epiSTEMe Teaching Notes

Forces and Proportional Relations

Overview of the Teaching Notes

INTRODUCTION

This module on 'Forces and Proportional Relations' is one of four topic-specific modules that have been developed as part of the epiSTEMe project (Effecting Principled Improvement in STEM Education). The Appendix outlines the epiSTEMe teaching model, and the way in which its principles have been encapsulated across the four modules.

The module that follows covers those aspects of forces that are suitable for the start of the Key Stage 3 curriculum. It builds on material covered in Key Stage 2, and paves the way for detailed treatment later. It is well known that students have powerful misconceptions about how forces operate, based on everyday experiences of action and language. These misconceptions often continue and undermine performance throughout many years of teaching, making forces a challenging area for students. This module attempts to rise to the challenge, by applying the messages for teaching from contemporary theory and research. At the same time, it employs engaging tasks that relate to real-life events, both past and present.

One specific message from research is that students are more likely to achieve a scientific understanding if they discuss their ideas with teachers and other students. 'Forces and Proportional Relations' has therefore been designed for use with a 'dialogic' approach to teaching (as explained in the Introductory Module), in which 'authoritative' teacher-talk is balanced with more 'dialogic' discussion in whole-class and small-group settings. It is vital that you use this approach, so if you are unsure about how to implement it, please refer back to the Introductory Module.

Another message is that mathematical representations can support understanding of the proportional concepts that are central to Key Stage 3 teaching about forces, e.g. stretching, density, stopping distance. To the extent that this second message is followed through, it has the further advantage of facilitating links with Key Stage 3 mathematics, because proportional relations are a central theme in that context too (and covered in a further epiSTEMe module). Current educational policy promotes linkages between mathematics and science.

Structure of the module

The main sequence of activities is set out in these Teaching Notes, and is supported with a Study Booklet for students and a set of Projection Slides for classroom use. Technician Notes are included to assist with preparing for the practical exercises. The sequence has been organised into Lessons, notionally of one hour, but with only 50 minutes of activity actually scheduled, leaving 10 minutes slack. To help in planning how to fit Lessons into sessions of a different length, or in adapting to unplanned circumstances, each Lesson has been chunked into shorter Parts. Many (but not all) Lessons end with optional homework to be used at your discretion. In case you do not wish students to take Study Booklets out of school, homework exercises have been copied onto separate sheets as well as into the Booklets.

Implementing the module

We ask that you follow the module fairly closely. However, you will need to translate the plans into a form that will work for your particular class. This includes whether or not you exactly follow our proposed division into whole-class, small-group and individual activity. Our main request is that you translate in a way that seeks to maximise the students' understanding of key concepts.

Use your discretion to decide whether certain activities require more or less emphasis and more or less time than suggested. Consequently, a Lesson may not fit neatly into a single class session. This is no cause for concern as long as you follow the sequence of activities as they are described in the Notes. In general, devoting additional sessions to the activities is preferable to rushed and scattered teaching within the current session structure. Recognising the need for flexibility over timing, we have not provided Projection Slides that summarise the *aims* of each Lesson. However, we appreciate that you may wish to add such slides and/or begin each session with a review of material covered in the previous session and an overview (including aims) of the new material to follow.

Also use your discretion about how much use to make of the 'extension work' that we provide. Although not strictly necessary, we know that students find the contextual material interesting, e.g. the references to historical figures. So do try to find time for some of this material if at all possible.

There are aspects of the Lessons, which we would ask you not to alter. A key feature of the module is that it includes a large amount of student thinking and talking. Try to ensure that, as far as possible, time for this thinking and talking is preserved. Likewise, these activities have been designed to allow students to formulate their own ideas about topics. Research shows that this will facilitate effective talk and thinking, and so aid progress in understanding. So while the Lessons should guide students in developing a 'scientific' view, we ask you (and any assistants working with you) to help them to test and refine their own ideas rather than give them ideas yourself. The point is to lead or support student activity rather than to proceed immediately to 'correct analyses'.

The tasks that we have designed for collaborative activity in small-groups should be effective regardless of ability or gender composition, or the existing social relations between group members (e.g. friendships). Within limits, they should also be effective regardless of group size. However, when groups become very large, students can sometimes experience difficulties with managing the dialogue. For instance, some students can get left out or groups can split into subgroups. For that reason, we ask that the students normally work in groups of two, three or four.

LESSON 1: INTRODUCING FORCES

Overview
Lesson 1 is detailed on Pages 8 to 10. The lesson starts by using real-world examples to highlight the situations in which forces operate, and concludes by outlining some elementary distinctions amongst forces.

Aims
Lesson 1 aims to teach students that:
- Forces operate in a wide range of everyday situations
- Forces are pushes, pulls, or twists
- There is a key distinction between contact and non-contact forces

Structure
The lesson is in two parts and uses a mixture of whole-class and small-group teaching as well as individual work.
- *Part 1* (whole-class): Signals that forces operate in a range of everyday situations
- *Part 2* (whole-class, individual work and small-groups): Highlights that forces are pushes, pulls, or twists, and differentiates between contact and non-contact forces

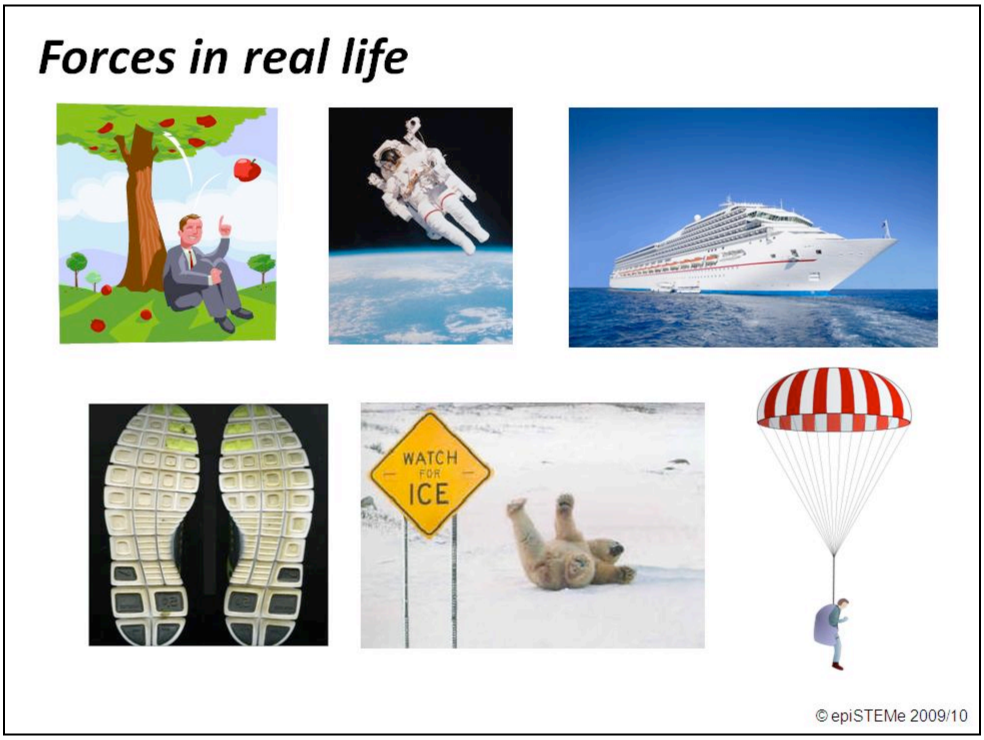
Resources
- PowerPoint Slides 1-4

LESSON 1: PART 1

Objective
To signal that forces operate in a range of everyday situations

Time
20 minutes

Resource
- Slide 1: Forces in real life



Activity
Whole-class activity
- Explain that the module is about forces and that by the end the students will understand the forces that are operating in a range of everyday situations.
- Use *Forces in real-life* (plus any other materials that seem suitable) to get the class to understand the forces operating in a range of situations.
- Invite the students to propose the forces that are operating in each situation in turn and help them understand what is actually happening.
- Make sure that general principles emerge as well as understanding of the specific situation.

LESSON 1: PART 2

Objectives

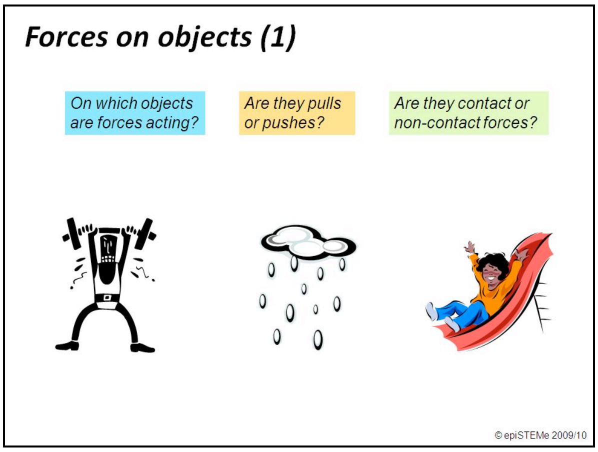
To highlight that forces are pushes, pulls, or twists, and to differentiate between contact and non-contact forces

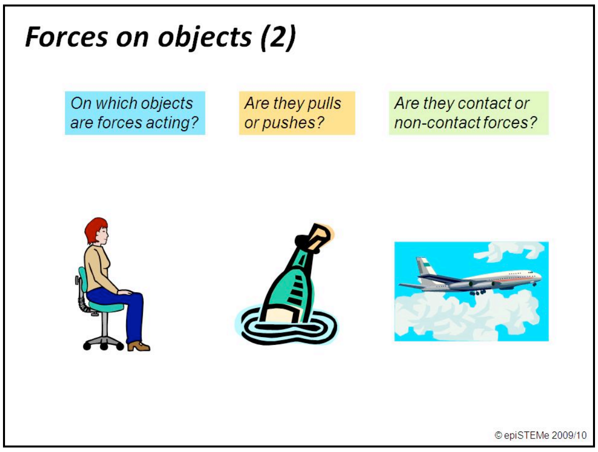
Time

30 minutes

Resources

- Slide 2: Forces on objects (1)
- Slide 3: Forces on objects (2)
- Slide 4: Push-Pull-Turn/Twist





Activities (Continue on Page 10)

Individual work

- Get the students to complete *Forces on objects* (1) as an individual written exercise.

Whole-class activity

- Let the students discuss on which objects in these examples forces are acting, if they are pushes or pulls, and if they are contact or non-contact forces.
- If needed, remind the students about the difference between contact and non-contact forces. Contact forces are forces between two objects that are in contact with each other, while non-contact forces affect objects from a distance, e.g. magnetic attraction.

Individual and whole-class

- Repeat the sequence of individual work followed by whole-class debriefing for *Forces and objects* (2).

LESSON 1: PART 2 CONTINUED

Push-Pull-Turn/Twist

Are the forces involved in each action
•a pushing force?
•a pulling force?
•a twisting / turning force?
Use ticks ✓ to complete the table.

Can you think of other situations in which forces are acting?

Action	Pushing	Pulling	Twisting/turning
A carrier bag hanging on your arm		✓	
A digger lifting earth in a scoop			✓
Kicking a football	✓		
Undoing the lid of a honey jar			✓
Throwing a baseball	✓		
A van towing a broken down car		✓	
A food processor chopping an apple			✓
Pedalling a bicycle	✓		
Towing a water skier		✓	

Activities

Small-group activity

- Remind the students that forces can be pulls, pushes, and twists/turns.
- Let the students work in groups on *Push-Pull-Turn/Twist* to consolidate the message.

Whole-class activity

- Collect the students' answers and let them explain their reasoning. Some examples are arguable, e.g. chopping an apple is not only twisting/turning, which is why there may be discussion amongst students.
- Make sure that the students can support their answers with arguments (in accordance with Ground Rules developed in the Introductory Module).

END OF LESSON 1

LESSON 2: BALANCED AND UNBALANCED FORCES

Overview

Lesson 2 is detailed on Pages 12 to 17. The first half of the lesson is devoted to balanced forces, while the second half introduces unbalanced forces and compares these with balanced.

Aims

Lesson 2 aims to teach students that:

- There is a difference between balanced and unbalanced forces
- Unbalanced forces can change the shape, speed, and direction of an object

Structure

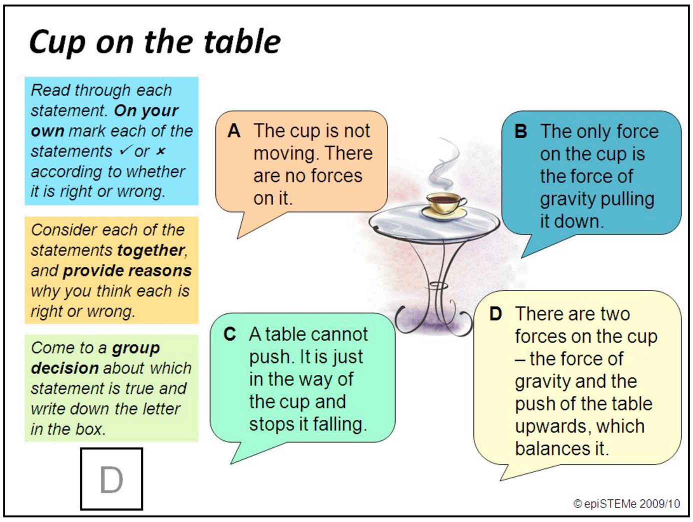
The lesson is in three parts and uses a mixture of whole-class and small-group teaching.

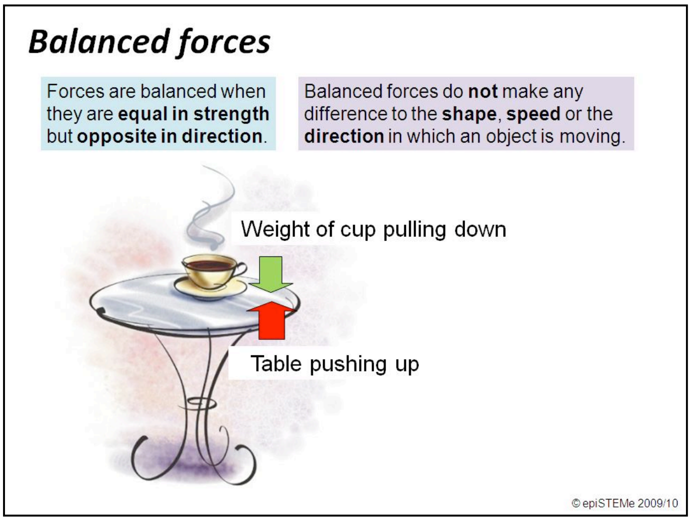
- *Part 1* (small-groups and whole-class): Introduces the concept of balanced forces
- *Part 2* (small-groups and whole-class): Introduces the concept of unbalanced forces
- *Part 3* (whole-class): Contrasts the effects of balanced and unbalanced forces

Resources

- PowerPoint Slides 5-11 (Possible homework is on Slide 12)

LESSON 2: PART 1





Objective

To define what is meant by 'balanced force'

Time

20 minutes

Resources

- Slide 5: Cup on the table
- Slide 6: Balanced forces
- Slide 7: Forces in action (1)

Activities (Continue on Page 14)

Small-group activity

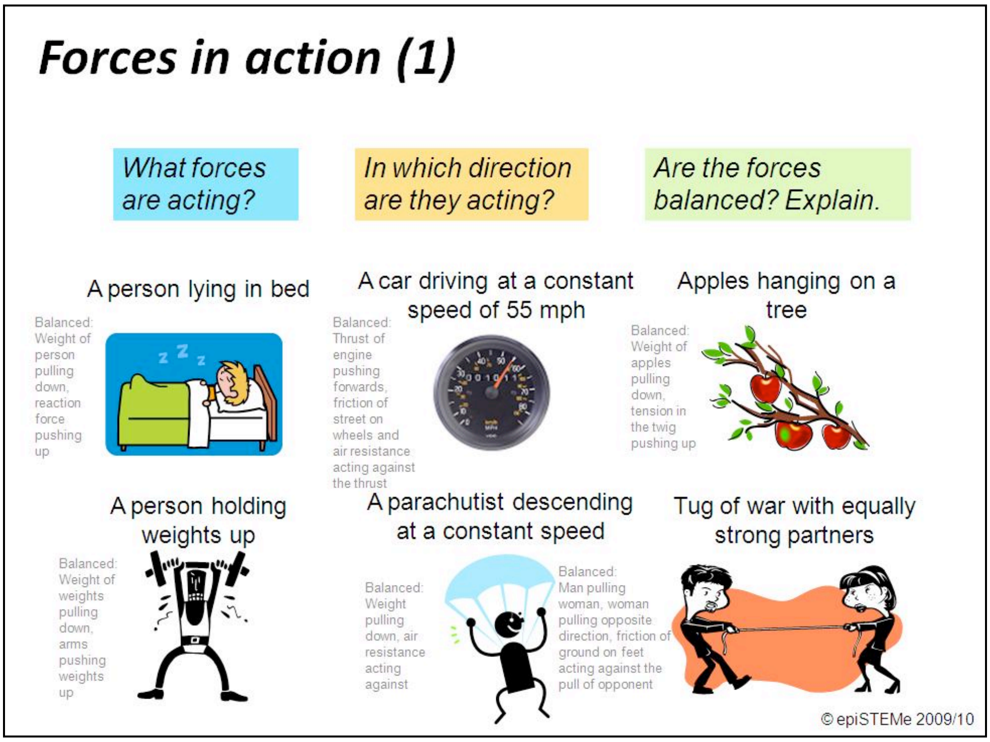
- Before working on *Cup on the table*, the students should decide independently whether they agree or disagree with each statement, and record this in their Study Booklets.
- The students should then work in small-groups on the task.
- Remind the students of the 'ground rules' for discussion and that they should try to agree in their group which statement is correct.

Whole-class activity

- Ask the groups to hold up their answers and read out which statements (A-D) have been proposed.
- Do not give correct answers at this stage but ask the students to explain and justify their answers in their own words, i.e. engage in whole-class dialogue as covered in the Introductory Module.
- Present the *Balanced forces* slide to support the students' understanding that the weight is balanced by the table pushing upwards.
- Explain that the forces on any single object are balanced when they are equal in strength but opposite in direction. They do not make any difference to the shape, speed or direction in which an object is moving.

Note

The students are likely to find the physics way of thinking about the cup on the table (balanced forces) counter-intuitive. They commonly think along the lines - the cup is pulled down, but that's as far as it can go because the table is in the way/supporting it. Make sure that in the whole-class discussion of this task, the students understand that the inert and apparently passive table actively pushes up on the cup.



Activity

Whole-class activity

- Consolidate the concept of balanced forces by working with the students on *Forces in action (1)*. Choose a minimum of two of the six examples provided (although you may wish to use more examples if time permits and the students will benefit from more extended treatment).
- With the whole-class, ask the students how they know that the forces are balanced in these situations. Ask individual students to come to the board and name the forces involved, where they are acting, and their size and direction. Ask other students to comment on what they say.
- By responding to what the students say, try to make sure that everyone understands the concept of balanced forces by the end of the lesson.

LESSON 2: PART 2

Objective

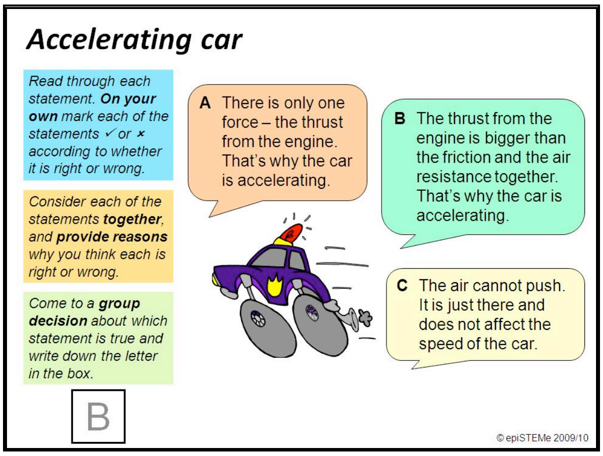
To characterise what is meant by ‘unbalanced force’

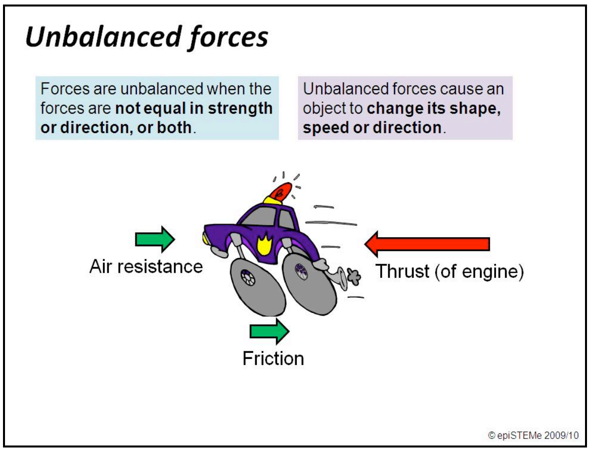
Time

20 minutes

Resources

- Slide 8: Accelerating car
- Slide 9: Unbalanced forces
- Slide 10: Forces in action (2)





Activities (Continue on Page 15)

Small-group activity

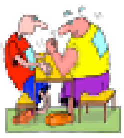
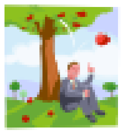
- The students should first be asked to decide whether they agree or disagree with each statement, and record this in their Study Booklets.
- Then they should work in groups.
- Remind them of the ‘ground rules’ and that they should come to an agreement in their group about which statement they think is correct.

Whole-class activity

- Ask the groups to hold up their answers and read out which statements (A-C) have been proposed.
- Do not give correct answers at this stage but ask the students to explain and justify their answers in their own words.
- Present the *Unbalanced forces* slide to support the students in understanding that the car is accelerating because the force of the engine thrust is greater than the forces of air resistance and friction together acting in the opposite direction.
- Explain that forces are unbalanced when they are not equal in strength or direction, or both. Unbalanced forces cause an object to change its shape, speed or direction.

Forces in action (2)

Think about the forces which are acting in these situations. Then, complete the table below.

Knuckling under a stronger person in arm wrestling	Kicking a football	Squeezing paper	Apple falling from tree	Reducing speed of car
A 	B 	C 	D 	E 

Situation	What are the forces acting in these situations?	In which direction are the forces acting?	Are the forces balanced? Why? Explain.
A	Pushes and friction	Arms pushing in opposite direction, elbows pushing down on table	No because one man pushes his elbow with a greater force on the table than the weaker man
B	Thrust from the leg, air resistance, ball's weight, and reaction force from ground	Thrust towards the ball, weight pulls ball down, ground pushes back	No because thrust of leg is bigger than air resistance
C	Push from hand and paper	Hand squeezing paper, paper pushing back	No because push of hand is bigger than push from paper
D	Weight of apple and tension in twig	Weight of apple pulling down, tension in the twig pushing up	No because weight of apple is bigger than tension in the leg
E	Thrust of engine and friction	Thrust of engine pushing forwards, friction of brake pads on tyre acting against	No because friction of brake pads on tyre is bigger than thrust of engine

Activity

Whole-class activity

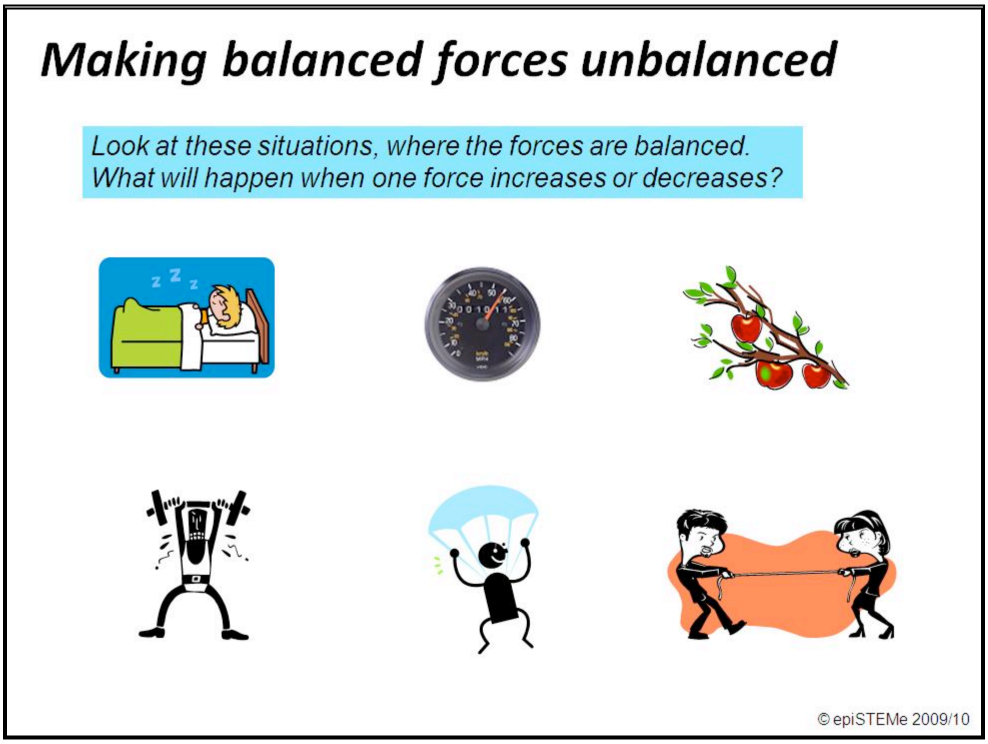
- Consolidate the concept of unbalanced forces by working with the students on *Forces in action (2)*.
- Again, choose a minimum of two of the five examples provided.
- Working with the whole-class, ask the students to discuss why the forces are unbalanced in these situations.
- Let the students come to the board and name the forces involved, where they are acting, and their size and direction. They should enter their answers in the table, either by writing on the board or typing into the PowerPoint slide.
- Make sure that all students have understood the concept of unbalanced forces.

LESSON 2: PART 3

Objective
To contrast the effects of balanced and unbalanced forces

Time
10 minutes

Resource
- Slide 11: Making balanced forces unbalanced



Activities
Whole-class activity
- Adopting the 'authoritative mode', summarise the concept of balanced and unbalanced forces and the effects of these forces on objects.
- Pick some of the balanced forces examples and ask individual students to predict what will happen when one force increases or decreases. Ask the other students for comments on their answers.

LESSON 2 HOMEWORK (OPTIONAL)

Forces in action (3)

Which forces are acting in the following situations?

Are they balanced or unbalanced?

	What forces are acting?	Are the forces balanced or unbalanced?
A car is moving at a constant speed of 30 mph	Thrust of engine and friction	Balanced
A person is floating on an air bed in water	Weight of person and air bed and upthrust of water	Balanced
A rocket is accelerating skywards	Thrust of rocket and weight of rocket and air resistance	Unbalanced
A person is coming to a halt at a red traffic light	Thrust of person and muscular force	Unbalanced
Flowers are standing in a vase	Weight of flowers and up-push of vase	Balanced
A skydiver is descending at a slow constant speed	Weight of person and air resistance	Balanced
A ship with a leak is sinking	Weight of ship and upthrust of water	Unbalanced
A car is hanging on a magnet crane	Weight of car and magnetic force	Balanced

Note

Completion of this exercise will require students to revisit most of the major topics that were addressed in Lesson 2.

END OF LESSON 2

LESSON 3: FORCE DIAGRAMS

Overview

Lesson 3 is detailed on Pages 19 to 22. It covers the measurement of forces in Newtons, the difference between mass and weight, and the depiction of forces via force diagrams.

Aims

Lesson 3 aims to teach students that:

- Forces are measured in Newtons, which can be calculated using a Newton meter
- There is a difference between mass and weight
- Forces can be depicted using force diagrams

Structure

The lesson is in three parts and uses a mixture of whole-class and small-group teaching as well as individual work.

- *Part 1* (whole-class and small-groups): Explains that forces are measured in Newtons, which can be calculated using a Newton meter
- *Part 2* (whole-class): Clarifies the difference between mass and weight
- *Part 3* (individual work, small-groups and whole-class): Covers the use of force diagrams to represent forces

Resources

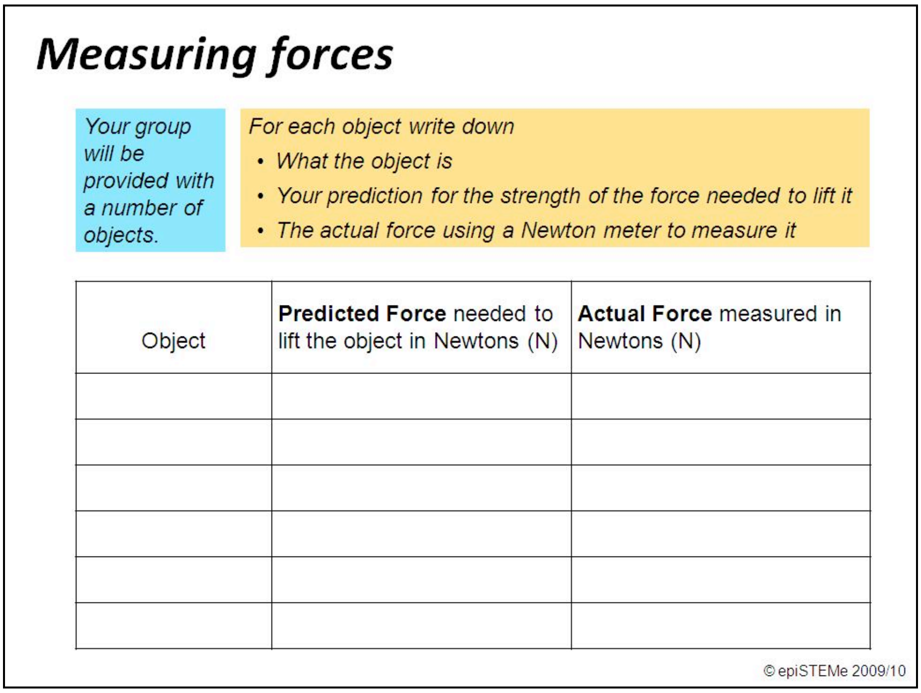
- PowerPoint Slides 13-19
- Newton meters and objects for each group

LESSON 3: PART 1

Objective
To explain that forces are measured in Newtons, which can be measured using a Newton meter

Time
25 minutes

Resources
- Slide 13: Measuring forces
- Newton meters and objects for each group



Activities
Whole-class activity
- Using 'authoritative talk', explain that forces are measured in Newtons, which are represented with the letter N.
- Present Newton meters and explain how to use them.

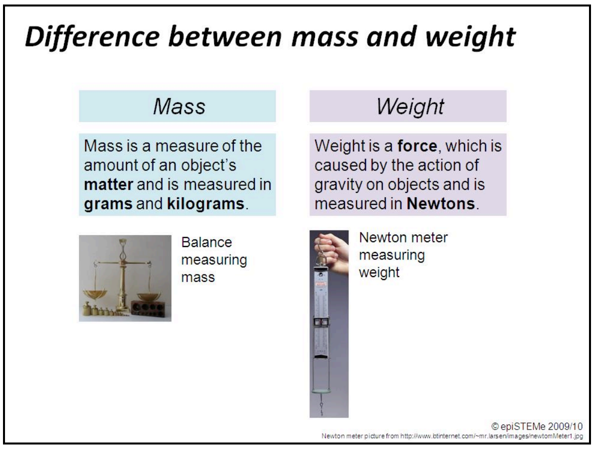
Small-group activity
- Let the students estimate the force required to lift several objects in the classroom (*Measuring forces)*. These objects could include pencil cases, rulers, study books etc.
- Remind the students to talk and work together using the 'ground rules' and to agree on reasons for their answers.
- Tell the students to check their predictions using Newton meters and report their results in the tables in their Study Booklets.

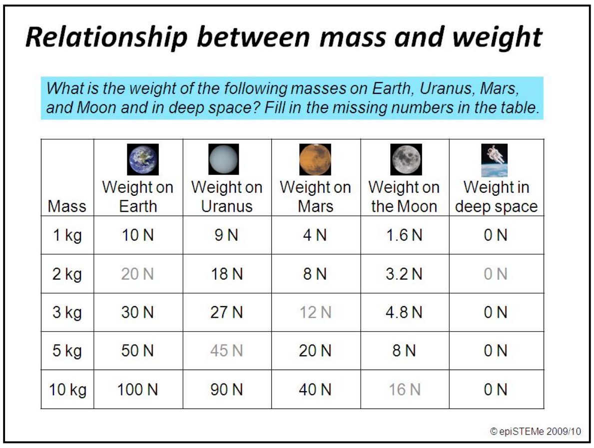
LESSON 3: PART 2

Objective
To explain the difference between mass and weight

Time
10 minutes

Resources
- Slide 14: Difference between mass and weight
- Slide 15: Relationship between mass and weight





Mass	Weight on Earth	Weight on Uranus	Weight on Mars	Weight on the Moon	Weight in deep space
1 kg	10 N	9 N	4 N	1.6 N	0 N
2 kg	20 N	18 N	8 N	3.2 N	0 N
3 kg	30 N	27 N	12 N	4.8 N	0 N
5 kg	50 N	45 N	20 N	8 N	0 N
10 kg	100 N	90 N	40 N	16 N	0 N

Activity
This part requires a clear, authoritative presentation from you to the class.

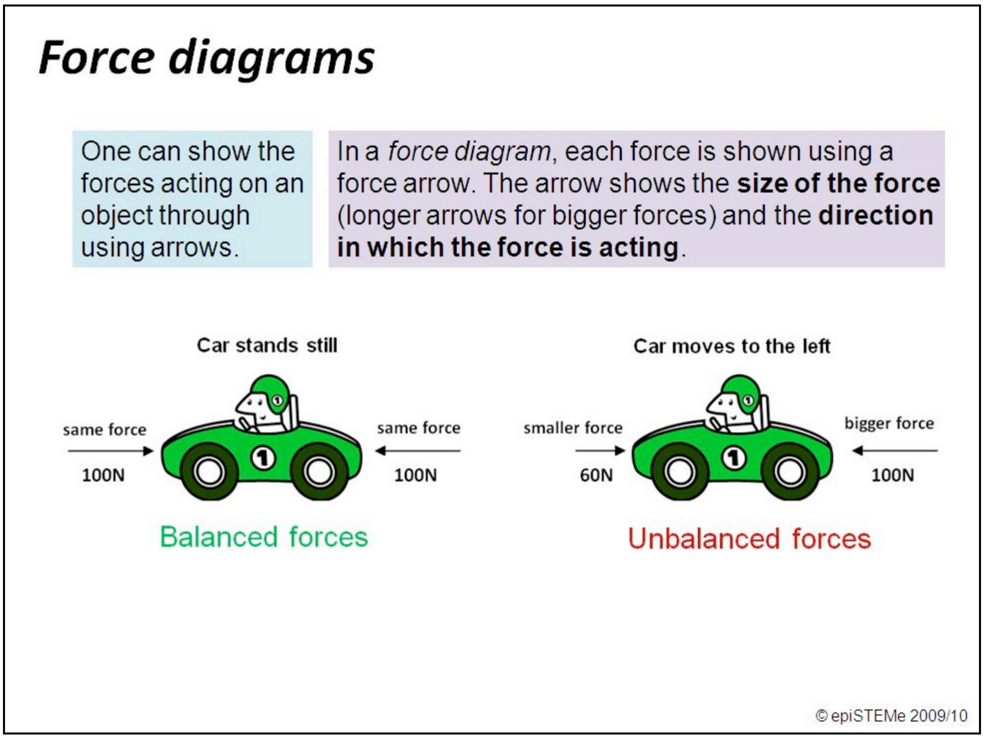
Whole-class activity
- Following on from the Part 1 practical, use the *Difference between mass and weight* slide to explain the difference between mass and weight.
- Explain that the relationship between mass and weight on Earth is in a ratio of 1:10, and that this mass-weight relationship changes in different contexts.
- As a whole-class exercise, use *Relationship between mass and weight* to consolidate this message.
- Emphasise the role of gravity in determining the mass-weight relation.

LESSON 3: PART 3

Objective
To learn to draw and interpret force diagrams

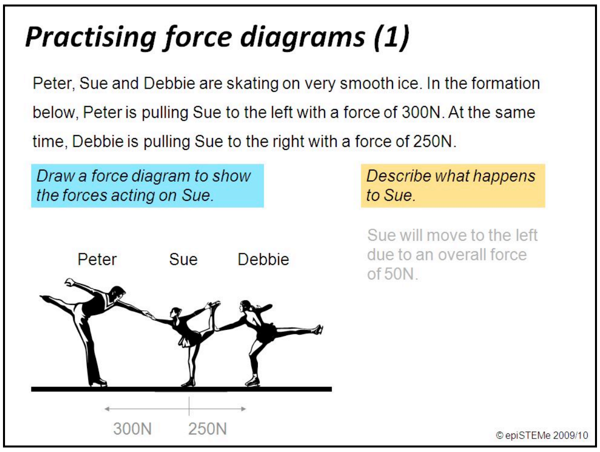
Time
15 minutes

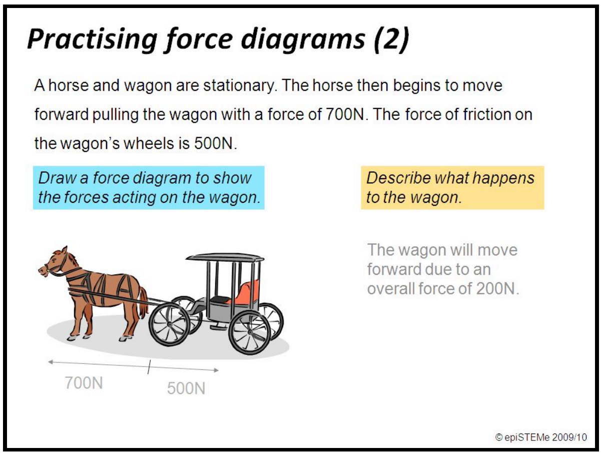
Resources
- Slide 16: Force diagrams
- Slide 17: Practising force diagrams (1)
- Slide 18: Practising force diagrams (2)
- Slide 19: Practising force diagrams (3)

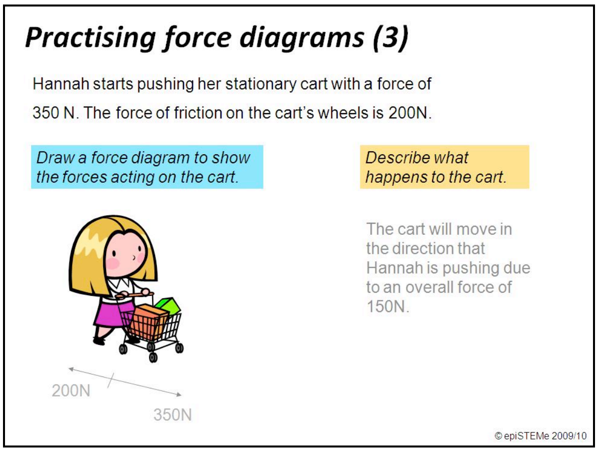


Activities (Continue on Page 22)
Whole-class activity
- Use the *Force diagrams* slide (and/or any force diagram/s that you may already have) to introduce the students to force diagrams.
- It needs to be made clear that this figure only applies if the car is initially at rest.

LESSON 3: PART 3 CONTINUED







Activities

Individual work

- Use *Practising force diagrams (1)-(3)* to let the students practise drawing and interpreting force diagrams.
- The students should independently draw each force diagram.

Small-group activity

- Ask the students in groups to consider the diagrams each of them has drawn.
- Ask them to come to a joint, group agreement on one correct version of the diagram.

Whole-class activity

- Nominate a student from each group to draw their group's force diagram on the board for whole-class discussion.
- If time is tight, the task could be completed for homework.

END OF LESSON 3

LESSON 4: SPRINGS, STRETCHES AND DIRECT PROPORTIONALITY

Overview

Lesson 4 is detailed on Pages 24 to 26. After an informal introduction to stretching, the lesson focuses on the relation between stretch and load. It emphasises that the relation is one of direct proportionality, and assists students in the use of proportional reasoning to work out the stretch of a spring when different loads are used.

Aims

Lesson 4 aims to teach students that:

- Springs stretch when a force is applied to them
- The stretch of a spring is directly proportional to the attached load

Structure

The lesson is in three parts and uses a mixture of whole-class and small-group teaching as well as individual work.

- *Part 1* (whole-class and small-groups): Highlights everyday instances of stretching
- *Part 2* (small-groups and whole-class): Establishes the relation between load and stretch
- *Part 3* (whole-class and individual work): Characterises the relation between load and stretch in terms of direct proportionality

Resources

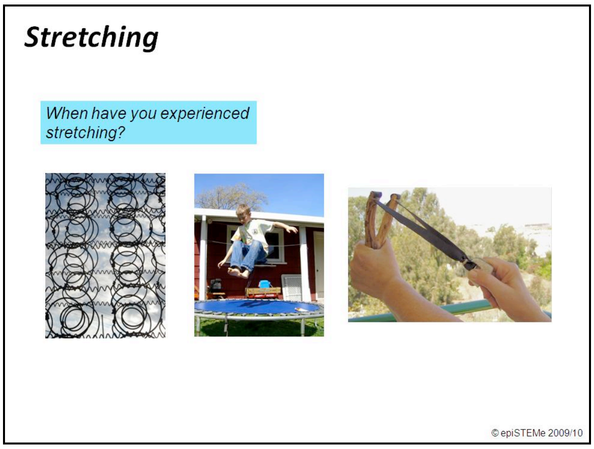
- PowerPoint Slides 20-25
- Loads and springs for the practical
- Graph paper (optional – see Part 2)

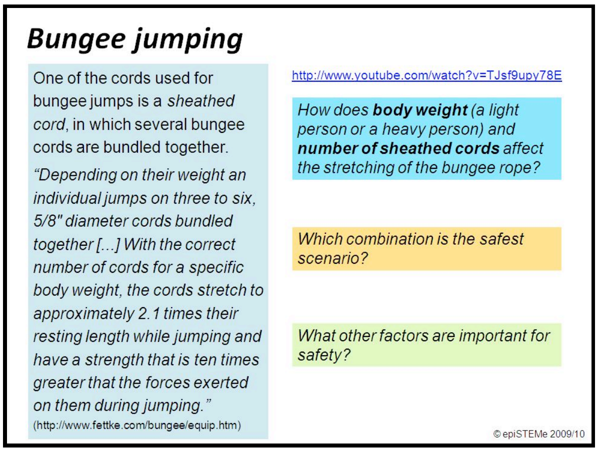
LESSON 4: PART 1

Objective
To highlight everyday instances of stretching

Time
15 minutes

Resources
- Slide 20: Stretching
- Slide 21: Bungee jumping



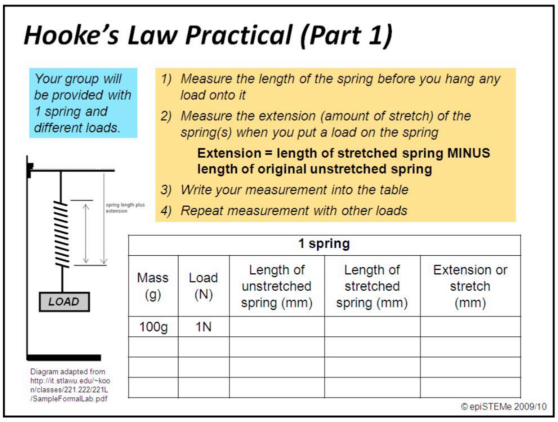


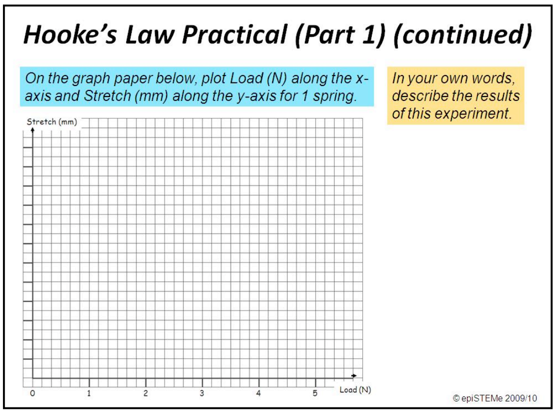
Activities
Whole-class activity
- Begin by asking the students to describe everyday contexts in which they have experienced stretching. If necessary, show the *Stretching* slide to elicit ideas (springs in beds, trampolines, elastic in clothes, slingshots, bows etc.).
- Moving to the *Bungee jumping* slide, show a video of a bungee jump (link on the slide) and explain what bungee cords are made of.

Small-group activity
- Ask the students to discuss in their groups the questions on the *Bungee jumping* slide.

Whole-class activity
- Collect the students' ideas on a board or flipchart and ask for any comments, in other words follow the whole-class dialogic mode (see Introductory Module)
- Explain that the students can test their ideas in the practical session that follows.

LESSON 4: PART 2





Objective

To establish the relation between load and stretch

Time

20 minutes

Resources

- Slide 22: Hooke's Law Practical (Part 1)
- Slide 23: Hooke's Law Practical (Part 1) (continued)
- Loads and springs for the practical
- Graph paper (optional – see below)

Activities

Small-group activity

- In groups, the students should work on the *Hooke's Law Practical (Part 1)* and *Hooke's Law Practical (Part 1) (continued)*. NB: The Hooke's Law practical is divided into two parts; the second part is covered in Lesson 5.
- Ask the students to measure the extension of a single spring when different loads are hung onto the spring. Results should be recorded in the table and then represented graphically. NB: Some teachers have preferred to use their own graph paper rather than the paper in the Study Booklets.

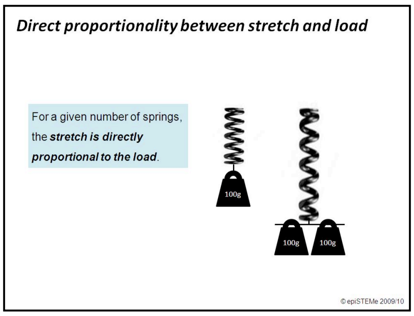
Whole-class activity

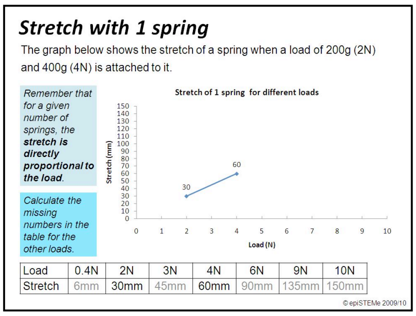
- With the whole-class, ask some students to describe the results of the experiment in their own words, e.g. 'the spring stretched more for bigger weights'.
- Make sure that the students understand the basic relationship, i.e. that stretch increases as load increases.

Note

If a 100g 'hanger' is used as the default set up, and its equilibrium positions indicated on a suitable fixed ruler, the students should measure extensions (how much stretch) when the (additional) loads are 100g (=1N), 200g, 300g, 400g etc. NB: Make sure that the students measure the EXTENSION of the spring, i.e. they should subtract the spring's original length from the total length. If time runs out, ask the students to finish the graph at home.

LESSON 4: PART 3





Objective

To characterise the relation between load and stretch in terms of direct proportionality

Time

15 minutes

Resources

- Slide 24: Direct proportionality between stretch and load
- Slide 25: Stretch with 1 spring

Activities

Whole-class activity

- Explain to the students that the language of proportionality can be used to describe the results of the practical. Use the *Direct proportionality between stretch and load* slide to teach them this relationship.
- Use the *Stretch with 1 spring* slide to support the students' understanding of the relationship. Tell the students that the figure shows the results of this practical for another type of spring, to which a 200g (2N) and a 400g (4N) load were hung.
- Explain that by applying the directly proportional relationship between stretch and load, they can see that by doubling the load (from 2N to 4N) the stretch also doubles (from 30mm to 60mm).

Individual work

- Ask the students to calculate the spring's stretch for other loads.
- Although the students could read the stretch from the line graph by extending it, they should, if possible, solve this task using mathematics, i.e. applying multiplicative strategies to predict the spring's stretch. Research shows that the use of multiplicative strategies will support students' understanding in science.
- Afterwards you can extend the line graph to 'prove' the calculated results.

Note

The students will most likely find it easiest to calculate the stretch for 6N and 10N since they are integral multiples of 2N, i.e. multiplying load (2N to 6N) and stretch (30mm to 90mm) by three, and multiplying load (2N to 10N) and stretch (30mm to 150mm) by five. It may be harder to calculate the stretch for 3N and 0.4 N. Please guide the students through the calculations as follows. If time runs out, ask the students to finish the calculations at home.

3N = 2N x 1.5, so the stretch for 3N is 30mm x 1.5 = 45mm

0.4N = 4N/10, so the stretch for 0.4N is 60mm/10 = 6mm

END OF LESSON 4

LESSON 5: SPRINGS, STRETCHES AND INVERSE PROPORTIONALITY

Overview

Lesson 5 is detailed on Pages 28 to 33. After reviewing material covered in the previous lesson, Lesson 5 revolves around an experiment that investigates how stretch changes in relation to the number of springs that are used. It emphasises that stretch is inversely proportional to the number of springs, and assists students in the use of proportional reasoning to calculate stretch with different numbers of springs. If time permits, students can be introduced to Robert Hooke and Hooke's Law.

Aim

Lesson 5 aims to teach students that:

- For a given load, stretch is inversely proportional to the number of springs that are used

Structure

The lesson is in four parts (with an optional extension) and uses a mixture of whole-class and small-group teaching.

- *Part 1* (whole-class): Reviews the practical exercise completed in Lesson 4
- *Part 2* (small-groups): Establishes the relation between stretch and number of springs
- *Part 3* (whole-class): Characterises the relation between stretch and number of springs in terms of inverse proportionality
- *Part 4* (whole-class): Relates the Hooke's Law practical to bungee jumping
- *Extension* (whole-class and small groups): Introduces Robert Hooke and Hooke's Law

Resources

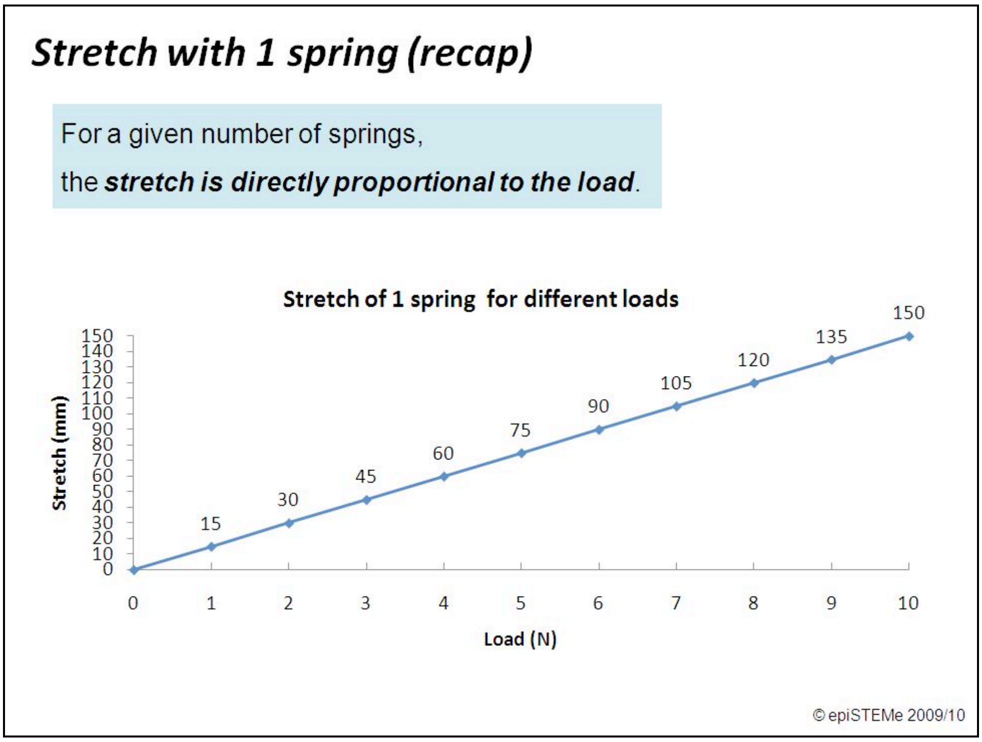
- PowerPoint Slides 26-33 (Possible homework is on Slides 34-40)
- Loads and springs for practical
- Graph paper (optional – see Part 2)

LESSON 5: PART 1

Objective
To review the practical exercise completed in Lesson 4

Time
5 minutes

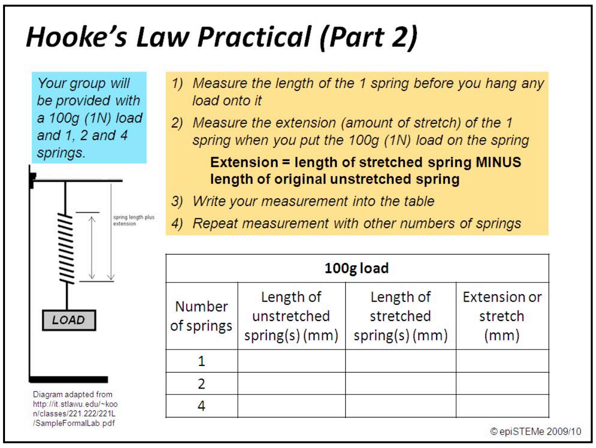
Resource
- Slide 26: Stretch with 1 spring (recap)



Activity
Whole-class activity

- Recap Lesson 4. Ask some of the students to explain what they found in the first part of the Hooke's Law practical and express the overall relations using the language of proportionality. Give them enough space and time to express their ideas, following the principles of whole-class dialogic teaching (see Introductory Module).
- Build upon this discussion by highlighting any issues you think the students may not yet have understood properly. You may want to use the *Stretch with 1 spring (recap)* slide to remind them of the relationship between 'stretch' and 'load'.

LESSON 5: PART 2



Objective

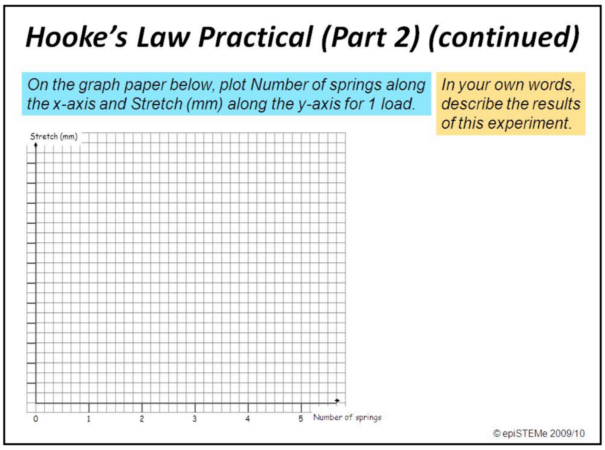
To establish the relation between stretch and number of springs

Time

20 minutes

Resources

- Slide 27: Hooke's Law Practical (Part 2)
- Slide 28: Hooke's Law Practical (Part 2) (continued)
- Loads and springs for practical
- Graph paper (optional – see below)

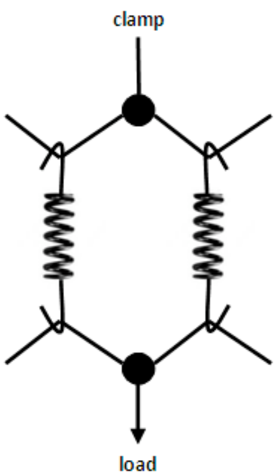


Activity

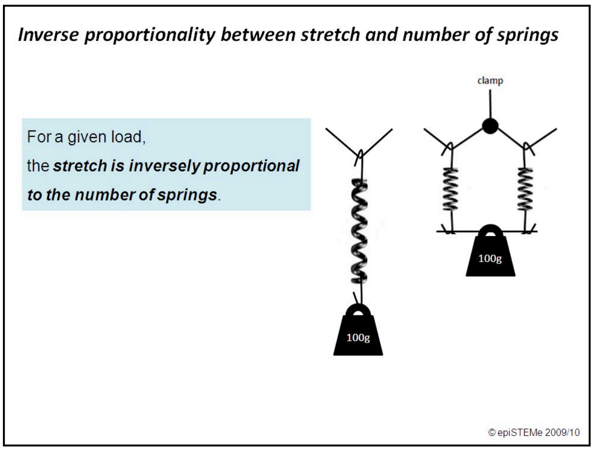
This is the second part of the Hooke's Law practical, in which the students keep the load constant (e.g. using a 100g hanger) and measure the extension for different numbers of springs (1, 2 and 4 springs).

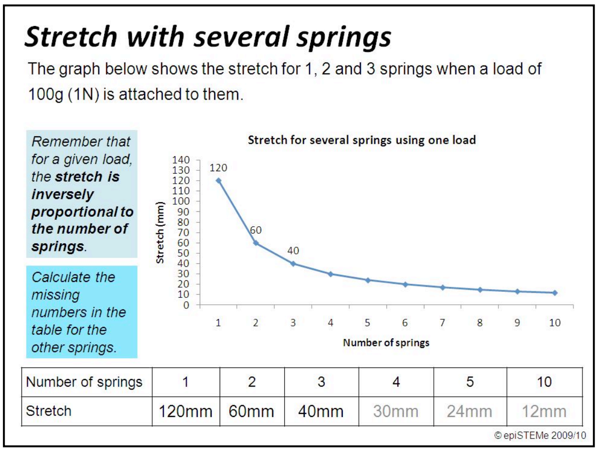
Small-group activity

- Organise the students into groups and ask them to carry out the *Hooke's Law Practical (Part 2)*, recording their results in the table and then representing them graphically - see *Hooke's Law Practical (Part 2) (continued)*. NB: Your own graph paper can be used if you prefer this.
- Hopefully, the students will find that for a given load, the stretch decreases as the number of springs increases.
- Please see the figure below for how to set up the springs when 2 or 4 springs are used.



LESSON 5: PART 3





Objective

To characterise the relation between stretch and number of springs in terms of inverse proportionality

Time

15 minutes

Resources

- Slide 29: Inverse proportionality between stretch and number of springs
- Slide 30: Stretch with several springs

Activity

Whole-class activity

- With the whole-class, ask several students to describe the results of the experiment in their own words (e.g., ‘the stretch was bigger when we used fewer springs’, or ‘the stretch was smaller the more springs that we used’). Give them enough time to express their ideas. Ask other members of the class if they want to comment.
- Then explain that the language of proportionality can be used to describe the results and teach the relationship on Slide 29 (*Inverse proportionality between stretch and number of springs*).
- Use the *Stretch with several springs* task to support understanding of the inverse relationship. Tell the students that the figure shows the results of this practical for another combination of springs, to which a load of 100g (1N) was hung.
- Explain that by applying the inverse relationship between stretch and springs, they can see that by doubling the number of springs (from 1 spring to 2 springs) the stretch halves (from 120m to 60mm), and by tripling the number of springs (from 1 spring to 3 springs) the stretch reduces to a third (from 120m to 40mm).
- Ask a few students to estimate the stretch for other numbers of springs, encouraging them to explain their reasoning each time they propose a solution.

Note

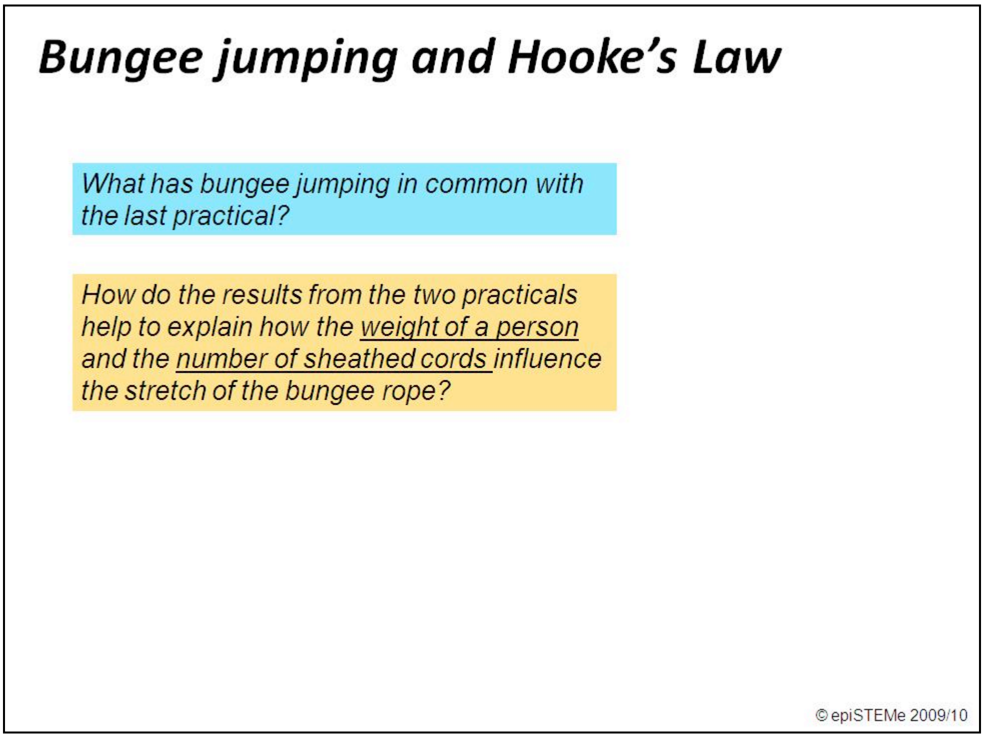
Due to the inverse relationship between numbers of springs and stretch for a given load, the students will not be able to read the stretch by extending the line graph as a straight line. Therefore they should, if possible, solve this task using mathematics, i.e. applying multiplicative strategies to predict the springs’ stretch.

LESSON 5: PART 4

Objective
To relate the Hooke's Law practical to the familiar context of bungee jumping

Time
10 minutes

Resource
- Slide 31: Bungee jumping and Hooke's Law



Activity
Whole-class activity
- Begin by reminding the class of the bungee jump topic discussed in Lesson 4.
- Use the *Bungee jumping and Hooke's Law* slide and ask one or two students to explain what it has in common with the Hooke's Law practical they have carried out in Lessons 4 and 5.
- Then ask other students how the results from the practical help to explain how the weight of a person and the number of sheathed cords influence the stretch of the bungee rope.

LESSON 5: EXTENSION (OPTIONAL)

Objective

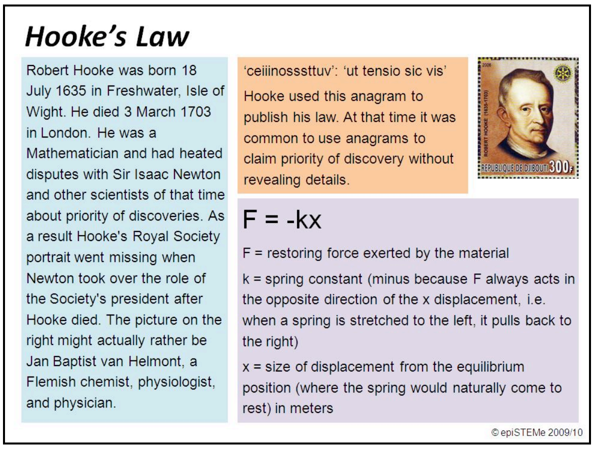
To introduce Robert Hooke and his Law

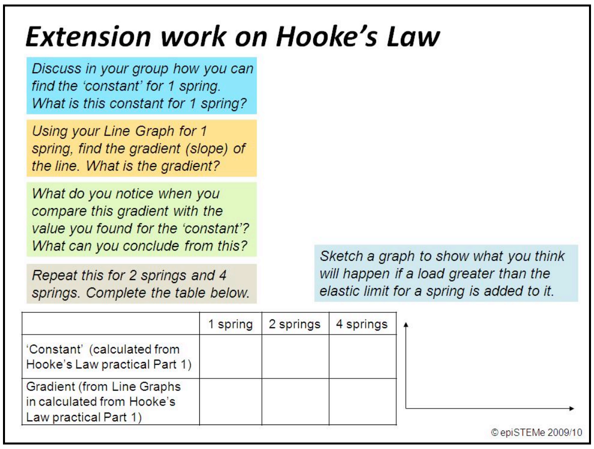
Time

10 minutes

Resources

- Slide 32: Hooke's Law
- Slide 33: Extension work on Hooke's Law





Activities

Whole-class activity

- Begin with some 'authoritative' talk in which you use the *Hooke's Law* slide to present background information about Hooke.
- Show the students the anagram 'ceiiinosssttuv': 'ut tensio sic vis' that Hooke used to publish his law. The anagram should provide a context for comparing modern and historical publication conventions. During Hooke's time, it was common to use anagrams to claim priority of discovery without revealing details. Hooke's secrecy can be compared to the way in which scientists today are expected to publish their results so that they can be repeated (replicated) and built upon by other scientists.
- You may also want to use the students' line graphs to introduce Hooke's Law. Emphasise the generality of the law, i.e. it applies to unimaginably huge and unimaginably tiny relations. However, explain that, in reality, there is an elastic limit on springs.

Small-group activity

- If time permits (and your students can cope with more demanding material), you could let them tackle *Extension work on Hooke's Law*.

LESSON 5 HOMEWORK (OPTIONAL)

Bungee jumping forum (1)

Read through the following statements in an online chat room about bungee jumps. Decide which answers seem right and which answers seem wrong. Explain why.

THREAD 1: LENGTH OF BUNGEE ROPE

Tom: I will jump from a crane that is 80 meters high. How long should my bungee cord be?

Jacob: For safety reasons the bungee cord needs to be somewhat shorter than the height of the crane. So, I guess it will be around 75 meters long so that you don't touch the ground when jumping.

Is Jacob right or wrong?	Right ☐	Wrong ☐
Explain your answer.		

Bungee jumping forum (2)

THREAD 1: LENGTH OF BUNGEE ROPE

Tom: I will jump from a crane that is 80 meters high. How long should my bungee cord be?

Paul: That all depends on your weight. Let's say they use cords that are 15 metres long. If you're a light person they will probably use 2 cords and bundle them together, which makes a bungee rope of 30 metres length. But if you're a bit heavier they will have to use 3 cords together and your bungee cord will be 45 meters long.

Is Paul right or wrong?	Right ☐	Wrong ☐
Explain your answer.		

Bungee jumping forum (3)

THREAD 1: LENGTH OF BUNGEE ROPE

Tom: I will jump from a crane that is 80 meters high. How long should my bungee cord be?

Amber: I always thought that normal bungee ropes stretch to approximately 2 times their normal length. So, I guess to be on the safe side, you will use a bungee cord that is approximately 20 meters long from the beginning.

Is Amber right or wrong?	Right ☐	Wrong ☐
Explain your answer.		

Bungee jumping forum (4)

THREAD 2: REACHING GROUND

Tom: My brother Cliff also wants to do a bungee jump. But he is much taller than me and weighs 15 kg more than I do. Who will get closer to the ground if we use the same cord?

Cathy: Cliff will be exactly 15 meters closer to the ground than you because he weighs 15 kg more than you.

Is Cathy right or wrong?	Right ☐	Wrong ☐
Explain your answer.		

Bungee jumping forum (5)

THREAD 2: REACHING GROUND

Tom: My brother Cliff also wants to do a bungee jump. But he is much taller than me and weighs 15 kg more than I do. Who will get closer to the ground if we use the same cord?

Brian: You will get closer to the ground. The cord will pull you back later than Cliff since you are much lighter.

Is Brian right or wrong?	Right ☐	Wrong ☐
Explain your answer.		

Bungee jumping forum (6)

THREAD 2: REACHING GROUND

Tom: My brother Cliff also wants to do a bungee jump. But he is much taller than me and weighs 15 kg more than I do. Who will get closer to the ground if we use the same cord?

Susan: Both of you will be pulled up at the same point because it is the same cord and therefore the same spring constant.

Is Susan right or wrong?	Right ☐	Wrong ☐
Explain your answer.		

Bungee jumping forum (7)

THREAD 2: REACHING GROUND

Tom: My brother Cliff also wants to do a bungee jump. But he is much taller than me and weighs 15 kg more than I do. Who will get closer to the ground if we use the same cord?

Albert: Your brother Cliff will get closer to the ground because he is heavier than you.

Is Albert right or wrong?	Right ☐	Wrong ☐
Explain your answer.		

END OF LESSON 5

LESSON 6: DENSITY AND FLOATING

Overview

Lesson 6 is detailed on Pages 35 to 39. It focuses on the concept of density, demonstrating that an object's density is crucial for determining whether it floats or sinks.

Aims

Lesson 6 aims to teach students that:

- Density is defined as mass per unit of volume
- An object's density is crucial for determining whether it floats or sinks

Structure

The lesson is in three parts (with an optional extension) and uses a mixture of whole-class and small-group teaching as well as individual work.

- *Part 1* (whole-class and small-groups): Uses a poem to initiate reflection on the factors, which determine whether objects float or sink
- *Part 2* (whole-class): Introduces the scientific concept of density and signals its relevance to floating and sinking
- *Part 3* (individual work, small-groups and whole-class): Establishes the relation between density and flotation
- *Extension* (whole-class): Poses an intriguing problem, whose solution depends upon understanding the concept of density

Resources

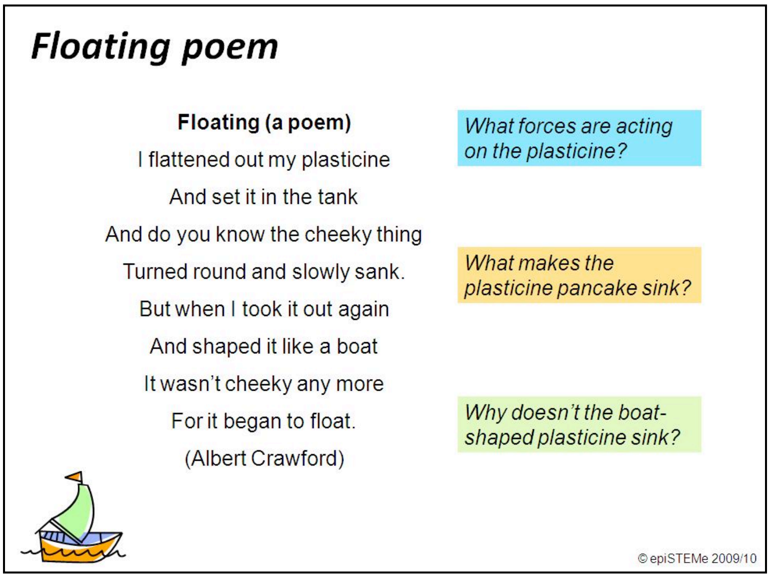
- PowerPoint Slides 41-46 (Possible homework is on Slide 47)
- Objects, beakers and water for the practical (see Note on Page 36)

LESSON 6: PART 1

Objective
To initiate reflection on the factors, which determine whether objects float or sink

Time
10 minutes

Resource
- Slides 41: Floating poem



Activities
Whole-class activity
- Present the *Floating poem* and let one student read the poem out loud.

Small-group activity
- Organise the students into groups and ask them to discuss the poem and the related questions together.
- Remind the students to follow the 'ground rules' for discussion and to give reasons when deciding on their agreed answers.

Whole-class activity
- Collect the answers the groups have agreed upon. Avoid evaluating their answers straight away, but ask members of the class for any comments.
- Then lead the discussion towards the correct answers.

Note
Some groups may use the variable 'surface area' to explain their answers. Guide the students towards 'volume' (or size) instead. That will make it easier to introduce the formula for density in Part 2.

LESSON 6: PART 2

Objectives

To introduce the scientific concept of density, and to signal its relevance to floating and sinking

Time

10 minutes

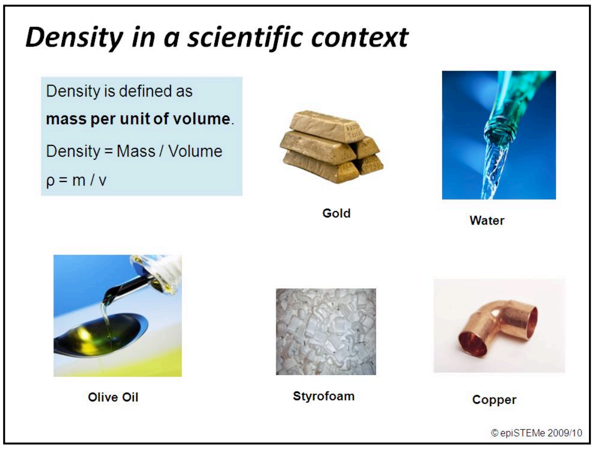
Resources

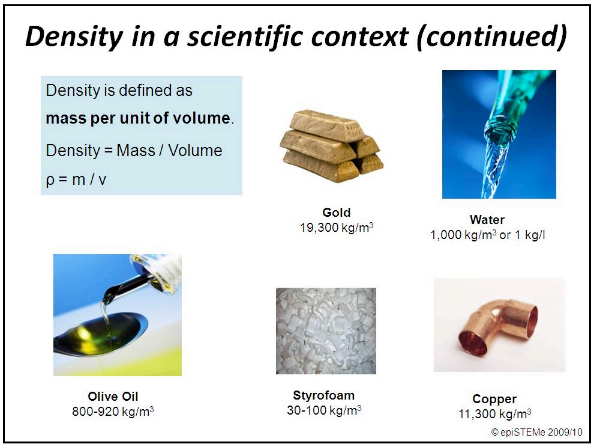
- Slide 42: Density in real-life situations
- Slide 43: Density in a scientific context
- Slide 44: Density in a scientific context (continued)

Activity

Whole-class activity

- Explain that the density of an object is crucial to whether it floats or sinks.
- Switching from authoritative to dialogic mode, use *Density in real-life situations* to explore what the students understand by the concept of density. Ensure an open dialogue in which you give the students enough space to explain what they understand by the concept.
- Then, using *Density in a scientific context*, tell the students that density in a scientific context is defined as mass per unit of volume.
- In order to support this message, the slide shows examples of objects and substances with differing densities. Ask the students to rank the objects/substances from expected smallest to largest density. Then, using *Density in a scientific context (continued)*, reveal the correct order.



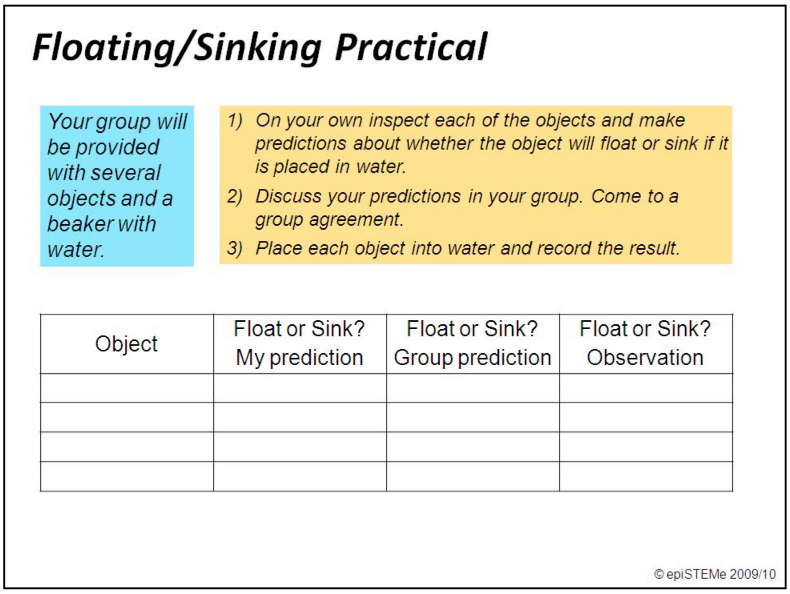


LESSON 6: PART 3

Objective
To establish the relation between density and flotation

Time
30 minutes

Resources
- Slide 45: Floating/Sinking Practical
- Objects, beakers and water for the practical



Activities
Individual work
- Using the *Floating/Sinking Practical* ask the students to predict individually which objects selected for the practical will float and which will sink.
- When explaining the task, you do not need to state explicitly that the objects vary in mass and volume (see Note below on preparation). It would be better if the students are encouraged to handle the objects first and make individual predictions in their workbooks, i.e. without discussion.

Small-groups activity
- Organise the students into groups.
- Ask them to share their predictions and encourage the groups to come to an agreed prediction before testing.
- Groups should then carry out the practical task, observing and interpreting results.

Whole-class activity
- Working with the whole-class, ask one person from each group to explain their findings.
- Write the conclusions that each group has reached on a board or flipchart.
- Drawing on what you have written, make sure that the students understand that the concept of density depends on both mass and volume, and it is density (and not mass or volume alone) that is relevant to floating.

Note
When preparing for this practical, make sure you provide students with several objects, some of which float easily on top of the water, others that just about float and some of which sink. In order to foster students' understanding of the importance of density in floating and sinking, provide objects that have the same/similar volume but different mass (e.g. a golf ball and a ping-pong ball) and objects that have the same/similar mass but different volume (e.g. 5g of plasticine and 5g of Styrofoam).

LESSON 6: EXTENSION (OPTIONAL)

Objective

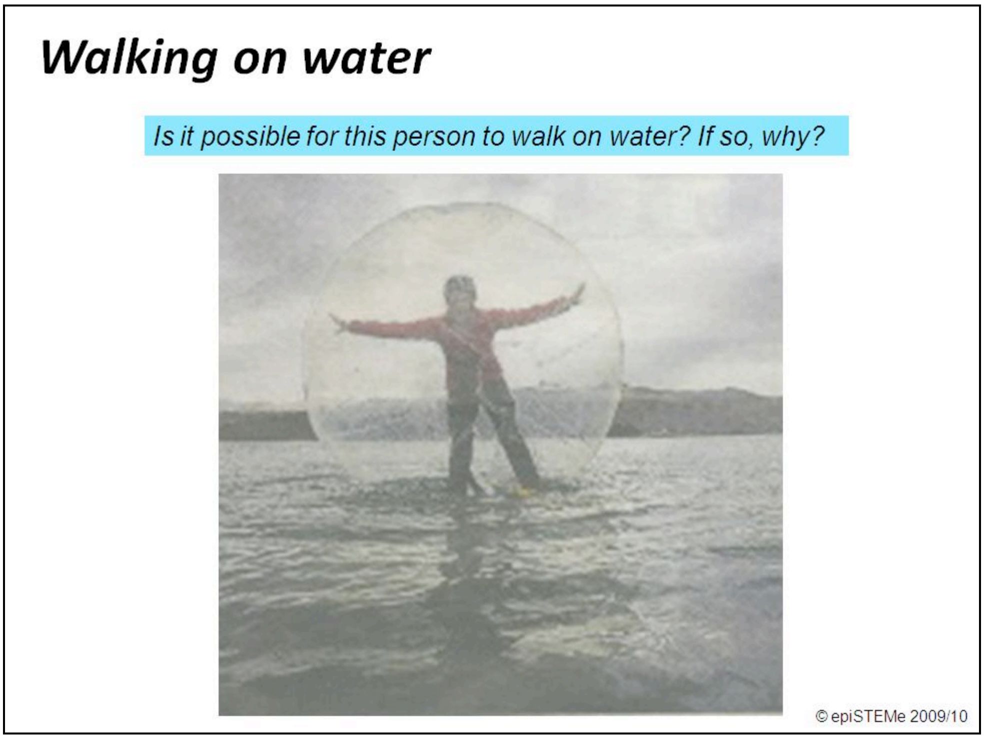
To pose an intriguing problem, whose solution depends upon understanding the concept of density

Time

5 minutes

Resource

- Slide 46: Walking on water



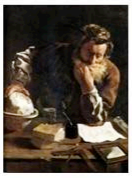
Activity

Whole-class activity

- Show *Walking on water* to the class and ask them to think about the task between now and the next lesson, when you will ask students whether it would really be possible for this person to walk on water, and if so why.

LESSON 6 HOMEWORK (OPTIONAL)

Archimedes



Check out who Archimedes was (using internet or library).

What is Archimedes' Principle? Write out a statement here.

Note

Understanding the work of Archimedes will help to consolidate Lesson 6 material, and underline its significance.

END OF LESSON 6

LESSON 7: FLOATING IN SALTY WATER

Overview

Lesson 7 is detailed on Pages 41 to 45. After reviewing related material covered in Lesson 6, the lesson focuses on the fact that flotation depends upon the *relative* density of objects and fluids. In particular, students will learn that the floating/sinking properties of objects change in relation to the density of the solution they are immersed in. At the same time, the lesson highlights several real-world contexts where density is relevant.

Aim

Lesson 7 aims to teach students that:

- Objects that are denser than the solution they are immersed in will sink, while those that are less dense will float

Structure

The lesson is in three parts (with an optional extension) and uses a mixture of whole-class and small-group teaching.

- *Part 1* (whole-class): Reviews the relation between density and flotation
- *Part 2* (small-groups and whole-class): Establishes that the density of objects relative to the fluid they are immersed in determines whether they float or sink
- *Part 3* (whole-class): Addresses floating in the Dead Sea
- *Extension* (whole-class)*:* Introduces the Plimsoll Line and the sinking of the Titanic

Resources

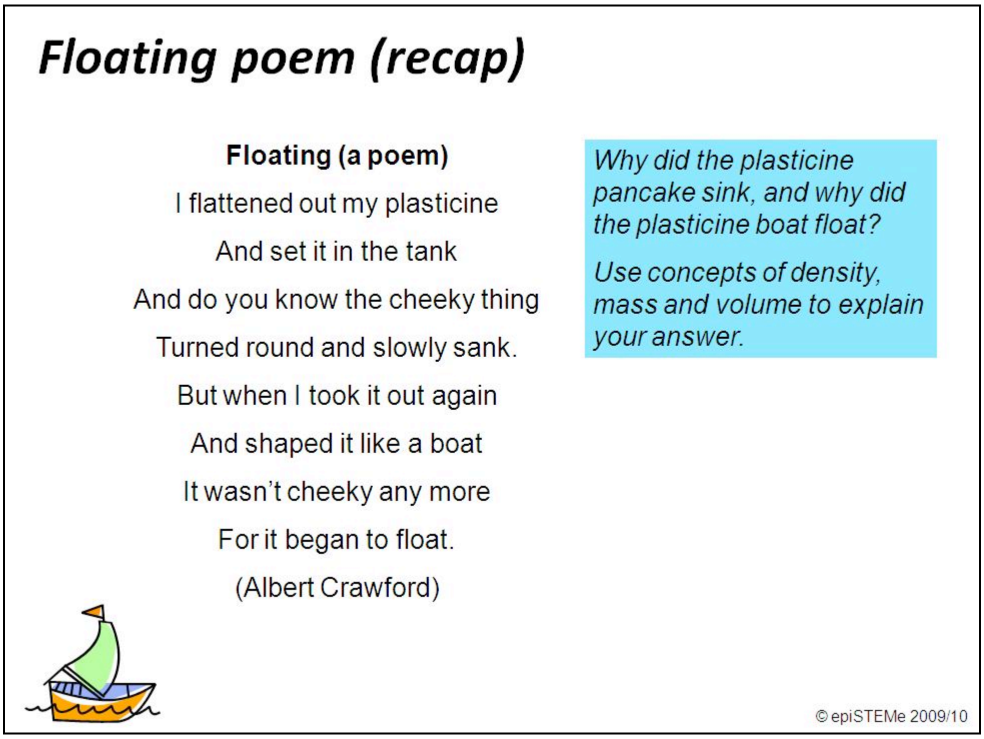
- PowerPoint Slides 48-52
- Objects, beakers, salt and water for the practical

LESSON 7: PART 1

Objective
To review the relation between density and flotation established in Lesson 6

Time
5 minutes

Resource
- Slide 48: Floating poem (recap)



Activity
Whole-class activity
- Use *Floating poem (recap)* to recap Lesson 6 by asking a sample of students to explain why the plasticine pancake in the Floating poem sank and the plasticine boat floated.
- Encourage the students to use the concepts of density, mass and volume (e.g., by paraphrasing the answers they offer using these terms).
- If you used the *Walking on water* slide in Lesson 6, it can be discussed during this part of Lesson 7.

LESSON 7: PART 2

Objective

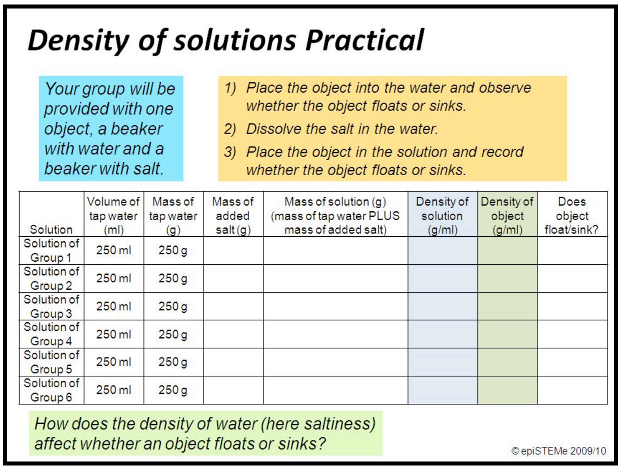
To establish that the density of objects relative to the fluid they are immersed in determines whether they float or sink

Time

35 minutes

Resources

- Slide 49: Density of solutions
- Objects, beakers, salt and water for the practical



Solution	Volume of tap water (ml)	Mass of tap water (g)	Mass of added salt (g)	Mass of solution (g) (mass of tap water PLUS mass of added salt)	Density of solution (g/ml)	Density of object (g/ml)	Does object float/sink?
Solution of Group 1	250 ml	250 g					
Solution of Group 2	250 ml	250 g					
Solution of Group 3	250 ml	250 g					
Solution of Group 4	250 ml	250 g					
Solution of Group 5	250 ml	250 g					
Solution of Group 6	250 ml	250 g					

Activities (Continue on Page 43)

Small-group activity

- Using the *Density of solutions Practical*, ask the students to explore in groups how the floating/sinking properties of objects change in relation to the salinity of water.
- For this practical choose an object from Lesson 6 that sank in normal tap water. First, give each group a beaker with tap water. Make sure that all groups use the same amount of water, e.g. 250 ml. Please amend the numbers in the table below if you choose a different volume for this practical.
- Ask the students to place the object into the water. The object should sink.
- Next, give each group a beaker of salt. The beaker should have a label telling exactly how much salt it contains (in grams) because this information will be needed later to calculate the solution's density.
- Ask the students to dissolve the salt in the water (using warm water will facilitate this process). Choose the amount of salt for each group by prior testing so that some groups will get solutions that make the object float whilst other groups will get solutions, in which the object still sinks. (If you choose to use a golf ball, you may find that it starts floating in 250ml tap water when you add 50-60g of salt to it.)
- Then, the students should place the object into the water and record their findings.

LESSON 7: PART 2 CONTINUED

Whole-class activity

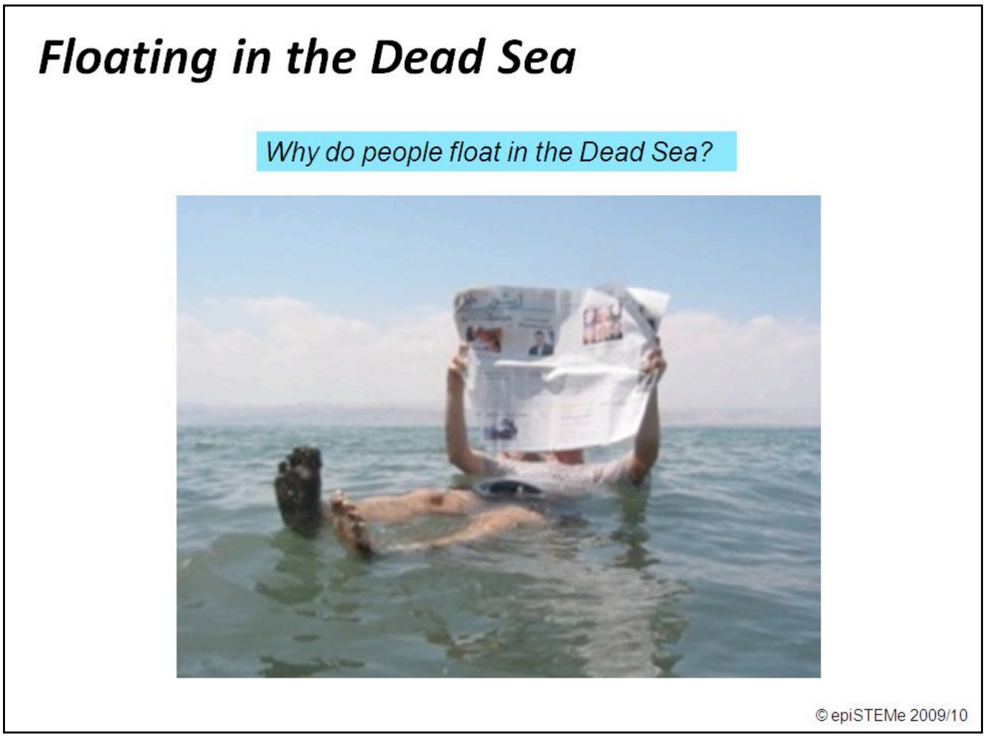
- Ask a member of each group to report whether their object sank or floated.
- Record the findings in the table. NB: You can make entries into the table either by writing on the projected slide or by typing into PowerPoint. Ask each group how much salt they added to the water (which can be read from the salt beaker's label) and what the mass of the solution will be. Add these data to the table.
- Now the students can calculate the solution's density. They should find out that the density of the solution increases as more salt is added since the mass of the water increases while the volume stays the same.
- Next, say that you want the students to compare the solution's density with the object's density. Use your discretion about whether you let them calculate the object's density (using a displacement can to measure the object's volume if it has a round shape), whether you show this as a teacher demonstration, or whether you just tell the students what the density is.
- In any case, in a whole-class dialogue, ask several students to explain how the floating/sinking properties of objects change in relation to the density of the solution they are immersed in.
- In the final part of the discussion, lead the students towards understanding that objects that are denser than the solution they are immersed in will sink, while objects that are less dense will float.

LESSON 7: PART 3

Objective
To relate the practical to floating in the Dead Sea

Time
10 minutes

Resource
- Slide 50: Floating in the Dead Sea



Activity
Whole-class activity
- To conclude the density topic, show the *Floating in the Dead Sea* slide and explore the students' ideas about why people float in the Dead Sea.
- Make sure that the students use density terms (mass and volume in combination) to explain their reasoning.
- Finally, show the video of the coke experiment, which also addresses the issue of salt in the Dead Sea (http://www.planet-scicast.com/view_clip.cfm?cit_id=2778).

LESSON 7: EXTENSION (OPTIONAL)

Objective

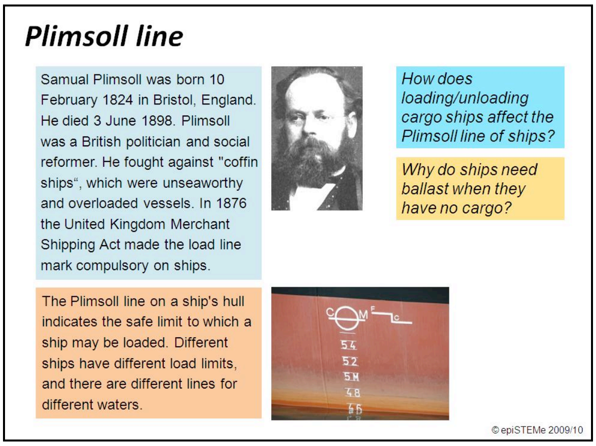
To highlight further applications of material covered in the lesson, i.e. to Plimsoll lines and the sinking of the Titanic

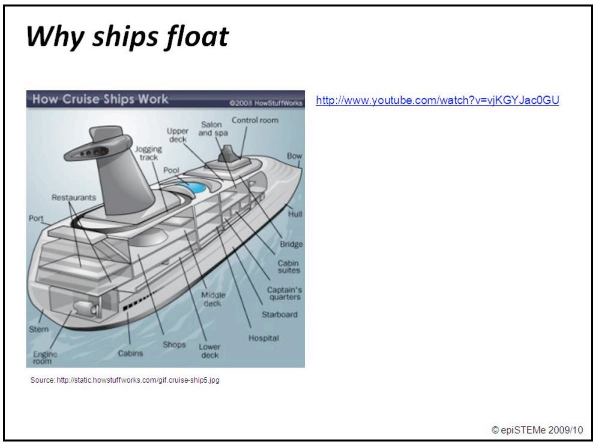
Time

10 minutes

Resources

- Slide 51: Plimsoll line
- Slide 52: Why ships float





Activity

Whole-class activity

- Show the students the *Plimsoll line* slide to introduce Plimsoll and his line.
- In addition, you could use a ship made of graph paper that shows a Plimsoll line.
- Through whole-class dialogue, ask the students about the effects on the Plimsoll line of a cargo ship unloading its cargo. Ask why ships need ballast when they have no cargo.
- Using *Why ships float*, show the students what the interior of a ship looks like to support their understanding that ships float because their density is smaller than the density of water.
- Play a video about the Titanic to support this message (link on the slide). As the inside of the ship fills with water, its density increases due to an increase of weight caused by the incoming water with the volume of the ship staying the same. The ship's density becomes greater than that of water making it sink in the end.

END OF LESSON 7

LESSON 8: FORCES OF FRICTION

Overview

Lesson 8 is detailed on Pages 47 to 49. It focuses upon surface friction and its effects on motion, but it is followed by an optional full-lesson extension that addresses friction from air.

Aims

Lesson 8 aims to teach students that:

- Friction is a force between two surfaces touching each other
- Friction works in the opposite direction to the direction of motion
- Friction slows objects down or prevents them from moving
- Helpful and unhelpful friction both occur in everyday situations

Structure

The lesson is in three parts and uses a mixture of whole-class and small-group teaching.

- *Part 1* (whole-class): Introduces the concept of friction and highlights that friction works in the opposite direction to the direction of motion
- *Part 2* (whole-class and small-groups): In the context of curling, quantifies the forces needed to preserve constant speed
- *Part 3* (small-groups): Highlights where friction occurs in everyday life (including a few examples where high friction might be regarded as unhelpful)

Resources

- PowerPoint Slides 53-61
- Friction - true or false? - A master copy is in the plastic folder

LESSON 8: PART 1

Objectives

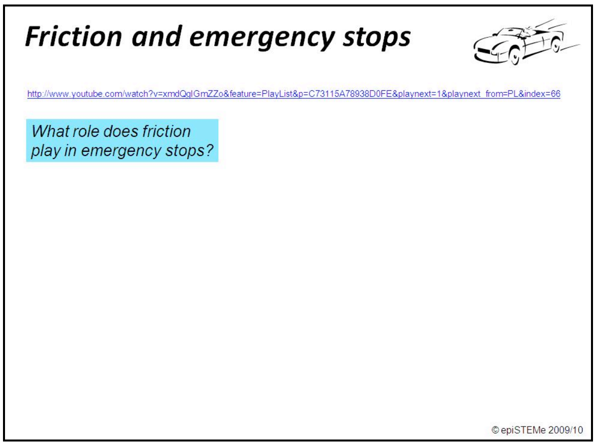
To introduce the concept of friction and highlight that friction works in the opposite direction to the direction of motion

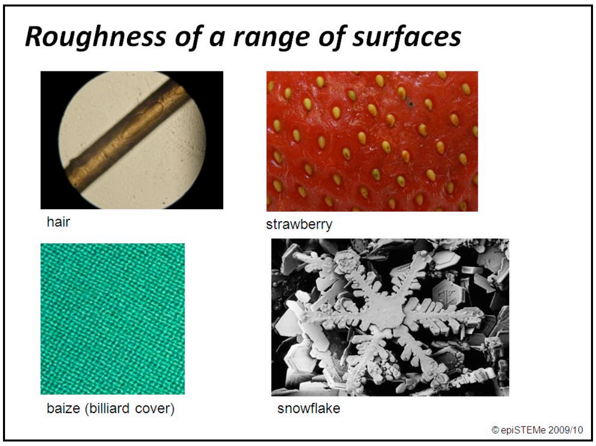
Time

10 minutes

Resources

- Slide 53: Friction and emergency stops
- Slide 54: Roughness of a range of surfaces



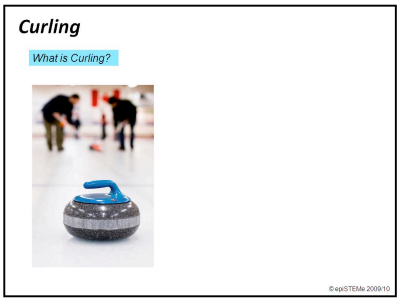


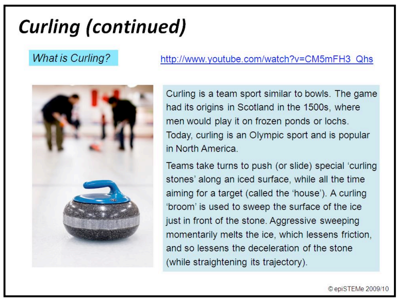
Activity

Whole-class activity

- Show a video of cars making ‘emergency stops’ (link on *Friction and emergency stops slide*). Explore the students’ ideas about the friction involved in emergency stops. In addition, let the students rub their hands together and explain what happens.
- Make the students aware that friction works in the opposite direction to the direction of motion.
- In order to support the students’ understanding of friction, show them a range of close-up pictures (*Roughness of a range of surfaces*) for a range of surfaces.

LESSON 8: PART 2





Objective

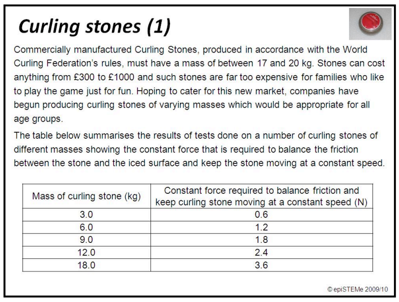
In the context of curling, to quantify the forces needed to preserve constant speed

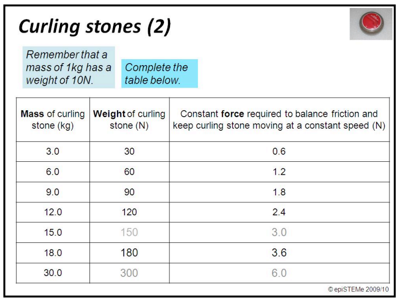
Time

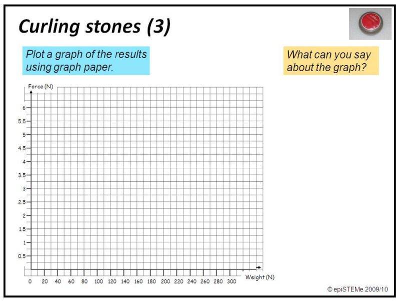
25 minutes

Resources

- Slide 55: Curling
- Slide 56: Curling (continued)
- Slide 57: Curling – Bonspiel in Scotland
- Slide 58: Curling stones (1)
- Slide 59: Curling stones (2)
- Slide 60: Curling stones (3)







Activities

Whole-class activity

- Using the *Curling* slide, ask the students if anyone knows the sport. If any student is familiar with curling, let them describe how it works. If not, or if the description needs extra information, present *Curling (continued)*. You might even want to show a short clip about Curling (link on the slide).
- It may interest the students to learn that in very cold winters, Scottish curlers still sometimes play on frozen lochs – it's called a 'bonspiel'. Photos of such a 'bonspiel' can be found on the slide *Curling – Bonspiel in Scotland*.

Small-group activity

- Ask the students to work in groups on *Curling stones (1)-(3)*.
- Remind them of the need to share all relevant ideas and to try to reach an agreed answer.

Whole-class activity

- Collect the answers from each group.
- In a whole-class discussion, ask them for their views on the correctness of the various answers.
- Towards the end of the discussion, guide them towards the correct solution.

LESSON 8: PART 3

Objective
To highlight where friction occurs in everyday life

Time
15 minutes

Resources
- Slide 61: Friction - true or false?
- Friction - true or false? - A master copy is in the plastic folder

Friction - true or false?

Read through the statements below. In your group, sort out the statements into two piles (True / False) and explain why.

STATEMENT	True / False
1. Cars need friction so as to start moving	True
2. Buses need friction to be able to stop	True
3. A person would not be able to walk without friction	True
4. Gymnasts find friction useful	True
5. Friction causes a match to light	True
6. There is more friction on wet roads than on dry roads	False
7. Zips keep jackets done up because of friction	True
8. You wouldn't be able to pick up a mug of coffee without friction	True
9. Pencils do not need friction to be able to write	False
10. There is no friction when you are ice skating	False

Activities
Small-groups activity
- Organise the students into groups to work on *Friction - true or false?*
- Make copies for each group and cut the statements so that each group gets a set of statements that they can arrange in true and false piles.
- Remind the students that they need to come to an agreement for each statement.

Whole-class activity
- Debrief using the whole-class dialogic mode.

Note
Some statements have deliberately been made very difficult – to stimulate discussion.

END OF LESSON 8

LESSON 8 EXTENSION: AIR RESISTANCE

Overview

This 50-minute lesson on air resistance can be used as an extension to Lesson 8 if time permits. If time is tight, please go straight to Lesson 9 (on Page 54), which covers stopping distance. The extension lesson on air resistance is detailed on Pages 51 to 53. After introducing the concept, the lesson examines the operation of air resistance during object fall and motion down an inclined plane.

Aims

Lesson 8 Extension aims to teach students about:

- The concept of air resistance
- The involvement of air resistance in slowing objects down

Structure

The lesson is in three parts and uses a mixture of whole-class and small-group teaching.

- *Part 1* (whole-class and small-groups): Defines air resistance, identifies helpful and unhelpful instances, and examines the implications of air resistance for object fall
- *Part 2* (whole-class and small-groups): Continues exploring the operation of air resistance during object fall
- *Part 3* (small-groups and whole-class): Examines air resistance in the context of motion down an inclined plane

Resources

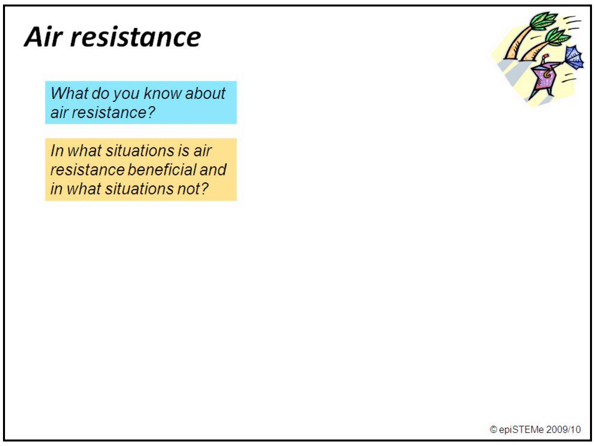
- PowerPoint Slides 62-65
- Cotton wool and plasticine
- Paper, string and a small weight such as a paper clip
- Slope, toy car, card, blu-tack

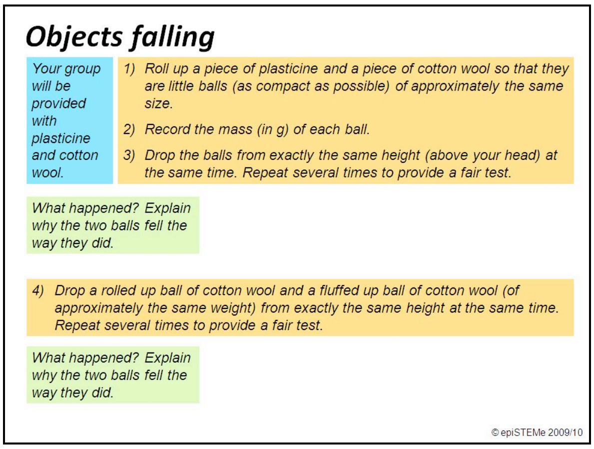
LESSON 8 EXTENSION: PART 1

Objective
To define air resistance, to identify helpful and unhelpful instances, and to examine the implications of air resistance for object fall

Time
15 minutes

Resources
- Slide 62: Air resistance
- Slide 63: Objects falling
- Cotton wool and plasticine





Activities
Whole-class activity
- Using the *Air resistance* slide, explore what the students know about air resistance and in what situations air resistance is beneficial and in what situations it is unhelpful.
- Try to give students enough time to explain their existing ideas. Don't correct errors immediately, but by prompting and guiding, lead the class towards a correct analysis.

Small-group activity
- Organise the students into groups to work on *Objects falling*.
- Remind them of the need to discuss the task properly together, and to give reasons for the solutions they offer.

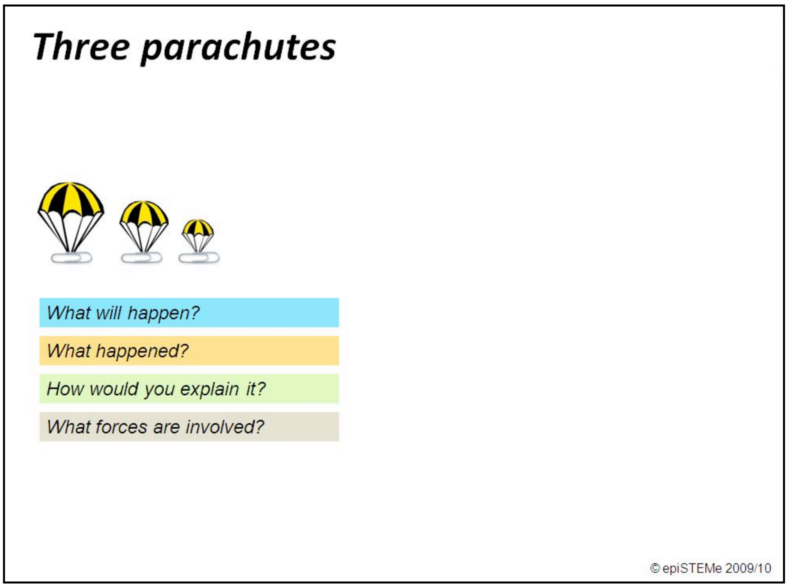
Whole-class activity
- Collect answers from each group.
- In a whole-class discussion, ask the students for their views on the correctness of the various answers.
- Towards the end of the discussion, guide the students towards the correct solution.

LESSON 8 EXTENSION: PART 2

Objective
To continue exploring the operation of air resistance during object fall

Time
15 minutes

Resources
- Slide 64: Three parachutes
- Paper, string and a small weight such as a paper clip



Activities
Whole-class activity
- Using the *Three parachutes* slide, explain to the students that you will drop three parachutes - a small, medium and large parachute (made from paper, string and a small weight such as a paper clip) - from the same height at the same time. The shapes of the parachutes are the same – they only vary over the size of the paper that is used.

Small-group activity
- Ask the students to discuss the scenario with their neighbours and predict what will happen to the three parachutes.

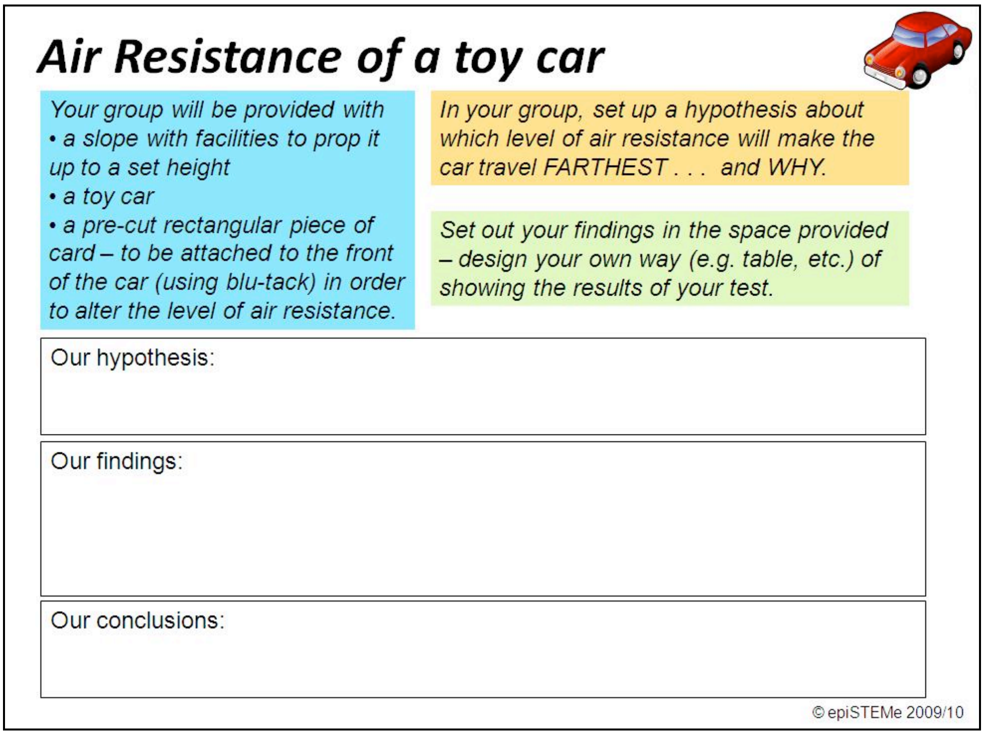
Whole-class activity
- Collect the students' predictions.
- Carry out the teacher demonstration.
- Ask a sample of students to describe what they have seen, how they would explain it, and what forces are involved. Ask other students for comments on these explanations, and try to avoid providing your own 'authoritative' answer until these comments have been discussed.

LESSON 8 EXTENSION: PART 3

Objective
To examine air resistance in the context of motion down an inclined plane

Time
20 minutes

Resources
- Slide 65: Air Resistance of a toy car
- Slope, toy car, card, blu-tack



Activities
Small-groups activity
- Organise the students into groups to work on *Air Resistance of a toy car*.
- Remind them of the 'ground rules' and the need for the group to record an agreed answer.

Whole-class activity
- Debrief using the whole-class dialogic mode.

END OF LESSON 8 EXTENSION

LESSON 9: SPEED AND STOPPING DISTANCE (1)

Overview

Lesson 9 is detailed on Pages 55 to 59. The lesson starts by introducing the basic concepts of speed, acceleration and deceleration. Continuing with the theme of deceleration, it addresses the relationship between speed and stopping distance. Stopping distance is shown to depend on thinking distance and braking distance, and the proportional relationship between thinking distance and speed is examined in detail.

Aims

Lesson 9 aims to teach students that:

- Motion can be characterised in terms of speed, acceleration and deceleration
- Stopping distance is made up of two parts: thinking distance and braking distance
- Thinking distance is directly proportional to speed

Structure

The lesson is in three parts (with an optional extension) and uses a mixture of whole-class and small-group teaching as well as individual work.

- *Part 1* (whole-class and small-groups): Introduces the concepts of speed, acceleration and deceleration
- *Part 2* (whole-class and individual work): Highlights that stopping distance depends upon thinking distance and braking distance, and identifies the proportional relationship between thinking distance and speed
- *Part 3* (small-groups and whole-class): Consolidates understanding of thinking distance, braking distance and stopping distance as a function of speed
- *Extension* (individual work and whole-class): Uses the realistic context of speed limits in a range of countries for further work on thinking distance

Resources

- PowerPoint Slides 66-74

LESSON 9: PART 1

Objectives

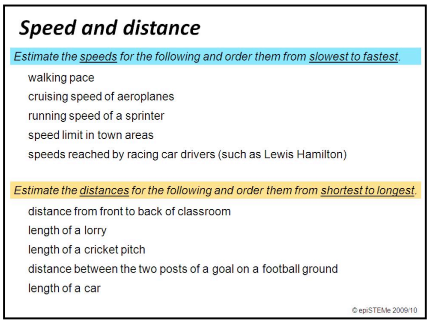
To introduce the concepts of speed, acceleration and deceleration

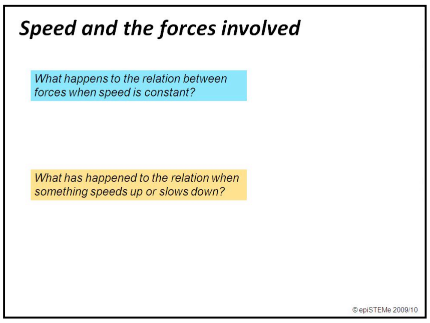
Time

10 minutes

Resources

- Slide 66: Speed
- Slide 67: Speed and distance
- Slide 68: Speed and the forces involved





Activities

Whole-class activity

- In a brief, open dialogue, ask students what they know about speed (*Speed* slide). For example, you could ask them how they think speed is measured, and what units are used. Then present *Speed and distance* and check that they understand it.

Small-group activity

- Organise the students into groups and ask them to work together to estimate the speeds and distances in the list in *Speed and distance*. Ask them then to order the five speed examples from slowest to fastest, and the five distance examples from shortest to longest.

Whole-class activity

- Collect responses from the groups.
- Use *Speed and the forces involved* to elicit the students' understanding of the relation between forces when: 1) speed is constant; 2) something speeds up or slows down. NB: Lesson 2 material has prepared the ground for discussing these issues.
- Make sure that the students know the terms 'acceleration' and 'deceleration' to describe speeding up or slowing down.
- Ask the students whether it is possible to stop instantaneously, and ask for reasons to back up their ideas.

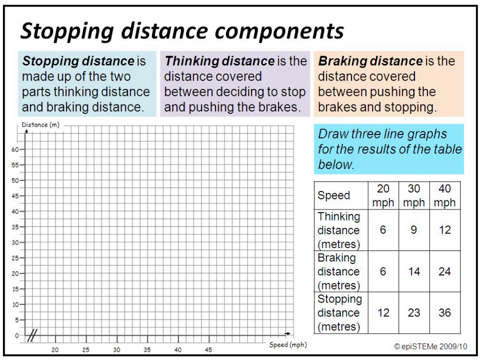
Note

If time permits (and your students would appreciate a more physical task), why not let them measure speeds in the playground?

LESSON 9: PART 2

Objectives

To highlight that stopping distance depends upon thinking distance and braking distance, and to identify the proportional relationship between thinking distance and speed



Time

25 minutes

Resources

- Slide 69: Speed and stopping distance
- Slide 70: Stopping distance components
- Slide 71: Direct proportionality between speed and thinking distance

Activities (Continue on Page 57)

Part 1 sets the scene for a simulation of stopping distances for a normal car travelling at 20, 25, 30, 35, 40 and 45 mph.

Whole-class activity

- Using the *Speed and stopping distance slide*, show the simulation for the speeds of 20, 30, and 40 mph (link on the slide). The Replay button shows the stopping of the car once more from a bird's view.
- Ask a sample of students what they can tell about the relationship between speed and overall stopping distance. Hopefully, the students will understand that the stopping distance increases when the speed increases.
- Present the information on *Stopping distance components* and explain that stopping distance is made up of the two parts: 1) thinking distance and 2) braking distance.

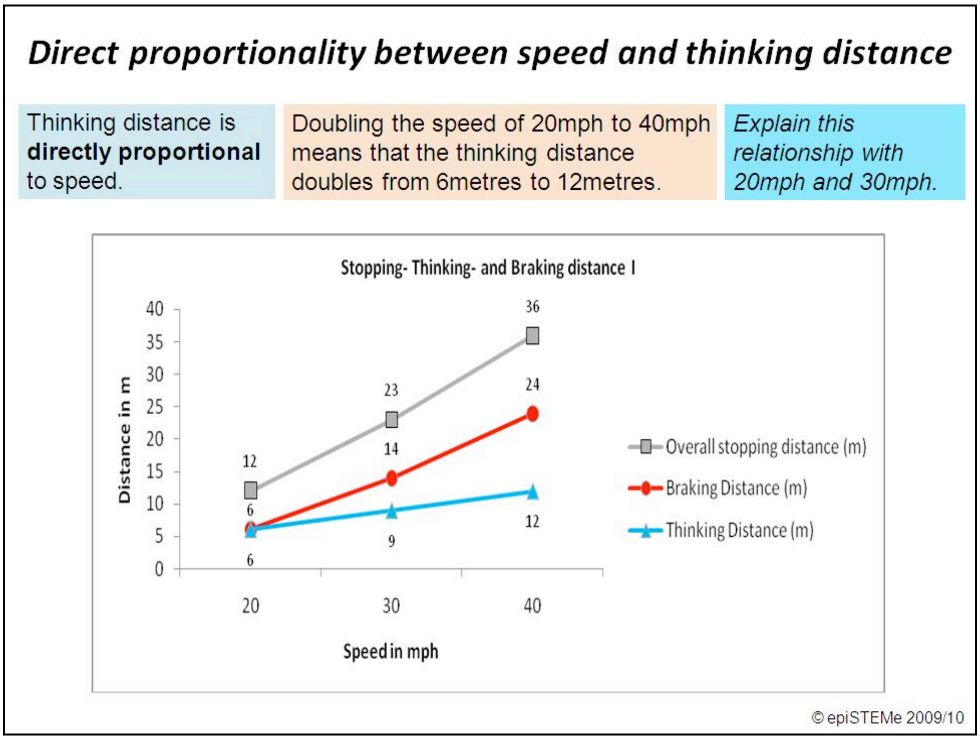
Individual work

- Ask the students to draw in their Study Booklets three line graphs (one each for thinking distance, braking distance, and stopping distance) for the data in the table of *Stopping distance components*. Check the students' progress with the drawing and give help where necessary.

Note

Some teachers have found it helpful to cover the relation between distance, time and speed between Parts 1 and 2 of Lesson 9, thereby extending the lesson's duration. Use your discretion here, since establishing that s = d/t is not strictly necessary for this lesson.

LESSON 9: PART 2 CONTINUED



Activity

Whole-class activity

- Present the *Direct proportionality between speed and thinking distance* slide and ask the students if their graphs look similar.
- Ask individual students to describe the three different lines. You may want to make the students aware of the general shape of the relation, e.g. braking distance increases more rapidly with speed than thinking distance.
- Draw the students' attention to the fact that thinking distance is directly proportional to speed. Show the students this relationship using the example of 20 mph and 40 mph. The students should understand that doubling the speed means that the thinking distance doubles too. Ask some specific students how this relationship can be seen with 20 mph and 30 mph. Ask for comments on their answers from the rest of the class.
- The students should understand that 30 mph is one and a half times 20 mph, which is why the thinking distance for 30 mph should be one-and-a-half times the thinking distance for 20 mph. These numbers can be easily calculated and interpreted from the table and the figure.

Note

You may consider using for top-set students *Braking distance is directly proportional to the square of the speed.*

LESSON 9: PART 3

Objective

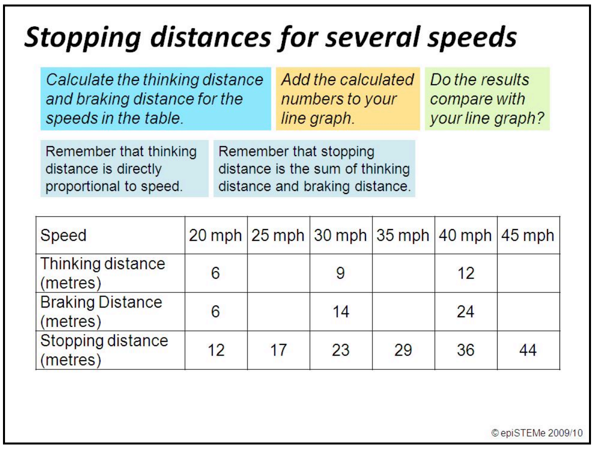
To consolidate understanding of thinking distance, braking distance and stopping distance as a function of speed

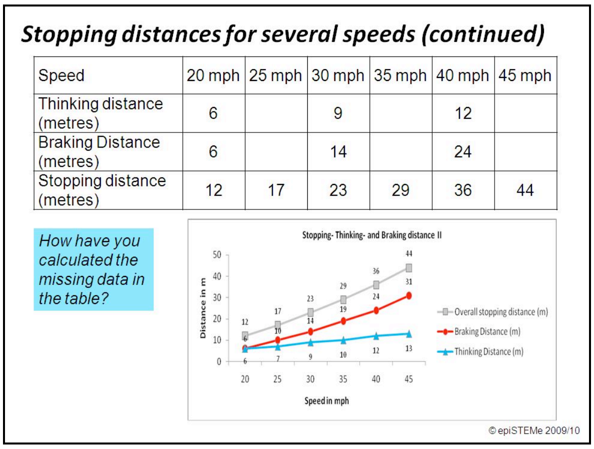
Time

15 minutes

Resources

- Slide 72: Stopping distances for several speeds
- Slide 73: Stopping distances for several speeds (continued)





Activities

Small-group activity

- Organise the students to work in groups on *Stopping distances for several speeds* and calculate the missing distances in the table.

Whole-class activity

- Present the *Stopping distances for several speeds (continued)* slide, which includes the results from the simulator for all speeds. NB: Some numbers are rounded and may not equal numbers calculated by the students.
- Ask the students if their line graphs look similar. Ask a representative of each group how they calculated the missing data in the table. Encourage them to use proportionality terms to describe their results.

LESSON 9: EXTENSION

Objective
To calculate thinking distance with more challenging (but realistic) numerical values

Time
10 minutes

Resource
- Slide 74: Speed limits in Europe

Speed limits in Europe

Calculate the thinking distances for the following European countries if a driver was driving at the maximum speed limit there and had to stop quickly.

Country	UK	UK	Norway	Cyprus	Denmark	Spain	Austria
Where?	Built-up areas	Motor ways	Motor ways	Motor ways	Motor ways	Motor ways	Motor ways
Speed limit	50 km/h	112 km/h	90 km/h	100 km/h	110 km/h	120 km/h	130 km/h
Thinking distance	9 m	20.2 m	16.2 m	18 m	19.8 m	21.6 m	23.4 m

Activities
Individual work
- Let the students work individually on *Speed limits in Europe*.

Whole-class activity
- Debrief using whole-class dialogic mode.

END OF LESSON 9

LESSON 10: SPEED AND STOPPING DISTANCE (2)

Overview

Lesson 10 is detailed on Pages 61 to 64. Most of the lesson is devoted to consolidating students' understanding of the proportional relationships between speed and thinking distance. Towards the end though, the factors that influence stopping distance are introduced.

Aims

Lesson 10 aims to:

- Consolidate understanding of the proportional relationships between speed and thinking distance
- Introduce the factors that influence stopping distance

Structure

The lesson is in three parts and uses a mixture of whole-class and small-group teaching as well as individual work.

- *Part 1* (whole-class): Reviews the relation between speed and thinking distance
- *Part 2* (small-groups and whole-class): Consolidates understanding of the relation between speed and thinking distance, and integrates speed and thinking distance with braking distance and stopping distance
- *Part 3* (whole-class): Considers the environmental and driver factors that influence stopping distance

Resources

- PowerPoint Slides 75-78 (Possible homework is on Slide 79)

LESSON 10: PART 1

Objective

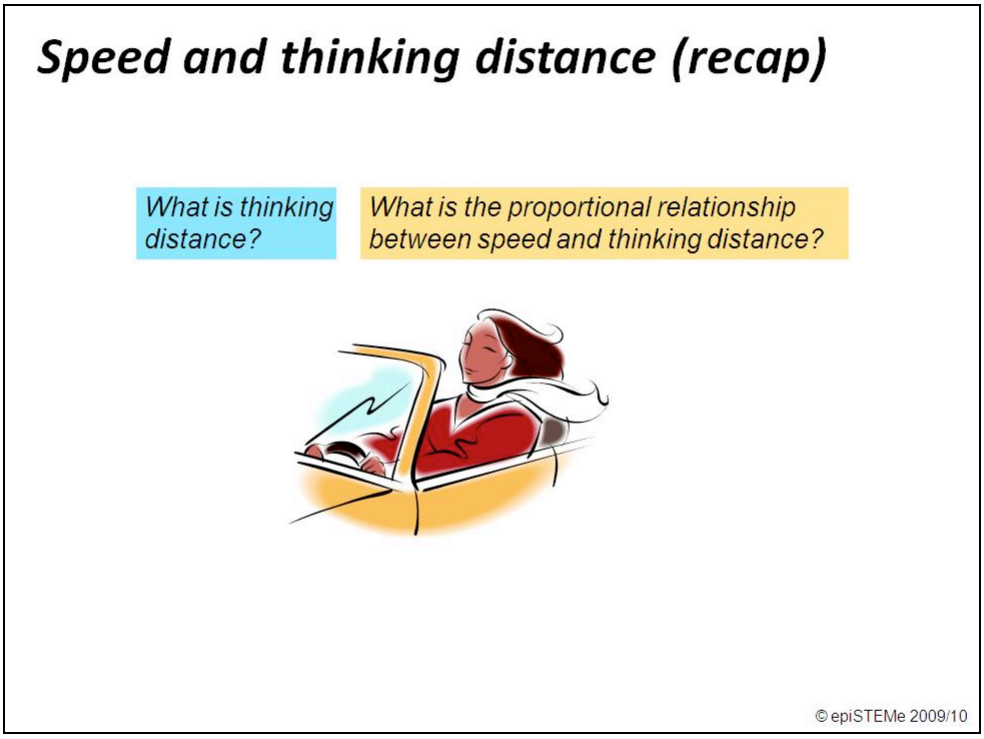
To review the relation between speed and thinking distance

Time

10 minutes

Resource

- Slide 75: Speed and thinking distance (recap)



Activity

Whole-class activity

- Using *Speed and thinking distance (recap)*, ask one or more students to recap the proportional relationship between speed and thinking distance.
- Write down this relationship on the board, so that it is easily accessible for the students for the following tasks.

LESSON 10: PART 2

Objectives

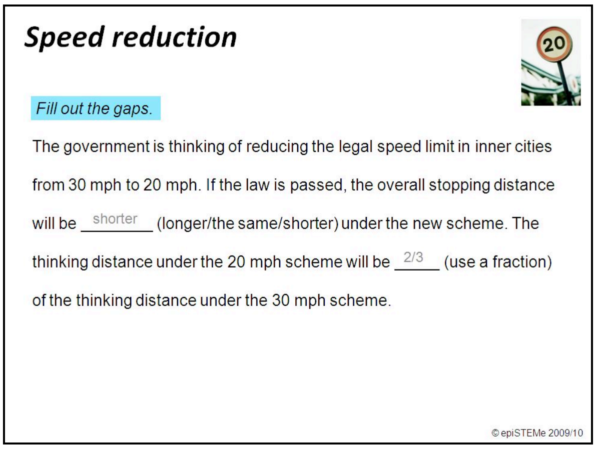
To consolidate understanding of the relation between speed and thinking distance, and to integrate speed and thinking distance with braking distance and stopping distance

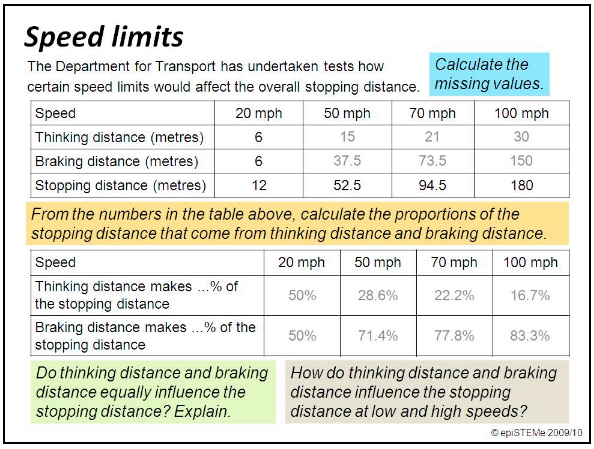
Time

30 minutes

Resources

- Slide 76: Speed reduction
- Slide 77: Speed limits





Activities

Small-group activity

- Organise the students into groups to work on *Speed reduction* and *Speed limits*.
- Remind them of the need to share ideas, listen to each other, and try to reach an agreed solution.
- Explain that the task requires them to apply proportional reasoning to work out the thinking distance for various speeds when one thinking distance for one specific speed is given.
- In addition, the task picks up the distinction between thinking distance and braking distance (see Part 2 of Lesson 9) and their different significance for the overall stopping distance.

Whole-class activity

- Collect the answers from each group.
- In a whole-class discussion, ask the students for their views on the correctness of the various answers.
- Towards the end of the discussion, guide the students towards the correct solution.

LESSON 10: PART 3

Objective
To consider the factors that influence stopping distance

Time
10 minutes

Resource
- Slide 78: Factors influencing stopping distance

Activity
Whole-class activity
- Continue with the difference between thinking distance and braking distance by showing the simulation from Lesson 9 once more (link on the slide). This time you should manipulate road conditions and driver conditions, with the former affecting the braking distance and the latter affecting the thinking distance.
- Ask a range of students for their views on the impact of wet weather on braking distance.
- End with the effect of drink driving on thinking distance. This will allow discussion of implications for legislation and international comparison since countries differ over allowable limits.

LESSON 10 HOMEWORK (OPTIONAL)

Road safety day and night

Paula and Peter participate in a road safety test. The table below shows their thinking distances during the day and during the night at a speed of 40 mph.

What would their thinking distances have been for the other two speeds listed in the table, assuming that all other factors influencing thinking distance had been held constant (e.g. alertness of driver etc.)?

Thinking distance			**25 mph**	**40 mph**	**65 mph**
	Paula	Day ☼	8.1 m	13 m	21.1 m
		Night ☽	11.9 m	19 m	30.9 m
	Peter	Day ☼	8.8 m	14 m	22.8 m
		Night ☽	10.6 m	17 m	27.6 m

Note

In addition to providing practice with material covered in Lessons 9 and 10, the homework exercise highlights a further factor that affects stopping distance – night vs. day.

END OF LESSON 10

APPENDIX: epiSTEMe

The epiSTEMe project [Effecting Principled Improvement in STEM Education] is part of a national programme of research that aims to strengthen understanding of ways to increase young people's achievement in physical science and mathematics, and their participation in courses in these areas. Drawing on relevant theory and earlier research, the epiSTEMe project has developed a principled model of curriculum and pedagogy designed to enhance student engagement and learning during a particularly influential phase in young people's development: the first year of secondary education. The module on 'Forces and Proportional Relations' is one of four topic-specific modules that have been developed to operationalise that model and support its classroom implementation.

The teaching model

The epiSTEMe teaching model builds on current thinking in the field and on promising exemplars that have been extensively researched. These suggest that students' learning and engagement can be enhanced through classroom activity organised around carefully crafted problem situations designed to develop key disciplinary ideas. These situations are posed in ways that appeal to students' wider life experience, and draw them more deeply into mathematical and scientific thinking. Such an approach is intended not just to help students master challenging new ways of thinking, but also to help them develop a more positive identity in relation to mathematics and science.

An important feature of epiSTEMe is that explicit links are made between mathematics and science. Within mathematics modules, science represents a major area where an unusually wide range of mathematics is applied, often for a variety of purposes. Within science, the understanding of scientific ideas is deepened by moving from expressing them in qualitative terms to representing them mathematically. Thus, this 'Forces and Proportional Relations' module has a partner mathematics module, 'Fractions, Ratios and Proportions'. Ideally, the mathematics module should be completed shortly before or concurrently with the science module, but this is not essential.

The teaching model also emphasises the contribution of dialogic processes in which students are encouraged to consider and debate different ways of reasoning about situations. These dialogic processes are designed to take place in the course of joint activity and collective reflection at two levels of classroom activity: student-led (and teacher-supported) collaborative activity within small-groups, and teacher-led (and student-interactive) whole-class activity. Because of the importance of developing dialogic processes that support effective learning, these processes are the focus of a separate Introductory Module, which is additional to the four topic-specific modules.

The design of the topic-specific modules

The function of all four topic-specific modules is to provide examples of concrete teaching sequences that incorporate classroom tasks that reflect the teaching model. The tasks will, in particular, support dialogic processes and will be supported by these processes.

First, each module has been designed to cover those aspects of the topic that are suitable for the start of the Key Stage 3 curriculum, and to do so in a way that is appropriate for students across a wide range of achievement levels. Taking account of available theory and research on the development of students' thinking, the module 'fills out' the official prescriptions in ways that should build strong conceptual foundations for the topic. Common misconceptions amongst students about each topic are addressed.

In this way, the modules take account of students' informal knowledge and thinking related to a topic. They also make connections with widely shared student experiences. Equally, with a view to helping students understand how mathematics and science play a part in their wider and future lives, the modules try to bring out the human interest, social relevance, and scientific application of topics.

Finally, the modules place a strong emphasis on the use of spoken dialogue for developing understanding. They also enable a teacher to consolidate key ideas, check individual students' understanding and provide them with constructive feedback.