AL MUSTAQBAL UNIVERSITY

ENGINEERING TECHNICAL COLLEGE

DEPARTMENT OF BUILDING & CONSTRUCTION ENGINEERING TECHNOLOGIES

ENGINEERING PHYSICS

FIRST CLASS

LECTURE NO. 5

ASST. LECTURER

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Linear Motion

In physics, motion can be defined and calculated using a few variables that all bodies in motion have or can have: velocity, acceleration, displacement, and time. Velocity is the same as speed but depends on the direction a body is traveling, and the same can be said for displacement in terms of distance. Acceleration is the same as velocity but describes how much of a change in speed occurs over some time, instead of how much of a change in distance.

Motion can be one-dimensional, two-dimensional, or three-dimensional.

Linear Motion

is a change in position from one point to another in a **straight line in one dimension.** Driving a car along a straight highway is an example of motion in one dimension.

Displacement

An object can only move in two directions in a straight line, namely forwards or backwards in our case. If we change the position of an object in a particular direction, we are causing a **displacement**.

To calculate displacement, we use the following equation,

$$\Delta x = \Delta x_f - \Delta x_i$$

Where

$\Delta x = is\ the\ displacement$

$\Delta x_f = is\ the\ final\ position$

$\Delta x_i = is\ the\ initial\ position$

Velocity: is a change in displacement over time.

Average velocity

The **average velocity** of a moving body is its total displacement divided by the total time needed to travel from the initial point to the final point.

To calculate average velocity, we use the following equation,

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

Where

$v = velocity$

$\Delta x = is\ the\ change\ in\ position$

$\Delta t = is\ the\ change\ in\ time$

$t_1\ \ is\ the\ time\ at\ which\ the\ object\ was\ at\ position\ x_1$

$t_2\ \ is\ the\ time\ at\ which\ the\ object\ was\ at\ position\ x_2$

The magnitude of the average velocity is called an average speed.

Instantaneous velocity

It is defined by letting the length of the time interval $\Delta \boldsymbol{t}$ tend to zero, that is, the velocity is the time derivative of the displacement as a function of time.

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

$$v = \frac{dx}{dt}$$

If the **acceleration is constant**, we can use one of the **kinematics equations** (equations of motion) **to find the instantaneous velocity**. Have a look at the equation below.

$$v = u + at$$

In the above equation,

$u = is\ the\ initial\ velocity$

$v = is\ the\ instantaneous\ velocity$ *at any instant of time **t** provided the acceleration remains constant for the whole duration of motion.*

Acceleration

Acceleration is the **rate of change of velocity**.

To calculate acceleration, we use the following equation,

$$a = \frac{\Delta v}{\Delta t}$$

If a_{avg} is the average acceleration and $\Delta v = v_2 - v_1$ is the change in velocity over the time interval Δt then mathematically,

$$a_{avg} = \frac{v_2 - v_1}{t_2 - t_1}$$

Instantaneous acceleration

A **change in velocity at any point in time is instantaneous acceleration**. The calculation for instantaneous acceleration is similar to instantaneous velocity.

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}$$

$$a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

Example1: The velocity of a moving particle is given by $v(t) = 20t - 5t^2 m/s$ Calculate the instantaneous acceleration at t = 1, 2, 3, and 5s.

Solution:

$$v(t) = 20t - 5t^2$$

$$\frac{dv(t)}{dt} = a = 20 - 10t$$

$$a = 20 - 10(1) = 10ms^{-2}$$

$$a = 20 - 10(2) = 0ms^{-2}$$

$$a = 20 - 10(3) = -10ms^{-2}$$

$$a = 20 - 10(5) = -30ms^{-2}$$

Linear motion equations

In case of constant acceleration, the four physical quantities acceleration, velocity, time and displacement can be related by using the equations of motion.

$$\boldsymbol{x = v_{avg} t}$$

$$\boldsymbol{v_{avg} = \frac{v_f + v_i}{t}}$$

$$\boldsymbol{a = \frac{v_f - v_i}{t}}$$

$$\boldsymbol{v_f^2 = v_i^2 + 2ax}$$

$$\boldsymbol{x = v_i t + \frac{1}{2} a t^2}$$

Example2: A body begins to move from rest with a constant acceleration of 8 m/s² in a straight line. Find:

(a) The speed after five seconds

(b) The average speed during the five-second period

(c) The distance traveled in five seconds

Solution:

(a)

$$a = \frac{v_f - v_i}{t}$$

$$8 = \frac{v_f - 0}{5}$$

$$v_f = 40 m/s$$

(b)

$$v_{avg} = \frac{v_f + v_i}{2}$$

$$v_{avg} = \frac{0 + 40}{2} = 20 m/s$$

(c)

$$x = v_{avg} t$$

$$x = 20 \times 5 = 100 m$$

Example3: The velocity of a truck increases regularly from 15 km/h to 60 km/h within 20 s. Calculate:

(a) Average velocity

(b) Acceleration

(c) Distance traveled. Use units of meters and seconds

Solution:

(a)

$$v_{ix} = \left(15\frac{km}{h}\right)\left(1000\frac{m}{km}\right)\left(\frac{1}{3600}\frac{h}{s}\right) = 4.17m/s$$

$$v_{fx} = 60km/h = 16.7m/s$$

$$v_{avg} = \frac{v_{ix} + v_{fx}}{2} = \frac{4.17 + 16.7}{2} = 10.4\ m/s$$

(b)

$$a = \frac{v_{fx} - v_{ix}}{t} = \frac{16.7 - 4.17}{20} = 0.63\ m/s^2$$

(c)

$$x = v_{avg}t = 10.4 \times 20 = 208m$$

H.W: A ball falls from rest at a height of 50 m above the ground.

(a) What is its velocity before it hits the ground directly?

(b) How long time it take to reach the ground?