Cambridge Assessment International Education

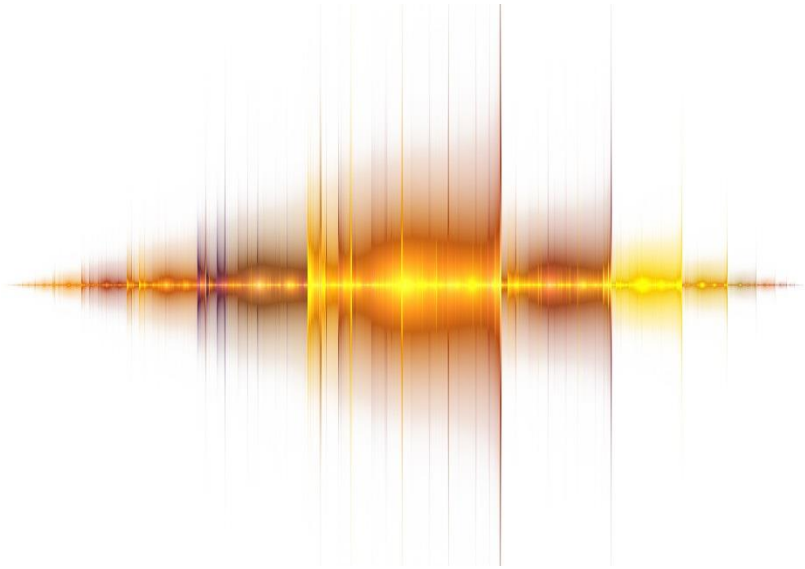
Teaching Pack

Speed-time graphs

Cambridge IGCSE™

Combined Science 0653

This *Teaching Pack* can also be used with the following syllabuses:
- Cambridge IGCSE™ Physics (9–1) **0972**
- Cambridge IGCSE™ (9–1) Co-ordinated Sciences (Double Award) **0973**
- Cambridge IGCSE™ Physical Science **0652**
- Cambridge O Level Physics **5054**
- Cambridge O Level Combined Science **5129**



Version 2.0

Cambridge Pathway

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Lab lesson: Option 2 – virtual experiment

Debriefing lesson

Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note

Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

↓

Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experiment skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experiment skills introduced in the *Briefing lesson*.

↓

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this *Teaching Pack* you will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Speed-time graphs

This *Teaching Pack* focuses on a speed-time experiment. Your learners should be able to define speed and calculate an average speed by using the equation: $\frac{\text{total distance}}{\text{total time}}$

In this experiment the speed of a toy car as it moves down a ramp will be investigated. Your learners will then have the opportunity to practise plotting and interpreting speed-time graphs.

This experiment has links to the following syllabus content (see syllabus for detail):

- P1.2 Motion

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- take readings from an appropriate measuring device or from an image of the device
- plan to take a sufficient number and range of measurements
- present and analyse data graphically
- draw an appropriate conclusion

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- P1.1 Length and time
- P1.2 Motion

Going forward

The knowledge and skills gained from this experiment will be useful for teaching other features of motion graphs with learners.

Briefing lesson: Application of graphs

Resources	• Metre rules (enough for one between two) • Stop watches (enough for one between two) • Toy cars, or tokens (enough for one between two) • Worksheets A, B, C, D and H • Sticky notes
Learning objectives	By the end of the lesson: • ***all*** learners should be able to recognise and interpret a distance-time graph • ***most*** learners should be able to use the average speed equation and apply it to graphs • ***some*** learners will be able to understand the link between distance-time graphs and speed-time graphs

Timings	Activity
15 min	**Starter/Introduction** Give your learners Worksheet A. It shows the speed-time graph for a 100m sprint. There are empty boxes for your learners to describe what is happening with the two runners at different points in the race. One example has been done to help them get started. They can work in pairs for this activity.
15 min	**Main lesson** Working in pairs, your learners should now look at Worksheet B. They need a metre rule, a stop watch and a token or toy car. One partner should choose a graph to act out using the equipment. They should not say which graph they are enacting – it is their partner's job to guess this by observing their demonstration. They can then swap roles so the observer becomes the enactor.
10 min	Your learners should use Worksheet C to compare the features of distance-time graphs with the equivalent speed-time graphs. You can provide differentiated tasks by directing your learners to complete Part A or B of the worksheet.
10 min	Your learners should use Worksheet D to consolidate their understanding of $\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$
10 min	**Plenary** Give your learners the method for the experiment (Worksheet H). Hand out the sticky notes and ask them to label any strengths and weaknesses of the method. They can share their findings in a class discussion.

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • Teacher walkthrough video • Worksheets E, F, G, H and I • Equipment outlined in Teacher notes
Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe an experiment and interpret a speed-time graph • ***most*** learners should be able to carry out an investigation to produce a speed-time graph for a range of situations • ***some*** learners will be able to carry out an investigation and analyse the results to find the acceleration of an object from a speed-time graph

Timings	Activity
10 min	**Starter/Introduction** Show your learners the equipment available to them to complete the experiment. Make sure that you briefly outline the role of any technical equipment, e.g. data loggers or apps you are going to use.
10 min	**Main lesson** Arrange you learners into small groups and ask them to use Worksheet E to help them to plan their method. Three levels of support are offered on the worksheet. Once they have decided on their method with their group, each learner should individually write up their method. Worksheet F (more able) and Worksheet G (less able) are available to help them to do this.
20 min	Working in groups, your learners should now collect the equipment and set this up to carry out the investigation. They may find it useful to follow the diagram on Worksheet I. Learners can refer to the method described in Worksheet H as they carry out the investigation. Please be aware that you may need to provide your own technical guidance sheet for your learners depending on the equipment/app you use to track the progress of the car down the ramp.
15 min	Your learners should draw their own graphs from the data, or interpret the graphs that have been produced by the programs/apps they have used and explain their findings. Abler learners should be able to find the gradient of the speed-time graph to find the acceleration of the toy car at various points. **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that any tablet/camera/equipment is securely positioned.
5 min	**Plenary** Your learners could estimate the area under their speed-time graphs to find out the distance travelled. They can compare this with the distance recorded on the distance time-graph generated by the program/app they have used.

Teacher notes

Watch the *Teacher walkthrough* video and read these notes.

Each group will require:

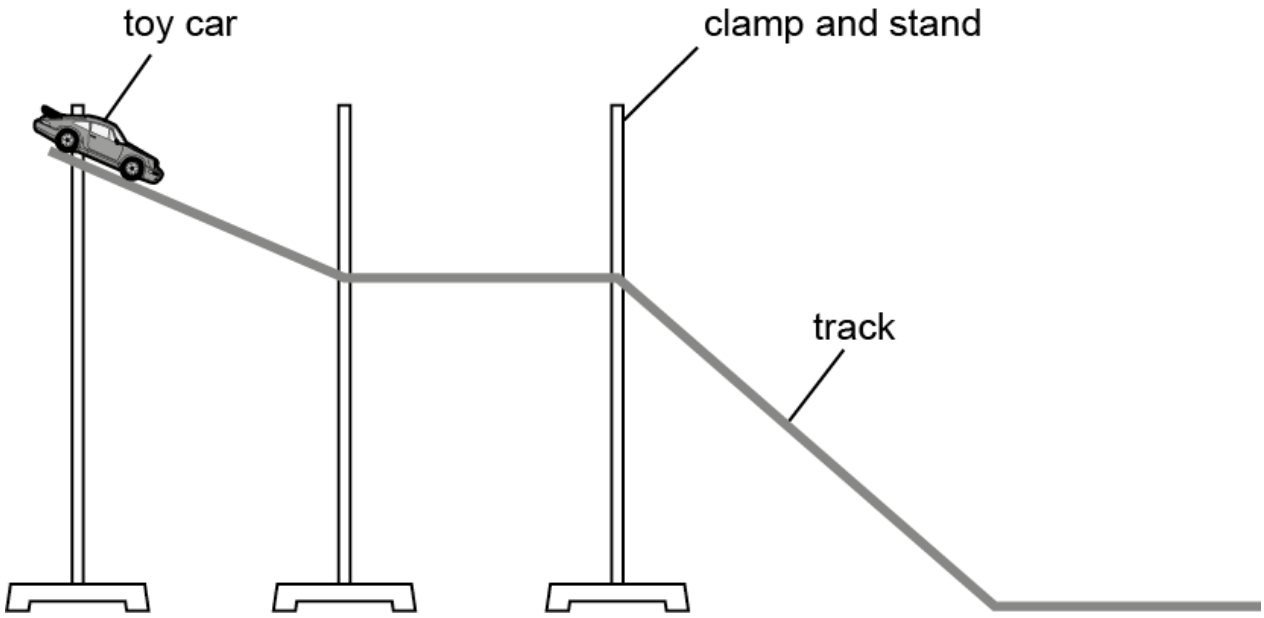
- a toy car
- a flexible track for the car
- clamps and stands to support the track
- materials to produce a marker for the top of the car, e.g. white-tac, card and a permanent marker
- a way to record the path of the toy car, e.g. a video analysis app or computer programme
- any equipment that is necessary to support the video analysis app/program you are using, e.g. a data logger, video camera, tablet or laptop
- graph paper, or access to a printer

Safety

There are no specific risks associated with this experiment.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. Give them Worksheet H.

Before you begin:
Plan how you will group your learners during the experiment session.

Think about:
- the number of groups you will need (group size 2–4 learners)
- the amount of equipment required
- the amount of electronic equipment required
- whether the groups using similar ramps and cars

Experiment
Circulate during the experiment in case your learners encounter any difficulties.

Steps	Notes
1. Learners should collect the equipment they require from the front of the class.	*There are different computer packages available that can be used to draw a motion graph of the toy car travelling down the ramp.*
2. They should find a space in the classroom where the equipment can be assembled safely	
3. Make sure your learners can switch on the equipment they are using and can find the relevant programme/app.	*Remind learners of any specific requirements for the app/program/electronic equipment you are using.*
4. Learners should run the car down the ramp several times in order to ensure that it travels smoothly	*Care must be taken during set up to ensure that the car does not travel too fast directly into any electronic devices.*
5. Learners should record the car travelling down the ramp using the video analysis program/app.	
6. Make sure your learners can export and print the data ready to create their speed-time graphs.	

Clear-up
After the experiment learners should:
- tidy up their work space and return all equipment to you.

Lab lesson: Option 2 – virtual experiment

Resources	• Virtual experiment video • Worksheets E, F, G, J, K and L
Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe an experiment and interpret a speed- time graph • ***most*** learners should be able, with help, to plan an investigation to produce a speed- time graph for a range of situations • ***some*** learners will be able to plan an investigation and analyse the results to find the acceleration of an object from a speed - time graph

Timings	Activity
10 min	**Starter/Introduction** Using Worksheet J, show your learners the equipment available to complete the experiment. Make sure that you briefly outline the role of the app.
10 min	**Main lesson** Arrange your learners into small groups and ask them to use Worksheet E to help them to plan their method. Three levels of support are offered on the worksheet. Once they have decided on their method as a group, each learner should individually write up their method. Worksheet F (more able) and Worksheet G (less able) are available to help them to do this.
20 min	Watch the first part of the virtual experiment video and ask your learners to compare the method used in that to their own method. They should note the differences, between them, and, for each one, decide which method is best and justify their choice. Then watch the remainder of the video.
15 min	Using Worksheet K, learners should plot a speed-time graph based on the data in the table, which was collected from the curved track experiment shown in the video. There is also data for a straight track for your learners to consider (Worksheet L). More able learners should be able to find the gradient of the speed- time graph to find the acceleration of the toy car at various points.
5 min	**Plenary** Your learners could estimate the area under their speed-time graphs to find out the distance travelled.

Debriefing lesson: Validity of data

Resources	• Worksheet M
Learning objectives	By the end of the lesson: • ***all*** learners should be able to calculate the average speed of the toy car travelling down the ramp and evaluate the method • ***most*** learners should be able to calculate the average speed of the toy car travelling down the ramp and agree on the best method to obtain valid results • ***some*** learners will be able to provide constructive comments on the best method to obtain valid results and evaluate the data

Timings	Activity
10 min	**Starter/Introduction** Ask the learners to predict the results from the equipment set-up shown on Worksheet M. What changes in speed would they expect to see as the car moves past each of the markers? They can share their ideas as a class.
20 min	**Main lesson** Worksheet M will provide your learners with some data from this experiment. They will need to calculate the mean value of the time taken for the toy car to travel between different markers and use the equation given to calculate the average speed between the markers. They then need to complete the questions on the worksheet.
10 min	In discussion, learners should be able to appreciate that the average speed between the markers varies and therefore using two points on a ramp does not provide an accurate method to measure instantaneous speed of the toy car at any point.
10 min	Learners should discuss how the validity of this method could be improved. It is likely they will compare this method to video analysis. A video analysis app provides an instantaneous speed at any given point on the ramp because it measures the speed of the car many times every second. Your learners should be able to understand why the method using the video analysis app provided a more accurate interpretation of the experiment and therefore more valid data.
10 min	**Plenary** Your learners should evaluate the method they used in the experiment, or saw in the video, and explain why the results were reliable. They should be able to explain how using video analysis improved the validity of the results and made the conclusions more accurate.

Worksheets and answers

	Worksheets	Suggested answers
For use in the *Briefing lesson*:		
A: 100 m sprint	**13**	**28**
B: Demonstrate the graph	**14**	**—**
C: Distance and velocity graphs	**15–16**	**29–30**
D: Distance, average speed and time	**17**	**31**
H: Method	**21**	**—**
For use in *Lab lesson: Option 1*:		
E: Planning an experiment	**18**	**—**
F: Writing a method	**19**	**—**
G: Writing a method with support	**20**	**—**
H: Method	**21**	**—**
I: Set-up diagram	**22**	**—**
For use in *Lab lesson: Option 2*:		
E: Planning an experiment	**18**	**—**
F: Writing a method	**19**	**—**
G: Writing a method with support	**20**	**—**
H: Method	**21**	**—**
J: Available equipment	**23**	**—**
K: Speed-time data for curved track	**24**	**32**
L: Speed-time data for straight track	**25**	**33**
For use in the *Debriefing lesson:*		
M: Data validity	**26–27**	**34–35**

Worksheet A: 100 m sprint

Look at the speed-time graph of a 100 m race. It shows how two runners proceed during the race. Use the spaces provided to describe what is happening at different points in the race. One has been done for you.

1 Runner 1 begins the race very fast, reaching 60 m in just 5 seconds.

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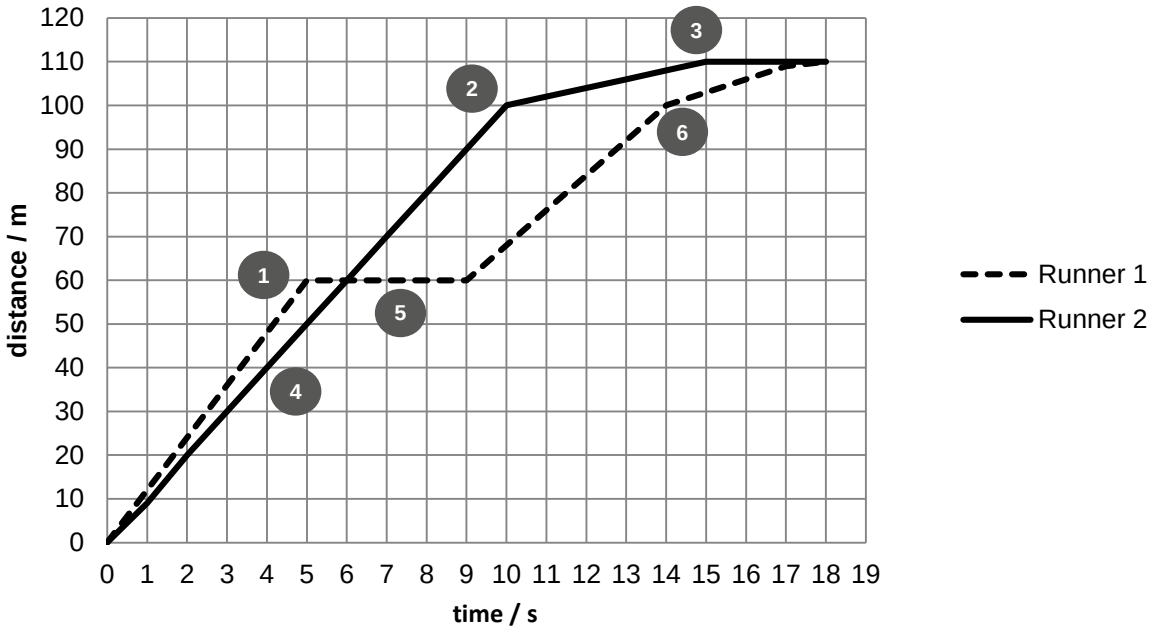

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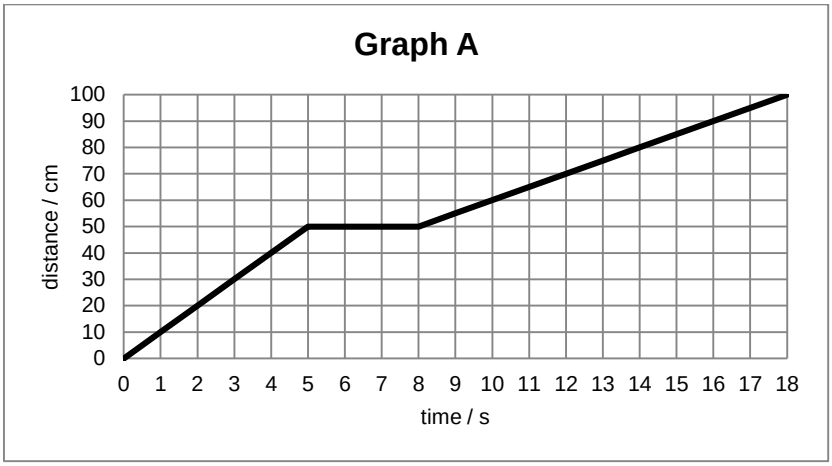
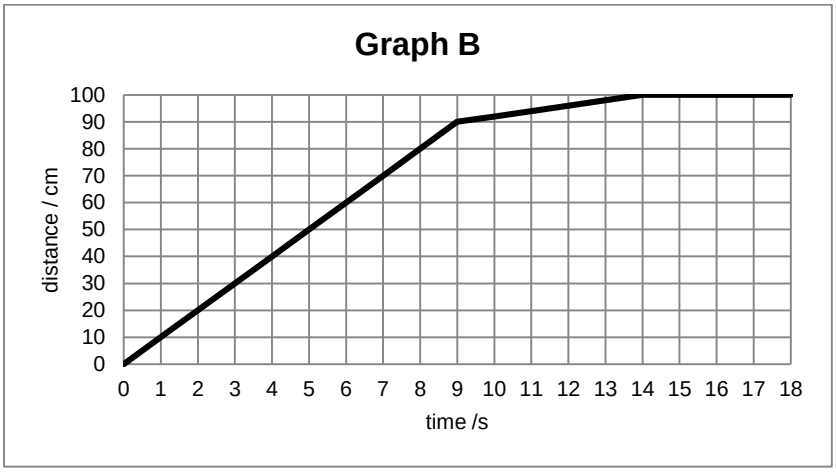
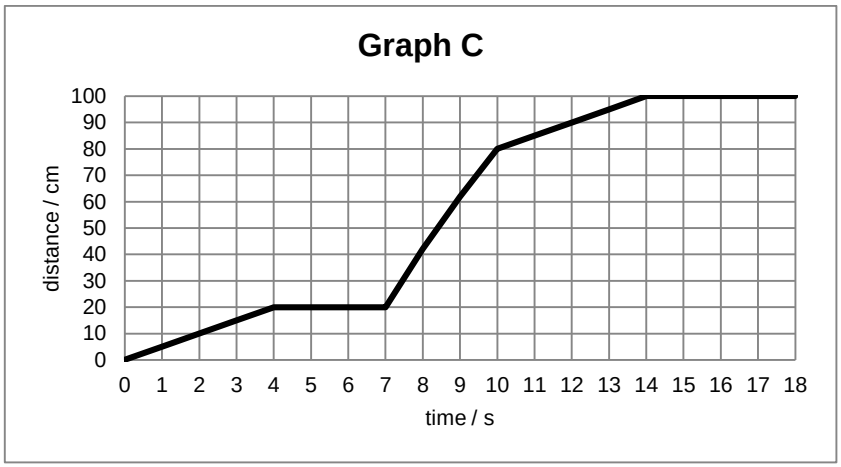
Worksheet B: Demonstrate the graph

You should work in pairs for this activity.

1. Lay out the metre stick on the floor or your desk.
2. One of you chooses one of the graphs below to demonstrate – do not tell your partner which one you have chosen.
3. Use the stop watch to help you move your toy car or token along the metre rule so that you act out the movement of the car shown on the graph.
4. Your partner should observe this and try to guess which graph you are acting out.



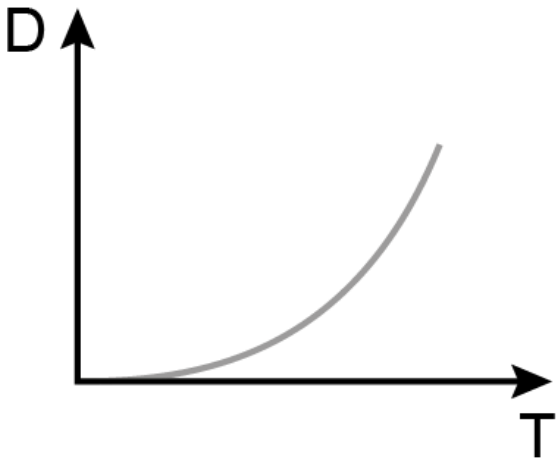


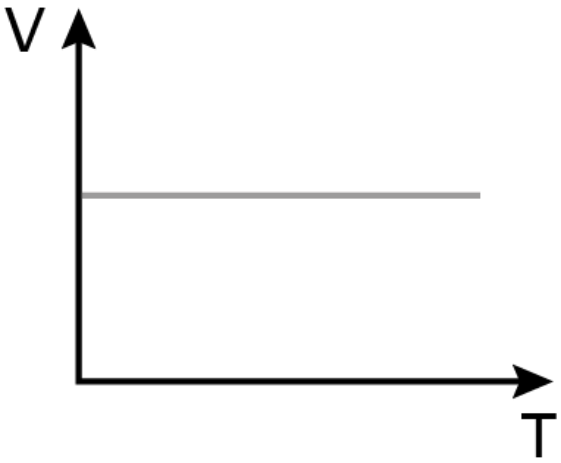


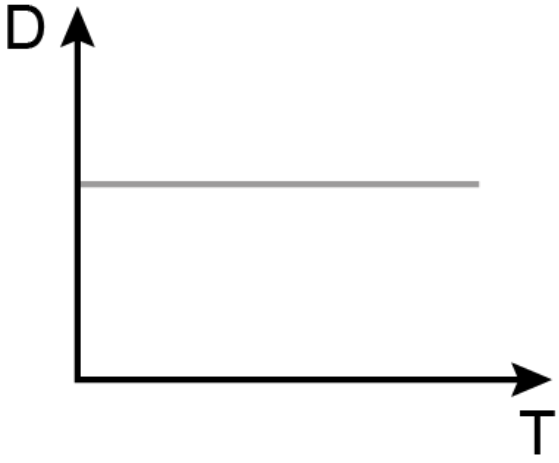
Worksheet C: Distance and velocity-time graphs

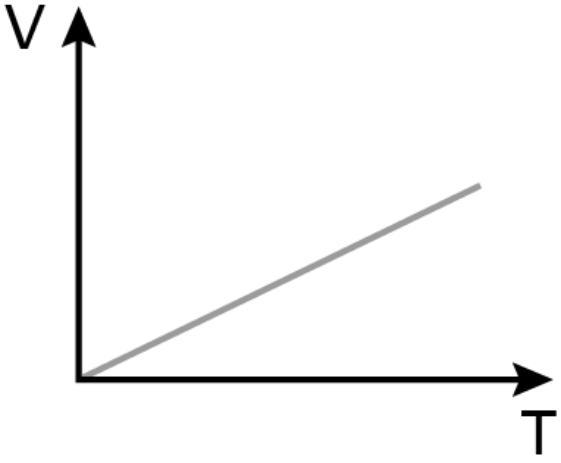
Part A

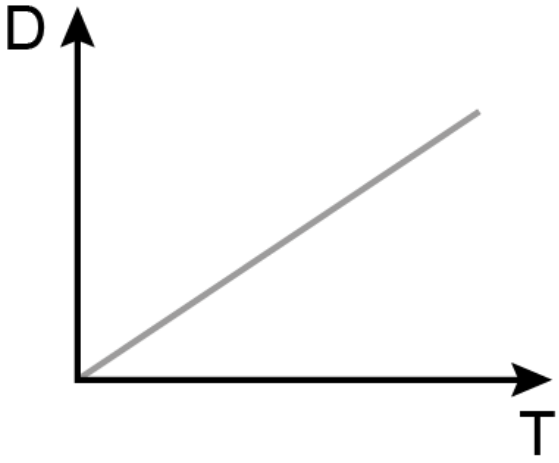
Look at the distance-time graphs shown on the left and draw a line to match them to the right velocity-time graph on the right.

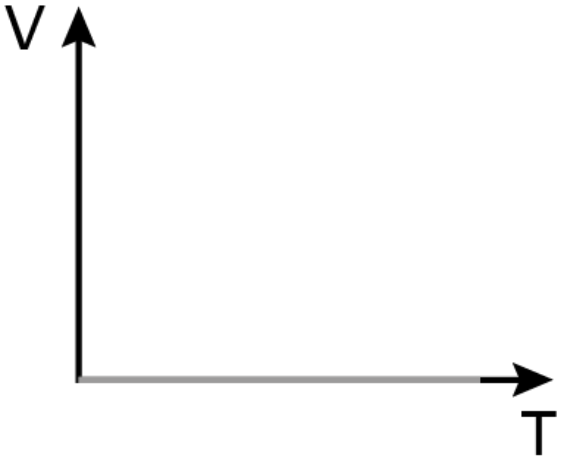








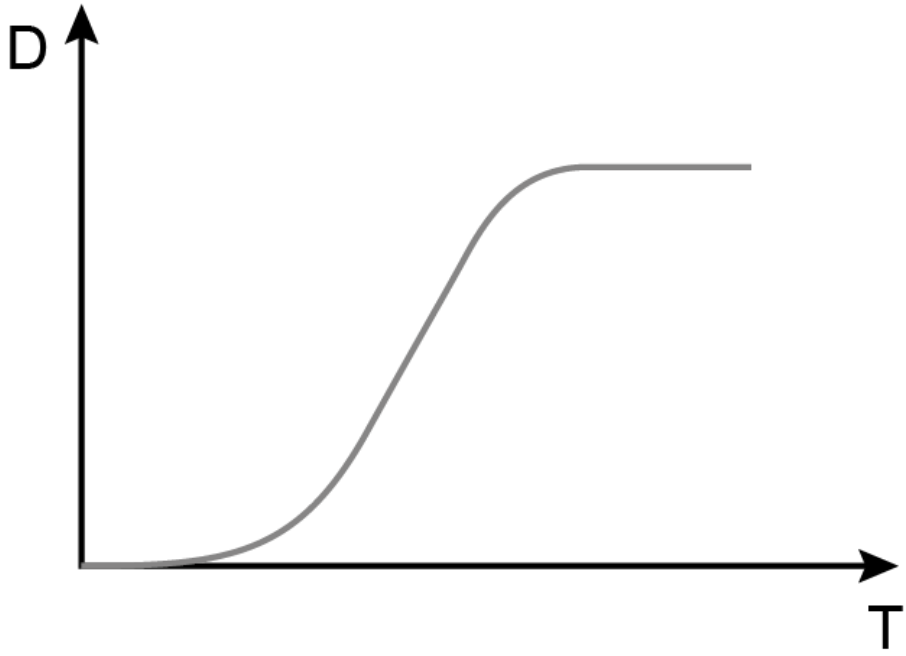




Worksheet C: Distance and velocity-time graphs

Part B

Sketch the velocity-time graph that would be produced from the distance-time graph shown below.



Worksheet D: Distance, average speed and time

Use this equation to answer the following questions.

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

1. The current world record for running a 100 m race is 9.58 s. What is the average speed?

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2. An arrow is shot by an archer and travels for 2.3 s at an average speed of 76 m/s before it hits the target. How far is the target from the archer?

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3. A sound wave in air travels at a speed of around 330 m/s. How long will it take for the sound wave to travel 524 m in air?

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4. If the sound of thunder reaches your house 3.5 s after you see the lightning, how far from your house did the lightning strike?

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Worksheet E: Planning an experiment

Use the suggestions below to help you decide how you could use the apparatus to record the speed-time graph of a toy car.

Depending on how confident you feel about planning your method, choose the column that gives you the right level of support.

Low-level support	Mid-level support	High-level support
How can we make sure that the speed of the toy car changes along the track?	How can you use clamps and stands to change the inclination of the track at different points?	If you lay out the track so that it slopes at two points, with a flat bit in the middle and at the end, how will the speed of the toy car change?
Problem: can we measure/calculate the speed of the toy car accurately at any point with just a stop watch and knowing the distance along the track?	What can you find out about the toy car, if you know the distance of the track and the time taken? Is that enough to plot the speed of the toy car at different times along the track?	The calculations of speed you can make from knowing the distance and time taken to travel down the track only tell you the average speed. Does that give you an accurate measure of the speed at different points on the track?
How can we use a motion analysis program/app to track the movement of the toy car?	How can we use a motion analysis program/app to track the movement of the toy car and then draw a speed-time graph?	A motion analysis program/app can track the position of the toy car at any point and time on the track. The program/app can also plot a distance-time and speed-time graph for you.

Worksheet F: Writing a method

Use the space below to record your method.

An investigation to study the speed of a toy car travelling down a track

Equipment	Method
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Don’t forget to think about safety precautions

Worksheet G: Writing a method with support

Use the space below to record your method.

An investigation to study the speed of a toy car travelling down a track

Equipment

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Method

Think about these questions:

1. What will you do with the toy car and the track?
2. What height will you release the toy car from? Why?
3. How will you release the toy car? Why?
4. Why are you using a motion tracking app instead of a normal stopwatch?

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Worksheet H: Method

1. Collect all of your equipment from the front of the class
2. Set up the car track as shown in the diagram on Worksheet I.
3. Use clamps and stands to secure the first slope to an angle of about 10º, then allow a flat section, followed by another steeper slope of about 20-30º.
4. The last flat section should rest on the table, or the floor.
5. Make sure the clamps and stands do not stop the car from running smoothly down the track.

To check this, release the car several times from the top of the track

6. Set up the electronic equipment you will be using to track the progress of your car down the track.

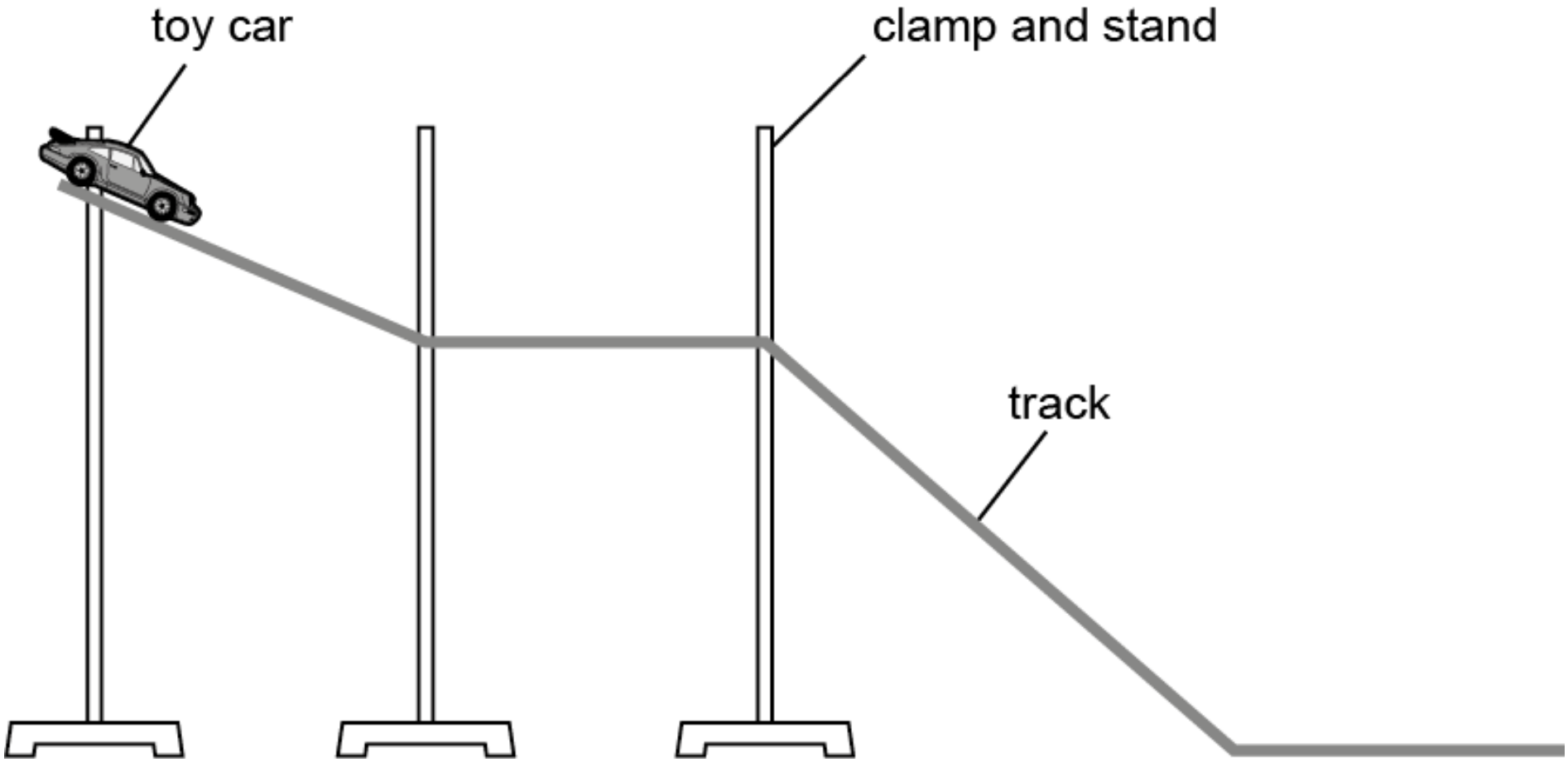
Be careful with the electronic equipment. Make sure it is held securely at all times. Your teacher will provide you with extra information to help you use the app or computer program to track the progress of your car.

7. View the output from your video analysis and check it is as you would expect.

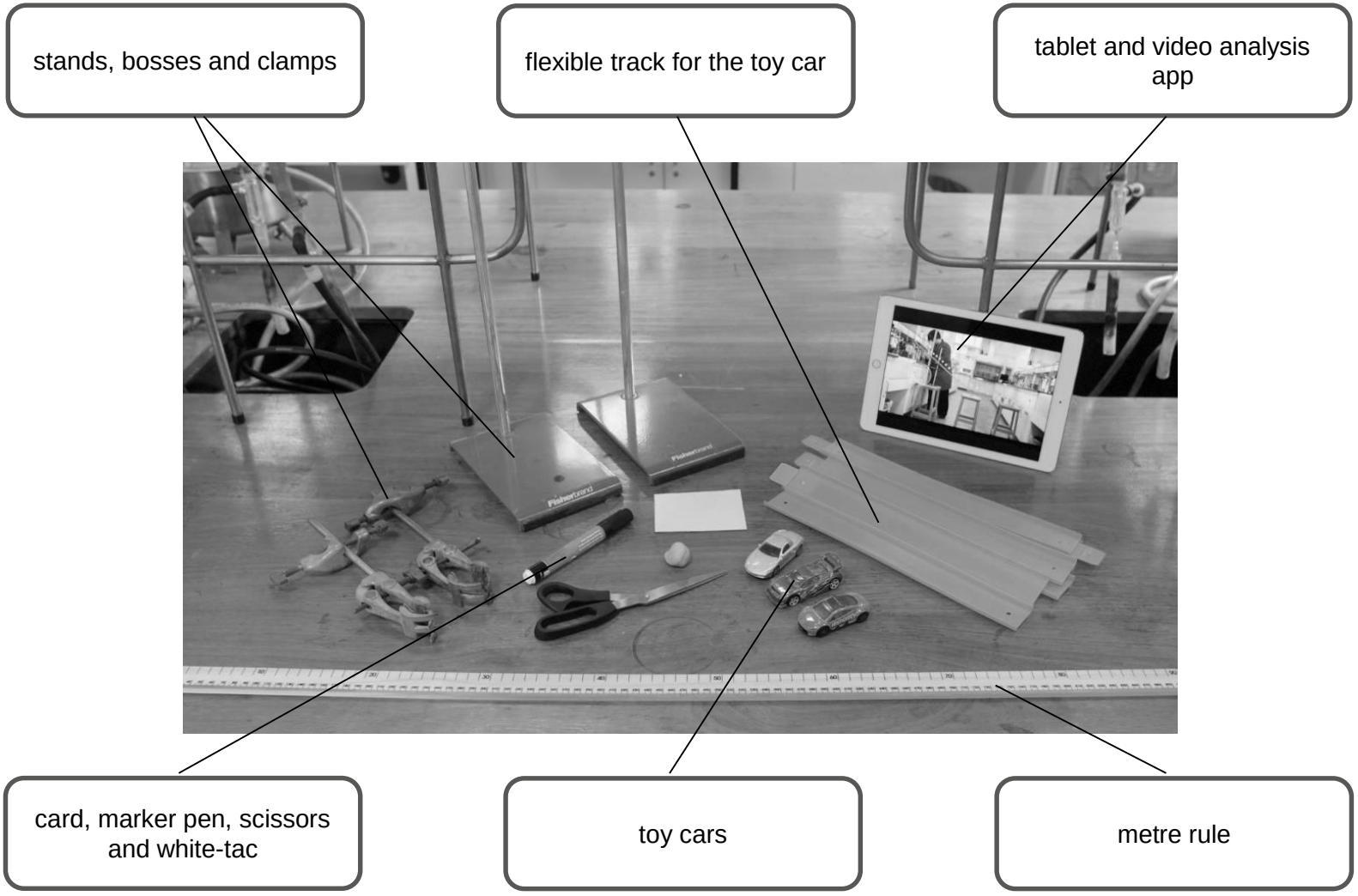
You may need to make adjustments and re-record the data

8. Extract the data from the video analysis program/app so that you can plot a speed-time graph for your experiment.

Worksheet I: Set-up diagram



Worksheet J: Available equipment



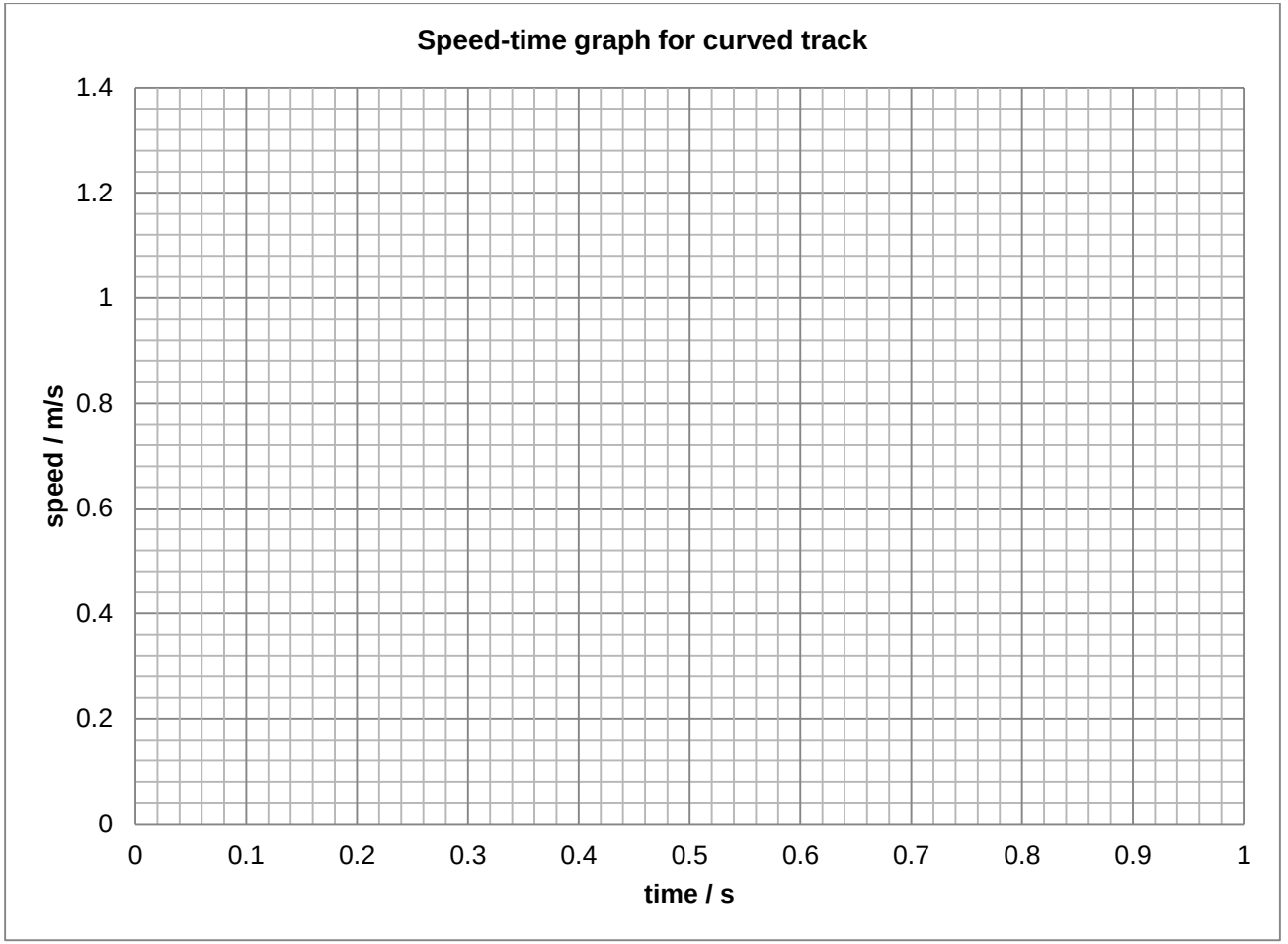
Worksheet K: Speed-time data for curved track

The data in the table below was collected from the curved track experiment shown in the video.

Use this to plot a speed-time graph for this experiment.

When you have finished plotting your points, make sure that you join them with a smooth line of best fit.

Time / s	Speed / m/s
0.00	0.00
0.04	0.01
0.10	0.28
0.14	0.31
0.20	0.46
0.24	0.55
0.30	0.67
0.34	0.71
0.40	0.84
0.44	0.90
0.50	0.97
0.54	1.00
0.60	1.06
0.64	1.08
0.70	1.14
0.74	1.16
0.80	1.21
0.84	1.23
0.90	1.29
0.94	1.30
1.00	1.32



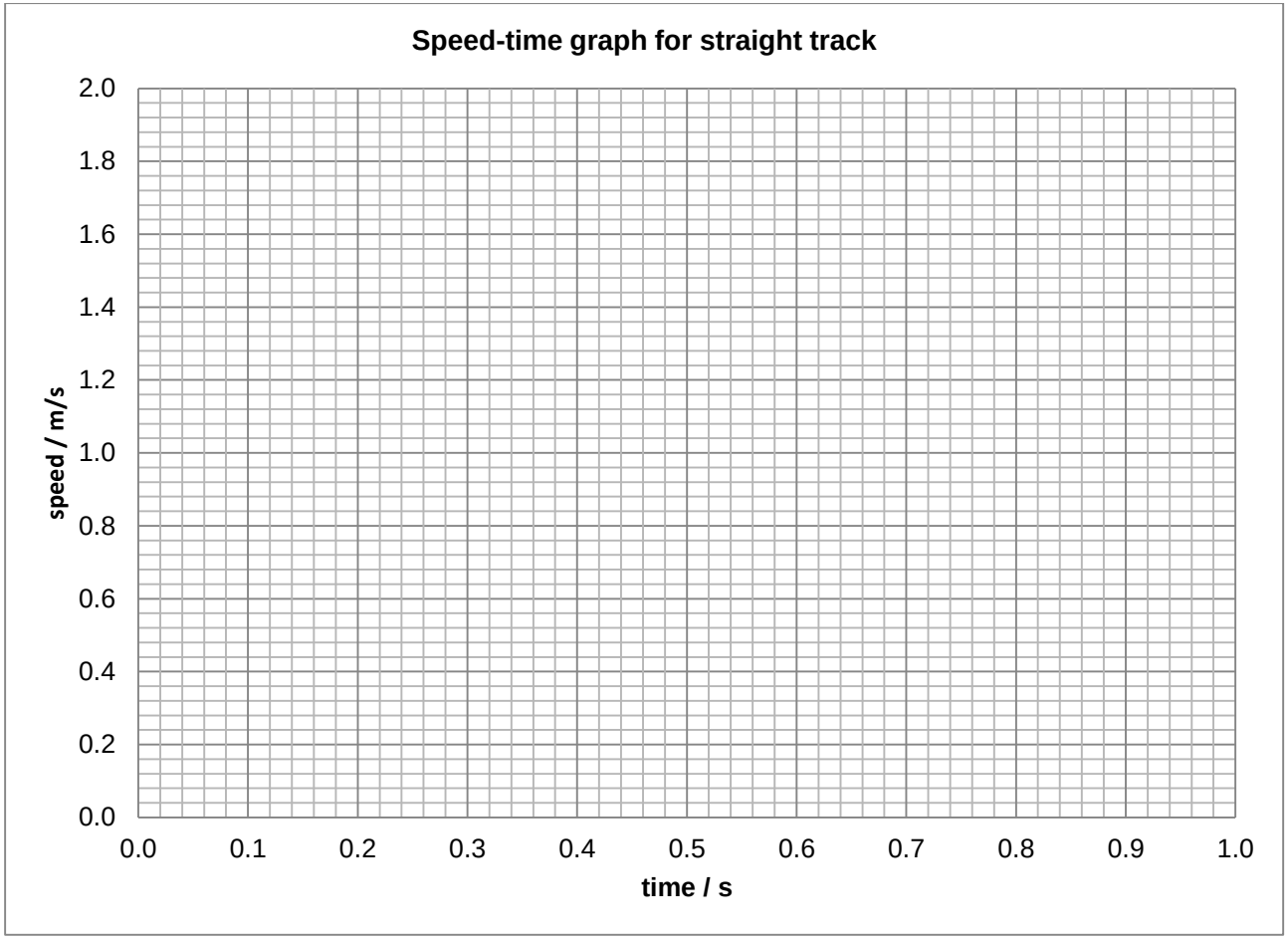
Worksheet L: Speed-time data for straight track

The data in the table below was collected from a straight track, set up using the same equipment as the curved track shown in the video.

Use this to plot a speed-time graph for this experiment.

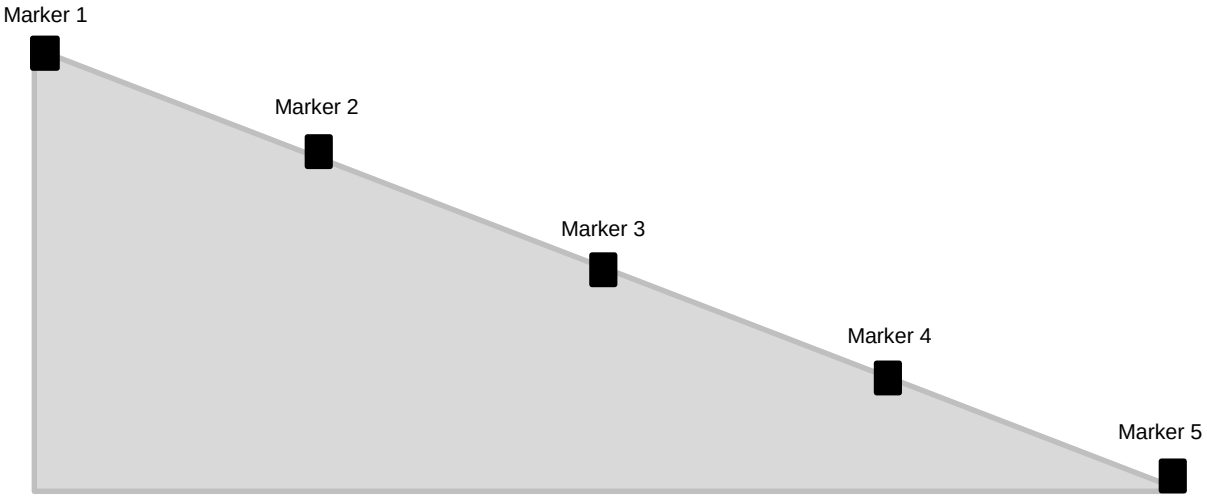
When you have finished plotting your points, make sure that you join them with a smooth line of best fit.

Time / s	Speed / m/s
0.00	0.00
0.03	0.03
0.10	0.23
0.13	0.32
0.20	0.52
0.23	0.60
0.30	0.74
0.33	0.82
0.40	0.95
0.43	1.03
0.50	1.16
0.53	1.23
0.60	1.37
0.63	1.42
0.70	1.55
0.73	1.62
0.80	1.72
0.83	1.78
0.90	1.86
0.93	1.92
1.00	1.99



Worksheet M: Data validity

A ramp was set up like the diagram below with five visible markers.



A toy car was released from the top of the ramp and a stop watch was used to measure the time taken by the car to travel between the different markers. The table below shows the results that were collected.

Complete the table and then answer the questions that follow.

Remember: $\text{speed} = \frac{\text{distance}}{\text{time}}$

Interval	Distance travelled (m)	Trial	Time taken (s)	Average time taken	Average speed (m/s)
Marker 1 to 5	2	1	2		
		2	2.2		
		3	1.8		
Marker 1 to 3	1	1	0.5		
		2	0.7		
		3	0.8		
Marker 3 to 5	1	1	0.3		
		2	0.5		
		3	0.5		
Marker 1 to 2	0.5	1	0.5		
		2	0.43		
		3	0.52		
Marker 2 to 3	0.5	1	0.22		
		2	0.2		
		3	0.25		
Marker 3 to 4	0.5	1	0.13		
		2	0.15		
		3	0.17		
Marker 4 to 5	0.5	1	0.1		
		2	0.13		
		3	0.17		
Marker 2 to 4	1	1	0.33		
		2	0.3		
		3	0.28		

Worksheet M: Data validity

1. What do you notice about the average speed at different intervals?

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2. Which interval shows the highest average speed? Explain why you think this happens.

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3. Which interval shows the lowest average speed? Explain why this happens.

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4. A motion analysis app calculates the average speed over very small intervals. Explain what advantage this has compared to the ramp method on the previous page.

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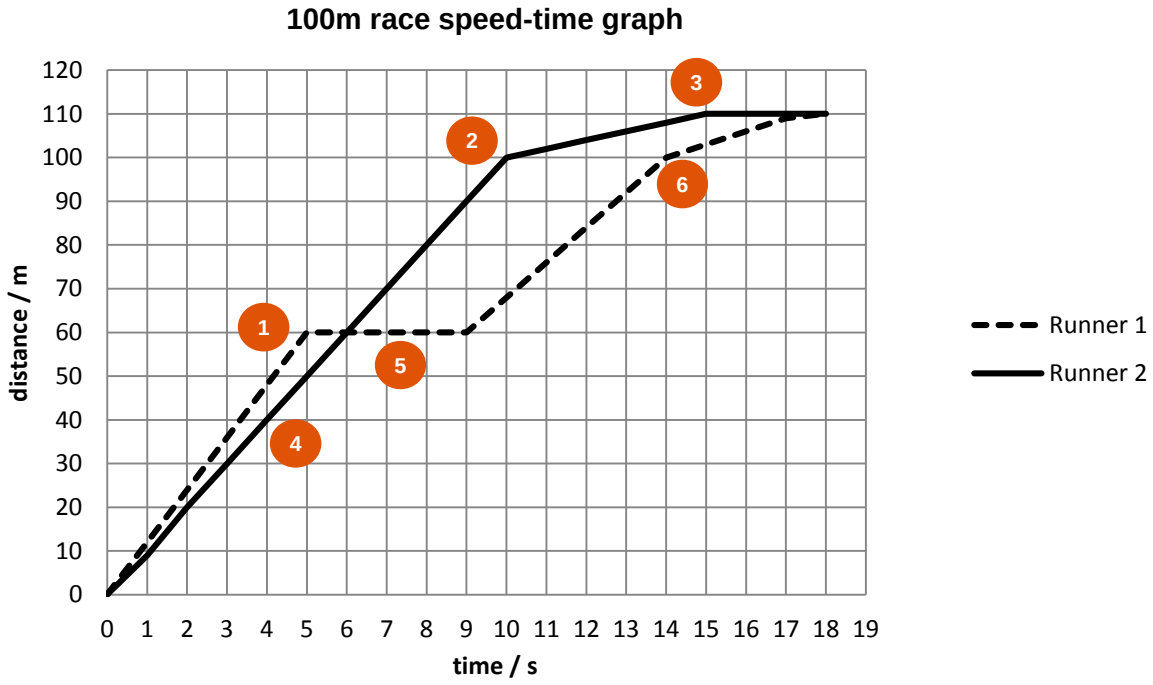
Worksheet A: Answers

Look at the speed-time graph of a 100 m race. It shows how two runners proceed during the race. Use the spaces provided to describe what is happening at different points in the race. One has been done for you.

1 Runner one begins the race very fast, reaching 60 m in just 5 seconds.

3 Runner 2 finally comes to a stop.

2 Runner 2 reaches the 100 m mark in 10 seconds and then begins to slow.



4 Runner 2 runs more slowly than runner 1, but travels at a consistent speed.

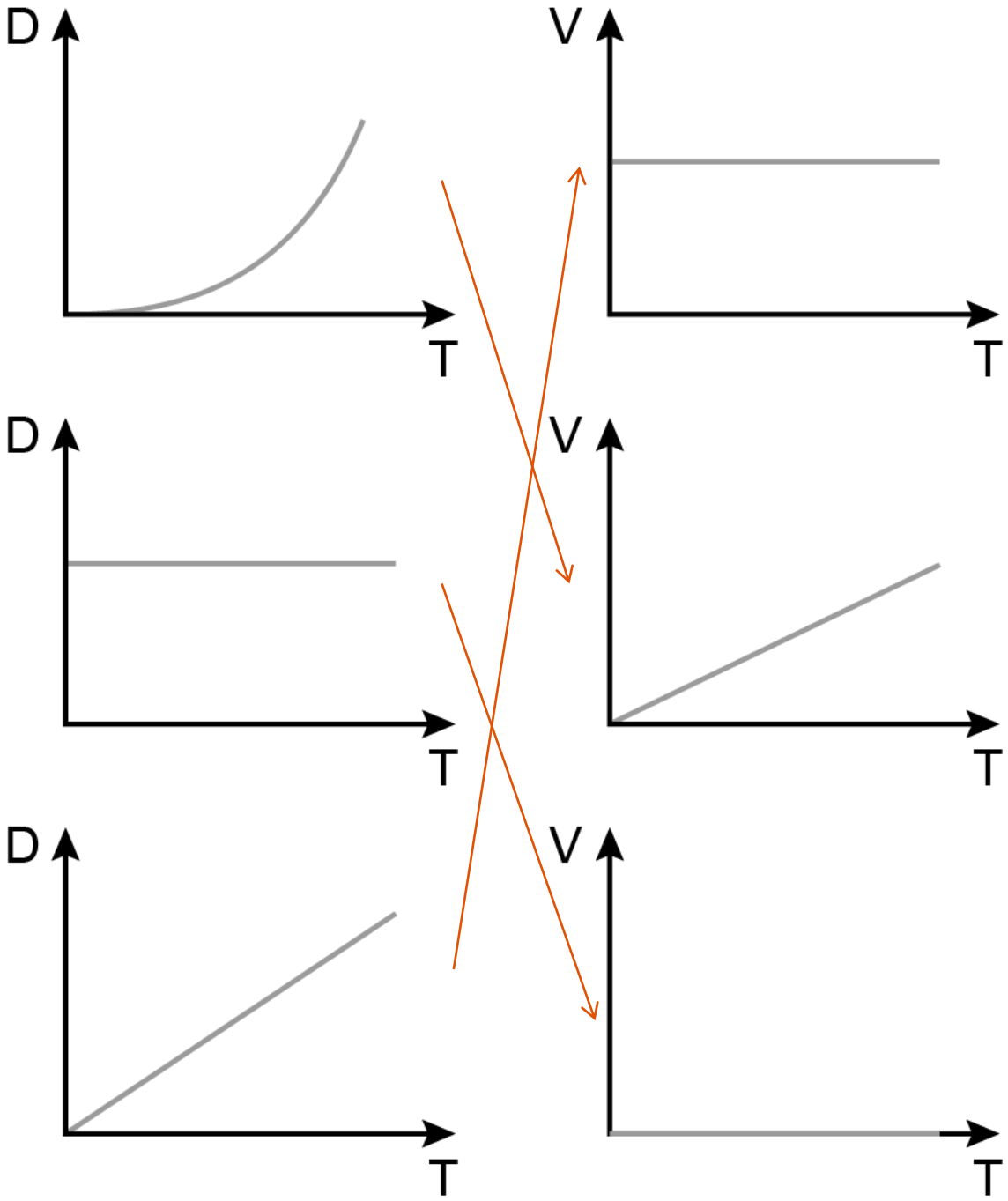
5 Runner 1 falls and is stationary for 4 seconds.

6 Runner 1 gets back up and runs on, completing the race in 14 seconds.

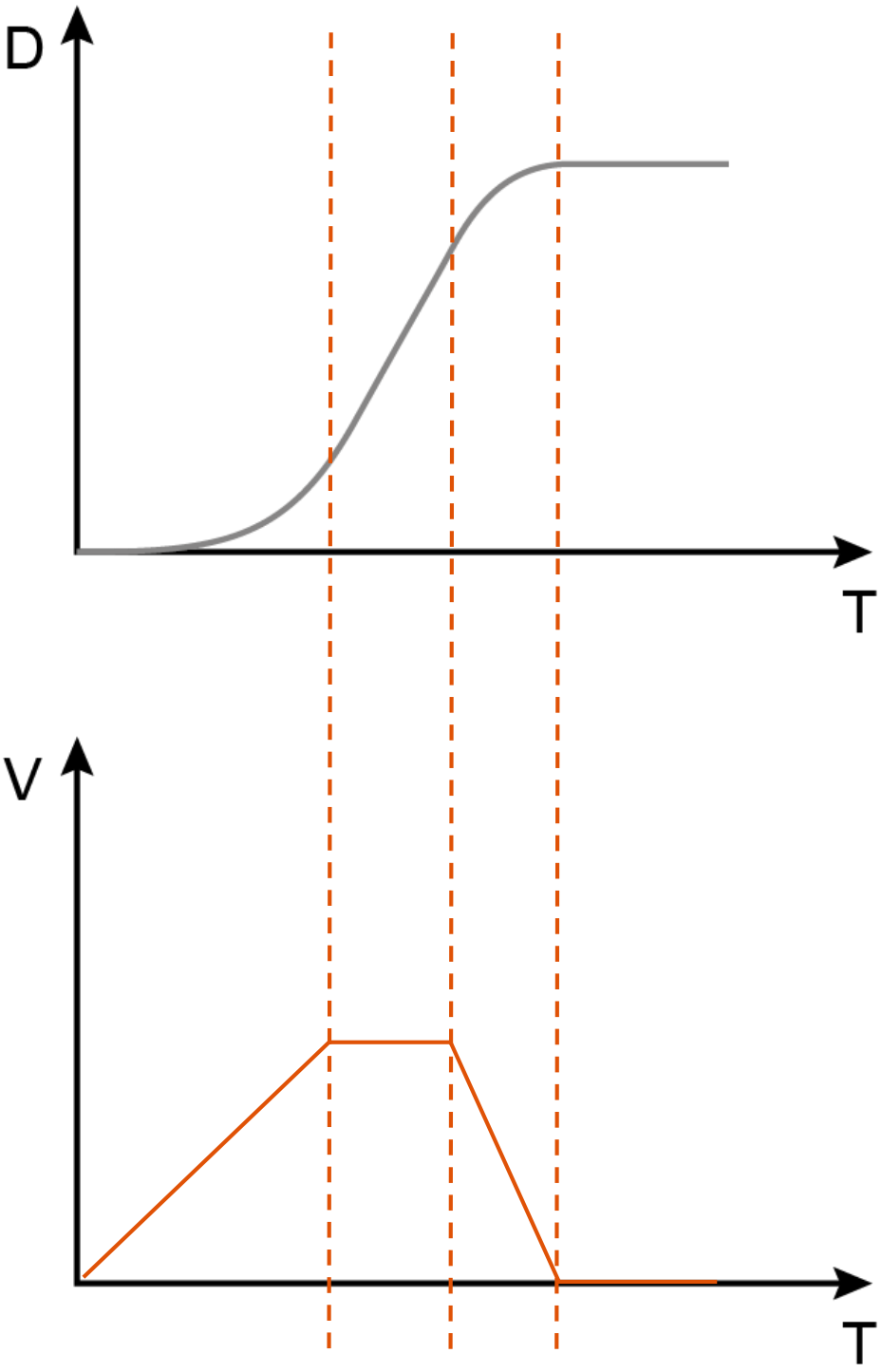
Worksheet C: Answers

Part A

Look at the distance-time graphs shown below and use a line to match them to the correct velocity-time graph on the right.



Worksheet C: Answers



Worksheet D: Answers

Use this equation to answer the following questions.

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

1. The current world record for running a 100 m race is 9.58 s. What is the average speed?

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{100}{9.58} = 10.44 \text{ m/s}$$

2. An arrow is shot by an archer and travels for 2.3 s at an average speed of 76 m/s before it hits the target. How far is the target from the archer?

$$\text{Distance} = \text{Speed} \times \text{Time} = 76 \times 2.3 = 178.4 \text{ m}$$

3. A sound wave in air travels at a speed of around 330 m/s. How long will it take for the sound wave to travel 524 m in air?

$$\text{Time} = \frac{\text{distance}}{\text{speed}} = \frac{524}{330} = 1.59 \text{ s}$$

4. If the sound of thunder reaches your house 3.5 s after you see the lightning, how far from your house did the lightning strike?

$$\text{Distance} = \text{Speed} \times \text{Time} = 330 \times 3.5 = 1155 \text{ m}$$

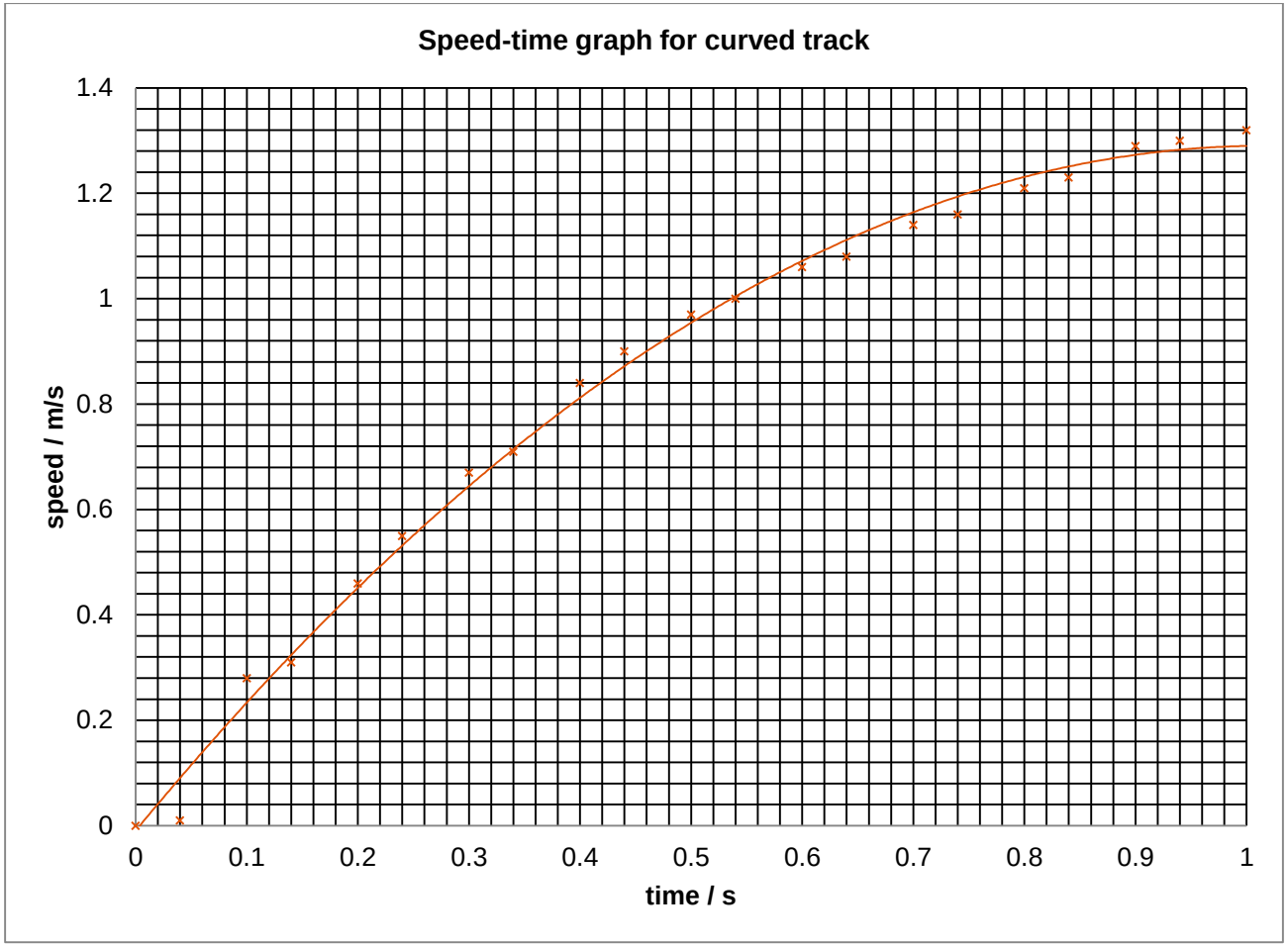
Worksheet K: Answers

The data in the table below was collected from the video of the curved track.

Use this to plot a speed-time graph for this experiment.

When you have finished plotting your points, make sure that you join them with a smooth line of best fit.

Time / s	Speed / m/s
0.00	0.00
0.04	0.01
0.10	0.28
0.14	0.31
0.20	0.46
0.24	0.55
0.30	0.67
0.34	0.71
0.40	0.84
0.44	0.90
0.50	0.97
0.54	1.00
0.60	1.06
0.64	1.08
0.70	1.14
0.74	1.16
0.80	1.21
0.84	1.23
0.90	1.29
0.94	1.30
1.00	1.32



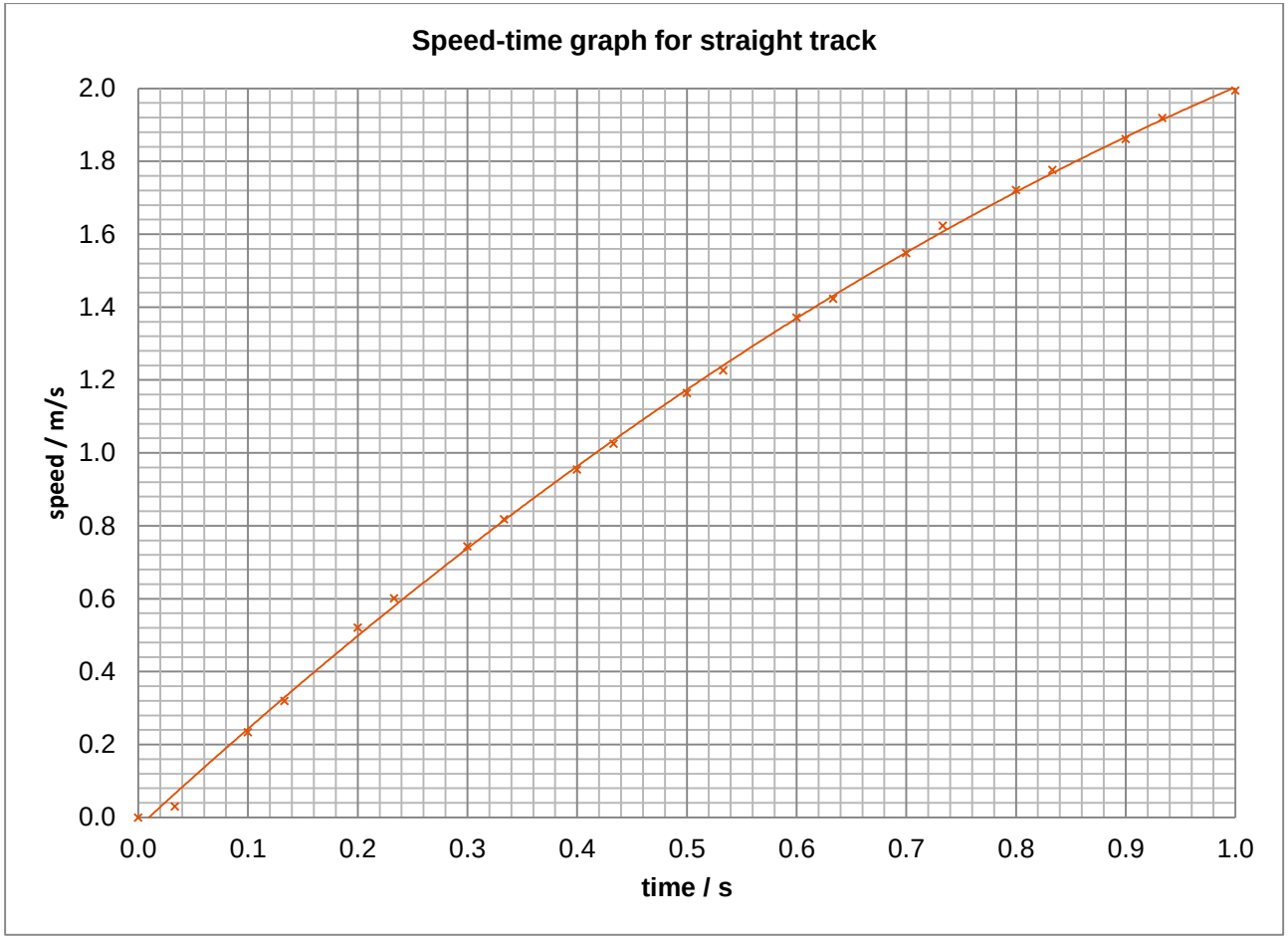
Worksheet L: Answers

The data in the table below was collected from a straight track, set up using the same equipment as the curved track shown in the video.

Use this to plot a speed-time graph for this experiment.

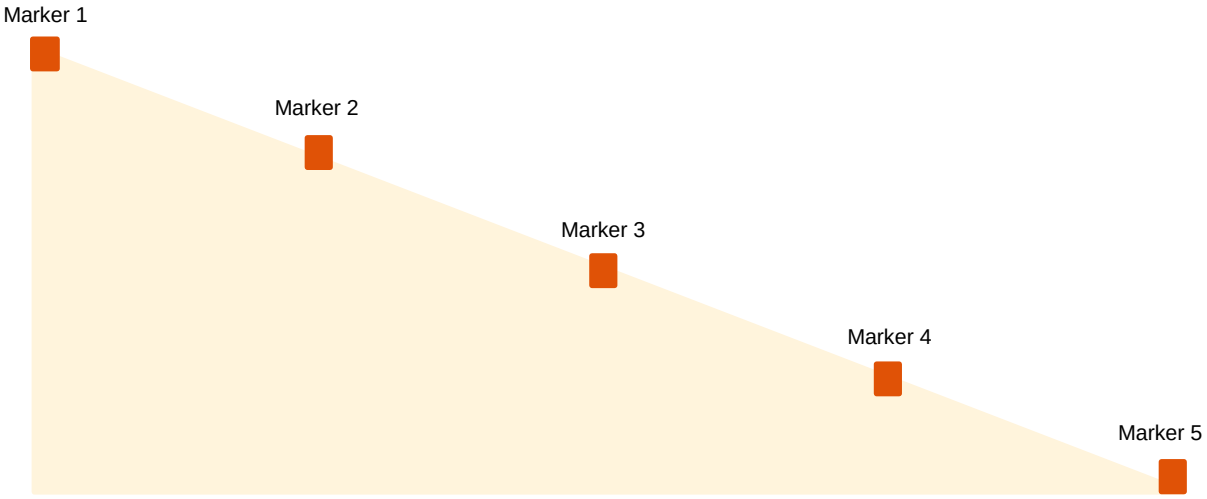
When you have finished plotting your points, make sure that you join them with a smooth line of best fit.

Time / s	Speed / m/s
0.00	0.00
0.03	0.03
0.10	0.23
0.13	0.32
0.20	0.52
0.23	0.60
0.30	0.74
0.33	0.82
0.40	0.95
0.43	1.03
0.50	1.16
0.53	1.23
0.60	1.37
0.63	1.42
0.70	1.55
0.73	1.62
0.80	1.72
0.83	1.78
0.90	1.86
0.93	1.92
1.00	1.99



Worksheet M: Answers

A ramp was set up like the diagram below with five visible markers.



A toy car was released from the top of the ramp and a stop watch was used to measure the time taken by the car to travel between the different markers. The table below shows the results that were collected.

Complete the table and then answer the questions that follow.

Remember: $\text{speed} = \frac{\text{distance}}{\text{time}}$

Interval	Distance travelled (m)	Trial	Time taken (s)	Average time taken	Average speed (m/s)
Marker 1 to 5	2	1	2	2	2
		2	2.2		
		3	1.8		
Marker 1 to 3	1	1	0.5	0.66	1.52
		2	0.7		
		3	0.8		
Marker 3 to 5	1	1	0.3	0.43	2.33
		2	0.5		
		3	0.5		
Marker 1 to 2	0.5	1	0.5	0.48	1.04
		2	0.43		
		3	0.52		
Marker 2 to 3	0.5	1	0.22	0.22	2.27
		2	0.2		
		3	0.25		
Marker 3 to 4	0.5	1	0.13	0.15	3.33
		2	0.15		
		3	0.17		
Marker 4 to 5	0.5	1	0.1	0.13	3.85
		2	0.13		
		3	0.17		
Marker 2 to 4	1	1	0.33	0.91	1.1
		2	0.3		
		3	0.28		

Worksheet M: Answers

1. What do you notice about the average speed at different intervals?

The average speed of the car is lower in the earlier intervals, e.g. between marker 1 and 2, than in later intervals like the interval between marker 4 and 5.

2. Which interval shows the highest average speed? Explain why you think this happens.

The interval between marker 4 and 5 has the highest average speed (3.85 m/s). The reason for this is that as the car moves down the ramp it gains speed due to gravitational potential energy.

3. Which interval shows the lowest average speed? Explain why this happens.

The lowest average speed is between marker 1 and 2 (1.04 m/s). The reason for this is that acceleration down the slope is non-uniform. At the beginning of the slope, the toy car has to overcome opposing forces like friction as it begins to move. This results in slower speeds at the top of the slope and greater ones at the bottom.

4. A motion analysis app calculates the average speed over very small intervals. Explain what advantage this has compared to the ramp method on the previous page.

The average speed between the markers varies and therefore using two points on a ramp does not provide an accurate method to measure the instantaneous speed of the toy car at any point.

Video analysis provides an instantaneous speed at any given point on the ramp, as it measures the speed of the car many times every second.

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