# *Lecture 6*: Interaction of Neutron with Matter

Neutrons differ from particles and gamma rays in terms of **interaction**, because they are **neutral**, so they do not interact with orbiting electrons, **but** rather enter the nucleus directly and penetrate the nuclear barrier. The neutron interactions are divided into **two** parts:

## 1. Fast neutron interaction

Fast neutron interaction in general depends mainly on the **type of target material**. Such as the **light** atoms, **medium** atoms and **heavy** atoms. In these interactions, the neutrons **collide** with the **nucleus**, and the nucleus becomes **excited**. In order for the nucleus to get remove of the state of excitation, it will **decay** in the following ways:

1. **Elastic decay: The neutron is ejected from the nucleus and returns to its stable state.**
2. **Inelastic decay: The neutron is ejected from the nucleus but with *less energy* which resulted in the nucleus is remains excited.**
3. **Neutron, proton decay: A neutron is absorbed by the nucleus and a proton is ejected. The nucleus remains unstable, so it is then decay by *beta decay* ($\beta^-$).**
4. **Neutron,2neutron decay: A neutron is absorbed and two neutrons are emitted, while the nucleus remains in an excited state. This happens if the neutron energy is *too high*.**
5. **Neutron-Gamma decay: In this type of decay, the nucleus reaches to stable state by emitting *gamma rays*.**

## 2. Slow neutrons interactions

In this type of interaction, the **neutron** is **absorbed** by the **nucleus**, and the nucleus will become **excited**. After that, the **nucleus** returns to the **stable state**, by **emitting energy** and this energy is in the form of ***kinetic energy*** for the products of the interaction, *i.e.*, the kinetic energy of the particles resulting from the interaction. These **interactions** depend on the type of matter, for the **light** nuclei, the interaction is neutron-alpha particle or a proton. *Also*, in the **medium** nuclei, a neutron-gamma decay occurs. As for the **heavy** nuclei, this is considered to be the type prevalent in the process of nuclear fission which is used in nuclear reactors.

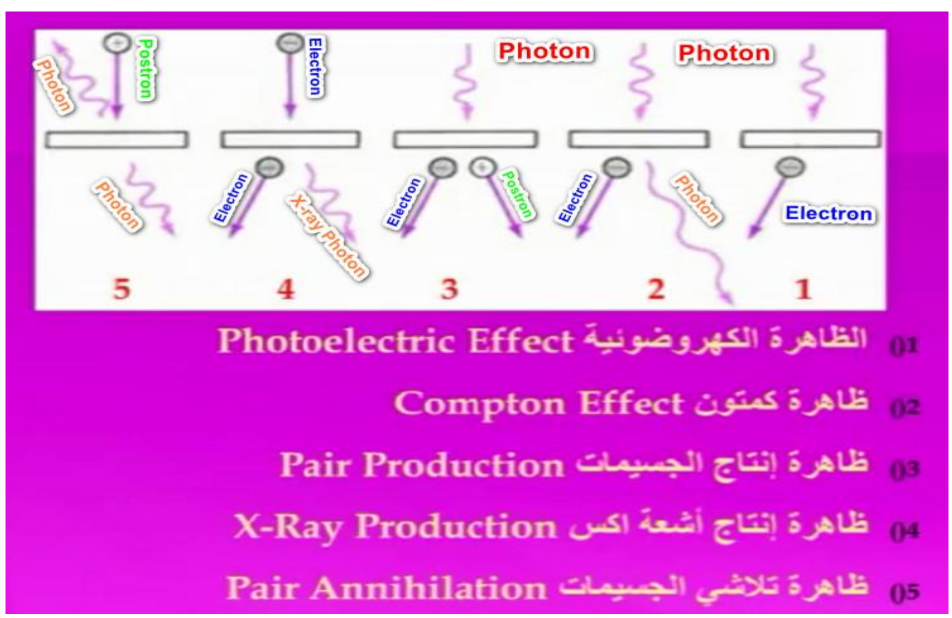
## 3. Photons Absorption

In all the interactions processes such as the photoelectric effect, the Compton effect, and the X-ray production processes, we have observed that photons are transformed into particles like electrons or vice versa.

All these processes were explained on the basis of considering the electromagnetic beam has energy and momentum, all of which are quantized called photons as follows:

Photon energy $\boldsymbol{E = hf}$

Photon momentum $\boldsymbol{P = \frac{h}{\lambda}}$

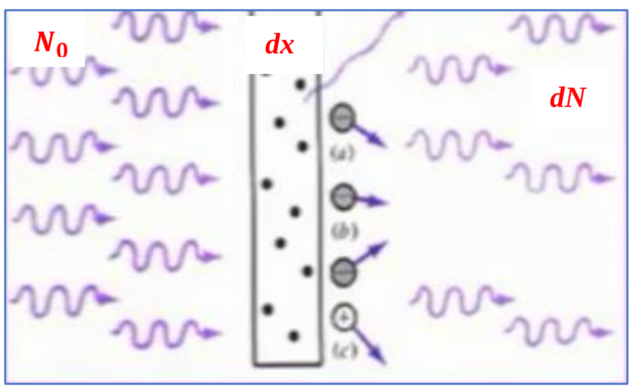


These processes lead to the absorption of a number of photons of the incident radiation, and this absorption reduces the number of photons that will transmitted from the surface.

$$I_0 = hf * N_0$$

Where: $N_0$ is **Photon flux density** كثافة الفيض الفوتوني

When an electromagnetic ray transmitted from the material surface of thickness $x$, the density of the photon flux $N_0$ decreases after the photons passes from the surface due to the absorption of a number of these photons into the material. where the number of photons absorbed into the material depends on the **density** of the incident **photon flux**, and on the **material** and also, on the **thickness** of this material $x$.




In the above figure, if $N_0$ is the density of the incident photons on a material whose thickness is dx and the density of the photons transmitted from the material is $dN$, so the relationship between the change in the density of the incident photons on the material and the thickness of the material is as follows:

$dN = -\mu N_0 dX$ μ is **absorption coefficient** معامل الامتصاص

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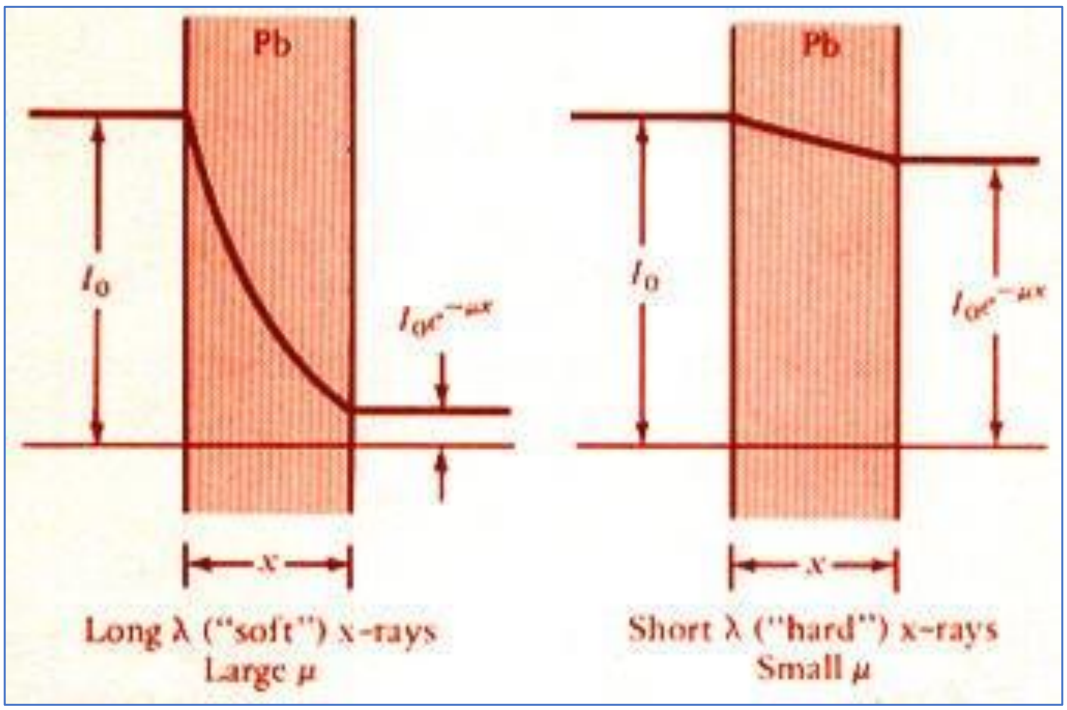
$$\therefore I = I_0 e^{-\mu x}$$

Where: $I_0$ is incident intensity on the material and, $I$ is transmitted intensity from the material.

The equation indicates that the intensity of the electromagnetic radiation decreases in an exponential function with the thickness of the material $x$ and the rate of decrease depends on the material absorption coefficient $\mu$.

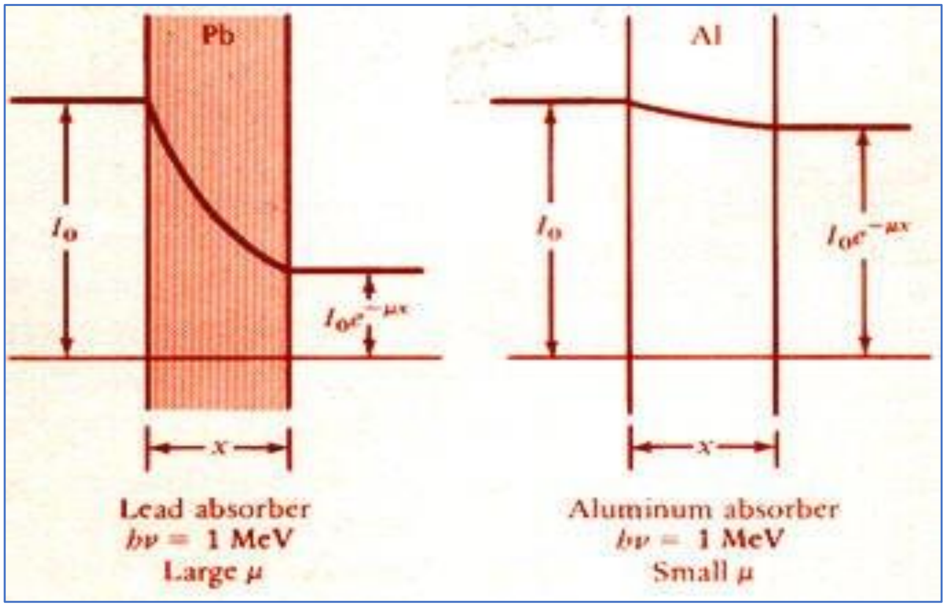
- **The absorption coefficient depends on the energy of the incident photon:**

where the absorption of the material **decreases** by **increasing** the **energy** of the incident rays.




- **The absorption coefficient depends on the type of material:**

As it is in the figure, lead absorbs more photons than aluminum, and this means that the absorption coefficient of lead is greater than the absorption coefficient of aluminum. For this reason, lead is used in the manufacture of protective walls from rays of high energies such as X-rays and gamma rays.




***Example:***

The absorption coefficient for **2**MeV gamma ray in water is $4.9m^{-1}$.

1. Find the relative intensity of a beam of **2**MeV gamma rays after it has passed through **10**cm of water?

**Solution**

$$\boldsymbol{I} = I_0 e^{-\mu x} \quad t\square en, \frac{I}{I_0} = e^{-\mu x} = e^{-(4.9m^{-1})(0.1m)} = e^{-0.49} = \mathbf{0.61}$$

The intensity of the beam is reduced by 61% of its original value after passing through 10cm of water.

2. How far must such a beam travel in water before its intensity reduced to 1% of its original value?

| |
|---|
| I=1% |
| $I_0$=100% |
| $I_0$/I=100 |

**Solution**

Since the intensity reduced to 1% of its original value then, $\frac{I_0}{I} = 100$, so:

$$\boldsymbol{x} = \frac{\ln(\frac{I_0}{I})}{\mu} = \frac{\ln(100)}{4.9m^{-1}} = \mathbf{0.94m}$$