Basic Motion

Distance - a measurement from point A to point B.

Speed - a measurement of how fast you are going between point A and point B.

Time - a measurement of elapsed time in seconds (minutes, hours, days, years, etc...)

Distance and speed are scalar quantities.

**Velocity Equation**

\[ \vec{v} = \frac{\vec{d}}{t} \quad \text{or} \quad \vec{d} = \vec{v} \cdot t \]

\(v=\)speed in meters per second (m/s or km/h)
\(d=\)distance in meters (m)
\(t=\)elapsed time in seconds (s)

**Example #1**

A car is moving at 150 kph. It moves for 2.0 seconds. How far does it go?

\[ \vec{v} = 150 \text{ kph} \quad \text{or} \quad \vec{v} = 150 \frac{\text{km}}{\text{h}} \]

\[ t = 2.0 \text{ s} \]

\[ \text{How far?} \]

1. \[ (150 \frac{\text{km}}{\text{h}}) \left( \frac{1000 \text{ m}}{1 \text{ km}} \right) \left( \frac{1 \text{ hr}}{3600 \text{ s}} \right) = 41.7 \text{ m/s} \]

2. \[ \vec{d} = \vec{v} \cdot t \quad \text{or} \quad \vec{d} = (41.7 \text{ m/s})(2.0 \text{ s}) = 83.4 \text{ m} \]

Displacement - a measurement from point A to point B where direction matters.

**Velocity** - a measurement of how fast you are going between point A and point B where direction matters.

**Time** - a measurement of elapsed time in seconds (minutes, hours, days, years, etc...)

Displacement and velocity are vector quantities.

If you move in a **positive** direction, your velocity must be **positive**. If you move in a **negative** direction, your velocity must be **negative**.
Example #2
State the relative speed in each case

Example #3
How long does it take these trains to completely pass each other?

solution: since both trains are moving, this seems like a difficult task. The longer train will catch up and then pass the shorter train, but we do not know how far both of them will travel during this time.

\[
\text{relative speed} = 13 \text{ m/s} - 5 \text{ m/s} = 8 \text{ m/s} \\
\text{distance} = 150 \text{ m} + 100 \text{ m} = 250 \text{ m} \\
\frac{d}{v} = \frac{250 \text{ m}}{8 \text{ m/s}} = 31.25 \text{ s} = 31.3 \text{ s}
\]
Example #4
An object moves East for 15.0 minutes at 80.0 kph, then West for 80.0 km at 40.0 kph, then moves East at 60.0 kph for an unknown time: t. If the average velocity for the whole trip is 30.0 kph East, then find
a) the time t
b) the total displacement
c) the total distance
d) the average speed
**Acceleration** \( (\vec{a}) \): The rate at which an object changes its velocity. Measured in m/s\(^2\)

\[
\vec{a} = \Delta \vec{v} / \Delta t
\]

where:
- \( \vec{a} \) = the acceleration of the object in m/s\(^2\)
- \( \Delta v \) = the change in velocity, \( v_f - v_i \)
- \( \Delta t \) = the change in time, \( t_f - t_i \)

Anytime an object’s velocity is changing (whether up or down) it is accelerating. Acceleration is a vector. Since acceleration is a vector quantity, it has a direction associated with it. The direction of the acceleration vector depends on two things:
- whether the object is speeding up or slowing down
- whether the object is moving in the + or - direction

The general principle for determining the acceleration is:

If an object is slowing down, then its acceleration is in the opposite direction of its motion.

**Example #5**

Draw a diagram and state the direction of the velocity (±î or j^) and acceleration in each case

a. an object is moving West and slowing down
b. an object is falling and slowing down
c. an object is moving East and speeding up
d. an object is moving up and slowing down
e. an object moves up, slowing down. It stops and then begins to fall, speeding up

When an object has constant acceleration we can use one of the following equations to describe the motion:

1. \( d = v_{avg}t \)
2. \( d = vt + \frac{1}{2} at^2 \)
3. \( v_f^2 = v_i^2 + 2ad \)
4. \( v_f = v_i + at \)
Example #6
An object starts at rest and travels 12.0 metres over the next 3.00 seconds while accelerating constantly. Find

a. the acceleration of the object
b. the final speed of the object

Example #7
Two cars are at rest, facing each other, and 300. metres apart. If car 1 accelerates at 6.00 m/s² up to maximum speed of 30.0 m/s and car 2 accelerates at 5.00 m/s² up to a maximum speed of 35.0 m/s, how long does it take the cars to meet? (assume they are in different lanes so there is no crash)
Assignment

1. How long does it take for these two trains to completely pass each other?

2. Rocket cars drive over a 1.0 kilometer long course and try to break the sound barrier (330 m/s). How long would it take such a car to travel the length of the track? (3.0 seconds)

3. The Earth travels around the sun in a circle of radius 150. million km and does a complete cycle in about 365 days. Find its speed. (29 800 m/s)

4. A car travels at 20.0 m/s for 12.0 seconds, then 10.0 m/s for 20.0 seconds then 30.0 m/s for 6.00 seconds (all in the same direction)
   a. find the total distance travelled (620. m)
   b. find the average speed of the car (16.3 m/s)

5. A car travels East for 20.0 seconds at 4.00 m/s, then West at 5.00 m/s for 75.0 metres, then East again for 15.0 seconds, covering 60.0 metres.
   a. find the total distance
   b. find the total displacement
   c. find the average speed
   d. find the average velocity

6. An object moves 100. km to the East at 30.0 kph, then moves West for 120.0 minutes. If the average speed for the trip is 35.0 kph, then where does the object end up? (assume it started at position 0.0 metres) (13.3 km East or +î)

7. A car travels 120. km East at 45.0 km/hr, then goes West 50.0 km at 70.0 km/hr, then goes East again for time t at 40.0 km/hr. If the average velocity for the entire trip is 30.0 km/hr East, find the time t (3.14 hrs)

8. What happens to the motion of an object if
   a. the object is moving East and the acceleration is West
   b. the object is falling and accelerating upwards
   c. the object is moving up and accelerating up

9. A dolphin accelerates from 1.0 m/s to 7.6 m/s in 5.5 seconds. Find
   a. the acceleration and b. the distance travelled. (1.2 m/s²; 24 m)

10. A car moving at 30.0 m/s to the right slows down (accelerates to the left) at 9.80 m/s². How far does the car go before stopping? (45.9 m)

11. A car travels at 15 m/s and speeds up uniformly. Over the next 5 seconds, it travels 85 m. Find the acceleration (0.8 m/s²)

12. A bungee jumper moving downward at 5 m/s ends up moving upwards at 8 m/s 2.0 seconds later.
   a. find the acceleration (+6.5 m/s² j^)
   b. why is the acceleration not 1.5 m/s² ?

13. A car starts at rest and accelerates in 4 seconds to a speed of 20 m/s, which it maintains for the next 8 seconds. Find the total distance travelled. (200m)
14. A child slides down a playground slide, accelerating from rest and travelling 6.00 metres in 4.50 seconds. When they hit the ground, their legs bend 20.0 cm as the child stops. What is the child's acceleration in stopping? (17.7 m/s^2)

15. How long does it take a 150m long train moving at 120 kph to pass a 100. m long train moving at 100. kph in the a) same direction b) opposite direction (45 s; 4.1 s)

16. Two cars are at rest, facing each other, and 200. metres apart. If car 1 accelerates at 6.00 m/s^2 up to maximum speed of 30.0 m/s and car 2 accelerates at 5.00 m/s^2 up to a maximum speed of 35.0 m/s, how long does it take the cars to meet? (6.08 s)