Third lecture

Basic Instrumentation and its clinical applications

Prof.Dr.Nihad A. Salih

Fourth Stage

Department of Medical physics sciences

Al-Mustaqbal University

2025- 2026

Basic Instrumentation and its clinical applications:

Two different types of counting are done in nuclear medicine:
1- Determining the amount of radioactivity in a sample or volume.
2- Determining the distribution of the radioactivity in the body (Imaging).

****

* The instruments that used to measure the amount of radioactivity:

I- Geiger-Muller counter:

The principle of operation:

It's a simple instrument; even the small amount of ionization produced by single beta particles entering the tube can trigger a discharge, producing a large pulse of electricity that can be counted electrically .As shown in figure (1)

It has the following properties:

1. GM counter dose not distinguish between large and small amount of ionization.
2. Its convenient for use in radiation protection.
3. Its inefficient for detecting γ-ray then it's of little use in clinical nuclear medicine.

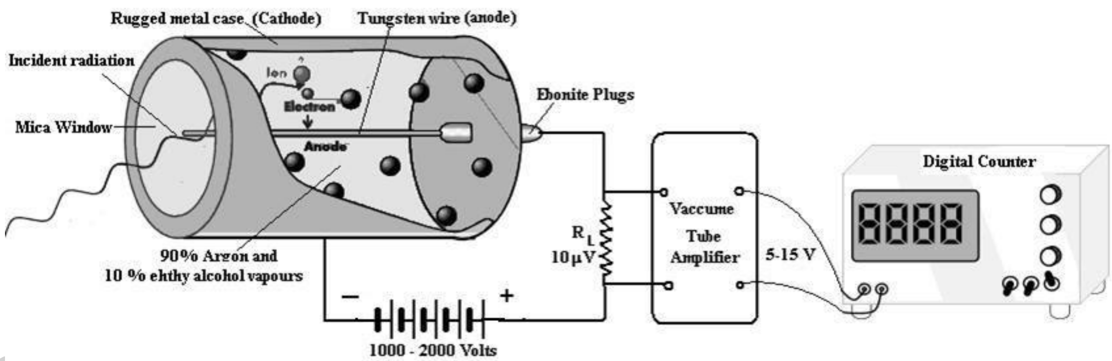

Figure (1). Geiger-Muller counter

II- Photomultiplier tube (PMT):-

It sensitive for detecting weak flash of light and estimate its amount.

The principle of operation:

A light photon releases an electron at photocathode that is accelerated to 1^{st} dynode where it causes several more electrons to be emitted and go on other dynodes (10 dynodes) so that an electron multiplication of 10^5-10^6 times occurs. Light photon produced in clear crystal of (NaI) Sodium iodide (that improved by the addition of small amount of thallium (Tl)), these crystals were attached directly to (PMT).

NaI(Tl) come in a wide variety of sizes and shapes for special purpose and are the most widely used detectors in nuclear medicine.

Crystal detector of PMT is:

1- About 2000 times more dense than the gas in GM.

2- They are quite efficient for detecting γ-rays.

PMT + Crystal of NaI(Tl) = Scintillator detector

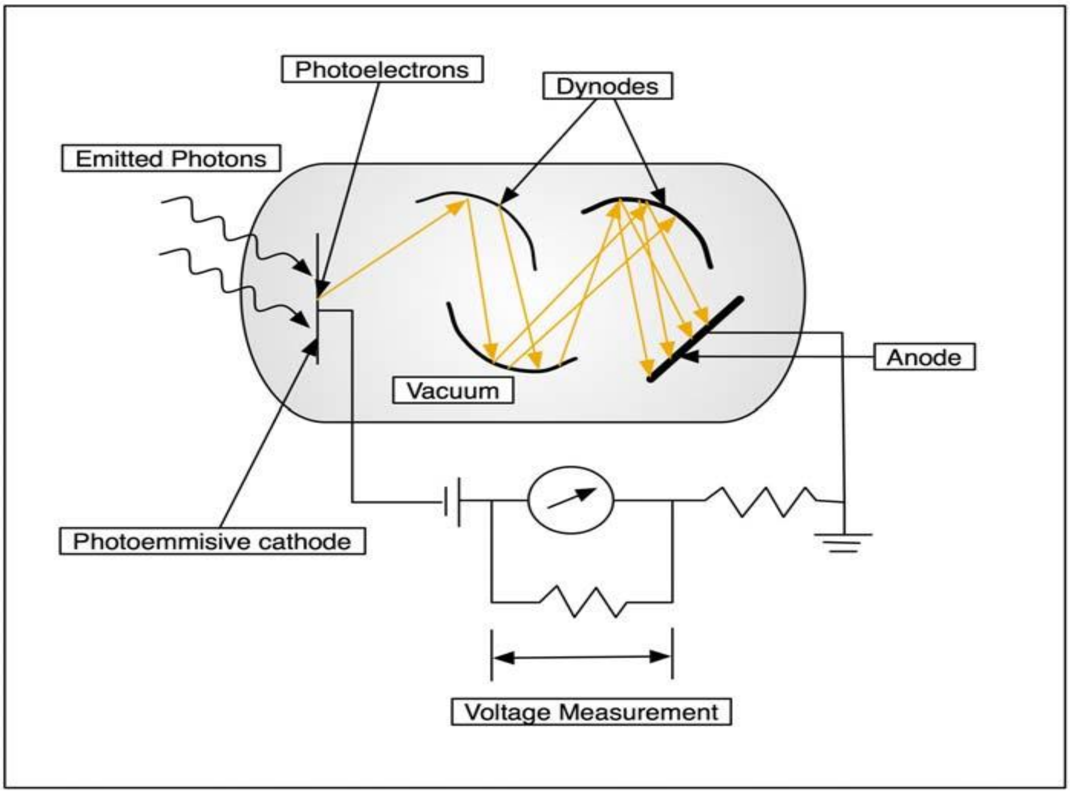

Figure (2). Photomultiplier tube (PMT)

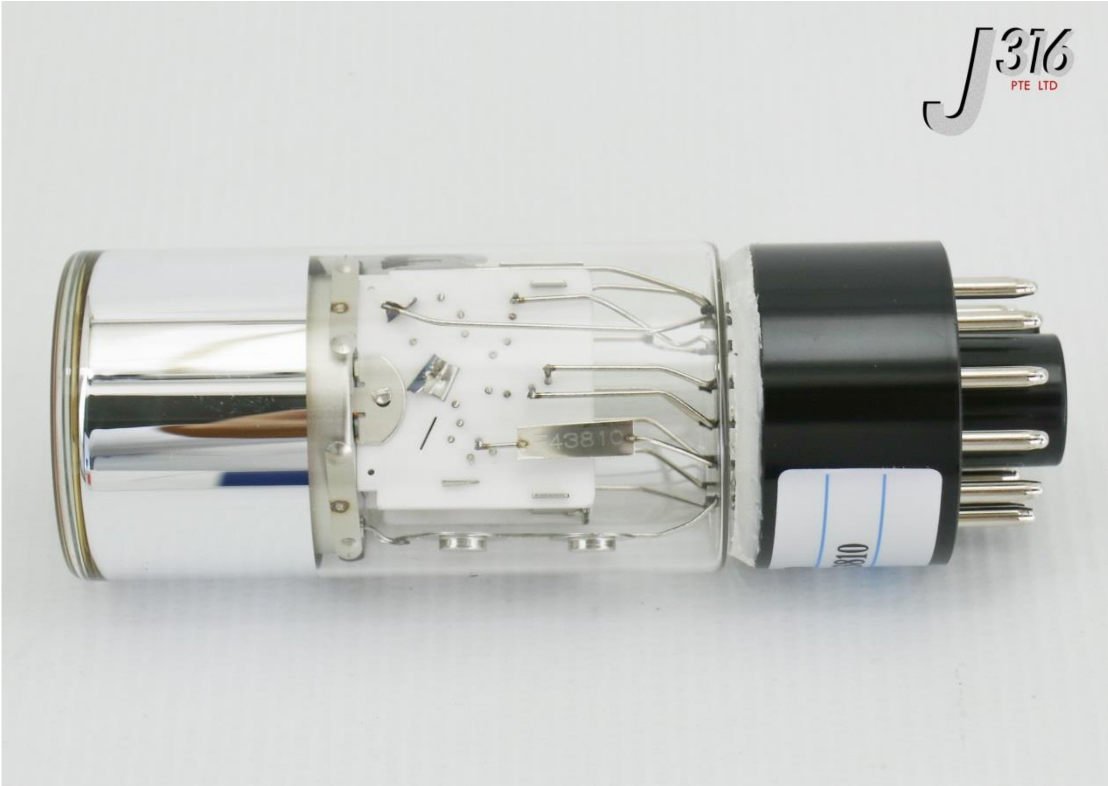

Figure (3). **Photomultiplier tube (PMT)**

III- Solid state semiconductor detector:

The principle of operation:

The semiconductor acts as a solid ionization chamber; that is, it acts as an insulator and does not allow current to flow until ionization has taken place in its volume. It's usually kept very cold in order to minimize current produced by the thermal activation of electrons. When gamma ray is absorbed in the semiconductor it produces a large number of ion pairs, about one ion pair for each 3 eV of energy absorbed.

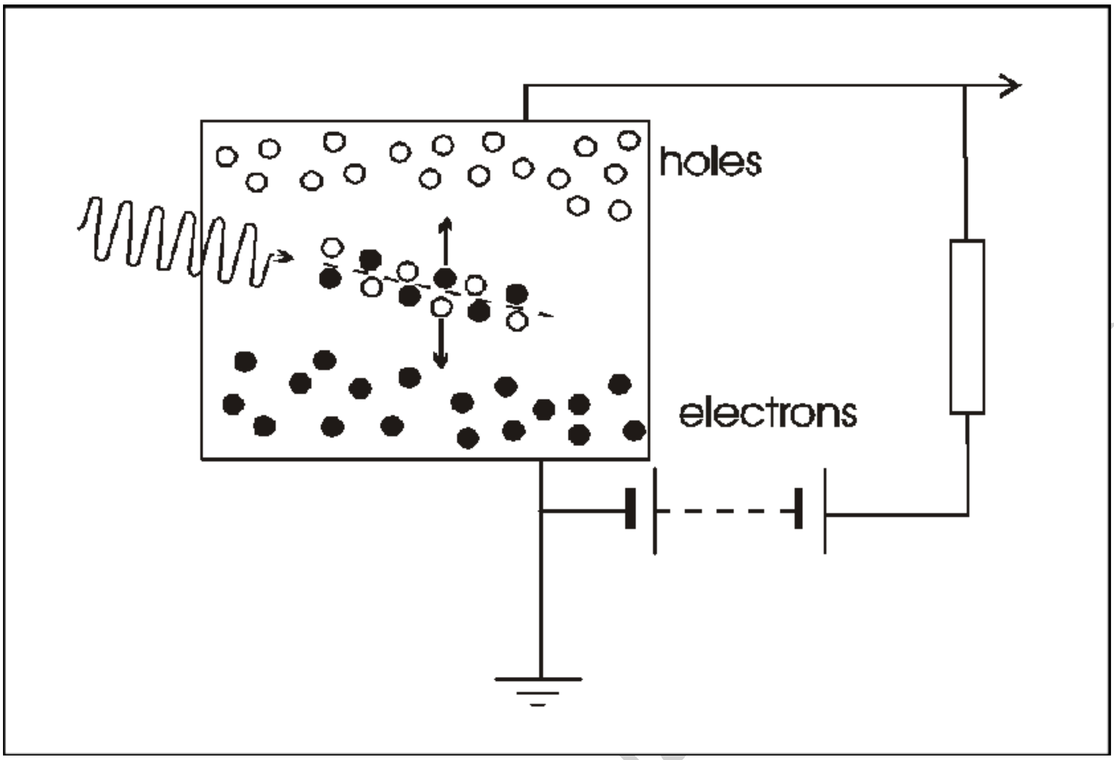

Figure (4). Solid state semiconductor detector

They are widely used in nuclear physics research, because: a- They have better resolution than NaI(Tl). b- They are very efficient to detect γ-ray at low energy.

<u>Disadvantage:</u>

a- They are not available in large sizes. b- They are much more expensive than Scintillation detectors.

Figure (5). Solid state semiconductor detector

** Determination of the amount of radioactivity in sample or specific volume:-*

***(1) 24 hour uptake of Iodine by the thyroid** to evaluate thyroid function.*

Thyroid uses Iodine in the production of hormones that control the metabolic rate of the body.

a- Person with under active thyroid (hypothyroid function) will take-up less iodine than a person with normal function (euthyroid).

b- Person with (overactive) thyroid (hyperthyroid) will take-up more Iodine than normal.

euthyroid uptake 10% - 40% (average 20%). hyperthyroid uptake >40%. But for uptake less than 10% will be hypothyroid.

Steps of 24 hrs uptake test:

1- The patient is given about 300 KBq of ^{131}I by mouth.
2- The same activity of ^{131}I is set a side as standard (~300 KBq)
3- After 24 hrs. the amount ^{131}I decays is counted for 1 min. in thyroid and in the standard.
4-The background activity of the test area is counted for 1 min. also to get the net of the activity.

X= Thyroid activity – Background activity = Net thyroid activity
Y= Standard activity- Background activity = Net standard activity

^{131}I has been decayed in the same rate for thyroid dose or standard dose, then no correction needs to be made. $\%24 \text{ hrs uptake} = \frac{X}{Y} \times 100\%$

(2) Kidney function study:

1- Patient under test is injected with 7 MBq of ^{131}I labeled on hippuric acid (hippuric acid is a chemical compound that can be easily excreted by the kidney to the bladder) to the blood stream.
2- The kidney radioactivity is monitored by scintillation detectors (each kidney monitored separately).
3- The signals from each detector are fed to a rate- meter to record the change in radioactivity with time to get a permanent record of the count rate versus time or renogram.

1-The kidney radioactivity is monitored by …………………(each kidney monitored separately).
A. scintillation detectors B. GM counter C. Solid state semiconductor detector D. PMT E. ionization chamber

2- …………… counter dose not distinguish between large and small amount of ionization and its convenient for use in radiation protection.
A. PMT B. GM C. Solid state semiconductor detector D. MRI E. PT-CT

3- ..……………is about 2000 times more dense than the gas detector and they are quite efficient for detecting γ-rays.
A. PMT B. GM C. CT D. MRI E. PT-CT

4. …………… is widely used in nuclear physics research, because they have better resolution than another detector and they are very efficient to detect γ-ray at low energy .
A. PMT B. GM C. Solid state semiconductor detector D. MRI E. PT-CT

5. Patient under test of Kidney function study is injected with ……………of ^{131}I labeled on hippuric acid (hippuric acid is a chemical compound that can be easily excreted by the
A. 7 MBq B. 9 MBq C. 11 MBq D.13 MBq E. 15 MBq