Velocity

The **velocity can only be measured with respect to an object**. Any time we mention the velocity, we have to specify with respect to what object this velocity is measured. When we say that the velocity of the car is 50 km/h it usually means that this is the velocity with respect to the ground. A physicist would say that the velocity is 50km/h in the ground's reference frame. The velocity (the speed and the direction of motion) depends on the choice of the reference frame.

The **velocity addition rule** is given below: If the object B moves with respect to the object A at the velocity $\overrightarrow{V1}$ and the object C moves with respect to the object B at the velocity $\overrightarrow{V2}$, then the object C moves with respect to the object A at the velocity $\vec{\boldsymbol{V}} = \overrightarrow{\boldsymbol{V1}} + \overrightarrow{\boldsymbol{V2}}$.

The arrows on top of the velocity symbols mean that the velocities have direction. In the case of motion along a straight line they are "left to right" and "right to left" or "plus" and "minus". The sign "plus" or "minus" will be chosen depending on the velocity direction. After we have chosen correct signs, we can drop the arrows.

Relative velocity is the velocity of one object with respect to another.
When two objects move in the same direction, their relative velocity is the difference between their individual velocities.
When two objects move in opposite directions, their relative velocity is the sum of their individual velocities.

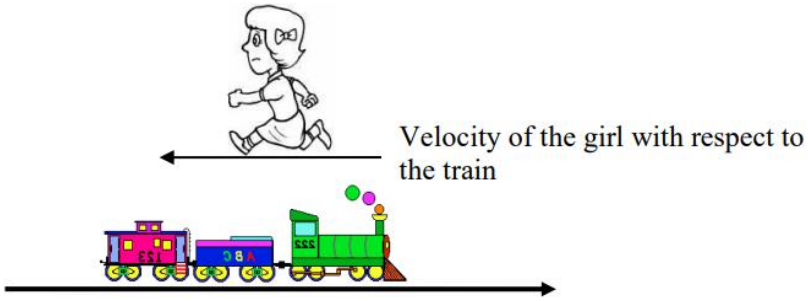
Average velocity is a rate of total displacement and time interval required to complete this displacement.

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

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.

Example 1:

A girl is walking in the moving train in the direction opposite to the train's motion. You are watching the passing train staying at the station. The velocity of the girl with respect to the train is 1m/s, the velocity of the train with respect to the ground is 36 km/h. Find the velocity of the girl with respect to you.



1) Make a picture

2) Choose the" positive" direction. You have two options:" left to right" or" right to left". You can pick up any one – the result will not depend on your choice. For this problem I choose left to right. From now on, all the velocities directed left to right are positive, all the velocities "looking" in the opposite directions are negative. The velocity of the train is positive; the velocity of the girl with respect to the train is negative, because it "looks" in the opposite direction.

3) According to the velocity composition rule:
Velocity of the girl with respect to the station (we denote it as $\vec{V}gs$) =
velocity of the girl with respect to the train ($\vec{V}gt$) +
velocity of the train with respect to the station ($\vec{V}ts$). Or

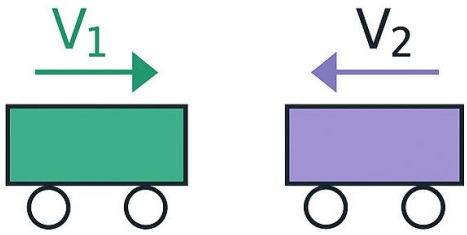
$$\vec{V}gs = \vec{V}gt + \vec{V}ts.$$

4) According to the problem, $\vec{V}$**gt** = - 1m/s (it is negative), $\vec{V}$**ts** = 36km/h =10m/s (it is positive). So,

$$\vec{V}\mathbf{gs} = -1\text{m/s} + 10\text{m/s} = 9\text{m/s}$$

Example 2:

Two cars a moving along a straight road toward each other from different towns. The speed of the left car (car A) is 72km/h, the speed of the right car (car B) is 36km/h. Find the velocity of the right car with respect to the left car.



1) Make a picture

2) We choose the positive direction to the right. Therefore, the velocity of left car is $\vec{V}_A$ **= 72 km/h** (it is positive), and the velocity of right car is $\vec{V}_B$ **= - 36 km/h** (it is negative).

3) If you are moving with B, then from your "moving perspective," B looks stationary. To get A's motion **relative to B**, you have to account for B's motion by subtracting it. So, the velocity of A relative to B will always be:

$$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$$

4) As we plug in the velocities, we got:

$$\vec{V}_{AB} = 72 \text{ km/h} - (-36 \text{ km/h}) = 72 \text{ km/h} + 36 \text{ km/h} = 108 \text{ km/h}$$

Again, as we can see, when two objects move in opposite directions, their relative velocity is the sum of their individual velocities.

Homework:

1) The Earth moves around the Sun with speed 30 km/s. The Moon moves around the Earth with speed 1 km/s. Find maximal and minimal speed of the Moon with respect to the Sun. Draw a picture supporting your answer.
2) The velocity of an object is changing. Does it necessarily mean that the speed of the object is changing too? Explain your answer.
3) 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.
4) River flows with speed v_r = 2 m/s. A fisherman uses his boat to get to a village situated at distance d = 2 km down the river and returns to his home. During the whole trip, the speed of the boat is V = 3 m/s with respect to the water. Find the total time of the two-way trip. Does river flow make it longer or shorter?