Unit 1
Part 2 - Kinematic Equations

Section 1: Acceleration (Text: 2.1 and 2.3)

When the speed of an object changes (slows down or speeds up) or the direction of an object changes, the object is accelerating.

Acceleration: is defined as the rate of change of velocity. Therefore, it is a vector quantity and directions are important.

Acceleration = Change in Velocity / Time Interval

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$$ and if $t_1 = 0$, then

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$$

where:

$\vec{v}_1$ is the initial velocity of the object in km/h or m/s

$\vec{v}_2$ is the velocity of the object some time later in km/h or m/s

t is the time in h or s

$\vec{a}$ is the acceleration of the object in km/h^2 or m/s^2

km/h/s

The SI unit for velocity is **m/s** and the unit for time is **s**. Hence, the unit for acceleration is **m/s/s** or **m/s^2**. Other units for acceleration include km/h^2, cm/s^2, cm/min^2, km/h/s.

Question: **What does an acceleration of 3 m/s^2 [E] mean?** $\frac{3m/s}{v} / \frac{s}{t}$

This means that the velocity of an object is changing by 3m/s each second in an easterly direction.

Question: **What does an acceleration of 6 km/h/s [E] mean?**

This means that the velocity of the object is changing by 6km/h every second in an easterly direction.

*Note: We cannot tell if an object is increasing or decreasing speed unless we know the direction of both the velocity and acceleration.

Acceleration is an example of **non-uniform** motion. There are **3** types of acceleration: constant, average, and instantaneous acceleration.

1. <u>Constant Acceleration</u>: An object has **constant acceleration** if it changes its velocity by equal amounts in equal intervals of time. **Example**: a pear falls from a tree.

2. <u>Average acceleration</u>: It is used to describe acceleration when the velocity changes in a non-uniform way.
   Example: A car that accelerates to a velocity of 50 km/h [W] from a traffic light has its greatest acceleration at the start. As the car goes faster and faster, its acceleration decreases until the velocity reaches the constant velocity of 50 km/h [W]. At this time its acceleration drops to zero.

NOTE: Average acceleration and constant acceleration are related. The average acceleration for a time interval is the same as the constant acceleration an object would need if it were to change velocity by an equal amount each time. Therefore, both use the same formula.

3. **Instantaneous acceleration**: It is acceleration at a specific instant of time and is found by calculating the tangent to the curve on a velocity-time graph.

Rearrangements of the formula $\vec{a} = \dfrac{\vec{v}_2 - \vec{v}_1}{t}$

directions

Solve for :

1) t

$$\frac{\vec{a}}{1} = \frac{\vec{v}_2 - \vec{v}_1}{t}$$

$$t = \frac{\vec{v}_2 - \vec{v}_1}{\vec{a}}$$

2) $\vec{v}_2$

$$\frac{\vec{a}}{1} = \frac{\vec{v}_2 - \vec{v}_1}{t}$$

$$at = v_2 - v_1$$

$$\vec{v}_1 + \vec{a}t = \vec{v}_2$$

$$\boxed{\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t}}$$

3) $\vec{v}_1 = ?$

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t}$$

$$\vec{a}t = \vec{v}_2 - \vec{v}_1$$

$$\vec{v}_1 = \vec{v}_2 - \vec{a}t$$

Examples:

1. A motorcycle, starting from rest and undergoing uniform acceleration reaches a velocity of 20.0 m/s [N] in 8.0 s. Find its average acceleration.

$\vec{v}_1 = 0$

$\vec{v}_2 = 20.0 m/s$ [N]

$t = 8.0 s$

$\vec{a} = ?$

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t}$$

$$\vec{a} = \frac{20 m/s [N]}{8.0 s}$$

$$\vec{a} = 2.5 m/s^2 [N]$$

$$\left[\frac{m/s}{s} \quad \frac{m}{s} \times \frac{1}{s} \quad \frac{m}{s^2} \right]$$

2. A car accelerates at a constant rate from 40 km/h [E] to 90 km/h [E] in 5.0 s. What is its acceleration?

$\vec{v}_1 = 40 km/h$ [E]

$\vec{v}_2 = 90 km/h$ [E]

$t = 5.0 s$

$\vec{a} = ?$

$$a = \frac{v_2 - v_1}{t}$$

$$= \frac{(90 km/h [E] - 40 km/h [E])}{5 s}$$

$$= 10 km/h/s [E]$$

3. A airline flight is behind schedule, so the pilot increases the air velocity from 135 m/s [W] to 165 ms/ [W] in 2.0 min. What is the airplane's acceleration in m/s^2?

$V_1 = 135 m/s$ [W]
$V_2 = 165 m/s$ [W]
$t = 2.0 min$
$t = 120 s$
$a = ?$

$$a = \frac{V_2 - V_1}{t}$$

$$a = \frac{165 m/s [W] - 135 m/s [W]}{120 s}$$

$$a = 0.25 m/s^2 [W]$$

4. A cyclist, initially traveling at 14 m/s [S], brakes smoothly and stops in 4.0 s. What is his average acceleration?

$V_1 = 14 m/s$ [S]
$V_2 = 0 m/s$
$t = 4.0 s$
$a = ?$

$$a = \frac{V_2 - V_1}{t}$$

$$a = \frac{0 - 14 m/s [S]}{4.0 s}$$

$$a = -3.5 m/s^2 [S]$$

$$a = 3.5 m/s^2 [N]$$

Note: When an object is slowing down, its acceleration is in the opposite direction to its velocity.

5. Judy, a sprinter, has a velocity of 6.0 m/s [S] at t = 3.0 s. Five seconds later, she is moving north at 4.0 m/s. Calculate Judy's acceleration.

$V_1 = 6.0 m/s$ [S]

$V_2 = 4.0 m/s$ [N]

$t = 5.0 s$

$$a = \frac{V_2 - V_1}{t}$$

$$a = \frac{4 m/s [N] - 6 m/s [S]}{5 s}$$

$$a = \frac{4 m/s [N] + 6 m/s [N]}{5 s}$$

$$a = 2.0 m/s^2 [N]$$

6. A car traveling at 12 m/s accelerates at 2.34 m/s^2 for 11 s. What is the final velocity of the car?

$V_1 = 12 m/s$

$a = 2.34 m/s^2$

$t = 11 s$

V_2

$$\frac{a}{1} = \frac{V_2 - V_1}{t}$$

$$V_2 - V_1 = at$$

✓ $V_2 = V_1 + at$

✓ $V_2 = 12 m/s + (2.34 \frac{m}{s^{\cancel{2}}})(11 \cancel{s})$

* $V_2 = 12 m/s + 25.74 m/s$

$V_2 = 37.7 m/s$

✓ $V_2 = 38 m/s$

7. After accelerating at a rate of 3.2 m/s^2 for 3.8 s, a car's final velocity is 30.2 m/s. What is its initial velocity?

$a = 3.2 m/s^2$
$t = 3.8 s$
$V_2 = 30.2 m/s$
$V_1 = ?$

$$\frac{a}{1} = \frac{V_2 - V_1}{t}$$

$$at = V_2 - V_1$$

$$V_1 = V_2 - at$$

$$V_1 = 30.2\frac{m}{s} - \left(3.2\frac{m}{s^{\cancel{2}}}\right)(3.8\cancel{s})$$

$$\underline{V_1} = 18\ \underline{m/s}$$

8. A spacecraft traveling at a velocity of 1210 m/s is uniformly slowing down at a rate of 150 m/s^2. If the acceleration lasts for 8.68 s, what is the final velocity of the spacecraft? Explain your results in words.

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$V_1 = 1210 m/s$
$*a = -150 m/s^2$
$t = 8.68 s$
$V_2 = ?$

* acceleration is negative b/c when an object is slowing down, its velocity & acceleration act in opposite directions.

$$a = \frac{V_2 - V_1}{t}$$

$$V_2 - V_1 = at$$

$$V_2 = V_1 + at$$

$$= 1210 m/s + (-150 m/s^2)(8.68 s)$$

$$= -92 m/s$$

* This means that the spacecraft slows to a stop & then reverses its motion.

Homework: Worksheet and Textbook page 73 Questions 44 - 53