Chapter 2: Describing Motion in One Dimension

Lecture 1A

Physics Department/University of Jordan

أ.د. محمود الجاغوب

2-1] Reference Frames and Displacement

student ①: standing on the ground (NOT moving)

student ② : sitting in the bus.

student ③ : moving to the right inside the bus

bus : moving to the right at 10 m/s.

How can we describe the motion of each ?

A] From the point of view of student ①
(This means how he sees the others moving)

Student ②: moving to the right at 10 m/s.

student ③ : moving to the right at 10 + 3 = 13 m/s.

B] From point of view of student ②

Student ① : moves to the left at 10 m/s.

student ③ : moves to the right at 3 m/s.

Note that the speed of student ③ (for example) is different depending on the observer (student ① or student ②).

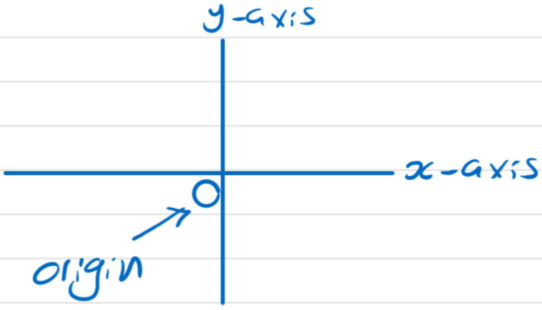
To specify velocity we need a frame of reference

In case A above we are in the frame of reference of student ①.

In case B above we are in the frame of reference of student ②.

What does a frame of reference consist of ?

In two dimensions it consists of the x and y axes.



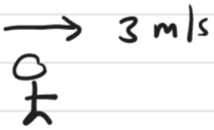
Cartesian Coordinate System in two dimensions.

In frame of reference of student ①, means that this student is at rest at the origin and gives positions with respect to the origin.

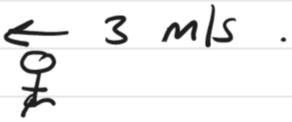
He also measures velocities with respect to this set of axes (x and y).

2-2] Average Velocity

Student Ⓐ



student Ⓑ



Both Ⓐ and Ⓑ have the same speed.

speed gives how fast some one or an object is moving.

If you move a distance of 9 m in 3 s ⇒

we define average speed $\bar{s}$ as :

$$\bar{s} = \frac{\text{total distance covered}}{\text{time elapsed}}$$

$$\bar{s} = \frac{9}{3} = 3 \text{ m/s.}$$

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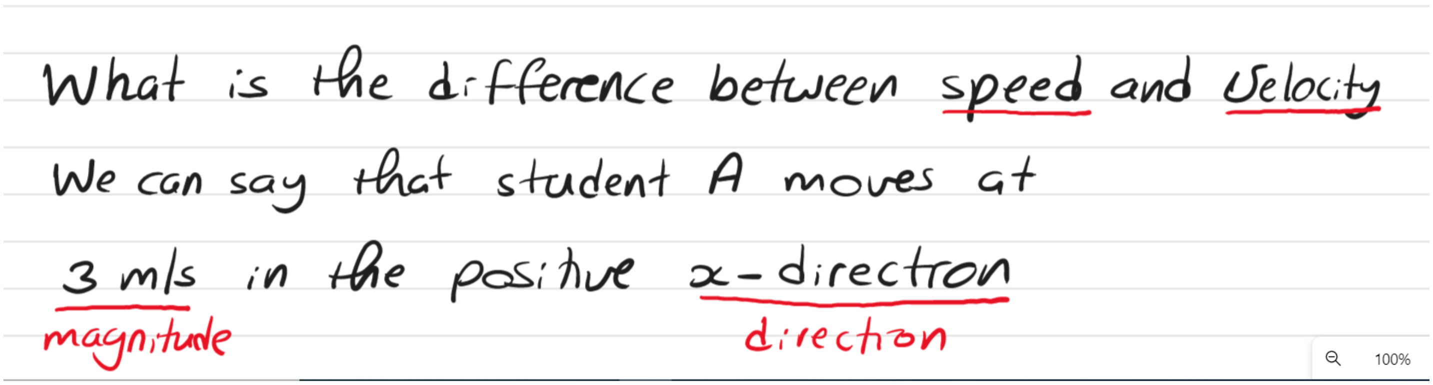
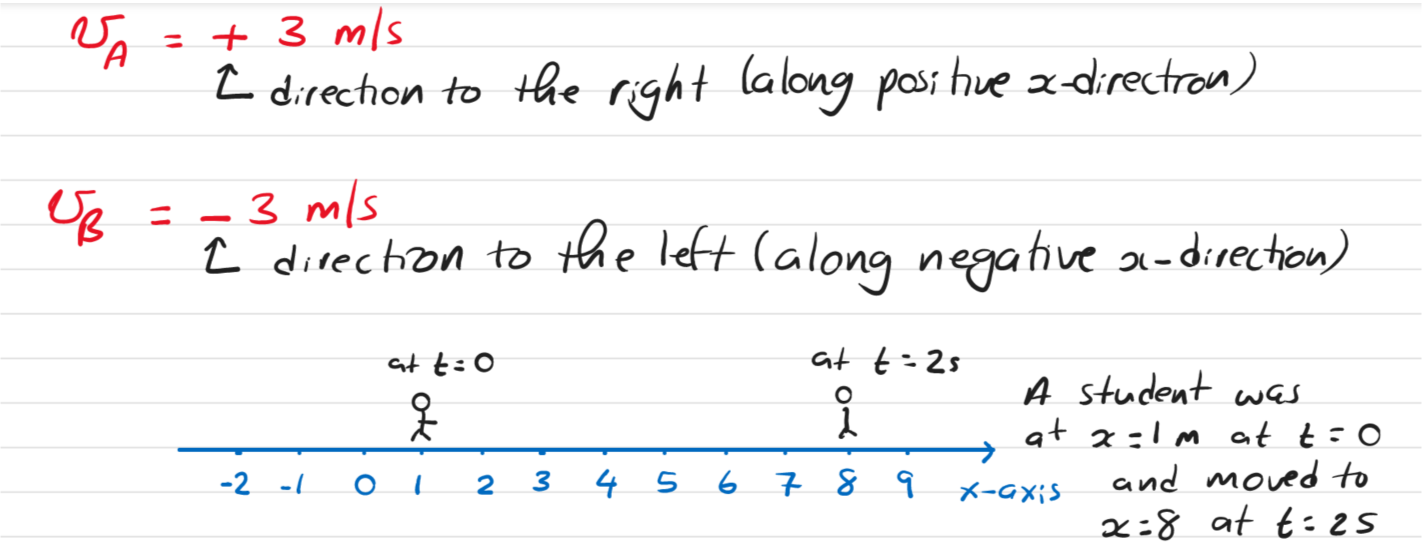


What is the difference between speed and velocity

We can say that student A moves at

3 m/s in the positive x-direction

magnitude direction



$v_A = +3\ m/s$

↳ direction to the right (along positive x-direction)

$v_B = -3\ m/s$

↳ direction to the left (along negative x-direction)

A student was at $x = 1\ m$ at $t = 0$ and moved to $x = 8$ at $t = 2s$

Define average velocity as :

final position at t_f

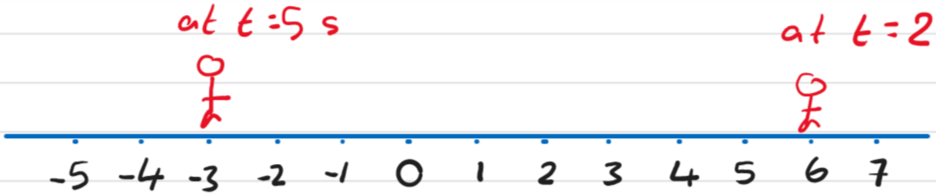
$$\text{means average} \rightarrow \overline{v} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

initial position at t_i

final time

initial time

$$\overline{v}_{0-2} = \frac{8-1}{2-0} = \frac{7}{2} = 3.5 \text{ m/s}.$$



Find the average velocity of the student over the time interval $t = 2\text{s} \rightarrow t = 5\text{ s}$.

$$\overline{v}_{2-5} = \frac{x_f - x_i}{t_f - t_i} = \frac{-3-6}{5-2} = -\frac{9}{3} = -3 \text{ m/s}$$

$$\overline{v}_{2-5} = -3 \text{ m/s}$$

$\llcorner$ means the average velocity is along the negative x-direction.

NOTE: Average velocity is given over a time interval.

2-3] Instantaneous velocity

When you drive your car, you look at the odometer (عداد السرعة) you may read 50 km/h.

This is the velocity at a given instant. We call this Instantaneous velocity. Which is given at a particular instant of time.

$v = 60$ km/h direction in positive x-axis.

$v = -40$ km/h " " negative x-axis.

2-4] Acceleration

When the velocity of an object changes with time then this object accelerates.

Acceleration is CHANGE in velocity with time.

Example: At $t = 2s$, the velocity of a train is 4 m/s.
After 3s, its velocity is 12 m/s.

Is the train accelerating? Why?

Yes it is accelerating, because the velocity changed with time.

Average acceleration $\bar{a}$

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

Defined over a time interval $\Delta t = t_f - t_i$

Example: Find the average acceleration of the car

$t_i = 2s$, $t_f = 2+3 = 5s$.

$v_i = 4 m/s$, $v_f = 12 \ m/s$

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{12 - 4}{5 - 2} = \frac{8}{3} \ m/s^2 .$$

Example: A car accelerates on a straight road from rest to in 5.0 s, what is the magnitude of its average acceleration?

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i} .$$

Since Δt is given in seconds, we need to convert the magnitudes of the velocities to m/s.

$$75 \frac{km}{h} = 75 \frac{\cancel{km}}{\cancel{h}} \times \frac{1000\,m}{\cancel{km}} \times \frac{\cancel{h}}{3600\,s} \approx 21\ m/s .$$

$$\therefore \quad \bar{a} = \frac{21-0}{5-0} = 4.2\ m/s^2 .$$

Question: If the velocity of an object is zero, does it mean that the acceleration is zero?

If $v = 0$ it does NOT necessarily mean that

the the acceleration is zero. Because the acceleration depends on CHANGE of v NOT v itself.

Note $\quad \bar{a} = \dfrac{v_f - v_i}{t_f - t_i}$