Lecture

General Physics

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MOTION

Motion

Everything in the universe moves. It might only be a small amount of movement and very very slow, but movement does happen. Don't forget that even if you appear to be standing still, the Earth is moving around the Sun, and the Sun is moving around our galaxy. The movement never stops.

LAWS OF MOTION

Newton's laws of motion in a brief description:

First Law: Any object will continue to remain in its existing state
of motion or rest unless a net external force acts on it.

Second Law: If an object has a certain mass, greater the mass of this object, greater will the force required be to accelerate the object. It is represented by the equation $F = ma$, where 'F' is the force on the object, 'm' is the mass of the object and 'a' is the acceleration of the object.

Third Law: For every action, there is an equal and opposite reaction.

Types of Motion in Physics

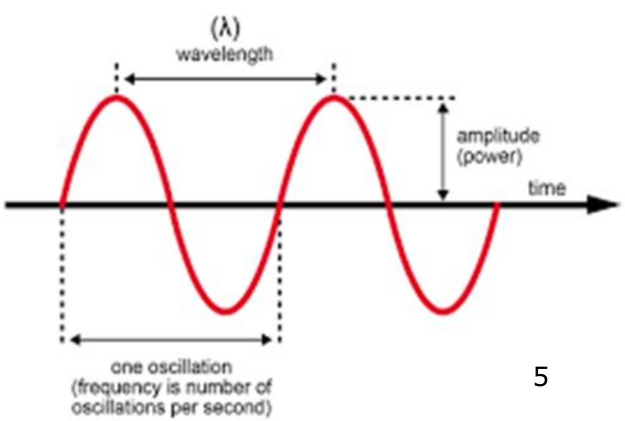
1-Translational Motion – **It is the type, where an object moves along a path in any of the three dimensions *like the motion of a train*.**

2-Random motion- **It is The disordered or irregular motion of a body like the random motion of gas molecules and the motion of insects and birds .**

3-Periodic Motion – **It is the type of motion that repeats itself after certain intervals of time.**

4-Wave Motion

Wave motion is the transfer of energy and momentum from one point of the medium to another point of the medium without actual transport of matter between two points.



5-Circular motion

The motion of an object in a circular path is known as *circular motion*.

Examples of circular motion in daily life

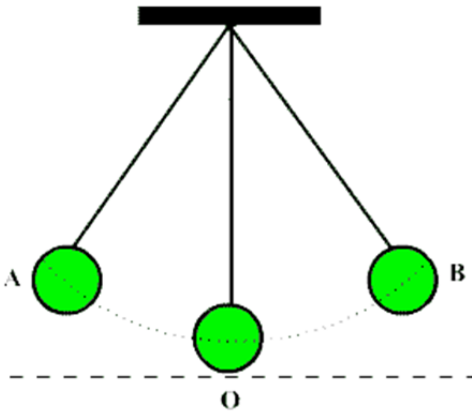
-The motion of the electron around the nucleus

-The motion of toy car on the circular track

-The motion of planets around the sun

6-Vibrational motion

It is the motion of a body about its mean position *like the motion of the pendulum of a clock about its mean position.*



7-Harmonic motion

Any motion that can be described by using Sin or Cos.

<u>Circular Motion</u>

To describe the translational motion, we will talk about:

- ***Position***
- ***Velocity***
- ***Acceleration***

Let us now consider the special case in which the path is a circle; i.e., *<u>circular motion</u>*.

	Linear Motion	Angular Motion
Displacement	L	θ
Velocity	$v=\frac{dl}{dt}$	Velocity
Acceleration	$a=\frac{dv}{dt}$	Acceleration

Angular velocity:

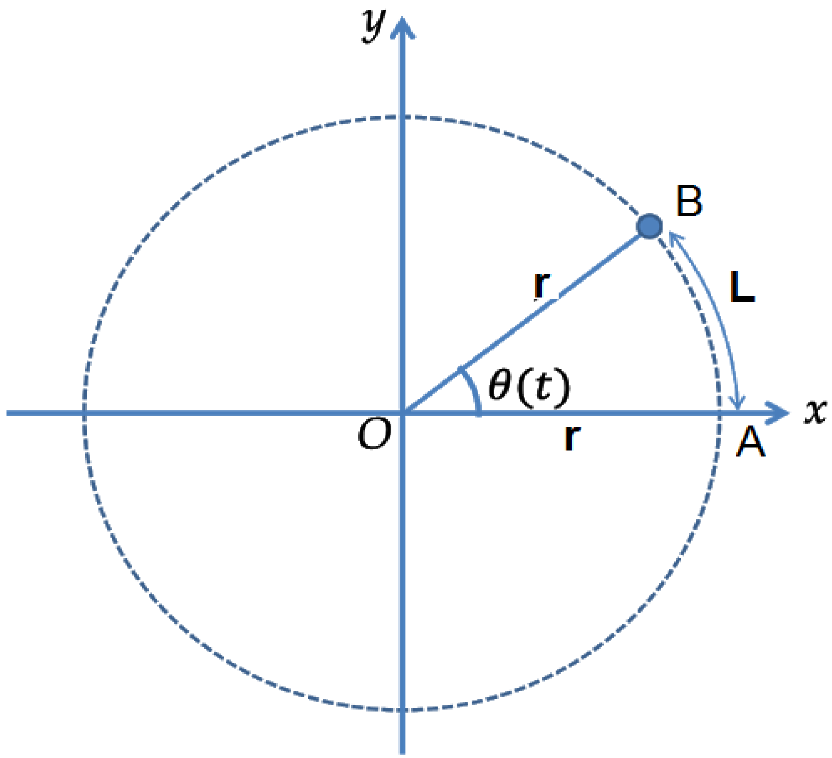
The rate of change of the angle *(degree/sec)* or *(rad/sec)* .

Angular acceleration:

The rate of change of the angular velocity *(degree/sec^2)* or *(rad/sec^2)* .

Circular Motion

The following figure represents an object that is moving in a circular path from A to B with radius r=OB.



When θ is very small:

$\tan\theta = \frac{L}{r} \approx \theta$

$$\begin{cases} L = r\,\theta \\ \frac{dL}{dt} = v = r\,\omega \\ \frac{dv}{dt} = a = r\,\alpha \end{cases}$$

The centrifugal acceleration is:

$$\rightarrow a = \frac{v^2}{r} = \frac{r^2\omega^2}{r} = \omega^2\, r$$

The angular velocity may be expressed as a vector quantity

$$\vec{v} = \vec{\omega} \times \vec{r}$$

The case of uniform circular motion is of special interest; i.e., motion with ω= constant. In this case, the motion is periodic, and the particle passes through each point of the circle at regular intervals of time.

The period T is the time required for a complete turn or revolution,

and the frequency F is the number of revolutions per unit time.

So, if the particle makes **n** revolutions, the *period* is **T =** $\frac{t}{n}$

and the *frequency* is F = $\frac{n}{t}$.

Both quantities are then related by the following expression, which we shall often use.

For the angular velocity (ω):

If ω is constant, we shall integrate the equation:

$$\omega = \frac{d\theta}{dt} \quad \text{or} \quad d\theta = \omega\, dt$$

$$\int_{\theta_o}^{\theta} d\theta = \int_{t_o}^{t} \omega dt = \omega \int_{t_o}^{t} dt$$

$$\theta - \theta_\circ = \omega\,(t - t_\circ)$$

In the initial state (beginning of motion): $\theta_\circ = 0$ & $t_\circ = 0$

$$\boxed{\theta = \omega t}$$

For a complete revolution, t = T and $\omega = 2\pi$, resulting in

$$\boxed{\omega = \frac{2\pi}{T} = 2\Pi F}$$

For the angular acceleration (α):

$$\alpha = \frac{d\omega}{dt} \qquad \text{or} \qquad d\omega = \alpha \, dt$$

By integrating both sides:

$$\int_{\omega_0}^{\omega} d\omega = \int_{t_o}^{t} \alpha dt = \alpha \int_{t_0}^{t} dt$$

$$\Rightarrow \quad \omega = \omega_0 + \alpha(t - t_0),$$

Where $\omega_\circ$ is the value of ω at time t=0.

Also we have $\omega = \frac{d\theta}{dt}$

$$d\theta = \omega_\circ \, dt + \alpha \, (t - t_\circ)$$

By integrating both sides, we find

$$\int_{\theta_0}^{\theta} d\theta = \int_{t_0}^{t} \omega_0 dt + \alpha \int_{t_0}^{t} (t - t_0) dt,$$

$$\theta - \theta_\circ = \omega_\circ\,(t - t_\circ) + \frac{(t - t_\circ)^2}{2}\,\alpha$$

$$\theta = \theta_0 + \omega_0\,(t - t_0) + \tfrac{1}{2}\,\alpha\,(t - t_0)^2$$

This gives the angular position at any time.

$\theta_\circ$ At $t_\circ$ where t=0 & where θ

$$\boxed{\theta = \omega_\circ\, t^2\ t + \frac{\alpha}{2}}$$

We have explained *position*, *angular velocity* and *angular acceleration* so, ***angular motion*** has been described.

EXERCISES

Q1 : If it takes a bike wheel *3 seconds* to complete *one revolution*, what is the wheel's angular velocity?

Sol.

The definition of angular velocity is

$$\omega = \frac{\theta}{t}$$

$$\omega = \frac{2\pi}{3} = 2.09 \, rad/sec$$

Q2 : A disk spins at a rate of *5000 radians* every *10 minutes*.

a)What is the angular velocity of the disk in *rad/sec*?

b)What is the linear velocity of the disk in (*m/s*) if the *diameter* of the disk is *20 cm*?

Sol.

$$\omega = \frac{d\theta}{dt} = \frac{5000}{10 \times 60} = 8.33\,\frac{rad}{sec}$$

d=20 cm

r=10 cm=0.1 m

$$\upsilon = \omega r$$

υ=8.33×0.1=0833 m/s

Q3 : The *frequency* of a spinning wheel is *30 Hz*.
a) If the *diameter* of the wheel is *50 cm*, what is the angular speed of the wheel in radians per second?
b) What is the periodic time?

Sol.

$$\omega = 2\pi f$$

$$\omega = 2\pi \times 30 = 60\pi \text{ rad/sec}$$

$$T = \frac{1}{f} = \frac{1}{30} = 0.033\ sec$$

Q4 : A disk speeds up from rest at a constant rate of *2.5 rad/sec²*.

a)What is the *final* angular speed of the disk *after 18 sec*?

b)What is the linear speed of a point *at the edge of the disk after 18 sec*.

(The radius of the disk is 50 cm)

Sol.

$$\alpha=2.5\ rad/s^2\ ,\ t=18\ sec\ ,\ r=50\ cm=0.5\ m$$

$$\omega_f=\omega_i+\alpha t$$

$$=0+2.5\times 18$$

$$=45\ rad/sec$$

$$\upsilon=\omega r=45\times 0.5=22.5\ m/s$$

THANKS