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# BTU 1113 Physics

## Chapter 2: Kinematics

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# Chapter Description

- Aims
  - Distinguish the concepts of vectors and scalar quantities and identify components of a vector and unit vectors.
  - Solve the problems regarding the displacement, position, velocity, speed and acceleration
  - Differentiate instantaneous velocity and speed.
  - Illustrate and solve example of free falling objects.

- Expected Outcomes
  - Students should be able to distinguish the concepts of vectors and scalar quantities and identify components of a vector and unit vectors.
  - Students should be able to solve the problems regarding the displacement, position, velocity, speed and acceleration
  - Students should be able to differentiate instantaneous velocity and speed.
  - Students should be able to illustrate and solve example of free falling objects.

- Other related Information
  - Mechanics is deal with the motion of object and has been categorized into two parts; kinematics and dynamics.

- References

  - Giancoli, D.C., 2008. Physics for Scientists & Engineers. 4th edition. Prentice Hall, USA.
  - Jones, E., 2002. Contemporary College Physics. 3rd Ed, McGraw-Hill, Singapore.
  - Young, H. D. and Freedman, R. A., 2012. University Physics with Modern Physics. 13th edition, Pearson, San Francisco

1st aim:
Distinguish the concepts of vectors and scalar quantities and identify components of a vector and unit vectors.

# Introduction to mechanics

- Mechanics: the study of the motion of objects and related concepts of force and energy

Kinematics: The description of how object is move.

Dynamics: Deals with force and why objects move as they do.

# Some Physics Quantities

- Vector - quantity with both magnitude (size) and direction
- Scalar - quantity with magnitude only.

- Vectors:
- Displacement
- Velocity
- Acceleration
- Momentum
- Force

Scalars:
Distance
Speed
Time
Mass
Energy

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# 2nd aim:
# Solve the problems regarding the displacement, position, velocity, speed and acceleration.

# Reference Frames and Displacement

We need to make a distinction between distance and displacement.

**Displacement** (blue line) is how far the object is from its starting point, regardless of how it got there.

**Distance traveled** (dashed line) is measured along the actual path.

The **displacement** is written: $\Delta x = x_2 - x_1.$

Left → Displacement is positive; Right → Displacement is negative.

Imagine this example: A person walks 70m east, then 30 m west.

Total distance traveled = 70 m + 30 m =100 m

Displacement = 40 m to the east

# Average Velocity

**Speed** is how far an object travels in a given time interval:

$$\text{average speed} = \frac{\text{distance traveled}}{\text{time elapsed}}.$$

**Velocity** includes directional information:

$$\text{average velocity} = \frac{\text{displacement}}{\text{time elapsed}}.$$

# Acceleration

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

$$\text{average acceleration} = \frac{\text{change of velocity}}{\text{time elapsed}}.$$

# Motion at Constant Acceleration

The average velocity of an object during a time interval *t* is

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x - x_0}{t - t_0} = \frac{x - x_0}{t}.$$

The acceleration, assumed constant, is

$$a = \frac{v - v_0}{t}.$$

In addition, as the velocity is increasing at a constant rate, we know that

$$\bar{v} = \frac{v_0 + v}{2}.$$

Combining these last three equations, we find:

$$x = x_0 + v_0 t + \frac{1}{2} a t^2.$$

# Motion at Constant Acceleration

We can also combine these equations so as to eliminate *t*:

$$v^2 = v_0^2 + 2a(x - x_0).$$

We now have all the equations we need to solve **constant- acceleration** problems.

$$v = v_0 + at$$

$$x = x_0 + v_0 t + \tfrac{1}{2}at^2$$

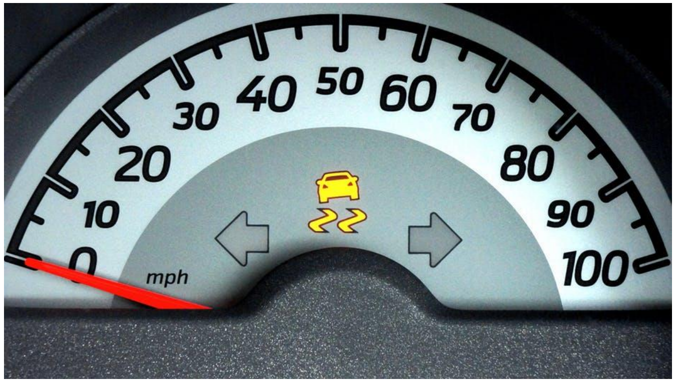
$$v^2 = v_0^2 + 2a(x - x_0)$$

$$\bar{v} = \frac{v + v_0}{2}.$$

3rd aim:
Differentiate instantaneous velocity and speed.

# Instantaneous Velocity

The **instantaneous velocity** is the average velocity in the limit as the time interval becomes infinitesimally short.



Source: https://www.pexels.com

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}.$$

Ideally, a speedometer would measure instantaneous velocity; in fact, it measures average velocity, but over a very short time interval.

# Instantaneous Velocity

The instantaneous speed always equals the magnitude of the instantaneous velocity; it only equals the average velocity if the velocity is constant.

Velocity of a car as a function of time:

(a)at constant velocity;

(a)with varying velocity.

4$^{th}$ aim:
Illustrate and solve example of free falling objects.

# The law of falling bodies

Galileo's law:

Distance $\propto$ (time)$^2$

or $y = ct^2$ .

In *the absence of air resistance*, all objects fall with the same acceleration, although this may be tricky to tell by testing in an environment where there is air resistance.

# The law of falling bodies

The acceleration due to gravity, *g,* at the Earth's surface is approximately **9.80 m/s$^2$**.

At a given location on the Earth and in the absence of air resistance, all objects fall with the same constant acceleration.

# Example: Ball thrown upward

A person throws a ball upward into the air with an initial velocity of 15.0 m/s. Calculate (a) how high it goes, and (b) how long the ball is in the air before it comes back to the hand. Ignore air resistance.

Solution: (a) At the highest position, the speed is zero, so we know the acceleration, the initial and final speeds, and are asked for the distance.

$$v^2 = v_0^2 + 2g\,(y - y_0)$$

$0 = (15)^2 + 2\,(-9.8)y$ gives $y = 11.5$ m.

(b) Use $v = v_0 + at$ to find t, gives $t = 3.06$ s.

Two possible misconceptions based on the example.

(1) that acceleration and velocity are always in the same direction, and (2) that an object thrown upward has zero acceleration at the highest point.

1. If acceleration and velocity were always in the same direction, nothing could ever slow down!

2. At its highest point, the speed of thrown object is zero. If its acceleration were also zero, it would just stay at that point.

# Conclusion of The Chapter

- Conclusion

It is important to know the reference frame in determining the vector quantities such as displacement, velocity, acceleration, momentum and force.

# Reference

Giancoli, D.C., 2008. Physics for Scientists & Engineers. 4th edition. Prentice Hall, USA.