Motion

Key Words

position	graph	uniform	speed
trajectory	ax-is (-es plural)	motion	velocity
velocity	unit	movement	distance
acceleration	relative	displacement	rectilinear
deceleration			

"A body in motion can maintain this motion only if it remains in contact with a mover"

Aristotle

Introduction

As we will see in the next unit, an object's change of motion is due to an unbalanced force acting upon it.
Therefore, "an object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force". Once an unbalanced force acts upon it, the object will experience some type of acceleration.

Motion: usually something abstract, such as the laws of motion.

Movement: a concrete displacement of something, such as the movement of the planets.

1. The concept of motion and its components

● A **movement** is a body's change of position with time.

● Motion is relative: the change of position is made with reference to a point we call a reference system.
(Imagine a train in motion, passengers in the train and trees along the railway. How many different reference systems can you find in the scenario?)

1. The line which describes the displacement of a body in motion is called its **trajectory.**

2. **Speed** refers to how fast an object is moving, it is therefore the rate at which an object covers a distance. Speed has a different meaning than velocity, as speed is a scalar quantity and velocity is a vector quantity. **Velocity** is speed in a given direction. For our purposes, as since we are not going to see vectors this year, we may interchange the terms speed and velocity.

The **average speed** of a moving object is the displacement of the object divided into the time the object takes to cover a distance.

$$\textbf{speed (s)} = \frac{\textbf{distance covered (d)}}{\textbf{time (t)}}$$

The instantaneous speed of a moving object is the speed of the object at a particular instant.

3. **Acceleration:**

The **accelerated movement** is a movement in which velocity changes with time.

The **acceleration** of a movement is the rapidity with which its velocity changes.

$$\text{acceleration} = \frac{\text{variation in velocity}}{\text{time}} \qquad a = \frac{v - u}{t}$$

2. Uniform rectilinear motion (URM)

In a **rectilinear motion**, the trajectory is a straight line. (such as the free fall of an apple from a tree).

For a uniform rectilinear motion, the trajectory is a straight line and the velocity is constant.

So, the speed or velocity equation for URM is: $speed, time, distance$

$$s = \frac{d}{t} \qquad \boxed{t = \frac{d}{s}}$$

$$d = t \times s$$

Where:

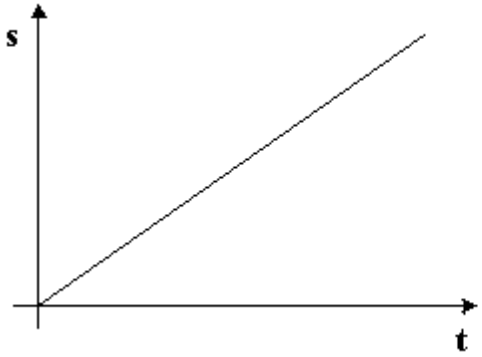
s = speed or velocity
so, s and v would both represent the same thing
d = distance
t = time
velocity = space /time ; **v = s/t** is the same formula as the one above **s = d/t**

Where: v = velocity ; s = space or distance traveled and t = time

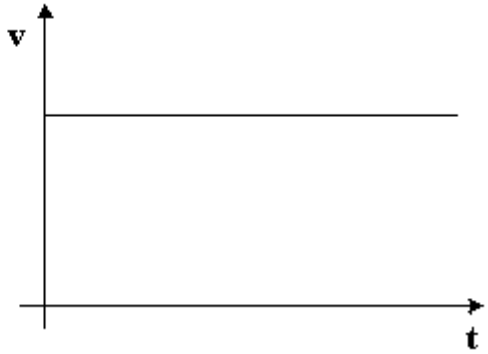
If the moving object is situated at a different place than the starting point when we start measuring the time, we call its position **initial space (s_o)**, and the whole trajectory **total space** (s).

$$s = s_0 + v \cdot t$$

Graphs to describe the URM (s-t and v-t):



The graph shows constant movement both in space and time.



This graph describes how time passes, but the velocity is the same.

The unit of speed in the International System is metre/second (m/s). However, we also often use kilometre/hour (km/h).

Do you remember how to change km/h to m/s? We learned how to use conversion factor in unit 1, you will need to revise it if you don't remember.

Exercises (unit conversion and URM)

1) A car passes the km 139 sign at 10:30 h and the km 202 sign at 11:15 h. Calculate its velocity in m/s if we suppose that the velocity is constant.

2) A car moves with a velocity of 110 km/h and a motorbike with a velocity of 31 m/s. Which one goes faster?

3) Runners A, B and C have been the three fastest in a race. Tell in which order they reached the goal if their average speed were 25 m/s, 120 km/h and 3000 m/min, respectively.

4) Calculate the distance in km, between two cities if an airplane takes 210 minutes to fly from one city to the other, keeping an average velocity of 830 km/h.

5) A car and a motorbike start from the same point with the same direction and sense at the same time. Calculate the distance, in dam, between the two of them when two hours have passed, if the velocity of the car is 72 km/h and the velocity of the motorbike is 25 m/s.

6) Luke and Peter have participated in a biking race. Peter kept an average velocity of 5 m/s and it took him 1 ½ h to reach the goal. Calculate the time, in minutes, it took Luke to complete the race if his average speed was 15 km/h.

3. Uniformly accelerated rectilinear motion (UARM)

For a uniformly accelerated rectilinear motion, the trajectory (the path the moving object traces or follows) is a straight line and the acceleration is constant.

Formulas:

$$s = s_0 + u \cdot t + \frac{a \cdot t^2}{2}$$

$$v = u + a \cdot t$$

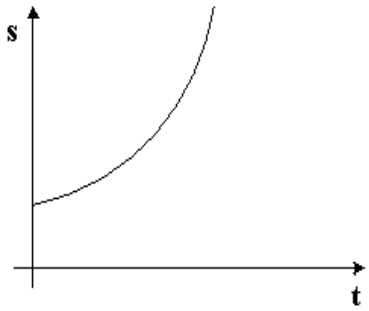
Where:

a = Acceleration
v = final velocity (sometimes given the symbol v_f)
u = initial velocity (sometimes given the symbol v_0)
t = time taken
s = displacement

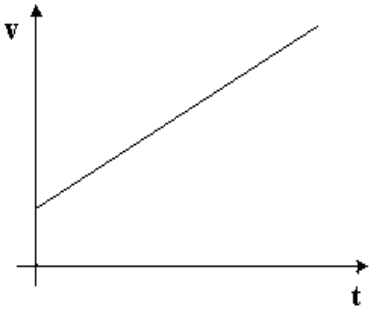
The unit of acceleration in the International System is m/s^2 . (We say 'metres per second squared').

If there is an increase in velocity, the acceleration is positive. If the velocity diminishes, the acceleration is negative or DECELERATION.

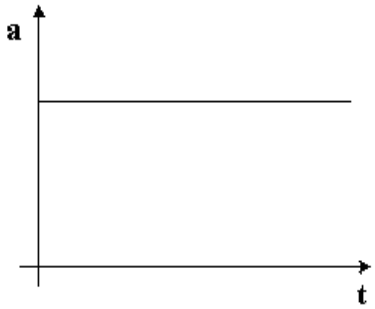
Graphs to describe the UARM (s-t, v-t and a-t):



Space-time: During the movement, more space is covered in less time.



Velocity-time: Velocity increases with time.



Acceleration-time: The value of the acceleration is the same throughout the movement.

Problems

URM:

1. A car keeps a velocity of 144 km/h and a motorbike travels at 31 m/s. Which of the two vehicles goes faster?

2. Determine the time, in minutes, that a moving object takes in covering a distance of 500 km if it keeps a constant velocity of 108 000 m/h.

3. Determine the distance covered by a moving object in 210 minutes if it keeps a constant velocity of 830 km/h.

UARM:

1. A car is standing still at a red light. The light turns green and it takes one minute to acquire a velocity of 72 km/h. Determine: a) the acceleration of the car and the displacement in that one minute. b) Represent the problem with a v-t graph.

2. Starting at rest, a moving object increases its velocity in a constant way by 0.5 m/s each second during 2 minutes. We want to know: a) the final velocity of the moving object, expressed in km/h; b) the displacement after 2 minutes.

3. A motorcyclist who circulates at a velocity of 72 km/h brakes during 10 seconds to get to a full stop. Calculate: a) the deceleration, b) the displacement before the motorcycle stops, and c) represent the problem with a v-t graph.

4. A car leaves from a garage with an initial velocity of 36 m/s and reaches the end of its journey with a final velocity of 90 km/h. Determine: a) the time of the movement, if the acceleration was –0.75 m/s^2, and b) the displacement of the car.

5. A car covers 6 hm in a quarter of a minute with constant velocity. Then it brakes during 5 s reaching a velocity of 72 km/h. Calculate: a) the deceleration, b) the displacement during the time it brakes, and c) make a v-t graph of the problem.

6. A car starts from full rest, and accelerates at a rate of 0.75 m/s^2 during one and a half minute to reach point A. Once it reaches point A and with the velocity, it continues with a uniform movement during 5 minutes, to finally arrive at point B. Calculate the following:

a) the final velocity at point A; b) the displacement of the car from full rest to point B, and c) a representation of the problem on a v-t graph.

7. A motorbike leaves a stoplight and accelerates 1.5 m/s^2 during half a minute. After this, it keeps a constant velocity during 10 s. Then it brakes, reaching a full stop after a quarter of a minute. Determine: a) the acceleration when it brakes, b) the displacement of the motorbike from the moment it leaves the stoplight, and c) represent the whole problem with a v-t graph.