IoT 4211: Sensor Technology

Radiation Measurement

$\alpha, \beta, \gamma \ldots$

type

Radiation

- Radiation is energy that moves from one place to another in a form that can be described as waves or particles.

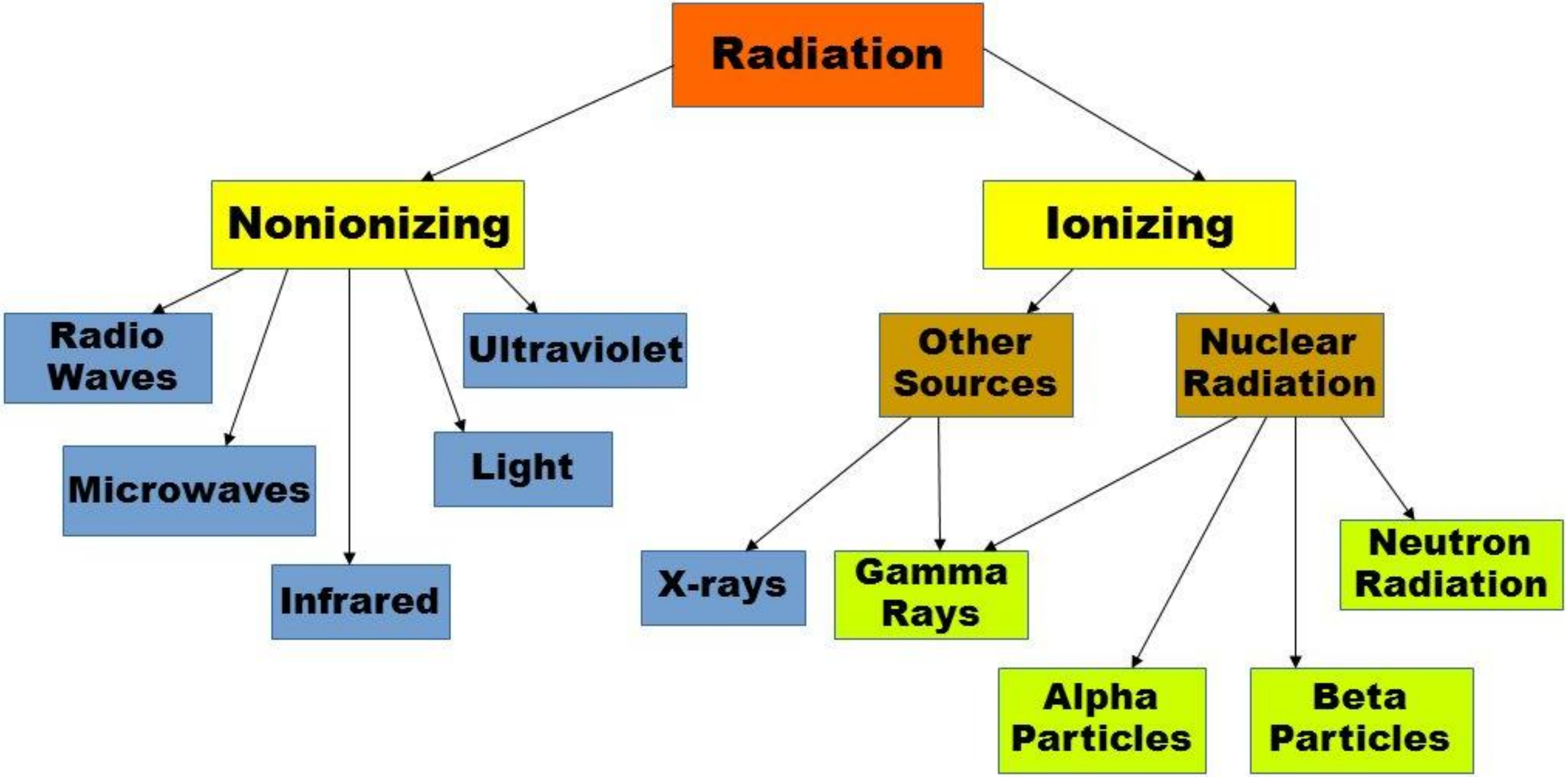
e.mag: wave γ α, β

- Some of the most familiar sources of radiation include the sun, microwave ovens, radios, etc.

- **Ionizing radiation** refers to those subatomic particles and photons whose energy is sufficient to cause ionization in the matter with which they interact. The ionization process consists of removing an electron from an initially neutral atom or molecule.

ionizatio: through which process, electrically nutral atoms or molecules turns into charged atoms or molcules

example: HCl + H2O -> H3O+ + Cl-
hydrochloric acid + water -> hydronium ion + chloride ion


Radiation
Nonionizing
Ionizing
Radio Waves
Microwaves
Infrared
Light
Ultraviolet
Other Sources
Nuclear Radiation
X-rays
Gamma Rays
Neutron Radiation
Alpha Particles
Beta Particles

Ionizing Radiation

He^{2+} α^{2+}

- **Alpha particles:** Consist of two protons and two neutrons and carry a positive electrical charge of two units.

e^- β^-

- **Beta particles:** A fast electron that carries a negative charge of one unit.

- **Gamma rays:** High-frequency electromagnetic photons, carries no electric charge.

30 ex Hz = 3* 10^19 Hz

γ γ^0

penetrates walls

was descoverd to descover what comes out from Ra radiation
Paul , physicist

src

Radiation Interaction with Matter

few cm

- Only charged radiations interact continuously with matter, and they are therefore the only types of radiation that are directly detectable.

quanta: discrete quantity/packet of energy

- Uncharged quanta must first undergo a major interaction that transforms all or part of their energy into secondary charged radiations. Properties of the original uncharged radiations can then be inferred by studying the charged particles that are produced.

- It is not unusual for an uncharged radiation to travel distances of many centimeters through solid materials before such an interaction occurs.

- Instruments that are designed for the efficient detection of these uncharged quanta therefore tend to have relatively large thicknesses to increase the probability of observing the results of such an interaction within the detector volume.

basically talks about alpha paricle

Interaction of Heavy Charged Particles

detection based on culomb force.

- The term heavy charged particle refers to those energetic particles whose mass is one atomic mass unit or greater. $m \geq 1.67 \times 10^{-27}$ kg α^{+}, ...

- This category includes alpha particles, together with protons, deuterons, fission fragments, and other energetic heavy particles often produced in accelerators.

- These particles carry at least one electronic charge, and they interact with matter primarily through the Coulomb force that exists between the positive charge on the particle and the negative charge on electrons that are part of the absorber material.

attractive force

- As a charged particle passes near an electron in the absorber, it transfers a small fraction of its momentum to the electron. As a result, the charged particle slows down slightly, and the electron (which originally was nearly at rest) picks up some of its kinetic energy.

Interaction of Heavy Charged Particles

- At any given time, the charged particle is simultaneously interacting with many electrons in the absorber material, and the net result of all the Coulomb forces acts like a viscous drag on the particle.
- From the instant it enters the absorber, the particle slows down continuously until it is brought to a stop.
- The average distance traveled by the particle before it stops is called its **mean range**.
- The mean range increases with increasing initial kinetic energy of the charged particle.

talks about beta particle

Interaction of Fast Electrons

- Energetic electrons also interact with electrons in the absorber material through the Coulomb force.

repulsive force

- The fast electron experiences the cumulative effect of many simultaneous Coulomb forces and undergoes a continuous deceleration until it is stopped.
- As compared with a heavy charged particle, the distance traveled by the fast electron is many times greater for an equivalent initial energy.

Heavy...:
1. positive particle
2. attarctive force
3. traveled distance greater

vs

fast electron...:
1. negative particle
2. repulsive force
3. traveled distance less

Interaction of Gamma Rays and X Rays

photon has no mass. all it has is energy

- Gamma rays and X rays are electromagnetic radiation that is made of photons.
- Since the photon is uncharged, it does not interact through the Coulomb force and therefore can pass through large distances in matter without significant interaction.
- A single interaction can profoundly affect the energy and direction of the photon or can make it disappear entirely. In such an interaction, all or part of the photon energy is transferred to one or more electrons in the absorber material.

photon will disapper

- The three major types of such interactions are **photoelectric absorption**, **compton scattering**, and **pair production**.

these are how the uncharged radiation turns into charged radiation to interact with the particle, [secndary charge transformation]

Interaction of Gamma Rays and X Rays

- **Photoelectric absorption:** In this process, the incident X-ray or gamma-ray photon interacts with an atom of the absorbing material, and the photon completely disappears; its energy is transferred to one of the orbital electrons of the atom.

- **Compton scattering:** In this process, the photon abruptly changes direction and transfers a portion of its original energy to the electron from which it scattered. The fraction of the photon energy that is transferred depends on the scattering angle.

nuclues's range of positive charge

- **Pair production:** In the field of a nucleus of the absorber material, the photon may disappear and be replaced by the formation of an electron-positron pair.

Interaction of Neutrons

same as gamma ray

- Owing to the absence of the Coulomb force, neutrons may penetrate many centimeters through solid materials before they interact in any manner.
- When they do interact, it is primarily with the nuclei of atoms of the absorbing material.
- When interacted, the neutrons may either disappear or undergo a major change in their energy and direction.
- Neutron interactions result in the formation of energetic heavy charged particles.

Passive Detector: Photographic Emulsions

- A photographic emulsion consists of a suspension of silver halide grains in an inert gelatin matrix and supported by a backing of plastic film or another material.

- If a charged particle or fast electron passes through the emulsion, interactions with silver halide molecules produce a similar effect as seen with exposure to visible light.

- After the exposure is completed, this latent record of the accumulated exposure can be made visible through the chemical development process.

- Photographic emulsions used for radiation detection purposes can be classified into two main subgroups: radiographic films and nuclear emulsions.

- Radiographic films register the results of exposure to radiation as a general darkening of the film due to the cumulative effect of many radiation interactions in a given area of the emulsion.

- Nuclear emulsions are intended to record individual tracks of a single charged particle.

Passive Detector: Photographic Emulsions

- Photographic emulsions, originally designed for photography, are also effective tools for measuring ionizing radiation. They consist of a gelatin matrix embedded with silver halide crystals. When exposed to radiation, these crystals undergo chemical changes, which are then developed to reveal the tracks or "spots" where radiation has interacted. This technique is commonly used for detecting various types of radiation, including alpha particles, beta particles, neutrons, and gamma rays.

How Photographic Emulsion Works for Radiation Detection:

Sensitive Layer: The emulsion is a thin layer with tiny crystals that are sensitive to radiation, like a "film" that can record where particles hit.

Exposure: When radiation (like alpha or beta particles) passes through, it hits the crystals, creating invisible "marks" or a pattern.

Development: To see these marks, the emulsion is chemically developed, turning only the exposed crystals into tiny silver dots or lines, making the radiation paths visible.

particle

wave

Counting Tracks: By looking at these tracks under a microscope, scientists can analyze the type and amount of radiation that was present

dense tracks by heavy particles
lighter or thinner tracks by small particles like e-

Passive Detectors: Bubble Detectors

- A **bubble detector** is a device used to detect neutron radiation by visualizing the neutron interactions as bubbles in a special gel or liquid. It's commonly used in fields like nuclear physics, radiation protection, and medical physics to monitor neutron exposure because it provides both a visible and quantitative way to measure neutron radiation.

How a Bubble Detector Works:

1. **Detector Composition**: The detector contains a superheated liquid (often a gel) inside a sealed tube or vial. The liquid is kept just below its boiling point and is stable until it's disturbed by neutron radiation.
2. **Neutron Interaction:** When neutrons pass through the detector, they interact with the superheated droplets, causing localized heating. This heating triggers the droplet to quickly vaporize into a small gas bubble.
3. **Bubble Formation**: The gas bubbles formed stay trapped in the gel, and the number of bubbles is proportional to the amount of neutron exposure.
4. **Counting and Analysis:** The bubbles are easily visible and can be counted manually or with an automated system to measure the neutron dose received. After counting, some bubble detectors can be reset by applying pressure, allowing the bubbles to dissolve back into the liquid.