TOPIC: MODERN PHYSICS

General Objective: The Learner should be able to use the nuclear and atomic models to understand the production of X-rays and radioactivity**.**

SUB-TOPIC: Atomic and Nuclear structure.

SPECIFIC OBJECTIVES: The Learner should be able to;-

- Describe the atom.
- Define nuclides and isotopes.
- Represent nuclides with their atomic numbers and atomic masses.
- Give examples of isotopes.
- Define nuclear fusion and fission.
- Balance equations of nuclear reactions.
- Identify the products of a nuclear reaction.
- Explain the use of nuclear energy in the generation of electricity and bombs.

Modern physics deals with the nuclear model of an atom.

STRUCTURE OF AN ATOM

According to Neil Bohr and Rutherford an atom consists of a central nucleus, in which the atom's mass is concentrated, surrounded by electrons that orbit round the nucleus. The simplest atom is that of hydrogen.

An atom consists of 3 particles namely -: Proton, Neutrons and Electrons.

The neutrons and protons are found in the nucleus and are referred to as nuclei particles or nuclide particles

Name	Symbol	Sign of change
Protons	${}_{1}^{1}H$	Positive
Neutrons	${}_{0}^{1}n$	No change
Electrons	${}_{-1}^{0}e$	Negative

Protons are heavier than electrons.

Protons are equivalent to a positive hydrogen ion.

ISOTOPES

Isotopes are atoms of the same element having the same atomic number but different mass numbers.

ATOMIC NUMBER

Atomic number is the number of protons in the nucleus of an atom.

Symbol for atomic number is **Z**

MASS NUMBER

Mass number is the sum of protons and neutrons in a nucleus of an atom. It is sometimes called atomic mass.

It is expressed using the letter **A**.

Note: Mass number = Atomic number + No. of Neutrons.

$A = Z + N$

An atom is usually electrically neutral, implying that the number of protons, Z is equal to its number of electrons.

An atom X is represented by : ${}_{Z}^{A}X$ Where A- mass number and Z – atomic number

e.g. ${}_{17}^{35}Cl$. Has 17 protons and 18 neutrons

QUESTIONS:

1. Given the atom : ${}^{59}_{27}X$, Find its
   - (i) atomic mass
   - (ii) atomic number
   - (iii) number of neutrons
   - (iv) number of electrons.
2. Describe the potassium atom represented by the symbol ${}^{39}_{19}K$.

SUB-TOPIC: RADIOACTIVITY

SPECIFIC OBJECTIVES: The Learner should be able to;

- Define radioactivity.
- Describe the nature of alpha and beta particles and gamma rays.
- List the properties of the radioactivity.
- Determine the effect of emissions on the parent nucleus.
- Define half-life to find the age and quantity remaining.
- State applications of radioactivity.

RADIOACTIVITY

This is the spontaneous disintegration (breaking) of heavy unstable nuclei to form stable nuclei with emission of radiations e.g beta particles (β), gamma rays(γ), alpha particles (α).

A RADIO ACTIVE ELEMENT

Is one whose nucleus spontaneously disintegrates and continuously emits powerful and invisible radiations.

DIFFERNCES BETWEEN RADITIONS

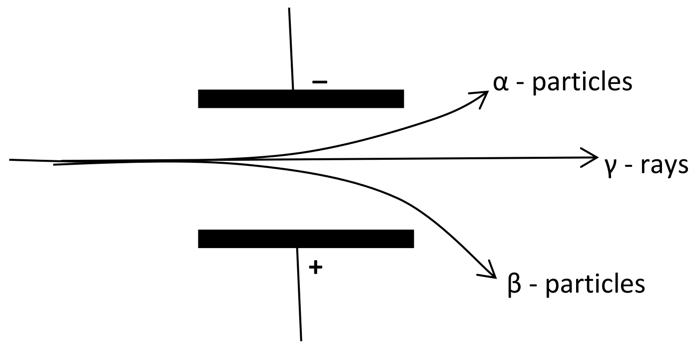
Alpha (α) particle	Beta (β) particle	Gamma rays (γ)
It is a helium particle, ${}^{4}_{2}He$	It is an electron, ${}^{0}_{-1}e$	Are electromagnetic waves
Are positively charged	Are negatively charged	Have no charge.
Are less deflected by both magnetic and electric fields	Are more deflected by both magnetic and electric fields	Are not deflected by both magnetic and electric fields

BEHAVIOUR IN AN ELECTIC FIELD

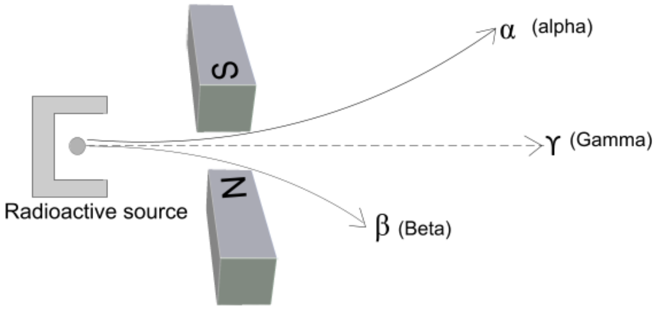
The alpha particles are deflected towards the negative plate indicating that they are positively charged. (Less deflected because they are heavy.)

The beta particles are deflected towards positive plate indicating that they are negatively charged. (sharply deflected because they are very light.)

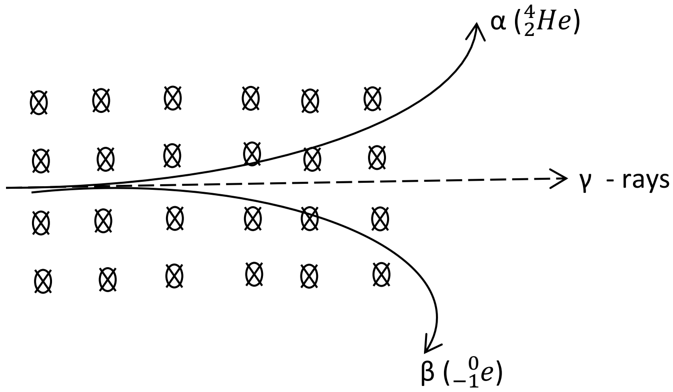
While gamma rays go through the field without being deflected showing that the carry on charge.

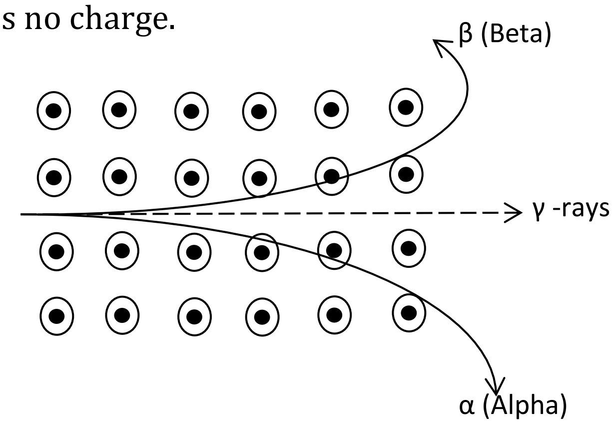


DEFLECTION BY A MAGNETIC FIELD



The beta particle is deflected down wards (north pole) because they are negatively charged. They are sharply deflected because they are very light.
While alpha particles are deflected upwards (South Pole) according to Flemings left hand rule because they are positively charged. They are less deflected because they are heavy.
Gamma rays are not deflected because they possess no charge.

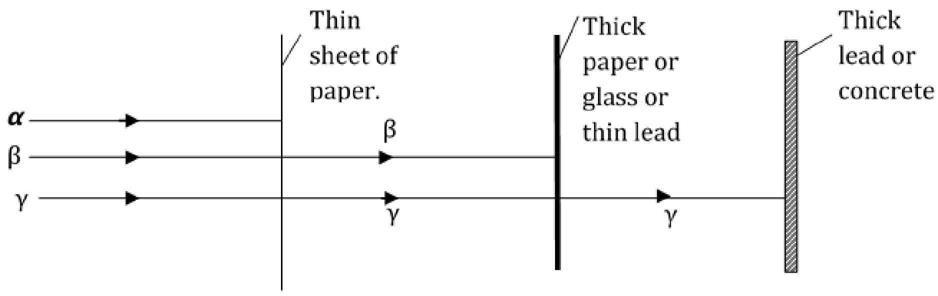




Magnetic field direction is into the paper. (ii) Magnetic field direction is out of the paper

PENETRATION OF MATTER:

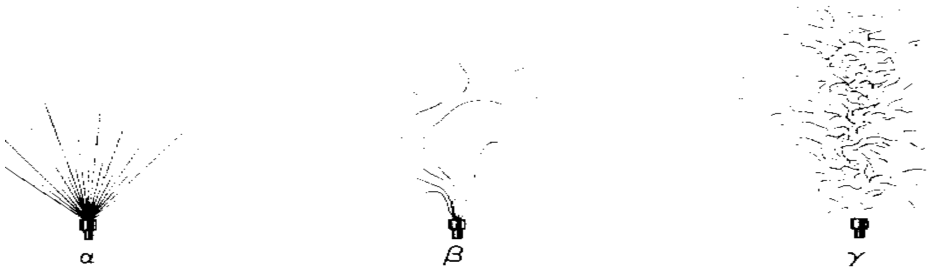
Alpha particles have low penetrating power and are easily stopped by a thin sheet of paper. They do not travel far in air because they are easily slowed down by collisions with air molecules.
Beta particles are more penetrative than alpha particles but less penetrative than gamma rays. They are stopped by thick paper, Perspex glass and thin aluminum.
Gamma rays possess the greatest penetrative power of the three radiations. They are stopped by thick lead or concrete. Travel in a straight line in air.



IONISATION OF AIR.

Alpha particles have the highest ionizing effect because they are heavy and carry a larger charge than beta particles.
Beta particles are less ionizing than alpha particles because they possess a smaller charge and are very light.
Gamma rays are the poorest ionizers of the three radiations.

TRACKS OF THE THREE RADTIONS AS DEMONSTRATED IN A CLOUD CHAMBER
When a radioactive source emits particles in an air space saturated with water vapour or alcohol vapour inside a vessel with a glass window, the speeding particles collide with the air molecules with great force knocking off electrons, and leaving a trail of positive and negative ions.
If the air space is suddenly expanded by moving the piston, cooling occurs and the vapour condenses out on the ions, thus revealing the paths of the particles.



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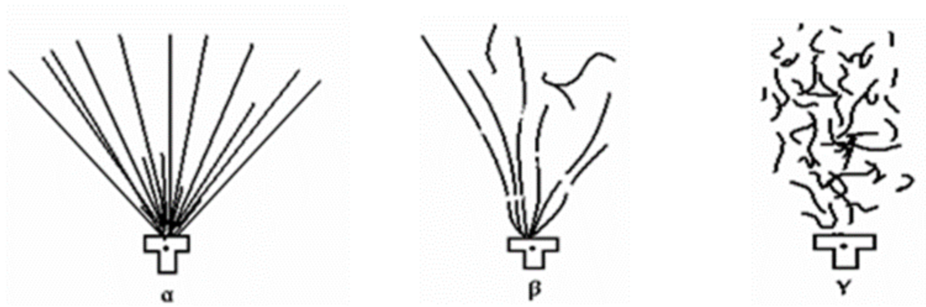


ALPHA PARTICLES
Are short straight and bold tracks, this is because they are good ionizers of gas. A large number of ions are observed. The tracks differ in length due to difference in energy

BETA PARTICLES
Tracks made by beta particles are longer and fainter.
They wonder as they are easily deflected by air molecules because beta particles are light compared to the heavier air molecules they collide with.

GAMMA RAYS
Gamma rays don't leave on actual track because they don't ionize gas. If gamma rays are present, whisky or wavy tracks.

FLUORESCENCE:
Only alpha particles cause fluorescence when incident on a screen.

NUCLEAR ENERGY
Nuclear energy is the type of energy made available from the disintegration of the nucleus of an atom.

1. **NUCLEAR FISSION**
   Nuclear fission is the splitting of nucleus of heavy atoms into two lighter nuclei of roughly equal mass.
   The process Nuclear fission can be started by the bombardment of a heavy unstable nuclei with a neutron. The products of the process are two lighter atoms and more neutrons which can make the process continue.
   The two lighter products of nuclear fission are called fission products or fission fragments.

They have less mass than the correct value. The difference in their mass is due to energy loss which is given by the Einstein equation, $E = mc^2$ where c is the speed of light and m is the mass difference (or defect).

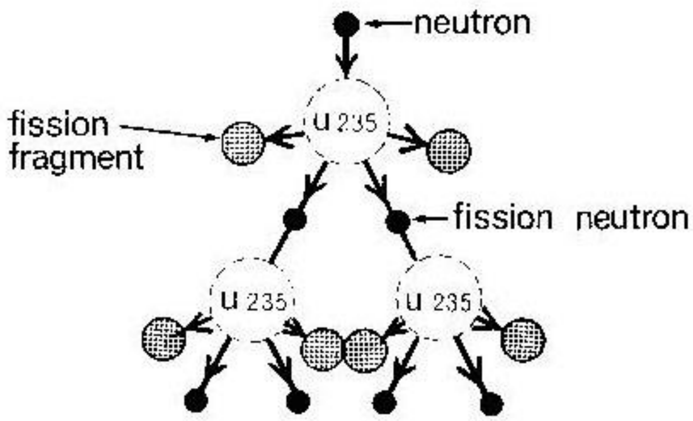
The neutrons produced after nuclear fission are called **fission neutrons**.

Fission neutrons ensure the continuity of nuclear fission indefinitely, resulting into a **chain reaction.**

EXAMPLE OF NUCLEAR FISSION EQUATION:

$$\underset{}{^{235}_{92}U} + \underset{\text{neutron}}{^{1}_{0}n} \rightarrow \underset{\text{fission fragments}}{^{144}_{56}Ba + ^{90}_{36}Kr} + \underset{\text{neutrons}}{2^{1}_{0}n}$$

ILLUSTRATION OF A CHAIN REACTION:



APPLICATION OF NUELEAR FISSION:

- Used in making atomic bombs.
- Used to generate electricity.
- Used to generate heat energy on large scale.

CONDITIONS NECESSARY FOR NUCLEAR FISSION TO OCCUR:

- There should be neutrons moving at a high speed that meet and are captured by the heavy nuclei to make it unstable.
- There should be a heavy unstable nucleus with isotopes which decay to produce isotopes and high speed neutrons.

2. NUCLEAR FUSION

Nuclear fusion is the union of two light atomic nuclei to form a heavy atom with the release of energy.

EXAMPLE OF NUCLEAR FUSION EQUATION.

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{1}He + \text{energy}$$

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{1}He + ^{2}_{1}n + \text{energy}$$

CONDITIONS NECESSARY FOR NUCLEAR FUSION TO OCCUR

- Temperatures must be very high.
- The light nuclei should be at very high speed to overcome strong repulsive forces between their charges.

USES OF NUCLEAR FUSION:

- Used to produce hydrogen.
- In the production of the Hydrogen bomb.

- Used to produce electricity.
- Used to produce heat energy on large scale.

Fusion reactions are sometimes known as thermonuclear reactions because thermo energy has to be supplied before energy can be released.

NOTE:

1. **The Sun produces its energy by nuclear fusion**. In the sun's core, vast quantities of energies are released as thermonuclear reactions convert hydrogen into helium.
2. The hydrogen bomb is a result of an uncontrollable fission chain reaction supplying heat needed for the thermonuclear reaction to start.

CHALLENGES IN ACHIEVING CONTROLLED NUCLEAR FUSION:

No ordinary container can withstand the high temperatures required for nuclear fusion to start and resist the expansion of the hydrogen so that the reactions can be maintained.

NUCLEAR EQUATIONS

Alpha decay:

$${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + \text{energy}$$

Parent nuclide — Daughter nuclide — α - particle

RULE 1: When an element disintegrates (decays) by emission of an alpha particle, it turns into an element two places earlier in the periodic table.

Beta decay:

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + \text{energy}$$

Parent nuclide — Daughter nuclide — β - particle

RULE 2: When an element disintegrates (decays) by emission of a beta particle, it turns into an element one place later in the periodic table.

Gamma Decay:

Gamma rays are emitted as a result of instability in the nucleus. Therefore, Gamma rays are emitted so that the nucleus acquire a more stable state.

The emission of Gamma rays causes no change in the atomic and mass numbers of the element.

EXAMPLES:

1. A radioactive substance ${}^{238}_{92}X$ undergoes decay and emits an alpha particle to form Y. Write down an equation for the process.

   SOLUTION

   An equation for the process

   $${}^{238}_{92}X \longrightarrow {}^{x}_{y}Y + {}^{4}_{2}He$$

   $238 = x + 4 \quad \leftrightarrow \quad x = 234$

   $92 = y + 2 \quad \leftrightarrow \quad y = 90$

   $${}^{238}_{92}X \longrightarrow {}^{234}_{92}Y + {}^{4}_{2}He$$

2. Unstable nuclei ${}^{226}_{88}X$ decays to form a stable nuclei Y and beta particle is emitted. Write down an equation for the process

   SOLUTION

   $${}^{226}_{88}X \longrightarrow {}^{n}_{m}Y + {}^{0}_{-1}e$$

$226 = n + 0 \quad \leftrightarrow \quad n = 226$
$88 = m + {}^{-}1 \quad \leftrightarrow \quad m = 89$
$^{226}_{88}X \longrightarrow {}^{226}_{89}Y + {}^{0}_{-1}e$

3. Radium $^{226}_{88}Ra$ loses 5 α – particles and 4 β particles and is converted into a new stable element, an isotope of lead Pb. Find the mass number and atomic number of this isotope.
SOLUTION
$^{226}_{88}Ra \rightarrow {}^{A}_{Z}Pb + 5({}^{4}_{2}He) + 4({}^{0}_{-1}e)$
226 = A +(5×4) +(4×0) = A + 20
Mass number of the isotope is, A = 206
Also
88 = Z + (5 ×2) + (4 × -1) = Z +10 - 4
Atomic number of the isotope is, Z = 82

4. Thorium $^{232}_{90}Th$ is converted into Radium $^{224}_{88}Ra$ by radioactivity transformation. How many α and β emissions have taken place?
SOLUTION
$^{232}_{90}Th \rightarrow {}^{224}_{88}Ra + x({}^{4}_{2}He) + y({}^{0}_{-1}e)$
Change in Atomic Number:
$90 = 88 + 2x - y$
$y - 2x = 2$ ……………………………………..(1)
Change in Mass Number:
$232 = 224 + 4x$
$x = 2$, therefore $y = 2$.
There are 2 α – particles and 2 β – particles.

ARTIFICIAL RADIOACTIVITY:
Artificial radioisotopes of some elements can be prepared by bombarding nuclei of stable atoms with α - particles, β – particles or neutrons.
The process of producing artificial radioactive nuclides is a reverse process of the decay process – stable nuclei absorb nuclear particles of gamma photons which strike them, and become unstable as a result.

Activity is the rate of disintegration or the number of disintegrations per second of the radioactive substance.

RADIO ISOTOPES:
A **radioisotope** is an unstable isotope produced by bombarding a stable nuclide with either alpha, beta or neutrons.

NOTE: Since radioisotopes are unstable, they can decay with the emission of α-, β-, or γ radiations to acquire a more stable state.

EXAMPLES:
When the nucleus of Aluminium is bombarded by an α – particle, a radioactive isotope of Phosphorus is obtained.

$^{27}_{13}Al$	+	$^{4}_{2}He$	→	$^{30}_{15}P$	+	$^{1}_{0}n$
Aluminium nucleus		Alpha particle		Phosphorous Isotope		neutron

$^{1}_{0}n \quad + \quad ^{23}_{11}Na \quad \rightarrow \quad ^{24}_{11}Na$

neutron Normal stable sodium nuclide *Radioisotope of sodium used in medicine*

$^{1}_{0}n + ^{127}_{53}I \rightarrow ^{128}_{53}I$

neutron stable iodine nuclide *Radioisotope of iodine used in medicine*

USES OF RADIOISOTOPES: - (SAME FOR APPLICATIONS OF RADIOACTIVITY)

Agricultural uses

- Used in tracer techniques to investigate the flow of liquids in chemical plants.
- Used to induce plant mutations to provide better seed varieties.

Industrial uses:

- Used in the automatic control of thickness of material in industries.
- Study of wear and tear in machinery. (detecting underground leakages in pipes)
- Gamma ray are used to detect faults in thickness of metals sheets in welded joints
- Used in packaging process by counting the correct amount or number per packet.

Medical uses

- Used in treatment of cancer.
- They are used to kill bacteria in food (x- rays)
- Used to sterilize medical equipment like syringes
- Used in the diagnosis and treatment of goiter.

CARBON DATING:

This is the estimation of age of a substance by studying the count rate of a radioactive sample in the substance.

Archeology

Used to determine the time that has elapsed since death of organisms occurred, a process called carbon dating.

Explanation

Living plants absorb and contain a radioactive isotope of carbon having a half-life of about 5600 years. As long as the plant lives, the count rate of this isotope is constant. When a plant dies, it stops absorbing the carbon isotope, but radioactivity continues. So, the count rate falls accordingly. By determining the count rate of wood, its age can be estimated.

The same procedure can be used to determine the age of dead fossils.

Geology

They are used to determine the age of rocks.

When rocks were formed, some radioisotopes were trapped in them. By the number of the radioisotopes (parent nuclides) remaining in a rock sample with the daughter nuclides, the age of the rock can be determined.

DANGER (HAZARDS) OF RADIATIONS

- Beta and alpha particles cause skin burns and sores.
- Can cause cancer and affect eye sight.
- May cause infertility and sterility, (reproductive organs and liver).
- May lead to genetic mutations (abnormalities).

SAFETY PRECAUTIONS WHEN DEALING WITH RADIOACTIVE SOURCES

- Radioactive sources must be kept in lead boxes
- Handle radioactive materials using tweezers.
- Workers should wear protective lead suits (protective clothing)
- Walls of industries are made of thick strong concrete to prevent exposure to surroundings.
- Using radioactive materials of short half – life
- Washing body thoroughly after exposure to radioactive materials.
- Avoid eating or drinking around radioactive sources.

Back ground radiation

These are radiations which naturally exist even in the absence of radioactive source. They are caused by natural tracks of radioactive materials in rocks, in air, Cosmic rays from outer space as well as bricks of buildings.

Cosmic rays are very high energetic radioactive particles which come from deep in space.

So the correct count = actual rate - back ground count rate.

E.g.

Given that the back ground rate is 2 counts per minute and the Geiger Muller count rate is 25 counts per minute, determine the approximate number of radiations present.

Count rate = 25 - 2 = 23c/min

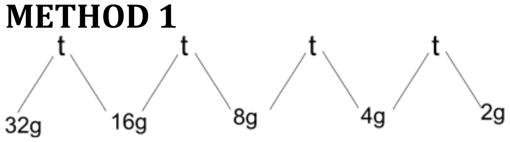
HALF LIFE:

The half – life of a radioactive substance, t is the time taken for the radioactive substance to decay to half of its original mass.

EXAMPLE 1

If a radioactive element of mass 32 decays to 2g in 96 days. Calculate the half life.

METHOD 1



4t = 96 ∴ t =2 4 days, is the half – life.

METHOD 2: TABLE FORM

No. of half – lives	Time taken	Amount present
0	0	32g
1	T	16g
2	2t	8g
3	3t	4g
4	4t	2g

Where t = the half-life

therefore, 4t = 96 days

$t = \frac{96}{4} = 24$ days.

EXAMPLE 2:

A certain radioactive substance takes 120years to decay from 2g to 0.125g. find the half life

Let the half –life be t.

METHOD 1.

4 t =120 t =30 years

METHOD 2: TABLE FORM

No. of half - lives	Time taken	Amount present
0	0	2g
1	T	1g
2	2t	0.5g
3	3t	0.25g
4	4t	0.125g

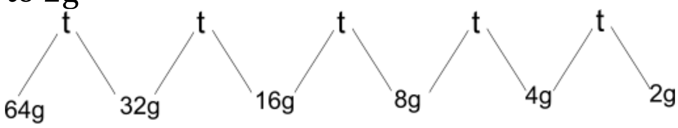
Where t = the half-life

therefore, 4t = 120 days

$t = \frac{120}{4} = 30$ days.

EXAMPLE 3:

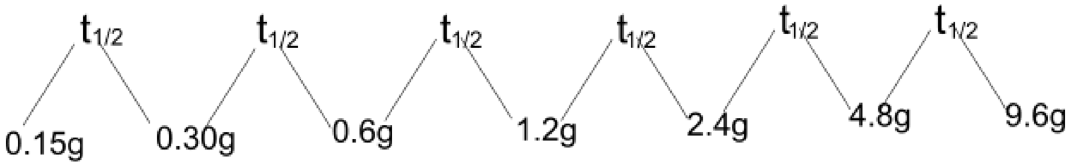
The half life of substance is 5 days. find how long it takes for its mass to disintegrate from 64g to 2g



5 x 5 =25 days

EXAMPLE 4:

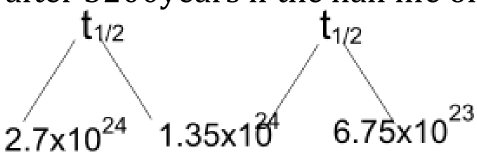
A radioactive element has a half life of 4 years. if after 24years. 0.15g remains. Calculate the initial mass of the radioactive material



M_o = 9.6g - check your notes girl.

EXAMPLE 5

A certain mass of a radioactive material contains 2.7 x 10^{24} atoms, how many atoms decayed after 3200years if the half life of material is 1600years



Mass remaining = 6.75 x 10^{23} atom

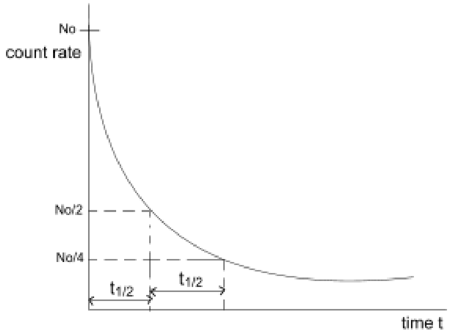
Mass decays = original mass - mass remaining

= (2.7 x 10^{24} - 6.75 x 10^{23})

= 2.025 x 10^{24} atoms

GRAPHICAL METHOD OF DETERMINING HALF LIFE

When a graph of account rate against time or radioactive nuclei is drawn, the half life of the radioactive nuclei can be determined as below.



Examples

1. The following values obtained from the readings of a rate meter from a radioactive isotope of iodine.

Time (min)	0	5	10	15	20
Count rate (min^{-1})	295	158	86	47	25

Plot a suitable graph and find the half-life of the radioactive iodine.

2. The following figures were obtained from Geiger Muller counter due to ignition if the sample of radon gas

Time (min)	0	102	155	…….	300
Rate (min^{-1})	1600		200	100	50

(a) (i) plot a graph of count rate against time
(ii) Determine the half life
(iii) Find the missing values

(b) (i) What is the count rate after 200 minutes
(ii) After how many minutes is the count rate 1000 minutes

NOTE:

In general, if N_0 is the initial number of atoms, then after n half-lives the number remaining is given by:

Number remaining/amount remaing = $\frac{\textit{Initial amount}}{2^n}$

Thus, the fraction remaining after n half-lives is f $= \frac{1}{2^n}$

Then, $\frac{\textbf{Amount remaining}}{\textbf{Original amount}} = \frac{1}{2^n}$

1. Given 20 g of a radioactive sample of half-life 12 minutes, how much of it remains after 36 minutes

Solution

Number of half-lives, n $= \frac{36}{12} = 3$

$$\frac{\text{Amount remaining}}{\text{Original amount}} = \frac{1}{2^3} = \frac{1}{8}$$

$\therefore$ Amount remaining $= \frac{1}{8}$ x 20 $=$ 2.5 g

2. The activity of a radioactive source decreases from 1000 counts per minute to 125 counts per minute in 42 minutes. What is the half-life?

Solution

Let n = number of half-lives

Then, $2^n = \frac{1000}{125} = 8$

$\therefore$ n = 3

So, 42 minute = 3 half-lives

$\therefore$ Half-life = 14 minutes

3. A radioactive sample has half-life of 2500 years. How long does it take for three-quarters of the sample to decay?

Solution

Fraction remaining $= \frac{1}{4} = \frac{1}{2^n}$

$\therefore$ number of half-lives that elapsed, n = 2

So, this will be after 2 x 2500 = 5000 years.

REVIEW QNS ON RADIOACTIVITY (HOW TO PASS PHYSICS PAGE 272)

SUB-TOPIC: Electrons
SPECIFIC OBJECTIVES: The Learner should be able to;

- Define thermionic emission and cathode rays.
- Describe the experiment to produce cathode rays.
- Investigate the properties of cathode rays.
- List the uses of cathode rays.
- Draw the CRO and explain how it works.
- Draw wave forms produced on a CRO.
- Mention uses of CRO.

THERMIONIC EMISSION

This is the process by which electrons are emitted from a hot metal surface.
The emitted electrons are called thermions.

EXPLANATION OF THERMIONIC EMISSION.

When a metal is heated to a certain temperature, some of its electrons gain sufficient energy to overcome the electrostatic attractive forces and break free from the metal surface and escape into the surrounding space.

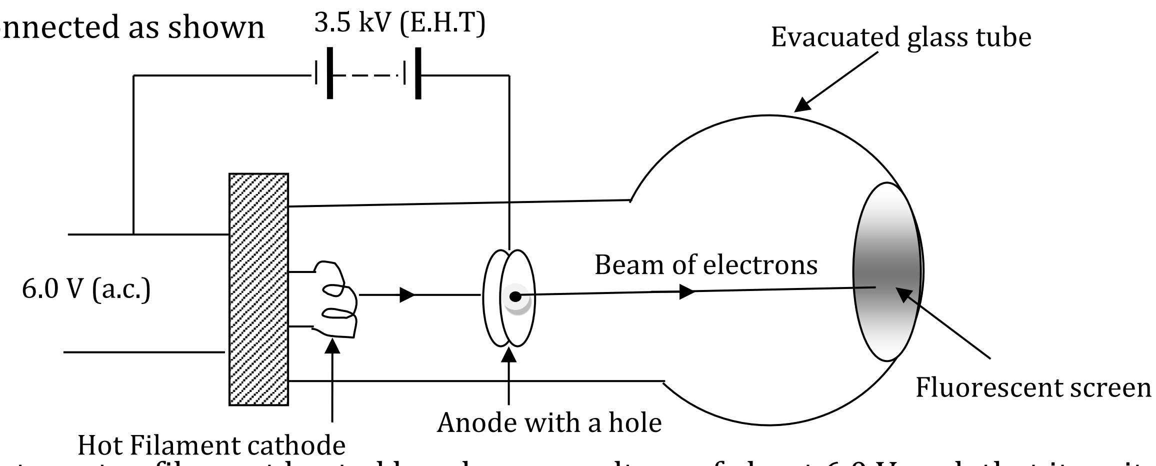
NOTE: Thermionic emission increases with temperature.

CATHODE RAYS

Cathode rays are streams of fast moving electrons.

PRODUCTION OF CATHODE RAYS

The circuit is connected as shown



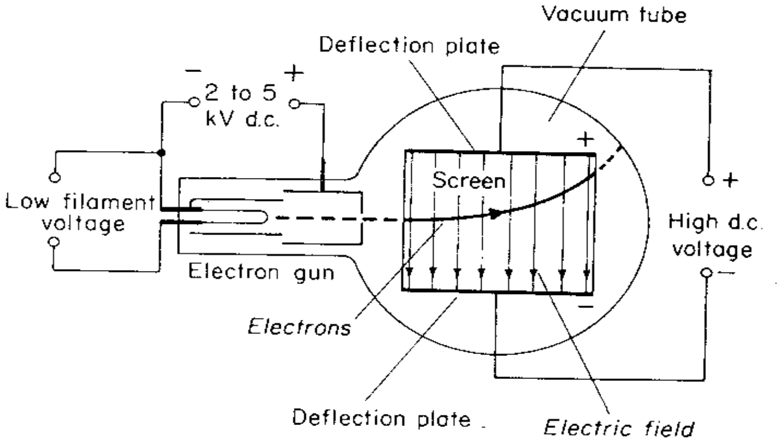
The cathode is a tungsten filament heated by a low a.c. voltage of about 6.0 V such that it emits electrons by method of thermionic emission.
The large p.d of about 3.5 kV across the anode accelerates the electrons from cathode towards the anode. The fast moving electrons pass through the anode and strike the fluorescent screen such it glows.
The glass tube is evacuated to ensure that electrons move freely so that they don't collide with the relatively heavier air molecules.

PROPERTIES OF CATHODE RAYS

- They carry a negative charge (since they are fast moving electrons).
- They are deflected by both electric and magnetic fields.

- They ionize gases.
- They cause some substance to fluorescence i.e. give off light when they strike the surface.
- They travel in a straight line.
- In an electric field, cathode rays are deflected towards the positive plate and in the magnetic field, the direction of deflection is determined using Flemings left hand rule.
- They possess energy.
- They can cause certain metals to produce X – rays when they are incident on them.

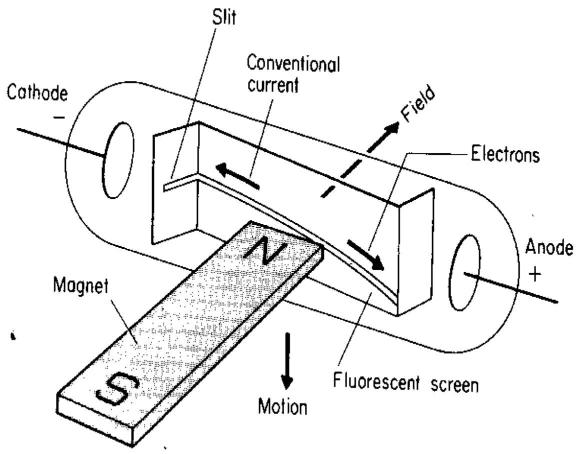
Deflection of cathode rays by an Electric field.

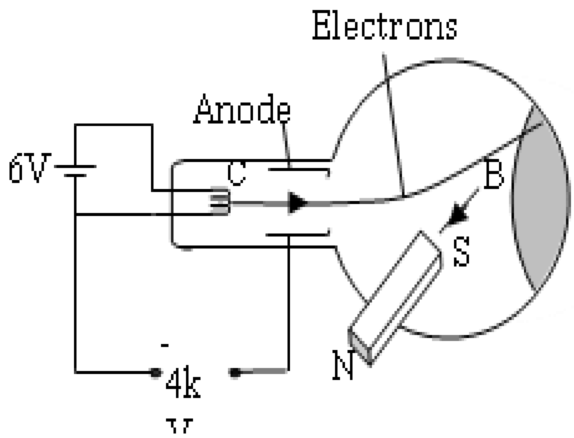


Cathode rays are deflected toward the positive plate by an electric field.

Deflection of cathode rays by a Magnetic field.

or



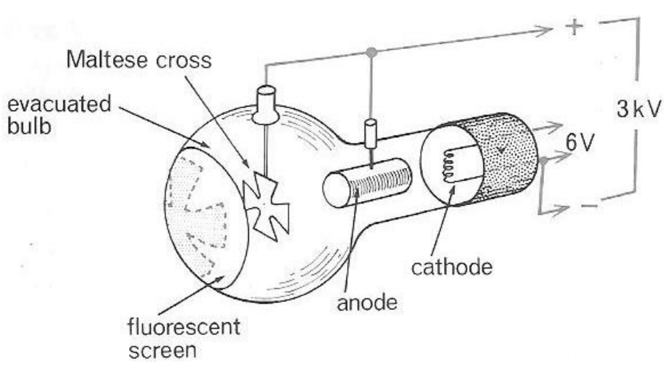


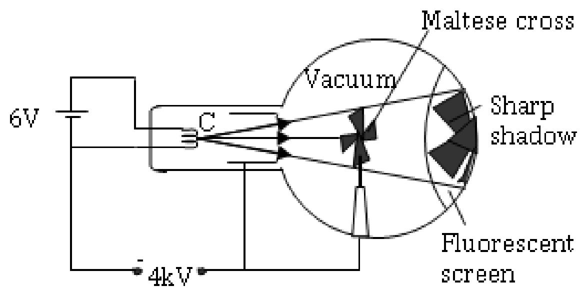
In a magnetic field, the deflection of the cathode rays is determined using Flemming's Left hand rule.

N.B. Cathode rays flow in the opposite direction of conventional current.

EXPERIMENT TO SHOW THAT CATHODE RAYS TRAVEL IN STRAIGHT LINE (THERMIONIC TUBE)

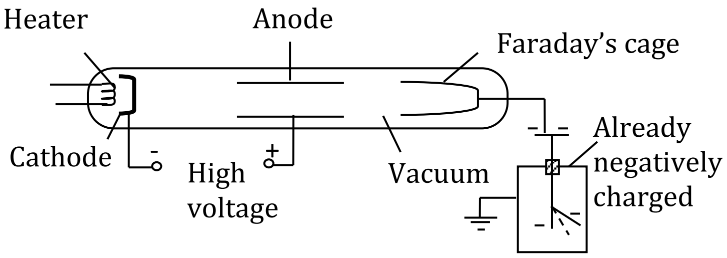
or





Cathode rays are incident on the maltase cross.
A shadow of the cross is formed on the fluorescent screen.
The formation of the shadow verifies that cathode rays travels in a straight line.

Showing that Cathode Rays Convey Negative Charge

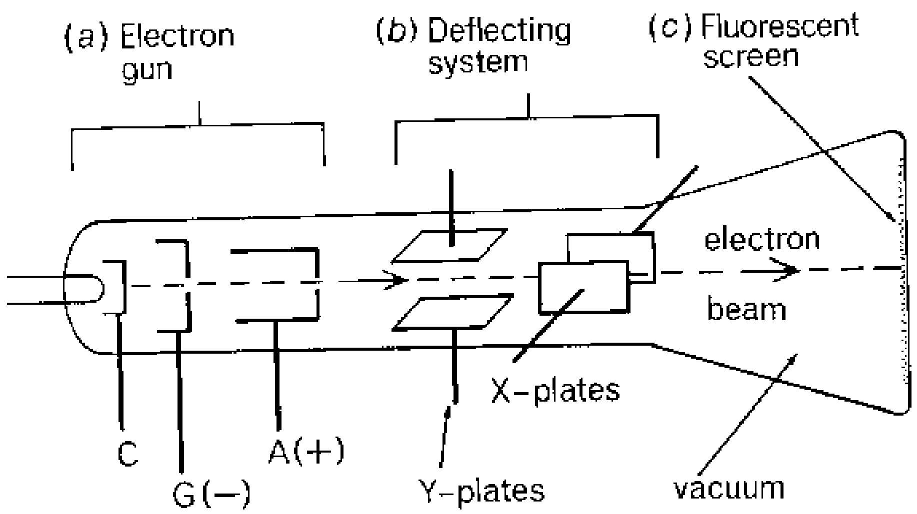


Cathode rays are directed to enter Faraday's cage in the tube which is connected to a negatively charged gold leaf electroscope. Further divergence of the leaf confirms negative charge.

THE CATHODE RAY OSCILLOSCOPE (C.R.O)

Thermionic emission is utilized in the:

- cathode ray oscilloscope (C.R.O)
- X –ray tube,
- TV etc



The C.R.O consists of three main components.

THE ELECTRON GUN

The electron gun consists of the following parts

(a) The cathode, C – used to emit electrons by thermionic emission.

(b)The control grid, G – this is connected to low voltage supply and is used to **control the number of electrons** passing through its central hole from the cathode to the anode. It acts as the **brightness control.**
(c)The anode – it accelerates the electrons and also focuses them on to the screen.

N.B: Since the grid controls the number of electrons moving towards the anode. It consequently controls the brightness of the spot on the screen.

DEFLECTING SYSTEM
This consists of the X and Y plates. They are used to deflect the electron beam horizontally and vertically respectively.

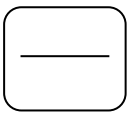
FLUORESCENT SCREEN.
This is where the electrons beam is focused to form a bright spot.

How the cathode ray oscilloscope works?
The cathode is heated by a low voltage power supply.
The cathode emits electrons by thermionic emission.
The electrons are attracted and accelerated by the anode and focused onto the screen.
The grid controls the brightness of the spot on the screen.

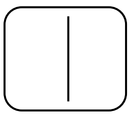
DEFLECTING SYSTEM
Beyond anode are two pairs of deflecting plates to which p.d.s can be applied.
The Y-plates are horizontal but create a vertical electric field which deflects the beam vertically. The X-plates are vertical and deflect the beam of electrons horizontally.

FLUORESCENT SCREEN
It produces a spot of light when electrons hit the screen.

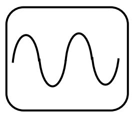
The Time base.
This is a special circuit connected to the X-plates for the purpose of controlling the horizontal movement of the spot.
Below are examples of the display on the screen:



(i) X-plate sweep switched on. (no signal on Y-plates)



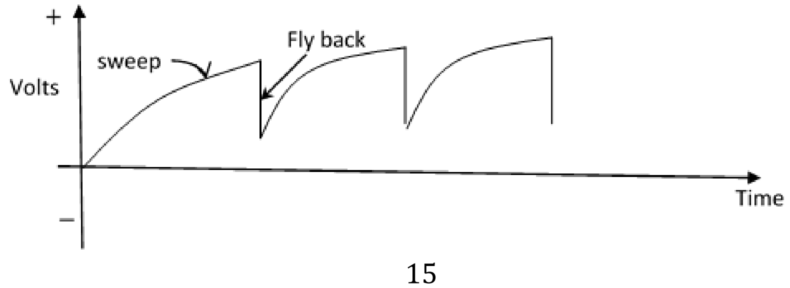
(ii) a.c signal applied to Y-plates with X-plates switched off



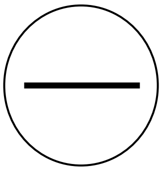
(iii) X-plate sweep and Y-plate signal combined

This is the circuit connected to the X – plates and is used to move the bright spot on the screen horizontally.
The time base uses a voltage referred to as a saw – tooth voltage.

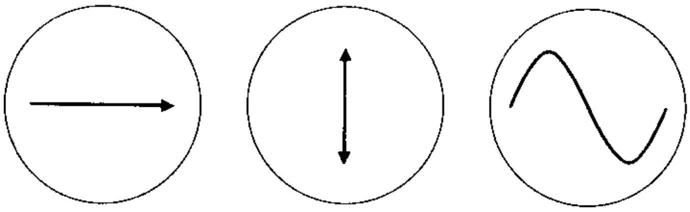
The time- base is an electrical circuit which generates a saw-tooth type of voltage shown below:



When the voltage rises, the spot moves to the right with uniform speed and then quickly flies back to the original spot as the voltage drops down. The process is rapidly repeated to result into a straight horizontal line across the screen.
The appearance of the horizontal line on the screen with Time base on X plate only.

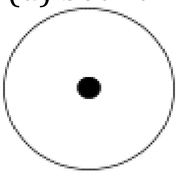


Different wave forms.
When time base (x- plate) is switched on and there is no signal on the y-plate, the spot is deflected horizontally. The horizontal line is observed.
When alternating current (a.c) is applied to the y- plate and time base (X –plate) is off, the spot is deflected vertically . The vertical line observed.
When a.c is applied on the Y-plate and X- plate is on ,a wave form is observed on the screen .
When time base is switched off and no signal to the Y- plate, a spot is observed.

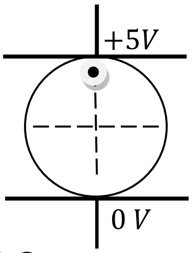


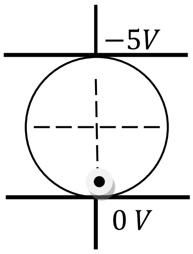
(a) X−plate sweep only (b) Y−plate a.c. signal only (c) Sweep and Y−plate signals combined

(d) both time base and Y – plate switched off



Direct current applied to the Y – plate.





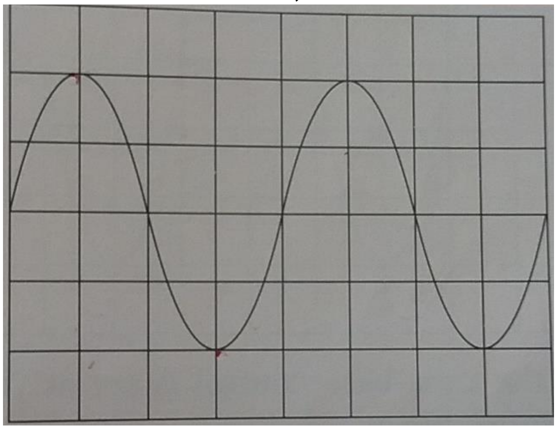
USES OF A C.R O
1. **Measurement of p.d (voltage)**
A C.R.O can be used as voltmeter because the distance through which the spot is deflected depends on the p.d between the plates.
Method
The sensitivity of the Y-scale is set to a particular voltage per division for example 5Vdiv^{-1} or 5Vcm^{-1}. The unknown voltage is then applied to the Y-plates and the distance moved by the spot from the mean position is noted. The voltage is then calculated using the formula:

$$\text{Peak voltage} = \text{Y} - \text{sensitivity} \times \text{number of divisions}$$

Examples (ref: Password – Numerical problems in Physics pages 230-231)
1. The sensitivity of the Y-scale is set to $3\ \text{V cm}^{-1}$. When a voltage is applied to the Y-plates, the spot on the screen moves 4cm from the mean position. Calculate the peak voltage applied. (Ans= 12V)
   Peak voltage $=$ Y $-$ sensitivity $\times$ number of divisions
   $$= 3 \times 4$$

$= 12V$

2. The figure above shows a waveform on a screen of a cathode ray oscilloscope. The Y-sensitivity is set at 2.5 V div^{-1}. Determine;



(a) the peak voltage

Peak voltage $=$ Y $-$ sensitivity $\times$ number of divisions

$$= 2.5 \times 2$$
$$= 5V$$

(b) the peak-to-peak voltage

Peak $-$ to $-$ peak voltage $= 5 \times 2 = 10V$

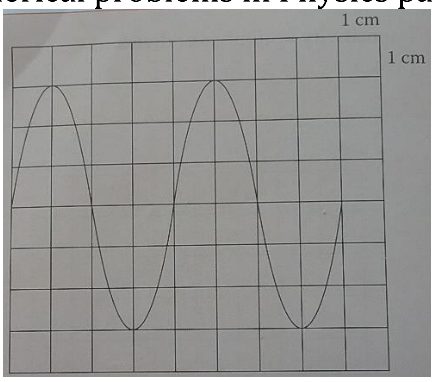
2. Frequency measurements

This is achieved by comparing a wave form of known frequency with unknown frequency.

Method

The time base control of the CRO is set to a particular value. The a.c signal of the unknown frequency is applied to the Y-plates. The number of divisions for one complete wave is noted. Time for one wave is calculated, which is the period, T. Frequency f, is then calculated using the formula: $f = \frac{1}{T}$

Examples (ref: Password – Numerical problems in Physics pages 232-233)

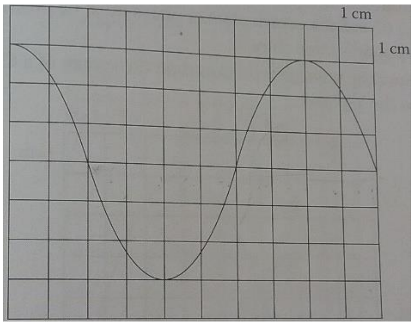


1. In the figure shown, the time-base control is set at 20 ms cm^{-1}. Calculate the frequency of the wave shown. (Ans = 12.5Hz).

For 1 complete wave, number of divisions $= 4$

$$1cm = 20ms$$
$$4cm = 20 \times 4ms = 80ms$$
$$f = \frac{1}{T} = \frac{1}{0.08}$$
$$= 12.5Hz$$

2. The Y-gain and the time base controls of a CRO are set at 200mV cm^{-1}. And 100ms cm^{-1} respectively. When an a.c signal is fed to the Y-plates, the waveform displayed is as shown in the figure. Determine the peak voltage and the frequency of the signal.



$$\text{Peak voltage} = \text{Y} - \text{sensitivity} \times \text{number of divisions}$$
$$= 3 \times 200$$
$$= 600\text{mV}$$
$$= 0.6\text{V}$$

$$\text{Time for 1 wave} = 8 \text{ divisions (cm)}$$
$$1\text{division (cm)} = 10\text{ms}$$
$$\text{Period, T} = 8 \times 10$$
$$= 80\text{ms}$$
$$= 0.08\text{s}$$
$$\text{f} = \frac{1}{T} = \frac{1}{0.08}$$
$$= 12.5\text{Hz}$$

3. Used to study wave forms of current and voltage.
4. Used in manufacture of T.V.

Summarised Uses of C.R.O

1. Measure voltage.
2. Measure frequency.
3. Measure phase difference.
4. Measure small time interval.
5. Used in manufacture of T.V.
6. Used to study wave forms of current and voltage.

REVIEW QNS ON CATHODE RAYS (HOW TO PASS PHYSICS PAGE 237) AND PASSWORD – NUMERICAL PROBLEMS IN PHYSICS PAGES 233-239

SUB-TOPIC: X-rays
SPECIFIC OBJECTIVES: The Learner should be able to;

- Draw the structure of the X-ray tube and describe how X-rays are produced.
- List properties and uses of X-rays.
- State health hazards of X-rays and safely precaution.

X – RAYS

X – rays are electromagnetic radiations produced when fast moving electrons are stopped by a metal target.

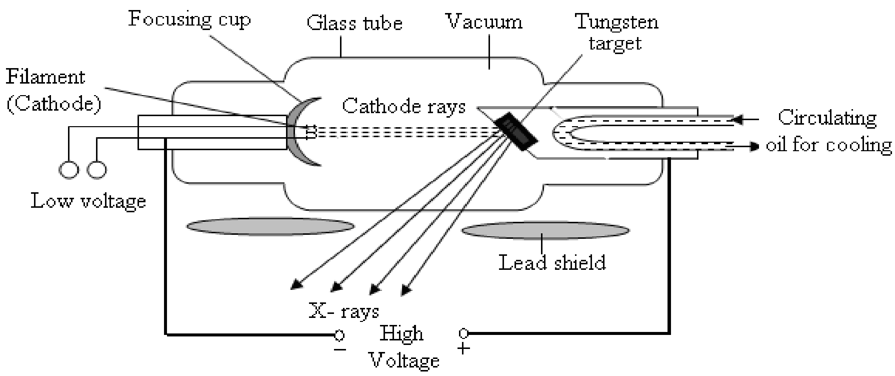
TYPES OF X – RAYS

There are two types of X – rays, namely

(i) Soft X- rays
(ii) Hard X – rays

Soft X –rays are produced at low voltages. They have a low penetrating power i.e low frequency and long wave length.
Hard X –rays are produced at high voltages. They have a high penetrating power i.e very high frequency and short wave length.

X – RAY PRODUCTION



Production of x-rays.
The cathode is heated to emit electrons by thermionic emission using a low voltage supply.
A large p.d is used to accelerate the electrons towards the anode along a highly evacuated tube.
On reaching the anode, they hit the metal target of a high melting point and their kinetic energy is converted into heat and X- rays.
The heat generated around the anode is conducted away through the copper anode to the cooling (radiator) fins.

N.B: The X– ray tube is evacuated to so that electrons can move freely with out any hindrance from the air molecules.
The target is a metal of high melting point like tungsten so that it does not melt as a result of the great amount of heat generated.
The Anode is of copper which rapidly conducts away the heat to the cooling fins.
The fins are painted black to quickly radiate heat to the surroundings.

PROPERTIES OF X- RAYS
- X-rays readily penetrate through matter.
- They are not affected by electric and magnetic fields (since they carry no charge).
- They have no charge.
- They cause ionization.
- They travel in straight lines.
- They affect photographic material (-by blackening it).
- They cause certain materials to fluorescence.
- They are electromagnetic waves and travel at the speed of light.

USES OF X- RAYS
(a) **Medicine**
In medicine X – rays are used to;
- Investigate born fractures.
- Detect lung tuberculosis.
- Treat cancer especially when it hasn't spread by radiotherapy i.e very hard x-rays are directed to the cancer cells so that the latter are destroyed
- Detect internal ulcers along a digestive track

- Locate foreign in the body e.g. swallowed metal objects

(b) **Industrial use**

In Industries, X – rays are used to;

- Detect cracks in car engines and und8erground pipes.
- Locate internal imperfections in welded joints e.g pipes, boilers,storage tanks e.t.c.
- Detect cracks in building.

(c) **X-ray crystallography**

Used to determine inter – atomic spacing in the crystal.

Differences between cathode rays and X- rays.

Cathode rays	X- rays
Are negatively charged	Have no charge
Are fast moving electrons	Are electromagnetic waves
Are deflected by both magnetic and electric fields	Are not deflected by both magnetic and electric fields

HOW AN X-RAY IS USED TO LOCATE BROKEN PARTS OF A BONE.

Bones are composed of much denser material than flesh hence, if X- rays are passed through the body, they are absorbed by the bones onto a photographic plate which produces a shadow photograph of the bones.

Differences between Gamma rays and X- rays.

Gamma rays	X- rays
They are produced by unstable radioactive material.	They are produced when fast moving electrons are stopped by a metal target.

SIMILARITIES BETWEEN X - RAYS AND GAMMA RAYS:

- They are both electromagnetic waves.
- They carry no charge.
- They are not deflected by both magnetic and electric fields.
- They penetrate matter.
- They cause fluorescence.
- They can cause harmful effects.
- They travel at the speed of light and in a straight line.

HARMFUL EFFECTS OF X-RAYS:

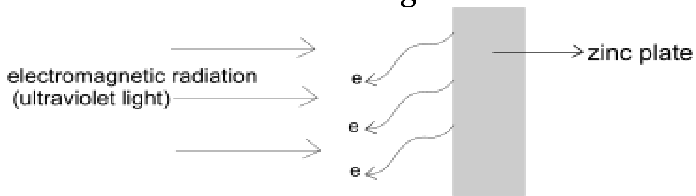
- Hard X -rays destroy healthy body cells.
- They cause genetic mutation or changes.
- They cause damage of eye sight and cause blood cancer.
- They produce skin burns.

PRECAUTIONS FOR SAFETY

- Avoid unnecessary exposure to X –rays.
- Keep exposure time as short as possible.
- The X- ray beam should only be restricted to parts of the body being investigated.
- Workers dealing with X-rays should wear shielding jackets with a layer of lead.
- Exposure should be avoided for unborn babies and very young children.
- Rooms where X- ray machines are located (e.g. hospitals and industries) are made of thick concrete walls to absorb stray radiations.

REVIEW QNS ON X - RAYS (HOW TO PASS PHYSICS PAGE 249)

PHOTO ELECTRIC EMISSION
This is the emission of electrons from a certain metal plate e.g zinc plate, when electromagnetic radiations of short wave length fall on it.

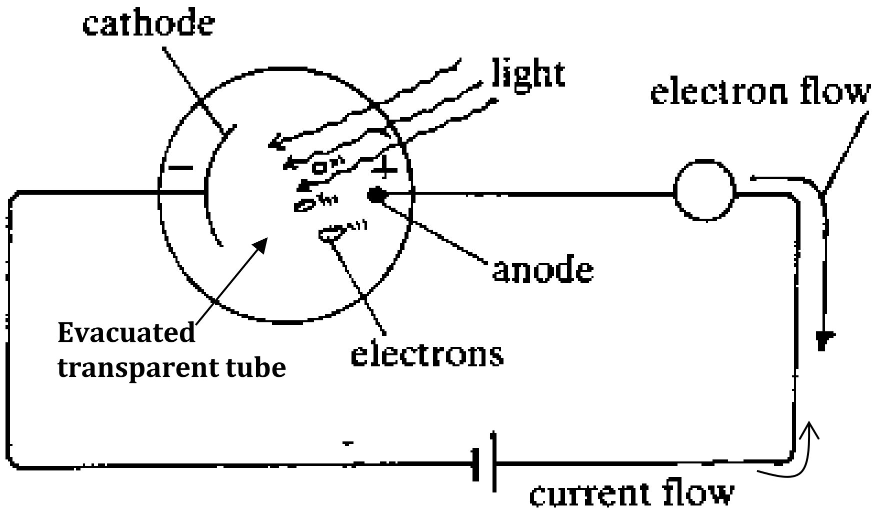


PHOTOELECTRONS:
Photoelectrons are the electrons emitted by a metal by the process of photoelectric effect.

Photoelectrons are emitted from any metal if the wavelength of incident electromagnetic radiation is below a certain critical value called the threshold wavelength.
OR if the frequency of the incident electromagnetic radiation is above the critical threshold frequency)
WORK FUNCTION:
The Work function is the minimum frequency of the incident radiation required to eject a photoelectron from a particular metal surface.

The number of photoelectrons emitted from the metal surface depends on;
(i) the intensity of the incident radiation. Increasing intensity increases the number of electrons emitted.
(iis) the type of metal.
The incident radiation provides sufficient energy to overcome the binding forces of the metal and the excess energy is converted to into kinetic energy which the electrons use to escape from the metal surface.

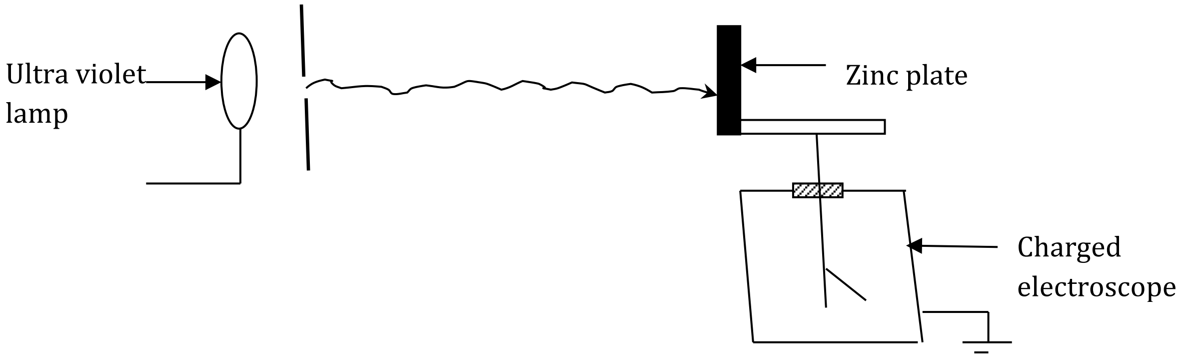
THE PHOTOELECTRIC CELL.
The photoelectric cell uses photoelectric effect to convert light energy into electric energy. The strength of the current produced depends on the intensity of the incident light radiation on the metal.



When a suitable radiation falls on the zinc cathode, it emits electrons by photoelectric emission.
The anode attracts the electrons which then pass through an external circuit causing an electric current.
N.B: If gas is introduced into the tube, the current decreases slowly because the gas particles collide with the electrons, hence reducing the number of electrons reaching the anode.

APPLICATIONS OF PHOTOELECTRIC EFECT:
Photoelectric effect is applied in:
- Burglar alarms.
- Automatic lighting systems
- In solar calculators.
- Television cameras
- Automatic door systems
- Sound track on a film.

EXPERIMENT TO DEMONSTRATE PHOTOELECTRIC EFFECT:



When Ultra violet light is incident on a clean zinc plate placed on the cap of a gold leaf electroscope:
- If the **electroscope is uncharged**, the leaf initially rises indicating that is acquiring charge.
- If the **electroscope is negatively charged**, the leaf divergence slowly decreases indicating that is losing charge.
- If the **electroscope is positively charged**, no loss of charge is observed. The photoelectrons are attracted back to the zinc plate and electroscope.

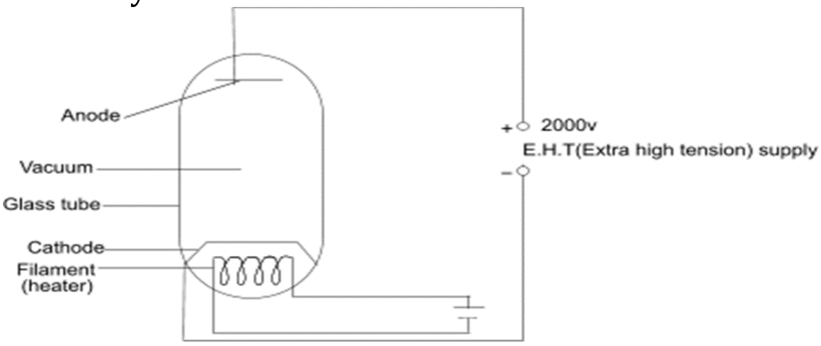
Conclusion:
The Zinc plate emits photoelectrons when ultra violet radiation falls on it.

Vacuum Diode

A diode is a device that allows the flow of current in only one direction.

A vacuum diode is one of such devices.

It works on the same principle as the C.R.O. It consists of an anode and a cathode which is heated by a filament. All these are housed in an evacuated glass envelope.



Action:
The heater raises the temperature of the cathode, which thermionically emits electrons. The electrons are accelerated to the anode by the high p.d between the cathode and anode and therefore a current I flows in the direction shown in the diagram. If the supply is reversed, the

diode does not conduct any current, since the cool anode cannot now release electrons to flow the other way to the cathode. This way the device acts as a rectifier.

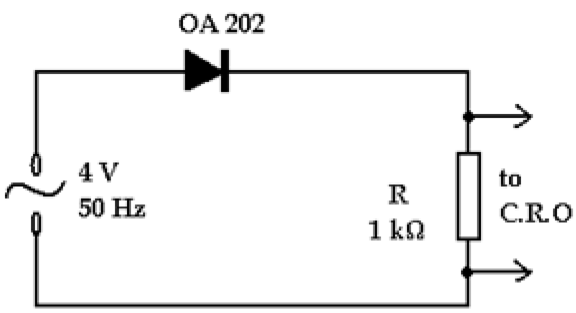
REVIEW QNS ON PHOTOELECTRIC EFFECT (HOW TO PASS PHYSICS PAGE 258)

RECTIFICATION
This is the conversion of alternating current to direct current.

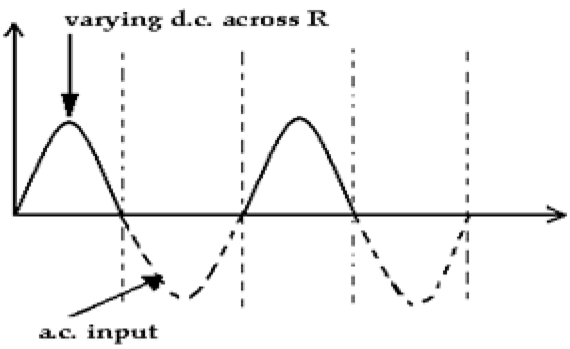
A semiconductor diode rectifies, i.e. converts a.c. to d.c.

(a) Half wave rectification

a)



b)

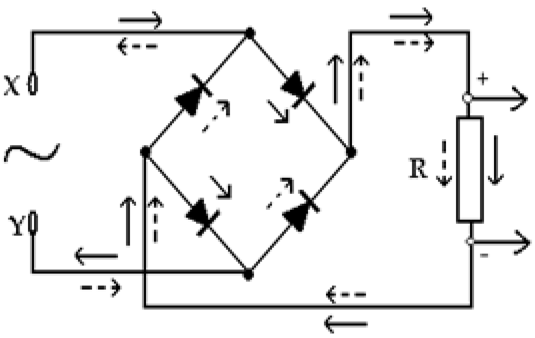


The diode removes the negative half-cycles of a.c. to give a varying but one-way (direct) p.d. across R, the 'load' requiring a d.c. supply, Figure b above.

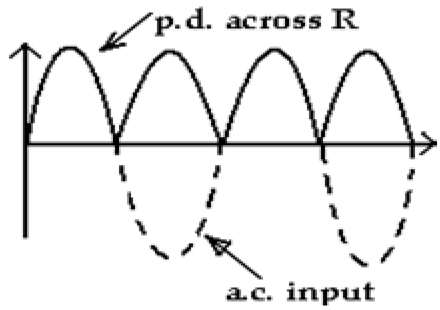
(b) Full wave rectification

Both the half-cycles of the a.c to be rectified are used. In the bridge circuit of fig. a, the current flows the solid arrows when X is positive and Y negative and the broken arrows on the negative half-cycles when the positive of X and Y are reversed. During both half-cycles, current flows in R and in the same direction giving a p.d. as shown below,

a)



b)



REVIEW QNS ON ELECTRONICS (HOW TO PASS PHYSICS PAGE 291)

THE END.