Defintion and Graphs of Motion, Vectors & Projectile Motion

See online here

Motion is defined as the act of changing location or position. Three types of motion exist: translational, oscillatory and rotational. Translational motions occur when a change in location takes place. Oscillatory motion is a motion that takes place without changing location. An example of such motion is the vibration of strings on a musical instrument. The rotational motion deals with the spinning of objects.

Definition of Motion

Uniform Linear Motion

Uniform linear motion is a motion that occurs at a constant speed in one direction. It means that an object covers equal displacements in equal intervals of time. In this case, acceleration is zero. This type of motion can be described in the following terms:

$$v = \frac{s}{\Delta t} = const.$$

v ⇒ velocity [m/s]
s ⇒ displacement [m]
t ⇒ time [s]

Motion with Uniform Acceleration

This type of motion can be characterized by the changing velocity. The object is moving faster or slower, which means that acceleration does not equal zero and remains constant. Motion with uniform acceleration can be described by **three equations**:

Displacement-Time

$$s = 0{,}5 * a * t^2 + v_0 * t * s_0$$

Velocity-Time

$$s = a * t * v_0$$

a ⇒ acceleration [m/s^2]

Free Fall

Freefall is the motion of an object where the force of gravity is the only force acting upon it. The force of gravity is a constant parameter with an acceleration a = g = 9.81 m/s, thus free fall refers to motion with uniform acceleration. With air friction and lift neglected, the following equations remain:

$$v(h) = \sqrt{2 * g * h}$$
$$v(t) = g * t$$
$$s(t) = \frac{1}{2} g * t^2$$
$$t(h) = \sqrt{\frac{2 * h}{g}}$$

g = 9.81 m/s

h ⇒ height

Uniform Circular Motion

In this type of motion, an object is moving along a circular path. Since the velocity is a vector, its constantly changing directions balance each other out. Thus, uniform circular motion is defined by the constant sum of velocity. Or to put it simply, if you are driving a car in a circle with the speed of 50 km/h, your acceleration is constant, yet your direction constantly changes.

$$\phi = \frac{1}{2}\alpha * t^2 = \frac{s}{r} = \frac{\omega * t}{2}$$
$$\omega = \frac{v}{r} = \alpha * t = \frac{\pi * n}{30}$$
$$\alpha = \frac{a}{r} = \frac{\omega}{t} = const.$$

ω ⇒ angular velocity [1/s]
α ⇒ angular acceleration [$1/s^2$]
n ⇒ rotational speed [1/s]
r ⇒ radius
π ⇒ Pi (approximated as 3.14)

Periodic Motion

Periodic motion refers to changes of a system or a physical variable based on a fixed position that is repeated approximately or exactly in equal intervals of time. It can be described in the following variables:

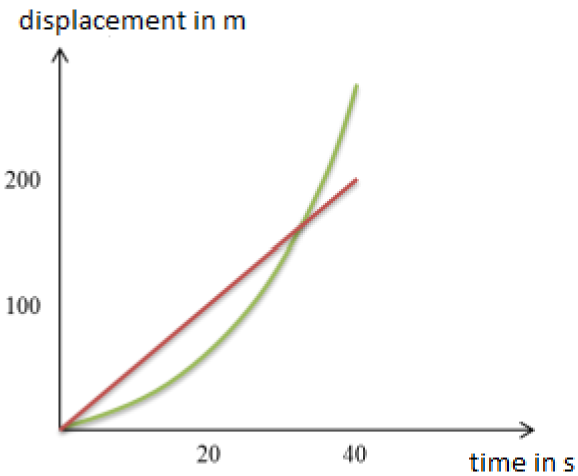
$$T = \frac{1}{f}$$
$$\omega = 2 * \pi * f$$

T ⇒ period, measured in seconds [s]
f ⇒ frequency, measured in hertz [Hz]
ω ⇒ angular velocity [1/s]

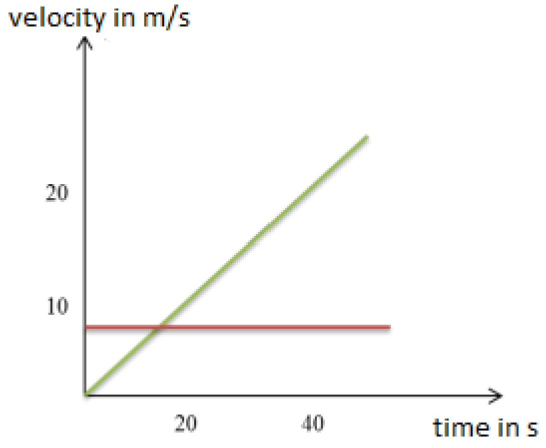
Graphs of Motion

The types of motion described above can be represented in the following graphs. Uniform linear motion is displayed in red and motion with uniform acceleration is displayed in green.

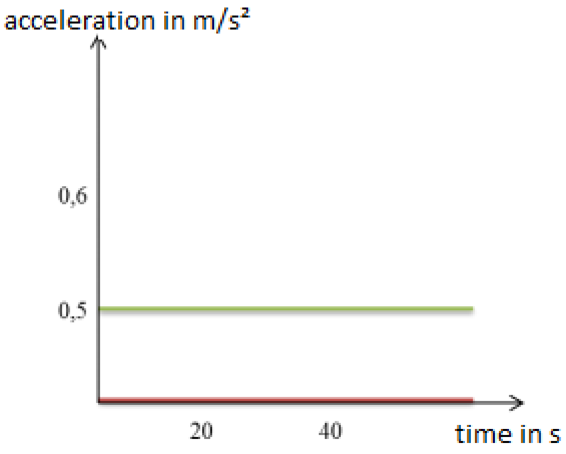
Displacement-time graph



Velocity-time graph



Acceleration-time graph



Visualizing Kinematics

Definition

Kinematics is associated with the geometry of motion, and thus, it is a branch of mathematics. It begins with a description of the geometry of the system with the initial conditions of known values. These values depict the position, the velocity and/or the acceleration of various points that are part of the system. This helps describe the motion of points, bodies and a group of bodies without taking into account the masses of the objects nor the forces that caused the motion.

Visualization Aspect

Kinematics can be displayed using two-dimensional graphs. The plots would help understand the motion of the object with respect to time. Usually, three graphs are utilized: position graph, velocity graph, and acceleration graph.

The position graph displays the location of the object as time passes.
The velocity graph displays the speed of the object as time passes.

The acceleration graph displays how fast the object is moving as time passes.

The graph is two-dimensional, so it contains an x-axis and a y-axis. The x-axis represents time in seconds. The y-axis can represent any of the three items above position (also called displacement), velocity and acceleration.

Vectors

Definition

A vector is a quantity possessing both a magnitude and a direction. This is different from a scalar quantity which has just magnitude without a direction. For instance, if one checks the temperature, the result is a scalar quantity since temperature does not have direction. However, if one is measuring the wind, it is completely different. The wind has a magnitude and direction since 30 mph from the west implies that the magnitude is 30 mph, and the direction is from the west.

Projectile Motion

Projectile motion is a form of motion in which an object (referred to as the projectile) is thrown near the Earth’s surface moving along a curved path under the action of gravity only. In this case, air resistance is treated as being negligible. The path the object takes is parabolic with the only force acting on it being gravity (acceleration) which was stated before as =9.8 m/sec^2.

Components of Projectile Motion

The components in the x-axis and y-axis are calculated differently.

In the horizontal axis (x-axis), acceleration is 0 since no wind nor air resistance is present. The velocity in the horizontal axis will equal the initial velocity in the horizontal axis. The distance traveled in the horizontal axis (displacement) can also be determined based on the time traveled. The following equations can be used.

$$\mathbf{a_x = 0}$$

(a_x = acceleration in x-direction)

$$\mathbf{v_x = v_{0x}}$$

(v_x = velocity in x-direction, v_{0x} = original velocity in x-direction)

$$\mathbf{x = x + v_{0x}\ t}$$

(x = displacement in x-direction, x = initial position, t = time)

In the vertical axis (y-axis), acceleration is equal to gravity. The velocity and displacement equations will be different since acceleration will affect the object in the vertical axis.

$$\mathbf{a_y = -g}$$

(a_y = acceleration in y-direction = -g)

$$\mathbf{v_y = v_{oy} - gt}$$

(v_y = velocity in y-direction, v_{oy} = original velocity in y-direction, t = time)

$$y = y_o + v_{oy}t - ½ gt^2$$

(y = displacement in y-direction, y = initial position)

List of Parameters

t (or t)	Time [s]
v (or v)	Velocity [m/s]
s (or s)	Displacement [m]
a	Acceleration [m/s^2]
$g = 9{,}81\ m/s^2$	Acceleration of gravity [m/s^2]
h	Height (or falling height)
α	Angular acceleration
s	Arc length (= displacement) [m]
r	Radius [m]
n	Rotational speed [1/s]
v	Velocity [m/s]
T	Period, measured in seconds [s]
f	Frequency, measured in hertz [Hz]
ω	Angular velocity (the frequency of circular motion per second) [1/s]
Φ	An exceeded angle
p	Momentum [kg * m/s], [N * s]
m	Mass [kg]
F	Force [N], [kg * m/s^2]
I →	Impulse [kg * m/s]
F_{av}	Average (or, net) force [N], [kg * m/s2]
M_s	Center of mass, no unit
M	Torque [N * m]
J	Moment of inertia [kg * m^2]
r	Axis of rotation
ρ	Mass distribution
L	Angular momentum [(kg * m^2)/s]
p	Angular momentum of point-mass [(kg * m)/s]
W	Work (J), [N * m]
E	Energy [J], [N * m]
P	Power [W], [J/s]
Δp	Collision [(kg * m)/s]
ρ	Pressure [Pa], [N/m^2]
A	Area of a surface [m^2]
V	Volume [m^3], [l]

Notes