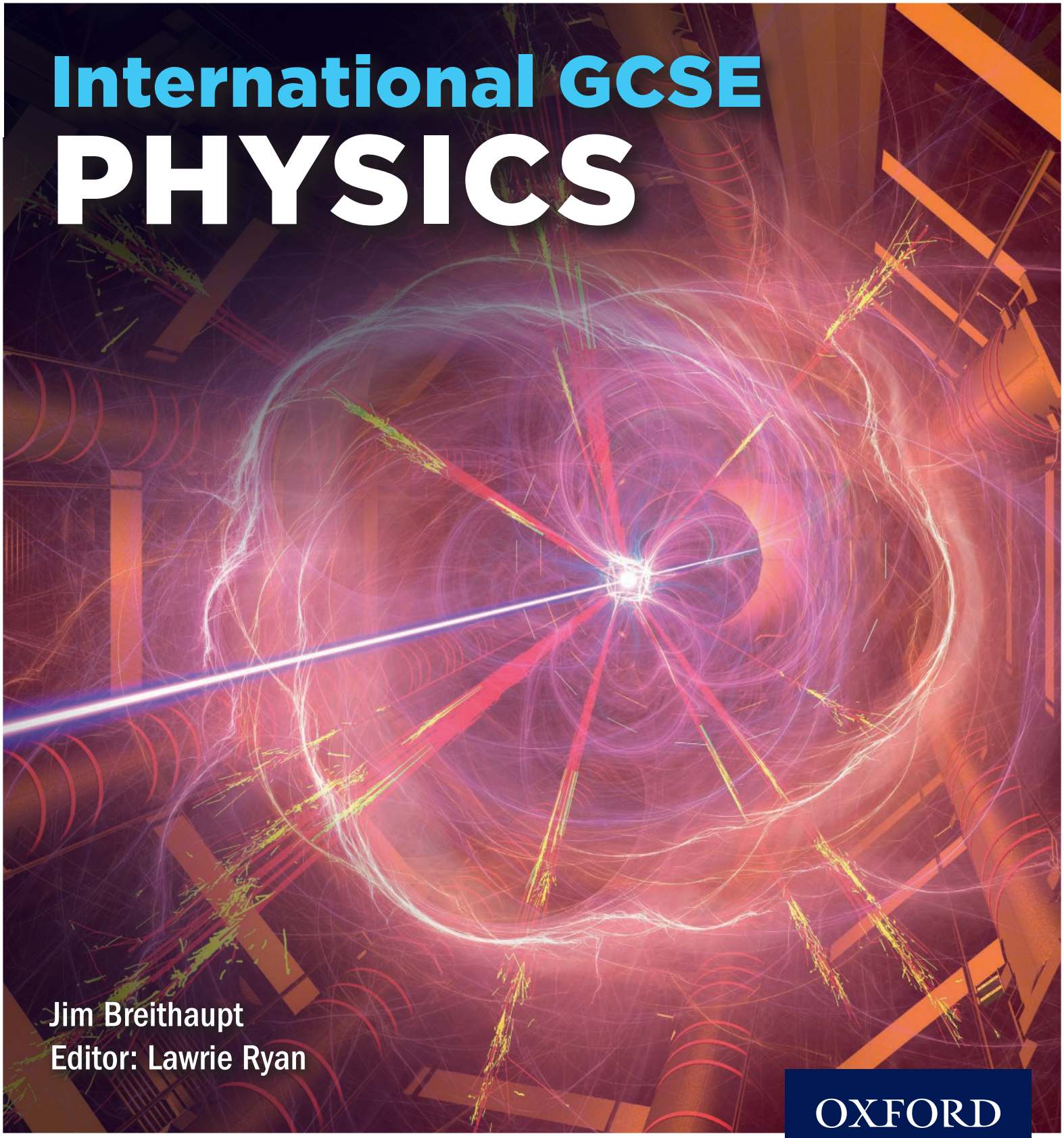
Published for
OXFORD INTERNATIONAL
AQA EXAMINATIONS

International GCSE
PHYSICS



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How to use this book

This book has been written for you by a team of very experienced teachers and subject experts. It covers everything you may need to know for your exams and is packed full of features to help you achieve the very best that you can.

Figure 1 *Many diagrams are as important for you to learn as the text, so make sure you revise them carefully*

Key words are highlighted in the text. You can look them up in the Glossary at the back of the book if you are not sure what they mean.

Learning objectives

Each topic begins with statements of key content that you should know by the end of the lesson.

Study tip

Hints to give you important advice on things to remember and what to watch out for.

Did you know … ?

There are lots of interesting and often strange facts about science. This feature tells you about many of them.

links

Links will tell you where you can find more information about what you are learning and how different topics link up.

Activity

An activity is linked to a main lesson and could be a discussion or task in pairs, in groups, or by yourself.

Demonstration or Required Practical

This feature helps you become familiar with key practicals. It may be a simple introduction, a reminder, or the basis for a practical in the classroom.

Summary questions

These questions give you the chance to test whether you have learnt and understood everything in the topic. If you get any wrong, go back and have another look. They are designed to be increasingly challenging.

And at the end of each chapter you will find …

Chapter summary questions

These will test you on what you have learnt throughout the whole chapter, helping you to work out what you have understood and where you need to go back and revise.

Practice questions

These questions are examples of the types of question you may encounter in your exam, so you can get lots of practice during your course.

Key points

At the end of the topic are the important points that you must remember. They can be used to help with revision and to summarise your knowledge.

Practical skills

During this course, you will develop your understanding of the scientific process and the skills associated with scientific enquiry. Practical work is an important part of the course, as it develops these skills and also reinforces concepts and knowledge you have learnt during the course.

As part of this course you will undertake practical work in many topics, and you are required to carry out five practicals as suggested below:

Required practicals

1. Investigating the relationship between force and extension for a spring. (3.1.1) [Topic 1.5]
2. Investigating refraction of light by different substances. (3.3.5) [Topic 10.2]
3. Investigating cooling curve for stearic acid. (3.4.1) [Topic 12.3]
4. Investigating the potential difference–current characteristics of a filament lamp, a diode, and a resistor at constant temperature. (3.5.1) [Topic 14.5]
5. Investigating the factors that determine the strength of an electromagnet. (3.5.2) [Topic 15.2]

In Paper 2, you will be assessed on aspects of the practical skills listed below, and may be required to read and interpret information from scales given in diagrams and charts, present data in appropriate formats, design investigations, and evaluate information that is presented to you.

Designing a practical procedure

- Design a practical procedure to answer a question, solve a problem, or test a hypothesis.
- Comment on/evaluate plans for practical procedures.
- Select suitable apparatus for carrying out experiments accurately and safely.

Control

- Appreciate that, unless certain variables are controlled, experimental results may not be valid.
- Recognise the need to choose appropriate sample sizes, and study control groups where necessary.

Risk assessment

- Identify possible hazards in practical situations, the risks associated with these hazards, and methods of minimising the risks.

Collecting data

- Make and record observations and measurements with appropriate precision and record data collected in an appropriate format (such as a table, chart, or graph).

Analysing data

- Recognise and identify the cause of anomalous results and suggest what should be done about them.
- Appreciate when it is appropriate to calculate a mean, calculate a mean from a set of at least three results, and recognise when it is appropriate to ignore anomalous results in calculating a mean.
- Recognise and identify the causes of random errors and systematic errors.
- Recognise patterns in data, form hypotheses, and deduce relationships.
- Use and interpret tabular and graphical representations of data.

Making conclusions

- Draw conclusions that are consistent with the evidence obtained and support them with scientific explanations.

Evaluation

- Evaluate data, considering its repeatability, reproducibility, and validity in presenting and justifying conclusions.
- Evaluate methods of data collection and appreciate that the evidence obtained may not allow a conclusion to be made with confidence.
- Suggest ways of improving an investigation or practical procedure to obtain extra evidence to allow a conclusion to be made.

1.1 Forces between objects

Learning objectives

After this topic, you should know:

- what forces can do
- what the unit of force is
- what you can say about the forces being exerted when two objects interact
- what you can say about frictional forces.

When you apply a **force** to a tube of toothpaste, be careful not to apply too much force. The force you apply to squeeze the tube changes its shape and pushes toothpaste out of the tube. If you apply too much force, the toothpaste might come out too fast.

Forces can change the shape of an object or change its state of rest or its motion.

A force is a push or pull that acts on an object because of an interaction with another object. If two objects must touch each other to interact, the forces are called **contact forces**. Examples include friction, air resistance, tension (or stretching forces), and normal contact forces when an object is supported by or strikes another object. **Non-contact forces** include magnetic force, electrostatic force, and the force of gravity.

Equal and opposite forces

When two objects push or pull on each other, they exert equal and opposite forces on one another.

The unit of force is the **newton** (abbreviated as N). The rule stated above is called **Newton's Third Law**. (You will meet Newton's First Law in Topic 1.2, and Newton's Second Law in Chapter 2, when you study forces and motion.) Here are some examples of Newton's Third Law:

- A boxer who punches an opponent with a force of 100 N experiences an equal and opposite force of 100 N from his opponent.
- Two roller skaters pull on opposite ends of a rope. The skaters move towards each other because they pull on each other with equal and opposite forces. Two newtonmeters could be used to show this. A newtonmeter is a spring balance calibrated in newtons (see Topic 1.4).

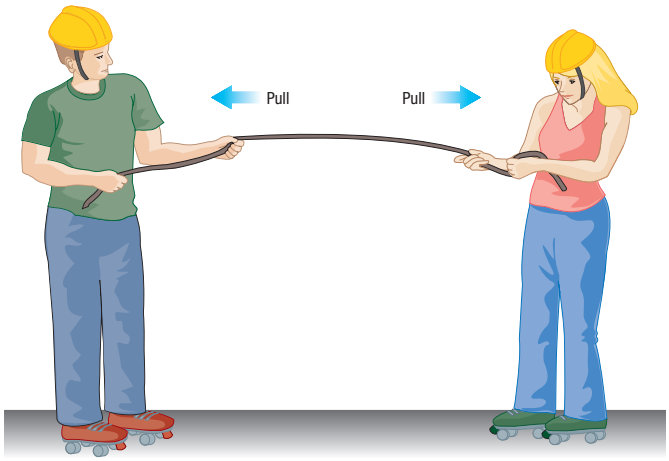


Figure 1 *Equal and opposite forces*

Study tip

Remember that when two objects interact, although they exert equal and opposite forces on each other, the effects of those forces will depend on the masses of the objects – larger mass, smaller effect.

Practical

Action and reaction

Test Newton's Third Law as shown in Figure 1 with a partner if you can, using roller skates and two newtonmeters. Don't forget to wear protective head gear.

- What did you find out?
- Evaluate the precision of your repeat readings.

Safety: You might want someone to help support you.

In the mud

A car stuck in mud can be difficult to shift. A tractor can be very useful here. Figure 2 shows the idea. At any stage, the force of the rope on the car is equal and opposite to the force of the car on the rope.

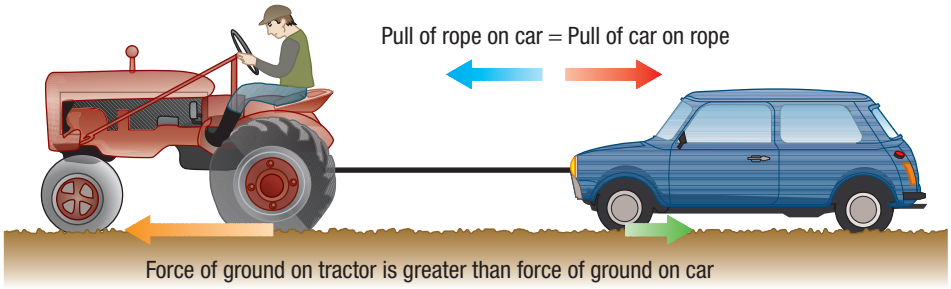


Figure 2 *In the mud*

To pull the car out of the mud, the force of the ground on the tractor needs to be greater than the force of the ground on the car. Note that these two forces are not equal and opposite to each other. The 'equal and opposite force' to the force of the mud on the tractor is the force of the tractor on the ground. The 'equal and opposite force' to the force of the mud on the car is the force of the car on the ground.

Friction in action

The driving force on a car is the force that makes it move. This is sometimes called the engine force or the **motive force**. This force is caused by **friction** between the road and the tyre of each drive wheel. Friction is a force that opposes the motion of any two surfaces in contact with each other when they slide or try to slide across each other. In Figure 3, friction acts between the tyre and the road where they are in contact with each other.

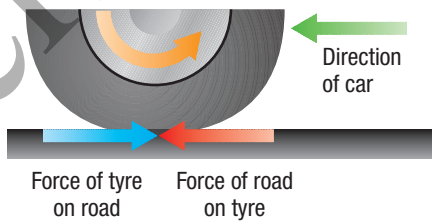


Figure 3 *Driving force*

When the car moves forwards:

- the force of friction of the road on the tyre is in the forward direction
- the force of friction of the tyre on the road is in the reverse direction.

The two forces are equal and opposite to one another.

Summary questions

1 a When the brakes of a moving car are applied, what is the effect of the braking force on the car?
b When you sit on a cushion, what forces act on you?
c When you kick a football, what is the effect of the force of your foot on the ball?

2 a i A hammer hits a nail with a downward force of 50 N. What is the size and direction of the force of the nail on the hammer?
ii A lorry tows a broken-down car. When the force of the lorry on the tow rope is 200 N, what is the force of the tow rope on the lorry?
b Copy and complete **i–iii** using the words below:

downwards equal opposite upwards

i The force on a ladder resting against a wall is ..... and ..... to the force of the wall on the ladder.
ii A book is at rest on a table. The force of the book on the table is ..... . The force of the table on the book is ..... .
iii When a ball is dropped onto the floor, the force of the floor on the ball is ..... .

3 When a student is standing at rest on bathroom scales, the scales read 500 N.
a What is the size and direction of the force of the student on the scales?
b What is the size and direction of the force of the scales on the student?
c What is the size and direction of the force of the floor on the scales?

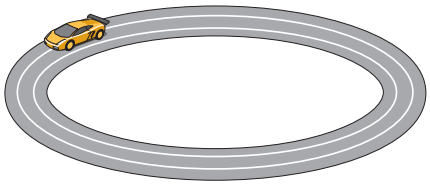
Key points

- A force can change the shape of an object, or change its motion, or its state of rest.
- The unit of force is the newton (N).
- When two objects interact, they always exert equal and opposite forces on each other.
- Friction opposes the motion of any two surfaces in contact with each other when they slide or try to slide across each other.

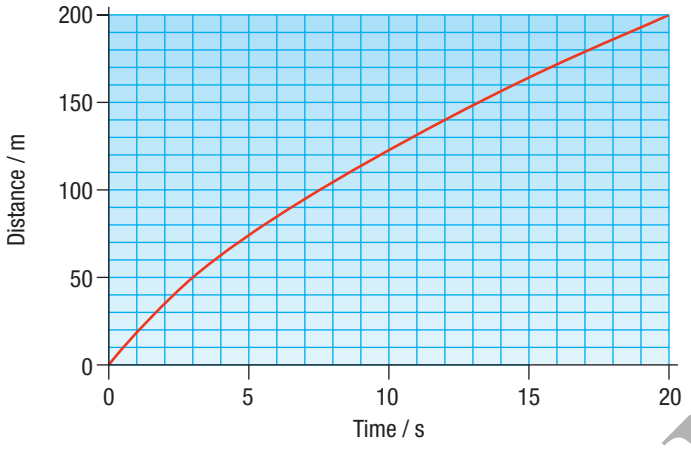
Chapter summary questions

1 A model car travels round a circular track at constant speed.

If you were given a stopwatch, a marker, and a tape measure, how would you measure the speed of the car?



2 The figure shows a distance–time graph for a motorcycle approaching a speed limit sign.



a Describe how the speed of the motorcycle changed with time.

b Use the graph to determine the speed of the motorcycle:
- **i** initially
- **ii** 10 seconds later.

3 The table shows how the velocity of a train changed as it travelled from one station to the next.

Time (s)	0	20	40	60	80	100	120	140	160
Velocity (m/s)	0	5	10	15	20	20	20	10	0

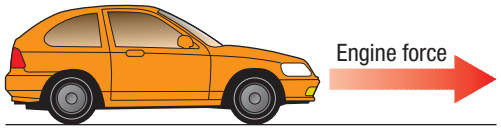
a Plot a velocity–time graph using this data.

b Calculate the acceleration in each of the three parts of the journey.

c Calculate the total distance travelled by the train.

d Show that the average speed for the train's journey was 12.5 m/s.

4 A car accelerates from rest with an initial acceleration of 1.2 m/s^2. The total mass of the car and its occupants is 800 kg.

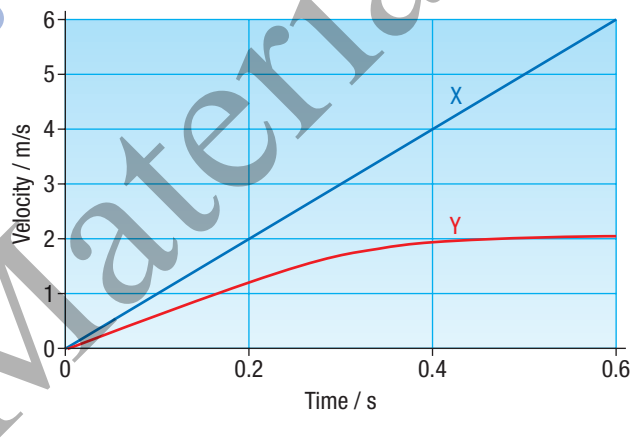


a Assuming the resultant force is initially due to the driving force of the car engine only, calculate the initial driving force on the car.

b **i** If the car was used to pull a trailer of mass 70 kg, what would be its initial acceleration for the same driving force?

ii Calculate the force on the car and trailer at this acceleration.

5



a The gravitational field strength g at the surface of the Earth is 10 N/kg. Explain why a freely falling object released near the Earth's surface has a constant acceleration of 10 m/s^2 as it falls.

b A stone dropped from the top of a water well hits the water in the well 1.7 s later. Calculate the speed of the object just before it hits the surface of the water.

c The figure above shows the velocity–time graphs for a metal object **X** dropped in air and a similar object **Y** dropped in a tank of water.
- **i** What does the graph for **X** tell you about its acceleration?
- **ii** In terms of the forces acting on **Y**, explain why it reached a constant velocity.

6 **a** A racing cyclist accelerates at 5.0 m/s^2 when she starts from rest. The total mass of the cyclist and her bicycle is 45 kg. Calculate:
- **i** the resultant force that produces this acceleration
- **ii** the total weight of the cyclist and the bicycle.

b Explain why she can reach a higher speed by crouching than by staying upright.

c When the cyclist was travelling at a velocity of 6.6 m/s on a level road, she used her brakes to slow down and stop in a time of 3.7s. Calculate the braking force acting during this time.

Practice questions

1 A van has a fault and leaks one drop of oil every second.

The diagram shows the oil drops left on the road as the van moves from **A** to **D**.

a Describe the motion of the van as it moves from:

i **A** to **B**

ii **B** to **C**

iii **C** to **D**. (3)

b The distance from **B** to **C** is 100 metres.

Calculate the average speed of the van between **B** and **C**. (3)

c Later in the journey, the van slows down from a speed of 25 m/s to 5 m/s in 10 s.

Calculate the acceleration of the van. (5)

2 Graphs can give useful information.

a Use words from the list to complete the sentences.

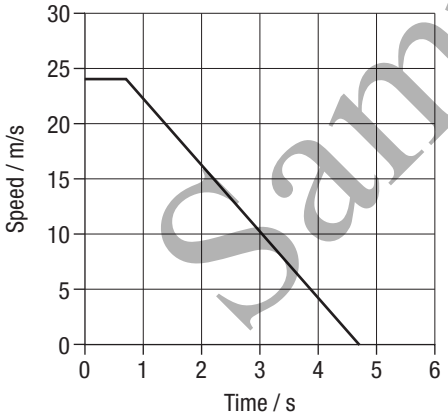
accelerating ***travelling at constant speed*** ***stationary***

i In a distance–time graph, a horizontal line shows that the vehicle was ..... . (1)

ii In a velocity–time graph, a horizontal line shows that the vehicle was ..... . (1)

b A car driver sees a dog on the road ahead and has to make an emergency stop.

The graph shows how the speed of the car changes with time after the driver first sees the dog.



i What is the time interval between the driver seeing the dog and applying the brakes? (1)

ii How far does the car travel between the driver seeing the dog and applying the brakes? (3)

c **i** Calculate the deceleration of the car, in m/s^2, after the brakes are applied. (4)

ii How far does the car travel after the brakes are applied? (3)

3 A headteacher wants the local council to put a 20 mph speed limit on the road outside the school.

She asks some students to carry out a survey of vehicles passing the school.

a She wants one group of students to investigate the average speed of vehicles passing the school.

i Describe how the students would obtain the data needed. Your description should include the equipment they would use. (6)

ii Outline how they could make the result as accurate as possible. (3)

b The headteacher wants another group of students to produce a graph showing the number of vehicles travelling at different speeds along the road.

i Which two of the following could the students use to display their results?
Give reasons for your choice. (5)

bar chart ***line graph*** ***pie chart*** ***scattergram***

ii Discuss how long the students should spend collecting their data. (2)

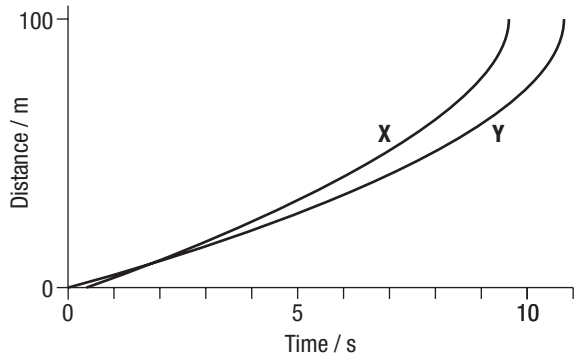
4 **a** Complete the following sentences about graphs.

i The gradient of a velocity–time graph represents ..... . (1)

ii The gradient of a distance–time graph represents ..... . (1)

iii Distance is represented by the area under a ..... graph. (1)

b The graphs describe the motion of two runners in a race.



Compare and evaluate the information shown in the two graphs. (6)