❖ 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 for two points on the tube

$$\frac{\Delta m_1}{\Delta t} = \frac{\rho_1 \Delta V_1}{\Delta t} = \frac{\rho_1 \; A_1 \; \Delta l_1}{\Delta t} = \rho_1 A_1 v_1$$

$$\frac{\Delta m_2}{\Delta t} = \frac{\rho_2 \Delta V_2}{\Delta t} = \frac{\rho_2 \; A_2 \; \Delta l_2}{\Delta t} = \rho_2 A_2 v_2$$

  - Since no fluids flowing into or out of the tube, the flow rates through the tube must be equal, therefore.

$$\boldsymbol{\rho_1 A_1 v_1 = \rho_2 A_2 v_2}$$ this is the *equation of continuity*

  - And if the fluid is incompressible (ρ doesn't change with pressure), then ($\rho_1 = \rho_2$)
  - And the **equation of continuity becomes**

$$\boldsymbol{A_1 v_1 = A_2 v_2}$$ where ρ 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:***

$\boldsymbol{A_1 v_1 = A_2 \; v_2}$ 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 $v_1\ \cancel{\pi}\, r_{aorta}^2 = v_2\, N\, \cancel{\pi}\, r_{cap}^2$

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

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

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

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

- ✓ ***Example:*** What area must a heating duct have if air moving 3m/s along it can replenish the air every 15 minutes in a room of volume 300 m^3 Assume the air's density remains constant.
- ✓ ***Solution:***

T = 15 min. = 900 s

v_1 = 3m/s

V = 300 m^3

Now

$A_1\, v_1 = A_2\, v_2 \quad \rightarrow \quad A_1\ v_1 = A_2\ \frac{l_2}{t}$ because $v = \frac{l}{t}$

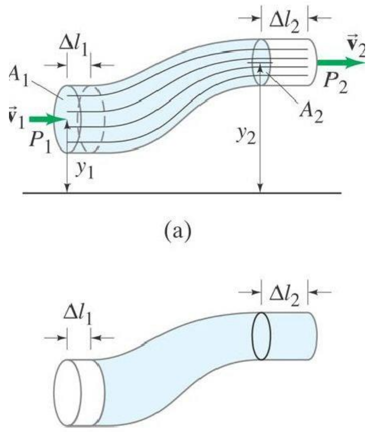
$A_1\, v_1 = \frac{V}{t}$ because $V = A\, l$

$A_1 = \frac{V}{v_1\, t} = \frac{\cancel{300}\ m^{\cancel{3}2}}{(3)\cancel{m/s}\ (\cancel{900})\cancel{s}} = 0.11\ m^2$

❖ 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.***
- The fluid to the left of area A_1 exerts a pressure P_1 on the section of fluid and does an amount of work.

$W_1 = F_1\ \Delta\, l_1 = P_1\, A_1\, \Delta\, l_1$ where $P = \frac{F}{A}$



(a)
(b)

- For A_2, the work done on our section of fluid is

$W_2 = -P_2\, A_2\, \Delta\, l_2$

(Negative sign is present because the force exerted on the fluid is **opposite** to the displacement)

- The work also done on the fluid by the force of gravity

$W_3 = -mg\,(y_2 - y_1)$

- The Network W done on the fluid is

$$W_{net} = W_1 + W_2 + W_3$$

$$= P_1 A_1 \Delta l_1 - P_2 A_2 \Delta l_2 - mg y_2 + mg y_1$$

According to the work – energy. ($W_{net} = \Delta KE$)

$$\frac{1}{2} m v_2^2 - \frac{1}{2} m v_1^2 = P_1 A_1 \Delta l_1 - P_2 A_2 \Delta l_2 - mg y_2 + mg y_1$$

$$\rightarrow \frac{1}{2} \rho A_2 \Delta l_2 v_2^2 - \frac{1}{2} \rho A_1 \Delta l_1 v_1^2 = P_1 A_1 \Delta l_1 - P_2 A_2 \Delta l_2 - \rho A_2 \Delta l_2 y_2 g + \rho A_1 \Delta l_1 y_1 g$$

Where $m = \rho A \Delta l$

Divide through $A_1 \Delta l_1 = A_2 \Delta l_2$

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

Which we rearrange to get

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 = πr^2)

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

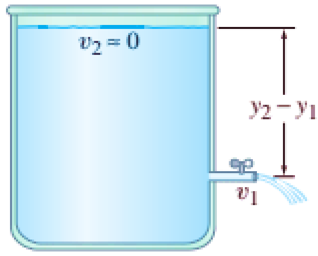
$$v_2 = 1.183\ m/s$$

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:**
  - ➢ To calculate the velocity v_1 of a liquid flowing out of a spigot at the bottom of a reservoir, two points are open to the atmosphere so the pressure at both points is equal to atmospheric pressure $P_1 = P_2$ so the Bernoulli's equation becomes



$$\frac{1}{2}\,\rho\, V_1^2 + \rho\, g\, y_1 = \rho\, g\, y_2$$

Where (V_2 will be almost zero because $A_2 >> A_1$)

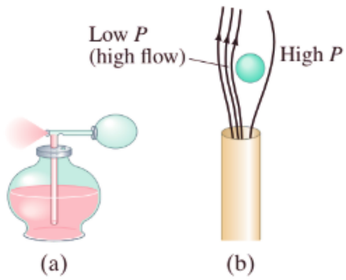
$$V_1 = \sqrt{2\,g\,(y_2 - y\_1)} = \sqrt{2\,g\,h} \qquad \text{(where } h = y_2 - y_1\text{)}$$

  - ▪ 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:***

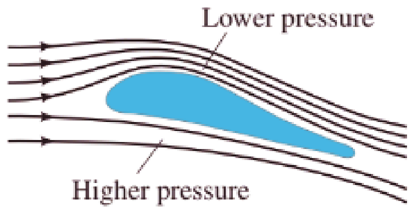
$$V_f = \sqrt{2\,g\,h} = \sqrt{2 * 9.8 * 4} = 8.854\ m/s$$



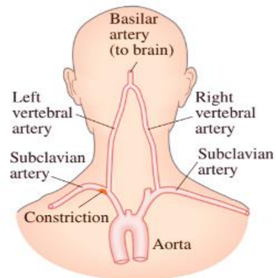
- Examples of **Bernoulli's Principle:**
  - ➢ Atomizer
  - ➢ Ping-pong ball in a jet of air
- These are examples where a special case of Bernoulli's principle arises, specifically when a fluid is flowing horizontally with ***no*** significant ***change in height*** ($y_1 = y_2$).
  - ➢ In such cases, when the velocity is high, the pressure is low, as described by the equation:

$$p_1 + \frac{1}{2}\,\rho\, v_1^2 = p_2 + \frac{1}{2}\,\rho\, v_2^2$$

- This principle is applied in a perfume atomizer. When the pressure (P) **outside** is *lower* than the pressure **inside** the perfume container, the perfume is pushed upwards through the vertical tube and out of the atomizer.
- **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



- **Transient Ischemic Attack (TIA):** It is a ***temporary*** lack of blood supply to the brain. It can cause symptoms such as double vision, headaches, and weakness in the limbs.
  - ➢ **In cases of TIA**, blood pressure in the right subclavian artery may be *higher* than in the left subclavian artery. As a result, instead of blood flowing to the brain, it is diverted to the left subclavian artery, where the pressure is lower.



❖ 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 $\frac{N \cdot s}{m^2}$ = (**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.
  - So it cannot be precisely **accurate** for ***blood*** whose flow is not without turbulence and that contains blood cells (whose diameter is almost equal to that of a capillary).
  - Nevertheless, Poiseuille's equation does give a reasonable first approximation. Because the radius of arteries is ***reduced*** as a result of arteriosclerosis and by cholesterol buildup, the pressure gradient must be increased to maintain the same flow rate.
    - ✓ If the radius is ***reduced*** by half, the heart would have to increase the pressure by a factor of about $2^4 = 16$ in order to maintain the same blood-flow rate.
    - ✓ The heart ***must work much*** harder under these conditions, but usually cannot maintain the original flow rate. Thus, high blood pressure is an indication both that the heart is working harder and that the blood-flow rate is **reduced**

Chapter -23-

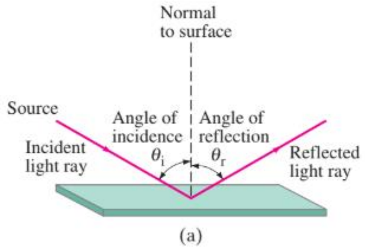
(Light: Geometric Optics)

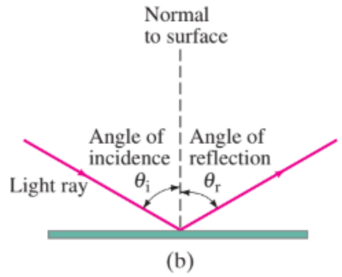
❖ Section (23.1): The Ray Model of light

- *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*10⁸ m/s**) .

❖ Section (23.2): Reflection

- The figure illustrates a beam of light striking a flat surface. In this context:
    - ➢ *The angle of incidence (θ_i)* is defined as the *angle* between the incoming ray (or wave) and the normal (the line perpendicular) to the surface.
    - ➢ *The angle of reflection (θ_r)* is defined as the *angle* between the reflected ray and the normal.





- 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 depending on the medium 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:

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

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

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.

✓ ***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 *10⁸ m/s

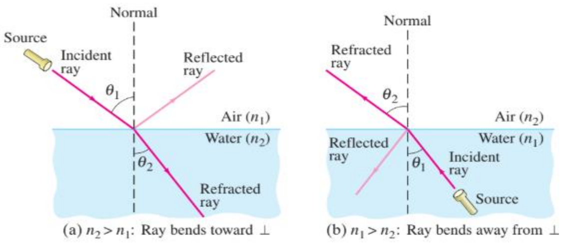
$v = \frac{c}{n} = \frac{3*10^8}{1.33}$ = 2.25 * 10⁸ m/s

$v = \frac{d}{t}$ 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**

- Returning to the direction of propagation, consider light traveling with speed $\boldsymbol{v_1} = \frac{c}{n_1}$ in one medium and with speed $\boldsymbol{v_2} = \frac{c}{n_2}$ in another medium. The **relationship** between the ***directions of propagation*** in these two media is given by ***Snell's law***, which is expressed as:



(a) $n_2 > n_1$: Ray bends toward ⊥ (b) $n_1 > n_2$: Ray bends away from ⊥

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

  - Here, θ_1 represents the angle of incidence, and θ_2 denotes the angle of refraction.
  - If $n_1 < n_2$ Which leads to $\theta_2 < \theta_1$ (refracted light bends to wards normal)
  - If $n_1 > n_2$ Which leads to $\theta_2 > \theta_1$ (refracted light bends away from normal)

✓ ***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 :

$n_1 sin\theta_1 = n_2 sin\theta_2$

$1 \sin(60^\circ) = 1.33\sin\theta_2$

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

$\theta_2 = 40.62^\circ$

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

$n_1 sin\theta_1 = n_2 sin\theta_2$

$1 \sin(60^\circ) = 2.42\sin\theta_2$

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

$\theta_2 = 20.96^\circ$

- *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*.

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

- When light passes from one material into a second material where the ***index of refraction is less*** (say, from water into air), the refracted light ray bends away from the normal, as for rays I and J in figure At a particular incident angle, the angle of refraction will be 90°, and the refracted ray would skim the surface (ray K).
- For case I and J part of the ray is reflected and part is reflected since $n_1 > n_2$ Which leads to refracted light is *bent away* from the normal .

- From Snell's law

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

At $\theta_1 = \theta_c$, and the $\theta_2 = 90^\circ$

Sin $\theta_c = \frac{n_2}{n_1}$

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

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 $\theta \leq 1$

For $\theta_1 > \theta_c$ 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

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

$\theta_c = 37.30^\circ$

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

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

$\theta_c = 53.71^\circ$

- *Fiber Optics; Medical Instruments:*

Total internal reflection is the principle behind fiber optics. Glass and plastic fibers as thin as a few micrometers in diameter are commonly used. A bundle of such slender transparent fibers is called a light pipe or fiber-optic cable.

Fiber- optic cables are use in :

I. communication :

This allows for extremely fast and high-capacity data transmission. Optical fibers can accommodate over 100 distinct wavelengths, with each one capable of carrying more than 10 gigabits of data per second.

II. medicine :

The ability of optical fibers to transmit light along curved paths has been effectively utilized in various medical fields. Notably, devices called endoscopes enable physicians to examine the inside of the body by guiding a flexible tube containing optical fibers into the area of interest. For instance, a type of endoscope known as a bronchoscope can be inserted through the nose or throat, navigated through the bronchial tubes, and eventually positioned in the lungs. Once there, the bronchoscope delivers light via one set of fibers and transmits an image back to the physician through another set. In some cases**, the bronchoscope** can even be used to collect small tissue samples for further analysis. Similarly, **the colonoscope** is used to examine the colon, making it a vital tool in the fight against colon cancer.

❖ 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*.

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.*

convex lens

- The P ray—or parallel ray—approaches the lens parallel to its axis. The P ray is bent so that it passes through the focal point of a convex lens .
- The F ray (focal-point ray) is directed through the focal point and then toward the lens. The lens bends this ray so that it travels parallel to the axis, which is essentially the reverse of how a parallel ray (P ray) is handled.

concave lens

- The P ray—or parallel ray— approaches the lens parallel to its axis and, when extended backward, appears to originate from the focal point on the same side of the lens.
- The F ray (focal-point ray) is directed toward the focal point on the opposite side of the lens. However, before reaching that point, the ray passes through the lens and is bent to travel parallel to the axis.

The midpoint ray (M ray) goes through the middle of the lens, which is basically like a thin slab of glass. For ideal lenses, which are infinitely thin, the M ray continues in its original direction with negligible displacement after passing through the lens .

❖ Section (23.8) The Thin Lens Equation

- We will now derive an equation that connects the *image distance* to the *object distance* and *the focal length* of a thin lens. **This thin-lens equation** allows for ***quicker*** and ***more accurate*** determination of *image position* compared to ray tracing. The derivation can be based on Figure, which illustrates the image produced by a convex lens along with the P and M rays used to locate the image. Observe that the P ray forms two similar blue-shaded triangles on the right side of the lens in Figure (a). Since ***these triangles are similar***, it follows that

$$\frac{h_\circ}{f} = \frac{-h_i}{d_i - f}$$

- where *f is the focal length* : is the distance from the lens to the focal point .
- we use $(-h_i)$on the right side of the equation, because$(h_i)$is ***negative*** for an inverted image. Next, the (M) ray forms another pair of similar triangles, shown with pink shading in Figure 5 (b), from which we obtain the following

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

- **Combining** these *two relationships*, 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:

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

- As previously mentioned, the sign of the magnification reveals the orientation of the image, while its magnitude shows how much the image size is enlarged or reduced compared to the object. The thin-lens equation, although originally derived for converging lenses, is applicable to both converging and diverging lenses in all cases if the following sign conventions are used:
- **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 (A) **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 $^{1}_{1}H$ a simple proton, as the nucleus; there are also $^{2}_{1}H$ called deuterium, and $^{3}_{1}H$ 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 :

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

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

I . $^{1}_{1}H$,

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

✓ ***Solution :***

I . for $^{1}_{1}H$

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

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

r = 1.2 *10^{-15} m

so the diameter

d = 2r

d = 2.4 * 10^{-15} m

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

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

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

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 ***10^3 and 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).***

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

❖ Section (30 .3) Radioactivity

- ➢ *Radioactivity* is the spontaneous emission of particles or radiation from the *unstable nucleus* of an atom as it undergoes decay to become more stable. This process occurs naturally in some isotopes, known as radioactive isotopes or radionuclides, and can also be induced artificially.

- ➢ There are three main types of *radioactive decay*:

1. **Alpha Decay (α-decay):** In this type of decay, the nucleus emits an alpha particle, which consists of ***two protons and two neutrons*** (essentially a helium-4 nucleus). This results in a reduction of the atomic number by 2 and the mass number by 4 which could barely penetrate a piece of paper.
2. **Beta Decay (β-decay):** Beta decay occurs when a neutron in the ***nucleus transforms*** into a proton, emitting a beta particle (an electron or positron) and an antineutrino or neutrino. This process **increases or decreases the atomic number by 1** without changing the mass number which could penetrate 3 mm of aluminum.
3. **Gamma Decay (γ-decay):** Gamma decay involves the release ***of energy in the form of gamma rays*** (high-energy photons) from a nucleus that has excess energy. Unlike alpha or beta decay, gamma *decay* ***does not*** *change the atomic or mass numbers* but **brings** the nucleus to a lower energy state which could penetrate several centimeters of lead .

- We now know that ***alpha rays*** are helium nuclei, ***beta rays*** are electrons, and ***gamma rays*** are electromagnetic radiation.

❖ 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 $^{238}_{92}U$:

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

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

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

II . to calculate half-life

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

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

➢ *Activity* 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 :***

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

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

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

-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 ${}^{13}_{7}N$ ⟶ Xmole

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)

λ = $1.155*10^{-3}$ 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 = $7.97*10^{13}\ e^{-\lambda t}$

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

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

λt = 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 (31.4) Passage of Radiation Through Matter; Biological Damage

- *Radiation* includes *alpha*, *beta*, and *gamma rays*; *X-rays*; along with *protons*, *neutrons*, pions, and *other particles*. These are *collectively referred* to as *ionizing radiation* because they ionize the materials they pass through. Although **X-rays** are a form of radiation, they ***are not classified as nuclear radiation***, as they ***do not originate from the nucleus***. Instead, X-rays are emitted during *transitions of electrons* between *atomic energy levels*.
- Both nuclear radiation and X-rays are classified as ***ionizing radiation*** because they ionize atoms by creating free electrons and positive ions as they travel through matter.

➢ ***Biological Damage:***
Radiation primarily **causes damage to biological cells through ionization**. The free electrons and positive ions generated by radiation can disrupt normal cellular functions, such as important chemical reactions. Ionization, which knocks electrons off atoms and molecules, can break molecular bonds and alter molecular structures, leading to interference with the cell's regular activities. Radiation can also damage DNA, and each change to the DNA may affect a gene, altering the molecule it encodes.

❖ 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 (ɣ) 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***.
- 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
350 *20 = 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) = $3.70*10^9$MeV/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) ($7.5*10^{-3}$)($3.7*10^9$MeV/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.

★ ***Question :***In the U.S., yearly deaths from radon exposure (the second leading cause of lung cancer) are estimated to exceed the yearly deaths from drunk driving. The Environmental Protection Agency recommends taking action to reduce the radon concentration in living areas if it exceeds 4 pCi/L of air .In some areas 50% of houses exceed this level from naturally occurring radon in the soil .Estimate I. The number of decay/s in $1m^3$ of air and II. The mass of radon that emits 4.pCi of $^{222}_{86}Rn$ radiation .

- ✓ ***Solution :*** (I . 150 decays/s. II. $2.6*10^{-17}$ g).

❖ Section (31.6) Radiation Therapy

- ➢ *Radiation therapy* is ***a medical treatment*** that uses ionizing radiation to target and destroy cancer cells. It is one of the most common and effective treatments for cancer, often used alone or in combination with other treatments like surgery or chemotherapy.

❖ Section (31.8) Emission Tomography PET and SPECT

- Radioactive tracers can be detected using ***tomographic techniques*** that create a three-dimensional image through multiple scans. This **process** is called *single photon emission computed tomography* (**SPECT**), or simply *single photon emission tomography* (**SPET**). Another important imaging method is *positron emission tomography* (**PET**).

❖ Section (31.9) Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging

- *Nuclear magnetic resonance (NMR)* is a phenomenon which soon after its discovery in 1946 became a powerful research tool in a variety of fields from physics to chemistry and biochemistry. It is also an *important medical imaging technique*.
- *Magnetic Resonance Imaging (MRI)* is *a non-invasive medical imaging technique* used to produce detailed images of the internal structures of the body. It operates by using strong magnetic fields, radio waves, and a computer to generate high-resolution, cross-sectional images of organs, tissues, and other internal body structures.
- How it **Works**:

1. *Magnetic Field: (NMR*) relies on the fact that certain atomic nuclei, such as hydrogen (^1H), behave like tiny magnets due to their spin. When placed in a strong magnetic field, these nuclei align with or against the field.

2. *Radio Frequency (RF) Pulse*: A radio frequency pulse is then applied, causing some of the nuclei to absorb energy and flip their orientation.

3. *Relaxation and Signal Detection*: When the pulse is turned off, the nuclei relax back to their original state, releasing the absorbed energy. This energy is detected as a signal, which can be analyzed to determine the molecular structure.

- It has many **Applications** like *Medicine* :In medical imaging, a version of NMR called *Magnetic Resonance Imaging* (**MRI** is used to produce detailed images of organs and tissues in the body.)

❖ ***Test bank:***

1) A man walks south at a speed of 2.00 m/s for 15.0 minutes. He then turns around and walks north a distance 1000 m in 15.0 minutes. What is the average speed of the man during his entire motion (in m/s)?

A) 3.35 B) 2.11 C) 1.56 D) 3.21 E) 2.82

2)The position of a particle moving along the x axis is given by x(t)=(21m)+(22m/s)t-(6.0m/s2)t2,wheretis in s. What is the average velocity during the time interval t=1.0 s to t=3.0 s?

A) 6.0 B)-8.0 C)16.0 D) -2.0 E) 8.0

3)A rock is thrown downward from an unknown height above the ground with an initial speed of 10m/s. It reaches the ground 3.5s later. The initial height (in m) of the rock above the ground is:

A) 60 B) 95 C) 25 D) 35 E) 0.0

4)A block of mass M= 6.00 kg is in contact with another block of mass m= 4.00 kg on a frictionless surface, as shown in the Figure. The M block is being pushed by a 20.0-N force toward them block. What is the magnitude of the M block on them block?
A) 6.00 N B) 12.0 N C) 4.00 N D) 10.0 E) 8.00 N

5)Two blocks connected by a string are pulled across a horizontal surface by a force applied to one of the blocks ,as shown. The coefficient of kinetic friction between the blocks and the surface is 0.25. If each block has an acceleration of 2.0m/s^2 to the right, what is the magnitude F of the applied force ?

A) 25 B) 18 C) 11 D) 14 E)7.0

6)In the figure the coefficient of kinetic friction between the mass $m_1$and the horizontal surface is μ_k=0.10and m_1= 6.0 kg, m_2= 2.0 kg. The acceleration of the system (in m/s^2) is:

A) 2.45 B)1.72 C) 1.30 D) 3.9 E) 10.25

6)In the figure shown, the coefficient of static friction between the mass M and the vertical wall is μ_k=0.20. Given that M = 2.0 kg, determine the minimum value of the horizontal force F required to keep the mass M stationary.

A)4 B) 20 C) 98 D) 47 E) 0

7)An object moving along the x-axis has an initial velocity v= 1 m/s at t=0.It's velocity two seconds later is -7 m/s. What is the average acceleration (in m/s^2) of the particle between t=0s and t=2s?

A) 2 B) 4 C) 0 D) -2 E) -4

8)A stone is projected vertically upwards from the surface of the ground with an initial speed of 25 m/s. It's average speed (in m/s) over the time interval from its projection to the moment just before hitting the ground is:

A) 7.5 B) 9.8 C) 0 D) 12.5 E) 5.9

9)A car is moving along the positive X-axis at a constant speed of 12 m/s. the driver notices a red traffic light 30m ahead of him. Thus the driver immediately applies the breaks , and the car decelerates uniformly at 3m/s^2. Which of the following statements is correct?

A) The car will stop at a position 7.5m before reaching the traffic light

B) The car will stop at a position 7.5m after the traffic light

C) The car will stop at a position 6.0m before reaching the traffic light

D) The car will stop at a position 6.0m after the traffic light

E) The car will stop exactly at the position of the traffic light

10) A helicopter is ascending vertically upwards at a constant speed of 12m/s. When it is at a height of 40m above the ground it releases a box. The speed (in m/s) of the box just before it hits the ground is:

A) 28.0 B) 30.5 C) 16.7 D) 9.8 E) 36.3

11)Which of the following statements is WRONG?

A) While mass is a scalar quantity, weight is a vector quantity.

B) The action force and the reaction force can never act on the same object.

C) If an object is moving at constant velocity, then the resultant force acting on it is zero.

D) An object can move at constant velocity if only one force acts on it.

E) The acceleration is always along the direction of the resultant force.

12) In the figure the force F = 40N, M = 4kg , θ = 30° and the coefficient of kinetic friction between the ground and the block is μ_k = 0.2, The acceleration of the block is:

A) 4.98 B) 6.81 C) 1.87 D) 9.81 E) 5.73

13) In the figure , M_1 =3kg ,M_2 =5kg and θ=30°. All the surfaces are frictionless . The acceleration (in m/s^2) of mass M_2 is:

A) 0.6 up the incline B) 0.6 down the incline C) 2.5 up the incline D) 2.5 down the incline E) 0

14) In the figure, all surfaces are rough, M_1 =3 kg and M_2 = 1 kg and the coefficient of friction μ_s = 0.5 and μ_k = 0.2 for all surfaces. Find the maximum value of mass m (in kg) such that mass M_2 will move with mass M_1 without sliding. Ignore masses of all strings and the mass of the pulley.

A) 8.4 B) 2.3 C) 4.0 D) 5.6 E) 4.9

15) A 12 kg child is sitting on the back seat of a car that is moving at a constant velocity of 10 m/s along a horizontal road. The driver notices a red traffic light ahead of him and applies the breaks, If the car comes to a stop in 12m, calculate the minimum value of the coefficient of static friction such that the child does not slide. (Assume only the force of friction acts on the child in the horizontal direction).

A) 0.2 B) 0.5 C) 0.4 D) 0.7 E) 0.1

16)A 4 kg object starts moving from the origin with a speed of 2 m/s under the effect of a variable force F_x that acts along the x-axis as shown in the figure. The speed (m/s) of the object at x = 10 m is:

A) 9.8 B) 6.8 C) 1.1 D) 10.0 E) 7.2

17) You run a race with a friend. At first your kinetic energy is the same as his kinetic energy, but he is running faster than you are. When you increase your speed by 20 percent, you are running at the same speed he is. If your mass is 85 kg what is his mass (in kg)?

A) 71 B) 59 C)78 D) 89 E) 67

18)The three blocks (A , B and C) shown below do rest on the table . The weight for block A is 1 N , the weight of block B is 2 N , and the weight of block C is 5 N . The magnitude of force (in N) exerted by block C on block B is :

A)2 B)0 C)8 D)3 E)6

19)Three masses (M, 15 kg and 10 kg) are connected by massless wires over a massless frictionless pulley as shown in the figure. If the tension in wire B connecting the 10.0 kg and 15.0 kg masses is 133 N, find the tension in wire A:

A)450 B) 333 C)400 D)517 E)350

20)Two masses M_1 and M_2 are moving on an inclined plane. A force F parallel to the incline is pushing M_2 up as shown in the figure. The surface of the inclined plane is frictionless and the angle θ =30 degrees. M_1=3 kg, M_2 =2 kg, and F= 40 N. Find the magnitude of the force exerted on $M_1$by M_2.

A)15 B) 24 C) 36 D) 18 E)30

21)Two masses A (5-kg) and B (10-kg) start sliding down a 20° inclined plane from rest a distance d = 6.6 m along the incline .The coefficient of kinetic friction between each block and the incline is 0.20. How long does it take mass A to reach the bottom?

A)1.51 B)3.59 C) 2.96 D)4.07 E)8.08

22) As shown the force F is pushing horizontally on the wedge m which is placed on the inclined surface, the coefficient of kinetic friction between the wedge and the incline is 0.16. Knowing that F = 300 N , m= 34-kg ,and theta=20. The magnitude of the wedge's acceleration (in m/s2) along the incline is:

A)1.9 B) 3 C) 14.3 D) 2.2 E) 0.9

23)Two masses M and 2M are connected by a string that passes over a very light frictionless pulley. Mass M slides on a 40 degrees inclined plane, while mass2M hangs suspended by the string, as shown in the figure, the coefficient of kinetic friction between the mass M and the incline is 0.2 . Find the magnitude of the acceleration of the suspended mass 2M as it falls:

A)5.4 B) 3.9 C)3.3 D) 3.7 E) 4.1

Answer

: