Rosary School – Marj Elhamam

Unit 1 - Forces and Motion
Chapter 1 - Movement and Position

Name: ___________________	Date: ____ /____ / 2025
Grade: 9 ( )	Subject: **Physics** **Summary notes**

Objectives:

1.3 plot and explain distance–time graphs

1.4 know and use the relationship between average speed, distance moved and time taken:

$$average\ speed = \frac{distance\ moved}{time\ taken}$$

1.5 *practical: investigate the motion of everyday objects such as toy cars or tennis balls*

1.6 know and use the relationship between acceleration, change in velocity and time taken:

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

1.7 plot and explain velocity–time graphs

1.8 determine acceleration from the gradient of a velocity–time graph

1.9 determine the distance travelled from the area between a velocity–time graph and the time axis

1.10 use the relationship between final speed, initial speed, acceleration and distance moved:

$(\text{final speed})^2 = (\text{initial speed})^2 + (2 \times \text{acceleration} \times \text{distance moved})$

$V^2 = u^2 + 2as$

Average speed:

- The speed of an object is the distance it travels every second.
- Speed is a **scalar** quantity. This is because it only has a **magnitude** (without a direction).
- The equation for calculating the average speed of a moving object is:

$$\boldsymbol{Average\ speed = \frac{distance\ moved}{time\ taken}}$$

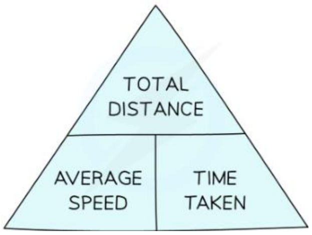
$$\boldsymbol{v = \frac{s}{t}}$$

v = average speed (velocity) in metres per second, m/s

s = distance in metres, m

t = time in seconds, s

- In exams you are expected to ***rearrange*** the formula for average speed to change the subject of the formula to time or distance. You can do this with the help of the formula triangle below:



$$* \, time\ taken = \frac{total\ distance}{average\ speed}$$

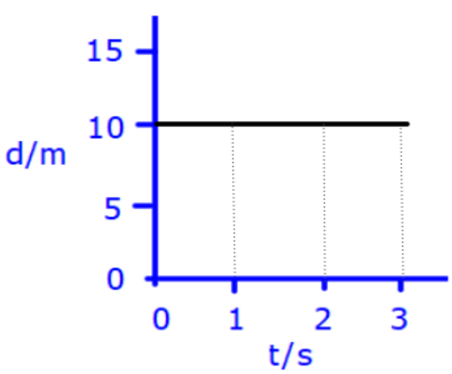
$$* \, total\ distance = average\ speed\ \times time\ taken$$

Example 1:

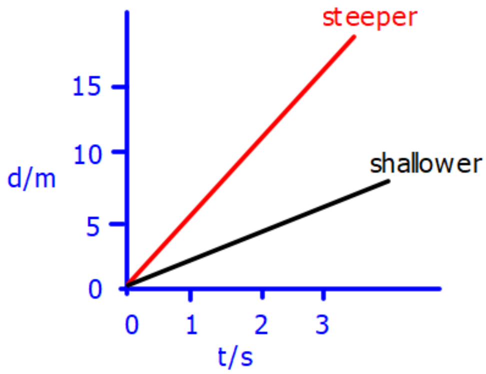
Planes fly at typical speeds of around 250 m/s. Calculate the distance travelled by a plane moving at this average speed for 2 hours. [3]

Distance-time graphs

- Distance-time graphs show how the **distance** of a moving object in a straight line (from a starting position) changes over time.
- Distance-time graphs also show the following information:
  - If the object is moving at a constant speed or changing speed.
  - How large or small the speed is.
- A **straight** line represents **constant** speed, a **curved line** represents changing speed.
- The **slope (gradient)** of the straight line represents the **magnitude** of the speed:

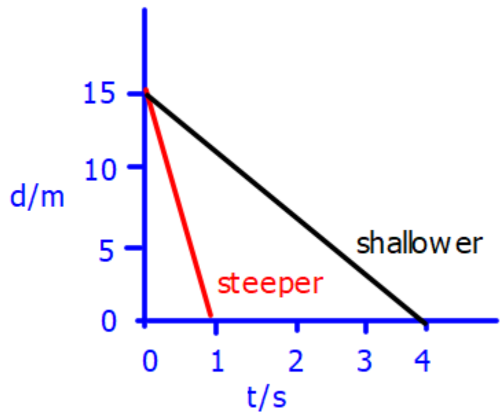


- ➢ flat, horizontal line.
- ➢ gradient = zero
- ➢ object is at rest (stationary)

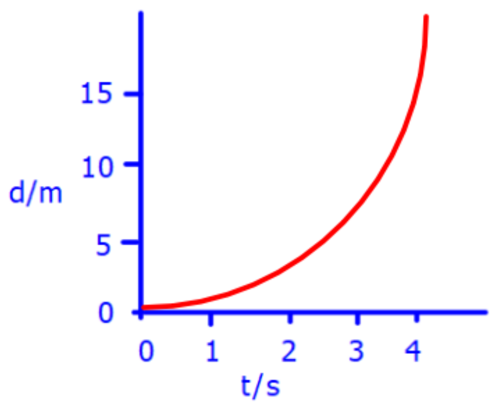


- Straight line, sloping upwards (constant positive gradient) → constant speed, moving away from starting position.
- Steeper line → larger speed.
- Shallower line → smaller speed.

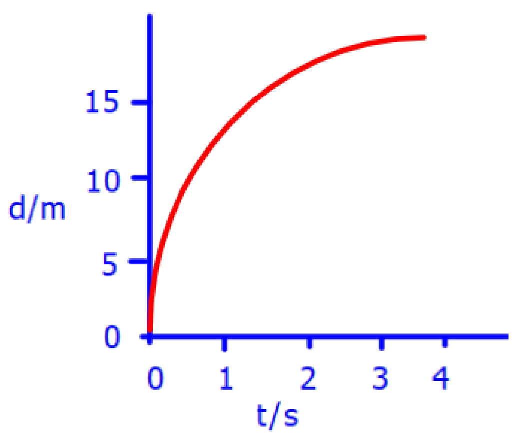
The distance is increasing **uniformly** → constant gradient → constant speed



- Straight line, sloping downwards (constant negative gradient) → constant speed, moving back to starting position.
- Steeper line → larger speed.
- Shallower line → smaller speed.



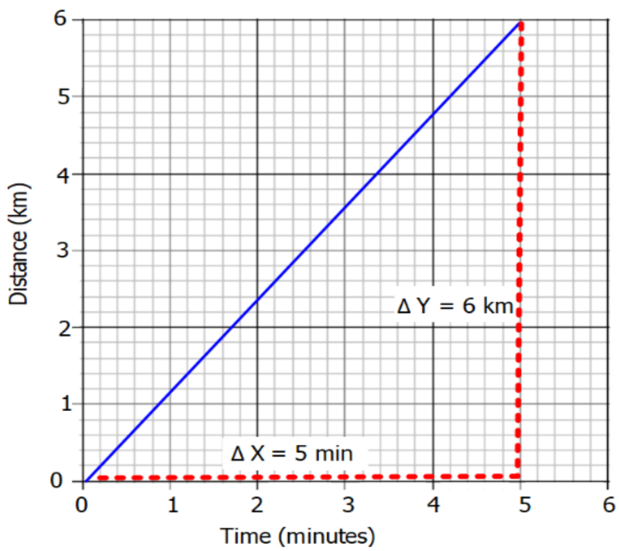
Gradient (steepness) increasing → speed increasing (**acceleration**)



Gradient (steepness) decreasing → speed decreasing (**deceleration**)

- The **speed** of an object can be found by calculating the **gradient** of a distance-time graph.

$$\text{Speed} = \text{Gradient} = \frac{change\ in\ y}{change\ in\ x} = \frac{\Delta y}{\Delta x} = \frac{Rise}{Run}$$



1. Draw gradient triangle and label the magnitudes of rise and run.
2. Pay attention to labelled units and convert to standard units.
   6 km = 6000 m, 5 min = 300 s
3. Calculate gradient to find speed

$$\text{Speed} = \text{gradient} = \frac{\Delta y}{\Delta x} = \frac{6000}{300\ s} = 20\ \text{m/s}$$

Exam tip

- When you draw the gradient triangle, use the entire graph line, where possible, to calculate the gradient.
- Remember to check the **units** of variables measured on each axis. Convert units of variables measured on each axis to standard units.
- *Always double – check which units to use in your calculations and final answer.*

Example 2:

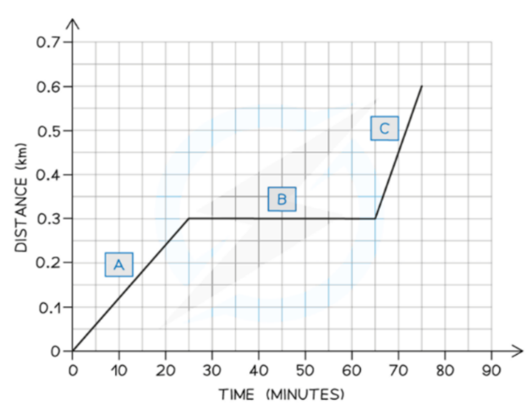
Ose decides to take a stroll to the park. He finds a bench in a quiet spot and takes a seat, picking up where he left off reading his book on Black Holes. After some time reading, Ose realizes he lost track of time and runs home. A distance-time graph for his trip is drawn below.

a. How long does Ose spend reading his book? _______________

b. Which section of the graph represents Ose running home? _____________

c. What is the total distance travelled by Ose? _______________

d. Calculate the speed of Ose in the last 10 minutes of the journey.



Homework: Questions 5, 6 and 7 page 16.

<u>Acceleration</u>:

- Acceleration is defined as **the rate of change of velocity**. In other words, it describes how much an object's **velocity** changes every **second**.
- The equation below is used to calculate the average acceleration of an object:

$$acceleration = \frac{change\ in\ velocity}{time\ taken}$$

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

a = acceleration in metres per second, m/s²

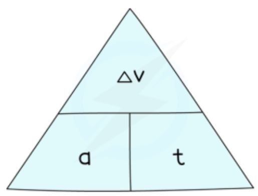
Δv = change in velocity in metres per second, m/s

v = final velocity in m/s

u = initial velocity in m/s

t = time in seconds, s

- In exams you are expected to ***rearrange*** the formula for acceleration to change the subject of the formula to time or change in velocity. You can do this with the help of the formula triangle below:



$$* change\ in\ velocity = acceleration\ \times time$$

$$v - u = a\ x\ t \rightarrow v = at + u$$

$$*time = \frac{change\ in\ velocity}{acceleration} \rightarrow t = \frac{v-u}{a}$$

- The acceleration of an object can be **positive** or **negative**, depending on whether the object is **speeding up** or **slowing down**.
- If an object is **speeding up**, its acceleration is **positive**.
- If an object is **slowing down**, its acceleration is **negative** (**deceleration**).

Example 3:

A Japanese bullet train decelerates at a constant rate in a straight line. The velocity of the train decreases from 50 m/s to 42 m/s in 30 seconds.

a. Calculate the deceleration of the train and explain how your answer shows the train is slowing down.

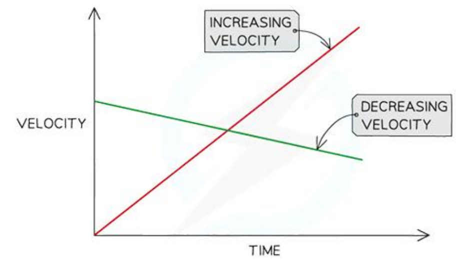
- If acceleration is uniform (constant / straight line on velocity-time graph) and initial velocity ***u*** and final velocity ***v*** are known, then the formula for average velocity is given by:

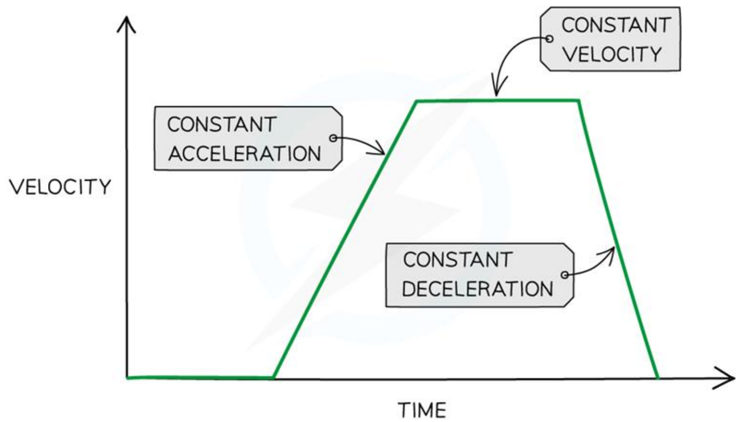
$$average\ velocity = \frac{u + v}{2}$$

b. Calculate the average speed of the bullet train during the 30 seconds.

Velocity-Time Graph and acceleration:

- A velocity-time graph shows how the velocity of a moving object varies with time.
- Velocity-time graphs also show the following information:
  - If the object is moving with a **constant** acceleration/deceleration.
  - The **magnitude** of the acceleration/deceleration



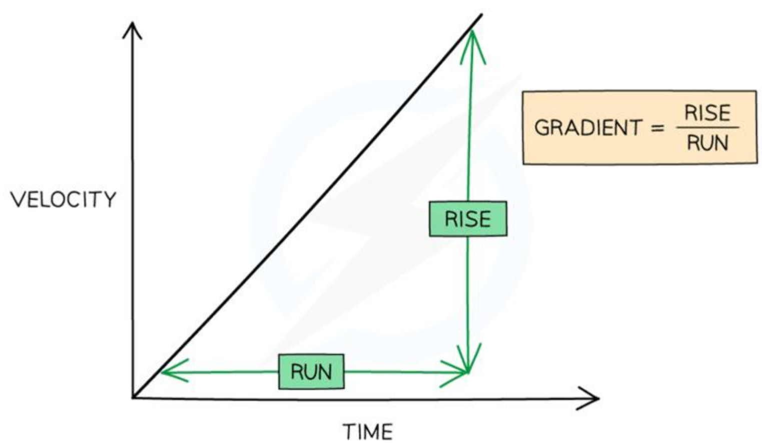


- ➢ Straight line sloping upwards (positive gradient) → constant acceleration.
  - Steeper line → larger acceleration.
  - Shallower line → smaller acceleration.
- ➢ Flat, horizontal line (zero gradient) → constant speed.
- ➢ Straight line sloping downwards (negative gradient) → constant deceleration.

Gradient of a Velocity-Time Graph

The **acceleration** of an object can be calculated from the **gradient** of a velocity-time graph.

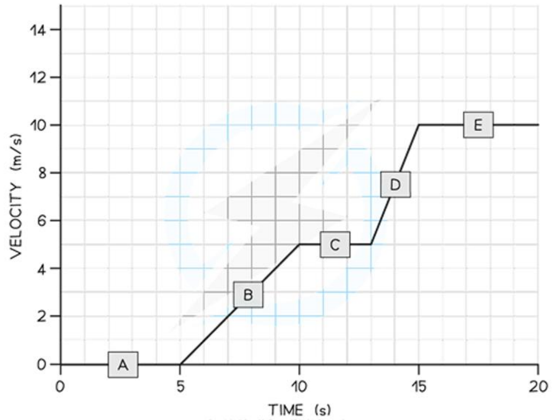
$$\text{Acceleration} = \text{Gradient} = \frac{change\ in\ y}{change\ in\ x} = \frac{\Delta y}{\Delta x} = \frac{Rise}{Run}$$



Example 4:

Tora is training for a cycling tournament.

The velocity-time graph below shows her motion as she cycles along a flat, straight road.



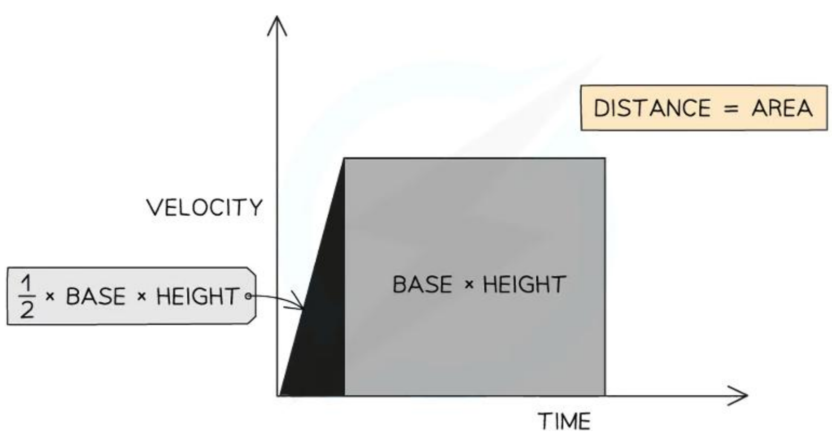
a. In which section (A, B, C, D or E) of the velocity-time graph is Tora's acceleration the largest? ____________________

b. Calculate Tora's acceleration between 5 and 10 seconds.

Homework: Questions 8, 10, 12, 14 &16 pages 16 and 17

Area under a Velocity-Time Graph

- The **area** under a velocity-time graph represents the **displacement** (or **distance** travelled) by an object.



- If the area beneath the graph forms a **triangle** (i.e. the object is accelerating or decelerating), then the area can be determined by using the following formula:

$$\text{Area} = \tfrac{1}{2} \times \text{Base} \times \text{Height}$$

- If the area beneath the graph forms a rectangle (i.e. the object is moving at a constant velocity), then the area can be determined by using the following formula:

$$\text{Area} = \text{Base} \times \text{Height}$$

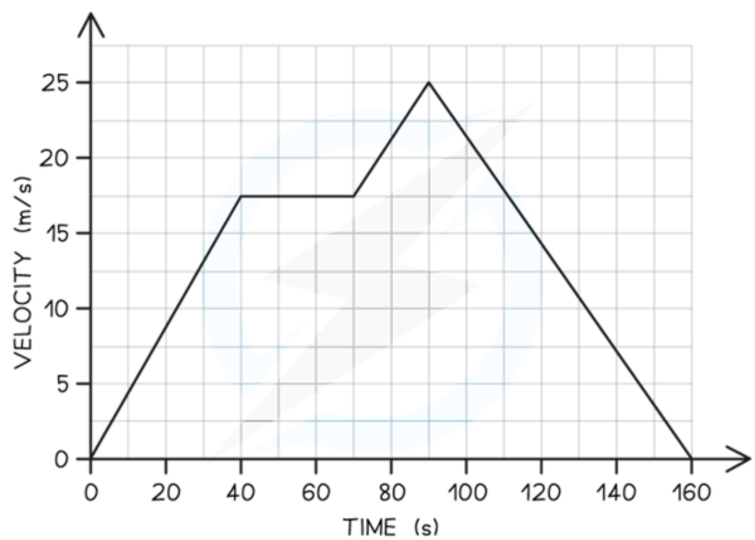
- Area of trapezium = $\frac{a+b}{2} \times height$

Determining Distance from a Velocity-Time Graph

Enclosed areas under velocity-time graphs represent total displacement (or total distance travelled)

Example 5:

The velocity-time graph below shows a car journey which lasts for 160 seconds.



Calculate the total distance travelled by the car on this journey.

- The following equation of motion applies to objects moving with uniform (constant) acceleration:

$(\text{final speed})^2 = (\text{initial speed})^2 + 2 \times \text{acceleration} \times \text{distance}$

$$v^2 = u^2 + 2as$$

- v= final speed in metres per second (m/s)
- u= initial speed in metres per second (m/s)
- a= acceleration in metres per second squared (m/s^2)
- s= distance moved in metres (m)

Example 6:

A car accelerates steadily from rest at a rate of 2.5 m/s^2 up to a speed of 16 m/s. Calculate how far the car moves during this period of acceleration.

Example 7:

A cyclist, whilst overtaking another bike, increases his speed uniformly from 4.2 m/s to 6.3 m/s over a time interval of 5.3 seconds.

a. Calculate the acceleration of the cyclist during this time period.
b. How far does the cyclist travel whilst overtaking?
c. What is the average speed of the cyclist during this time period?

<u>**Homework**</u>: Question 17 page 17

Core practical 1: investigating motion

Aim of the experiment

- The aim of this experiment is to investigate the motion of some everyday objects, by measuring their speed
- Examples of objects that could be used are:
  - a **paper cone**
  - a **tennis ball**
- Measuring speed **directly** is difficult to do; therefore, by measuring distance moved and time taken, the average speed of the object can be calculated
- This is just one method of measuring the speed of different objects - some methods involve the use of light gates to measure speed and acceleration, e.g. for a **toy car** moving down a slope

Variables

- **Independent variable** = Distance, *s*
- **Dependent variable** = Time, *t*
- Control variables:
  - Use the same object (paper cone, tennis ball etc.) for each measurement

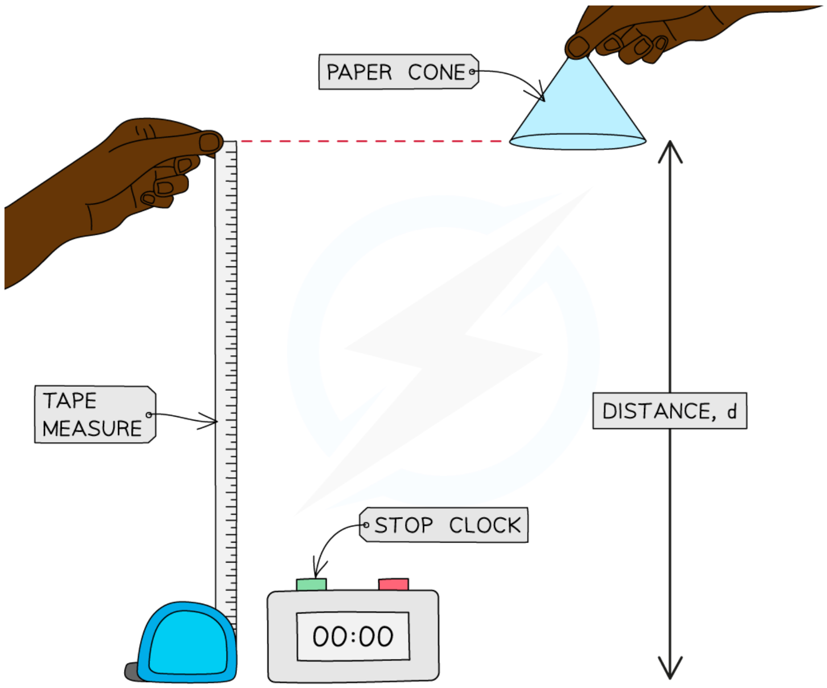
Equipment

Equipment list

Equipment	Purpose
Paper cone / tennis ball	To measure the speed of
Stop watch	To measure time taken
Tape measure / metre rule	To measure distance moved

- **Resolution** of measuring equipment:
  - Ruler = 1 mm
  - Stop clock = 0.01 s

Method



1. Measure out a height of 1.0 m using the tape measure or metre ruler
2. Drop the object (paper cone or tennis ball) from this height, which is the distance travelled by the object
3. Use the stop clock to measure how long the object takes to travel this distance
4. Record the distance travelled and time taken
5. Repeat steps 2-3 three times, calculating an average time taken for the object to fall a certain distance
6. Repeat steps 1-4 for heights of 1.2 m, 1.4 m, 1.6 m, and 1.8 m

Results

Example results table

DISTANCE / m	TIME 1 / s	TIME 2 / s	TIME 3 / s	AVERAGE TIME / s
1.0				
1.2				
1.4				
1.6				
1.8				

A results table should include spaces for all the measurements taken and space to perform any necessary calculations, such as averages

Analysis of results

- The average speed of the falling object can be calculated using the equation:

$$average\ speed = \frac{distance\ moved}{time\ taken}$$

- Where:
    - Average speed is measured in metres per second (m/s)
    - Distance moved is measured in metres (m)
    - Time taken is measured in seconds (s)
- Therefore, calculate the average speed at each distance by dividing the distance by the average time taken.

Evaluating the experiment

Systematic errors

- Make sure the measurements on the tape measure or metre rule are taken at eye level to avoid **parallax error.**
- The average human reaction time is 0.25 s, which is equivalent to half a second per when starting and stopping the timer.
    - This is likely to be significant when small intervals of time are measured.
    - To reduce this systematic error, larger distances could be used resulting in larger time intervals.
    - Using a **ball bearing** and an **electronic data logger**, like a trap door, is a good way to remove the error due to human **reaction time** for this experiment.
- Consider using an electronic sensor, such as **light gates**, to obtain highly accurate measurements of time.
    - The timer on a light gate starts and stops automatically as it passes the sensors positioned at the start and stop points.

Random errors

- Ensure the experiment is done in a space with no draft or breeze, as this could affect the motion of the falling object.

Safety considerations

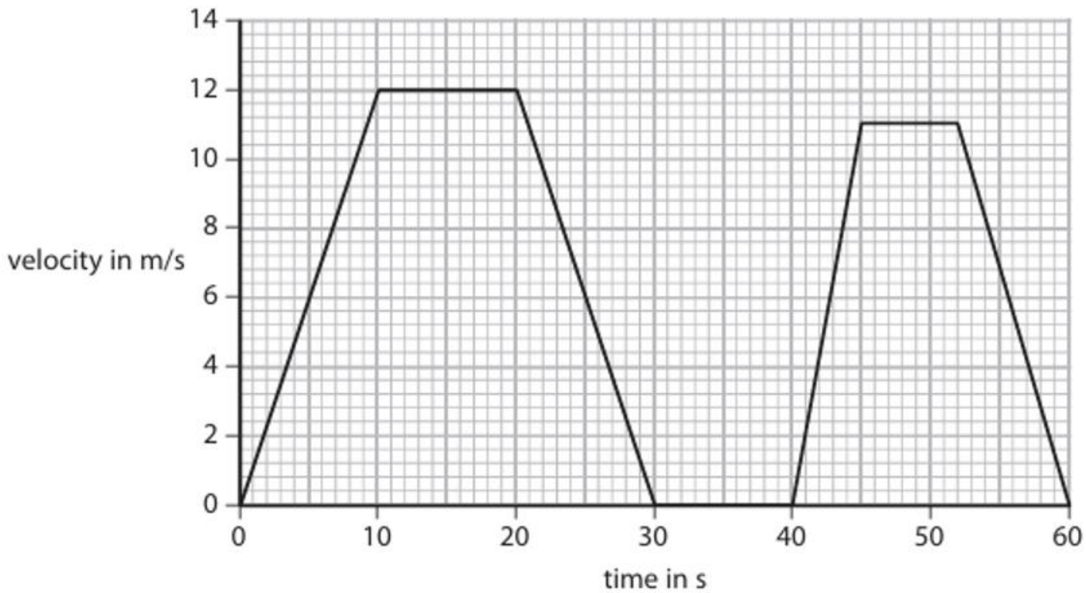
- Place a mat or a soft material below any falling object to cushion its fall.

Past Paper Questions

1- (4Ph0-S 2015- paper 1P – Q2)

A bus travels along a straight road.

The graph shows how the velocity of the bus changes during a short journey.



(a) (i) State the velocity of the bus after 25 s.

(1)

velocity = ... m/s

(ii) How long is the bus stationary during its journey?

(1)

time = ... s

(b) (i) State the equation linking acceleration, change in velocity and time taken.

(1)

(ii) Calculate the acceleration of the bus during the first 10 seconds.

Give the unit.

(3)

acceleration = ... unit ....

(c) (i) State the equation linking average speed, distance moved and time taken.

(1)

(ii) The bus moves a total distance of 390 m during the journey.

Calculate the average speed of the bus.

(2)

average speed = ... m/s

(d) The bus travels further in the first 30 seconds of its journey than it does during the last 30 seconds.

Explain how the graph shows this.

(2)

....

....

....

....

(Total for Question 2 = 11 marks)

2- (4Ph0-S 2015- paper 1PR – Q5)

5 A student investigates the speed of different toy cars as they roll down a slope.

(a) The student makes this prediction.

'The more weight a toy car has the faster it will roll down the slope.'

(i) What is the independent variable in the student's prediction?

(1)

....

(ii) What is the dependent variable in the student's prediction?

(1)

....

(b) State two factors that the student should keep constant in his investigation.

(2)

1 ....

....

2 ....

....

(c) Put ticks (✓) in the boxes to show which pieces of apparatus the student needs for his investigation.

One has been done for you.

(2)

battery	
joulemeter	
micrometer	
newtonmeter	
ruler	✓
stopwatch	
thermometer	

(d) Describe what the student should do to test his prediction that the more weight the toy car has, the faster it will roll down the slope.

(5)

....

....

....

....

....

....

....

....

....

....

(Total for Question 5 = 11 marks)

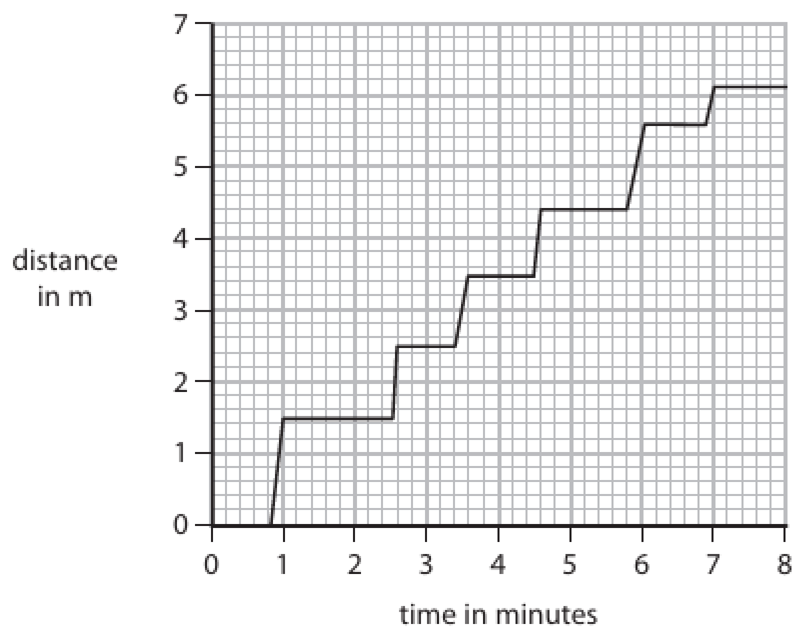
3- (4Ph0-W 2015- paper 1P – Q4)

The diagram shows some people waiting in a queue at a supermarket.

The queue moves forward each time a person leaves the checkout.

Person X spends seven minutes in the queue before reaching the checkout.

The graph shows how distance changes with time for person X.



(a) (i) What is the initial length of the queue?

(1)

initial length = ... m

(ii) Explain how you could use the graph to work out the number of times person X is stationary.

(2)

....

....

....

....

(b) (i) State the equation linking average speed, distance moved and time taken.

(1)

(ii) Calculate the average speed of person X in the queue.

Give the unit.

(3)

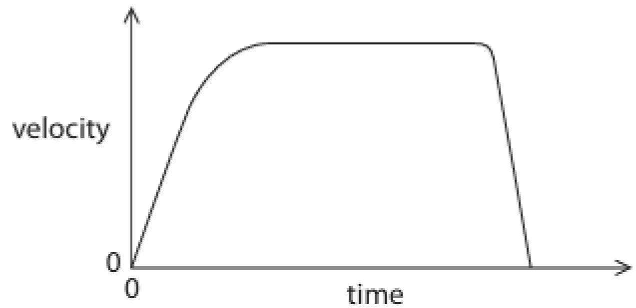
average speed = ... unit ....

(Total for Question 4 = 7 marks)

4- (4Ph0-S 2016- paper 1P – Q1)

A toy car rolls down a ramp and hits a cushion.

The graph shows how its velocity changes with time.



(a) Constant velocity on the graph is shown by

(1)

☒ **A** the area under the line

☒ **B** the horizontal part of the line

☒ **C** the sloping line at the end

☒ **D** the sloping line at the start

(b) The distance travelled is shown by

(1)

☒ **A** the area under the line

☒ **B** the horizontal part of the line

☒ **C** the sloping line at the end

☒ **D** the sloping line at the start

(c) The average velocity of the toy car is given by

(1)

☒ **A** the change in velocity divided by the time taken

☒ **B** the distance moved divided by the time taken

☒ **C** the time taken divided by the change in velocity

☒ **D** the time taken divided by the distance moved

(Total for Question 1 = 3 marks)

Teacher: Zeina Abu Manneh