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Department of Biomedical Engineering

Course Name: 19BME301 – Medical Physics

III Year : V Semester

Unit IV – PRINCIPLES OF RADIATION DETECTOR

OUTLINE

- Introduction
- Why to Detect Radiation?
- Interaction of Radiation with Matter
- Types of Detectors
- How to Detect Radiation?
- Conclusion
- References

INTRODUCTION

What is Radiation?

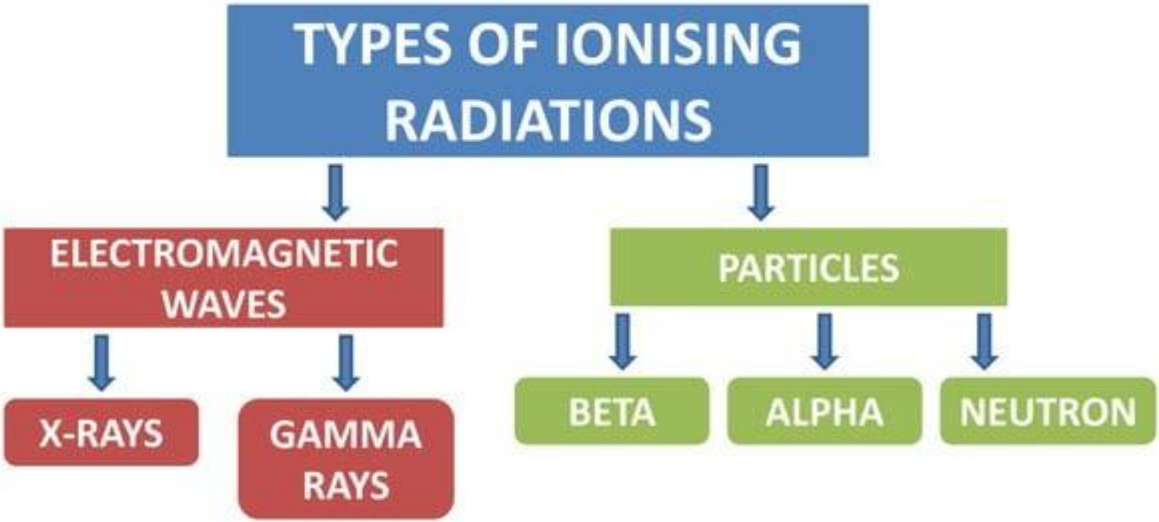
Radiation is the emission or transmission of energy in the form of waves or particles through space or through a material medium.

Ionizing or non-ionizing depending on the energy.

What is Detection?

The action or process of identifying the presence of something concealed.

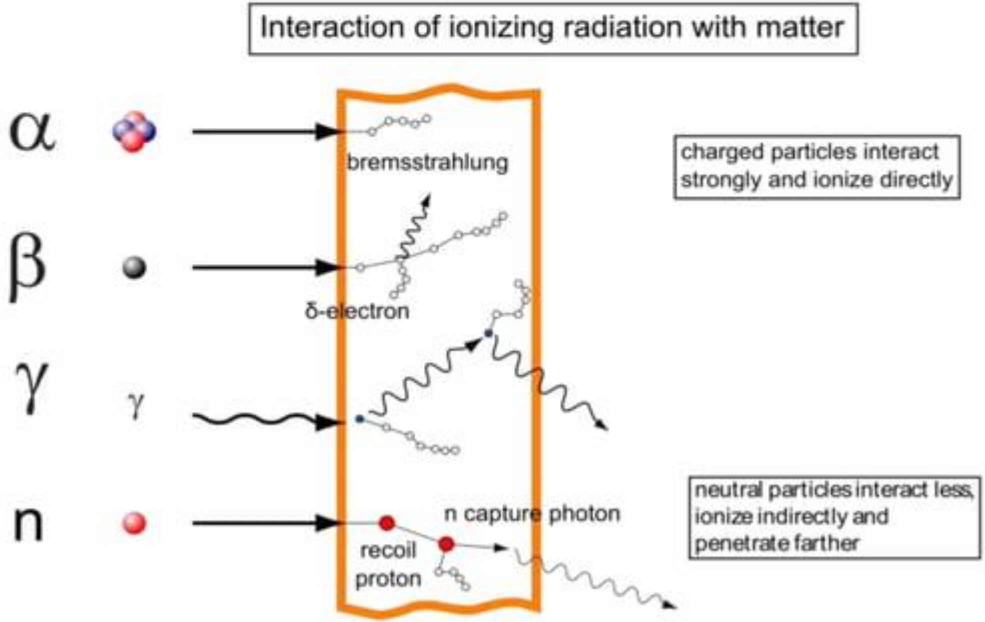
INTRODUCTION



WHY TO DETECT RADIATION?

1. Research application
2. Environmental Safety
3. Power regulation in nuclear reactors
4. Personal protection of occupational workers
5. Estimation of Radiation dose in treatment of patients
6. Calibration of radioactive isotopes etc..

INTERACTION OF IONISING RADIATION WITH MATTER

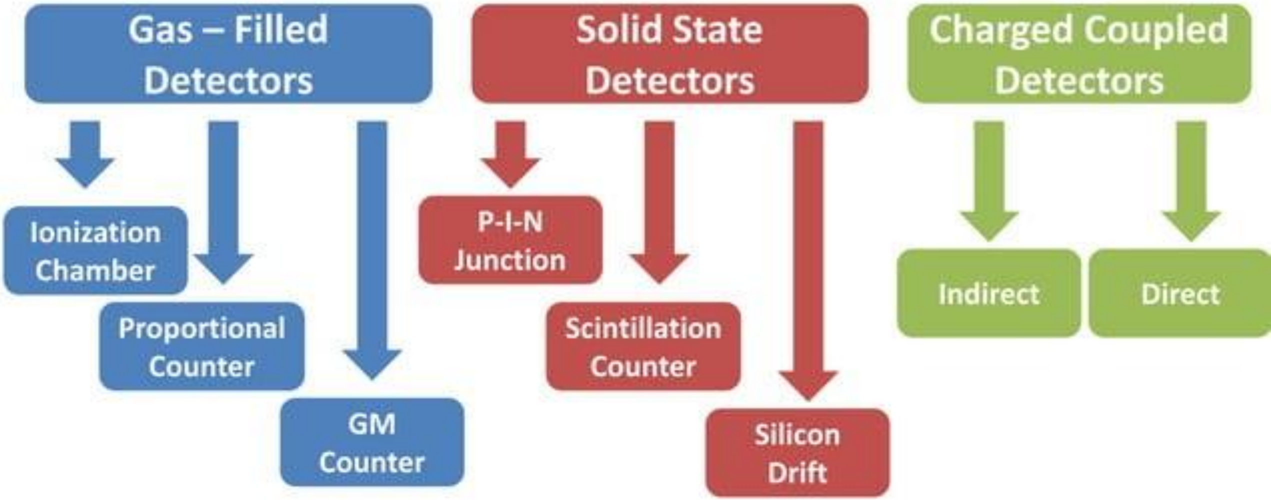


- Detection, characterization and effects of radiation are almost entirely dependent upon their interaction with matter.

- *Direct ionizing radiation* charged particles (alpha particles, beta particles ;coulomb interaction with matter) it directly causes ionization and excitation of atoms.

- *Indirect ionizing radiation* (neutrons, photon) which have no charge and during interaction with matter can transfer energy to charged particles.

TYPES OF DETECTOR



IONISATION CHAMBER

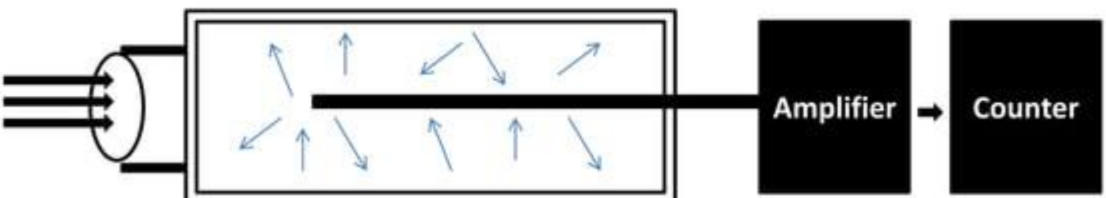
PRINCIPLE

Gas molecules get ionized when energetic charged particles propagated through a gas.

CONSTRUCTION

A metallic cylinder filled with with a suitable gas at atmospheric pressure

A metal rod (fixed along the axis of cylinder) connected to a counter through an amplifier.



WORKING

A suitable potential difference is applied between cylinder and applied electrode.

When an energetic charged particle is allowed to enter the cylinder, ionization of gas molecules takes place.

+ve and –ve ions so created, start moving towards oppositely charged electrodes (cylinder and rod)

Depending upon the number of particles entering the cylinder, an electric pulse of proportional magnitude is developed.

This pulse reaches an electronic counter after amplification and number of particles is counted.

Two types of ionization chamber

Non-integrating type Ionization Chamber

The type of gas is so chosen that the response time of gas is small relative to the frequency of the entering particles.

Different pulses are recorded for each particle entering the cylindrical chamber.

Integrating type Ionization Chamber

The type of gas is so chosen that the response time of gas is large relative to the frequency of the entering particles.

The pulse showing ionization by each particle is not recorded separately but a continuous flow of current is recorded.

The quantity measured is not the number of particles, but total ionization charge accumulated on the electrodes.

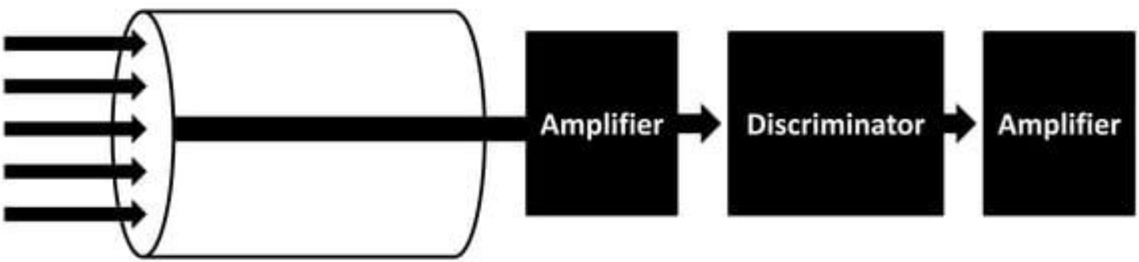
PROPORTIONAL COUNTER

PRINCIPLE

Gas molecules get ionized when energetic charged particles propagated through a gas.

CONSTRUCTION

A cylindrical tube containing a mixture of methane and argon.
A fine tungsten wire fixed along the axis of the tube.
Amplifier and Discriminator.

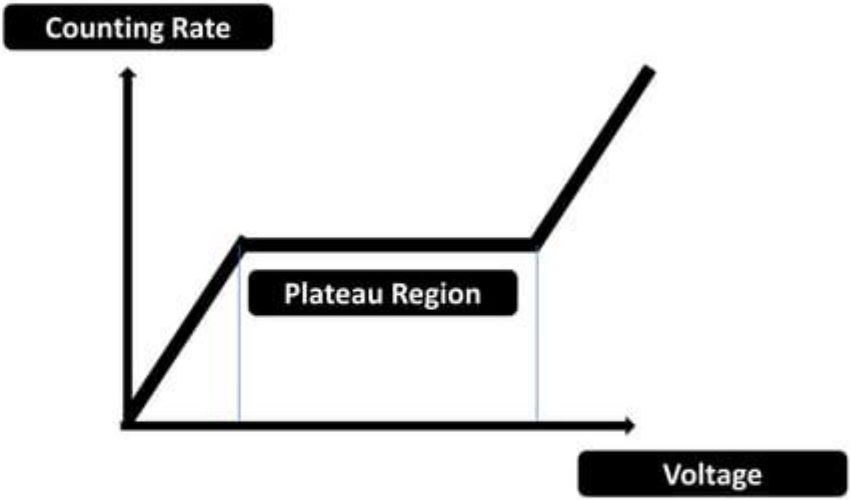


WORKING

- When an energetic charged particle enters the cylindrical tube, it ionizes the gas molecule colliding with the particle.
- The ions so produced, get accelerated due to high potential difference between electrodes and cause further ionization of gas molecules.
- The total number of ion pairs created by a single primary ion is called multiplication factor of the gas.
- The charged accumulated on the electrodes, give rise to an electric pulse that is fed to discriminator that is cuts-off low voltage undesired noise pulses.

PLATEAU REGION

The range of voltage, within which the counting rate remains constant is called *Plateau region.*



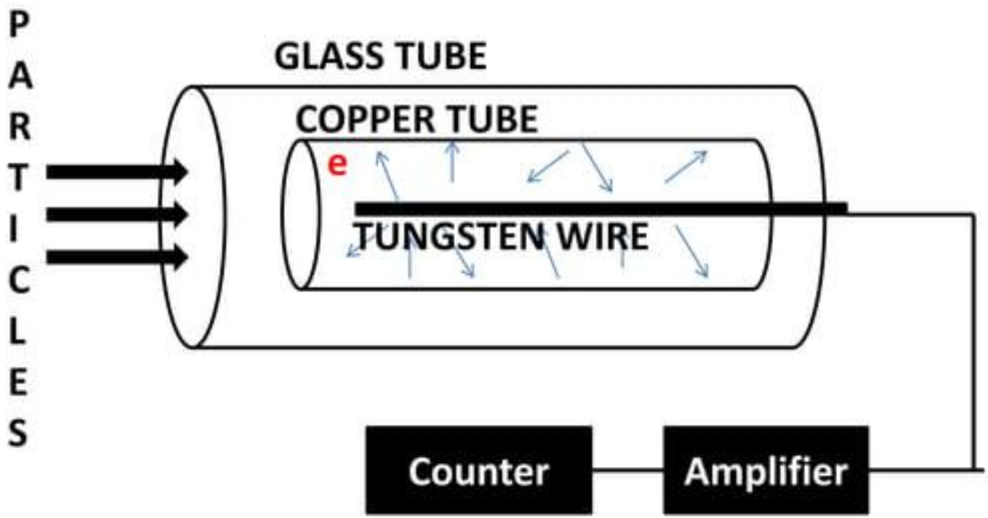
G M COUNTER

PRINCIPLE

Gas molecules get ionized when energetic charged particles propagated through a gas.

The electrons produced by ionization, if accelerated by a high potential can cause further ionization of gas molecules thereby generating a large number of more electrons.

CONSTRUCTION



- Its consists of hollow cylindrical tube of length about 15 – 50 cm and is made of copper. (called GM Tube)
- The GM tube is filled with some inert gas (generally argon) at a pressure of 10 cm of HG, with 10% vapors of ethyl alcohol.
- GM tube is enclosed in a partially evacuated glass tube.
- A tungsten wire of about 0.5mm of diameter is fixed along the axis of GM tube (but insulated from the tube).
- The tungsten wire is connected to the positive terminal and metallic GM tube to the negative terminal of HT (about 1000V)
- A thin window (generally made of mica), is provided on one side of tube for entrance of particles to be detected.

WORKING

- When an energetic charged particle enters GM tube through the window, the gas molecules which interact with the charged particle get ionized.
- The generated electrons, get accelerated towards the central anode and +ve ions towards cathode tube.
- The accelerated electrons cause ionization of more gas molecules, generating large number of electrons within a very short interval of time (called avalanche)
- The avalanche gives rise to a high current pulse.
- For each particle entering the tube, successive current pulses are produced and counting is done by a suitable device.

DEAD TIME OF GM COUNTER

- During the working of GM counter, the heavier +ve ions take enough time to reach the surface of cathode tube. Until all the +ve ions have reached the surface of the cathode tube, the next particle is not detected.
- The time interval for which GM counter is completely insensitive to the incoming particles, is called dead time of GM Counter (Generally of the order of a few hundred microseconds)
- If N particles enter the tube per second and the counter shows n particles per second, then dead time can be written as:

$$T = \frac{1}{n} - \frac{1}{N}, T = \frac{N-n}{nN}$$

QUENCHING OF GM TUBE

- Just on the completion of dead time of GM Tube, the slow moving +ve ions reach the surface of cathode tube and get discharged there. As a result a current pulse is again generated, that gives and indication, as if another particle has entered the GM tube, which is not the case in reality.
- Thus a single particle is counted twice (once at the starting and the other the end of DEAD TIME INTERVAL)
- It is desirable that the +ve ion sheath formed around the anode wire, must be eliminated before it reaches the cathode tube.
- The process of eliminating undesired +ve ions sheath around the central anode wire in GM tube is called quenching.
- Many methods have been suggested for quenching, but the most acceptable method is "SELF QUENCHING METHOD".

SELF QUENCHING METHOD

- Some halogen gas is introduced along with inert gas in GM Tube. The accelerated inert gas +ve ions, collide with halogen gas molecules and ionize them.
- The electrons so created neutralize the already existing innert gas +ve ions and the +ve halogen gas ions get very rapidly drifted towards the surface of cathode tube where they get neutralized.

HOW TO DETECT RADIATION ?

Choose a radiation detector working on a particular principle of interaction (ionization, scintillation/etc) with known sensitivity to estimate the radiation under detection.

<u>For example</u>: we are using

451P Ion chamber Survey Meter

to detect X-ray scattered radiation

It is designed to measure gamma and x-ray radiation above 25 keV, and beta radiation above 1 MeV, using the latest CMOS and LCD technology

451P ION CHAMBER SURVEY METER

Specifications

Radiation Detected - Beta above 1 MeV & gamma above 25 KeV

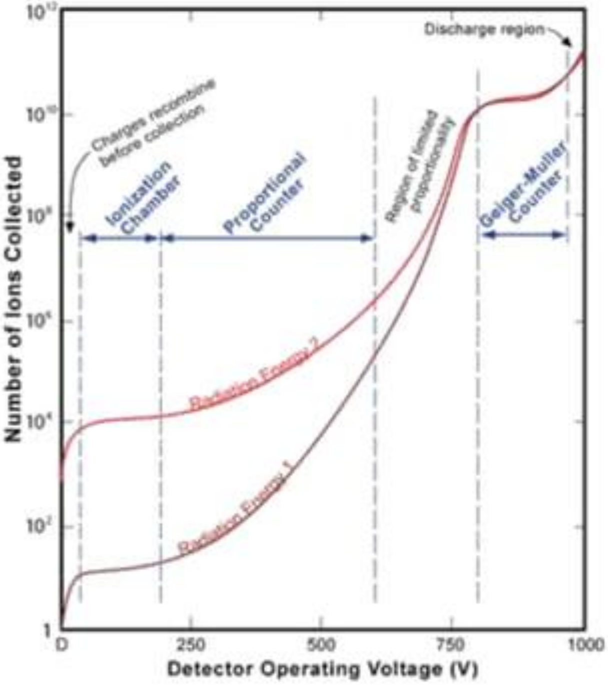
Operating Ranges - 0 μR to 5 R/h

Accuracy - ± 10 % of reading between 10 % and 100 % of full-scale indication on any range, exclusive of energy response (calibration source is 137 Cs)

Detector - 230 cc active volume air ionization chamber, pressurized to 8 atmospheres.

Environmental -20 °C to +50 °C

CONCLUSION



Discharge region
Charges recombine before collection
Ionization Chamber
Proportional Counter
Region of limited proportionality
Geiger-Muller Counter
Radiation Energy 2
Radiation Energy 1
Number of Ions Collected
Detector Operating Voltage (V)
0
250
500
750
1000

Thank You