Unit 3.1: MOTION

At the end of this lesson, students should be able to:

- □ Understand the relationships between speed, time and distance
- □ State the quantities involved in finding speed.
- □ Define speed ***and*** know the formula for calculating speed and its unit.
- □ Measure distance and time of a moving object
- □ Carry out experiments to find the relationships between speed, distance and time

DISTANCE AND TIME

The motion (movement) of an object such as a car or rugby ball is described using quantities like

- ✓ distance,
- ✓ speed,
- ✓ time and
- ✓ acceleration.

Time (symbol **t**) is measured in **seconds** (symbol **s**).

- Other units for measuring time are **minute** (min) and **hour** (h)

Distance (symbol **d**) refers to "how far" an object moves.

- It is measured in metres (m). Other units for distance are kilometre (km) and centimetre (cm).

  1 km = 1000 metres
  1 m = 100 cm

Speed (symbol **v**) is the distance travelled per unit of time. Unit for measuring speed is **meter per second** (m/s or ms^{-1})

For a particular moving object, such as a car journey – the

(i) **Average speed** is *calculated* using the distance travelled divided by the time taken to travel that distance:

$$Speed\ (V_{av}) = \frac{total\ distance\ travelled}{total\ time\ taken}$$

or

$$v = \frac{d}{t}$$

Note: The average speed is usually calculated for a complete journey rather than for parts of a journey.

(ii) **Instantaneous speed** – refers to the actual speed of an object at any moment.

- ✓ The speedometer of a car measures the instantaneous speed.
- ✓ To find the car's speed at any instant we can look at the 'speedometer' and read from it the instantaneous speed.
- ✓ The instantaneous speed usually changes considerably during a car journey.

(iii) **Uniform Speed (Constant/Steady Speed)**

- ✓ If the instantaneous speed does not change, that is, the speed stays the same, then the speed is described as being **constant** (also called **uniform** *or* **steady).**

Answer all questions given below;

EXAMPLE #1: It's 8:25 a.m and Sione knows that if he doesn't speed up he will be late to work. He lives at Vaini and have only 5 minutes to get to work in Nuku'alofa.

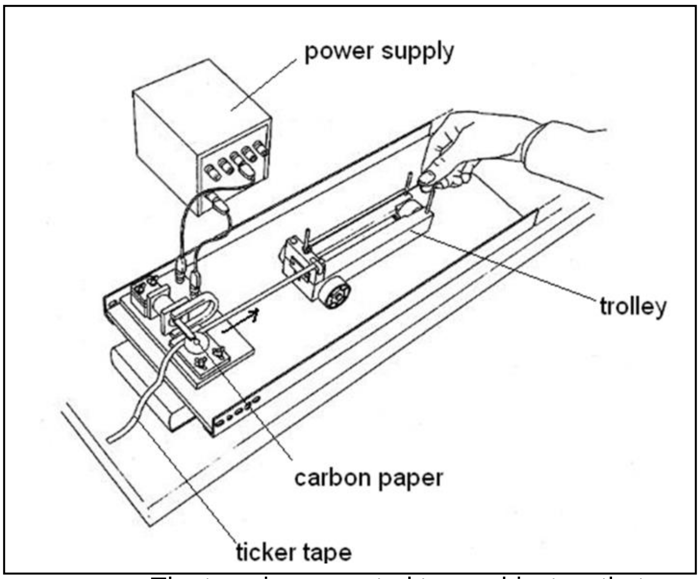
a) A traffic officer finds that Sione has travelled 600m in 20 seconds. What is the **average speed** of the car?

b) If the distance from Vaini to Nuku'alofa is 20 km. Use the average speed in which the car travelled in (a) to determine the total time it took for Sione to arrive at Nuku'alofa.

c) Was Sione late to work?

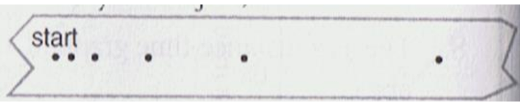
TICKER – TIMER

- In the laboratory, a ticker-timer is used to record distance and time information for a moving object.
- A ticker-timer is connected to a power supply which moves a vibrating steel strip up and down 50 times each second (or once every 0.02 of a second).
- Each time the steel strip comes down it leaves a mark on the ticker-tape being fed through the ticker timer.

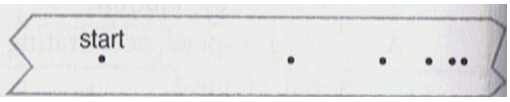


- The tape is connected to an object so that, as the object moves, the ticker-tape is pulled through the timer.
- The dots on the ticker tape gives *speed* information and distance information (the distance between dots is the distance travelled by the object):

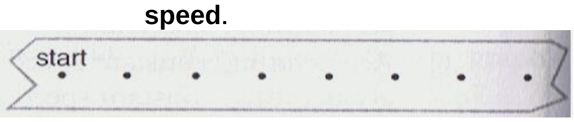
(i) When the dots are spreading out, the object is **accelerating** (increasing in speed).



(ii) When the dots are getting closer together, the object is **decelerating** (decreasing in speed).



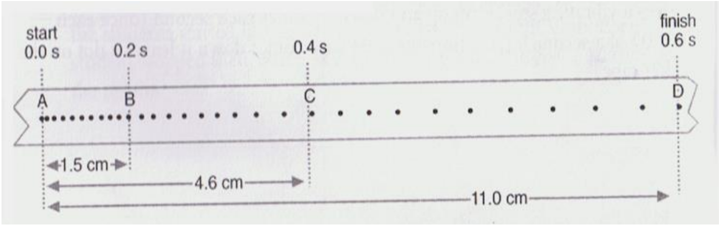
(iii) Where the dots are evenly spaced, the object has a **constant speed**.



Example:

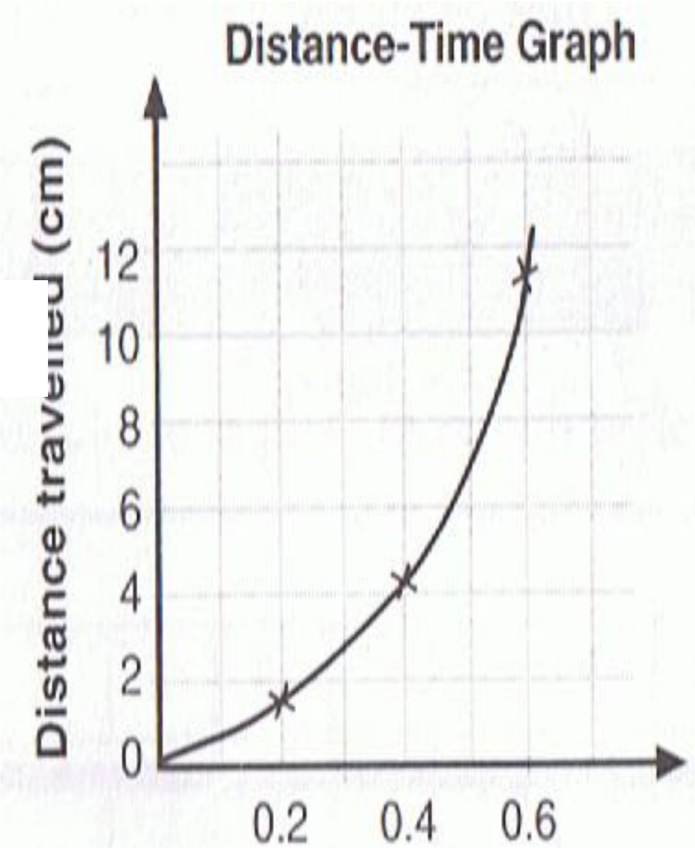
A ticker-tape is attached to a trolley and the motion analysed every 0.2s. The dots made at 0.2, 0.4 and 0.6s are found by counting lots of ten spaces between (10 x 0.02 s = 0.2s). A ruler is used to measure the distance between the dots.

In the tape below the distance between the dots is increasing showing that the trolley is accelerating (speed up).



The time and distance information on the tape can be shown in a table and on a distance-time graph.

Dots	Time (s)	Total distance from the start (cm)
Start	0	0
A to B	0.2	1.5
A to C	0.4	4.6
A to D	0.6	11.0

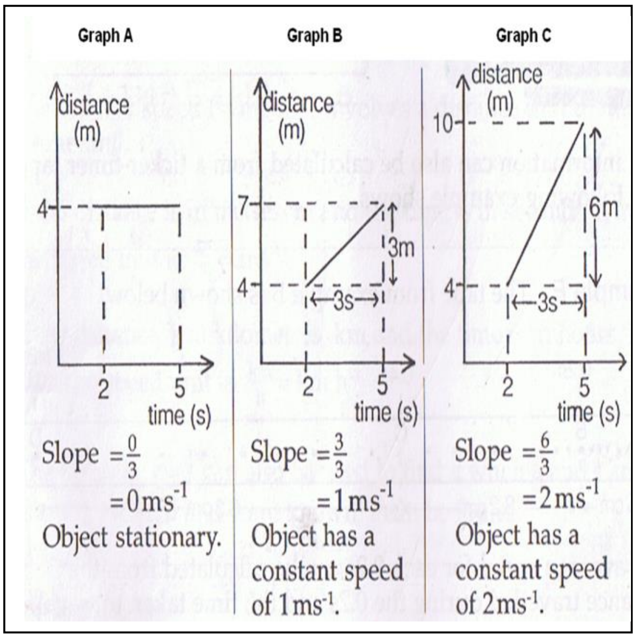


NOTE: From the data recorded in the table – we can also calculate the velocity of the trolley and this information can be used to sketch at velocity-time graph for the trolley.

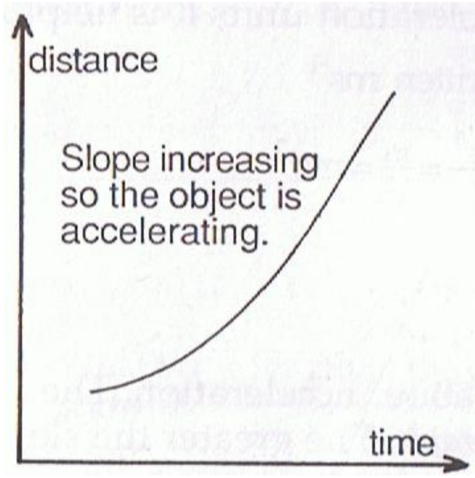
DISTANCE – TIME GRAPHS

- Distance – Time graphs give information about the motion of an object.
- In particular the **slope (gradient)** of the graph gives information about the ***speed*** of the object:

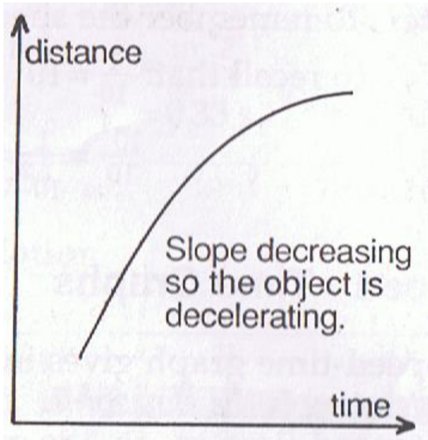
Example: The greater the slope, the greater the speed.



- When the distance-time graph is a **straight line**, the speed is **constant**. (Graph B and Graph C)
- The *speed of an object* is represented by the slope of the distance – time graph.
- If the graph is a **horizontal line** (Graph A), the speed is zero because the object is **stationary** and the slope is zero.
- The greater the slope, the greater the speed (compare Graph B and Graph C).
- When a distance-time graph is not a straight line and the slope is increasing as time increases, the object is accelerating.



- When a distance – time graph is not a straight line and the slope is decreasing as time increases, the object is **decelerating**.



ACCELERATION

- When the speed of an object changes, either slowing down or speeding up, the object is accelerating.
- **Acceleration** (symbol **a**) is calculated from the change in speed divided by the time taken or the change in speed to occur.

$$Acceleration = \frac{change\ in\ speed}{change\ in\ time}$$

$$a = \frac{\Delta v}{\Delta t}$$

Note: ‘Δ’ means a “change in”. Thus ‘Δv’ means the ‘change in speed’ and ‘Δt’ means the “change in time”.

- The unit of calculated acceleration is **meter per second square** or **m/s^{-2}.**

Example: A car is moving at $15ms^{-1}$. The car then speeds up uniformly to $35ms^{-1}$ in 40 seconds. What is the acceleration of the car?

Solution: The change in speed is $\Delta v = 55 - 14 = 20ms^{-1}$.

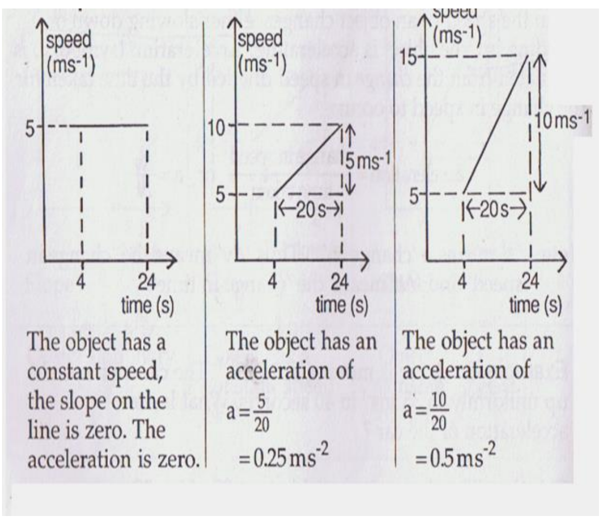
The change in time is 40s

∴ The acceleration is

$$a = \frac{\Delta v}{\Delta t} = \frac{20}{40} = 0.5ms^{-2}$$

SPEED-TIME GRAPHS

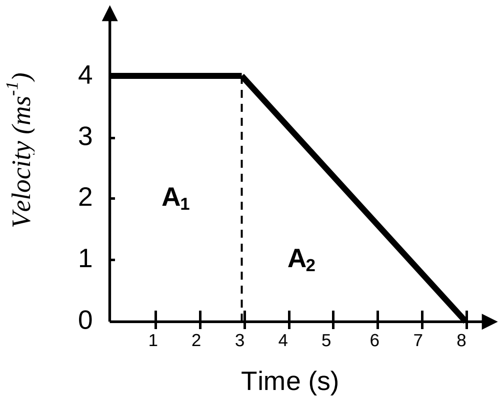
- A speed-time graph gives information about **acceleration**.
- The acceleration is the slope of the speed-time graph.
- The greater the slope of a distance-time graph, the greater the acceleration.



The formula $a = \frac{\Delta v}{\Delta t}$ can be used to find the change in speed, $\Delta \boldsymbol{v}$, if **a** and Δ**t** are known, or it can be used to find the change in time, Δt, if **a** and Δ**v** are known:

- The distance travelled by an object can be calculated from a velocity-time graph by calculating the area under the graph.

Example: Find the **distance** travelled for the velocity-time graph shown and hence find the **average velocity.**



Total distance = Area under the Velocity-Time graph

Total Area = A_1 + A_2

A_1 = L x W (Area of a rectangle)
= 4 x 3
= 12 m

A_2 = ½ (B x H) [Area of a triangle]
= ½ (5 x 4)
= ½ x 20
= 10 m

∴ **Total Area = 12m + 10m = 22m**

$$Average\ Velocity = \frac{total\ distance\ travelled}{total\ time}$$

$$Average\ Velocity = \frac{22}{8}$$

$$\boldsymbol{Average\ Velocity = 2.75ms^{-1}}$$