constant acceleration / non-uniform motion

Uniform Accelerated Motion

- **<u>Acceleration</u>** ($\vec{a}$): the rate at which an object's velocity changes *or* how much an object's velocity changes over time.
  - Vector quantity
  - In uniform accelerated motion, acceleration remains constant but velocity changes. (Remember that uniform motion is when velocity remains constant, which means there is no acceleration.)

- **<u>Instantaneous velocity</u>**: The velocity of an object at a specific/particular point in time during non-uniform motion (ie. accelerated motion)
  - This is why we need to specify *initial* and *final velocity*

- There are several equations relating acceleration, time, displacement, and velocity that can be used for accelerated motion
  - $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ OR $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$ (not on data sheet)
  - $\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$
  - $\vec{d} = \vec{v}_f t - \frac{1}{2}\vec{a}t^2$
  - $\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right) t$
  - $v_f^2 = v_i^2 + 2ad$

all equations on data sheet!

where $\vec{d}$ is displacement (m)
t is time (s)
$\vec{v}_i$ is initial velocity (m/s)
$\vec{v}_f$ is final velocity (m/s)
$\vec{a}$ is acceleration (m/s^2)

***Remember that these are vector quantities so direction and signs are absolutely crucial in the calculations and answer!**

- How do you know what equation to use?!
    - Whichever variable you don't know and don't want/need to know, use the equation that doesn't include that variable
    - The only equation you can **never use** for accelerated motion is $\vec{v} = \frac{\vec{d}}{t}$!

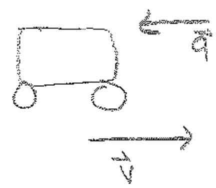
The **direction of acceleration** depend on two things:

1. If the object is speeding up or slowing down

2. If the object is moving at (+) or (-) velocity direction

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

For example: Let's think of a car slowing down



② then they put on brakes in opposite direction of initial movement — slowing car

① car initially drives north at uniform velocity

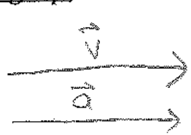
In summary:

1. **positive acceleration** can happen in two ways:
    a) speeding up & positive direction (+ · + = +)
    b) slowing down & negative direction (− · − = +)

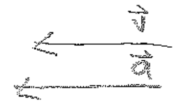
2. **negative acceleration** can happen in two ways:
    a) speeding up & negative direction (+ · − = −)
    b) slowing down & positive direction (− · + = −)

Let's look at this concept using vectors (pg. 28)

- When an object is *speeding up*, the acceleration and velocity vectors are in the ***same direction/sign***

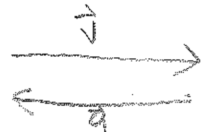


speeding up

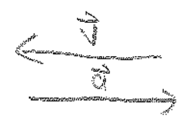


speeding up

- When an object is *slowing down*, the acceleration and velocity vectors are in ***opposite directions/signs***



slowing down



slowing down

EXAMPLES:

1. An object accelerates north uniformly from rest in a time of 2.70s. In this time, the object travelled 20.0m. What was the final velocity?

$v_i = 0.0 m/s$

$t = 2.70 s$

$d = 20.0 m$

$v_f = ?$

$$d = \left(\frac{v_f + \cancel{v_i}^{0}}{2}\right)t$$

$$\frac{d}{t} = \frac{v_f}{2}$$

$$\frac{2d}{t} = v_f = \frac{2(20.0m)}{2.70s} = 14.814... m/s$$

$$\boxed{v_f = 14.8 m/s, \text{north}}$$

2. A golf ball is hit from the tee box. The golf ball has a speed of 14.6m/s as it strikes a tree. The golf ball bounces straight back off the tree with a speed of 11.3m/s. If the golf ball is in contact with the tree for 84ms, what is the acceleration of the golf ball?

$V_i = 14.6 m/s$

$V_f = -11.3 m/s$

$t = 84 ms \times \left(\frac{10^3}{1m}\right)$

$t = 8.4 \times 10^{-2} s$

$a = ?$

$a = \frac{V_f - V_i}{t} = \frac{(-11.3 m/s) - 14.6 m/s}{8.4 \times 10^{-2} s}$

$a = -308.\bar{3} \ m/s^2$

$\boxed{a = 3.1 \times 10^2 m/s^2, \text{ away from tree}}$

3. A vehicle travelling along the highway brakes suddenly to avoid hitting a deer that jumped onto the road. The vehicle decelerates at $3.00m/s^2$ to a speed of 60km/hr. According to the skid marks on the road, the vehicle skidded a distance of 56.3m. Based on this information, what was the initial speed of the vehicle?

$a = -3.00 m/s^2$

$V_f = \frac{60 km}{hr} \times \left(\frac{1 hr}{3600 s}\right) \times \left(\frac{10^3}{1k}\right)$

$V_f = 16.\bar{6} m/s$

$d = 56.3 m$

$V_i = ?$

$V_f^2 = V_i^2 + 2ad$

$V_i^2 = V_f^2 + 2ad$

$V_i = \sqrt{V_f^2 - 2ad}$

$V_i = \sqrt{(16.6 m/s)^2 - 2(-3.00 m/s^2)(56.3 m)}$

$V_i = 24.8108.... m/s$

$\boxed{V_i = 25 m/s}$

Uniform Accelerated Motion Summary

Equations	Variables				
	v_i	v_f	a	d	t
$d = v_f t - \frac{1}{2} a t^2$		✓	✓	✓	✓
$d = v_i t + \frac{1}{2} a t^2$	✓		✓	✓	✓
$d = \left(\frac{v_f + v_i}{2}\right) t$	✓	✓		✓	✓
$a = \frac{(v_f - v_i)}{t} = \frac{\Delta v}{\Delta t}$	✓	✓	✓		✓
$v_f^2 = v_i^2 + 2ad$	✓	✓	✓	✓	

* never use $\vec{v} = \frac{\vec{d}}{t}$

Practice questions

pg. 53 #1-7