Velocity, Displacement & Time

The most basic information you must have to describe the motion of an object is its **displacement**, and the **time** it took to move that far.

· The displacement of an object is always measured from some **reference point** (which is usually "zero", at a location at the start of the motion of the object).

· Although we use the words "**distance**" and "**displacement**" interchangeably in everyday language, they mean very different things in physics.

· The **distance** between two objects is scalar, since it doesn't matter which direction you measure it from. e.g. "We are standing 2.3m apart."

· The **displacement** of an object is a vector, since you have to state the direction the object has traveled. e.g. "The car moved 2.56km east."

The most simple formula for calculating the **displacement** of an object is…

$\Delta d = d_f - d_i$

· The Δ symbol is the greek letter "delta" and means "a change in…"

· The subscript "f" and "i" stand for final and initial.

· So, in this formula, we calculate the displacement of an object by taking the final position minus the initial position.

Eg 1: A truck is passing a mark on the road that says 300m, and then passes another one 10s later that says 450m. **Determine** the **distance** the truck moved.

$\Delta d = d_f - d_i = 450 - 300 = 150m$

Note: If the example had asked for the ***displacement***, we would have to include a direction (like "east") in our answer.

Eg 2: You start walking home from school. After walking 1.3 km North, you get a phone call on your cell from your mom asking if you can meet her at the mall. You will have to turn around and walk 2.5 km South. **Determine** your **distance** and **displacement** to get to the mall.

Let's start by looking at a quick sketch of the situation, as shown at right.

- From the school you first walked 1.3 km [N].
- You then turned around and walked 2.5 km [S].

If we want the **distance** you walked, we need to look at all the walking you did, without considering direction.

$d = 1.3 + 2.5 = 3.8$ km

When we look at your **displacement**, we need to consider the direction that you walked. Even though you walked North at first, turning around and walking South cancelled out all of your initial movement. When we measure **displacement** we are only where you started and where you finished, not all the stuff in between. We will consider moving North to be positive, and South to be negative.

$=+1.3\text{ km}+-2.5=-1.2\text{km}$ [South]

Notice that the **displacement** is smaller and negative when compared to your **distance**. That's because even though you actually moved your body around the city 3.8 km, all you really accomplished by the end was moving 1.2 km South of where you started.

Average Velocity

This leads to the first major formula for the calculation of **average velocity**.

$v=d/t$

v = velocity (m/s)

d = displacement (m)
t = time (s)

· It is called **average velocity** because it looks at your overall velocity for the entire trip, not at any one particular velocity you might have been traveling at during the trip.
· What you have to measure is the **total displacement** divided by the **total time**.
· If you drive 275 km to Perth in 3.00 hours, I calculate your velocity based on this information. The velocity I calculate, 91.7km/h, will be your **average velocity**.
○ I'm looking at the entire trip. It would certainly be rare if you had driven at exactly 91.7km/h every single moment during your drive to Perth.
○ Sometimes you would have been going faster, sometimes slower, but overall your **average velocity** was 91.7km/h.
· You basically have to look at the start and finish only, how far did you move from where you started (displacement) in a certain amount of total time.
· These questions can also involve moving at different velocities for different periods of time; we need to be really careful with these questions...

Eg 3: A car drives along the highway at 115 km/h for 2.50 h.
Once in the city, the car drives at 60.0 km/h for the next 0.500 h.
Determine the average velocity of the car.
The average velocity is based on the total displacement of the car for the entire time it was moving, so we first need to figure out the total displacement and the total time.

First part of the drive...

$$v=\frac{d}{t}$$
$$d=vt=115(2.50)$$
$$d=287.5\,km$$

Second part of the drive...

$$v=\frac{d}{t}$$
$$d=vt=60(0.50)$$
$$d=30\,km$$

So, in total, the car moved 317.5 km in 3.00 h. Its average velocity is...

$$v=\frac{d}{t}$$
$$v=\frac{317.5}{3.00}$$
$$v=105.83=106\,km/h$$

Eg 4: I try to run the 100m race to break the world's record. Unfortunately, it takes me 16.83s to complete the run. **Determine** my average velocity.

$$v=\frac{\vec{d}}{t}=\frac{100}{16.83}=5.94\,m/s$$

This is my **average** velocity. It does not show that I have to speed up at the start of the race, or that maybe I was slowing down near the end.

· To convert m/s to km/h multiply by 3.6 (this is an exact value and has an infinite number of sig digs.)

· The answer from **Eg 5** would be 21.4 km/h.

· If you ever do a calculation like this, use the original number on your calculator, not the rounded off answer.

· Also, you can **convert km/h to m/s by dividing by 3.6**. *This is more important because you must make sure all your numbers are in standard units before starting a calculation*.

In the above Eg's displacement and the velocity were **positive** numbers.

· **Positive** and **negative** tell you which direction you are going with respect to the reference point.

· A **positive** velocity means you are moving **forward** , to the **right**, or **up**, while **negative** means you are going **backwards**, to the **left**, or **down**.

Eg 5: A train is moving backwards at a velocity of 13.5 km/h for 6.40 minutes. **Determine** the train's displacement.

v = -13.50 km/h = -3.75 m/s
t = 6.40 minutes = 384 s

$$v=\frac{d}{t}$$

$$d=vt=-3.75(384)=-1440\,m=-1.44e3\,m$$

Eg 6: Look back at Eg 2. **Determine** your speed and velocity if the walk took you one hour and ten minutes. First thing you should do is change the time into seconds.

1 hour = 3600 s
10 minutes = 600 s
1h 10min = 4200s

To figure out the **speed**, we need to use the **distance** (in metres!) you travelled in 4200 s. That way we are using only **scalar** measurements.

$$v=\frac{d}{t}$$
$$v=\frac{3.8e3}{4200}$$
$$v=0.90\,m/s$$

To figure out the **velocity** we need to use the **displacement** you travelled. Now we are using only **vector** measurements.

$$v=\frac{d}{t}$$
$$v=\frac{-1.2e3}{4200}$$
$$v=-0.29\,m/s$$

Uniform Motion

In many of the questions we will be doing we have to assume that the object is moving at exactly the same velocity the whole time.

· Although this is not very realistic, it makes doing the questions a lot easier.

- For now we will assume that the object is not accelerating at all.
- If the velocity of an object is always the same, we say it has a **constant velocity**. We can also call this **uniform motion**.

You still use the same formula as for average velocity.

- **Uniform motion** is the easiest kind of motion to describe and measure, since it is always the same. If the object is accelerating in any way we have to use different formulas
- Assume that it is **uniform motion** unless you are told otherwise.

Instantaneous Velocity

In real life we often have to deal with an object traveling without uniform velocity. Things are always speeding up and slowing down.

- This is the situation if you ask your friend how fast she is driving when you're in a car.
- She'll glance down at the speedometer and tell you how fast she is going, but that is only how fast she was going at that instant of time!
- A split second later, she might be going a bit faster or a bit slower. Most people don't drive their cars at a totally constant velocity.
- That's why we call the measurement she gave you an **instantaneous velocity**.

Instantaneous velocity is the velocity of an object at one moment of time.

- It is often easier to measure **instantaneous velocity** if you are looking at a graph of the motion of an object