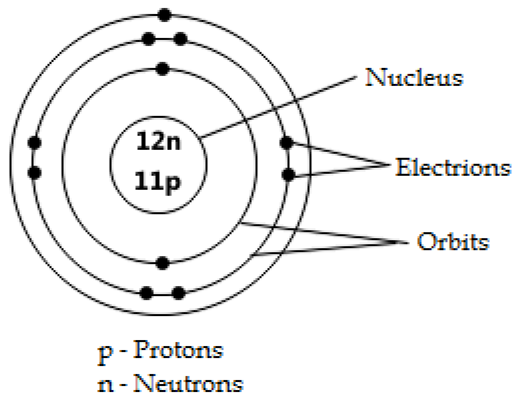
MODERN PHYSICS
An atom
This is the smallest electrically neutral indivisible particle of an element that can take part in a chemical reaction but cannot exist on its own.
Structure of a Sodium atom



Composition
The particles inside the nucleus of an atom are protons and neutrons, they are collectively called **nucleons**.
Electrons are located outside the nucleus within circular orbits.
In a neutral atom the number of protons is equal to the number of electrons surrounding the nucleus.
Charge
Protons are positively charged particles.
Electrons are negatively charged particles.
Neutrons are neutral particles without charge.
Symbols
Electron ${}_{-1}^{0}e$
Proton ${}_{1}^{1}H$
Neutron ${}_{0}^{1}n$
Atomic Number (Z)
This is the number of protons in the nucleus of an atom. It is represented by the letter Z.
Mass number (A): This is the total number of protons and neutrons in the nucleus of an atom. ie A=Z+N
Nuclide: This is an atom which has a specified number of protons and neutrons. A nuclide X of mass number A and atomic number Z is represented by ${}_{Z}^{A}X$
Eg sodium atom is symbolized by ${}_{11}^{23}Na$, A = 23 and Z = 11 Find the number of neutrons in the nucleus of this atom
N=A-Z, N=23 – 11 = 12
The following symbols represent nuclides of copper and nickel respectively
${}_{29}^{53}Cu$ and ${}_{28}^{60}Ni$ Write down the number of protons, neutrons and electrons in each nuclide.
Isotopes These are atoms of the same element with the same atomic number but different mass numbers.
The difference in mass number is caused by the isotopes having a different number of neutrons.
Examples Hydrogen ${}_{1}^{1}H$, Deuterium ${}_{1}^{2}H$ and Tritium ${}_{1}^{3}H$

Chlorine ${}_{17}^{35}Cl$ and ${}_{17}^{37}Cl$

Neon ${}_{10}^{20}Ne$ and ${}_{10}^{22}Ne$

RADIOACTIVITY

This is the spontaneous, random disintegration of the unstable nucleus of an atom forming stable nuclides by emission of radiations.

The radiations emitted are alpha particles (α), beta particles (β) and gamma rays (γ).

Nuclear Equations

Alpha particle (α): This is a helium nuclei of mass number 4 and atomic number 2.In nuclear reactions it is written as $\alpha = {}^{4}_{2}\mathrm{He}$

During alpha decay the mass number of the parent nuclide decreases by 4 and the atomic number decreases by 2. ie.

$${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A-4}_{Z-2}\mathrm{Y} + {}^{4}_{2}\mathrm{He}$$

The first law of radioactivity

When an element disintegrates by the emission of an alpha particle it turns into an element with chemical properties similar to those of an element two places earlier in the periodic table.

Polonium decays by emission of an alpha particle and it is transformed into a stable element lead (Pb)

Eg. ${}^{210}_{84}\mathrm{Po} \rightarrow {}^{206}_{82}\mathrm{Pb} + {}^{4}_{2}\mathrm{He}$

Beta particle (β): This is an electron of negligible mass and atomic number 1. In nuclear reactions it is written as $\beta = {}^{0}_{-1}e$. During beta decay, the mass number of the parent nuclide remains unchanged and the atomic number increases by 1.

Ie ${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+1}\mathrm{Y} + {}^{0}_{-1}\mathrm{e}$

In the process a neutron is changed into a proton and an electron is produced.

$${}^{1}_{0}\mathrm{n} \rightarrow {}^{1}_{1}\mathrm{p} + {}^{0}_{-1}\mathrm{e}$$

The second law of radioactivity

When an element disintegrates by the emission of a beta particle it turns into an element with chemical properties similar to those of an element one place later in the periodic table.

A radioisotope of Barium ${}^{139}_{56}\mathrm{Ba}$ decays by emission of a beta particle and is transformed into a stable isotope of lanthanum

$${}^{139}_{56}\mathrm{Ba} \rightarrow {}^{139}_{57}\mathrm{La} + {}^{0}_{-1}\mathrm{e}$$

Gamma radiation (γ):

Gamma radiation does not affect the mass number or atomic number of the parent nuclide. They are electromagnetic radiations moving at the speed of light.

Sample questions

1. Radium ${}^{226}_{88}\mathrm{Ra}$ disintegrates by emission of an alpha particle to form radon (Rn). What is the atomic number and mass number of radon? Write down the equation of the reaction.
2. An element X has mass number 228 and atomic number 90. It emits a beta particle forming Y. write down the atomic symbol of Y.
3. A radioisotope of sodium atom decays by emission of a beta particle as shown in the equation below. Find the values of A and Z

$${}^{24}_{11}\mathrm{Na} \rightarrow {}^{A}_{Z}\mathrm{Y} + {}^{0}_{-1}\mathrm{e}$$

4. Uranium ${}^{228}_{88}\mathrm{U}$ disintegrates emitting one alpha particle and gamma radiation and changes into an isotope of thorium (Th). Write an equation for this change.
5. ${}^{232}_{90}\mathrm{X} \underset{L}{\rightarrow} {}^{228}_{88}\mathrm{Y} \underset{M}{\rightarrow} {}^{228}_{89}\mathrm{Z} \underset{N}{\rightarrow} {}^{228}_{89}\mathrm{Z}$

Identify the particles or radiations L, M and N emitted in the decay shown in the equation.

6. $^{234}_{90}A \xrightarrow{(i)} {}^{234}_{91}B \xrightarrow{(ii)} {}^{234}_{92}C \xrightarrow{(iii)} {}^{230}_{90}D$

The above equation shows three stages of radioactive series. Name the particles emitted at each stage.

Nature of radiations (α, β, γ) from radioactive substances

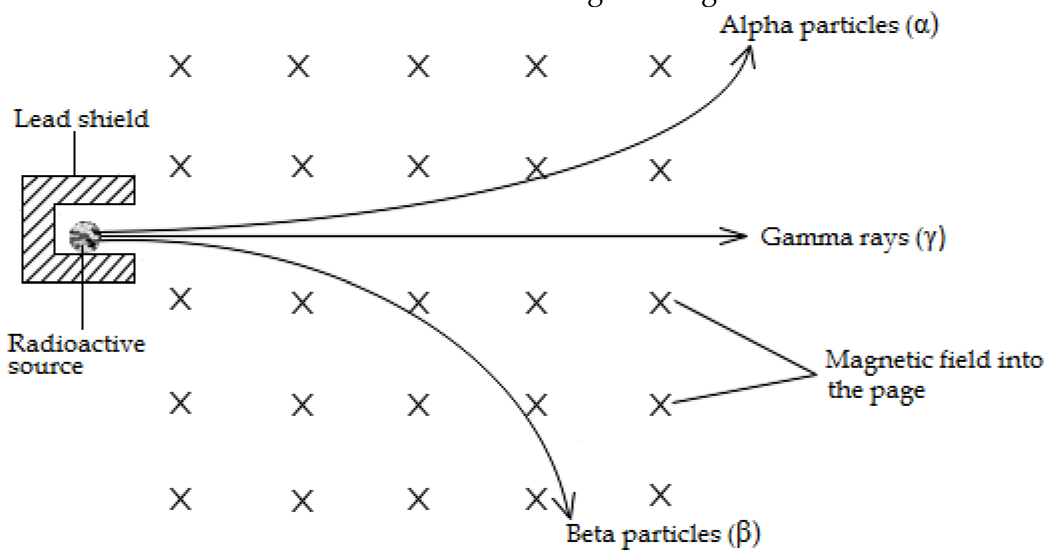
Effect of a magnetic field

The deflection of radiation by a magnetic field can be demonstrated by placing a strong magnetic field between the radiation source and a detector. The alpha particles have a relatively large mass and are slightly deflected in a direction which shows that they are positively charged.

Beta particles are greatly deflected because of their small mass. Their direction of deflection shows that they are negatively charged.

The gamma rays are not deflected because they have no charge.

The direction of deflection is determined using Fleming's left hand rule.



Effect of an electric field

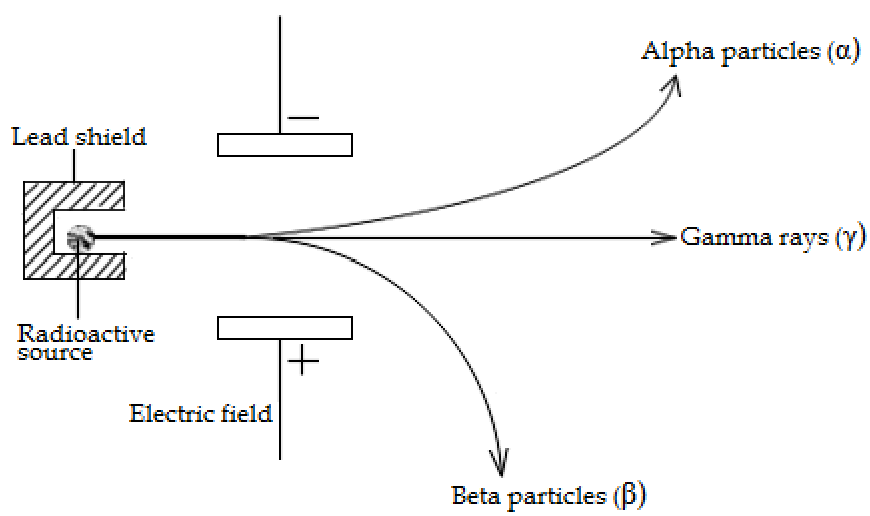
The alpha particles are deflected towards the negative plate because they are positively charged

The beta particles are deflected towards the positive plate because they are negatively charged.

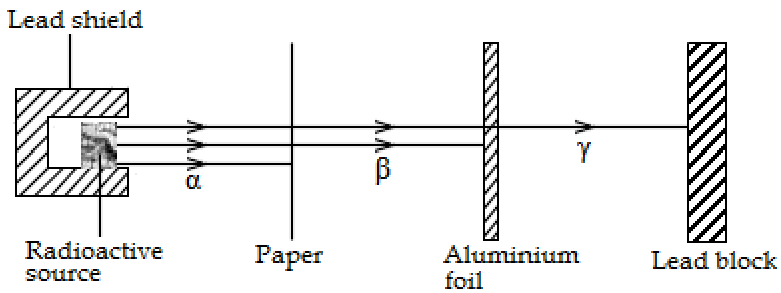
There deflection is greater because of their negligible mass.

The gamma rays are not deflected because they have no charge.

They are electromagnetic waves in nature.



Penetrating power of radiations



Alpha radiations are stopped by a thin sheet of paper.
Beta radiations can penetrate a thin sheet of paper but are stopped by an Aluminium foil.
Gamma rays can penetrate both a sheet of paper and aluminium foil but are stopped by a lead block of a few centimetres thick.

Range in air.
The range in air of a radiation is the distance the radiation can penetrate in air before it is totally absorbed.
Alpha particles have a range in air of a few centimetres because they are massive and therefore cause strong ionisation as they pass through air.

Beta particles have a range in air of several metres because they are light and cause less ionisation in air compared to alpha particles.

Gamma rays have a range in air of a few kilometers because they have no mass and cause the least ionisation in air.

Properties of alpha particles, beta particles and gamma rays
Alpha particles
1. They are positively charged.
2. They are slightly deflected by electric and magnetic fields.
3. The cause the most ionization in air.
4. They travel slowly in air.
5. They have the least penetrating power and are stopped by a thin sheet of paper.

Beta particles
1. Are negatively charged
2. Are greatly deflected by electric and magnetic fields
3. Cause less ionization in air
4. They travel relatively faster than alpha particles
5. They are highly energetic compared to alpha particles
6. They have a relatively large penetrating power. Can penetrate a sheet of paper but are stopped by an aluminum foil.
Gamma rays
1. They have no charge
2. They are not deflected in both electric and magnetic fields
3. They cause the least ionization

4. They travel at the speed of light
5. They have the largest range in air
6. They have the most penetrating power and are only stopped by a thick lead block.

Detectors of radioactive radiations

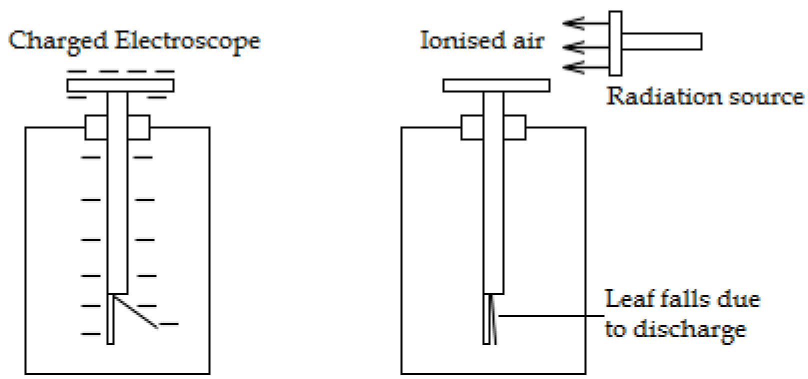
1. Gold-leaf electroscope
2. Cloud chamber
3. Geiger-Muller tube
4. Ionization chamber
4. Photographic plate

How a gold-leaf is used to detect radiations

The gold leaf of a charged electroscope remains diverged, because the charges on the gold repel the charges on the metal plate. Dry air is a good insulator, so charge on a charged electroscope cannot escape.

When a radioactive source comes near the cap, the air is ionised and starts to conduct electricity. This makes the charge on the electroscope "leak" away, discharging the electroscope. Hence the gold leaf falls.

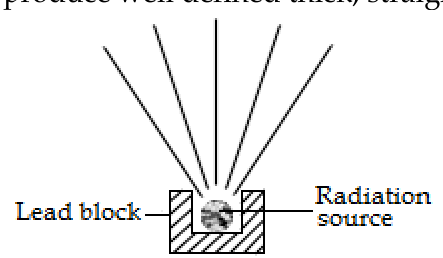
The rate at which the electroscope discharges is proportional to the radiation intensity.



Appearance of the three radiations in a cloud chamber

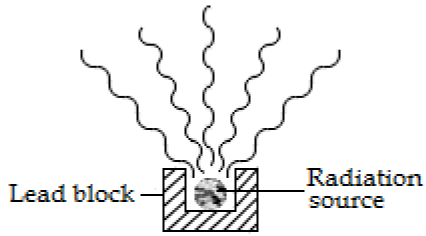
Alpha particle tracks

Since alpha particles are large, they are good ionisers and are less likely to be deviated. They produce well defined thick, straight tracks.



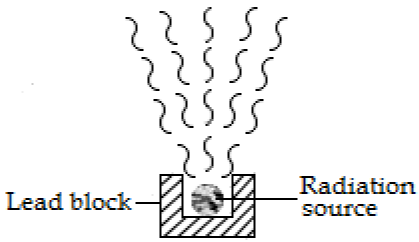
Beta particle tracks

Beta particles are electrons and due to their small size they are poor ionisers and are easily deviated. The tracks produced are thin wavy lines.



Tracks of Gamma rays

Unlike alpha and beta particles gamma rays must hit the atom directly in order to ionize it this is very unlikely so the tracks are not clearly defined.



HALF LIFE

This is the time taken for a radioactive element to decay to half of its original mass.

Determining the remaining mass after decay

For each half life that elapses the mass is successively reduced by half until the accumulated half lives add up to the given time of decay. You end up with the mass that remains after the given decay time has elapsed.

Example

Given 32g of a radioactive material whose half life is 20 days we can find the mass that remains after 80 days

$32g \xrightarrow{20days} 16g \xrightarrow{20days} 8g \xrightarrow{20days} 4g \xrightarrow{20days} 2g$

Four half lives add up to 80days

The mass remaining is **2g**

The mass that decayed = 32 – 2 = 30g

Alternative method

Given that the radioactive sample has an original mass of M_o and a half life of $t_{1/2}$, the mass M_t remaining after a radioactive substance has decayed for a time t is given by

$$M_t = \frac{M_o}{2^n}$$

Where $n = \frac{t}{t_{1/2}}$

Decayed mass = $M_o - M_t$

Considering the previous example

$M_0 = 32g$

$t_{1/2} = 20$ days

t = 80 days

$M_t = 32g$

$$n = \frac{t}{t_{1/2}}$$

$$n = \frac{80}{20}$$

n = 4

$$M_t = \frac{M_o}{2^n}$$

$$M_t = \frac{32}{2^4} = \frac{32}{16}$$

$\mathbf{M_t = 2g}$

Examples

1. A radioactive sample has a half life of 4 hours. If the initial mass of the sample is 96g, find how much of the original sample will remain after 24 hours.
2. A radioactive sample has a half life of 24 days. If the initial mass of the sample is 38.4 g, find how much of the original sample will remain after 96 days.
3. The half life of a radioactive substance is 10 s. How long will it take for a mass of 16 g of that substance to reduce to 2 g?
4. The mass of a radioactive substance falls to a quarter of its original mass after 10 days. Calculate its half life.
5. A sample of a radioactive material contains 10^{18} atoms. The half life of the material is 2000years. Find;

(i) The number of atoms present after 6000years

(ii)The fraction of radioactive material decayed after this time

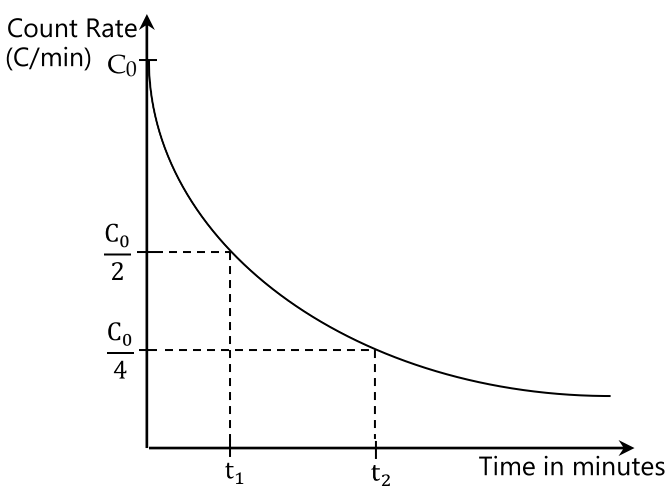
6. A 64g sample of a radioactive substance was reduced to 4g in 96 days. What is its half life? How much will remain after another 96days?
7. $1/64$ of a radioactive sample remains after 2 weeks. What is its half life?
8. The half life of the isotope cobalt-60 is five years. What fraction of the isotope remains after 1 year?
9. The mass of a radioactive sample decays to $1/32$ of its original mass after12 days. Find the half life of the substance.
10. In 168 seconds Thoron decays to one eighth of its original value. What is its half life?
11. A certain mass of radioactive material contains 2.7×10^{24} atoms. How many atoms would have decayed after 3200 years if the half life of the material is 400 years?

(Leave a space of four pages in your books for solutions)

THE COUNT RATE

The count rate is the amount of radiation from a radioactive substance detected per second. Count rate is measured using a Geiger Muller (GM) tube connected to a counter.

Count rate is measured in counts per second or counts per minute. The count rate decreases with time as the number of unstable atoms in a radioactive substance reduces. This is shown on the graph of count rate against time known as the **decay curve.**



Points to note about the decay curve

(i) In theory, every radioactive substance should stay slightly radioactive forever. The graph should never actually fall to zero.

(ii) A decay curve is also represented by a graph of mass of the radioactive substance remaining against time.

(iii) The activity is the total number of emission per second in all directions from the radioactive substance.

(iv)The count rate is always much less than the activity of the source because count rate is measured by detecting radiations from a small angle.

Finding half-life from the decay curve

From the graph the half-life is determined by finding the time taken for the count rate of the radioactive sample to reduce by a half.

From the graph the count rate at a time $t = 0$ is C_0 and that at a time t_1 is $Co/2$. The half-life is t_1

The count rate at a time t_1 is $Co/2$and that at a time t_2 is $Co/4$. The half life is $t_2 - t_1$

A number of half-lives are measured and their average value is calculated. The average value is the half-life of the radioactive source.

Examples

1. The table below shows the count rate produced a radioactive source at different times

Count rate/min	1800	1360	1080	880	760	600	500	400
Time (min)	0	1	1.8	2.5	3	3.8	4.5	5.5

Plot a graph of count rate against time. Use the graph to calculate the half-life of the sample. How long will it take the count rate to reduce to 625 counts per minute?

2. The table below shows the count rate produced a radioactive source at different times

Count rate/min	6400	5380	3810	2700	1910	1350	850	440
Time (min)	0	1	3	5	7	9	11	13

Plot a graph of count rate against time. Use the graph to calculate the half-life of the sample. How long will it take the count rate to reduce to 2000 counts per minute?

3. The table below shows results obtained in an experiment to determine the half-life of a radioactive substance.

Count rate	250	175	76	38	25
Time (min)	0	5	10	15	10

Draw a graph of count rate against time and use it to determine the half-life of a radioactive substance.

4. The half-life of a radioactive element is 24 days. Given an initial mass of the substance of 128g calculate the mass remaining after the time shown in the table.

Mass (g)	128						
Time (Days)	0	24	48	72	96	120	148

Plot a graph of mass against time and use it determine;

(i) The mass remaining after 55 days

(ii) How long will it take to remain with a mass of 32g?

5. A researcher measures 200 counts per minute coming from a radioactive source at midday. At 3 o'clock, she finds that this has dropped to 25 counts per minute. What is the half-life of the radioactive source?

6. The count rate of a radioactive sample is 40 counts per second. The count rate after 15minutes is 20 per second. How long is the half-life of the substance? What will be the new count rate after 10 minutes?

7. A chemist determines that a sample of an old petrified wood has a carbon-14 decay rate of 6.00 counts per minute per gram. The decay rate of carbon-14 in fresh wood today is 13.6 counts per

minute per gram, and the half-life of carbon-14 is 5730 years. What is the age of the piece of wood in years?
8. The C-14 content of an ancient piece of wood was found to have three tenths of that in living trees this indicates that 70% of the C-14 had decayed. How old is that piece of wood?
9. The count rate of a radioactive isotope falls from 600 counts per second to 75 counts per second in 75 minutes. What is the half-life of the radioactive isotope?
10. The activity of a radioactive element with a half-life 30 days is 2400 counts per second. Find the activity of the element after 120 days.
11. The half-life of Uranium is 24 days
(i) Explain the meaning of the above statement
(ii) Calculate the mass of Uranium which remains after 120days if the initial mass is 64g
(Leave a space of four pages in your books for solutions)
USES OF RADIOACTIVITY
Biological uses
1. Gamma rays are used in treatment of cancer. They are used to kill cancer cells by a process called **Radiotherapy**
2. Gamma rays are used to sterilize medical equipment especially that used in surgery.
3. Gamma rays are used to preserve some food products.
4. Radio isotopes are used to induce plant mutations which lead to improved seed varieties with high yields and high resistance to crop diseases.
5. Radio isotopes are used as tracers in medicine to examine the function of body organs.
6. Radioactive Iodin-131 is used to diagnose and treat goitre (thyroid disorder).
7. Carbon dating is used to determine the number of years an organism has been dead.

Carbon dating
Living organisms have a known quantity of Carbon-14 a radioisotope of Carbon in their tissues. When an organism dies, its Carbon-14 starts decaying with a half-life of 5700 years. The age of ancient animal or plant remains can be found by measuring the amount of Carbon-14 left. This age is the period for which an organism has been dead.

Industrial uses
1. The nuclear energy released during nuclear reactions is used to generate electricity for industrial and domestic use.
Steps of generating electricity
(i) Radioactive element undergoes nuclear fission
(ii) Large amount of heat produced is used to boil water to produce steam at high pressure
(iii) The steam rotates turbines which in turn rotate coils is a magnetic field to produce electricity.
2. Nuclear energy is used in nuclear bombs and weapons for defense purposes.
3. Radiations are used to monitor the thickness of paper and metal sheets by monitoring the count rate of the sample across the sheet. This principle is used to monitor level of contents in sealed containers. Eg paint, oil, tooth paste etc.
4. Leaks in underground pipes are detected by adding a small quantity of the radioactive sample to the liquid in the pipe. The leakage of radiation through a crack is detected.
5. Gamma rays from the isotope of cobalt are used to detect faults in thick metal sheets and welded joints.
6. Alpha radiation is used in smoke detectors found in smoke alarms.

Health Hazards /Dangers of radiations from radioactive substances
- The radiations cause burns and sores on the skin.
- Radiations destroy body cells

- Radiation exposure causes long term effects such as cancer, eye cataracts, sterility, infertility,suppressed immunity etc.
- Radiations cause genetic mutations that lead to birth of babies with serous abnormalities.

Safety **Precautions** when dealing with radioactive sources:

- Radioactive materials should be handled using forceps, long tongs and never with bare hands.
- Radioactive materials should be stored in thick lead boxes
- People who deal with radioactive materials should wear protective clothing.
- Should avoid unnecessary exposure to radioactive substances by pointing sources away from people. Containers and rooms keeping radioactive sources must be clearly marked with a warning symbol.

Nuclear fission

This is a nuclear reaction in which a heavy nucleus splits into smaller nuclei with emission of energy.

Nuclear fission occurs in atomic bombs, nuclear reactors etc

Nuclear fission is achieved by bombarding a heavy nuclide using neutrons.

The difference in mass between the parent nuclide and the daughter nuclides is turned into energy.

Examples

$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{148}_{57}\mathrm{La} + {}^{85}_{35}\mathrm{Br} + 3\,{}^{1}_{0}\mathrm{n} + \text{energy}$

$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{90}_{38}\mathrm{Sr} + {}^{143}_{54}\mathrm{Xe} + 3\,{}^{1}_{0}\mathrm{n} + \text{energy}$

$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} + \text{energy}$

Nuclear fusion

This is the union of light nuclei to form a heavy nucleus with emission of energy.

Nuclear fusion occurs in the sun and in a hydrogen bomb.

Conditions

(i) The particles approaching each other should be at very high speeds to overcome the strong nuclear repulsion.

(ii) The particles approaching each other should be heated to very high temperatures.

Example

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

Similarities between Nuclear Fission and Nuclear Fusion

Both fission and fusion release huge amounts of energy.

Both fission and fusion reactions can occur in nuclear bombs.

Differences between Fission and Fusion

1. Nuclear Fission breaks a heavy nuclide into smaller nuclides. The parent nuclide has a higher atomic number than the daughter nuclides.
2. Nuclear Fusion joins light nuclides. The nuclide formed has more neutrons and protons than the fusing nuclides.

Thermionic emission

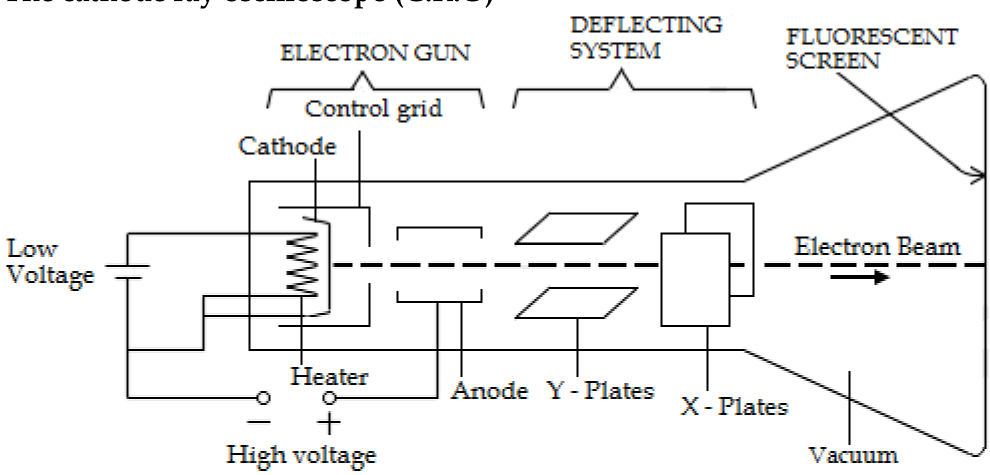
This is the release of electrons from a heated metal surface.

The surface emitting electrons is called a cathode.

Cathode rays
Cathode rays are a stream of fast moving electrons.
The electrons are emitted by thermionic process when the cathode is heated. The electrons are accelerated through a potential difference of several kilovolts between the cathode and the anode producing cathode rays.

Properties of cathode rays
1. They are fast moving electrons.
2. They are negatively charged.
3. They travel in a straight line.
4. They are deflected by both electric and magnetic fields.
5. They cause certain substances to fluoresce.
6. They produce X-rays when they hit a metal target,

The cathode ray oscilloscope (C.R.O)



The electron gun
It consists of a heater, a cathode, control grid and the anode.
The grid is set at a slightly negative potential with respect to the cathode. It controls the number of electrons leaving the cathode. The grid therefore controls the brightness of the screen.
The anode is in form of a hollow metallic cylinder and it is at a positive potential relative to the cathode. The anode is used to accelerate and focus electrons onto the screen.

The deflecting system
It comprises of the X-plates and Y-plates. When a potential difference is applied across either pair of plates, a deflecting electric field is created. The X – plates deflect the electron beam horizontally. The Y – plates deflect the electron beam vertically.

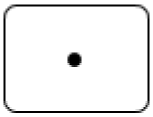
The fluorescent screen
A bright spot is displayed on the screen at the point where the electron beam hits. The spot traces out a pattern that depends on the voltage variations applied to the X and Y-plates.

TIME BASE
The time base circuit in the C.R.O applies a p.d across the X-plates which repeatedly moves (sweeps) the spot steadily across the screen from left to right horizontally and then returns it rapidly to the left. When the frequency of the time base is increased a horizontal line is observed across the screen.

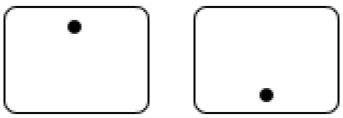
Note: The time base is also known as the sweep generator.

Traces displayed on the C.R.O. screen

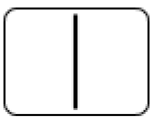
A spot at the centre represents a signal with both the Y-plates and time base switched off.



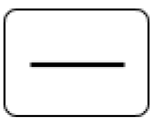
A spot above or below the horizontal axis represents a D.C voltage applied to the Y-plates with the time base switched off.



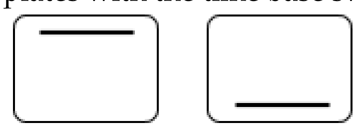
A straight line along the vertical axis represents an A.C voltage applied to the Y-plates with the time base switched off.



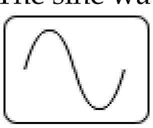
A horizontal straight line along the horizontal axis represents no voltage applied to the Y-plates with the time base switched on.



A horizontal straight line above or below the horizontal axis represents a D.C applied to the Y-plates with the time base switched on.



The sine wave represents an A.C applied to the Y-plates with the time base switched on.



Uses of a cathode ray oscilloscope

1. A CRO is used to measure voltage (p.d)
2. A CRO is used to measure frequency of a wave form.
3. A CRO is used to study different wave forms
4. A CRO is used to compare frequencies of different wave forms

How to determine voltage from a C.R.O

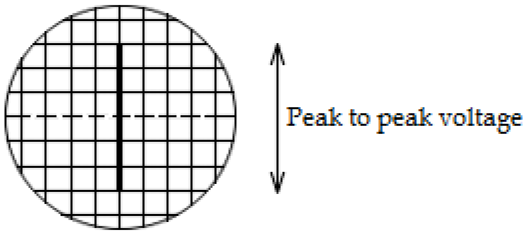
A known A.C voltage is applied to the Y-plates to adjust the Y- sensitivity (gain) to a suitable value like $2Vcm^{-1}$ for low voltage and $50Vcm^{-1}$ for high voltage. The A.C voltage to be measured is connected to the Y-plates and the peak to peak value is measured. To get the peak A.C voltage we divide the peak to peak voltage by two.

Measurement of frequency from a C.R.O

We measure the periodic time (T) of the wave form using the expression

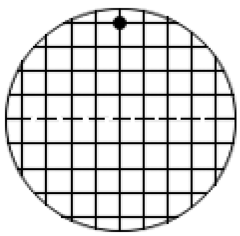
T = (horizontal distance of one cycle on screen in cm) x (time-base setting)
We calculate frequency from $f = \frac{1}{T}$

Examples
1. The C.R.O trace shown below was obtained when an A.C was connected to the Y-plates and the Y-gain set at $2Vcm^{-1}$ Determine the A.C peak voltage.

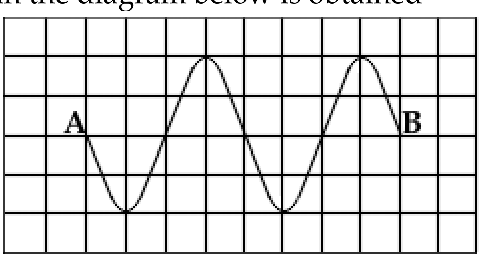


Length of trace = 6cm
Length of trace from zero to peak $= \frac{6}{2} = 3cm$
Peak voltage = 3 X Y-Sensitivity
Peak voltage = 3 X 2 = 6V

2. A D.C applied to a C.R.O showed a spot at a position shown on the screen. Given that the Y-Sensitivity (gain) was set at $5Vcm^{-1}$ determine the voltage of the D.C.



Displacement of the spot = 4cm
Voltage = 5 X 4 = 20V
3. A C.R.O with time base switched on is connected across a power supply. The wave form shown in the diagram below is obtained



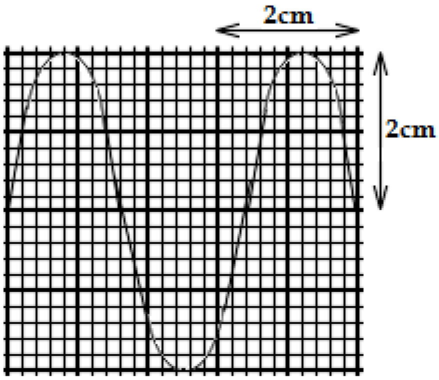
Distance between each line is 1cm
(i) Identify the type of voltage generated by the power supply
(ii) Find the amplitude of the voltage generated if the voltage gain is $5Vcm^{-1}$
V = 2 X 5
V = 10V
(iii) Calculate the frequency of the power source if the time base setting on the C.R.O is $5.0 \times 10^{-3} scm^{-1}$

$1cm \rightarrow 5.0 \times 10^{-3}s$ $\qquad$ $f = \frac{1}{T}$

$4cm \rightarrow 4 \times 5.0 \times 10^{-3}$
$4cm \rightarrow 2.0 \times 10^{-2}$seconds
$T = 2.0 \times 10^{-2}$seconds

$$f = \frac{1}{2.0 \times 10^{-2}}$$
$f = 0.5 \times 10^{2}$
f = 50Hz

4. The wave form shown in the figure below was produced on a C.R.O when a certain oscillating source was connected to the Y-plate of the C.R.O. The Y-gain reads 0.5Vcm^{-1} and the time base reads 10mscm^{-1}.

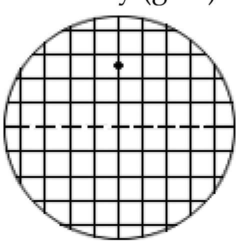


(i) Determine the peak voltage of the wave form.
Peak voltage = 2 X 0.5 = 1.0V

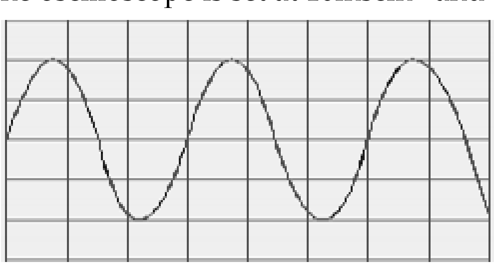
(ii) Find the frequency of the wave.
$1cm \rightarrow 10ms$
$1cm \rightarrow 0.01s$
$3.4cm \rightarrow 3.4 \times 0.01$
$3.4cm \rightarrow 0.034$seconds
One cycle is 3.4cm
$T = 0.034$seconds

$$f = \frac{1}{T}$$
$$f = \frac{1}{0.034}$$
f = 29.41Hz

Exercise
1. A D.C applied to a C.R.O showed a spot at a position shown on the screen. Given that the Y-Sensitivity (gain) was set at 2.5Vcm^{-1} determine the voltage of the D.C.



2. The diagram below shows the trace obtained on the screen of an oscilloscope. The time base of the oscilloscope is set at 10mscm^{-1} and the voltage sensitivity at 15 Vcm^{-1}.

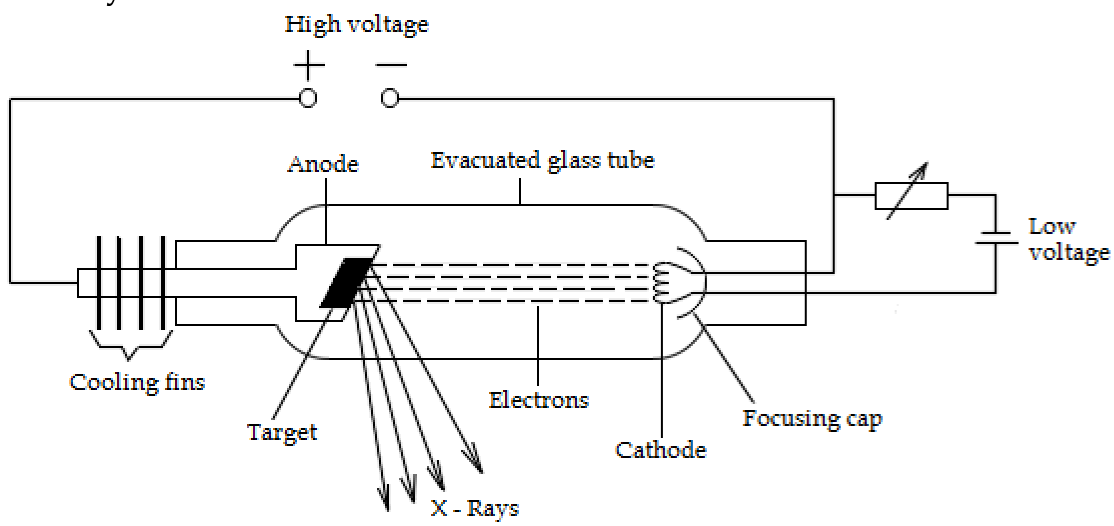


Distance between each line is 1cm
For the ac source, calculate the

(i) Voltage.
(ii) Frequency.

X-Rays
X-rays are electromagnetic radiations produced when fast moving electrons hit a metal target such as tungsten.

The X-ray tube



How X-rays are produced
A low voltage is applied across the filament which heats up and emits electrons thermionically. The concave cap focuses emitted electrons onto the tungsten target.
The anode is a copper block in which a target is fitted.
A high voltage set up between the cathode and anode accelerates the electrons at a very high speed towards the anode. When electrons strike the target, a small fraction of their kinetic energy is converted into X-rays and the rest into heat.

The heat generated at the anode is lost to the surrounding by the cooling fins and a cooling liquid which circulates a behind the anode.
The glass tube is evacuated to prevent collisions between electrons and air atoms which would slow down the electrons.

Quality of X-rays
The quality of x-rays is defined by their penetrating power.
The quality of x-rays is determined by the velocity of electrons hitting the target. The velocity in turn depends on the p.d across the tube.

Hard X-rays
These are produced when a very high voltage is applied across the x-ray tube. They have short wave length and a high penetrating power.

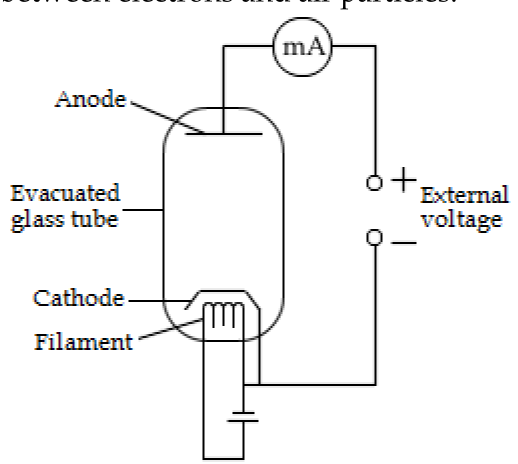
Soft X-rays
These are produced when a relatively small voltage is applied across the x-ray tube. They have long wave length and a low penetrating power.

Properties of X-rays
1. They travel in a straight line at the speed of light

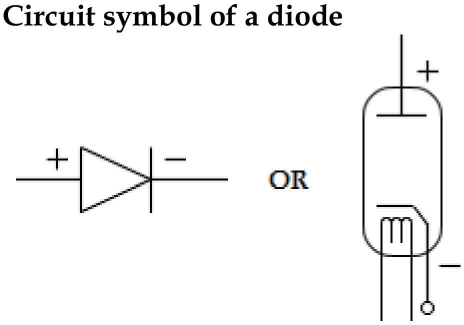
2. They have no charge
3. They are not deflected by electric and magnetic fields
4. They are electromagnetic waves of very short wave length
5. They readily penetrate matter
6. They cause ionization of gases
7. They cause fluorescence in some materials
8. They affect photographic plates
9. They eject electrons from matter by photo electric effect
10. They are diffracted by crystals

Uses of X-rays
1. Detection of fire arms in public places
2. Used in medical treatment of cancer and tumours by burning cancerous cells
3. Used to locate bone fractures in human bodies using X-ray photography
4. Used to detect flaws and cracks in metals and welded joints by examining X-ray photographs.
5. X-rays are used to study crystal structures

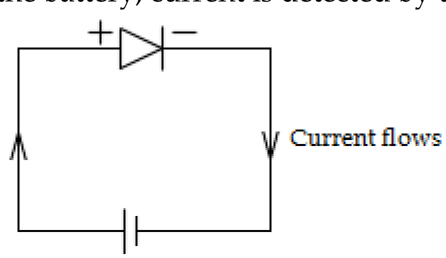
Thermionic Diode
It consists of an evacuated glass tube with an anode and a cathode which releases electrons when heated. The electrons are attracted by a positive anode. The air is removed to avoid collisions between electrons and air particles.



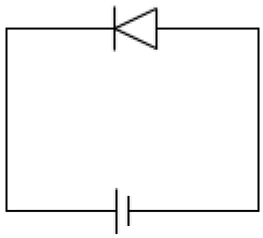
Circuit symbol of a diode



When the anode is connected to the positive terminal and the cathode to the negative terminal of the battery, current is detected by the ammeter. The diode is **forward biased**.



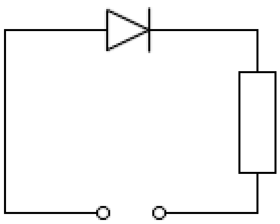
When the diode is reversed, no current flows. This happens because electrons are not attracted to the negative electrode. The diode is **reverse biased**.



A thermionic Diode is therefore called a diode valve because it allows flow of current in only one direction.

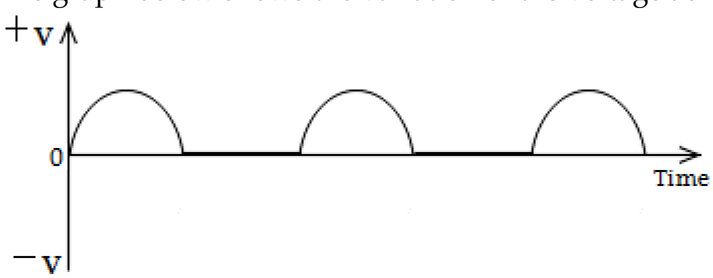
Rectification of alternating current

A diode valve is used to convert alternating current (A.C) to direct current (D.C).

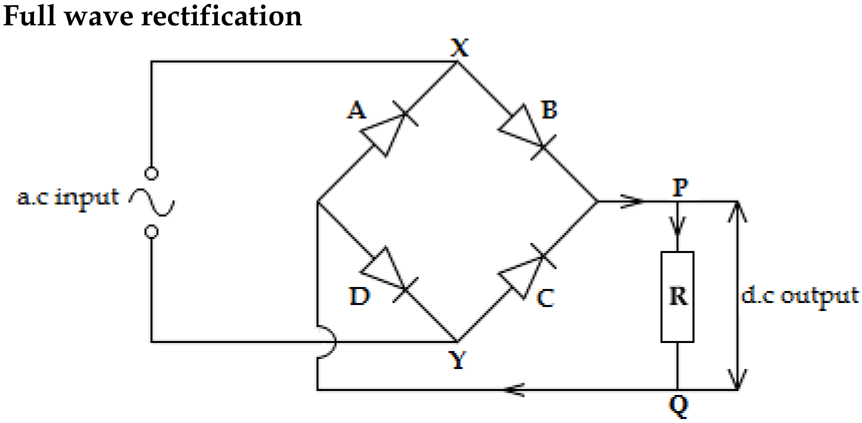


A diode is connected in a circuit in which alternating current is flowing. The diode conducts current only during the half cycle when the cathode is negative and the anode positive. During the reversed half cycle no current flows. This process is called half-wave rectification.

The graph below shows the variation of the voltage across the resistor.



Full wave rectification

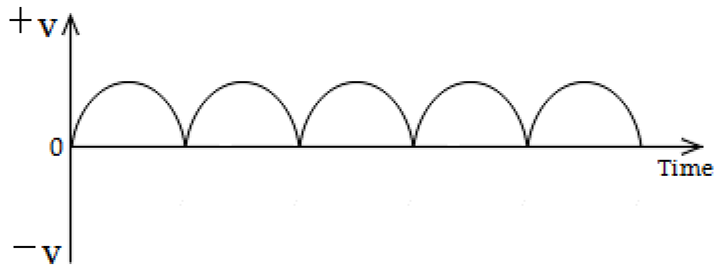


A bridge rectifier circuit is used to rectify both half-cycles of the alternating current.

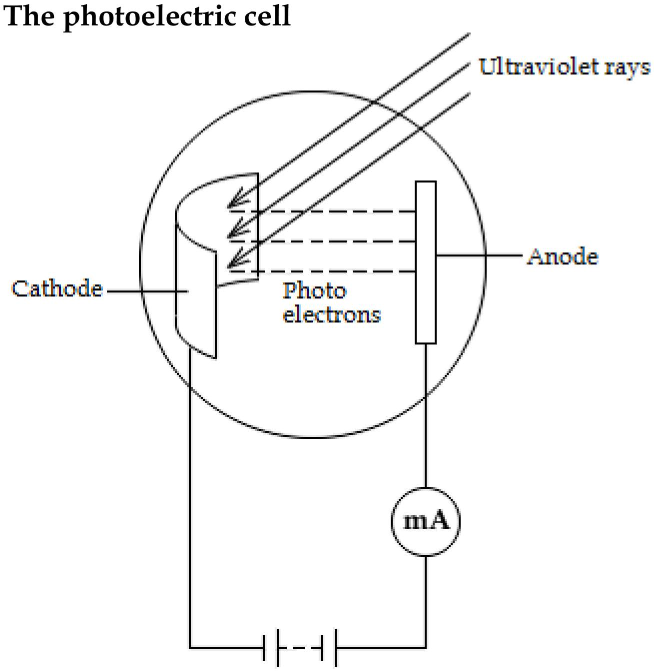
During the half cycles when X is positive and Y is negative, diodes B and D are forward biased and conduct current which flows through resistor R along PQ.

During the half cycles when Y is positive and X is negative, diodes C and A are forward biased and conduct current which flows through resistor R along PQ.

During both half cycles current flows through resistor R in the same direction PQ. Hence the output is continuous direct current



Photoelectric emission (effect)
This is the process by which electrons are emitted from a metal surface when an electromagnetic radiation falls on it.
Eg a clean, negatively charged zinc plate emits electrons when exposed to an ultraviolet source.
Electrons emitted this way are called photoelectrons.
Photoelectric emission occurs when the electrons have gained enough energy from the radiation to overcome the attractive force of the positive nucleus.
Work function
This is the minimum energy required to remove an electron from a metal surface.
Each metal has its own work function. This means it is easier to remove electrons from some metals than others.
If the energy of the radiation falling on the metal surface is greater than the work function, then the excess energy is converted into kinetic energy of the emitted electrons.
Threshold frequency (f_o)
This is the minimum frequency of the radiation required to cause photoelectric emission.
In general, the smaller the work function the lower the threshold frequency.
The photoelectric cell



Photoelectric effect is applied in a photoelectric cell which converts light energy into electrical energy. When a suitable radiation falls on the cathode it emits electrons. The positive anode attracts electrons which then go through an external circuit causing an electric current to flow.
The strength of the current depends on the intensity of the radiation falling on the metal cathode.

Uses of photoelectric cells
They are used in alarm circuits
They are used as automatic switches for street lights
They are used to Control lift doors
They are used to measure the temperature of stars