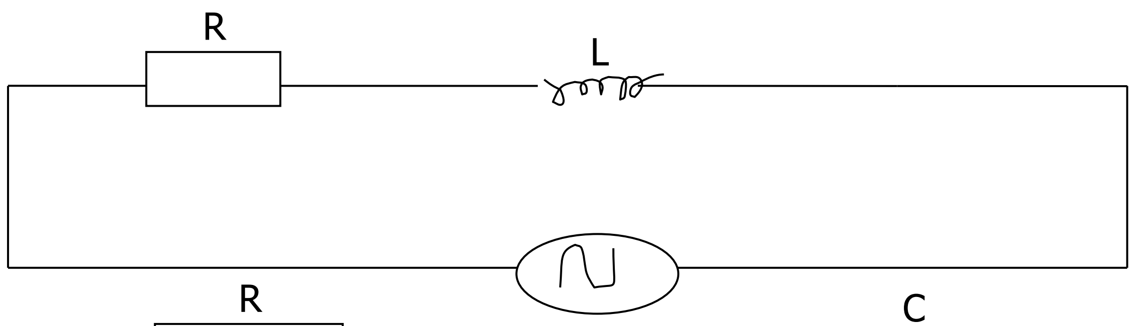
IMPEDANCE (Z)

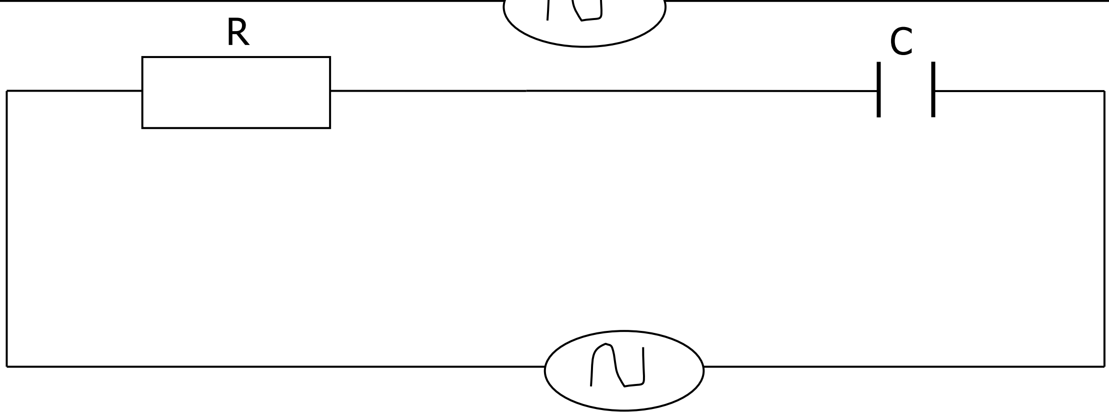
This is the overall opposition offered to the passage of an alternating current mixed circuit containing a resistor and anyone or both of an inductor and a capacitor. It is measured in ohms (Ω) and denoted by Z.

$$Z = \frac{Vo}{Io} = \sqrt{R^2 + (X_L - X_C)^2}$$

Diagrammatically, it is represented as



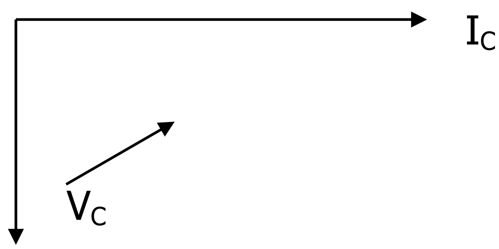




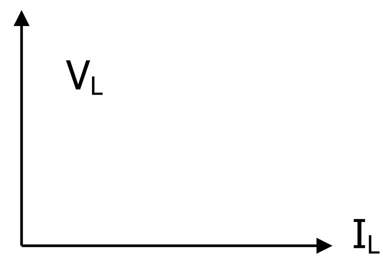
REACTANCE

This is the opposition offered to the passage of an alternating current by either the inductor or capacitor or both. It is measured in ohm (Ω). (**WAEC 2002 Q14 THEORY TEST YOURSELF)**

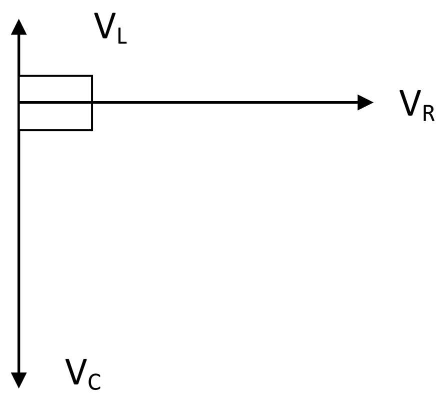
VECTOR DIAGRAM

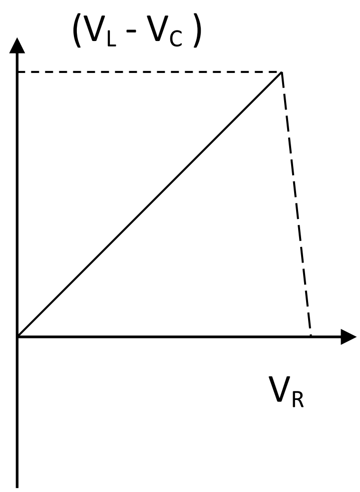


Capacitor



Inductor





By Pythagoras' theorem

$V_L < V_R < V_C$

$$\boxed{V^2 = V_R^2 + (V_L - V_C)^2}$$

R-L CIRCUIT

This contains only a resistor and an inductor. The impedance is

$$Z = \sqrt{R^2 + X_L^2}$$

R-C CIRCUIT

This contains only a resistor and a capacitor. The impedance is

$$Z = \sqrt{R^2 + X_C^2}$$

PHASE ANGLE

$$\tan \theta = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} \quad \text{(RLC Circuit)}$$

$$\tan \theta = \frac{X_C}{R} \quad \text{(RC Circuit)}$$

$$\tan \theta = \frac{X_L}{R} \quad \text{(RL Circuit)}$$

POWER IN AN AC CIRCUIT DERIVATION

$P = IV \cos \theta$ ---------------- (1)

Power factor $= \cos \theta = \frac{R}{Z} = \frac{\text{Resistance}}{\text{Impedance}}$ ---------------- (2)

Substitute equation (2) into equation (1)

$P = \frac{IVR}{Z}$ (if $V=IZ$)

$P = I^2R$

RESONANCE IN RLC CIRCUIT

Resonance is said to occur in an a.c series circuit when the maximum current is obtained from such a circuit. The frequency at which this resonance occurs is called the resonance frequency (fo). This is given by

$$\boxed{f_o = \frac{1}{2\pi\sqrt{LC}}}$$

Also $W_o = \frac{1}{\sqrt{LC}}$

CONDITIONS FOR RESONANCE TO OCCUR IN AN A.C CIRCUIT ARE:

(i) $X_L = X_C$

(ii) $Z = R$

(iii) $\theta = 0$ between current and voltage

(iv) Current is maximum and impedance is minimum.

APPLICATIONS OF RESONANCE

1. It is used to tune radio and television.
2. It responds strongly to one particular frequency.

ADVANTAGES OF AC OVER DC FOR POWER TRANSMISSION

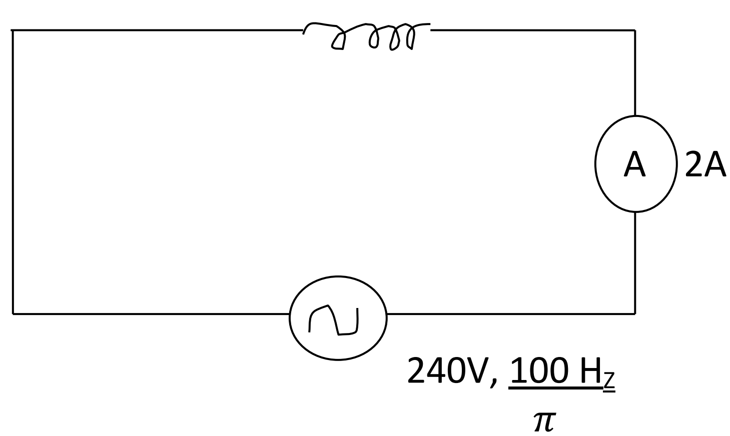
1. It can be easily or cheaply be stepped up or down by a transformer.
2. It minimizes loss of heat energy which can be transmitted over long distances.
3. It can be transmitted in a large quantity.

NOTE:

1. There is no practical LC circuit.
2. The current in a reactance is lower than that in the resistance.

CLASS WORK

1. Calculate the inductance L of the coil in the circuit shown below



WEEK2

TOPIC: ALTERNATING CURRENT

CALCULATIONS ON ALTERNATING CURRENT CIRCUIT

Example 1

A series RLC circuit comprises a 100Ω. Resistor, a 3H inductor and a 4μF capacitor. The a.c source of the circuit has an e.m.f of 100V and a frequency of $\frac{160}{\pi}$ Hz

(i) Draw the circuit diagram of the arrangement. Calculate the.

(ii) Capacitive reactance.

(iii) Inductive reactance.

(iv) Impedance of the circuit.

(v) Current in the circuit.

(vi) Average power dissipated in the circuit.

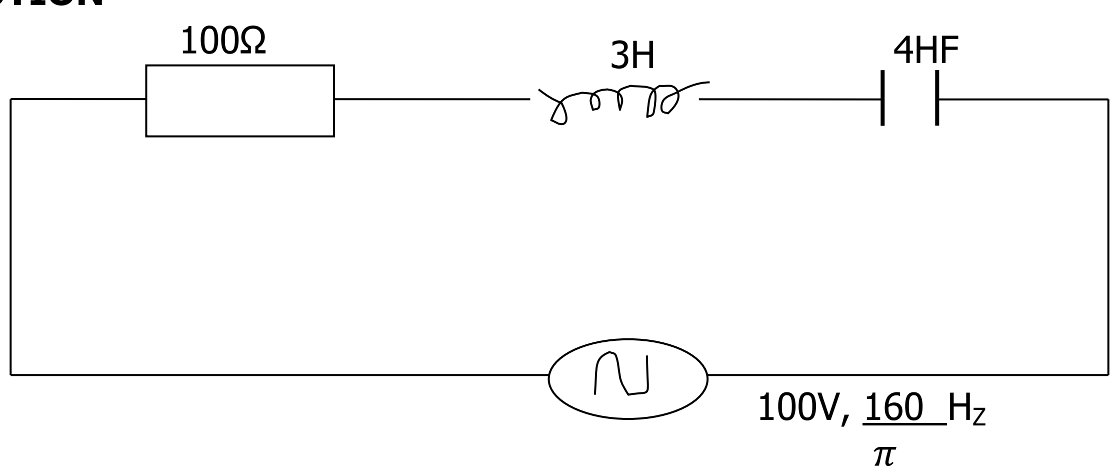
(vii) Power factor

(viii) Phase angle

(WASSCE MAY/JUNE 1999 Q 14 THEORY)

SOLUTION

(i)



(ii) $X_C = \frac{1}{2\pi fc} = \frac{1}{2 \times \pi \times \frac{160}{\pi} \times 4 \times 10^{-6}} = 781.25\Omega$

(iii) $X_L = 2\pi fl \qquad 2 \times \pi \times \frac{160}{\pi} \times 3 = 960\Omega$

(iv) $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{100^2} + (960 - 781.25)^2 = 205\Omega$

(v) $V = I Z$

$I = \frac{V}{Z} = \frac{100}{205} = 0.49A$

(vi) $P = I^2R = 0.49^2 \times 100 = 24$ watt

OR

$P = IV \cos \Theta = \frac{IVR}{Z} = \frac{0.49 \times 100 \times 100}{205} = 24$watt

(Vii) Power factor $\cos \Theta = \frac{R}{Z} = \frac{100}{205} = 0.49$

(viii) Phase angle $\tan \Theta = \frac{X_L - X_C}{R}$

$= \frac{960 - 781.25}{100}$

$\tan \Theta = 1.7875$

$\Theta = \tan^{-1} 1.7875$

$\Theta = 60.8^0$

Example 2

A source of e.m.f 240v and frequency $50H_Z$ is connected to a series arrangement of a resistor, an inductor and a capacitor. When the current in the capacitor is 10A, the potential difference across the resistor is 140V and that across the inductor is 50V. Calculate the,

i. Potential difference across the capacitor.

ii. Capacitance of the capacitor

iii. Inductance of the inductor

(WASSCE MAY/JUNE 1991 & 2002 Q14a,b,c &d)

Solution

i. $V^2 = V^2_R + (V_L - V_C)^2$

$240^2 = 140^2 + (50 - V_C)^2$

$240^2 - 140^2 = (50 - V_C)^2$

$57600 - 19600 = (50 - V_C)^2$

$\pm\sqrt{38000} = (50 - V_C)$

$50 - V_C = \pm 194.9$

$V_C = 244.9\text{v}$ and -144.9v

ii. $X_C = \frac{Vc}{Ic} = \frac{1}{\omega c} = \frac{1}{2\pi fc}$

$\frac{1}{2\pi fc} = \frac{Vc}{Ic}$

$\frac{1}{2 x \pi x 50 x C} = \frac{244.9}{10}$

$C = \frac{10}{2 x \pi x 50 x 244.9} = 129.97 x 10^{-6}F$

iii. $X_L = 2\pi f l = \frac{V_L}{I_L} = \dot{\omega} L$

$$2\pi f l = \frac{V_L}{I_L}$$

$$2 \times \pi \times 50 \times L = \frac{50}{10}$$

$$L = \frac{50}{1000 \times 3.142} = 0.0159H$$

Example 3

Calculate the instantaneous value of such a current, if in a circuit it has r.m.s value of 15A when its phase angle is 30^0 **(SSCE NOV. 1989)**

SOLUTION

$I_{r.m.s} = 15A$, $\Theta = 30^0 = \dot{\omega}t$

$$I_{r.m.s} = \frac{I_O}{\sqrt{2}}$$

$$I_O = I_{r.m.s} \times \sqrt{2} = 15\sqrt{2}$$

$$I = I_O \sin \Theta$$

$$= 15\sqrt{2} \times \sin 30$$

$$= 15\sqrt{2} \times 0.5$$

$$= 10.6A$$

CLASS WORK

A resistor of resistance 50Ω, a capacitor of capacitance 0.1μF and an inductor of inductance 0.1H with 150Vrms alternating voltage supply,

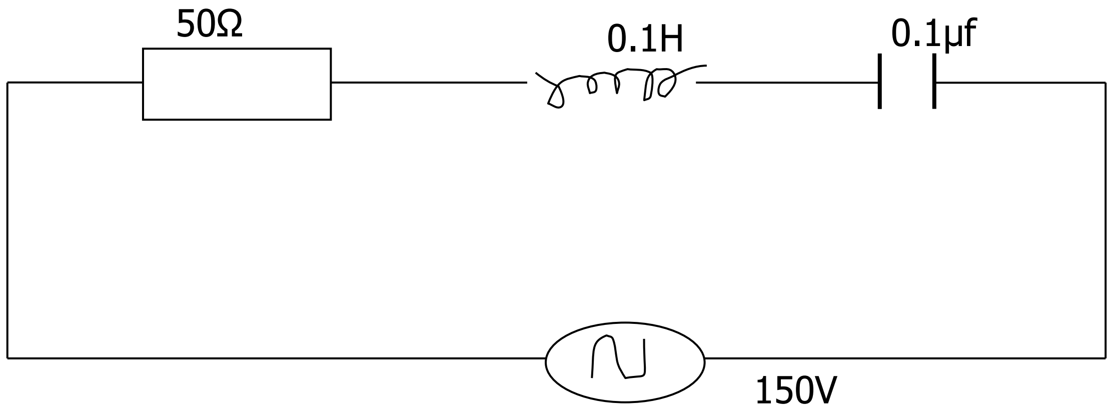
(i) Draw the diagram of the circuit **(2marks)**

(ii) Calculate the root mean square current. **(4marks)**

(iii) Calculate the resonant frequency **(2marks)**

(WASSCE NOV/DEC 2004)

Solution



(ii) $V_o = I_o Z$

$$I_o = \frac{V_o}{Z} = \frac{150}{50} \text{ (At resonance R = Z and } I_{r.m.s} = V_o \text{)}$$

$$= \frac{15}{5} \quad 3A$$

$$I_{r.m.s} = \frac{I_o}{\sqrt{2}} = \frac{3}{\sqrt{2}} = 2.12A$$

(iii) $$f_o = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.142\sqrt{0.1 \times 0.1 \times 10^{-6}}} = 1591.34H_Z$$

ASSIGNMENT

1. The current I in an a.c circuit is given by the equation $I = 30 \sin 100\pi t$ where t is the time in seconds. Deduce the following from this equation.

(i) Frequency of the current

(ii) Peak value of the current

(iii) r.m.s value of the current **(SSCE JUNE 1993Q4C)**

2. An alternating source of 10V and frequency 100H_Z is connected in series with a 5Ω resistor and 20mH. Calculate the

(i) Reactance of the inductor

(ii) Impedance of the circuit

(iii) Potential difference across the inductor

(WASSCE NOV/DEC 2001)

3. A source of e.m.f 110V and frequency 60H_Z is connected to a resistor, an inductor and a capacitor in series. When the current in the capacitor is 2A, the potential difference across the inductor is 40v. Draw the vector diagram of the potential differences across the inductor, the capacitor and the resistor. Calculate the

   (i) Potential difference across the capacitor

   (ii) Capacitance of the capacitor

   (iii) Inductance of the inductor (π = 3.142)

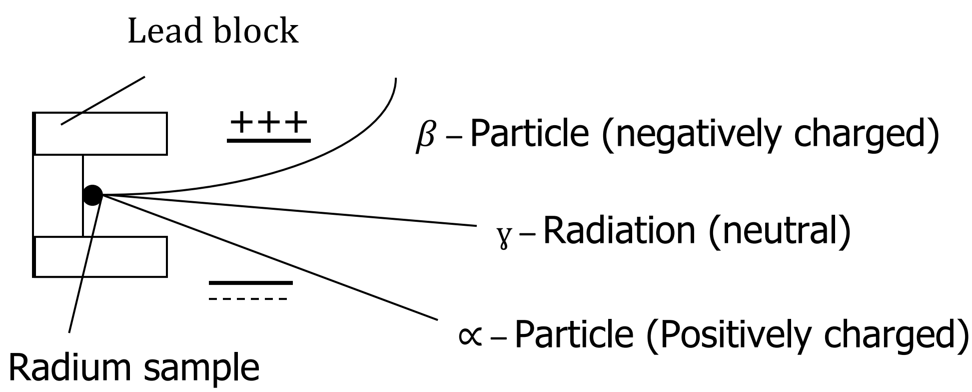
   (WASSCE MAY/JUNE 2009 N0 14 theory

WEEK3.

TOPIC: NUCLEUS

RADIOACTIVE ELEMENT AND TYPES OF RADIOACTIVITY

Radioactivity is the spontaneous decay or disintegration of unstable nuclei of an atom of a radioactive element during which alpha (∝) particle, beta (β) particle and gamma (ɣ) radiation or any of the combination may be emitted with the release of heat energy (Q)



Behaviour of∝, β particle and ɣ-radiation to electric field

RADIOACTIVE ELEMENTS

Radioactive elements are elements with unstable nucleus e.g. radon ($^{222}_{86}Rn$), radium ($^{226}_{88}Ra$), uranium ($^{238}_{93}U$),

Thorium ($^{234}_{90}Th$), etc

TYPES OF RADIOACTIVITY

There are two types of radioactivity which include:

1. Natural radioactivity (Atomic number ≥ 84)

2.Artificial radioactivity (Atomic number < 84)

NATURAL RADIOACTIVITY

Natural radioactivity occurs when a radioactive element absorbs heat energy from its surrounding, its nucleus becomes unstable and may split up by itself to emit alpha ($\propto$) particle, Beta (β) particle or gamma radiation or any combination of the three.

TYPES OF NATURAL EMISSION OR DECAY

1. **Alpha ($\propto$) Decay:-**The symbol for alpha particle is $^{4}_{2}He$ i.e. Helium nucleus.

Example 1

Radium $^{226}_{88}Ra$ decay producing Radon $^{222}_{86}Rn$, with the emission of

heat. What is the name of the particle emitted in this reaction process?

Solution

$$^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{a}_{b}X + Q$$

226 = 222 + a   88 = 86 + b

226 – 222 = a   88 – 86 = b

4 = a   2 = b

… $^{a}_{b}X = {}^{4}_{2}X$, The particle emitted is alpha

Q = heat energys

(i) **Beta (β) Decay :-** The symbol for beta particle is $^{0}_{-1}e$ an electron

Example 2

From the equation below, what is the ratio of X to Y?

$^{238}_{92}U \longrightarrow X^4_2He + Y\ ^o_{-1}e + ^{230}_{90}Th$ + energy (Q)

Solution

Considering the mass numbers

$238 = 4x + yxo + 230$

$238 - 230 = 4x$

$\frac{8}{4} = \frac{4x}{4}$

$X = 2$

considering the atomic numbers

$92 = 2x - y + 90$

$92 - 90 = 2x - y$, but $x = 2$

$2 = 2x2 - y$

$2 = 4 - y$

$y = 4 - 2 = 2$

$X/Y = {}^2/_2 = 1$

(ii) **Gamma (ɣ) Decay:-**The symbol for gamma radiation is : ɣ
which means that when a radioactive element emits gamma radiation, the element formed is identical with the decayed element.

$^{222}_{86}Rn \longrightarrow\ ^0_0ɣ + ^x_yQ$ +Energy

$222 = 0+x = 222,$ $86 = 0+y = 86$

… $^x_yQ = ^{222}_{86}Q$

That is both the reactant and the new product formed has the same chemical properties.

<u>ARTIFICIAL RADIOACTIVITY</u>

Artificial radioactivity may be induced by firing neutrons or ∝ - particles into stable (i.e. naturally non-radioactive) nuclei e.g.

$^{27}_{13}Al + ^4_2He \longrightarrow\ ^{30}_{4}Si + ^1_1H$ + Energy (Q)

$^{9}_{4}Be + ^{4}_{2}He \longrightarrow ^{13}_{6}C \longrightarrow ^{12}_{6}C + ^{1}_{0}n$ + Energy (Q)

Unstable Stable

DIFFERENCES BETWEEN NATURAL AND ARTIFICIAL RADIOACTIVITY

S/N	NATURAL RADIOACTIVITY	ARTIFICIAL RADIOACTIVITY
i.	Disintegration is not induced	Disintegration is induced
Ii	Nucleus is unstable	Nucleus is stable
Iii	Has heavy nucleus	Has light nucleus
Iv	Has single reactant	Has double reactant

HALF-LIFE AND DECAY CONSTANT

Half-life ($T_1/_2$) is defined as the time taken for half of the radioactive element to decay or disintegrate into half of its original value. Half-life ($T^1/_2$) is basically measured in seconds (s).

Or it is defined as the time taken for a given mass of radioactive substance to disintegrate to half its initial mass.

Example 1

After three half-lives, what fraction of a radioactive material has decayed? **(JAMB 1992).**

Solution

Let the original value of the radioactive element be

A_o and its half-life be $T^1/_2$

$$A_o \xrightarrow{T^1/_2} A\,^o/_2 \xrightarrow{T^1/_2} A\,^o/_4 \xrightarrow{T^1/_2} A\,^o/_8$$

$A_o/8$ is the remaining element after three half-lives.

The fraction that has decayed after three half-lives

is $A_o - A_o/8 = \frac{8A_o - A}{8} = {}^{7}/_{8}$ of A_o

CLASS WORK

4g of radioactive material of half-life 10 days is spilled on a laboratory floor. How long would it take to disintegrate 3.5g of the material?

Decay constant (λ) is defined as the instantaneous rate of decay per unit atom of the substance or

$$\text{Decay constant } (\lambda) = \frac{\text{no of atoms disintegrating per second}}{\text{No of atoms in the source at that time}}$$

CLASS WORK

1. The following nuclear equations represent two types of radioactivity

   $^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}\alpha$ (Equation A)

   $^{14}_{7}N + {}^{4}_{2}\alpha \longrightarrow {}^{17}_{8}O + {}^{1}_{1}P$ (Equation B)

   Identify each type and explain briefly the difference between them. (JUNE 2010 WASSCE)

2. A nuclide $^{A}_{Z}X$ emits β-particle to form a daughter nuclide Y. write a nuclear equation to illustrate the charge conservation (JUNE 2006 WASSCE).

3. Tabulate the properties of ∝-particles, β-particles and ɣ –rays

4. Who discovered radioactivity?

Assignment

1. (a) Define the following terms (i) radioactivity (ii) Half-life (iii) decay constant

   (b) Write down the relationship between half-life and decay constant.

   (c) In 180 minutes, the activity of a certain radioactive substance falls to one-eight of its original value. Calculate its half-life.

   (d) The half-life of a radioactive element is 60 minutes explain.

2. The half-life of radioactive iodine is measured to be 8.0 days. A solution contained 1.5mg of this iodine on a certain day. Write down on a table the mass of iodine remaining after 0, 8, 16, 24 and 32 days. Plot a graph of mass against time and from it deduce the mass of iodine that would remain at the end of 30days. Justify this remaining mass using calculation method.

APPLICATIONS OF RADIOACTIVITY

When the same elements have the same atomic number but different mass number such elements are known as isotopes.

When two or more elements have the same mass number but different atomic number, such elements are known as isobar.

DETECTION OF RADIATION

Some of the radioactive detectors are:

(i) Rate meter (ii) Geiger – muller tube counter

(iii) Photographic plate (iv) solid state detector

(v) Diffusion cloud chamber (vi) Dekatron counter

APPLICATIONS OF RADIOACTIVITY

Radioactive substances can be applied or used in the following areas:

(i) Agricultural and scientific research

- As tracer to trace the path of metabolic processes in plants and animals
- To induce mutation in plants and animals
- To induce recent organic remains

(ii) Medical field

- ɣ – rays is used to treat cancer patients
- ɣ – rays is used to sterilize surgical equipment

(iii) Industry/industrial field

- To study defects in metals and welded joints
- To check metal fatigue
- To trace underground pipe leakages
- To detect wears of parts of machine e.g. gear-box

Assignment

1. A radioactive nucleus of mass 6.0g has a half-life of 8 days. Calculate the time during which 5.25g of the nuclei would have decayed (Ans 24 days).

2. A radioactive substance has half-life of 3 days, if a mass of 1.55g of this substance is left after decaying for 15 days, determine the original value of the mass (Ans 49.6g) **JUNE 2004 Q49**

3. The isotope of a nuclide has a half-life of 5.40×10^3s. Calculate the decay constant (Ans $1.283 \times 10^2 s^{-1}$ **JUNE 2005 Q15**)

WEEK4

TOPIC: NUCLEUS

NUCLEAR REACTION

A nuclear reaction is a process that causes a change in an atomic nucleus, which can be triggered by a collision or occur spontaneously. This change results in the transformation of at least one nuclide (an atom with a specific number of protons and neutrons) into a different nuclide, often involving the release or absorption of significant energy. Common examples of nuclear reactions include nuclear fission (splitting an atom), nuclear fusion (combining atoms), and radioactive decay (spontaneous emission of particles).

Key characteristics of nuclear reaction

1. Atomic transformation:

Unlike chemical reactions that involve only electrons, nuclear reactions affect the protons and neutrons within the nucleus thereby changing the element itself.

2. Energy change:

These reactions can either release or absorb large amounts of energy.

TYPES OF NUCLEAR REACTION

The two types of nuclear reactions are:

1. Nuclear fission
2. Nuclear fusion

Nuclear fission is a nuclear reaction in which a heavy nucleus splits into different lighter nuclei, emitting neutrons (!n) with the release of large amount of energy.

e.g. !n + ${}^{235}_{92}U \longrightarrow {}^{236}_{92}U \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr$ + 3!n+ Energy (Q)

Nuclear fusion is a nuclear reaction between two light nuclei at high temperature forming a heavier nucleus with the release of very large amount of energy.

e.g. ${}^{3}_{1}H + {}^{1}_{1}H \longrightarrow {}^{4}_{2}He$ + Energy

Tritium + protium $\longrightarrow$ helium + Energy

<u>DIFFERENCES BETWEEN NUCLEAR FISSION AND NUCLEAR FUSION</u>

S/N	NUCLEAR FISSION	NUCLEAR FUSION
1.	Heavy nucleus split	Light nuclei combine to form a heavier nucleus
2.	One or more neutrons are produced per parent nucleus	Neutrons are not produced
3.	It can take place at room temperature	It takes place at a very high temperature
4.	Releases less energy	Releases more energy

5.	Produces dangerous radioactive by products	Produces less dangerous (non-radioactive) by – products

Fusion is not put to use because it takes place at a very high temperature. The sun produces its energy through nuclear fusion.

CLASS WORK

1. Explain (i) Nuclear fission (ii) nuclear fusion.

2. State three applications of atomic energy. **[JUNE 2002 WASSCE Q 15]**

Answer

1.

i. Nuclear fission is a nuclear reaction in which a heavy nucleus splits into different lighter nuclei, emitting neutrons (!n) with the release of large amount of energy.

ii. Nuclear fusion is a nuclear reaction between two light nuclei at high temperature forming a heavier nucleus with the release of very large amount of energy.

2. Applications of atomic energy

(a) Power generation and industry

1. Electricity: Nuclear power plants use fission to generate steam, which spins turbines to produce electricity.

2. Process heating: Provides high-temperature heat for industries like steel and cement manufacturing, as well as for hydrogen production and seawater desalination.

3. **Space applications:** Nuclear energy is used to power satellites and space probes, providing energy for long-duration missions.
4. **Industrial processes:** Techniques like industrial radiography, non-destructive testing, and material modification use nuclear technology.

(b) Medicine and healthcare

1. **Cancer therapy:** Radiation therapy uses atomic energy to treat cancerous cells and tumors.
2. **Diagnostic imaging:** Techniques such as PET scans and the use of X-rays use radioactive materials to visualize the inside of the body.
3. **Sterilization:** Radiation is used to sterilize medical equipment.
4. **Surgery:** Radioactive isotopes can assist in certain surgical procedures.

(c) Agriculture and food

1. **Pest control:** Radiation can be used to sterilize insects, preventing them from reproducing.
2. **Crop improvement:** Radioactive tracers can help in monitoring the uptake of fertilizers and improving crop yields.
3. **Food preservation:** Radiation can be used to extend the shelf life of food.

(d) Research and other uses

1. **Dating:** Radiocarbon dating uses radioactive isotopes to determine the age of archaeological and geological samples.
2. **Security:** Radiation is used in imaging scanners to detect illegal substances in cargo.
3. **Scientific research:** Atomic and nuclear physics have led to advancements in technologies like quantum computing and atomic clocks.

BINDING ENERGY

Binding energy is the energy required to separate a system into its constituent parts, such as the energy needed to pull an atomic nucleus apart into its protons and neutrons.

Types of binding energy

1. **Nuclear binding energy:** This is the energy required to separate a stable nucleus into neutrons and protons. This energy can be calculated from the difference between mass of the nucleus and mass of the nucleon. **Nucleon is the sum of neutrons and protons in the nucleus of an atom.**
2. **Chemical Binding Energy:** This is the energy required to break a chemical bond between atoms in a molecule.
3. **Atomic Binding Energy:**
   This is the energy required to separate all the electrons from the nucleus of an atom.

EINSTEIN MASS-ENERGY RELATION

From Albert Einstein theory of relativity, mass and energy are equivalent and are related by the equation $E = \Delta MC^2$

Where ΔM = the difference between mass of the nucleus and mass of the nucleon. It is called mass defect and C = velocity of light = 3.0×10^8 m/s

Energy released $\propto \Delta M$

Example 1

The radioactive nuclei $^{210}_{84}P_o$ emits an $\propto$- particle to produce $^{206}_{82}P_b$. Calculate the energy in MeV released in each disintegration. 1U =931MeV

Take the masses of $^{210}_{84}P_o$ = 209.936730U

$^{206}_{82}P_b$ = 205.929421U

$^{4}_{2}He$ = 4.001504U

And that 1U = 931MeV. **WASSCE 2006**

Solution

Mass defect ΔM = [209.936730 – (205.929421 + 4.001504)]U

= (209.936730 – 209.930925)U

$\triangle M = 0.005805U$

Energy released $= 0.005805 \times 931MeV$

$= 5.404455MeV$

CLASS WORK

Deuterium and Tritium fused to form a helium nucleus according to the equation

$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n + Energy$

Calculate in joule, the energy released.

$^{3}_{1}H=3.01605U$; $^{2}_{1}H=2.01410U$

$^{4}_{2}He=4.00260U$; $^{1}_{0}n= 1.00867U$

$1U=931MeV$; $1eV =1.6 \times 10^{-19}J$ (**NECO 2004**)

NUCLEAR ENERGY AND ITS USES

The energy released during nuclear reaction is called nuclear energy.

Nuclear energy is used for the production of destructive hydrogen or nuclear bombs.

PEACEFUL USES OF NUCLEAR ENERGY/ATOMIC ENERGY

1. Generation of electric power
2. For radiotherapy in medical field
3. For radioactive tracers and preservatives in agricultural field.
4. For detecting of leakages in underground pipes carrying oil and gas
5. To power some spacecraft's, ships and submarines

Assignment

(a) Write an equation to show the relationship between mass defect and binding energy of a nucleus.

(b) A nuclide of $^{40}_{19}K$ of mass 39.964001U decays to a nuclide of $^{40}_{20}Ca$ of mass 39.962582U.

(i) Write the energy equation which describes the energy of $^{40}_{19}K$ atom into a $^{40}_{20}Ca$ atom.

(ii) Identify the particles emitted by the decaying nucleus.

(iii) Calculate the energy released from the $^{40}_{19}K$ nucleus during the decay. [1U=1.6604 x 10^{-27}kg, c=3 x 10^{8}m/s]

(**WASSCE NOV/DEC 2004 N0 15 THEORY**)

HEALTH HAZARDS FROM RADIOACTIVE SUBSTANCES

When the body is exposed to radioactive substances for a long time, the radiation

1. Can destroy cells in tissues
2. Upset natural chemical reactions
3. Can bring about genetic changes or mutation
4. Can cause cancer
5. $\propto$ -particles can damage the skin
6. Can cause sterility
7. Can cause blood abnormalities
8. Can kill

SAFETY PRECAUTIONS

Because of the health hazard from radioactive substances, workers in radiological laboratories must:

1. Monitor their radiation exposure regularly.
2. Be shielded with thick blocks of lead, iron or concrete

WEEK 5

TOPIC: ENERGY QUANTIZATION

Energy quantization is the fundamental quantum mechanics principle that energy isn't continuous but exists in discrete, specific packets or levels, like steps on a staircase, meaning a system can only absorb or emit energy in exact multiples of a base unit (a "quantum"), explaining why atoms have stable energy states and emit/absorb light at precise frequencies. From Neil Bohr's atomic model, electrons in an atom can only exist in certain orbits, they take a fixed value. We say that the electrons have energy that is quantized (fixed). These quantized values are known as the energy levels of the atom.

The energy levels are usually represented by a series of horizontal lines with the lines numbered n = 1, 2, 3, ………………., ∞; n is known as quantum number. These energy levels get lower in value as the orbits gets nearer to the nucleus. The lowest energy level i.e. n = 1 is called ground state of the atom.

In the case where n = ∞, the atom is said to be ionized.

The energy of an electron $E_n = -\frac{R}{n^2}$ ………………….. (1)

The energy of an electron $E_n = \frac{E_0}{n^2}$ ………………….. (2)

Where R = Rydbergs constant = $1.097 \times 10^{7} m^{-1}$

n = 1, 2, 3, …………..∞ = quantum number.

E_0=Ground state energy

When is an atom said to be ionized?

An atom is ionized when it gains or loses one or more electrons, resulting in an electrical charge.

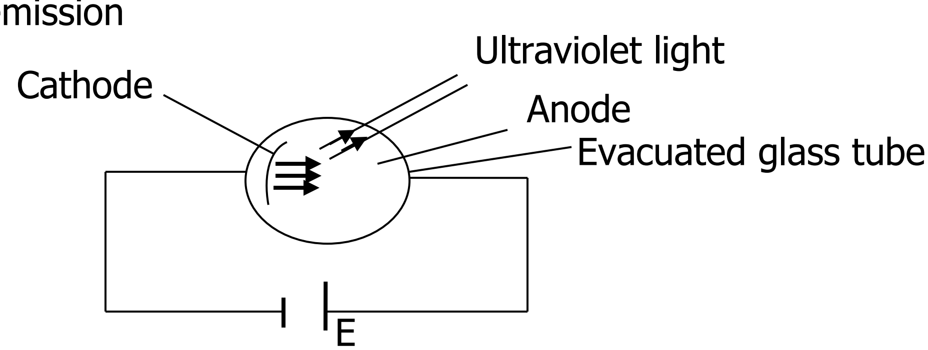
1. **Losing an electron:** An atom that loses an electron becomes positively charged because it now has more protons than electrons.
2. **Gaining an electron:** An atom that gains an electron becomes negatively charged because it has more electrons than protons.
3. **Ionization energy:** The minimum energy required to remove an electron from an atom is called its ionization energy

PHOTOELECTRIC EMISSION [WAEC 1989 Q4ai]

Photoelectric emission is the ejection of electrons from the surface of a metal when electromagnetic radiation (light) of appropriate frequency/wavelength is incident on the metal.

PHOTOCELL

Photocell is a device whose mode of operation depend on photoelectric emission



Photocell

PHOTOCELL MODE OF OPERATION

When radiation of high frequency ($\geq$ threshold frequency) falls on the cathode with a photo sensitive surface, electrons are emitted. This is because the anode is positive and the cathode is negative, electrons are attracted to the anode which completes the circuit and hence current flow through the circuit.

APPLICATIONS OF PHOTOCELL

Photocell finds its application in

1. Photometers
2. Burglar alarms
3. Automatic doors
4. Television camera
5. Sound production from film tracks
6. Automatic digital counters
7. Automatic street lighting

Factors which affect the number of emitted electrons per second are:

(i). Intensity of radiation

(ii). Number of photons

Factors which affect the maximum kinetic energy of the emitted electrons are:

(i). frequency

(ii). wavelength of light ($E_{(max)K}=hf=hc/\lambda$).

Atomic spectra

Atomic spectra are series or band of coloured lines observed in an emitted light when atoms are excited emitting light of certain wavelengths and frequencies which correspond to different colours. They are frequencies of electromagnetic radiation emitted or absorbed during transitions of electrons between energy levels within an atom

Types of atomic spectra

1. **Emission spectra.**

   This is a series of bright coloured lines on a dark background. It is formed when an atom absorbs heat or electrical energy exciting its electrons to higher energy levels. When these electrons fall back to lower levels, they emit photons of specific energies , creating these bright lines. Examples include: neon signs, xenon signs, fireworks, amber glow of sodium in a flame, colourful light from mercury vapour lamps, unique bright lines from hydrogen gas, bright lines from iron observed in laboratories.

2. **Absorption spectra.**

   These are dark lines (missing wavelengths) on a continuous spectrum (rainbow). It works when white light passes through a cool gas. The atoms in the gas absorb photons with energies matching their electron trnasitions, causing dark gap where those wavelengths were removed. Chlorophyll's blue/red absorption for photosynthesis, copper sulphate solution's blue-green appearance(absorbing yellow/red), distinct gas/element like hydrogen gas.

3. **Continuous absorption spectra (solids/liquids).**
   Blue glass: Absorbs most colours except blue, mixing the transmitted light appear blue.
   Copper sulphate solution: Appears blue because it absorbs yellow, orange and red light from white light.

Black body: A perfect black body absorbs all wavelengths, creating a continuous absorption spectrum.

4. **Line absorption spectra (Gases/Atoms)**

   Hydrogen gas shows dark lines at specific wavelengths when white light passes through cool hydrogen as electrons absorb energy to jump to higher levels

5. **Band absorption spectra (molecules)**

   Organic compounds: They show broad bands of absorption due to molecular rotations and vibrations, not just electronic jumps.

MODELS OF THE ATOM

SUB-TOPIC: CONCEPT OF THE ATOM

Atom was considered to consist of the simplest component of matter which is an indivisible tiny hard spheres but the discovery of radioactivity by Henry Becquerel showed that atoms are complex rather than indivisible. It showed that atoms are not indivisible but can disintegrate to form atoms of different elements. Also, the discovery of cathode rays in electric discharge tube by William Crookes revealed that negatively charged electrons are components of the atom.

ATOMIC STRUCTURE

The basic building blocks of an atom are;

(i) The electrons (Z) which revolve round the atom with a charge of $1.6 x 10^{-19}$C and of mass $9.1 x 10^{-31}$Kg

(ii) The dense nucleus which contain:

(a) The proton (Z) which is positively charged with the value of $1.6 x 10^{-19}$C and of mass $1.673 x 10^{-27}$Kg.

(b) The neutron (N) which has no charge and of mass 1.675×10^{-27}Kg.

The sum of the proton number (Z) and the neutron number (N) is called mass number (A) or nucleon number (A)

Mathematically

$A = N + Z$

Example 1

What is the proton number (Z) of an element whose nucleon number (A) is 226 with a neutron number (N) of 138.

Solution

$A = 226, N = 138 \quad A = N+Z, \quad Z = A - N = 226 - 138 = 88$

VARIOUS MODELS OF THE ATOM AND LIMITATIONS

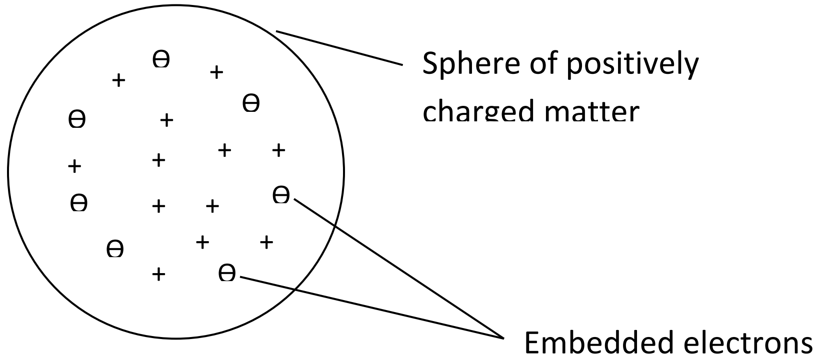
Before the real knowledge of atomic structure, different people explain their own view about an atom. These different views of an atom are known as models of the atom.

John Dalton is generally credited as the father of atomic theory but the early Greek Philosophers were the originator of atomic concept.

JOHN DALTON'S LIMITATION

He viewed the atom as indestructible but radioactivity showed that atoms are not indestructible but can disintegrate forming atoms of different elements.

Sir J.J. Thomson the English physicist propose an atomic model which visualized the atom as a homogeneous sphere of positive inside of which are embedded with negatively charged electrons as shown below in fig (i)



Fig(1) J.J. Thomson's model of the atom.

J.J. Thomson also determines the ratio of charge (e) to mass (m) and found e/m to be constant for all cathode-ray particles.

SIR J.J. THOMSON'S LIMITATION

Rutherford experiment showed that charges are not homogeneous in an atom but the positive charges are concentrated in the nucleus

Ernest Rutherford and his co-workers performed an experiments where beam of positively charged alpha ($\propto$) particles was directed at a thin sheet of a metal foil. It was found that most of the alpha-particles passed through the foil without deflection as if the foil were mostly empty space. Only a few of them were diverted from their paths.

The conclusions of Rutherford's experiment on the scattering of alpha particles by a thin foil are

(i) The nucleus is massive

(ii) Most of the atom is empty space

(iii) The nucleus is positively charged

(iv) Electrons revolve round the nucleus

(v) It explains the periodicity of elements in the periodic table.

ERNEST RUTHERFORD'S LIMITATIONS

(i) He predicted that light of a continuous range of frequencies will be emitted whereas experiment shows line spectra instead of continuous spectra.

(ii) He predicted that atoms are unstable but we all know that atoms in general are stable since the matter around us are stable.

ASSIGNMENT 5

(1) **Define:**

(i) Proton number

(ii) Nucleon number

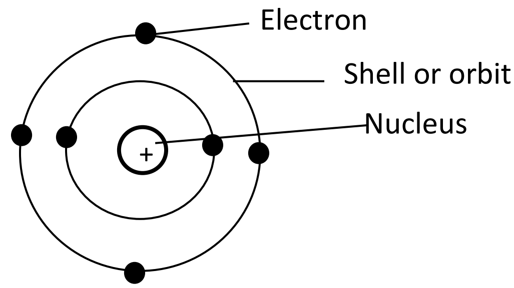
(iii) Isotopes **(JUNE 2006 WASSCE)**

(2) State three (3) conclusions that can be drawn from Rutherford's experiment on the scattering of alpha particles by a thin metal foil in relation to the structure of the atom. **(JUNE 2010 WASSCE)**

THE NEIL BOHR'S ATOMIC MODEL

Niels Bohr who had studied in Rutherford's laboratory, suggested a model of the hydrogen atom in which he stated that

(i) The electron moves around the nucleus in certain specific circular orbits or shell called energy level located at some distance from the nucleus.



(ii) Electrons in an atom cannot lose energy continuously but must do so in quantum jump. In other words, as long as any electron stays in one orbit, it does not radiate energy. When an electron jumps from higher to a lower energy level, a single photon of light would be emitted whose energy is given by

$$hf = Eu - E_L \text{ .... } (f_1)$$

Where Eu and E_L are the upper and lower energy value, h = Planck's constant = 6.6×10^{-34} J.S and f is frequency of the emitted light.

When an electron absorbs energy and move to a higher energy level, the electron is said to be excited

(iii) The angular momentum values (L) of the electron in an atom are quantized i.e. they are limited to number of discrete values that are integral (n) multiples of a constant h divide by 2π

Angular momentum $L = n (h)/2\pi$
Where n = 1, 2, 3, 4. called quantum numbers.

CLASS WORK

In a model of the hydrogen atom, the energy levels Wn are given by the formula $Wn = -^{R}/n^2$, where n is an integer and R is a constant. Determine the energy released in a transition from n = 3 to n = 2 **(JUNE 2002 WASSCE Q 45)**

NIEL BOHR'S MODEL LIMITATIONS

(i) It is not a complete model

(ii) It cannot be used to calculate many important properties of the atom such as intensities or the spectra lines

(iii) It is not useful for atoms with more than one electron.

(iv) It completely violates the uncertainty relationship.

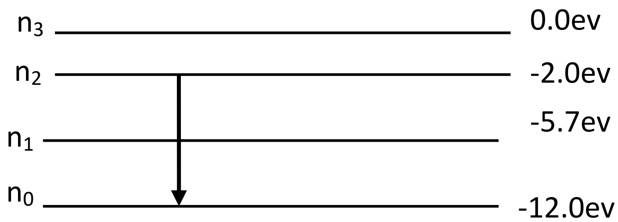
(v) It deals with only circular orbit

(vi) It deals with only hydrogen like atom

Assignment

2001 Q44, 2000 Q 15b

(1)



The diagram illustrates the energy levels of an electron in an atom. If an excited electron moves from n_2 to n_0,
Calculate the;
(i) Frequency (ii) Wavelength of the emitted radiation
[$h = 6.6 \times 10^{-34}$ J.S $1ev = 1.6 \times 10^{-19}$ J, $C = 3 \times 10^{8}$ m/s]
(JUNE 2010 WASSCE)

WEEK6

TOPIC: ENERGY QUANTIZATION

EINSTEIN'S PHOTOELECTRIC EQUATION AND ITS EXPLANATION

Photons are packets of energy contained in radiation.

1. Threshold frequency (f_o): this is the minimum frequency of the radiation incident on a metal surface required to liberate electrons without giving them any additional kinetic energy.
2. Work function (W or Ø): work function of a metal is the minimum energy required to liberate free electrons from the metal surface.
6. Electron volt (eV): electron volt is the work done when an electron is accelerated under a p.d. of one volt. ($1eV = 1.6 \times 10^{-19}$J)

7. Stopping potential (V_s): this is the minimum value of the reverse p.d that gives zero current.

Einstein's photoelectric equation is given as

$hf = W + ½ M_eV_e^2$ -----------------------(1)

$w = hf_0$ = work function

K.Emax= $½ M_eV_e^2$ = maximum kinetic energy of the accelerated electron

$eV = ½ M_eV_e^2$

f = frequency of light

E = hf = energy of the radiation

$hf = hf_o + eV$-----------------------------(2)

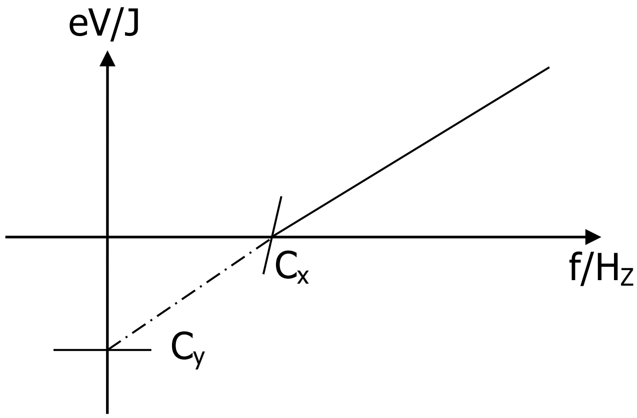
f_o = threshold frequency

$eV = hf – hf_o$ -----------------------------(3)

h = Planck's constant

$h = 6.6x10^{-34}J.s$

Considering equation (3), when the maximum energy (electron energy) is plotted against the frequency of incident light for a given metal, the graph obtained is as shown below.



Slope represent h (Planck's constant)

C_y represent work function W = hfo

To obtain C_x, eV = O in equation (3)

$O = hf – hf_o$

$hf_o = hf$

$f = f_o$

i.e C_x represent threshold frequency f_o.

Example (1) Calculate the frequency of the photon whose energy is required to eject a surface electron with a kinetic energy of $1.97x10^{-16}$eV if the work function of the metal is $1.33x10^{-16}$eV ($1eV = 1.6x10^{-19}J$, $h = 6.6x10^{-34}J.S$) **[WAEC 1989 Q4b]**

Solution

f =?, K.E = $1.97x10^{-16}eV = 1.97x10^{-16}x1.6x10^{-19}J = 3.15x10^{-35}J$

$W = 1.33x10^{-16}eV = 1.33x10^{-16}x1.6x10^{-19}J = 2.2128x10^{-35}J$

$h = 6.6x10^{-34}J.S$

Using Einstein photoelectric equation

hf = W + K.E

$$f = \frac{W+K.E}{h} = \frac{(2.2128\times10^{-35} + 3.15\times10^{-35})J}{(6.6\times10^{-34})\ J.S} = 0.08s^{-1} = 80ms^{-1}$$

Example 2

The energy flux of sunlight reaching the earth is $1.388\times10^{-3}w/m^2$. How many photons (nearly) per square meter are incident on the earth per second? Assume that the photons in the light have an average wavelength of 550nm.

Solution

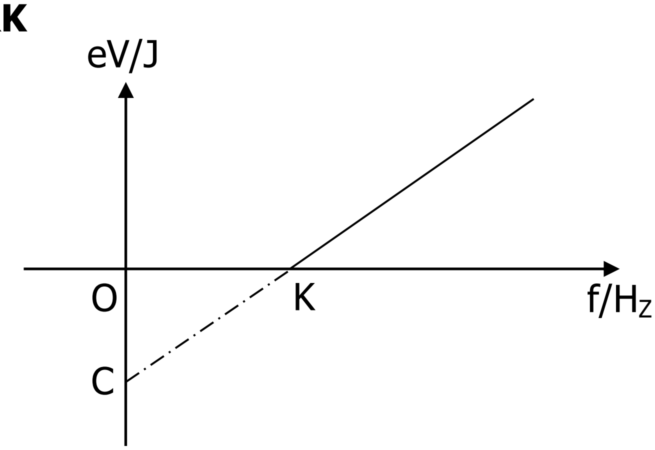
$P = 1.388\times10^{-3}w$, n = number of photons/second =?, $\lambda = 550\times10^{-9}m$

$P = nE = nhf = nhc/\lambda$

$\therefore p = \frac{nhc}{\lambda}$

$$n = \frac{p\lambda}{hc} = \frac{1.388\times10^{-3}\times550\times10^{-9}}{6.6\times10^{-34}\times3\times10^{8}} = \frac{7.634\times10^{-4}}{1.98\times10^{-25}} = 3.86\times10^{15}\ \frac{\text{photons}}{\text{second}}$$

CLASS WORK



The diagram represents the graph of electron energy against the frequency of the radiation incident on a metal surface.

Interpret the

(i) Slope of the graph

(ii) Intercept OC

(iii) Intercept OK

Assignment

The work function of caesium metal is 2.14eV. When light of frequency $6x10^{14}$Hz is incident on the metal surface, photoemission of electrons occurs.

What is the:

(i) Maximum kinetic energy of the emitted electrons

(ii) Stopping potential

(iii) Maximum speed of the emitted photoelectrons

h = $6.6x10^{-34}$J.S, 1ev =$1.6x10^{-19}$J, Me =$9.1x10^{-31}$kg

X – RAYS [2007 Q15] [1991 Q4] [2004 Q15]

X – Rays are electromagnetic waves of short wave length from 10^{-10}cm – 10^{-7}cm

The two types of X-rays are:

(i) Soft X – rays

(ii) Hard X – rays

DIFFERENCES BETWEEN HARD AND SOFT X – RAYS

S/N	HARD X – RAYS	SOFT X – RAYS
1.	Has short wavelength	Has long wavelength
2.	Has high penetrating power	Has low penetrating power
3.	Produced by high voltage	Produced by low voltage

Hardness is the strength or penetrating power of the X – ray.

Intensity is the energy radiated per unit time per unit area.

Mathematically,

Intensity I = power ÷ Area

ASSIGNMENT

Draw a modern X – ray tube and label it

(page 489 New school Physics)**.**

MODE OF OPERATION OF THE X – RAY TUBE

(i) Thermally generated electrons from the filament are accelerated through high potential difference and focused by the focusing cathode to a target.

(ii) The energy of the impinging electrons is converted mostly into heat which is conducted through the copper anode.

(iii) A small percentage of the energy is converted into X-rays which are radiated from the target through the window.

ENERGY CONVERSION DURING X – RAY PRODUCTION

Electrical Energy $\longrightarrow$ Thermal Energy $\longrightarrow$ (Mechanical Kinetic Energy) $\longrightarrow$ Electomagnetic wave (X – ray)

PROPERTIES OR CHARACTERISTICS OF X – RAYS

(i) They travel in straight lines

(ii) They undergo reflection, refraction, diffraction and polarization

(iii) They affect photographic plate or paper, causing it to be fogged.

(iv) They have high penetrating power

(v) They are able to ionize gases

(vi) They cause fluorescence in zinc substances

(vii) They cause photoelectric emission.

(viii) They are not deflected by magnetic or electric field because they are electrically neutral.

(ix) They have high frequency.

(x) They are produced from stopped fast moving electrons

USES OF X-RAYS

X – Rays are used to:

(i) Analyze crystal structure

(ii) Locate fractures in machines (industrial use)

(iii) Ionize gases

(iv) Detect metallic weapons (security use)

(v) Detect fracture in bones (medical use)

(vi) Kill germs /sterilize equipment (Agriculture & medical use)

(vii) Cure cancer (medical use)

HAZARDS OF OVER EXPOSURE TO X – RAYS

(i) Cataracts (ii) Tissue damage (iii) Skin burn(iv) Leukemia

(v) Genetic mutation (vi) Graying (vii) Baldness

SAFETY PRECAUTIONS FOR RADIOLOGICAL WORKERS

(i) Wearing of lead coat

(ii) The uses of dosimeter, badge or Geiger Muller counter

(iii) Periodic medical check-up

ASSIGNMENT JUNE 2012 Q15 WASSCE

1a(i) Explain why X – rays can be used to produce photograph of fractures in bones **[2mks]**

(ii) List four uses of X – rays other than in medicine **[2mks]**

b. State the energy transformations which take place during the operation of an X – rays tube **[2mks]**

c(i) Explain three named dangers to which human beings may be exposed when subjected to large doses of X – rays **[3mks]**

(ii) State two precautions that must be taken by a person working with X – rays **[2mks]**

d. In an X – ray tube, an electron is accelerated from rest towards a tungsten target biased at a potential of 33KV. Calculate for the electron, the;

(i) Kinetic energy (ii) velocity **[4mks]**

[$h = 6.6x10^{-34}$J.S Me = $9.1x10^{-31}$Kg, C=$3x10^{8}$m/s and e = $1.6x10^{-19}$C]

WEEK 7

TOPIC: DUALITY OF MATTER

WAVE NATURE OF MATTER

Duality of matter simply means that matter (electrons, protons, neutrons and alpha-particles) sometimes behaves like a wave or like a particle but not simultaneously.

Light also has these dual behaviour.

According to Albert Einstein, light has a tiny particle called photon which actually accounts for the transfer of heat energy in light-rays. [eV=hf – hfo].

According to De-Broglie, light behave like waves and the observable phenomena used to explain wave behaviour are:

i. reflection
ii. refraction

iii. diffraction
iv. polarization
v. interference

De-Broglie's equation is given by

$$\lambda = \frac{h}{p} = \frac{h}{meVe}$$

Where λ = De Broglie wavelength

h = Planck's constant = 6.6×10^{-34} J.S

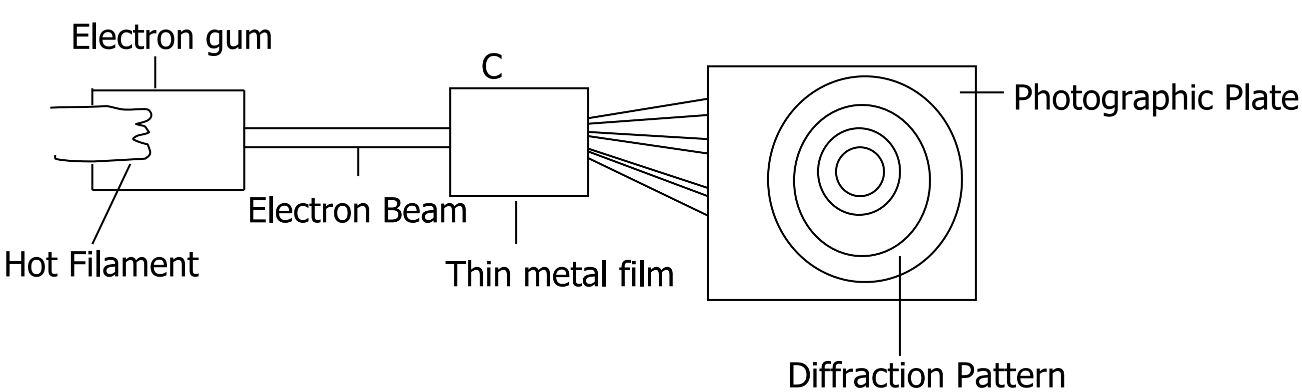
M_eV_e = momentum of the electron

M_e = mass of electron = 9.1×10^{-31} Kg

V_e = velocity of electron

In the Davisson and Germer experiment, a beam of electrons emitted from a heated filament was made to impinge on a layer of a thin metal film at C.

The electrons were diffracted and the diffraction rings were produced on a photographic plate placed behind the thin metal film as shown below



electron diffraction experiment.

PARTICLE NATURE

According to Albert Einstein, light behaves like a particle. The observable phenomena which can be used to explain light as a particle are:

(i) Photoelectric effect

(ii) Compton scattering effect

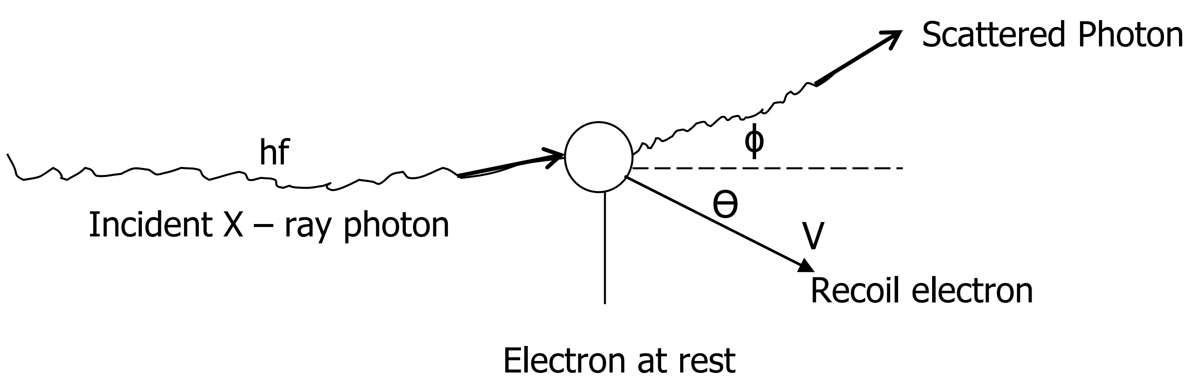
(iii) Thermionic emission

(iv) Hot body radiation/black body radiation

(v) Emission and absorption of light

THE COMPTON EFFECT

When a single X-ray photon collides with a free electron, the electron recoils off as though it were a perfectly elastic sphere. This is known as Compton effect. In this effect, the scattered photon has a slightly lower frequency than the incident X-ray photon. In this phenomenon, matter in form of X – ray is shown to behave as a particle. The recoiling electron and scattered photon are able to conserve energy and momentum.



Compton Effect

Assignment

1. Calculate the momentum and De-Broglie wavelength of the electrons accelerated through a potential difference of 56V. (ans 4.04×10^{-24}Kgm/s 0.163nm)

   [$h = 6.6\times10^{-34}$J.S, $C = 3\times10^{8}$m/s, $e = 1.6\times10^{-19}$C, $Me = 9.1\times10^{-31}$Kg

2. An electron of mass 9.1×10^{-31}Kg moves with a velocity of 4.2×10^{7}m/s between the cathode and anode of an X-ray tube. Calculate the wavelength [$h = 6.6\times10^{-34}$J.S] **2000 WASSCE**

The Uncertainty Principle

Uncertainty principle states that, it is impossible to determine (accurately) both the wave properties of matter and its particulate properties at the same time.

Or

Uncertainty principle states that, it is impossible to determine with accuracy both the momentum (P) of a particle and its position (X) at the same time.

Mathematically,

$\triangle P . \triangle X \geq h$ ------------------- (1)

$\triangle V . \triangle X \geq h$ ------------------------ (2)

$\triangle E . \triangle t \geq h$ ------------------------- (3)

Where $\triangle$ P is the uncertainty in momentum

$\triangle$ X is the uncertainty in position

$\triangle$ E is the uncertainty in energy

$\triangle$ t is the uncertainty in time

The uncertainty principle explains the uncertainty in the following:

1. Momentum and position
2. Velocity and position
3. Energy and time

Each of the pairs above is known as complementary variables.

Example 1

Why is it that uncertainty principle is of no consequence for objects above atomic sizes?

Answer

Because of the extremely small value of Planck's constant ($h = 6.6 \times 10^{-34}$J.S)

Example 2

The uncertainty in determining the duration during which an electron remains in a particular energy level before returning to the ground state is 2.0×10^{-9}s. Calculate the uncertainty in determining its energy at that level.

[$h/2\pi = h = 1.054 \times 10^{-34}$J.S] **2011 WASSCE Q10**

Solution

$\triangle t = 2.0 \times 10^{-9}$s

$\triangle E = ?$

$h/2\pi = h = 1.054 \times 10^{-34}$J.s

$$\triangle E. \geq h/\triangle t = \frac{1.054 \times 10^{-34}\text{J.s}}{2.0 \times 10^{-9}\text{s}} \geq 5.27 \times 10^{-26}\text{J}$$

Assignment

The uncertainty in the measurement of the position of a particle is 3.3×10^{-10}m. What is the uncertainty in the momentum of the particle? [$h=6.63 \times 10^{-34}$J.s] **NECO 2015**

WEEK8

TOPIC: SEMI-CONDUCTORS

CONDUCTORS, INSULATORS AND SEMI-CONDUCTORS

(i) **Conductors:-** These are materials which allow electric current to flow through them. Free electrons are the charge carriers for pure conductors.

(ii) **Insulator:-** These are materials which do not allow electric current to flow through them because they do not have free electrons.

(iii) **Semiconductors:-** These are materials which have electrical properties between insulators and conductors

Types of semiconductors

1. Pure Semiconductors (intrinsic semiconductors)
2. Impure semiconductors (extrinsic semiconductors)

PURE SEMICONDUCTORS

Pure semiconductors (intrinsic semiconductors) are from group (iv) elements of the periodic table e.g. Silicon (Si), germanium (Ge), etc.

DISTINCTION BETWEEN CONDUCTOR, INSULATOR AND SEMICONDUCTOR

CONDUCTORS	INSULATORS	SEMICONDUCTORS

1. Possess free electrons	No free electrons	Fewer free electrons
2. Has low electrical resistivity	Has very high electrical resistivity	Has resistivity intermediate between conductors and insulators.
3. Electrical conductivity decreases with rise in temperature	Has no conductivity at all	Electrical conductivity of a pure semiconductor increases with a rise in temperature

CLASS WORK

1a. What is doping?

b. Explain how doping improves the conductivity of a semiconductor

(WASSCE 2016 Q 6)

Charge carriers

These are the conveyors of electric current. The charge carriers of electricity through:

(a) Metals are free electrons

(b) Electrolyte are ions (+ve and -ve)

(c) Gas are free electrons and ions

(d) Semiconductors are free electrons and holes, free electrons are negative charges while holes are positive charges

DOPING OF SEMICONDUCTORS

Doping is the addition of suitable impurities in small amount to a pure semiconductor in order to improve its conductivity.

Examples of such impurities are:

(i) Trivalent elements (Group III elements e.g. B, Al, etc)

(ii) Group III elements are called acceptor impurities because it will require one electron to complete the bond formed when introduced to a pure semiconductor [conduction occur due to extra hole (P)]

(iii) Pentavalent elements (group V elements e.g N, P, As, Sb, etc) Group V elements, one electron will be remaining after forming each bond when introduced to a pure semiconductor. The electron remaining will be denoted as free electron. (Conduction occurs due to extra electron). Impurities in general are called dopants e.g acceptor dopants (group III elements) Donor dopants (group V elements).

Assignment

1. List the two types of extrinsic semiconductors and explain how they are produced including their diagrams.
2. Explain why impurities are called

   (a) Acceptor dopants?

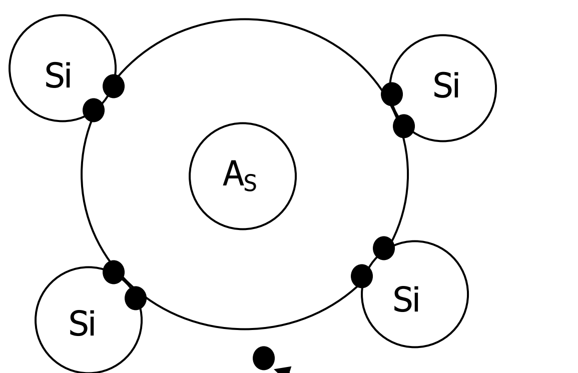
   (b) Donor dopants?
3. Explain how electricity is conducted through semi - conductors

IMPURE SEMICONDUCTORS (EXTRINSIC)

There are basically two types of **extrinsic** semiconductors which include:

1. The n – type semiconductors:-These are produced by doping group IV semiconductors (si or Ge) with donor dopants (group V elements) i.e (N, P, As, , etc).

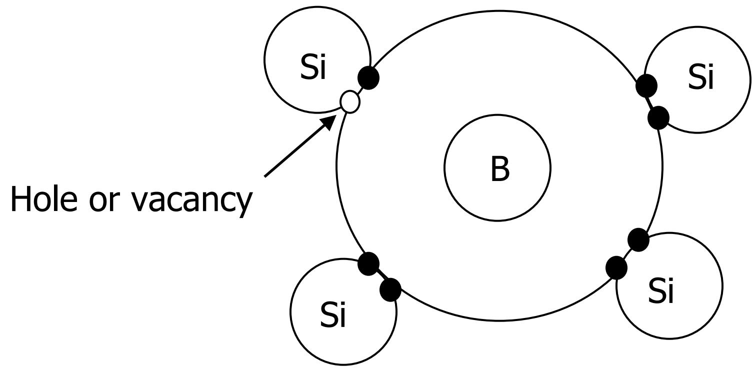
In the n-type semiconductors, n signifies negative charge which is electron. The n-type semiconductors conduct electricity as a result of the excess electron remaining after forming the bond (covalent bond), so the majority charge carriers in the n-type semiconductors are free electrons while the minority charge carriers are holes.



production of n-type

2. The p – type semiconductors:- These are produced by doping Group IV semiconductors (Si or Ge) with acceptor dopants (Group III elements) ie (B, Al, etc).

In the P – type semiconductors, P signified positive charge which is called hole or vacancy. The P – type semiconductors conduct electricity as a result of excess hole or vacancy remaining after forming the bond (covalent bond). So the majority charge carriers in the P – type semiconductors are the holes or vacancies while the minority charge carriers are the electrons.



production of P-type

Acceptor dopants are the group III elements used as impurities in the production of P – type semiconductors.

Donor dopants are the group V elements used as impurities in the production of n – type semiconductors.

Assignment

1a. What are charge carriers in semiconductors

(ii) List the charge carriers in semiconductors

b. In one sentence state why some semiconductors called

(i) n-type

(ii) P-type

2a. Explain how a gas can be made to conduct electricity

b. Name the electric charge carriers in gases

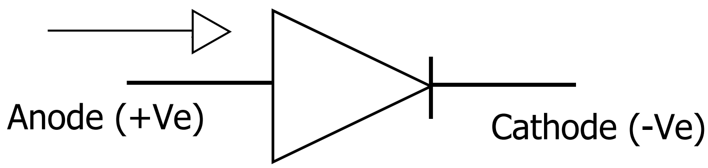
(JUNE 2014 WASSCE Q5)

SEMICONDUCTOR DEVICES

P-N JUNCTION DIODE AND RECTIFICATION

P-n junction diode is an electronic device produced when a p –type semiconductor is industrially joined to an n-type semiconductor.

p-n junction diode in general is an electronic device which allow the passage (flow) of current through them in one direction and restrict the flow of current in the opposite direction.



Diode Circuit symbol

p-n JUNCTION BIAS CONDITIONS

Connection on the p-n junction diode can be done in two ways which include:

1. **Forward Bias:-** This type of biasing is done when the positive terminal of a battery is connected to the p-type region and the negative terminal connected to the n-type region of the p-n junction diode.

Due to repulsion of like charges, the positive terminal of the battery pushes the holes towards the junction and the negative terminal of the battery pushes the free electron towards the junction. Large current is produced in forward bias

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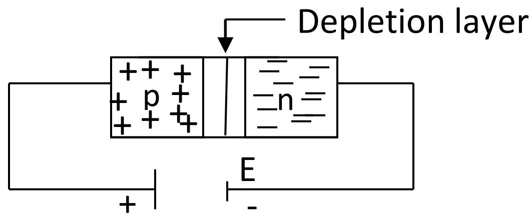
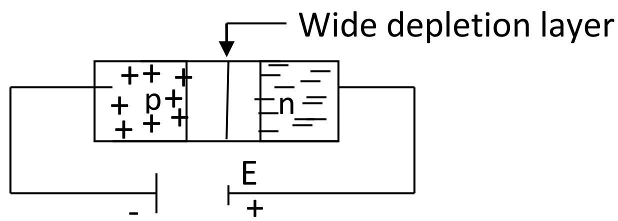


forward bias

2. **Reverse Bias:-** This type of biasing is done when the positive terminal of a battering is connected to the n-type region and the negative terminal connected to the p-type region of the p-n junction diode.

Due to attraction of unlike charges, the positive terminal of the battering attracts charges (electrons) from the n-type region and the negative terminal of the battery attracts charges (holes) from the p-type region of the p-n junction diode. This makes the depletion layer widens. Very small current is produced in the reverse bias.



Reverses bias

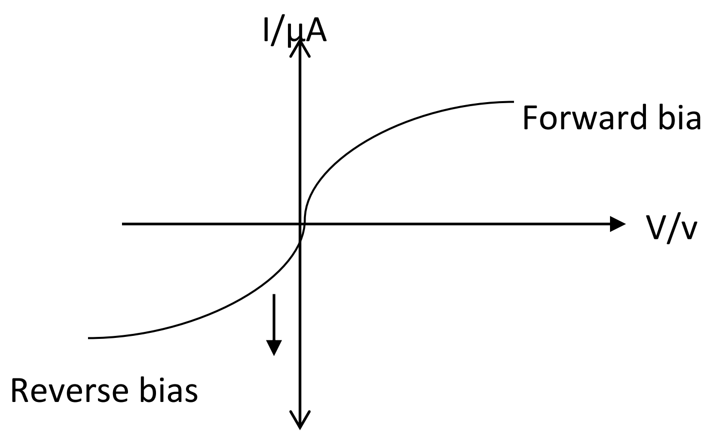
RECTIFICATION

Rectification is the process of converting a.c to pulsating d.c

Because diode allow current to pass through them easily in one direction only, diodes are used in rectifier circuits.

I-V CHARACTERISTICS AND RECTIFIER CIRCUIT

When you plot a graph of current obtained from a p-n junction diode against its voltage, the graph obtained shows the current – voltage characteristics called I-V characteristics as shown below



I-V characteristics of a p-n junction diode

The graph does not obey Ohm's law; therefore the junction diode is a non-ohmic conductor like the thermionic diode. Other non-ohmic conductor devices are crystal gold, thermistor, capacitor, electrolyte, etc.

APPLICATIONS OF THE P-n JUNCTION DIODE

1. They are used in rectifier circuits because of their unique ability to conduct current in one direction.

2. They are used in signal diodes in communication circuits

ADVANTAGES OF THE P-n JUNCTION DIODE OVER THE THERMIONIC DIODE

1. It is much smaller

2. It needs only a small potential difference to operate in a radio receiver

3. It requires no time to warm up to produce the current carriers since these are already available in the semiconductor

4. It is cheaper to manufacture in large numbers

5. It is durable

RECTIFIER CIRCUIT

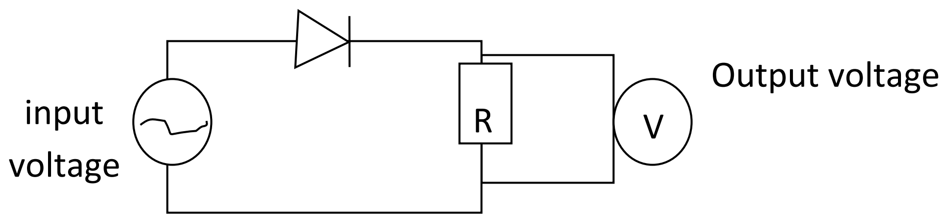
Rectifier circuit is a circuit that converts alternating current to direct current.

The two types of rectifier circuits are:

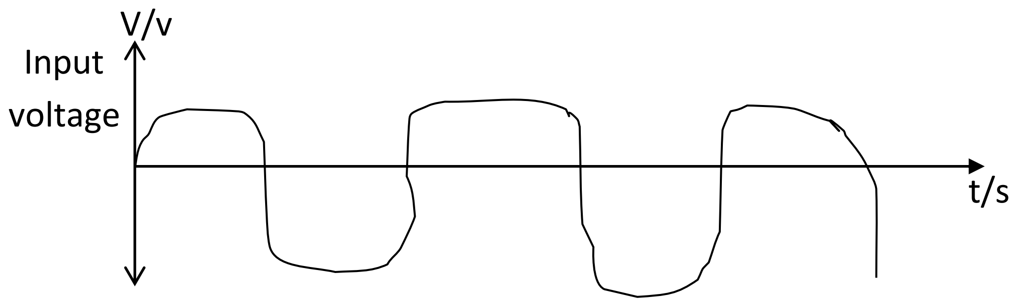
(i) Half-wave rectifier circuit

(ii) Full wave rectifier circuit

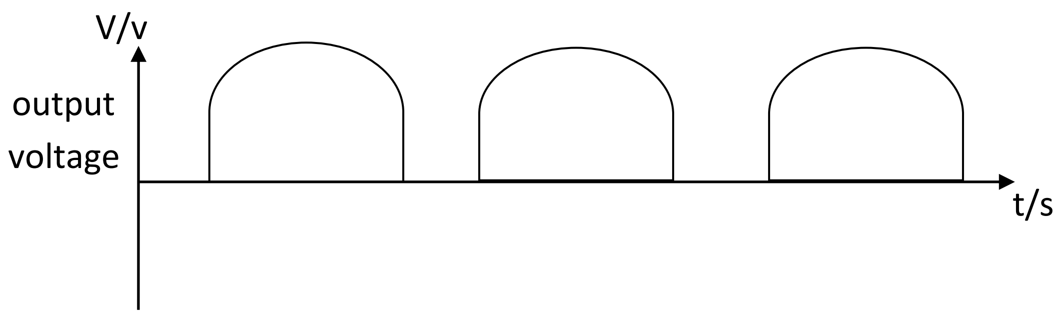
Half wave rectifier circuit consists of an a.c voltage input, a diode, a resistor and a voltmeter.



half-wave rectifier circuit

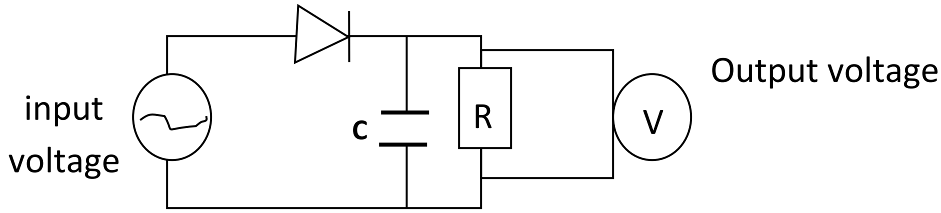


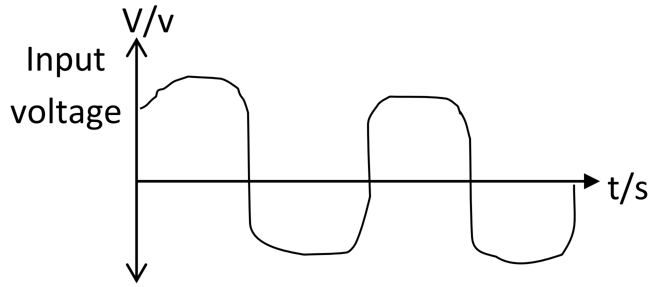
Input waveform for half-wave rectifier circuit



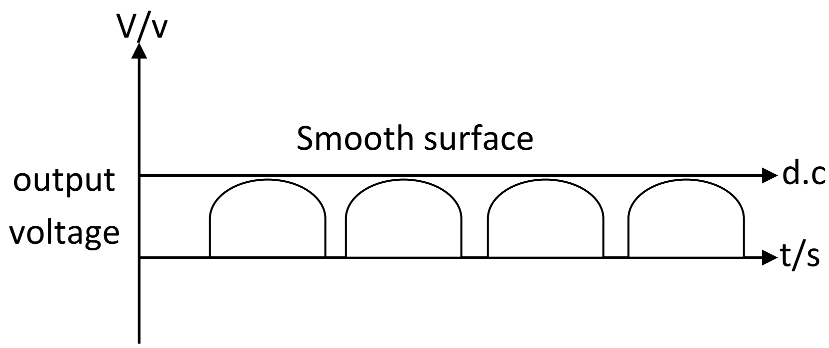
Output waveform for half-wave rectifier circuit

When capacitor is connected in parallel to the resistor above, the output wave form produced will be smooth. In this case, the circuit is said to be filtered as shown below.





Input waveform for filter circuit



Output waveform for filtered circuit

TRANSISTORS

Transistors are three pin electrical devices used for power amplification.

Transistors are produced when two p-n junction diodes are industrially joined back to back.

The two families of transistors are

(i) Field effect transistor (FET)

(ii) Bipolar junction transistor (BJT)

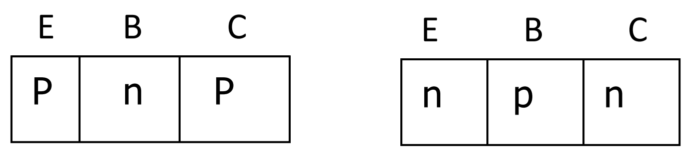
Amplifier designed using FET are voltage controlled while those designed using BJT are current controlled. The BJT is however, more widely used than FET.

BIPOLAR JUNCTION TRANSISTORS (BJT)

There are two types of BJTs which include

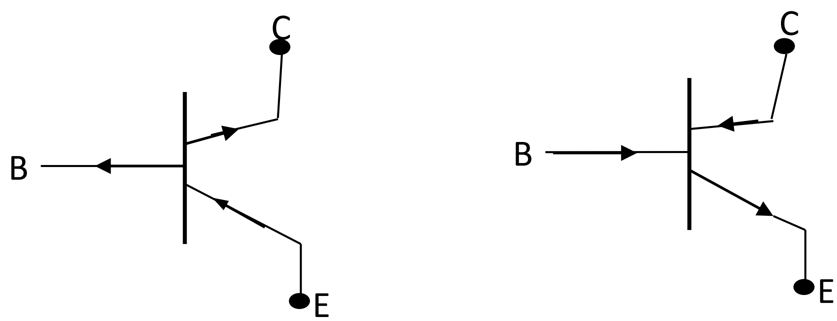
(i) p-n-p transistor

(ii) n-p-n transistor



p-n-p n-p-n

Schematic BJT diagrams



p-n-p n-p-n

Circuit symbols of BJT

The three terminals of the BJT are emitter (E), base (B) and collector (c). The base region is thin and lightly doped while the **emitter** and **collector** regions are heavily doped.

WEEK9

TOPIC: OPTICAL FIBRES

OPTICAL FIBRE CABLES

Optical fiber cable is a data transmission cable that makes use of light pulses traveling down a long fibre, often constructed of plastic or glass. Electromagnetic interference does not affect optical fibers. The total internal reflection of light is used in the fibre optic cable. The core, cladding, and outer coating are all components of an **optical fibre**.
The section of the fiber that transmits light is called the core. The material used for cladding often has a lower refractive index than the core (usually about 1 percent lower). Because of the index difference, total internal reflection occurs at the index border along the length of the fiber, preventing light from escaping through the sidewalls.

What are optical fibre cables?

They are

Parts of optical fibre cables

Key Components Breakdown:

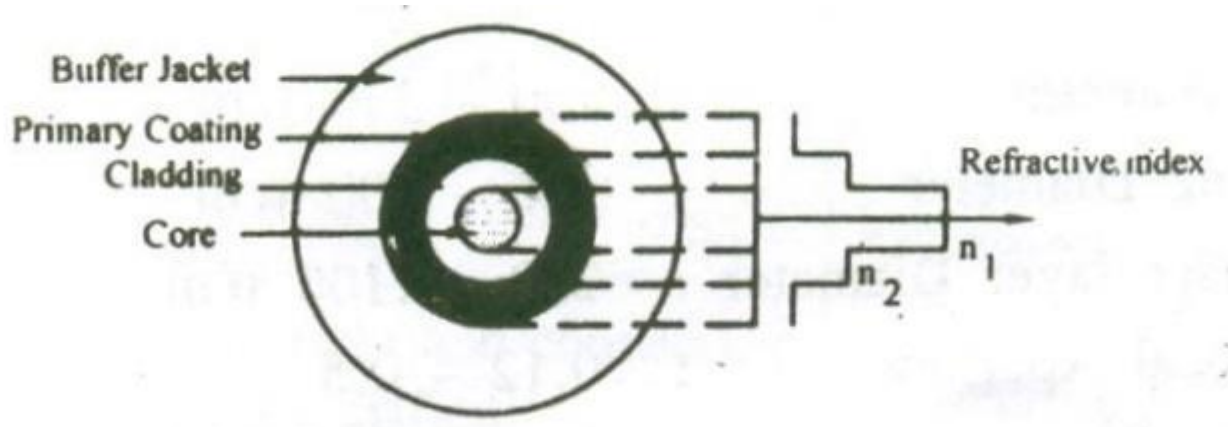
1. **Core:** The center of the fiber, made of glass or plastic, which transmits light signals.
2. **Cladding:** The layer surrounding the core, which has a lower refractive index to ensure total internal reflection.
3. **Coating (Buffer Coating):** A plastic layer that covers the cladding, protecting the fiber from moisture, dust, and damage.
4. **Strength Members:** Material such as Aramid (Kevlar), fiberglass, or steel, which provides tensile strength to protect the cable during installation.
5. **Outer Jacket:** The outermost layer, usually made of PVC or LSZH (Low Smoke Zero Halogen) materials, which protects the inner components from environmental factors.

Types of fibre Structure:

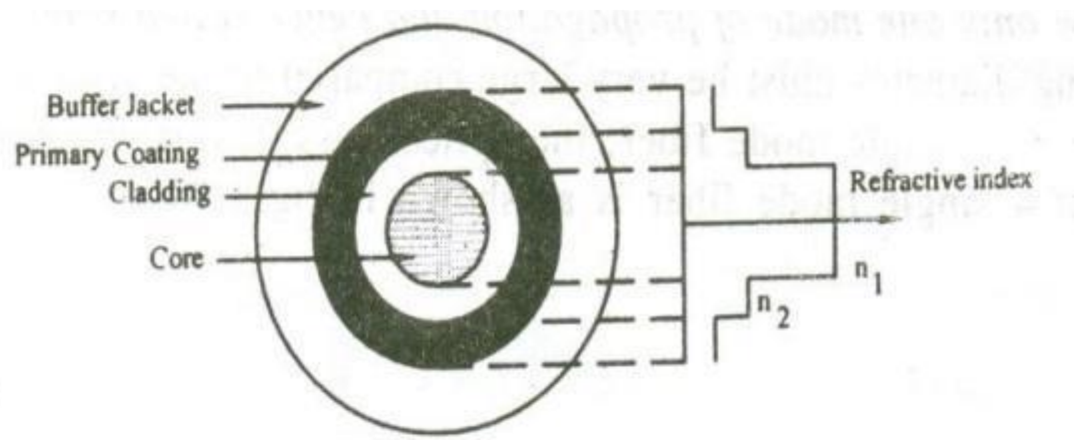
1. **Tight Buffer:** Each fiber is tightly covered by a buffer coating, making it ideal for indoor and flexible cables.
2. **Loose Tube:** One or more fibers are placed loosely inside a tube, often used for outdoor applications to protect against moisture and stress

Types of optical fibre cables

1. Glass fibre
2. Plastic fiber
3. Single-mode fiber



4. Multimode fibre



5. Step Index Fibre

6. Graded Index Fibre

Applications of optical fibre cables

i. Medical industry: In several instruments, it is utilised to observe interior body components by entering into hollow places in the body because of its thin and flexible nature. Surgical lasers, endoscope lasers, microscope lasers, and biomedical lasers all make use of fiber lasers.

ii. Communication: **Optical fibre** cables play an important role in the **principle of optical fibre communication** systems because they are used for both transmission and reception. Speed and accuracy can be improved by using it in many networking applications.

iii. Defense: High-level data security sectors of military and aerospace applications use fiber optics for data transfer. Hydrophones for SONAR and aviation wiring, make use of this material.

iv. Broadcasting: Such cables deliver high-speed and high-bandwidth signals. When compared to the same amount of copper cables, fibre optic cable is less expensive.

v. Decorations and lighting: Optical fibre cable is very popular in Christmas decorations and trees: It is inexpensive, easy to use, and beautiful.

Characteristics of optical fibre cables

1. **High Bandwidth & Transmission Speed:** Fiber optics offer vastly superior bandwidth compared to copper, supporting high-speed data, voice, and video transmission

2. **Low Signal Loss (Attenuation):** Light signals experience significantly less loss over long distances, allowing for transmission over miles without needing amplification

3. **Electromagnetic Interference (EMI) Immunity:** Because they transmit light rather than electrical signals, they are immune to EMI, lightning strikes, and radio signals, ensuring high-quality transmission

4. **High Security & Privacy:** Data transmission is secure because light does not radiate, making it difficult to tap or intercept signals

5. **Physical Properties (Size/Weight/Durability):** They are small, lightweight, flexible, and often more durable, making them easier to install and resistant to corrosion or harsh environments

Total internal reflection in optical fibre cables

Total internal reflection (TIR) in optical fibres occurs when light signals, travelling through a high-refractive-index core, strike the boundary of a lower-refractive-index cladding at an angle exceeding the critical angle. This causes the light to be entirely reflected back into the core, trapping it and allowing it to zig-zag along the cable with minimal loss.

Key Components and Process involved in total internal reflection:

1. **Core and Cladding:** The fiber consists of a central, high-index glass/plastic core surrounded by a lower-index cladding, ensuring the necessary conditions for TIR.
2. **Critical Angle:** Light must hit the core-cladding boundary at an angle greater than the critical angle.
3. **Light Transmission:** Because the angle of incidence exceeds the critical angle, no light escapes into the cladding; instead, it is reflected back into the core, enabling the transmission of data (as laser pulses) over long distances.

If the cable is bent too sharply, the incident angle might fall below the critical angle, allowing light to leak into the cladding and causing signal loss.

ADVANTAGES OF OPTICAL FIBRE CABLES (O.F.C)

1. The fibre material is made of silica glass which is available in surplus in the world compared to copper or aluminium.
2. Silica is very much cheaper than copper.
3. There is no electrical danger, since no electric current flows through the fibre. It carries only optical signal.
4. Optical fibre can be handled more easily because of their light weight, smaller in size and flexibility.
5. The optical signal transmitted through the fibre cannot be disturbed by the radio frequency interference.
6. Tapping of information is impossible in fibre optic systems.
7. A large number of signals can be simultaneously transmitted along the optical fibre cables compared to the metallic cables.
8. The loss of intensity of energy is less in optical fibre cables compared to the metallic cables.

Disadvantages of Optical Fiber Cables:

1. **High Initial Cost:** While maintenance costs can be lower, the initial expense of fiber cables, connectors, and optoelectronics is higher than copper alternatives.

2. **Fragility and Physical Damage:** The core is made of thin glass or plastic, making it fragile and prone to damage if bent too tightly (beyond its bending radius) or crushed.

3. **Difficult Installation and Splicing:** Connecting (splicing) fiber optic cables requires specialized tools and precision. They are difficult to connect to existing electrical equipment, often needing specialized technicians.

4. **Limited Durability:** Fiber optic cables are less rugged than copper, making them more susceptible to becoming cut or damaged during construction or in high-traffic areas.

5. **Signal Attenuation and Distance Limits:** Although better than copper over long distances, signals can still suffer from attenuation (loss of light strength) and dispersion (spreading), needing boosters or amplifiers.

6. **Chemical Sensitivity:** Certain environments, particularly underwater, can pose issues with hydrogen damage, affecting the transmission performance.

7. **One-Way Signal Transmission:** Fiber cables generally carry data in one direction only. To achieve full duplex communication (two-way communication), two fibers are needed.

Commonly Associated Dangers with optical fibre cables:

1. **Eye Damage:** Looking directly into the end of an active fiber cable can cause permanent retinal damage.

2. **Glass Shards:** Broken fiber shards can be dangerous and difficult to see if they enter the skin or eyes. Glass shards are small, sharp, broken pieces of glass or other brittle materials like pottery or metal

Frequently Asked WAEC Questions on Optical Fibres

WAEC Physics questions on optical fibres frequently focus on the principles of total internal reflection, the structure of fibres (core/cladding), and their advantages in telecommunication. Core concepts often tested include higher bandwidth, lower signal attenuation, immunity to interference, and applications in medicine like endoscopes.

1. Principles and Operation

a. **What is the principle of operation of fibre optics?**
- *Answer:* Total Internal Reflection.

b. **How is total internal reflection achieved in a fibre optic cable?**
- *Answer:* Light passes through a high-refractive-index core and strikes a lower-refractive-index cladding at an angle greater than the critical angle.

2. Structure and Materials

a. **What type of material is most suitable for the design of the core?**
- *Answer:* Glass or plastic.

b. **State three materials used for making optical fibres.**
- *Answer:* Glass, Silica, Polycarbonate, Sapphire, or Teflon.

3. Applications and Advantages

a. **State two reasons why optical fibres are preferred to copper cables in the telecommunication industry.**
- *Answer:* Higher bandwidth (more data transmission), lower attenuation (longer distances), and immunity to electromagnetic interference.

b. **State two applications of fibre optics in medicine.**
- *Answer:* As light guides in endoscopes, imaging tools, and lasers for surgery.

Common Key Concepts for Exam

- **Core/Cladding Ratio:** The refractive index of the core must be greater than that of the cladding.
- **Function:** They transmit data as light signals over long distances.

ASSIGNMENT

Draw an optical fibre cable and label all its parts

WEEK10

TOPIC: LASERS

The concept of LASERS

The term LASER stands for Light Amplification by Stimulated Emission of Radiation. The LASER is a device which amplifies light waves similar to the transistor which amplifies electric current. The laser is a powerful source of light. Laser radiation is different from normal light radiation.

Characteristics of LASER

1. Laser radiation is monochromatic. It contains only one particular wavelength (colour) of light. The wavelength is determined by the amount of energy released.
2. Laser radiation is coherent. In emitted radiation all the photons are having single wavelength, the same phase and amplitude.
3. Laser radiation is highly directional. Laser beam of light can travel very long distance, without much divergence.
4. Laser radiation is very intense. The intensity and hence the brightness of the laser radiation is high.

The radiation having single wavelength, same amplitude and same phase is called ‘coherent radiation’.

Working principle

Laser works on the principle of quantum theory of radiation. When an atom in the lower energy E_1 absorbs the photon energy of incident radiation, it is excited to the higher energy level of energy E_2. This process is called absorption. The number of absorption transition take place per unit time per unit volume is directly proportional to the number of atoms in the lower energy level and the number of photons in the incident radiation. The energy difference $E_2 - E_1$ is called excitation energy and it is equal to the energy of the photon absorbed by the atom. In higher energy level (E_2), the atom cannot remain long time, since it has a tendency to drop energy. So the atom jumps to the lower energy level (E_1). At that time, the energy difference E2 –E1 is emitted in the form of radiation as photon. The energy of the photon released, $E_2 - E_1 = hf$, where f is the frequency of the radiation and h, the Planck's constant.

Einstein found a new process called stimulated emission to increase the number of transition of atoms from higher energy levels to lower energy levels. Stimulated emission is the process of photon emissions and takes place by an inducement given by another photon incident on the atoms in higher energy levels. The energy of the photon emitted is equal to the energy of the photon incident. This process of stimulated emission is used to produce laser beam. Stimulated transition per volume is directly proportional to

1) The number of atoms in the higher energy level (N)

2) The number of photons in the incident radiation (Q)

The stimulated emission can be multiplied through a chain reaction. When a single photon hits an atom in the higher energy level, two photons are emitted by stimulated emission. Then these two photons hit on two atoms of higher level, four photons are emitted. This process is continued as a chain reaction and the photons are getting multiplied. Finally it leads to the emission of the powerful, coherent, monochromatic and highly directional beam of laser light. This is called Light amplification by stimulated emission of radiation.

Uses of LASERS

5. Laser is used to find the long distances by direct pulse reflection method e.g the distance between the moon and earth was measured accurately.
6. It is used to produce high temperature to melt and vapourise the metals in a very short period.
7. It is used to bore holes in hard substances like tungsten and diamond.
8. It can be modulated to transmit hundred messages at a time on radio, television and telephone.

9. The big size objects like aeroplane, missiles etc. can be destroyed in a few seconds by passing a powerful laser beam on to them. For this reason, laser is called a “Death ray” instrument.
10. In surgery, a laser beam is used in spot-welding of a detached retina in the eye ball. It is also used for painless drilling and welding the surface of a tooth to prevent its decay.
11. The laser beam is not easily absorbed by water. So it can be used under-water communication between submarines.

WAEC questions on LASER

1. **What does the acronym LASER stand for?**

   Answer: Light Amplification by Stimulated Emission of Radiation.

2. **What is a laser?**
   Answer: It is a device that generates an intense beam of coherent, monochromatic light.

3. **Which process is responsible for the production of coherent light in a LASER?**
   Answer: Stimulated emission.

4. **Which of the following is not a characteristic of LASER light?**
   A. Monochromatic B. Coherent C. Polychromatic D. Highly directional
   Answer: C. Polychromatic.
5. **What is the function of the optical cavity in a laser?**
   Answer: To amplify light by reflecting it back and forth through the gain medium.

Section B: Theory / Essay Questions

1. **(a) State three properties of lasers that make them preferable to ordinary light beams.**
   Answer: (1) It travels a very long distance without losing intensity. (2) It has a very narrow bandwidth (monochromatic). (3) It is coherent (all light waves are in phase).

(b) Name one use of LASER in each of the following areas: (i) Communication (ii) Medicine (iii) Security.
Answer: (i) Fiber-optic communication or CD/DVD data transfer. (ii) Eye surgery or skin treatments. (iii) Guidance systems for missiles/aircraft.

2. **(a) Describe the process of population inversion and explain why it is necessary for laser action.**
   Answer: Population inversion is the process of achieving a state where more atoms exist in the excited state than in the lower (ground) state. It is necessary because stimulated emission can only dominate over absorption when a majority of atoms are already in an excited state.

   (b) State two dangers associated with the use of lasers.
   Answer: Damage to the human eye and skin burns.

3. **(a) Describe how a laser is used in the field of medicine.**
   Answer: Laser beams are used as "scalpels" for precise cutting, welding the retina of the eye, burning away cancerous tissue, and in dental procedures. **A scalpel is a bladed surgical instrument used to make cuts into the body.**

4. Write three safety precautions during the use of LASER

   Answer

   a. Wear appropriate eye protection: Use Laser safety eye wear designed for the specific wavelength and power of the Laser
   b. Never look directly into the laser beam: Even a brief exposure can cause serious eye damage
   c. Ensure the laser is properly labeled and operated: Follow safety protocols and training when operating Lasers. Make sur the Laser is in a controlled environment to prevent accidental exposure to others

ASSIGNMENT

1. A laser produces a beam of light frequency $4.82x10^{14}$Hz. Calculate the energy of a photon in the laser beam(h = $6.6x10^{-34}$Js)

   Solution

   E = hf = $6.6x10^{-34}x4.82x10^{14}$ = $3.18x10^{-19}$J
2. Calculate the frequency of a laser photon that has an energy of $2.5x10^{-19}$J

   Solution

   F = E/h = $(2.5x10^{-19})/(6.6x10^{-34})$ =$3.79x10^{14}$Hz