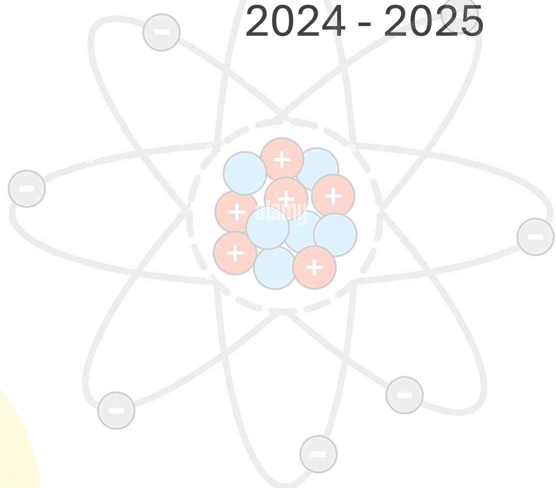
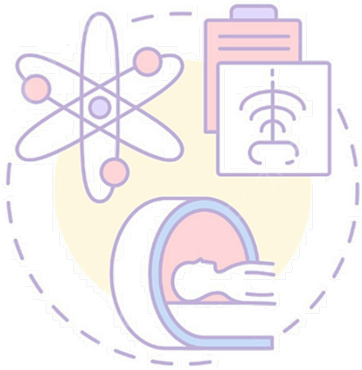
Radiation Protection

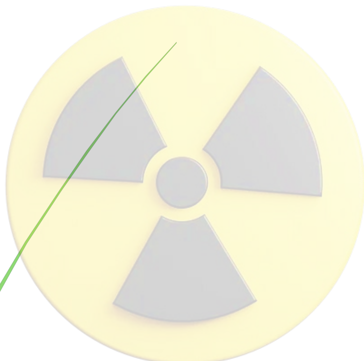
The Second Stage

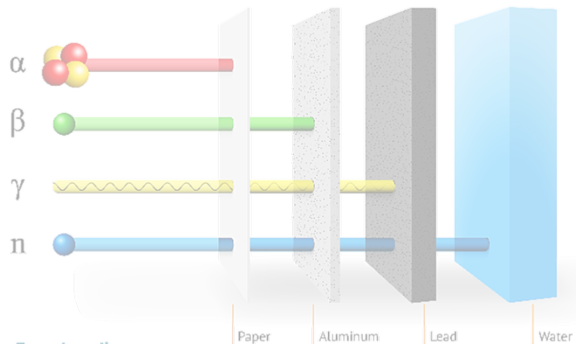
First Semester –Fourth Lecture

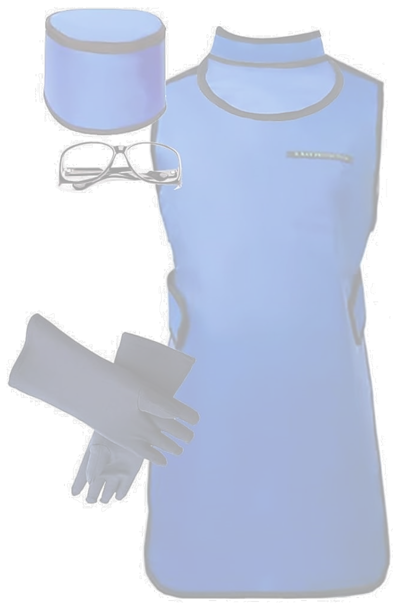
2024 - 2025











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Radiation Measurement Units

OUTLINES:

- System of Physics Units.
- Radiation Units.
- Exposure Units.
- Absorbed Dose.
- Equivalent Dose.
- Effective Dose.

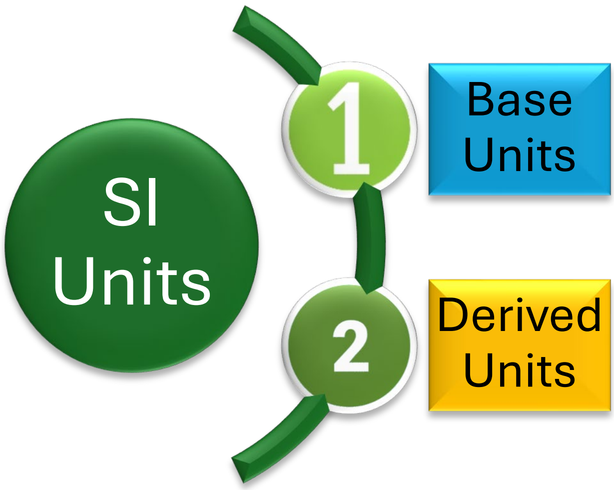
- Peak Skin Dose.
- Background Radiation.
- ALARA principles.

- **System of Physics Units.**

What are system units in physics?

A system of units is a set of related units that are used for calculations. The system includes base units, which represent base dimensions, and derived units, which represent products of powers of base dimensions. Some units exist in more than one system of units.

This also known as <u>*system international units in physics*</u> (SI units in physics).



1- SI Base Units

These are the fundamental units and are considered as the building blocks of the system. All the other units are derived from the SI Base units. One of the examples is that the SI unit of mass is kilogram. This is often confused with grams.

There are <u>***7 SI base units***</u>. The seven units along with their SI unit and symbol are given below:

Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of substance	mole	mol
Electrical current	ampere	A
Light intensity	candela	cd

2- SI Derived Units

The derived units are unlimited as they are formed by different operations on the base units. For derived units, the dimensions are expressed in terms of the dimensions of the base units. The derived units might also be expressed with the combination of base and derived units.

Name	Symbol	Quantity	Name	Symbol	Quantity
potential, voltage, emf	V	volt	force, weight	N	newton
electric current	A	ampere	pressure, stress	Pa	pascal
resistance,impedance,reactance	Ω	ohm	energy, work, heat	J	joule
power, radiant flux	W	watt	thermodynamic, temperature	K	kelvin
frequency	Hz	hertz	temperature, Celsius°	C	degree
capacitance	F	farad	temperature, Fahrenheit°	F	degree
electric charge	C	coulomb	amount of substance	mol	mole
electrical conductance	S	siemens	time	s	second
magnetic flux	Wb	weber	length	m	meter
magnetic flux density	T	tesla	mass	kg	kilogram
inductance	H	henry	measuring angles	rad	radian
luminous intensity	cd	candela	radioactivity	Bq	becquerel
luminous flux	lm	lumen	ionizing radiation dose	Sv	Sievert
illuminance	lx	lux	catalytic activity	kat	katal
Resistivity	ρ	Ω m	Conductivity	σ	S m−1

Radiation Units:

1- Radiation Activity:

Radioactivity refers to the amount of ionizing radiation released by a material. Whether it emits alpha or beta particles, gamma rays, x-rays, or neutrons, a quantity of radioactive material is expressed in terms of its radioactivity (or simply its activity). This represents how many atoms in the material decay in a given time period.

The units of measurement for radioactivity are the Becquerel (**Bq, SI unit**) and the Curie (Ci, U.S. unit).

Becquerel (***Bq***): The becquerel (symbol: ***Bq***) is the SI derived unit of radioactivity. One becquerel is defined as the activity of a quantity of radioactive material in which one nucleus decays per second.

The becquerel is named after Henri Becquerel, who worked in discovering radioactivity.

1 Bq=1s^{-1} & 1Bq=2.7x10^{-11} Ci

2- Radiation Exposure

Exposure describes the amount of radiation traveling through the air. Many radiation monitors measure exposure.

The units for exposure are the Coulomb/kilogram (***C/kg***), Roentgen (***R***), and KERMA.

- Coulomb/kilogram (***C/kg***): is the SI unit used to measure the radiation-induced ionization created in a unit mass.
- Roentgen (***R***): is a legacy unit of measurement for the exposure of X-rays and gamma rays and is defined as the electric charge freed by such radiation in a specified volume of air divided by the mass of that air (coulomb per kilogram). It is named after the German physicist Wilhelm Röntgen, who discovered X-rays.

KERMA: kerma is an acronym for "Kinetic Energy Released per unit MAss" or "Kinetic Energy Released in the MAtter", defined as the sum of the initial kinetic energies of all the charged particles liberated by uncharged ionizing radiation (i.e., indirectly ionizing radiation such as photons and neutrons) in a sample of matter, divided by the mass of the sample.

3- Absorbed Dose

The absorbed dose is the radiation energy absorbed per unit mass of an organ or tissue. Placing your body near a radioactive source results in exposure. To evaluate the hazard from this exposure one must compute the absorbed dose.

- Radiation doses are often calculated in the units of Gray and Rad.
- Gray (***Gy***): One of the two units used to measure the amount of radiation absorbed by an object or person, known as the "Absorbed Dose", which reflects the amount of energy that radioactive sources deposit in materials through which they pass. One Gray (Gy) is the international system of units

(SI) equivalent of 100 rads, which is equal to an absorbed dose of 1 Joule/kilogram.

1 Gy = 100 rad

1 Gy = 1 Joule/kilogram

Rad: A rad is a unit of absorbed radiation dose, defined as

1 Rad = 0.01 Gy = 0.01 J/kg.

- The material absorbing the radiation can be human tissue or silicon microchips or any other medium (for example, air, water, lead shielding, etc.). It has been replaced by the Gray (***Gy***) in SI-derived units but is still used in the United States.

4- Equivalent Dose

An equivalent dose is a measure of the radiation dose to the tissue where an attempt has been made to allow for the different relative biological effects of different types of ionizing radiation. In quantitative terms, the equivalent dose is less fundamental than the absorbed dose, but it is more biologically significant.

- The equivalent dose is measured using the Sievert (***Sv***) and ***Rem***.

- The Radiation Weighting Factor (W_R): is used to modify the absorbed dose (Gray) by multiplying to obtain a quantity called the equivalent dose (***Sv***). It is used because some types of radiation, such as Alpha particles, are more biologically damaging internally than other types such as Beta particles.
- Sievert (***Sv***): it measures the amount of energy emitted by the radiation per a given amount of tissue mass. This is one of the most commonly used units when discussing the harmful effects of radiation on people and animals.

For example, a generally fatal dose for people is about 4 sieverts (***Sv***). A person may still be saved if treated quickly, but a dose of ***8 Sv*** is lethal.

- Rem: unit of radiation dosage (such as from X-rays) applied to humans. Derived from the phrase (Roentgen Equivalent Man), the rem is now defined as the dosage in rads that will cause the same amount of biological injury as one rad of X-rays or gamma rays.

5- Effective Dose

The "effective dose" is a biological dose commonly used in radioprotection, as it determines how dangerous an individual's exposure to radiation can be. It takes into consideration not only the nature of the incoming radiation but also the sensitivities of the body parts affected.

The unit of 'effective dose' is the Sievert and Rem, the same unit as is used for the equivalent dose absorbed locally by an organ, a gland, or any other part of the body.

In the field of radioprotection, it is this effective dose that interests us, though the equivalent dose is what matters in medicine. The unfortunate decision by radio protectionists to use the same unit for both doses does not help the non-expert to clarify these matters.

- The Tissue Weighting Factor (W_T): is a relative measure of the risk of stochastic effects that might result from the irradiation of that specific tissue. It accounts for the variable radiosensitivities of organs and tissues in the body to ionizing radiation.

Important Conversions of Radiation Units:

1) **1 Bq = 1 s^{-1}**
2) **1 Bq ≅ 2.703 × 10^{-11} Ci**
3) **1 Ci = 3.7 × 10^{10} Bq**
4) **1 R = 1 C/kg**
5) **1 Gy = 1 Joule/kilogram = 100 rad**
6) **1 Rad = 0.01 Gy = 0.01 J/kg**
7) **1 Sv = 1 J/kg = 100 rem**
8) **1 rem = 0.01 Sv**

In summary:

1- Measurements of Radiation Dose Radiation.

Radiation dose emitted from radioactive isotope (decay rate).

- Absorbed dose: energy deposited in a kilogram of a substance by the radiation.
- Equivalent dose: weighted for susceptibility to harm of different tissues (tissue weighting factor w_T); measured in rem (sievert).
- Absorbed dose: weighted for harmful effects of different radiations (radiation weighting factor w_R); it measured in rad (gray).

So:

1- Radiation dose in air that can produce ionization (exposure dose) or it is the number of ion pairs that are formed in a given volume of air when it is exposed to radiation (only to gamma and x-rays).

•This dose is measured by Roentgen (***R***) unit.

2- Radiation dose that enters the body (absorbed dose).

3- Radiation dose that causes damage (equivalent dose).

✓ Equivalent dose of different types of radiation *which causes different biological effects on the same tissue* equal to:

Equivalent dose (rem or Sievert) = absorbed dose (rad) x quality factor (Q); therefore, the same absorbed dose of radiation with high Q causes more effect in our body than radiation with lower Q.

Example:

Equivalent dose (neutron) = 100 rad x 20 = 2000 Sievert

Equivalent dose (X-ray) = 100 rad x 3 = 300 Sievert

✓ Equivalent dose of certain radiation which *causes various effects in different organs & tissues (soft & solid)*.

In this case an effective dose is used to estimate the risk of radiation in whole body which is equal to the sum of equivalent doses to each organ and tissue factor.

Example:

Effective dose of gamma ray= equivalent dose of skin+ equivalent dose of muscles + equivalent dose of bone + ……etc.