2024 SUMMARY

PHYSICS 105

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ARKAN ACADEMY

❖ Section (10.8): Fluids in motion, flow rate and the equation of continuity

- In the previous lesson, we talked about static fluids
- In this section, we will discuss dynamic fluids:
  - When the fluid is water, this field is called ***hydrodynamics***

- There are **two** main types of fluid flow:
  - Laminar (streamline) flow:
    - ✓ Each ***particle follows*** a smooth path called a *streamline*
    - ✓ The ***paths do not cross*** one another.
  - Turbulent flow:
    - ✓ Above a certain speed, the flow becomes turbulent.
    - ✓ It is characterized by erratic, small, whirlpool like circles called eddy currents or eddies.
    - ✓ Eddies absorb a ***great deal of energy***.

- **Viscosity:** the internal friction between the layers of a moving liquid. It behaves similarly to the ***friction*** between two rough surfaces in contact.

- ***Equation of continuity:***
  - The mass flow rate $= \frac{\Delta m}{\Delta t}$
  - And the **equation of continuity becomes**

$$A_1 v_1 = A_2 v_2 \quad \text{where } \rho \text{ is constant}$$

Small A ⟶ Large v , Large A ⟶ Small v

- ✓ ***Example:*** In humans, blood flows from the heart into the aorta, from which it passes into the major arteries, then branch into the small arteries (arterioles), which in turn branch into myriads of tiny capillaries. The blood returns to the heart via the veins. The radius of the aorta is about 1.2 cm, and the blood passing through it has a speed of about 40 cm/s. A typical capillary has a radius of about $4 * 10^{-4}$ cm and blood flows through it at a speed of about $5 * 10^{-4}$ m /s , Estimate the number of capillaries that are in the body.

- ✓ ***Solution:***

$A_1 v_1 = A_2 v_2$ Where A_1 is the area of the aorta , A_2 is the area of all capillaries

The area of the aorta $= \pi \ r_{aorta}^2$

And the area of all capillaries $= N \pi r_{cap}^2$ (N = Number of capillaries)

Then $v_1 \ \pi r_{aorta}^2 = v_2 N \pi r_{cap}^2$

$v_1 \ r_{aorta}^2 = v_2 N r_{cap}^2$

$$N = \frac{v_1}{v_2} \ \pi \frac{r_{aorta}^2}{r_{cap}^2} = \left(\frac{0.4\frac{m}{s}}{5 * 10^{-4} \ m/s}\right) \left(\frac{1.2*10^{-2} m}{4*10^{-6} \ m}\right)^2$$

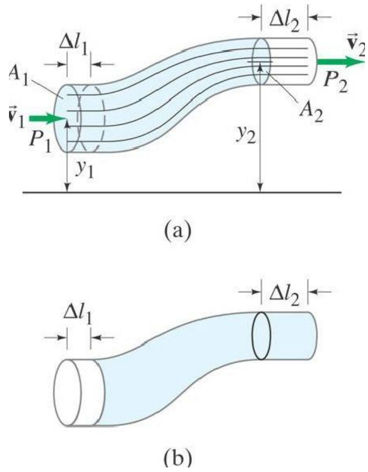
$N = (800)(9 * 10^6) = 7.2 * 10^9$

(where N is the estimated number of capillaries in the human body)

❖ Section (10.9): Bernoulli's Equation

- **Bernoulli's principle** states that where the *velocity* of a fluid is ***high*** the pressure is ***low***, and where the *velocity* is ***low*** the pressure is ***high.***

➢ *Bernoulli's Equation:* $\boldsymbol{P_2 + \frac{1}{2}\,\rho\, v_2^2 + \rho\, g\, y_2 = P_1 + \frac{1}{2}\,\rho\ v_1^2 + \rho\, g\, y_1}$



✓ ***Example:*** Water circulates throughout a house in a hot-water heating system. If the water is pumped at a speed of through a 4.0-cm-diameter pipe in the basement under a pressure of 3.0 atm. What will be the flow speed and pressure in a 2.6-cm-diameter pipe on the second floor 5.0 m above? *Assume the pipes do not divide into branches.*

✓ ***Solution:***

$V_1 = 0.50\, m/s\ ,\ d_1 = 4cm\ ,\ P_1 = 3\ atm\ ,\ P_2 = ?\ ,$
$d_2\ 2.6\ cm\ ,\ y_1 = 0\ ,\ y_2 = 5\ cm$

We use Bernoulli's equation to find P_2

$$P_2 + \frac{1}{2}\,\rho\, v_2^2 + \rho\, g\, y_2 = P_1 + \frac{1}{2}\,\rho\ v_1^2 + \rho\, g\, y_1$$

$$P_2 = P_1 + \frac{1}{2}\,\rho\,(V_1^2 - V_2^2) + \rho\, g\,(y_1 - y_2) \quad (1)$$

All variables are given in the question except V_2 , to find it we use the equation of continuity.

$$A_2\, v_2 = A_1\ v_1$$

$$v_2 = \frac{A_1\ v_1}{A_2}$$ (where water circulates so $A = \pi\ r^2$)

$$= \frac{(0.04)^2\ m^2\ \pi\ (0.50)}{(0.026)^2\ m^2\ \pi} = \frac{8 * 10^{-4}}{6.76 * 10^{-4}}$$

$$v_2 = 1.183\ m/s$$

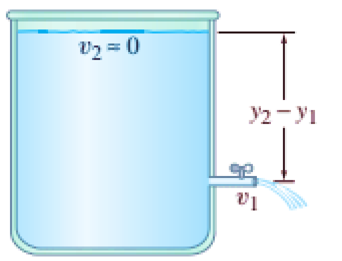
Now, substitute all variables to find P_2

$$P_2 = 250425.26 \approx 2.504 * 10^5\ N/m^2 \approx 2.504\ atm$$

❖ Section (10.10): Applications of Bernoulli's principle: Torricelli, Airplanes, Baseballs, Blood flow

- **Torricelli's theorem:**

$$\boldsymbol{V_1 = \sqrt{2\, g\,(y_2 - y\_1)} = \sqrt{2\, g\, h}}$$ (where $h = y_2 - y_1$)



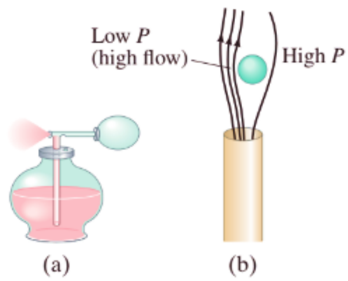
  - ▪ This result is called Torricelli's theorem

✓ ***Example:*** A stone is released from rest from a high h = 4 m above the surface of the ground. Find its **speed** the moment it hits the ground.

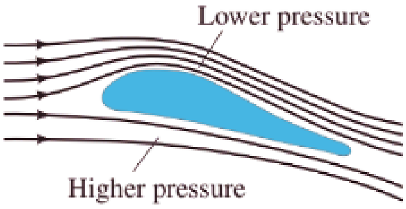
✓ ***Solution:***

$$V_f = \sqrt{2\, g\, h} = \sqrt{2 * 9.8 * 4} = 8.854\ m/s$$

- Examples of **Bernoulli's Principle:**
  - Atomizer
  - Ping-pong ball in a jet of air



- **Lift Force on an Airplane Wing:**
  - The lift force allows an airplane to fly
  - It is generated due to a ***difference in pressure*** between the upper and lower surfaces of the **wing:**
    - ✓ Below the wing: Low velocity (v) → High pressure (P)
    - ✓ Above the wing: High velocity (v) → Low pressure (P)
  - The resultant lift force (F) acting on the wing is ***directed upwards***, according to the formula: F = P A



❖ Section (10.12): **Flow in tubes: Poiseuille's Equation, Blood Flow**

- Poiseuille studied the factors that affect the ***flow rate*** of an incompressible fluid undergoing laminar flow in a cylindrical tube. His equation, known as ***Poiseuille's Law***, is given by:

$$Q = \frac{\pi \ R^4 \ (P_1 - P_2)}{8 \eta \ l}$$

Where:

- **Q** is the volumetric flow rate, measured in cubic meters per second **(m^3/s)**.
- **R** is the inner radius of the tube, measured in meters (**m**).
- **P_1** and **P_2** are the pressures at the two ends of the tube, measured in pascals (**Pa)**.
- **η** is coefficient of viscosity of the fluid, measured in Pascal-seconds $\frac{N.s}{m^2}$ = (**Pa**·s).
- **l** is the length of the tube, measured in meters (**m**).

- When the radius ***decreases to half*** the **Q** is

$$Q \propto R^4$$
$$Q \propto R$$

  - When R goes to $\frac{R}{2}$ the Q goes to $\frac{Q}{16}$
  - An interesting example of this dependence is blood flow in the human body.

- Poiseuille's equation is **valid** only for the streamline flow of an incompressible fluid.

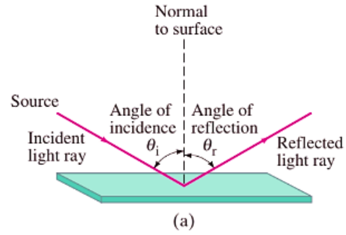
Chapter -23-

(Light: Geometric Optics)

❖ Section (23.1): **The Ray Model of light**

- The Ray Mode: light travels in straight-line called light rays paths in uniform ***transparent media*** like air and glass, Because these explanations involve straight-line rays at ***various angles***, this subject is referred to as geometric optics
  - The speed of light in vacuum is (**c = 3*10^8 m/s**)

❖ Section (23.2): Reflection



- According to the ***law of reflection***, these two angles are always equal:

$$\theta_r = \theta_i$$

- Additionally, it is ***important to note*** that the incident ray, the normal, and the reflected ray all lie within the ***same plane***.

❖ Section (23.4): Index of Refraction

- When a wave moves from one medium, where its speed is v_1, to another medium with a different speed v_2 (**where $v_2 \neq v_1$**), its ***direction*** of motion generally changes. This change in direction is known as refraction.
- The speed of light varies <u>depending on the medium</u> it travels through. For instance, in a vacuum, the speed of light is **$c = 3.00\times10^8$**. However, when light travels through water, its speed ***decreases*** by a factor of **1.33.** In general, the speed of light in a medium, denoted as v, is related to the medium's index of refraction n, which is defined as follows:

$$v = \frac{c}{n}$$

TABLE 23–1 Indices of Refraction[†]	
Material	$n = \frac{c}{v}$
Vacuum	1.0000
Air (at STP)	1.0003
Water	1.33
Ethyl alcohol	1.36
Glass	
Fused quartz	1.46
Crown glass	1.52
Light flint	1.58
Plastic	
Acrylic, Lucite, CR-39	1.50
Polycarbonate	1.59
"High-index"	1.6–1.7
Sodium chloride	1.53
Diamond	2.42

[†] λ = 589 nm.

- The index of refraction is defined as the ***ratio*** of the speed of light in a <u>vacuum</u> to the speed of light in a specific *material*.
- It is always greater than or equal to 1.

✓ ***Example:*** How much time does it take for light to travel 1.20 m in water? (where **n** for water = 1.33)

✓ ***Solution:***

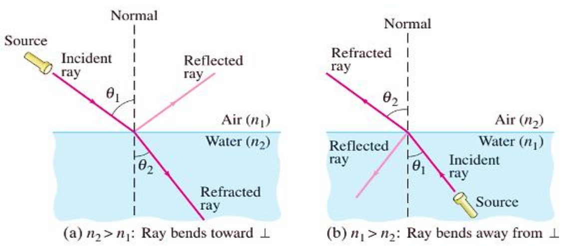
n for water = 1.33 , c = 3 *10^8 m/s

$v = \frac{c}{n} = \frac{3*10^8}{1.33}$ = 2.25 * 10^8 m/s

$v = \frac{d}{t}$ so the time equal

$t = \frac{d}{v} = \frac{1.2}{2.25*10^8}$ = 0.533 *10^{-8}

❖ Section (23.5): Refraction: Snell´s Law



- The **r**<u>elationship</u> between the *directions of propagation* in these two media is given by **Snell's law**, which is expressed as:

$$n_1 sin\theta_1 = n_2 sin\theta_2$$

✓ ***Example***: A beam of light in air enters

I. water (n = 1.33) an angle of 60.0° relative to the normal.
II. diamond (n = 2.42) at an angle of 60.0° relative to the normal.

Find the angle of refraction for each case (where n for light = 1)

✓ ***Solution:***

I. To find θ of refraction of water use Snell's law:

$n_1 sin\theta_1 = n_2 sin\theta_2$

1 sin(60˚) = 1.33sinθ_2

$\theta_2 = \sin^{-1}(\frac{\sin(60°)}{1.33}$

$\theta_2 = 40.62˚$

II . To find θ of refraction of diamond use Snell's law :

$n_1 sin\theta_1 = n_2 sin\theta_2$

1 sin(60˚) = 2.42sinθ_2

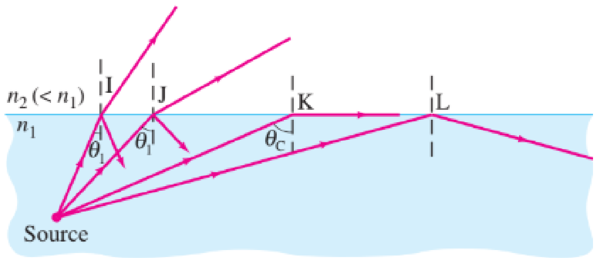
$\theta_2 = \sin^{-1}(\frac{\sin(60°)}{2.42})$

$\theta_2 = 20.96˚$

- Apparent depth: it refers to the ***phenomenon*** where an object seems to be nearer to the water's surface than its true depth.

❖ Section (23.6): Total Internal Reflection; Fiber Optics

- Sometimes, ***refraction*** can "trap" a light ray, stopping it from exiting the material.
  - ➢ The critical angle: is the ***angle*** of incidence beyond which light traveling from a denser medium to a less dense medium is completely reflected back into the denser medium, rather than refracted.



- This occurs when the angle of incidence causes the refracted ray to lie along the boundary between the two media.

$$\boldsymbol{sin\theta_c = \frac{n_2}{n_1}}$$

- ➢ From Snell's law:

$\boldsymbol{n_1 sin\theta_1 = n_2 sin\theta_2}$

At $\theta_1 = \theta_c$, and the $\theta_2 = 90˚$

Sin $\theta_c = \frac{n_2}{n_1}$ (1)

If $\boldsymbol{\theta_1 > \theta_c}$ that's leads to $\boldsymbol{\sin\theta_1 > \frac{n_2}{n_1}}$

But in Snell's law $\frac{n_1}{n_2} sin\theta_1 = sin\theta_2$,sin θ_2 >1 which cannot happen since sin θ ≤ 1

For $\boldsymbol{\theta_1 > \theta_c}$ no light is refracted and all light is reflected this is called ***total internal reflection***

- ➢ Total internal reflection: is a **phenomenon** that occurs when a light ray traveling from a denser medium to a less dense medium hits the boundary at **an angle greater than the critical angle**.
- ➢ Instead of refracting into the second medium, the light is completely reflected back into the original, denser medium. This effect is key in technologies like ***fiber optics*** and ***prisms***.

- ✓ ***Example:*** Consider a sample of glass whose index of refraction is n = 1.65.
  Find the critical angle for total internal reflection for light traveling from this glass to

  I. air (n = 1.00).
  II. water (n = 1.33)

- ✓ ***Solution:***

  I . $sin\theta_c = \frac{n_2}{n_1}$ so the θ_c for air equal

  θ_c = $\sin^{-1}(\frac{1}{1.65})$

  $\theta_c = 37.30^\circ$

  II. $sin\theta_c = \frac{n_2}{n_1}$ so the θ_c for water equal

  θ_c = $\sin^{-1}(\frac{1.33}{1.65})$

  $\theta_c = 53.71^\circ$

- **Fiber Optics; Medical Instruments**.

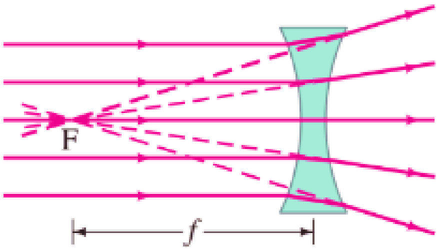
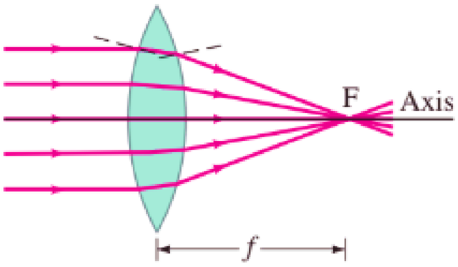
❖ Section (23.7): Thin Lenses; Ray Tracing

- A Lens: is a transparent optical device, typically made of glass or plastic, that bends or refracts light to ***converge*** or ***diverge*** it. Lenses are commonly used in various devices like microscope, and telescopes to focus light and form images.

- There are **two** primary types of lenses:

I. Convex (converging) lenses: which focus light rays by bringing them together. These lenses take *parallel rays* of light and converge them at a focal point.
- ✓ Convex lenses are thicker in the **center** compared to the edges.
- ✓ Images formed by convex lenses change depending on the distance between the object (light source) and the lens.
  1. When the object is far from the lens (farther than twice the focal length):
     The type of image is created: real, inverted, and smaller than the body.
  2. When the object is at twice the focal length (2f):
     The type of image is created: real, inverted, equal in size.
  3. When the object is between the lens and twice the focal length (closer than twice the focal length):
     The type of image is created: real, inverted, and larger than the body.
  4. When the object is within the focal length (closer than the focus):
     The type of image is created: virtual, straight, and larger than the object

II. Concave (diverging) lenses: which ***cause light rays*** to spread apart. These lenses make *parallel rays* diverge as if they are originating from a point source.
- ✓ Concave lenses are thinner in the ***center*** *than at the edges.*
- ✓ concave lenses: To generate a more upright and smaller virtual image.



❖ Section (23.8): The Thin Lens Equation

- we obtain a result known as the **thin-lens equation**:

$$\frac{1}{d_\circ} + \frac{1}{d_i} = \frac{1}{f}$$

➢ Magnification of the image: is the ratio of the image height to object height

$$m = \frac{h_i}{h_\circ}$$

✓ ***Rearranging*** the Equation:

$$m = \frac{h_i}{h_\circ} = \frac{-d_i}{d_\circ}$$

- ***Focal Length***
  - ✓ f is positive for converging (convex) lenses.
  - ✓ f is negative for diverging (concave) lenses.

- ***Magnification***
  - ✓ m is positive for upright images (same orientation as object).
  - ✓ m is negative for inverted images (opposite orientation of object).

- ***Image Distance***
  - ✓ d_i is positive for real images (images on the opposite side of the lens from the object).
  - ✓ d_i is negative for virtual images (images on the same side of the lens as the object).

- ***Object Distance***
  - ✓ d_o is positive for real objects (from which light diverges).
  - ✓ d_o is negative for virtual objects (toward which light converges).

- The power: Ophthalmologists and optometrists use the reciprocal of the focal length to define the strength of eyeglass or contact lenses, rather than the **focal length itself**.

$$p = \frac{1}{f}$$

➢ The unit for lens power is the diopter (D), which is an inverse meter: **1 D = 1 m^{-1}**

- ✓ ***Example:*** An object is placed 12 cm in front of a diverging lens with a focal length of -7.9 cm. Find:

  (a) The image distance

  (b) The magnification

- ✓ ***Solution:***

  (a) $\frac{1}{d_\circ} + \frac{1}{d_i} = \frac{1}{f}$

  $\frac{1}{12*10^{-2}} + \frac{1}{d_i} = -\frac{1}{7.9*10^{-2}}$

  $d_i = -0.0476$ m

  (b) $m = \frac{-d_i}{d_\circ}$

  $m = \frac{-(-0.0476)}{0.12}$

  $m = 0.3966$

Chapter -30-

(Nuclear Physics and Radioactivity)

❖ Section (30.1): Structure and Properties of the Nucleus

- Nucleus refers to the central part of an atom, composed of *protons* and *neutrons*, and it carries most of the ***atom's mass***. The number of protons in the nucleus determines the element of the atom.
  - ➢ Proton: is the nucleus of the simplest atom, hydrogen.
    - ✓ The proton has a positive charge (**+1.60*10**$^{-19}$) and it has a mass (**m_p = 1.67262 *10^{-27} kg**)
  - ➢ Neutron: is subatomic particles located in the nucleus of an atom.
    - ✓ It is electrically neutral, meaning it carries no charge, and it has a mass (**m_n = 1.67493 * 10^{-27} kg**)

- Nuclides refer to ***different types*** of atomic nuclei.
  - ➢ Atomic number: is the number of protons in nucleus and is designated by the **symbol (Z)**.
  - ➢ Atomic mass number: is the total number of nucleons neutrons plus protons, is designated by the **symbol (A).**

- To identify a specific **nuclide**, only the values of A (mass number) and Z (atomic number) are needed. A commonly used special symbol represents this information in a specific format:

$$^{A}_{Z}X$$

  - ➢ Isotopes: are nuclei that have *the same* number of *protons* but *different* numbers of *neutrons*
    - ✓ Like $^{12}_{6}C$, $^{11}_{6}C$, $^{13}_{6}C$
  - ➢ Isotones: are nuclides that have *the same* number of *neutrons*, but *different* number of *protons*
    - ✓ Like $^{40}_{18}B$, $^{13}_{6}C$
  - ➢ Isobars: are nuclides that have *the same mass number*
    - ✓ Like $^{40}_{18}Ar$, $^{40}_{19}K$

- For many elements, several ***different isotopes*** exist in nature.
  - Natural abundance: is the *percentage of a particular element* that consists of a particular isotope in nature.
    - ✓ Hydrogen has isotopes (99.99%) of natural hydrogen is $_1^1\boldsymbol{H}$ a simple proton, as the nucleus; there are also $_1^2\boldsymbol{H}$ called deuterium, and $_1^3\boldsymbol{H}$ tritium, which besides the proton contain 1 or 2 neutrons. (The bare nucleus in each case is called the deuteron and triton)

- Due to ***wave-particle duality***, the exact size of the nucleus is somewhat indeterminate. Nuclei generally have a *spherical shape*, and the radius of a nucleus is given by:

$$\boldsymbol{r = 1.2 * 10^{-15} * A^{\frac{1}{3}}\, m}$$

✓ ***Example:*** Estimate the diameter of the smallest and largest naturally occurring nuclei:

I. $_1^1H$

II. $_{92}^{238}U$

✓ ***Solution:***

I. for $_1^1H$

$r = 1.2 * 10^{-15} * A^{\frac{1}{3}}$

$r = 1.2 * 10^{-15} * (1)^{\frac{1}{3}}$

$r = 1.2 * 10^{-15}$ m

so the diameter

d = 2r

$d = 2.4 * 10^{-15}$ m

II. for $_{92}^{238}U$

$r = 1.2 * 10^{-15} * A^{\frac{1}{3}}$

$r = 1.2 * 10^{-15} * (238)^{\frac{1}{3}}$

$r = 7.436 * 10^{-15}$

$d = 14.873 * 10^{-15}$

✓ ***Example:*** Approximately what is the ***value of A*** for a nucleus whose radius is $3.7 * 10^{-15}$ m?

✓ ***Solution:***

$r = 1.2 * 10^{-15} * A^{\frac{1}{3}}$

$3.7 * 10^{-15} = 1.2 * 10^{-15} * A^{\frac{1}{3}}$

$A = 29.31 \approx 29$

- **Nuclear density** is about 10^{15} times greater than the density of normal matter.
  - While the density of *normal matter* ranges between $\mathbf{10^3}$ **and** $\mathbf{10^4}$, nuclear density falls within the range of 10^{18} to 10^{19}
  - The masses of nuclei are measured in ***atomic mass*** units (u).

    1 u = 1.6605 × $\mathbf{10^{-27}}$ kg = 931.5 MeV/$\mathbf{c^2}$

TABLE 30–1
Rest Masses in Kilograms, Unified Atomic Mass Units, and MeV/c^2

Object	Mass kg	Mass u	Mass MeV/c^2
Electron	9.1094×10^{-31}	0.00054858	0.51100
Proton	1.67262×10^{-27}	1.007276	938.27
$^1_1$H atom	1.67353×10^{-27}	1.007825	938.78
Neutron	1.67493×10^{-27}	1.008665	939.57

❖ Section (30.8): Half -life and Rate of Decay

- Nuclear decay: is a random process the decay of any nucleus is *not influenced* by the decay of any other.
- Therefore, the number of decays in a short time interval is **proportional** to the number of nuclei present and to the time:

$$\Delta N = -\lambda N \Delta t$$

  - ✓ Where λ is a constant characteristic of that particular nuclide, called the *decay constant*
- This equation can be solved, using calculus, for N as a function of time:

$$N = N_{\circ} e^{-\lambda t}$$

  - ✓ N = *remaining* number of radioactive nuclei at time t
  - ✓ $N_{\circ}$ = *initial* number of radioactive nuclei at time $t_{\circ}$ = 0
  - ✓ λ = decay constant

➢ The half-life: is the time it takes for *half the nuclei* in a given sample to decay. It is related to the decay constant:

$$T_{\frac{1}{2}} = \frac{In\, 2}{\lambda} = \frac{0.693}{\lambda}$$

- ✓ Large λ ⟶ small $T_{\frac{1}{2}}$ ⟶ fast decay
- ✓ Small λ ⟶ large $T_{\frac{1}{2}}$ ⟶ slow decay

- ✓ ***Example:***

  I . What is the decay constant of $^{238}_{92}U$ whose half-life is $4.5*10^9$ yr?

  II . The decay constant of a given nucleus is $3.2*10^{-5}$ s^{-1} .What is its half-life?

- ✓ ***Solution:***

I . For the decay constant of $^{238}_{92}U$:

$$T_{\frac{1}{2}} = \frac{In\, 2}{\lambda} = \frac{0.693}{\lambda}$$

$$4.5 * 10^9 = \frac{0.693}{\lambda}$$

$$\lambda = 1.54 * 10^{-10} \text{ yr}^{-1}$$

II . To calculate half-life

$$T_{\frac{1}{2}} = \frac{In\, 2}{\lambda} = \frac{0.693}{\lambda}$$

$$T_{\frac{1}{2}} = \frac{0.693}{3.2*10^{-5}} = 21656.25 \text{ s}$$

- Activity: It is the number of *decays per second*, or *decay rate(R)*, represents the magnitude of the decay process.

$$A = \frac{|\Delta N|}{|\Delta t|} = A_{\circ} e^{-\lambda t} = \lambda N$$

  - ✓ A = activity at time t
  - ✓ $A_{\circ}$ = initial activity t = 0

- The unit of activity is the number of disintegrations per second, often measured in curies, Ci

1Ci = 3.70*10^10 disintegrations per second

- The SI unit for source activity is the Becquerel (Bq):

1 Bq = 1 disintegration/s

➢ ***Mean life***: is *average life time* of all the radioactive nuclei of a given radioactive element.

$$\tau = \frac{1}{\lambda} = \frac{T_{\frac{1}{2}}}{In2}$$

❖ Section (30.9): Calculations Involving Decay Rates and Half-life

- ✓ ***Example:*** The isotope $^{14}_{6}C$ has a half-life of 5730yr. If a sample contains $1.00*10^{22}$ carbon-14 nuclei ,What is the activity of the sample ?
- ✓ ***Solution:***

$$T_{\frac{1}{2}} = \frac{0.693}{\lambda}$$

$$\lambda = \frac{0.693}{T_{\frac{1}{2}}} = \frac{0.693}{(5730yr)\left(3.156*10^{7}\frac{s}{yr}\right)}$$

λ = $3.83*10^{-12}$ s^{-1}

$$A = \frac{|\Delta N|}{|\Delta t|} = \lambda N$$

A = $(3.83*10^{-12})$ $(1*10^{22})$

A = $3.83*10^{10}$ Bq

- ✓ ***Example:*** The activity of a sample drops by a factor of 6.0 in 9.4 minutes. What is its half-life?
- ✓ ***Solution:***

$$A = A_{\circ} e^{-\lambda t}$$

$$\frac{\cancel{A_{\circ}}}{6} = \cancel{A_{\circ}} e^{-\lambda(9.4\text{ min})}$$

In $\left(\frac{1}{6}\right)$ = - $\lambda(9.4 * 60)$

-In6 = - $\frac{In2}{T_{\frac{1}{2}}}$ (564)

$$T_{\frac{1}{2}} = \frac{(564)In2}{In6}$$

$T_{\frac{1}{2}}$ = 218.18 s

✓ ***Example:*** A laboratory has 1.49 µg of pure ${}^{13}_{7}N$, which has a half-life of 10 min

I. How many nuclei are present initially?

II. What is the rate of decay (activity) initially?

III. What is the activity after 1h?

IV. After approximately how long will the activity drop to less than one pre second (=$1s^{-1}$)?

✓ ***Solution:***

I. The atomic mass is 13.0, so 13.0 g will contain $6.02*10^{23}$ nuclei (Avogadro's number).
We have only $1.49*10^{-6}$g, so the number of nuclei N_0 that we have initially is given by the ratio

13 grams of ${}^{13}_{7}N$ ⟶ 1 mole

$1.49 * 10^{-6}$ grams of ${}^{13}_{7}N$ ⟶ X mole

$X = \frac{1.49*10^{-6}\cancel{grams}*1mole}{13\cancel{grams}} = 1.146 *10^{-7}$ mole

Number of nuclei of ${}^{13}_{7}N$ is $N = X*N_A$ ($N_A = 6.02 *10^{23}$)

$N = 6.89 *10^{16}$ nuclei

II. $A = A_\circ e^{-\lambda t}$

$A = \lambda N_0\, e^{-\lambda t}$

$A_0 = \lambda N_0$

$\lambda = \frac{In2}{T_{\frac{1}{2}}}$ ($T_{\frac{1}{2}} = 10*60 = 600$ s)

$\lambda = 1.155*10^{-3}\ s^{-1}$

$A_0 = \lambda N_0$

$A_0 = 1.155*10^{-3} * 6.9*10^{16}$

$A_0 = 7.969*10^{13}$ Bq

III. $A = A_\circ e^{-\lambda t}$

$A = 7.97*10^{13}\, e^{-\lambda t}$

$\lambda t = \frac{In2}{T_{\frac{1}{2}}} * t$

$\lambda t = \frac{In2}{10\ \cancel{min}} * 60\cancel{min}$

$\lambda t = 6$ In2

$A = 7.97*10^{13}\, e^{-6In2}$

$A = 1.25 *10^{12}$ Bq

IV. $A = A_\circ e^{-\lambda t}$

$1 = 7.97*10^{13}\, e^{-\frac{In2}{600}t}$

$In(\frac{1}{7.97*10^{13}}) = \frac{-In2}{600}\, t$

$t = 2.7707*10^{4}$ s

Chapter -31-
(Nuclear Energy; Effects and Uses of Radiation) .

❖ Section (31.5): Measurement of Radiation - Dosimetry

- Another important measurement is the ***absorbed dose***, which reflects the effect radiation has on the material that absorbs it. Dosimetry is used to quantify the amount or dose of radiation received.

$$\textbf{Dose} = \frac{energy}{mass}$$

- The definition of exposure is limited to specific radiation types, such as X-rays and gamma (γ) radiation, and applies to situations where energy is deposited in air. Exposure is measured in units of Roentgen (R), with 1 R equal to 0.878×10^{-2} joules of energy per kilogram of air.
- ***The Roentgen*** has largely been replaced by the rad, a unit of absorbed dose that applies to any type of radiation.
  - ➢ One rad is equivalent to 1.0×10^{-2} joules per kilogram (J/kg).
  - ➢ The SI unit for absorbed dose is the gray (Gy), where **1 Gy equals 1 J/kg**, which is also **equal to 100 rad**.

TABLE 31–1 Relative Biological Effectiveness (RBE)

Type	RBE
X- and γ rays	1
β (electrons)	1
Protons	2
Slow neutrons	5
Fast neutrons	≈10
α particles and heavy ions	≈20

- The effective dose is expressed as the product of the dose in rads and the relative biological effectiveness (RBE), measured in ***rems.***
  - ➢ This unit has been replaced by the SI unit for ***effective dose***, the Sievert (Sv), where **1 Sv equals 100 rem**.
  - ➢ The **formula** for effective dose is as follows:
    - ▪ Effective dose (in **rem**) = **dose (in rad) × RBE**
    - ▪ Effective dose (in **Sv**) = **dose (in Gy) × RBE, where 1 Sv = 100 rem**
  - ➢ RBE, or relative biological effectiveness: is defined as the number of rads of X-rays or gamma radiation that cause the same biological damage as 1 rad of the radiation being measured and it has no units.

- Natural background radiation is approximately 0.3 rem per year. For radiation workers, the maximum allowable exposure is 5 rem in a single year, with an average of less than 2 rem per year over a 5-year period. A short-term exposure of 1000 rem is almost always fatal, while a short-term dose of 400 rem has a 50% fatality rate.

✓ ***Example:*** 350 rads of α-particle radiation is equivalent to how many rads of X-rays in terms of biological damage? (RBE for α-particle = 20 , RBE for X-rays = 1)

✓ ***Solution:***

Equivalent that's mean:

Effective dose for α-particle = Effective dose for X-rays

Dose * RBE = Dose * RBE

3500 = Dose * 1

Dose = 7000 rads

- ***Example:*** How much energy is deposited in the body of a 65-kg adult exposed to a 2.5-Gy dose?
- ***Solution:***

Dose = $\frac{energy}{mass}$

2.5 Gy = $\frac{energy}{65\ kg}$

Energy = 162.5 J (Gy .kg)

- ***Example:*** What whole-body dose is received by a 70-kg laboratory worker exposed to a 40-mCi $^{60}_{27}Co$ source, assuming the person's body has cross-sectional area 1.5 m^2 and is normally about 4.0 m from the source for 4.0 h per day? $^{60}_{27}Co$ emits ɤ rays of energy 1.33 MeV and 1.17 MeV in quick succession. Approximately 50% of the ɤ rays interact in the body and deposit all their energy. (The rest pass through.)
- ***Solution:***

The total ɤ ray energy per decay:
(1.33 + 1.17) MeV = 2.50MeV ,

So the total energy emitted by the source per second is:
(0.040Ci) (3.7*10^{10} decays/Ci.s) (2.50MeV) = 3.70*10^9MeV/s

The proportion of this energy intercepted by the body is its 1.5 m^2 area divided by the area of a sphere of radius 4.0 m

$\frac{1.5m^2}{4\pi r^2} = \frac{1.5m^2}{4\pi(4m)^2} = 7.5 * 10^{-3}$

So the rate energy is deposited in the body (remembering that only 50 % of the ɤ rays interact in the body) is:
E = (0.5) (7.5*10^{-3})(3.7*10^9MeV/s)(1.6*10^{-13}J/MeV) = 2.2 *10^{-6} J/s
1Gy = 1J/kg so
Dose = $\frac{2.2*10^{-6}}{70} = 3.1 * 10^{-8} Gy/s$

In 4 h this amount to a dose of:
(4 h *3600 s/h) (3.1*10^{-8} Gy/s) = 4.5*10^{-4} Gy

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