Science KS3:

Year 7

Blended Learning Booklet

Unit 1: Forces

Stewards Academy

Name:

Form:

- *Aim to complete three lessons each week.*
- *Make a note of the title, date and just the 1st learning objective.*
- *Answer the in text question A, B, C….*
- *Also answer the summary questions (1 flask questions are easy, 2 flask question are medium and 3 flask question are challenging)*
- At the end of sections 1 & 2 please complete the revision questions
- Please use the mark schemes provided to self assess your work and make corrections in blue pen.

Big Picture – Year 7 Overview
Science

Year 7

UNIT 1 – The Enquiry Process

I will be able to plan and carry out a scientific investigation. This procedure will include being able to write a hypothesis, design a method, collect and analyse data and finally be able to critically evaluate the whole process.

- Asking scientific questions
- Planning scientific investigations
- Collecting, recording and presenting data
- Analysing patterns in data
- Evaluating data and methods
- End of Unit Test

UNIT 2 – Organisms

I will be able to explain How cells are the basic building blocks of life for both plants and animals. How some organisms can exist as simple single celled organisms and how in others cells are organized into tissues, organs and organ systems to create more complex multicellular organisms. **I will also be able to** explain the structure and function of some of these organ systems and how they are affected by different lifestyle choices

- Using a microscope & Plant and animal cells
- Uni-cellular organisms
- Drugs, alcohol and smoking
- Breathing and gas exchange
- Nutrients, healthy diet and food tests
- Digestive system
- End of Unit Test

UNIT 3 – Forces

I will be able to explain that a forces are a push or a pull that can change the speed, direction or shape of an object. **I will be able to** explain how some forces such as gravity act at a distance (non-contact) and some such as friction and drag require objects to touch (contact). **I will be able to** use an equation to calculate speed and be able to represent changing speeds on a graph. Finally **I will be able to** use and equation to link force and pressure.

- Introduction to forces
- Speed
- Gravity
- Friction and drag
- Squashing, stretching and turning
- Pressure in solids, liquids and gases
- End of Unit Test

UNIT 4 – Matter

I will be able to use the particle model to explain how particles are arranged in solids, liquids and gases and how a substance can change between these states. **I will be able to** use the particle model to explain the process of diffusion and gas pressure. **I will be able to** recognize a pure substance and be able to describe methods for separating mixtures. **I will be able to** identify substances as elements or compounds and know that the periodic table shows how the elements are grouped together.

- States of matter
- Particle model
- Pure substances and mixtures
- Solutions and solubility
- Separation techniques
- Atoms and elements
- Compounds and chemical formulae
- The periodic table. Groups 1, 7 & 0
- End of Unit Test

UNIT 5 – Ecosystems

I will be able to explain that plants are able to make their own food by photosynthesis and that animals are consumers eating other organisms to take in energy. **I will be able to** explain that plants and animals are linked through food chains and webs which show the relationships between organisms in an ecosystem. **I will be able to** explain the processes and the importance of respiration and photosynthesis and how these are linked ,as well as how plants are uniquely adapted to carry out photosynthesis

- Food chains and webs
- Ecosystems and competition
- Flowers and pollination
- Respiration
- Microbial Bio-technology
- Photo-synthesis
- Plant structure and function
- End of Unit Test

UNIT 6 – Energy

I will be able to explain that there is energy in food and fuel and that it is measured in Joules. **I will be able to** explain how energy from non-renewable or renewable resources can be used to provide electricity**. I will be able to** use equations to link energy and power and to calculate the unit cost of energy. **I will be able to** state the Law of conservation of energy, describe 3 methods of heat transfer and how to prevent heat transfer using an insulator.

- Energy resources
- Energy and Power
- Cost of energy
- Work energy and machines
- Energy and temperature
- Energy transfer
- End of Unit Test

End of Year Assess-ment

Next Year

ZOOM IN…

MY LEARNING JOURNEY:

Subject: Forces Year: 7 Unit: 3

In this unit students will learn how objects interact and how forces on the speed, direction and shape of objects. This unit will provide key knowledge that forms a basis of understanding for: Contact forces, specifically friction; Pressure including atmospheric pressure and pressure within a liquid; Magnetism and also Work Done, including the elastic and inelastic behaviour of a stretching spring.

DEVELOPING COURAGE

- **C** The laws of phycics are consistant
- **O** To explore the physical world
- **U** Work together to to carry out experiments
- **R** Use of equations to explain phyical processes
- **A** How every action gets a reaction
- **G** Share our knowledge
- **E** Understanding how the physical world works

UP NEXT

Matter.

- Particle model
- States of matter
- Pure substances
- Separating mixtures
- Atoms & Elements
- Compounds
- The periodic table

CAREERS

- Computer game engineer
- Insurance assessor
- Materials engineer

PREVIOUS LEARNING

Pupils should have some experience of the following:
Some forces need contact and some can act at a distance
Friction slows things down
Gravity is a force acting between the Earth and any object.
Forces can be used to squash, bend, stretch and object

WHAT WE KNOW/ REMEMBER

- ……………………………
- ……………………………
- ……………………………
- ……………………………
- ……………………………

RECOMMENDED READING

1. Forces Make Things Move by Kimberly Brubaker Bradley,
2. Powerful Forces by Jon Richards & Rob Colson,
3. Gravity: Why What Goes up Must Come Down by Brian Clegg.

PERSONAL OBJECTIVES

- ………………………………
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Part 1 - Lessons

Part 1 – Summary (Check List)

1 Forces

What is the link between the Moon orbiting the Earth and a falling object on Earth? In this Big Idea you will learn about forces, how they arise, and how they change the motion of an object. You will also learn how to measure speed and how to tell the story of a journey with a graph.

You already know

- Some forces need contact between two objects.
- Friction, air resistance, and water resistance act between moving surfaces to slow things down.
- Most forces require direct contact.
- Magnetic forces can act at a distance.
- There is a force of gravity acting between the Earth and any object.
- Unsupported objects fall towards Earth because of the force of gravity.

Q

What happens to a moving object when the force of friction acts on it?

1 Forces: Summary

Key Points

- Forces are pushes or pulls, measured in newtons (N) using a newtonmeter.
- You can use force arrows to show the size and direction of forces.
- Forces arise when objects interact to produce contact forces and non-contact forces.
- Resultant forces can change an object's speed or the direction of its motion. No resultant force means no change in motion.
- speed = distance ÷ time, and is measured in metres per second (m/s).
- average speed = overall distance travelled ÷ overall time taken.
- Speed is always relative. An object's speed is relative to the speed of the observer.
- The slope of the distance–time graph tells you the speed.
- A straight line on a distance–time graph shows a constant speed.
- An object that is speeding up, slowing down, or changing direction is accelerating.
- Weight is the force of the Earth (or Moon or other planet) on an object and is measured in newtons (N).
- Mass is the amount of stuff an object is made up of and is measured in kilograms (kg).
- weight (N) = mass (kg) × gravitational field strength, g (N/kg)
- g = 10 N/kg on Earth and 1.6 N/kg on the Moon, and can be larger for planets such as Jupiter.
- A field is a region where something feels a force. For example, a mass experiences a force in a gravitational field.
- Every object with mass exerts a force on every other object.
- The gravitational force that an object exerts is larger if the mass of the object is larger and smaller if the object is further away.
- Gravity holds planets and moons in orbit around more massive objects.

Key Words

push, pull, contact force, friction, air resistance, gravity, non-contact force interaction pair, newtonmeter, newton (N), resultant force, balanced, equilibrium, unbalanced, driving force, resistive force, speed, metres per second, average speed, relative motion, distance–time graph, acceleration, gravitational force, gravity, field, weight (N), mass, kilogram (kg), gravitational field strength

Lesson 1

1.1.1 Introduction to forces

Learning objectives

After this section you will be able to:

- state the unit of force
- describe what is meant by an interaction pair.

▲ This rocket took a rover to Mars.

Link

You can learn more about contact forces (drag and friction) in Book 2, 1.3.1 Contact forces.

Foul Fact!

Astronauts on the International Space Station cannot burp. The gas and liquid do not separate in their stomachs while they are in orbit.

What does a rocket have in common with you? There are forces acting on you and on the rocket.

What do forces do?

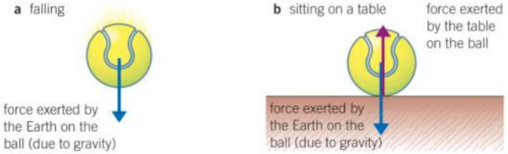
A rocket going to Mars moves away from the surface of the Earth very quickly. There is a force pushing the rocket up and forces pulling it down. A force can be a **push** or a **pull**.

Forces explain *why* objects move in the way that they do or why they don't move at all. That's not all. Forces can change the direction that objects are moving in and change their shape.

A List three things that forces do.

Describing forces

You can't see forces but you can see the effect of them. When you draw a diagram you add arrows to show the forces that are acting. 'Force arrows' show the direction *and* the size of the force. Forces act on objects so the arrow must touch the object in the diagram.



▲ These force arrows show the forces acting on a tennis ball.

Different types of force

Some forces act when you are touching something. These are **contact forces**. **Friction** and **air resistance** are contact forces. Support forces, like upthrust, are also contact forces.

The force of **gravity** acts on a tennis ball travelling through the air. The Earth pulls the ball down even though it is not touching it. Gravity is a **non-contact force**. The force between magnets is another non-contact force.

B Describe the difference between a contact force and a non-contact force.

Pairing up

A girl and her sister are hanging from a bar in a playground. Think about the forces acting on the girls.

▲ Forces act on the girls hanging from a bar.

- Gravity pulls the girls down. *This is the force of the Earth on the girls.*
- The girls pull the Earth up. *This is the force of the girls on the Earth.*

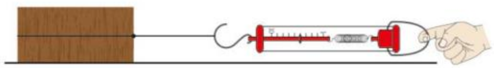
Forces always come in pairs. The pairs are called **interaction pairs**.

There is another interaction pair of forces acting on the girls.

- The bar supports the girls. *This is the force of the bar on the girls.*
- The girls pull on the bar. *This is the force of the girls on the bar.*

How do you measure forces?

You can measure force with a **newtonmeter** (sometimes called a spring balance). All forces are measured in **newtons** (N).



▲ A student is pulling the block with a force of 5 N.

C State the unit of force.

Newton predicts...

In the 1600s, Isaac Newton first explained how gravity affects objects. Scientists later used his ideas to predict that there was a planet beyond Uranus. In 1846 they discovered Neptune. A good explanation means that you can make predictions and test them.

▲ The force of the water on you (upthrust) supports you when you float.

Link

You can learn more about non-contact forces in 1.2.1 Gravity, and in Book 2, 2.4.1 Magnetism.

Key Words

push, pull, contact force, friction, air resistance, gravity, non-contact force, interaction pair, newtonmeter, newton (N)

Summary Questions

1 Copy and complete the sentences below.

A force is a ______ or a ______.
We can show the forces acting on an object using force ______.
Forces come in pairs, called ______ pairs. To measure forces you use a ______.

(5 marks)

2 Describe *one* of the interaction pairs for an apple hanging from the branch of a tree.

(2 marks)

3 You are probably sitting on a chair as you read this book. Explain in detail why the two forces acting on you are not two forces in the *same* interaction pair.

(6 marks)

Lesson 1: Answers

1.1.1 Introduction to forces

In-text questions	**A** Forces change the shape, speed, or direction of motion. **B** For a contact force to act the objects have to be touching (e.g., the air and a car for air resistance) but non-contact forces act at a distance. **C** newtons
Summary questions	**1** push, pull, arrows, interaction, newtonmeter (5 marks) **2** The force of the Earth on the apple AND the force of the apple on the Earth OR the force of the tree on the apple AND the force of the apple on the tree. (2 marks) **3** Extended response question. Example answers (6 marks): The Earth exerts a force on you. You exert a force on the Earth. The chair exerts a force on you. You exert a force on the chair. These are two interaction pairs. The two forces acting on you are from two different interaction pairs. This means one can be bigger than the other.

Lesson 2

1.1.2 Balanced and unbalanced

Learning objectives

After this section you will be able to:

- describe what happens when the resultant force on an object is not zero
- use a force diagram to describe situations involving gravity that are in equilibrium.

▲ When the teams pull with the same force the forces are balanced.

Equal and opposite...?

Isaac Newton said, 'For every action there is an equal and opposite reaction'. The forces in an interaction pair are equal and opposite. Is lying in bed an example of this law? No, it is not. Each of the forces acting on you comes from a *different* interaction pair.

Key Words

resultant force, balanced, equilibrium, unbalanced, driving force, resistive force

To get out of bed in the morning you need a force to get you moving.

What is a resultant force?

If more than one force is acting on an object you add the forces together to work out the **resultant force**.

This is the single force that can replace all the other forces acting on the object and still have the same effect on the object.

What are balanced forces?

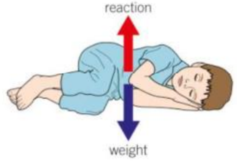
When the forces acting on an object are the same size but act in opposite directions we say:

- the resultant force is zero
- the forces are **balanced**
- the object is in **equilibrium**.

You can think of this situation like a tug of war. If each team pulls with the same force the rope doesn't move.

A State what equilibrium means.

All stationary objects are in equilibrium. There has to be a support force acting on them to balance out their weight.



◀ You are in equilibrium when lying in bed.

B State the resultant force on you when you are lying stationary in bed.

What are unbalanced forces?

The forces acting on a rocket-powered car are **unbalanced**. They are not the same size so they do not cancel out, therefore the resultant force is not zero.

The **driving force** from the engine is much, much bigger than the **resistive forces** from air resistance and friction.

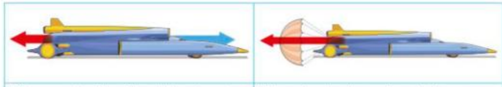
▲ The Thrust SSC was the first car to travel faster than sound.

C State the difference between balanced forces and unbalanced forces.

How do unbalanced forces change speed or direction?

When the car's rocket-powered engine starts up, the driving force will become very big very quickly. When the driver wants to stop he will fire a parachute to slow the car down. In both cases the forces on the car are unbalanced, as you can see from the diagram below.

The driver uses a parachute because this gives a much bigger resistive force on the car than just using the brakes. The speed of the car will change much more quickly. The car will stop in a much shorter time.



When accelerating, the driving force is bigger than the resistive forces acting on the car. The speed of the car increases.	When slowing down, the only forces acting on the car are resistive forces, such as friction and air resistance. The speed of the car decreases.

▲ The forces on the Thrust SSC when accelerating and when slowing down.

Every time you go around a corner in a car the friction between the tyres and the road changes the direction of the car.

If you see a situation where the speed, or direction of motion, of any object changes, then there is a resultant force acting on the object.

An object moving in a straight line with a steady speed does *not* have a resultant force acting on it.

Link

You can learn more about speed in 1.1.3 Speed.

▲ Friction changes the direction of a motorbike.

Summary Questions

1 Copy and complete the sentences below.

If the forces on an object are the same______ but act in ______ directions they are balanced. The object is in ______. The forces acting on any stationary object are ______. If the resultant force on an object is not zero we say the forces are ______, and the speed or ______ of motion will change, or both will change. *(6 marks)*

2 A cyclist is speeding up as she is cycling along a road.

a Draw a diagram to show the forces acting on the cyclist. *(1 mark)*

b Label the forces using the words 'resistive' and 'driving'. *(1 mark)*

c Predict and explain what would happen if the resistive forces increase until they balance the driving force. *(3 marks)*

3 A diver on a diving board holds a newtonmeter with an apple attached to it. The newtonmeter reads 1N. Suggest and explain what happens to the reading on the newtonmeter when he steps off the diving board. *(3 marks)*

Lesson 2: Answers

1.1.2 Balanced and unbalanced

In-text questions	**A** An object is in equilibrium of the forces on it are balanced, or if the resultant force is zero. **B** Zero **C** Balanced forces cancel out/are equal in size and opposite in direction. Unbalanced forces are not of equal size/direction/do not cancel out.
Summary questions	**1** size, opposite/opposing, equilibrium, balanced unbalanced, direction (6 marks) **2a** Force diagram with an arrow showing that the resistive force is smaller than the driving force. (1 mark) **b** Arrow pointing backwards labelled resistive, arrow pointing forwards labelled driving. (1 mark) **c** She continues to speed up but not as much, until she moves at a steady speed because the forces are balanced. (3 marks) **3** The newtonmeter reads zero. (1 mark) The resultant force on the spring inside the newtonmeter is zero. (1 mark) For the reading to be bigger than zero, the Earth and the diver have to exert forces in opposite directions. (1 mark)

Lesson 3

1.1.3 Speed

Learning objectives

After this section you will be able to:

- state and use the formula for speed
- describe the link between speed and journey time
- describe how the speed of an object depends the movement of the observer.

▲ A cheetah can travel faster than a car.

▲ A speed camera measures how long it takes a car to travel a certain distance by taking a photo at the start of the distance and another at the end. It can then calculate the car's speed.

It feels fast when you travel downhill on a bike. However, even when going downhill, you could not travel as fast as a cheetah.

What is speed?

Speed is a measure of how far something travels in a particular time, like 1 second or 1 hour. In science you measure speed in **metres per second** (m/s). A speed of 2 m/s means you travel 2 metres each second. In 10 seconds you travel 20 m.

Car speed limits are measured in miles per hour (m.p.h.) or kilometres per hour (km/h).

A Write a definition of the word speed.

How do you calculate speed?

To find the speed of an object moving at a steady speed you need to measure the time it takes to travel between two points.

You work out the speed from the distance travelled divided by the time taken:

$$\text{speed (m/s)} = \frac{\text{distance travelled (m)}}{\text{time taken (s)}}$$

A long-distance runner runs part of his race at a steady speed. It takes him 20 seconds to run 100 m.

$$\text{speed} = \frac{100\text{ m}}{20\text{ s}}$$

$$= 5\text{ m/s}$$

When you are using a formula to calculate speed it is helpful to write it out like this. If you write the units of distance and time in the formula then you will have the correct units for the speed.

▲ A marathon runner's speed changes during a race.

What is average speed?

A marathon runner will take several hours to run the 26.2 miles (42.2 km) of a marathon. She does not run at exactly the same speed throughout the race.

You can work out the **average speed** by dividing the *overall* distance by the *overall* time that it took to run the race. This average speed makes it easier to compare how fast different people, or boats, or cars travel.

B What happens to the time for a journey if your speed for the journey increases.

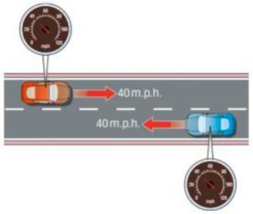
Marathon times

A marathon runner runs the marathon in 2 hours 30 minutes, or 2.5 hours. Calculate the average speed of the runner in km/h.

What is relative motion?

Have you ever looked out of the window of a stationary train in a station at a moving train and felt that your train is moving? This is an example of **relative motion**. The speed of an object is always relative to the speed of the observer. Being on a moving train looking at a stationary one feels the same as being on a stationary train looking at a moving one.

C State what is meant by relative motion.



▲ The speed of each car relative to the road is 40 m.p.h, but the speed of each car relative to each other is 80 m.p.h.

Speed is relative. If two cars are moving at the same speed in the same direction, then their speeds, relative to each other, are zero. If a car is travelling at 30 m.p.h that means 30 m.p.h relative to a stationary object.

If the same car is travelling behind a truck moving at 20 m.p.h. in the same direction, then the speed of the car relative to the truck is 10 m.p.h.

Foul Fact

You cough at 60 m.p.h. but your sneeze would break the motorway speed limit. You sneeze at over 100 m.p.h.

Key Words

speed, metres per second, average speed, relative motion

Summary Questions

1. Copy and complete the sentences below.
   To calculate speed you need to know the ______ and the ______.
   To calculate average speed you divide the ______ ______ by the ______ ______. You measure speed ______ to a stationary object.
   (5 marks)
2. A runner runs 100 metres in 12.5 seconds. Calculate her average speed.
   (2 marks)
3. A car is travelling east at 50 km/h. On the same road another car is travelling west at 20 km/h. The cars are moving away from each other. Describe their relative speeds.
   (2 marks)
4. Use the speed formula to explain how a speed camera calculates a car's speed.
   (6 marks)

Lesson 3: Answers

1.1.3 Speed

In-text questions	**A** How far something travels in a particular time. **B** It is less/shorter/decreases. **C** The movement of a body compared to another.
Activity	**Marathon times** distance in a marathon = 42.2 km; time taken to run marathon = 2.5h average speed = distance ÷ time = 42.2 ÷ 2.5 = 16.88 km/h
Summary questions	**1** distance, time, total distance, total time, relative (5 marks) **2** Average speed = total distance ÷ total time = 100 m ÷ 12.5 s = 8m/s (2 marks) **3** Their relative motion is 70 km/h, either towards each either if they haven't passed yet, or away from each other if they have already passed. (2 marks) **4** Extended response question (6 marks). Example answers: Lines are painted on the road a set distance apart. The camera takes a photograph of the car on the road. The camera takes a photograph of the car a short time later. From the position of the car the camera can work out how far the car has travelled in the time between the two photographs were taken. The camera can use the time between the photographs to find the time using the equation speed = distance ÷ time. The speed camera uses the information obtained from the two photographs to calculate the speed of the car. If the car is travelling faster than the speed limit it will travel too far in the time between the photographs.

1.1.4 Distance–time graphs

Learning objectives

After this section you will be able to:

- state and use the formula for speed
- state what a straight line or a curved line on a distance–time graph tells you about speed
- calculate speed from a distance–time graph
- illustrate a journey with changing speed on a distance–time graph, and label changes in motion.

Key Words

distance–time graph, acceleration

▲ The car and motorbike are travelling at different speeds.

Fantastic Fact

You might hear people talk about the time it takes a car to accelerate from 0 to 60 m.p.h. A very fast car can accelerate from 0 to 60 m.p.h. in 2.3 seconds.

Working it out

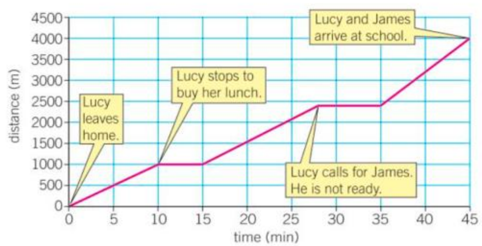
Look at the distance–time graph opposite for a constant speed. Calculate the speed using information on the graph.

How long does it take you to get to school? You can tell the story of a journey with a graph.

What is a distance–time graph?

A **distance–time graph** is a useful way of showing how something moves. It shows the distance that something travels over a certain time. A graph tells a story.

Here is a graph that shows Lucy's journey to school. The line shows how far she travelled each minute of the journey.



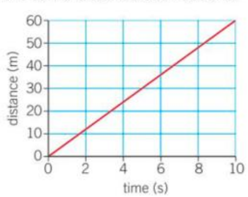
▲ A distance–time graph for Lucy's journey to school.

A State what a distance–time graph shows.

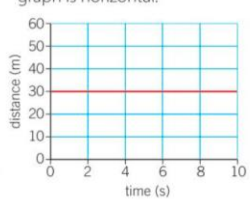
What does the graph tell us?

This is a very simple distance–time graph. The object moves the same distance each second.

What happens if you stay still? The line on the distance–time graph is horizontal.

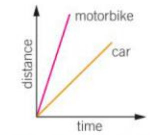


▲ A distance–time graph for a constant speed.



▲ A distance–time graph for a stationary object.

The slope of a distance–time graph tells you the speed. If the line is steep the object is moving fast. If it is not very steep then the object is moving more slowly.



▲ A distance–time graph for two vehicles travelling at different speeds.

B State what the slope of a distance–time graph shows you.

In the graph at the top of the page, both the car and the motorbike are moving at a steady speed. The line for the motorbike shows a faster speed and the line for the car shows a slower speed.

Acceleration

When you are travelling in a car, your speed does not stay the same for the whole journey. The speed changes through the journey.

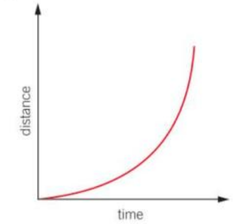
The changing speed is shown by the slope of the graph. The slope changes gradually, not suddenly.

If your speed is changing you are accelerating. **Acceleration** tells you how quickly your speed is changing.

C State what acceleration means.

When you drop a ball it gets faster and faster. It accelerates towards Earth. The distance–time graph is curved. The distance–time graph is also curved if an object is slowing down.

▲ The distance a ball falls in one second increases as it accelerates.



▲ A distance–time graph for an accelerating object.

Working out speed from a distance–time graph

You can calculate speed from a distance–time graph. For example, in the first section of Lucy's graph she walks 1000 metres in 10 minutes or 600 seconds.

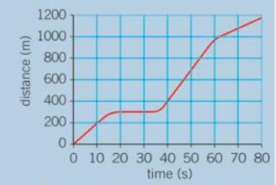
$$\text{average speed (m/s)} = \frac{\text{total distance (m)}}{\text{total time (s)}}$$

$$= \frac{1000\text{ m}}{600\text{ s}}$$

$$= 1.7\text{ m/s}$$

Summary Questions

1. Copy and complete the sentences below.
   A distance–time graph shows the ______ that an object travels in a certain ______. The ______ of the line tells you the speed. If the line is horizontal the object is ______. If the line is a curve the speed of the object is ______. *(5 marks)*

2. 

   ▲ A more realistic distance–time graph.

   a Describe two differences between this journey and Lucy's journey to school.
   b Explain how you used the graph to work out the answers to part **a**. *(4 marks)*

3. Imagine two students travelling 3 km to school. One walks and the other travels by car. Sketch a distance–time graph for each journey and compare the graphs that you have drawn. *(6 marks)*

Lesson 4: Answers

1.1.4 Distance–time graphs

In-text questions	**A** The distance that something travels in a certain time. **B** The speed of the object shown in the graph. **C** Acceleration tells you how quickly your speed increases or decreases.
Activity	**Working it out** speed = distance ÷ time = 60 ÷ 10 = 6 m/s
Summary questions	**1** distance, time, slope, stationary, changing (5 marks) **2a** (2 marks) Two from: Journey is not as far/Speed for sections of the journey are different from each other/Journey took less time/In this graph the object was only stationary once **b** (2 marks) Corresponding reason: The scale only goes up tp the 1000m, not 4500/The gradient of the graph change, but for Lucy's journey the speeds are similar/stationary/The scale only goes up to 80s not 45 minutes/There is only one horizontal section of this graph, but there are two on the graph of Lucy's journey. **3** Extended response (6 marks). Example answers: Both graphs start at a distance of zero and finish at a distance of 3 km. The graph for the car reaches 3 km faster than the graph for walking. Both graphs might have horizontal sections (e.g., the car may stop at a traffic light, or the person walking might stop at a shop). If the graph is horizontal the car or person has stopped. The slope of the graph for the car is much steeper. Cars travel faster than people walking. The car reaches school in a shorter time. The average speed of a car is much higher than that of a person. Both graphs should include curved lines. Curved lines show periods of changing speeds.

Lesson 5

1.2.1 Gravity

Learning objectives

After this section you will be able to:

- state the value of g on Earth and on the moon
- describe the difference between mass and weight
- describe how gravitational force varies with mass and distance
- use the formula to calculate your weight on different planets and explain changes in weight
- explain why objects stay in orbit.

Foul Fact!

The strongest gravitational field in the Universe is made by a black hole. If you stood close to a black hole, the force of gravity on your feet would be much bigger than the force of gravity on your head. You'd be stretched. This is called 'spaghettification'.

Units of mass

Smaller masses are measured in grams (g).
There are 1000 g in 1 kilogram (kg).
Convert these masses into grams:
a 2 kg **b** 3.5 kg **c** 0.4 kg
Convert these masses into kilograms:
d 4700 g **e** 250 g

Link

You can learn more about electrostatic forces in 2.2.2 Charging up.

If you let go of your pen and it moved upwards you'd be very surprised. We are so familiar with the force of gravity that sometimes we don't even think of it as a force.

What is gravity?

When a diver jumps off a diving board he moves towards the Earth because there is a force on him. This is **gravitational force** or gravity. The Earth pulls on the diver, and the diver pulls on the Earth. Forces come in pairs.

The same force acts on the Earth but the Earth does not move because it is much more massive.

Gravitational force is a non-contact force because the diver and the Earth do not need to touch to exert a force on each other.

The gravitational force on the diver or on the Earth depends on:

- the mass of each object
- how far apart they are.

If the mass is larger the force is larger. If the distance is larger the force is smaller.

A What factors affect the size of a gravitational force.

Force fields

In physics you can use the idea of a **field** to explain non-contact forces. A field is a special region where something, like a mass, experiences a non-contact force.

▲ A magnet picks up filings.

▲ A balloon rubbed on your jumper attracts a baby's hair.

- In a gravitational field, a mass experiences a force.
- In a magnetic field, a magnetic material, like iron, experiences a force.
- In a electrostatic field, charged objects experience a force. You can charge an object like a balloon by rubbing it.

B Describe what is meant by a field.

What is the difference between weight and mass?

Weight is a force so it is measured in newtons (N). **Mass** is the amount of 'stuff' something is made up of. It is a measure of how hard it is to get something to move. Mass is measured in **kilograms** (kg).

You can calculate weight using a formula.

weight (N) = mass (kg) × **gravitational field strength**, g (N/kg)

On Earth, gravitational field strength is about 10 N/kg. This is the force that acts on 1 kg in the Earth's gravitational field.

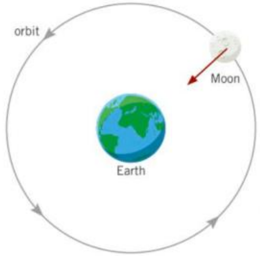
Gravitational field strength is different on other planets, on moons, and on stars. Your weight would be different on different planets because g would be different.

The Apollo astronauts could jump much higher on the Moon because g on the Moon is 1.6 N/kg. Their weight decreased as they moved away from the Earth, which made it challenging to do things like eat and sleep.

C State what is meant by gravitational field strength.

How does gravity keep things in orbit?

Isaac Newton worked out that the Earth exerts a force on the Moon. The force of gravity acting on the Moon keeps the Moon in orbit around the Earth. It is this same force that acts on an apple and pulls it to the ground. It changes the *direction* of motion, not the speed.



◀ The force of gravity keeps the Moon in orbit.

D Describe how the Earth stays in orbit around the Sun.

◀ Your weight on Jupiter would be much heavier than on Earth, but your mass would be the same.

Key Words

gravitational force, field, weight, mass, kilogram (kg), gravitational field strength

Summary Questions

1 Copy and complete the sentences below.
Some forces act a distance. The force of gravity acts on things that have ______. Your weight is a ______ and is measured in ______. Your ______ is the amount of stuff you are made up of and is measured in ______. *(5 marks)*

2 Calculate the weight of a person with a mass of 60 kg in the gravitational field of Jupiter where g = 27 N/kg. *(3 marks)*

3 Describe how the force of gravity depends on:
a the distance from a planet *(1 mark)*
b the mass of the planet. *(1 mark)*

4 Imagine the first Olympic Games conducted on the Moon in a specially designed dome. Use the ideas on this page to state and explain which sports would produce new records and which would not. *(6 marks)*

Lesson 5: Answers

1.2.1 Gravity

In-text questions	**A** masses of both bodies, distance between the bodies **B** A field is a region in which certain objects experience a force. The object does not need to be touc hing anything to experience this force. **C** The force on 1 kg in a gravitational field. **D** The Sun exerts a gravitational force on the Earth.
Activity	**Units of mass a** 2000 g **b** 3500 g **c** 400 g **d** 4.7 kg **e** 0.25 kg
Summary questions	**1** mass, force, newtons, mass, kilograms (5 marks) **2** weight = mass x gravitational field strength (1 mark) = 60 kg x 27 N/kg (1 mark) = 1620 N (1 mark) **3a** As the distance increases the force of gravity decreases. (1 mark) **b** As the mass increases the force of gravity increases. (1 mark) **4** Example answers (6 marks): Because the gravitational field strength is less, objects will travel further before they hit the ground. As such, events that involve throwing something a distance would produce new records; such as javelin/shot put/hammer throw. Because the gravitational field strength is less, events that involve lifting things would also produce new records as mass would weigh less on the Moon than it did on Earth; such as weightlifting.

Part 1 – Revision Questions

End-of-Big Idea questions

1 Choose units of speed from the list below.

m/s m s h m.p.h. km/s km

*(**3 marks**)*

2 **a** Write down the letter of the object below, for which the resultant force is zero. *(1 mark)*

A A boat that is speeding up

B A boy who is floating in a swimming pool

C A cyclist who is slowing down.

b Name the force that keeps the Earth in orbit around the Sun. *(1 mark)*

*(**2 marks**)*

3 A cyclist is sitting on her bicycle at the start of a race.

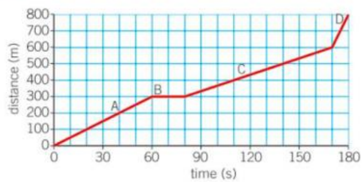
a Draw a diagram of the cyclist and label the forces acting on her. *(2 marks)*

b Explain how the bicycle seat exerts a force on the cyclist. *(2 marks)*

c The race begins. State whether the resultant force on her as she goes around a corner at a steady speed is zero or non-zero. *(1 mark)*

*(**5 marks**)*

4 **a** Here is a graph of a person riding his bike.



State the letter of the section where the student was:

i stationary *(1 mark)*

ii moving fastest *(1 mark)*

iii moving slowest. *(1 mark)*

b Calculate the speed in section A of the graph. *(3 marks)*

*(**6 marks**)*

5 A car is travelling at 70 m.p.h. and a lorry is travelling at 50 m.p.h. in the same direction.

a Calculate the speed of the car relative to the lorry. *(2 marks)*

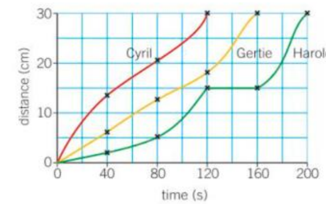
The car slows down to 50 m.p.h.

b State the new speed of the car relative to the lorry. *(1 marks)*

c The car starts off ahead of the lorry. Describe how the car appears to the lorry driver in part **a**. *(2 marks)*

*(**5 marks**)*

6 Here is a distance–time graph for three snails – Cyril, Gertie, and Harold.



Compare the journeys of the three snails, and describe what happened to their speed during the journeys.

*(**6 marks**)*

7 A toolkit on Earth has a mass of 5 kg. The gravitational field strength on Earth is 10 N/kg and on the Moon is 1.6 N/kg. Calculate the difference in the weight of the toolkit on the Earth and the Moon.

*(**3 marks**)*

8 Jupiter has moons in orbit around it, and Jupiter itself orbits the Sun. Compare and contrast the gravitational forces between Jupiter and its moons, and Jupiter and the Sun.

*(**6 marks**)*

Lesson 6: Revision Answers

1 Forces – Part 1 Checkpoint

End-of-Big Idea questions	**1** m/s; m.p.h; km/s (3 marks) **2a** B (1 mark) **b** gravity (1 mark) **3a** Diagram of cyclist with weight acting downwards (1 mark) and normal reaction acting upwards (1 mark). **b** The normal reaction force (1 mark) of the ground on the cyclist acts upwards through the bicycle seat on the cyclist (1 mark) **c** non-zero (1 mark) **4a i** B (1 mark) **ii** D (1 mark) **iii** C (1 mark) **b** 300 ÷ 60 (1 mark) = 5 (1 mark) m/s (1 mark) **5a** 20 m.p.h (2 marks) **b** 0 m.p.h (2 marks) **c** The car appears to be moving away from the lorry (1 mark) at 20 m.p.h (1 mark). **6** Extended response (maximum 6 marks) All three snails travel the same distance of 30cm. Cyril's average speed is highest, followed by Gertie, and then Harold. Cyril begins quickly then slows to a constant speed. He travels at constant speed for a time, then accelerates towards the end. Gertie travels at constant speed, then also accelerates towards the end. Harold accelerates slowly, stops for a while, then accelerates towards the end. **7** weight on Earth = 5 x 10 = 50 N (1 mark) Weight on Moon = 5 x 1.6 = 8 N (1 mark) difference = 50 – 8 = 42 N (1 mark) **8** Extended response (maximum 6 marks). The mass of the Sun is far greater than the masses of Jupiter's moons. Hence the gravitational force between Jupiter and the Sun is much stronger than the gravitational force between Jupiter and its moons. However, the distance between Jupiter and the Sun is much greater than the distance between Jupiter and its moons. This means that the force between Jupiter and the Sun is much smaller than it would be if the Sun were as close to Jupiter as its moons are.

Part 2

Part 2 – Summary (Check List)

1 Forces

You may have seen videos of skydivers jumping out of a plane and landing safely. Their motion changes between jumping and landing. Understanding the forces acting on an object allows you to explain how it is moving, or not moving.

The air skydivers move through is a fluid – it is like a spread-out liquid. In this Big Idea you will learn about pressure in fluids (gases and liquids) and relate it to floating and sinking. You will also learn about the pressure of one solid object, like the skydiver, on another solid object, like the ground.

Q

How do brakes on cars and bikes work?

You already know

- Some forces need contact between two objects.
- Friction, air resistance, and water resistance act between moving surfaces to slow things down.
- Most forces require direct contact.
- The shapes of solid objects made from some materials can be changed by squashing, stretching, bending, and twisting.

1 Forces: Summary

Key Points

Contact forces

- When the forces acting on an object are equal in size and acting in opposite directions then they are balanced and the object is in equilibrium. The resultant force is zero.
- There is a force of friction when objects are in contact because surfaces are rough. Friction can be reduced by lubrication.
- Drag (air and water resistance) slows objects down because the object has to push the air or water out of the way. Drag can be reduced by streamlining.
- Forces can deform objects.
- Springs or ropes extend when you apply a force and produce a tension.
- For some objects, like springs, if you double the force the extension will double. The extension is proportional to the force. This is Hooke's Law, and is a special case. There is a linear relationship between them and the graph is a straight line through (0,0).

Pressure

- Fluids, like gases or liquids, exert a pressure on a surface because of the collisions of molecules with the surface.
- Atmospheric pressure decreases with height, and water pressure increases with depth.
- Fluid pressure or stress on a surface = force/area, measured in N/m^2 or N/cm^2. The pressure tells you how the force is spread out over an area.
- The turning effect of a force is called a moment. You calculate a moment by multiplying the force by the distance from a pivot.
- If the clockwise moments acting on an object equal the anticlockwise moments the object will be in equilibrium. This is how see-saws balance.

Key Words

friction, contact force, newton, drag force, water resistance, air resistance, resultant force, equilibrium, streamlined, lubrication, deformation, compression, tension, reaction, extension, elastic limit, Hooke's Law, linear relationship, pivot, moment, newton metres, law of moments, centre of gravity, centre of mass, fluid, pressure, gas pressure, atmospheric pressure, liquid pressure, incompressible, upthrust, stress, newtons per metre squared

1.3.1 Friction and drag

Learning objectives

After this section you will be able to:

- sketch the forces acting on objects when there are contact forces acting
- describe what happens to a moving object when the resultant force acting on it is zero
- describe the factors that affect the size of the drag forces and friction, and how friction and drag can be reduced.

▲ You need friction to move across surfaces.

Link

You learnt about contact forces and newtons in Book 1, 1.1.1 Introduction to forces, and about resultant forces and equilibrium in 1.1.2 Balanced and unbalanced forces.

Fantastic Fact!

In 1995 Fred Rompelberg travelled at 167 mph... on a bicycle! He did it by cycling behind a lorry where there was very little air resistance.

Slide your finger along the desk. Does the surface feel smooth or rough? Even really smooth surfaces exert a force.

What is friction?

A surface such as a metal slide in a playground looks and feels really smooth. Now imagine zooming in on it – you will see that it is actually rough.

When a book is resting on the table you can push on it but it may not move. **Friction** grips objects. As you increase the force by pushing harder the book will start to move. If you remove the force the book slows down and stops. This is because the rough surfaces can no longer move past each other.

A State whether friction is greater on a rough or a smooth surface.

What is drag?

As you learnt in Book 1, 1.1.1 Introduction to forces, friction and air resistance are **contact forces**. They act when surfaces are in contact. Forces are measured in **newtons**.

If an object is moving through a fluid, such as air or water, the force slowing it down is called a **drag force**. A dolphin swimming through the water and a surfer paddling through water will both experience **water resistance**. As a snowboarder jumps through the air he will experience **air resistance**.

◀ When you move through water you experience water resistance.

To understand drag forces you need to think about the particles in the air and the water.

A solid moves through a gas. A solid moves through a liquid.

▲ A moving object is in contact with air or water particles.

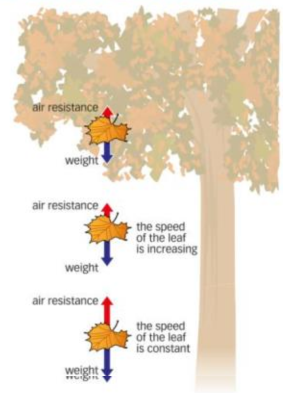
As a dolphin moves through the water it pushes the water particles out of the way. This produces a drag force, which slows it down.

B Sketch a diagram showing the forces on a stone falling through water.

How do drag forces and friction affect motion?

As you learnt in Book 1, 1.1.2 Balanced and unbalanced forces, an object will keep moving at a steady speed in the same direction (or stay still) unless a **resultant force** acts. So if friction or drag forces are acting you need to apply a force to cancel them out, not to keep an object moving.

The resultant force on an object moving with a steady speed in the same direction is zero. The object is in **equilibrium**.



▲ When the resultant force is zero the leaf falls with a steady speed.

C Write down two things that an object does when the resultant force on it is zero.

How can you reduce drag forces and friction?

An Olympic cyclist will tuck her arms in close to her body as she cycles. She will even make sure that her thumbs are as close to the handlebars as possible. This makes her more **streamlined**, which reduces the force of air resistance. One way to reduce friction is by using oil or grease. This is called **lubrication**.

Key Words

friction, contact force, newton, drag force, water resistance, air resistance, resultant force, equilibrium, streamlined, lubrication

Testing a parachute

A company wants to compare different materials for making parachutes. Name **three** ways that they could make it a fair test.

Summary Questions

1. Copy and complete the sentences below.
   The force of ______ acts between two solid surfaces in contact that are sliding across each other. The surfaces are ______ and will grip each other. This is why you need to exert a ______ to make something move. There are two drag forces: ______ and ______. When a moving object is in contact with ______ or ______ particles it has to push them out of the way. *(7 marks)*
2. Describe the factors that affect the size of the frictional force. *(2 marks)*
3. **a** Explain how a bird diving through water can be in equilibrium. *(2 marks)*
   b Sketch a force diagram for the bird in equilibrium. *(2 marks)*
4. A dragster is a car that uses a parachute as a brake. Use the ideas on this page to compare the forces of drag and friction on the car when it accelerates and when it brakes. *(6 marks)*

Lesson 7: Answers

1.3.1 Friction and drag

In-text questions	**A** rough **B** Diagram of stone with force arrow labelled gravity going downwards, and force arrow labelled water resistance going upwards. **C** moves with a steady speed or remains stationary
Activity	**Testing a parachute** Keep these things the same: the weight of the object beneath the parachute, the area of the parachute, and the thickness of the material.
Summary questions	**1** friction, rough, force, air resistance, water resistance, air/gas, water (7 marks) **2** type of surface, weight of object (2 marks) **3a** The drag cancels out the weight of the bird. (1 mark) The bird travels at a steady speed through the water. (1 mark) **b** Diagram showing downwards force on bird, labelled weight. (1 mark) Upwards forces, labelled drag. (1 mark) **4** Example answers (6 marks): Air resistance depends on area. Bigger area means that more molecules hit the parachute. The air resistance is bigger with a bigger parachute. Air resistance depends on speed. Bigger speed means that more molecules hit the parachute. The air resistance is bigger with a bigger speed. The biggest air resistance will act on a large parachute attached to a fast car.

Lesson 8

1.3.2 Squashing and stretching

Learning objectives

After this section you will be able to:

- describe how forces deform objects
- explain how solid surfaces provide a support force
- use Hooke's Law
- explain what 'linear relationship' means.

▲ Even a solid golf ball changes shape when you hit it.

Foul Fact!

When a footballer heads a ball the forces deform both the ball and the footballer's head.

Link

You can learn more about particles in solids, liquids, and gases in Book 1, 5.1.1 The particle model.

Key Words

deformation, compression, tension, reaction, extension, elastic limit, Hooke's Law, linear relationship

Why don't you fall through the chair you're sitting on? The chair changes shape, or deforms, when you sit on it. This produces the force that pushes you up.

Changing shape

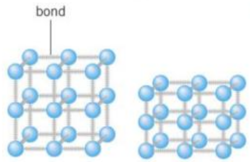
Forces can change the shape of objects. This is called **deformation**. Your weight is the force that causes the chair to deform when you sit on it.

When forces squash an object, they cause **compression**. When they stretch an object, they cause **tension**.

A Describe what happens to a tennis ball when it hits the ground.

How can the floor push you up?

The floor pushes up on you when you stand on it. It seems strange to talk about the floor exerting a force on you. You can't see anything happening.



◀ These diagrams show what happens when you exert a force on a solid object.

The floor is a solid. Solids are made up of particles arranged in a regular pattern. The particles are joined strongly together by bonds. This is what happens when you stand on the floor:

- Your weight pushes the particles together.
- The bonds are compressed.
- They push back and support you.

Solid materials are only compressed a very small amount when you apply a force to them. A support force from a chair or the floor is called the **reaction** force.

Stretching

Bungee cords, springs, and even lift cables all stretch when you exert a force on them. The amount that they stretch is called the **extension**.

A bungee cord stretches as the jumper falls. When the bungee cord has stretched as far as it will go, it pulls her back up.

◀ The shape of a bungee cord changes when you stretch it.

What happens when you stretch a spring?

Springs are special. If you ***double*** the force on the spring the extension will ***double***. You can use the length of the spring to measure the size of a force. When you remove the force the spring goes back to its original length.

What's the limit?

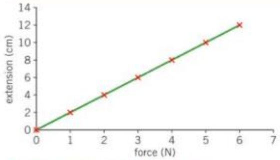
At some point the spring will not go back to its original length when you remove the force. This is the **elastic limit**. Trampoline springs are designed to never go past their elastic limit.

Hooke's Law

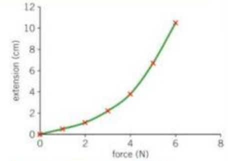
If the extension doubles when you double the force then the object obeys **Hooke's Law**. The graph of force against extension is a straight line, through the origin (0,0), which shows a **linear relationship**. The force and extension are proportional.

Hooke's Law is a special case. Not everything behaves like a spring when you stretch it. If you double the force on an elastic band the extension may not double.

B Write down what happens to a spring as you increase and then decrease the force on it.



▲ This graph shows how the extension of a spring changes as you pull it.



▲ This graph shows the relationship between force and extension for poly(ethene). It is not linear.

A straight-line graph

Using the graph for the extension of the spring below, find the extension when the force is 3 N and again when it is 6 N. Does this spring obey Hooke's Law? Explain your answer.

How long?

You have a spring that is 4 cm long. When you exert a force of 3 N it stretches to a length of 6 cm. What is the extension? What would the extension be if you doubled the force?

Summary Questions

1. Copy and complete the sentences below.

Forces can change the shape of objects or ______ them. Solid surfaces are made of ______. The bonds between particles are compressed when you apply a force. They ______ back on you. This provides a ______ force called the ______ force. When you sit on a wooden chair you ______ it. When you sit on a swing, you ______ the chain. *(7 marks)*

2. Describe and explain what happens to the extension of a spring when you double the force on it. *(2 marks)*

3. Use the graphs to the left to compare the behaviour of a spring and poly(ethene). *(6 marks)*

Lesson 8: Answers

1.3.2 Squashing and stretching

In-text questions	**A** The shape of the tennis ball changes/is deformed. **B** It gets longer, then shorter.
Activity	**A straight-line graph** When the force is 3 N the extension is 6 cm and when the force is 6 N the extension is 12 cm. This shows that if you double the force the extension doubles. The spring obeys Hooke's Law. **How long** The extension = 6 cm – 4 cm = 2 cm If you doubled the force the extension would be 4 cm.
Summary questions	**1** deform, particles, push, support, reaction, compress, stretch (7 marks) **2** It doubles. The extension is proportional to the force. (2 marks) **3** Example answers (6 marks): The spring obeys Hooke's Law. There is a linear relationship between force and extension. If you double the force on the spring the extension will double. The relationship between force and extension for polythene is not linear. The polythene does not obey Hooke's Law. So doubling the force on the polythene means the extension may be more or less than double.

Lesson 9

1.3.3 Turning forces

Learning objectives

After this section you will be able to:

- describe what is meant by a moment
- calculate the moment of a force.

▲ Tightrope walking at Monte Piana, Italy.

▲ You need to apply a turning force to open a door.

Key Words

pivot, moment, newton metres, law of moments, centre of gravity, centre of mass

A tightrope walker uses a long pole to help him to balance.

A force that turns

Whenever you open a door you are using a turning force. A turning force acts a certain distance from a **pivot**.

The turning effect of a force is called a **moment**. The moment depends on the force being applied and how far it is from the pivot.

moment (Nm) = force (N) × perpendicular distance from the pivot (m)

You measure force in newtons (N) and distance in metres (m). You calculate a moment in **newton metres** (Nm).

A State the unit of a moment.

The law of moments

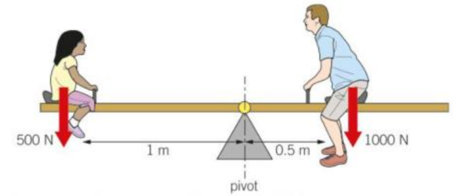
You sit on the left of a see-saw with your friend at the other end. It balances.

The moment of your weight acts anticlockwise. The moment of your friend's weight acts clockwise.

When an object is in equilibrium the sum of the clockwise moments is equal to the sum of the anticlockwise moments. This is the **law of moments**.

▲ These apples are in equilibrium because the clockwise moment equals the anticlockwise moment.

B State the law of moments.



▲ The see-saw doesn't turn if it is in equilibrium.

You can work out if a see-saw is going to be balanced by calculating the clockwise and the anticlockwise moments.

clockwise moment = force × distance on the right
= 1000 N × 0.5 m
= 500 Nm

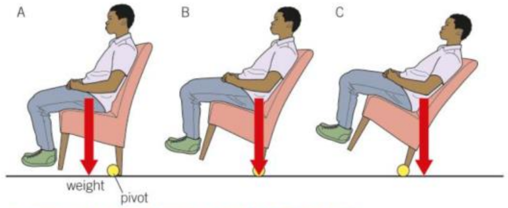
anticlockwise moment = force × distance on the left
= 500 N × 1 m
= 500 Nm

The moments are the same. The see-saw balances.

Falling over

When you lean back and tip your chair slightly, there is a turning force that brings your chair back. That turning force is your weight acting about the point where the legs touch the floor. If you lean back far enough you will topple over.

All the weight of an object seems to act through a point called the **centre of gravity** (or **centre of mass**). If the centre of gravity is above the pivot there is no turning force. If the centre of gravity is to the left or right of the pivot there will be a turning force.



▲ There is a turning force in A and C, but not in B.

C Describe what is meant by centre of gravity.

Sitting on a see-saw

A mother and daughter are on a see-saw 2 m long. The mother has a weight of 600 N and the child has a weight of 150 N.

Calculate where the mother must sit to balance the child who is sitting at the other end.

Fantastic Fact

The world's largest see-saw is in New York. It is just over 24 metres long. It lifts you higher than a house.

Summary Questions

1. Copy and complete the sentences below.

   The _____ effect of a force is called a moment. You can calculate the moment of a force by multiplying the _____ by the _____. If the anticlockwise moments equal the clockwise moments the object will be in _____. This is the _____ of moments. The _____ of an object acts through a point called the centre of _____.

   (7 marks)

2. A girl applies a force of 5 N to close a door. The handle is 0.75 m from the hinge. Calculate the moment of the force.

   (2 marks)

3. Design a balancing game that children can play. Explain in terms of the law of moments and centre of gravity how to play it.

   (6 marks)

Lesson 9: Answers

1.3.3 Turning forces

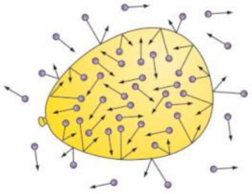
In-text questions	**A** newton metre (Nm) **B** An object is in equilibrium if the total anticlockwise moments equal the total clockwise moments. **C** The point through which all the weight of an object seems to act.
Activity	**Sitting on a see-saw** If the child sits on one end she is 1 m from the pivot. Clockwise moment = 150 N × 1 m = 150 Nm You need the anticlockwise moment to be the same: 600 N × distance from the pivot = 150 Nm Distance from the pivot = $\frac{150\ \text{Nm}}{600\ \text{N}}$ = 0.25 m
Summary questions	**1** turning, force, distance, equilibrium, law, weight, gravity (7 marks) **2** moment = force × distance, so 5 N × 0.75 m = 3.75 Nm (2 marks) **3** Example answers (6 marks): A ruler or beam that you hang things from, or something that can balance. A system of adding things to one side or the other. An explanation of what is meant by a moment. An explanation of the law of moments. A scoring system that uses the law of moments, for example, predicting where you have to put something before you add it. An element of skill in terms of the items you can hang, or where you can put them.

1.4.1 Pressure in gases

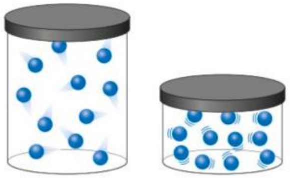
Learning objectives

After this section you will be able to:

- describe how fluids exert a pressure in all directions
- calculate fluid pressure
- explain the behaviour of objects using ideas of pressure
- describe how atmospheric pressure changes with height.



▲ If there are more collisions on the inside than the outside the balloon gets bigger.



▲ In a smaller volume gas molecules will collide more often with the walls of the container.

Balloon pressure

A student wants to investigate how the volume of a fixed amount of air in a balloon changes with temperature. Write a plan for the investigation.

Have you ever blown a balloon up until it bursts?

◀ The moment when a balloon bursts.

What is a fluid pressure?

You are surrounded by a **fluid** called air. A fluid is a substance with no fixed shape, like a gas or a liquid. Gases and liquids contain atoms or molecules that collide with the surfaces to produce fluid **pressure**. Pressure in a gas or a liquid acts in all directions, so when you blow up a balloon it inflates in all directions.

Lots of collisions of air molecules, such as inside a balloon, make a high gas pressure. There is a big force over a small area.

Calculating fluid pressure

You calculate the pressure of a gas or liquid using this equation:

$$\text{fluid pressure (N/m}^2\text{)} = \frac{\text{force (N)}}{\text{area (m}^2\text{)}}$$

You measure force in newtons (N) and area in metres squared m^2.

For example, inside a balloon the force exerted by the gas on an area of $0.0001\,m^2$ is 11 N.

A Write down the direction, or directions, that pressure in a gas acts.

$$\text{fluid pressure (N/m}^2\text{)} = \frac{\text{force (N)}}{\text{area (m}^2\text{)}}$$

$$= \frac{11\,\text{N}}{0.0001\,\text{m}^2}$$

$$= 110\,000\,\text{N/m}^2.$$

This is equivalent to a force of 110 000 N acting on a m^2 of the balloon. This force is the same as the weight of about six cars!

B Write down the two quantities you need to know to calculate fluid pressure.

You increase **gas pressure** if you squash or heat a gas. The same amount of gas in a smaller volume results in more collisions between air molecules and the container walls, so the pressure is higher.

Atmospheric pressure

There is air all around you. The air exerts a pressure on your body all the time called **atmospheric pressure**. You do not feel the pressure. It is cancelled out by the pressure of the gases and liquids in your body pushing out.

◀ Marshmallows contain pockets of air that expand when you pump out the air around them.

Changing atmospheric pressure

The atmospheric pressure near the ground is bigger than the pressure higher up. Near the ground there is more air above you, so the weight of air above you is heavier. The pressure is higher.

The gas has a higher density at sea level because gravity pulls the air molecules towards the Earth. This makes it harder for mountain climbers to breathe because there is less oxygen.

Mountaineers often take oxygen tanks when they climb high mountains such as Everest. The tanks contain oxygen gas that has been compressed into a small volume.

C State what happens to the atmospheric pressure as you go up a mountain.

Key Words

fluid, pressure, gas pressure, atmospheric pressure

Foul Fact

Think of your favourite famous person. When you breathe in you are breathing in at least 10 air molecules that they have breathed out.

Link

You can learn more about gas pressure in Book 1, 5.1.7 Gas pressure.

Summary Questions

1. Copy the sentences below, choosing the correct bold words.

   A gas exerts a pressure on the walls of its container because the particles **collide with/stick to** the walls. The pressure is exerted in **all/one** direction. As you go deeper into a fluid the pressure **decreases/increases**. To calculate fluid pressure you need to know the **force/mass** and the **area/temperature**.

   (5 marks)

2. Draw diagrams to explain the size of the marshmallows before and after you remove the air around them.

   (2 marks)

3. A climber climbs a mountain.

   a Explain why he might take a cylinder of oxygen with him.

   (3 marks)

   b There is 200 N on each $0.002\,m^2$ of a mountaineer at the bottom of a mountain. Calculate the fluid pressure. Describe and explain what happens to the force on this area as he climbs.

   (3 marks)

Lesson 10: Answers

1.4.1 Pressure in gases

In-text questions	**A** All directions **B** force, area **C** Atmospheric pressure decreases.
Activity	**Balloon pressure** The plan should include: a method of changing temperature – by location or changing temperature of water, a method of measuring volume – by circumference of balloon, variables to control, a range of temperature, the need to repeat measurements, and a risk assessment.
Summary questions	**1** collide with, all, increases, force, area (5 marks) **2** Diagram of small marshmallow showing pockets of air with gas molecules inside and air outside. Arrows on the molecules to show collisions with the surfaces. (1 mark) Diagram of large marshmallow showing pockets of air with gas molecules inside and no air outside. Arrows on the molecules to show collisions with the surfaces. (1 mark) **3a** You need to take oxygen, which is compressed into a cylinder so that you have enough of it. (1 mark) As you go up a mountain there is less air. (1 mark) Air contains the oxygen that you need to breathe. (1 mark) **b** Fluid pressure = $\frac{\text{force}}{\text{area}} = \frac{200\ \text{N}}{0.002\ \text{m}^2} = \frac{100\ 000\ \text{N}}{\text{m}^2}$ (3 marks)

1.4.2 Pressure in liquids

Learning objectives

After this section you will be able to:

- state how liquid pressure changes with depth
- explain why some things float and some things sink, and how area affects upthrust
- calculate pressure in liquids in a range of situations
- explain how hydraulic machines work.

◀ The cup on the left was taken down to a depth of 3000 m.

▲ The water comes out in all directions.

Why does it float?

A primary-school student says that 'heavy things sink and light things float'.

Use the example of a ferry to explain to them why that is not the case.

How do you squash a polystyrene cup without touching it? Take it deep beneath the sea and the pressure in the water will do it for you.

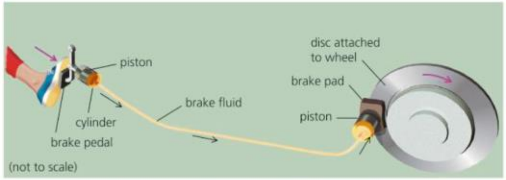
Liquid pressure

Water is a fluid. When you swim underwater it exerts a pressure on you. The water molecules are pushing on each other and on surfaces, and this **liquid pressure** acts in all directions.

When you squeeze a bag with holes in it the water is pushed out of all the holes because of liquid pressure. The water comes straight out of each hole and then falls because of gravity.

If you put water in a syringe, cover the end, and try to compress the liquid you will find it impossible. Liquids are **incompressible**. This is because the particles in a liquid are touching each other and there is very little space between them.

Liquids pass on any pressure applied to them. We use this property of liquids to make hydraulic machines, like brakes in a car.

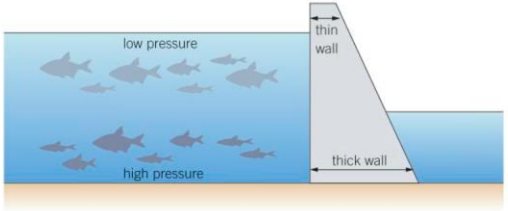


▲ The hydraulic fluid transmits the force of the driver's foot on the brake to the brake pads and discs in a car.

A Write down the direction, or directions, that pressure in a liquid acts.

Pressure and depth

The wall of a dam is not straight. It curves outwards at the bottom. The pressure at the bottom of the lake is bigger than the pressure at the top. The pressure at a particular depth in a liquid depends on the weight of water above it. This is like atmospheric pressure. The pressure at any point in a fluid depends on the weight of fluid above that point.



▲ A dam is thicker at the bottom.

B State what happens to liquid pressure as you go deeper in a lake.

Floating and sinking

Upthrust acts on any object that is floating, or is submerged in a liquid. It is easy to work out why a rubber duck floats. There are lots more water molecules hitting the bottom of the rubber duck than there are air molecules hitting the top. There is a resultant force acting on the duck, called upthrust. The duck sinks until there is enough upthrust to balance the weight. If the area in contact with the water is too small, there is not enough upthrust to balance the weight, so it sinks.

The underside of a boat has an area of 10 m^2, and a weight of 1000 N. It sinks to a depth where the pressure produces a force to balance its weight. At that depth:

$$\text{pressure (N/m}^2) = \frac{\text{force (N)}}{\text{area (m}^2)}$$

$$= \frac{1000\text{ N}}{10\text{ m}^2}$$

$$= 100\text{ N/m}^2.$$

When a submarine is submerged there is a difference in pressure between the top and bottom of the submarine. That produces a force that pushes the submarine up and balances the weight.

C Write down two factors that affect the upthrust on a floating object.

Key Words

liquid pressure, incompressible, upthrust

Fantastic Fact

The water pressure at the bottom of the Atlantic Ocean is equivalent to the weight of eight cars pushing on an area the size of your thumb.

Link

You learnt about upthrust in Book 1, 1.1.1 Introduction to forces.

Summary Questions

1 Copy and complete the sentences below.

The pressure in a liquid acts in ______ directions. The pressure ______ as you go deeper because the ______ of the water above you gets ______. The difference in pressure explains why there is a force called ______ on a floating object. *(5 marks)*

2

a Explain in terms of pressure why a boat made of modelling clay floats. *(2 marks)*

b Explain why the same mass of modelling clay shaped into a ball sinks. *(2 marks)*

c Calculate the water pressure when the force exerted by the water is 2000 N, and the area is 0.5 m^2. *(2 marks)*

3 You push a ping pong ball to the bottom of a bucket of water. Explain in detail what happens to the ball when you let it go. *(6 marks)*

4 A hydraulic machine has two pistons of area 1 cm^2 and 10cm^2. Calculate the force exerted by the large cylinder if you exert a force of 25 N on the small cylinder. *(2 marks)*

Lesson 11: Answers

1.4.2 Pressure in liquids

In-text questions	**A** All directions **B** It gets bigger. **C** Area, pressure
Activity	**Why does it float?** The bottom of the ferry is in contact with the water. The top of the ferry is in contact with the air. The water molecules and air molecules collide with the ferry. There are more water molecules hitting the bottom of the ferry than there are air molecules hitting the top. The water pressure is higher than the air pressure. This produces upthrust that keeps the ferry afloat if the area is big enough. The ferry floats when upthrust is the same as the weight of the ferry.
Summary questions	**1** all, increases, weight, bigger, upthrust (5 marks) **2a** Water pressure from the bottom creates the force upthrust. The clay boat floats because the upthrust balances out the weight of the boat. (2 marks) **b** The area is much smaller, the difference between the force pushing down and the force pushing up is not enough for the upthrust to balance the weight. (2 marks) **c** Pressure = $\frac{N}{m^2} = \frac{\text{force (N)}}{\text{area (m}^2)} = \frac{2000\text{ N}}{0.5\text{ m}^2} = \frac{4000\text{ N}}{m^2}$ (2 marks) **3** Example answers (6 marks): The ping pong ball has a small weight. When it is held at the bottom of the bucket there is the force of your hand pushing down. The force from your hand is bigger than the upthrust due to the difference in pressure. When you let the ball go the upthrust is bigger than its weight. When the ball reaches the surface it floats. The pressure on the bottom of the ball produces a (upthrust) force that depends on the area of the ball in contact with the water. **4** P =

Lesson 12

1.4.3 Stress on solids

Learning objectives

After this section you will be able to:

- state what is meant by stress
- explain the effect of solid surfaces on each other using ideas about stress.

▲ There is no wind on the Moon to blow Neil Armstrong's footprints away.

▲ The tracks on the earthmover stop it sinking into the mud.

Key Words

stress, newtons per metre squared

When Neil Armstrong walked on the Moon in 1969 he left footprints. The footprints are still there.

What is stress?

When you stand on any surface you exert a force on it because of your weight. Your weight is spread out over the area of your foot. You are exerting a pressure on the ground, called **stress**. If you are standing on a soft surface such as mud the pressure might be big enough for you to sink.

An earthmover is very heavy. It has a weight of about a million newtons, the same as about 15 000 people! A single person standing on the same muddy ground might sink. The earthmover does not sink because its weight is spread out over a bigger area.

The stress acts in a direction that is at 90°, or normal, to the surface.

A State the direction in which stress acts.

How do you calculate stress?

Stress is a measure of how much force is applied over a certain area. You calculate stress using this equation:

$$\text{stress (N/m}^2) = \frac{\text{force (N)}}{\text{area (m}^2)}$$

You measure force in newtons (N) and area in metres squared (m^2). Stress is measured in **newtons per metre squared** (N/m^2).

Sometimes it is easier to measure smaller areas in centimetres squared (cm^2). If you measure the area in cm^2 then the stress is measured in N/cm^2.

When you do calculations it is very important to look at the units of area. If you write them next to the number in your equation then you will see which unit of pressure you need to use.

B State the units of stress.

Fantastic Fact

To produce the same stress on the floor that you exert when you push in a drawing pin, you would need over 5000 people standing on your shoulders.

Big and small stresses

The studs on the bottom of a hockey or football boot have a small area compared with the area of the foot. This produces a bigger stress. The studs sink into the ground and help the player to move quickly.

The weight of a hockey player is 600 N.

The area of her two feet is 200 cm^2.

$$\text{stress} = \frac{\text{force}}{\text{area}} = \frac{600\ \text{N}}{200\ \text{cm}^2} = 3\ \text{N/cm}^2$$

The total area of the studs is 20 cm^2.

$$\text{stress} = \frac{\text{force}}{\text{area}} = \frac{600\ \text{N}}{20\ \text{cm}^2} = 30\ \text{N/cm}^2$$

▲ The studs increase the grip on the ground.

▲ Snowshoes increase the area of your feet so the stress is less.

A solid can scratch another solid if the stress is large. You sink into soft surfaces like mud or snow if your weight is spread over a small area.

Spreading out the force over a large area, by wearing snow shoes for example, stops you sinking. Stresses can break the surface of a material, which produces a scratch.

Finding the force

Which of these is the correct equation for working out the force?

A force = stress ÷ area

B force = stress × area

C force = area ÷ stress

▲ The stress is bigger if your weight is concentrated over a smaller area, such as your hand.

Summary Questions

1. Copy the sentences below, choosing the correct bold words.

   Stress is a measure of how much **force/mass** there is on a certain **area/volume**. A nail scratches a surface because the area of the nail is **big/small**. A large stress can **break/heat** a surface. The stress needed to **float on/sink into** a solid surface depends on the type of surface.

   (5 marks)

2. A gymnast has a weight of 600 N. The area of each hand is 150 cm^2. Calculate the stress on the floor when he is doing a handstand.

   (3 marks)

3. The point of a nail has an area of 0.25 cm^2, and an average person has a weight of 700 N. Explain in detail why it is possible to lie on a bed of 4000 nails, but not on a single nail.

   (6 marks)

Lesson 12: Answers

1.4.3 Stress on solids

In-text questions	**A** At 90°, or normal to the surface. **B** N/m^2 or N/cm^2
Activity	**Finding the force** **B** force = stress × area
Summary questions	**1** force, area, small, break, sink into (5 marks) **2** stress = force/area force = 600 N, area = 2 × 150 = $300 cm^2$ stress = 600 N/300 cm^2 = 2 cm^2 (3 marks) **3** Example answers (6 marks): stress =force/area small area = large stress The stress of lying on one nail =700 N/0.25 cm^2 = 2800 N/cm^2 A bed of nails consists of 4000 nails, so the total area is bigger. And the stress is much less. total area = 4000 × 0.25 cm^2 = 1000 cm^2 The stress of lying on a bed of nails = 700 N/1000 cm^2 = 0.7 N/cm^2

Part 2 – Revision Questions

End-of-Big Idea questions

1 Match the word or phrase and its definition.

A: Fluid pressure	1: a force opposing motion when one surface is a fluid
B: Atmospheric pressure	2: a force opposing motion when both surfaces are solid
C: Drag	3: produced by the collision of particles with a surface
D: Friction	4: caused by the weight of air above a point

(**3 marks**)

2 You can make a hole in a piece of wood if you bang in a nail with a hammer. If you hit the wood with the hammer it does not make a hole. Choose the best explanation for this from the statements below:

A The area of the nail is much smaller so the pressure is smaller.
B The area of the nail is much smaller so the pressure is bigger.
C The area of the hammer is bigger so the pressure is bigger.

(**1 mark**)

3 **a** Explain why it can hurt your hands when you carry heavy shopping in carrier bags. *(2 marks)*

b Explain why road bikes have narrow tyres but off-road bikes have wide tyres. *(2 marks)*

(**4 marks**)

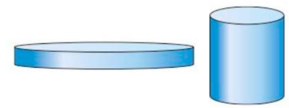
4 An acrobat can balance on one finger. Her weight is 500 N, and the area of one finger is 0.0001 m^2. Calculate the stress on the floor.

(**3 marks**)

5 You do not see most of an iceberg because most of it is underwater.

a Explain in terms of forces why an iceberg floats. *(1 mark)*

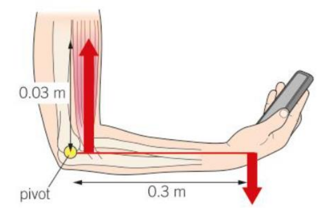
b You model icebergs with ice from the freezer. You make two different shapes that have the same mass:



Suggest and explain in terms of fluid pressure what happens when you put your 'icebergs' in water. *(3 marks)*

(**4 marks**)

6 Look at the diagram of an arm holding a phone. The phone has a weight of 1.5 N.



a Calculate the moment of the force exerted by the phone. *(2 marks)*

b Calculate the force that the muscle exerts to keep the phone in equilibrium. *(2 marks)*

c Explain why the force exerted by the muscle is much greater than the weight of the phone. *(2 marks)*

(**6 marks**)

7 You buy a bag of crisps in an airport. After take-off you take the crisps out of your rucksack. Explain in detail why the bag has expanded.

(**6 marks**)

Lesson 13: Revision Answers

1 Forces – Part 2 Checkpoint

End-of-Big Idea questions	**1** A3, B4, C1, D2 (3 marks) **2** B (1 mark) **3a** The force (weight) of the bag can be large and the area of the handles is small (1 mark) So the stress (force/area) is large (1 mark) **b** When you ride off road the surface can be soft, so you need a smaller stress (1 mark) So you have wide tyres to increase the area, which reduces the stress (1 mark) **4** Stress =force/area=500 N/0.0001 m^2 = 5 000 000 N/m^2 (3 marks) **5a** The force of the Earth on the iceberg = force of the water on the iceberg/weight = upthrust (1 mark) **b** The icebergs float. The bottom of the first iceberg is closer to the water surface than the bottom of the second iceberg. This is because the area of the first iceberg is bigger than the area of the second iceberg. (3 marks) **6a** Clockwise moment = force × distance = 1.5 N × 0.3 m = 0.45 Nm (2 marks) **b** anticlockwise moment = 0.45 Nm = force (exerted by muscle) × 0.03 m force exerted by muscle = 0.45 Nm/0.03 m = 15 N (2 marks) **c** The force is bigger because anticlockwise moment = clockwise moment (for the system to remain balanced). The distance from the pivot is much less. (2 marks) **7** Examples of correct scientific points (6 marks): The bag of crisps contains air. Air molecules collide with the inside of the bag. Air molecules in the atmosphere collide with the outside of the bag. If the pressure is the same inside and outside the bag, the bag does not get bigger. Atmospheric pressure decreases with height, because gravity pulls the air molecules down. There are fewer collisions between air molecules and objects as you go higher. The air pressure inside the plane is less than the air pressure on the ground (inside the crisp packet) so the bag gets bigger.

Attainment Band	Forces Knowledge and Understanding
Yellow/Yellow +	• Describe the main types of force and accurately draw force diagrams to explain the relative size (magnitude) and direction of applied forces and their effects • Provide an effective explanation of the concept of speed and independently derive the equation for speed; link their understanding of the speed equation to explain the operation of speed cameras • Explain what is represented on a more complex distance–time graph and construct a graph to represent a more complex journey • Apply the concept of relative motion to a situation with more than two objects moving at different speeds • Explain examples of balanced and unbalanced forces and correctly predict the relative motion produced by unbalanced forces; explain the concept of a reaction force using simple examples • Explain how a more complex set of opposing forces may or may not result in an object being in equilibrium • Explain how forces can cause an object to deform, link the deformation to the size of the force, and recognise that for a range of forces the amount of deformation is linear and that this can be used to design machines for measuring forces • Obtain a precise set of data by investigation, produce accurately drawn graphs to illustrate Hooke's Law, and explain the behaviour of a material at the elastic limit • Include the essential features in a plan to investigate the force of friction • Understand that frictional drag is a contact force acting in the opposite direction to movement and explain the motion of a sky diver in relation to the effects of frictional forces • Evaluate data from an investigation into streamlining and explain the findings in terms of frictional drag • Evaluate the concept of a gravitational field as a means of explaining the effects, including acceleration • Explain weight in relation to the idea of a gravitational field and apply this to deep space and different planets • Explain how the force and area can be varied to alter the pressure applied • Identify the causes and implications of pressure increase with depth in a liquid • Apply ideas of density and displacement to predict the outcome of various situations • Identify implications of differing atmospheric pressure at different heights and across the world

Blue	• State the main types of force and draw force diagrams to show the size and direction of forces; identify force pairs • Explain the concept of speed and demonstrate how the speed equation is derived using their understanding of speed • Construct a graph to represent a journey explain what it represents • Apply the concept of relative motion to a situation with two objects moving at different speeds • Apply an understanding of forces to explain simply the changes caused by forces of different magnitudes and directions • Explain how opposing forces may or may not result in an object being in equilibrium • State that applying a force can compress or stretch an object, and state that the bigger the force the larger the deformation • Carry out an investigation into springs and gather data to show simply the relationship between load and extension • Use their own data to state Hooke's Law and explain the elastic limit of a material • Describe the effects of friction and explain why friction is beneficial in a range of situations • Explain air and water resistance in terms of frictional drag, and recognise this as a contact force • Investigate streamlining and use scientific vocabulary to explain how streamlining reduces the forces of friction on an object moving through a fluid • Apply the concept of a gravitational field to describe the causes and effects of gravity • Explain the relationship between gravity and weight • Explain the term 'weightless' and apply understanding to explain why weight changes on different planets • Explain how the pressure on a solid surface may vary and the effects this has • Calculate the pressure applied from the force and the area • Explain why pressure increases with depth in a liquid • Explain why some objects float and others sink using concepts of density, displacement and upthrust • Explain why atmospheric pressure changes according to height
Green	• List some types of force and label diagrams to show the direction of forces • State that forces are needed to change the motion of an object, and draw force arrows in diagrams • Describe a method in simple terms to find the speed of an object • Label a distance–time graph and explain some of its features • Describe the effects of balanced and unbalanced forces, and know that an unbalanced force is needed for a change to take place • Predict relative motion produced by different forces on an object • Explain how forces can cancel each other out • Carry out an investigation into springs and gather data to show simply the relationship between load and extension • Identify the force of friction between two objects and list examples of situations that need friction • Know that objects are slowed down by drag forces • Recognise streamlined shapes and know that this helps them to move through air or water • Explain the effects of gravity and how they vary around the Earth • Describe the effect of an object being in a gravitational field • Know that objects have different weights on different planets and that in deep space objects are weightless • Describe the effects of varying pressure on a solid surface and suggest factors that affect this • Describe how pressure increases with depth in a liquid and some effects of this • Suggest why some objects float and others sink • Describe how atmospheric pressure changes according to height
White	• Some of the above elements have been achieved