SPEED AND VELOCITY

SEPTEMBER 24, 2023

Theory recap

We started discussing speed and velocity. Speed is a distance passed per unit time. To find speed we have to divide the distance by the time, which required to pass the distance.

$$speed = \frac{distance}{time}$$

From now on we will start using letter to denote different physical quantities. In particular, let us denote distance by l, speed by v and time by t. Then we could write a formula which connects them more compactly:

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

Speed is a scalar. It means that it is just a number and has no direction. As we mention speed the direction of the motion is not important for us. For example, a speed limit sign specifies the maximum speed independently on the direction of your motion. In contrast to speed, the velocity is a vector. The velocity is a displacement per unit time.

$$\overrightarrow{velocity} = \frac{\overrightarrow{dispacement}}{time}$$

Or again more compactly

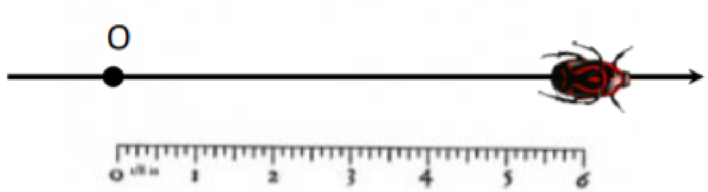
$$\vec{v} = \frac{\vec{d}}{t}$$

The arrows over the characters show that the corresponding parameters are vectors.

If the velocity of the object does not change, the motion is called *uniform*. Since the velocity is a vector, it has, as we already know, both magnitude and direction. If the velocity does not change, both speed and direction of the motion remain constant (which means that they do not change as well).

Therefore, uniform motion is motion along a straight line. Motion along a straight line is called *rectilinear motion*. Although any uniform motion is rectilinear, rectilinear motion is not necessarily uniform.

This year we will be mostly studying rectilinear motion. To specify the position of an object moving along a straight line we need a reference point. It is convenient to choose a point at the line of motion and calculate all the distances and displacements with respect to this point. We will call this point "origin" and mark with the character O.



The direction from the origin to our right we will call positive. The opposite direction is negative. This choice is arbitrary. You may choose the positive direction as you wish. Positive or negative sign of the velocity or displacement will just indicate the direction of the motion. In contrast, speed and distance cannot be negative - they have no direction.

Most of the motions around us are nonuniform. It means that the speed and /or velocity are changing during the motion. In this case we can introduce *average speed* and *average velocity*.

Average speed is a ratio of total distance and time interval required to cover this distance:

$$average\ speed = \frac{total\ distance}{total\ time}$$

For example, you have to go for 1km. First you run, then stop for a while to take a break and, finally, you walk. It took 15 minutes to cover 1 km. The average speed in this case is

$$average\ speed = \frac{total\ distance = 1\text{ km} = 1000\text{ m}}{total\ time = 15\text{ min} = 15 \times 60\text{ sec} = 900\text{ sec}} \approx 1.11\text{m/s}$$

It means that instead of running, taking a rest and, finally, walking you just keep going with a uniform speed of 1.11 m/s you will pass 1 km for the same time of 15 min.

Average velocity is a ratio of total **displacement** and time interval required to complete this displacement:

$$\overrightarrow{average\ velocity} = \frac{\overrightarrow{total\ displacement}}{total\ time}$$

For example, if at the end of a very long trip you returned to the starting point, your average velocity is zero, because your displacement is zero.

Homework

1. A rubber ball falls 5 feet down, hits the floor and bounces 3 feet up. Find the distance passed by the ball and the displacement. Make a drawing and show the displacement vector of the ball.

2. A car passed 30 km at the speed of 15 m/s. Then the car turned back and spent 1 hour to pass 40 km. Find average speed and average velocity of the car. Make a picture.

3. The velocity of an object is changing. Does it necessarily mean that the speed of the object is changing too? Explain your answer.

***4.** Athletes form a line of length l and run together with speed v along the direction of this line. A coach runs towards them with speed $u < v$. Upon meeting the coach each athlete instantly turns around and starts running in the opposite direction with the same speed v. What will be the length of the line of athletes after they all turn around?