Physics

GCSE (9–1) | AQA | 8463

Practical Companion

for GCSE (9–1) AQA Physics

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POD 9937

Contents

Teacher's Introduction

This resource contains all the information required to prepare, execute, analyse and revise for the required practical activities for the physics components of the AQA GCSE science courses. Each section provides a complete resource for the delivery of lessons to cover each of the required practicals in all the courses. A comprehensive description of the contents is provided below. Additional information and sheets are included to give students further context and understanding of the course. Developed after more than 25 years of practical science teaching, each practical includes:

Remember!
Always check the exam board website for new information, including changes to the specification and sample assessment material.

- **Introduction:** Each section begins with a teacher's introduction to explain the purpose of the practical. Practical considerations are highlighted, including aspects of the set-up that must be prepared before the lesson. A set of starter questions is presented to aid the planning of the lesson. A full apparatus list is also given in this section. Suggestions are made for the timing of the lesson; this is given as a rough guide to aid individual planning.
- **Pre-lab:** This work is intended to be completed prior to the lesson, potentially as a pre-lesson homework, or as the final section to the theory lessons in preparation for the practical in the next lesson. The practical lesson can then begin with a review of the answers as part of the starter activity.
- **Student instructions:** These easy to photocopy sheets provide the method for each of the required practicals. They give step-by-step instructions and diagrams. Any safety information is highlighted at the start of each sheet.
- **Analysis and evaluation:** These sheets can be completed in two parts. It is advisable to aim to complete the analysis section in class as some students might require support to produce the correct graphs and complete the calculation. The evaluation section can be completed independently, either as homework or as part of a review lesson.
- **Exam-style questions:** Questions focusing on the practical work to afford the students practice for these questions in the final examination. Each set of questions should take an average student around 15–20 minutes to complete.
- **Answer sheets:** Answers to the questions posed in the pre-lab and exam-style questions sections are given on these pages. These also contain a theoretical set of data for use in the event of a problem with the practical, or for students who are absent. This also suggests a design for a table which can be shown to any students who need help designing a suitable table for recording their data.
- **Student design sheet:** Some of the practicals contain this alternative to the instructions. These should be used instead of the student instruction sheets to allow students to plan their own method for the practical.
- **Sample results:** Sample results are provided for use in the event of practical problems or if a student is away during the lesson.

The completion of practical work is central to the tenets of Science and Physics. As well as helping to reinforce the knowledge imparted in regular lessons, the methods and concepts behind required practical activities can be tested in the final examinations for the Trilogy, Synergy and Physics GCSE courses. The following practical activities are designed to prepare students for their final examinations, while ensuring they have completed the Apparatus and Techniques (AT) skills that are expected by the examination board. A grid has been provided overleaf which illustrates how each required practical activity links to the ATs.

Apparatus and Techniques criteria addressed

	Apparatus and Techniques crite				
Required practical	**1**	**2**	**3**	**4**	**5**
Specific heat capacity	X				X
Thermal insulation	X				X
Resistance	X				
I–V characteristics					
Density	X				
Force and extension	X	X			
Acceleration	X	X	X		
Waves				X	
Light (Physics only)				X	
Radiation and absorption	X			X	

AT number	Summary of technique
1	use appropriate apparatus to accurately measure mass, time an
2	use appropriate apparatus to measure and observe the effect o of springs
3	use appropriate apparatus and techniques to measure motion, i determination of speed and rate of change of speed (acceleratio
4	make observations of waves in fluids and solids to identify the s apparatus to measure speed, frequency and wavelength
5	use, in a safe manner, appropriate apparatus to measure energy associated values, such as work done
6	use appropriate apparatus to measure current, potential differe and to explore the characteristics of a variety of circuit elements
7	use circuit diagrams to construct and check series and parallel ci common circuit elements
8	make observations of waves in fluids and solids to identify the s apparatus to measure the effects of the interaction of waves wi

Required Practical 1: Specific He

Teacher's notes

Before the required practical

	Trilogy	Synergy
Specification reference	6.1.1.3 Energy changes in systems	4.1.1.4 Heating and changes of state
AT criteria		AT 1, AT5

The purpose of this practical is to allow students to compare the heat capacity o
identical masses. The materials suggested are copper, iron and aluminium, but o
brass) may be used, depending on the resources you have available. The studen
the following measurements and calculations:

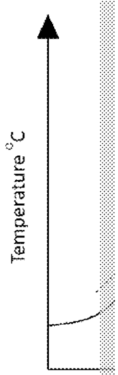
- Thermal energy in joules
- Electrical power in watts, calculated from the measurement of potential diff
  using voltmeters and ammeters. Formula: *electrical power = potential diffe*
  - Depending on the apparatus used, the ability of the students and the ti
    acceptable to tell the students the power rating of the heater, if desire
    depending on supplier.)
- Mass in kg – although each block should have a mass of 1 kg, this should be
- Work done or energy transferred in joules, calculated from: *energy transfer*

Critically, the students should understand the idea of specific heat capacity as th
temperature of 1 kg of a material by 1 °C.

Key formula: *change in thermal energy = mass × specific heat capacity × change i*

Students will need to be familiar with calculating the gradient of a line from a graph. A reminder of this may be required prior to either the lesson or the section on analysis of data.

The graph illustrate a typical set of data from this investigation.



Suggested questions

At the start of the lesson consider asking some of the following questions:

- What do we use to measure current and voltage in an electrical circuit?
- What are the equations for electrical power and energy transferred?
- What does the specific heat capacity of a material tell us about that materia
- Do all materials have the same specific heat capacity?
- How could knowing the specific heat capacity of a material be useful (for ex
- When a manned spacecraft re-enters Earth's atmosphere, it experiences ve
  the craft and the passengers from being harmed, the outside of the craft is c
  the tiles need to have a high or low specific heat capacity?

Planning considerations

When setting up the apparatus, students often need reminding that an ammeter is wired in series and a voltmeter in parallel; this is covered in the first activity in the pre-lab questions as a reminder.

The blocks have some thermal inertia, so the change in temperature will be non-linear for the first part of the investigation for each new block used. Students should be advised to ignore this section of the graph when adding lines of best fit and calculating gradients in the analysis section of their work. Similarly, the readings on the ammeter and the voltmeter should be allowed to settle when first used as these readings can change as the heater warms at the beginning of the session.

St… c… ha… sh… hea… be… th… Th… in…

It is important to insulate the blocks to reduce heat lo… ...h …air. Most comme… come with suitable insulation. Adding a small drop of water into the hole for the… responsiveness of the thermometer to the changes in the temperature of the ma…

It is advisable to have dem… …this equipment during the teaching of the t… familiar with the se… …data collection using this apparatus, which is not alw… or used for … investigations.

Included sheets

- Pre-lab task – work for the students prior to the start of the practical
- Student instructions – apparatus list and method
- Analysis and evaluation – student instructions for completing calculations, g…
- Exam-style questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data

Apparatus

- Three blocks of metal: one each of copper, iron and aluminium. Each of the… drilled into the top. The smaller hole is for the thermometer; the larger hole…
- Insulating material to wrap around the blocks
- Low voltage supply set at 12 V (or as directed by your teacher)
- An ammeter and a voltmeter with connecting leads
- Heater unit
- Thermometer
- Pipette
- Stopwatch
- Electric balance
- Heatproof mat

Each student, or group of students, will need each piece of apparatus, with the ex… which can be shared. This is needed only briefly to verify the mass of each black…

Blocks of material: these can be shared, with each person working on a different ma… use them is not important. Note, however, that some time … be needed to let ea…

Blocks purchased from many suppliers can be …cc…ire… …ith suitable insulating m… pack, or may have to be added to the … …ending on the supplier. Alterna… in cotton wool or cotton-wool … m… …s as an insulator. Plastics, including b… some of the blocks can … …arm – over 70 °C.

Timings

Pre-lab task: …15 minutes with an additional 5 minutes for checking of answer…
Practical: Allow a minimum of 45 minutes. Each block is heated for 10 minutes, … tables, etc.
Analysis: 15–20 minutes to draw graphs, add lines of best fit and complete calcu…
Evaluation: 20 minutes, plus discussion time if desired. Sheets can be collected … holding a class discussion.
Exam-style questions: 15 minutes if completed in class time. However, as this p… course, students may not be familiar with working at the pace required in a form… be required. It is a good idea to indicate to students that, in the final exam, they … these types of question in around 10–15 minutes maximum.

Specific heat capacity required practical: pre-lab task

1. The circuit diagram shows the simple circuit you will use in this practical. The ammeter and the voltmeter are missing from the diagram. Using the correct symbols, suggest where each of them should be placed to gain a correct reading of the current and the potential difference across the heater.

2. a. If the reading on the ammeter were 5 A [illegible] reading on the voltme rating of the heater? ($P = IV$)

   b. How many joules of energy are transferred by the heater in a two-minu done by the heater.)

3. Once you have collected your data, you will need to use the following equat capacity of the different materials: *change in thermal energy = mass × specifi temperature*. Rearrange this to make specific heat capacity the subject of th

4. During this practical you will be using the electrical heater to heat the blocks considerations when working with any method that involves heating.

   1.

   2.

5. Give a brief explanatio[illegible] *specific heat capacity* and state the units of materials.

Specific heat capacity required practical: student instructi

Apparatus

- Three blocks of metal: one each of copper, iron and aluminium. Each block the top. The smaller hole is for the thermometer; the larger hole is for the h
- Insulating material to wrap around the blocks
- Low voltage supply set at 12 V (or as directed by your teacher)
- An ammeter and a voltmeter with connecting leads
- Heater unit
- Thermometer
- Pipette
- Stopwatch
- Electric balance
- Heatproof mat

Method

1. Draw a table to record the mass of each block.
2. Collect your first block; measure and record the mass.
3. Wrap the insulating material around the block; place the block on the heatp
4. Insert the heater into the larger of the two holes in the block.
5. Connect the heater to the circuit as shown. Ensure the low voltage supply is your teacher).
6. Turn the heater on briefly, just long enough to ensure the ammeter and the voltmeter are giving steady readings. Record these values to one decimal place below Table 1.

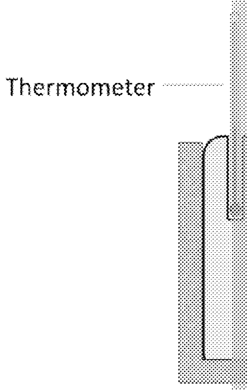
   Current = _____ amps

   Potential difference = ________ volts

   Calculate the power of the heater using:

   power (watts) = current × potential difference

   Record your result. You will need this to complete Table 2 **after** you have collected all your results.



7. Draw a results table to record the time in seconds (up to 10 minutes) agains the work done by the heater for each of the three blocks.
8. Using the pipette, place a drop of water into the hole for the thermometer. into the hole.
9. Record the initial temperature before the heater is switched on.
10. Turn on the heater and start the stopwatch.
11. Measure the temperature every ... seconds for 10 minutes (600 seconds).
12. Repeat steps 2 to 5 ... for the other two materials.
13. Calculate the work done at each time interval for each material used, and co Work ... measures the energy transferred from the heater to the block.

    work done (J) = power of heater (W) × time (s

    Note: the power of the heater was calculated in step 6 and should be record

Caution: when packing away, remember that the heater and the block m with care.

Specific heat capacity required practical: analysis and eval

Analysis

Task 1

Plot the results onto three graphs. For each graph, label the x-axis 'Work done (J)
'Temperature (°C)'.

Task 2

Add a line of best fit for each graph.

Task 3

Calculate the gradient of the line of best fit for each graph.

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....

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Task 4

Calculate the heat capacity of each block, using the following formula:

heat capacity = 1 ÷ gradient of the line

This gives the amount of energy needed to heat the individual blocks by 1 °C.

Heat capacity of copper block ____________________ J / °C

Heat capacity of iron block ____________________ J / °C

Heat capacity of aluminium block ____________________ J / °C

Task 5

Calculate the specific heat capacity of each material using the following formula

change in energy = mass × specific heat capacity × change in

Rearrange this formula to find the specific heat capacity. Check your answer with

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Record your results for each material in a suitable table in the space below.

Evaluation

1. Which material requires the least amount of energy to increase its temperatu

   Material requiring the least amount of energy: ....

   Material requiring the most amount of energy: ....

2. All data collected during investigations will have some experimental error.
   a. What did you do in this investigation to minimise any experimental erro

      ....

      ....

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   b. B[illegible]g at each graph and comparing the line of best fit with the sca
      ex[illegible] how accurate your lines of best fit are.

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3. Suggest one way in which this investigation could be made more accurate a
   made more reproducible.

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4. Cooking pans are often made from aluminium, steel (containing iron) or cop
   which material would be the best for this application? Explain your reasoni

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Specific heat capacity required practical: exam-style questi

1. A student wishes to find the specific heat capacity of the alloy brass. She us heats it with an electric heater, connected to a power supply.

   a. The student measures the current through and the potential difference voltmeter and an ammeter. The current was measured at 5.0 A, and th Using her results, calculate the power rating of the heater used.

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   b. The student measured the temperature of the block as 20.0 °C at the st 5 minutes, the temperature had risen to 31.6 °C.

      i. Show that the work done (energy transferred) by the heater durin

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      ....

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      ii. Calculate the specific heat capacity of the brass using the data obt experiment and the equation from the equation sheet.

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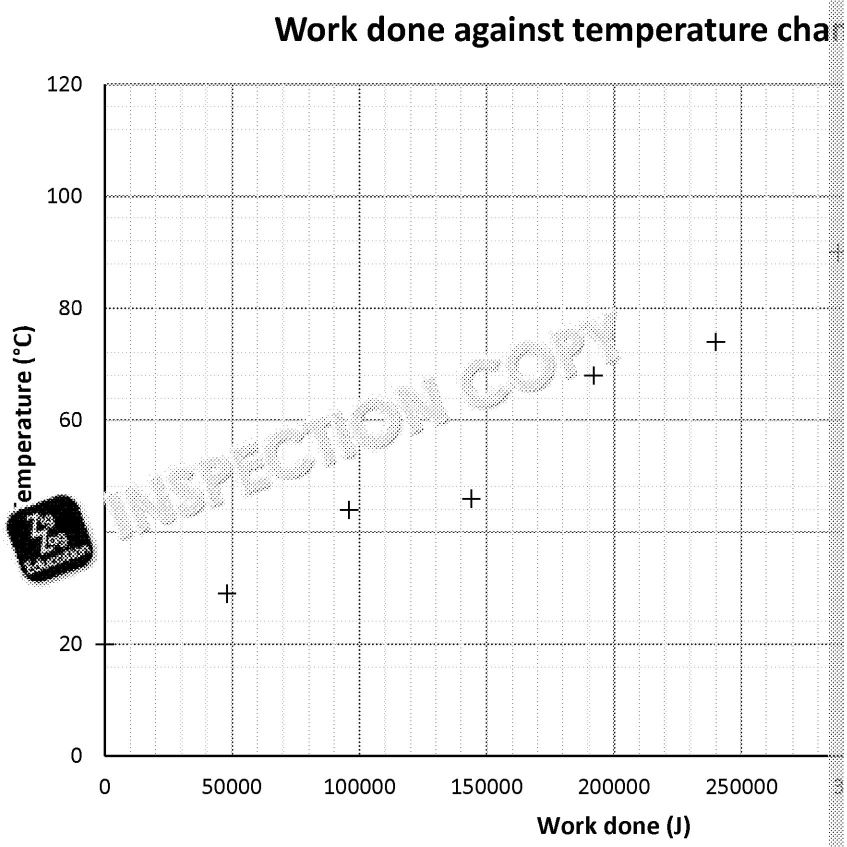
2. The temperature change of 1 kg of water was measured as it was heated fro
point using an immersion heater. The data is presented in the graph below.



a. Draw a line of best fit to show the relationship between the work done
temperature of the water.

b. How much energy was transferred to the water to heat it to boiling poi

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c. Identify which data point(s) may be anomalous. Explain your reason fo

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d. How could yo ... y whether the result/results identified in part c is an

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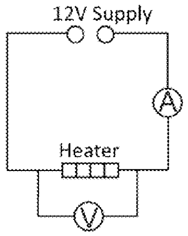
Specific heat capacity required practical: answer sheet

Pre-lab task

1.



2. a. Power = current × potential difference (P = IV)
   Power = 5 × 12 = 60 watts
   b. Work done = power × time (E = Pt)
   Work done = 60 × (2 × 60 seconds) = 7200 joules

3. Specific heat capacity = $\frac{\text{Change in thermal energy}}{\text{Mass} \times \text{Change in temperature}}$

4. Any two of the following – allow other sensible suggestions:
   - Place apparatus on a heatproof mat.
   - Do not touch hot materials/objects with bare hands.
   - Consider whether safety goggles may be needed.
   - Allow apparatus to cool before handling.
   - Avoid rapid cooling of materials as this can lead to them shattering.

5. Specific heat capacity indicates the amount of energy exchanged with the environm
   1 kg of a material by 1 °C.
   [Students may reasonably express this as the energy needed to raise the temperatu
   J/kg °C (or joules per kilogram per degree Celsius).

Analysis

Tasks 1 to 4 will need to be checked against student's own data.

Task 5

Specific heat capacity = $\frac{\text{Change in thermal energy}}{\text{Mass} \times \text{Change in temperature}}$

Specific heat capacities of materials used – allow reasonable experimental error:
Copper – 385 J/kg °C
Iron – 500 J/kg °C
Aluminium – 913 J/kg °C

Where a student's data is in error compared to expected results, give credit for correct c

Evaluation

1. Least energy: copper
   Most energy: aluminium
   Student's individual data may not agree with the theoretical answer; give credit for
   while acknowledging that this differs from theoretical values.

2. a. Answer might include:
   - Used insulation to reduce the heat lost to the environment (air)
   - Used a drop of water to improve the accuracy of the temperature meas
   - Used an accurate stop clock for timings
   - Used a digital ammeter and voltmeter

   b. Answer will depend on the student's data. Credit should be given for explainin
   to the line of best fit the more reliable the data.

3. Accuracy could be improved by using either a digital thermometer or a thermomete
   more insulation to the top and bottom of the block to further reduce heat loss.
   The reproducibility can be improved by replication of the experiment / sharing of da

4. Assuming the student's data is in line with the theoretical values, copper is the best
   heat up, thus it will transfer the heat to the food faster and use less energy to do so
   materials if the student's individual data supports the logic.

Exam-style questions

1. a. Power = current × potential difference (1)
   Power = 5 × 8 (1)
   = 40 watts (1)

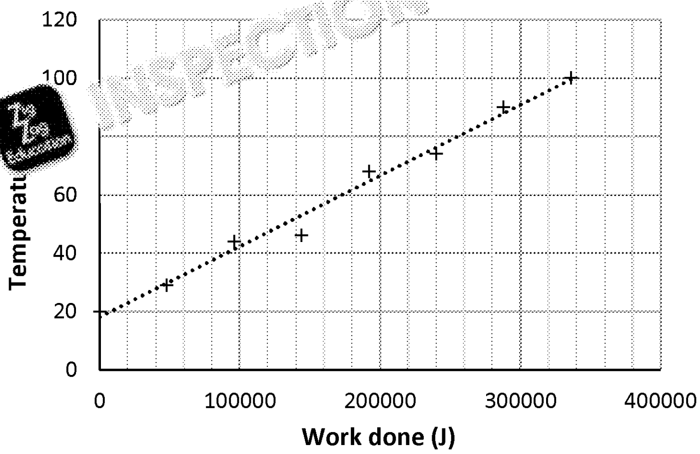
   b. i. Work done = power × time (1)
   Work done = 40 × (5 × 60 seconds) (1)
   Work done = <u>12 000 J</u>

   b. ii. Change in thermal energy = mass × change in temperature × specific hea

   $$\text{Specific heat capacity} = \frac{\text{Change in thermal energy}}{\text{Mass} \times \text{Change in temperature}} \quad (1)$$

   Change in thermal energy = work done = 12 000 J
   Change in temperature = 51.6 – 20 = 31.6 °C (1)
   Specific heat capacity = 12 000 ÷ (1 × 31.6) = 37[illegible]/kg °C (to 2 sf) (1)

2. a.



   Allow 2 marks for a reasonable line of best fit. A reasonable line of best fit wil
   Deduct 1 mark if the line is not straight, i.e. a ruler has not been used.

   b. 33 500 J (1)

   c. All students should identify the data point for 144 000 J as an error for 1 mark
   Others may also identify the point at 288 000 J.
   The point(s) may be anomalous as it falls / they fall below the line of best fit. A
   the pattern described by the other data points. (1)

   d. This could be verified by either replication of the data through repeating the e
   compare with the original data (1) or by comparing their data with the results o
   Maximum 2 marks.

Appendix: Sample Results

Student instructions

Results for use in the event of practical problems or if a student is away during the lesso

This data uses a 50 W heater and assumes no heat loss or thermal inertia.

50 W	Copper		Iron		
Time (s)	Temp (°C)	Work done (J)	Temp (°C)	Work done (J)	Te
0	[illegible]		22.0		
[illegible]	29.8		28.0		
12	37.6		34.0		
180	45.4		40.0		
240	53.2		46.0		
300	61.0		52.0		
360	68.8		58.0		
420	76.5		64.0		
480	84.3		70.0		
540	92.1		76.0		
600	99.9		82.0		

Required Practical 2: Thermal

Teacher's notes

Before the required practical

	Trilogy	Synergy
Specification reference	N/A	N/A
AT criteria		AT 1 and AT 5

The purpose of this pra… a… … allow the students to compare different forms … carried out … p… :
- Part A: …rison of different materials
- Part B: comparison of the effect of the number of layers of a single material

This practical is a good opportunity for students to design their own investigati… direct instructions for the two parts of the method mentioned above, plus an ad… guidance to allow the students to plan their own investigation without direct ins…

Suggested questions

- What types of material are used in winter clothing (jackets, jumpers, etc.) to
- Do any of these materials, or their construction, have any common features
- When it is very cold, why do we put on extra layers, such as a jumper then a … keep us warm?
- Where does the thermal energy come from to keep you warm when wearin… in the cold?
- Provide the students with some samples of the materials they will use in th… why these materials might be good or bad thermal insulators. This can mak… giving one material per group then allowing students a few minutes to prep… the class.

Planning consideration

Starting temperature

Option 1: At or near boiling point. This is easy to set up using a kettle to boil water. It gives a rapid decline in temperature due … e larger thermal gradient with the ambient air temperatu… … th… ab. Note that it is a good idea to have several kett… …his, and to boil them prior to (or at the start of) the se… … t… …ve some time. This can be done while the student… … … …ting the pre-lab section of work.

Option 2: A… …r body temperature (40 °C). This is a better model of the therm… insulation of materials used in clothing as it mimics the human body. This can help students to put the theory into a practical context. This can be used by placing the practical in the context of what sorts of materials and design would be good for making a sleeping bag / jacket to use on a Duke of Edinburgh expedition. (Bronze and silver awards are often part of the wider curriculum for Year 10 students.)

Stud… Plea… wit… glas… u… gog… hand…

If available, it can be quicker to use a set of water baths set at 40 °C or near boili approach, the water baths should be placed in a position which you can supervis instruction along with a demonstration of how to extract the water sample witho

The instruction sheet assumes that one student is working on one material at a t layers at a time. It is possible for a student to set up and monitor serval beakers a degree of organisation and concentration on their part. The decision to allow th apparatus and the individual students in your class.

When choosing the material for method B of this practical (layers of material), it i good insulator so that the students get a clear and easier to analyse set of data.

Included sheets

- Pre-lab task – work for the students p... the start of the practical
- Student instructions – apparatus list and method
- Student design sheet – an alternative to the student instructions to allow st method
- Analysis / evaluation – student instructions for completing calculations, g
- Exam-style questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data

Apparatus

- 250 ml beaker
- Measuring cylinder
- Thermometer (analogue or digital)
- Elastic bands × 2
- Cardboard lid with hole for thermometer
- Heatproof mat
- Heatproof gloves
- Goggles
- Stopwatch or stop clock
- Kettles or water baths
- Insulating materials, such as newspaper, cotton wool, bubble wrap; cloth of cotton and polyester

Each student will need their own apparatus. The kettle / water baths and the ma group. To save time it is preferable to prepare the materials in advance by cutting wrap around the beaker. Once this is done, they can be stored and reused with o

Timings

- **Pre-lab task** plus starter questions: **10–15 minutes**
- **Practical activity with direct instruction:** parts A and B will both require **at 100 minutes)**; therefore, in many situations, these will need to be complete
- **Student's own planning** stage: **20 minutes**
- **Analysis: 20 minutes** to draw graphs then add a cooling curve for each m
- **Evaluation: 20 minutes**, plus discussion time if desired. Sheets can be colle holding a class discussion.
- **Exam-style questions: 15 minutes** should be allowed for this exercise

Thermal insulation required practical: pre-lab task

1. a. What are the three ways that thermal energy can move away from a w

....

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....

b. Which of these three means of thermal energy transfer allows heat to m **through** the material of your clothing into the air?

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2. During this investigation you will use hot water to model the heat energy pro Suggest variables that must be controlled <u>about the water</u> used to ensur

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3. Hot water represents a hazard in this investigation. Suggest at least two ways to yourself, and to others, when handling hot water in this practical. The wat

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4. You will be asked to record your results in a suitable table. This will need to drop in temperature over a 15-minute period for at least three materials and the column headings needed, along with any units, then draw out a table re check this before you start the practical work.

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Thermal insulation required practical: student instructions

CAUTION

- *Wear goggles and heatproof gloves when handling hot water and hot bea*
- *Always wear goggles and heatproof gloves when pouring hot water into a*
- *Place hot objects onto a heatproof mat.*
- *Report any spillages/breakages to your teacher or technician.*

Apparatus

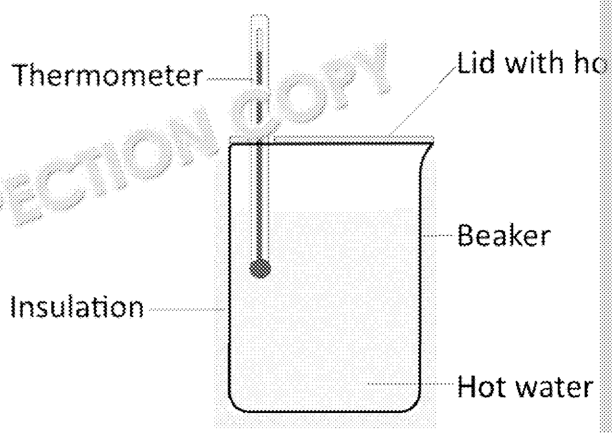
- 250 ml beaker
- Thermometer (analogue or digital)
- 250 ml measuring cylinder
- Elastic bands × 2
- Cardboard lid with hole for thermometer
- Heatproof mat
- Heatproof gloves
- Goggles
- Stopwatch or stop clock
- Kettle or water baths for heating water
- Insulating materials, such as newspaper, cotton wool, bubble wrap; cloth of cotton and polyester

Method Part A – Comparing the thermal insulation of different ma

1. Place 200 ml of warm water into the 250 ml beaker using the measuring cyli (Note: the water should be at either 100 °C or 40 °C as directed by your teac

The first set of data is collected ***without*** *wrapping the beake*

2. Place the cardboard lid onto the beaker and place the thermometer through
3. Record the starting temperature of the water and start the stopwatch.
4. Record the temperature of the water every minute, for 15 minutes.
5. Pour away the water.
6. Choose your first material and record the name of this material in your resu
7. Wrap the material around the beaker, including the base. Secure it with the
8. Repeat steps 1 to 5.
9. Repeat for two other materials.



Method Part B – Investigating the effect of layers of material on th

In this part of the investigation you will use only one material. You will investiga this material around the beaker affects the heat loss from the beaker. You will b control, then increase the number of layers to a maximum of three layers.

1. Using your table from part A as a template, draw a suitable table for your re place to record the type of material used.
2. Place 200 ml of warm water into the 250 ml beaker using the measuring cyli *(Note: the water should be at either 100 °C or 40 °C as directed by your teac*

*The first set of data is collected **without** wrapping the beaker i*

3. Place the cardboard lid onto the beaker and place the thermometer through
4. Record the starting temperature of the water and start the stopwatch.
5. Record the temperature of the water every minute for 15 minutes.
6. Pour away the water.
7. Wrap the first layer around the beaker, securing it with the elastic bands, th
8. Add an additional layer and repeat the method for two layers, then three la NOT use different materials for this part of the investigation.)

Thermal insulation required practical: student design brie

A group of students are setting off on a summer camp. As part of their challenge, to make their own sleeping bags. These must keep them warm overnight at air te 20 °C (close to room temperature).

You have been supplied with a range of affordable materials from which the stud their sleeping bags.

You challenge is to provide them with suitable advice on the best material to use of that material.

Tasks

1. Design an investigation to compare the thermal insulation properties of the data as a table and a graph showing the cooling curves of each material.
2. You must then make a recommendation as to which material is the best one
3. Adjust your original method to test the effect of increasing the number of la material. Present this data as a table and as a graph.
4. Conclude your report by explaining which material the students should use, material should the students use, and why? Additionally, you should explain good insulator in terms of how it controls thermal energy loss. Use your und convection and radiation in your explanation to the group.

You have access to the following apparatus:

- 250 ml beakers
- Thermometers
- Measuring cylinders
- Elastic bands
- Cardboard
- Scissors
- Heatproof mats
- Heatproof gloves
- Goggles
- Stopwatch or stop clock
- Kettle or water baths for heating water
- Insulating materials

Your plan must include:

1. A full apparatus list
2. Safety / risk assessment information
3. A diagram of your set-up
4. A set of step-by-step instructions
5. A plan for your results table

You must not start the experiment until your work and plan have been a

Thermal insulation required practical: analysis and evalua

Analysis

Part A

1. Use your data to produce <u>a graph</u> to show the cooling curves for each mate
   - Decide which data will be plotted along the x-axis and the y-axis.
   - Decide how you will represent the four different sets of data – colours,
   - Plot each set of data, adding a line of best fit for the cooling **<u>curve</u>**.
   - Add a key or labels to your graph to identify the curve for each materia

2. Using your graph, place the materials in order of best to worst insulator.

   ....

   ....

   ....

3. Calculate the overall temper[illegible] for each material and the control.

   ....

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4. Calculate the average drop in temperature per minute for each material, inc 15 minutes of this experiment.

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Part B

1. Draw a graph of your data to illustrate how increasing the number of layers c temperature.

2. Calculate the overall drop in temperature for each set of layers.

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3. Use the results in part 2 (above) and the graph to describe the trend for hov drop in temperature.

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Evaluation

1. Thinking about the material that provided the best insulation, what physical it a good insulator? (Hint: think about how the material and its construction convection or the radiation of the heat energy.)

   ....

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2. a. As you increased the number of layers around the beaker in the second happened to the drop in temperature over the 15 minutes?

   ....

   ....

   b. Suggest two r... adding extra layers has this effect on the drop

   ....

   ....

3. How could you check the repeatability of your data?

   ....

   ....

4. Which material would you suggest could be used as a suitable filler in a sleep when camping in the UK during the summer? You may refer to both sets of your suggestion.

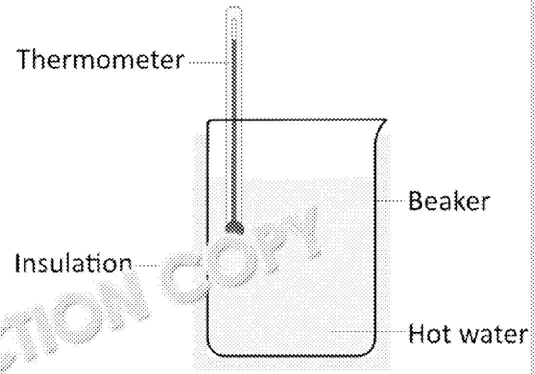
   ....

   ....

   ....

Thermal insulation required practical: exam-style questio

1. A student has designed a practical to investigate the thermal insulation prop materials that could be used in the lining of a winter jacket. They have used for their investigation.



a. Suggest a suitable temperature to use for the hot water at the start of th

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b. Looking at the diagram of the suggested experiment, how might the stu reduce unwanted heat loss?

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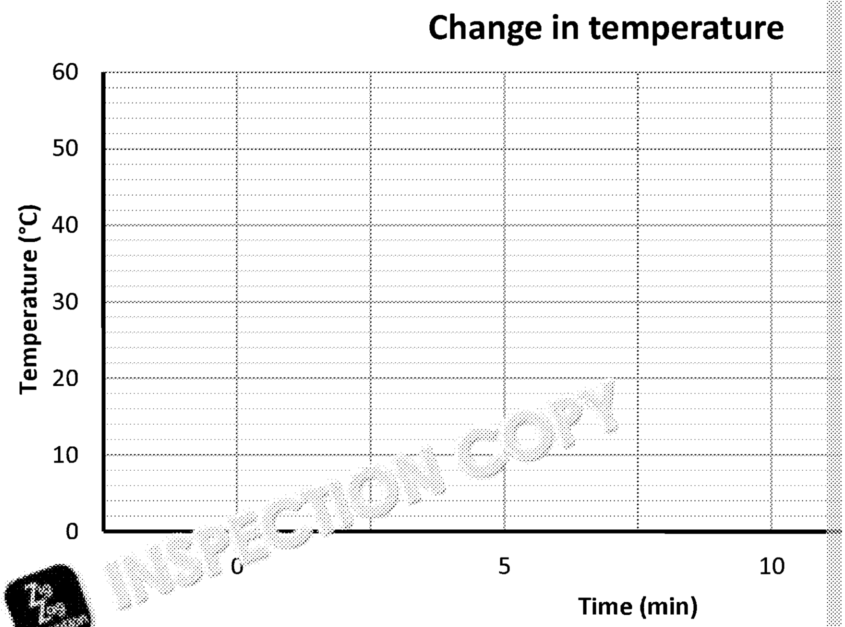
c. The student collected the following results:

Time (min)	0	5	10
Material	**Temperature (°C)**		
Cotton wool	50	44	40
Hollow polyester fibres	51	48	47

Draw a graph on the following page to represent the student's data. In suitable key.



d. Using the graph, justify your choice of material to use for the jacket fillin
the hollow polyester fibres.

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Thermal insulation required practical: answer sheet

Pre-lab task

1. a. Conduction, convection and radiation (order unimportant)
   b. Conduction

2. Volume of water used and starting temperature of the water. Students might sugg
   this response.

3. Suggestions might include:
   - Adhere to good lab procedures, i.e. check for obstructions.
   - Use heatproof gloves to handle the beakers containing the hot water.
   - Wear goggles.
   - Keep hands out of the way when pouring hot wa… …m … kettle, i.e. do not h
     surface.

   Do not accept using a heatproof mat … … protect the bench not to reduce th

4.

	Control (no material)	Material 1	Material 2
Time (min)	Temperature (°C)		
0			
1			
2			
3			

   Note that the same basic structure can be used for the table the students are asked
   investigation. The column headings will change from types of material to number o
   also provide a place for the material used in part B to be record as part of the table

Analysis

Part A

1. The graph should place the time (minutes) along the x-axis and the temperature (°C
   four lines with a key. The lines should be curved not straight to best fit the data.
2. The order of the materials will vary according to individual results, but the one with
   best insulator.
3. Answers will vary depending on individual results.
4. The results should have the answers from point 3 above divided by 15 to give the a

Part B

1. The set-up of the graph is the same as above (Part A, point 1).
2. Data will vary according to student's results.
3. The increase in layers should produce a shallower curve to the line and result in a lo
   Student might also note that there is a more gradual decline in temperature as the

Evaluation

1. Answers will vary depending on th… …er … used. However, students might identi
   - Conduction of heat … … …y plastics, wool, etc. as these materials are no
     poor therm… … …. This slows the transfer of heat away from the hot w
   - C… …n …yers of air trapped within the material (wool, bubble wrap, etc
     th… …ing heat loss.
   - Tapped air – air is a poor conductor of heat and, when trapped, acts as a good
   - Radiation – any heat radiated from the beaker is quickly absorbed by the insul

2. a. The increase in layers leads to a reduction in the overall drop in temperature.
   b. The layers trap air. These layers of trapped air are poor conductors of heat.
      Each new layer acts as a barrier to the conduction of heat and slows the process

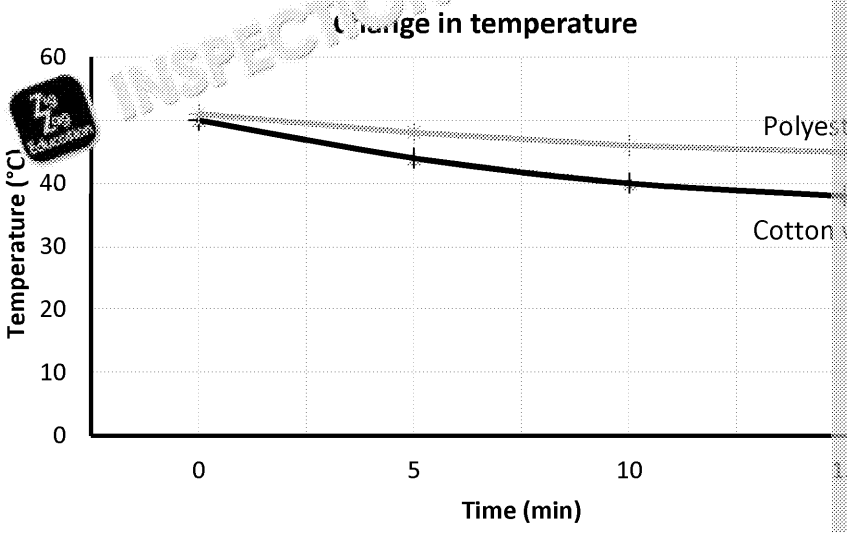
   Note: It is a common error for students to suggest that layers of material or layers o
   misconception should be corrected as they slow the loss rather than stop it.

3. Repeat the experiment several times to gain averages or compare data with other g

4. The answer will vary according to the materials used and the student's data.
   - They should choose the material that is suitable for the purpose and which gav Some students might also use the data in part B to suggest that the filling of th thin layers to help further improve the thermal insulating properties of the bag mention other useful properties such as comfort and water resistance.

Exam-style questions

1. a. A temperature close to 37 °C (1) to mimic body temperature (1).
   Allow other starting points, providing they state a temperature and justify this to replicate at each set-up, e.g. 100 °C as it is boiling point and easy to replicat 1 mark is allocated to stating a given temperature that is logical and the other
   b. Place a covering over the top of the beaker; add more layers of insulation; use th
   c.



   Correct plotting of data points – 2 marks (1 mark for each set of data)
   Cooling curves passing through each point – 1 mark
   Inclusion of key or labels on lines – 1 mark
   d. Hollow polyester fibres (1)
   Either – the line has the shallowest curve (1),
   or – evidence that the student used the graph to calculate the overall drop in te

Appendix: Sample Results

Results for use in the event of practical problems or if a student is away during the lesso

Part A

	Control (no material)	Cotton wool	Paper (80 GSM)
Time (min)	**Temperature (°C)**		
0	40.0	40.0	40.0
1	37.0	40.0	38.0
2	35.0	39.0	37.0
3	33.0	39.0	35.0
4	32.0	38.0	33.0
5	31.0	[illegible]	33.0
6	31.0	[illegible]	32.0
7	30.0	35.0	31.0
8	[illegible]	35.0	31.0
9	28.0	34.0	30.0
10	27.0	33.0	29.0
11	26.0	33.0	29.0
12	25.0	32.0	29.0
13	23.0	31.0	28.0
14	22.0	30.0	27.0
15	21.0	30.0	25.0

Part B

	Control (no material)	1 layer	2 layers
Time (min)	**Temperature (°C)**		
0	40	40	40
1	39.0	39.0	39.5
2	37.5	38..0	38.5
3	36.5	37.0	38.0
4	35.0	36.0	37.5
5	34.0	35.0	37.0
6	32.5	34.0	36.0
7	31.5	33.0	35.5
8	30.0	32.5	35.0
9	29..0	31.0	34..0
10	28.0	30.5	33.5
11	26.5	29.5	33.0
12	25.5	28.5	32.5
13	24..0	27.5	31.5
14	23.5	[illegible]	31.5
15	23.0	[illegible]	31.0

Required Practical 3: Resis

Teacher's notes

Before the required practical

	Trilogy	Synergy
Specification reference	6.2.1.3 Current, resistance and potential difference	4.7.2.2 Current, resistance and potential difference
AT criteria	AT 1, AT 6 and AT 7	

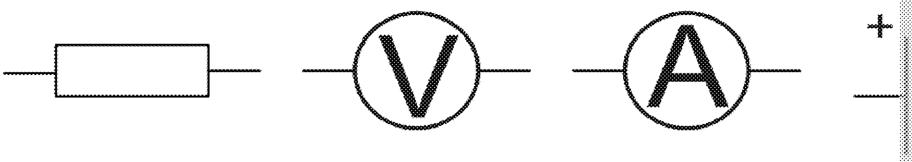
The purpose of these two investigations is to explore how resistance changes in a
sections:
Part A: investigating how resistance is changed by the length of a conductor
Part B: investigating how resistors behave in series and parallel circuits

The two parts can be conducted as separate activities in either order by the stud

A key feature of the practical is for the students to be able to assemble a circuit fr important for them to be able to recall and distinguish between series and paral

Suggested questions

- Ask the students to identify common electrical components from their symb names of the components and ask the students to draw the correct symbols.



- Draw a simple series circuit and a simple parallel circuit with the common co
- What is the mathematical relationship between current, potential differenc the Ohm's law equation?
- What are the units of electrical resistance?
- What is electrical resistance and how would you define it?
- Name a material that has:
  - a high electrical resistance (good insulator)
  - a low electrical resistance (conductor)
- Suggest a situation in which we might want to use a material that has a high

Planning considerations

One of the commonest practical errors in setting up the circuits is for the ammet **incorrect** positions. Please check this before the students begin the data collecti wasted collecting invalid data.

Although batteries can be used in these investigations, it is recommended that a as this provides a more consistent output than batteries, especially if the batteri recommended the LVS used has a lockable voltage control to prevent students fr Note that for consistency with the exam board's approach, the diagrams have be rather than an LVS.

The resistance wire used to construct the apparatus for [illegible] should be constan 22 SWG.

It is important to do a test run of the first part of the investigation with the wir the correct voltage from [illegible] or batteries. This task should be completed **pr** or the tech[illegible] T[illegible] a voltage will result in the wire becoming hot and po of burns and [illegible]equire the apparatus to be replaced during the investigation. A the students ask them to set the voltage as advised by their teacher, rather than

Included sheets

- Pre-lab task – work for the students prior to the start of the practical
- Student instructions – apparatus list and method
- Analysis and evaluation – student instructions for completing calculations, g
- Exam-style questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data

Apparatus

Part A:

- Low voltage supply, or batteries at a voltage of the teacher's choosing (see considerations')
- Ammeter
- Voltmeter
- Connecting wires
- Crocodile clips × 2
- Metre ruler with resistance wire attached

Part B:

- Low voltage supply or batteries
- Ammeter
- Voltmeter
- Connecting wires
- 2 identical resistors (10 [illegible]
- Crocodile clips [illegible] to connect to resistors

Each studen[illegible] need their own apparatus.

Timings

- **Pre-lab task** plus starter questions: **10 minutes**
- **Practical activities:** Parts A and B will require a total of **30 minutes**
- **Analysis: 15 minutes** to draw a graph with line of best fit and complete calc
- **Evaluation: 15 minutes**, plus discussion time if desired. Sheets can be colle holding a class discussion.
- **Exam-style questions: 15 minutes** should be allowed for this exercise

Resistance required practical: pre-lab task

1. During this practical you will be using an electrical supply from either a batte supply. Give two safety considerations when using electricity in any investig

2. Rearrange the following equation to make resistance the subject:

   potential difference = current × resistance

3. a. In the simple circuit illustrated, the ammeter had a reading of 0.25 A, ar 2.50 V. Calculate the resistance of the circuit.

   b. If a second identical resistor were added in series in the above circuit, a remained at 2.50 V:

      i. What would happen to the reading on the ammeter?

      ii. What is the total resistance of the circuit?

Resistance required practical: student instructions

CAUTION

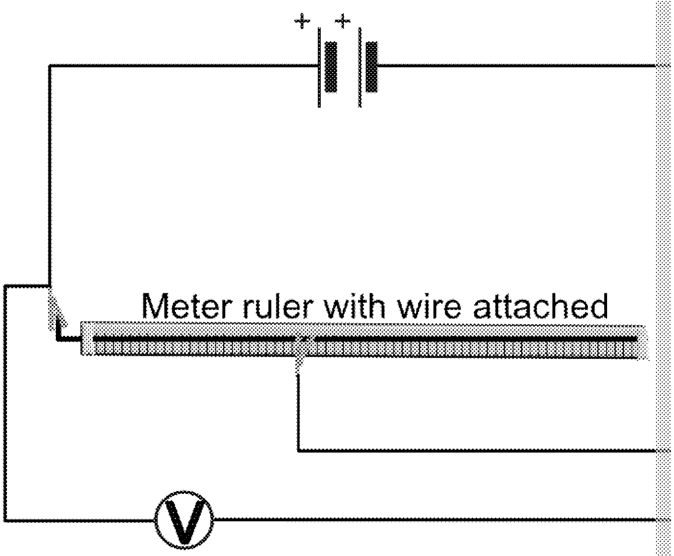
Do not exceed the maximum voltages recommend by you
This can result in damage to the apparatus and can cause burns fro

Part A: Investigating how the resistance of a wire is affe

Apparatus

- Low voltage supply, or batteries at a voltage ... y ... teacher
- Ammeter
- Voltmeter
- Connecting wires
- Crocod... s
- Metre ... ith resistance wire attached

Circuit diagram



During this part of the practical, you will need to record the potential difference a you increase the length of wire through which the current has to flow. At the en resistance of the circuit for each length of wire.

Design and draw a results table before you start th... ...d. You will need spac

Show thi... ...o your teacher before continuin

Method

1. Assem... ci...it as shown in the diagram above. The crocodile clip con power ... remains attached throughout the practical. The second croco negative side of the power supply, will be moved during the investigation.

   Show this circuit to your teacher before continuing with th

2. Connect the second crocodile clip at the 10 cm marker on the ruler.
3. Turn on the low voltage supply if being used.
4. Record the readings on both the ammeter and the voltmeter.
5. Move the crocodile clip along the wire by 10 cm, then record the new readi
6. Continue this process until you have reached 90 cm.
7. Turn off the power supply and disconnect the components.

Part B: Resistors in series and in paralle

In this part of the practical you will compare the total resistance of two identica in parallel.

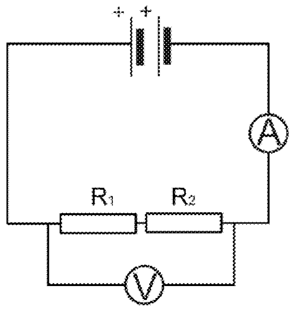
Apparatus

- Low voltage supply, or batteries at a voltage set by the teacher
- Ammeter
- Voltmeter
- Connecting wires
- 2 identical resistors (10 Ω)

During this investigation you will record the current and the potential difference i parallel circuit. Produce a suitable table in which to record your data.

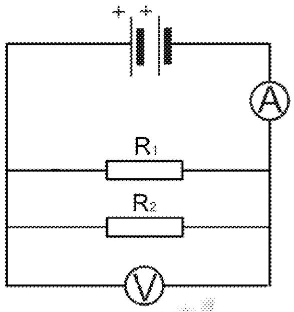
Method

1. Set up the circuit illustrated in the circuit diagram below.



Note: R_1 and R_2 must have the same resistance.

2. Turn on the low voltage supply or connect the batteries.
3. Record the reading on the ammeter and the voltmeter.
4. Set up the circuit as a parallel circuit as shown in the circuit diagram below.



5. Turn on the low voltage supply or connect the batteries, then record the rea the voltmeter.
6. Disconnect the components.

Resistance required practical: analysis and evaluation

Analysis

Part A:

1. Calculate the values for resistance for each length of wire and add them to t
   Use the formula: *potential difference = current × resistance (V = IR)*

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

2. Draw a graph to illustrate the relationship between the length of the wire an

3. Draw a line of best fit for your data.

Part B:

1. Calculate the values for resistance for each circuit and add them to the table
   Use the formula: *potential difference = current × resistance (V = IR)*

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

Evaluation

1. Describe the relationship between the length of a conductor and its resistan part A of this practical.

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2. How accurate were your results for part A of this experiment? Justify your a and the graph.

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3. What might be the cause of any error in your data for part A of the practical? the method that might reduce this source of error.

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4. Write a short paragraph to explain how placing resistors in series and in para of the circuit. Refer to your data from part B of this practical to justify your a

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5. Suggest what would happen to the value of the total resistance in your serie additional identical resistors in series with the existing two. How would this a

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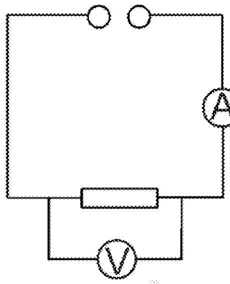
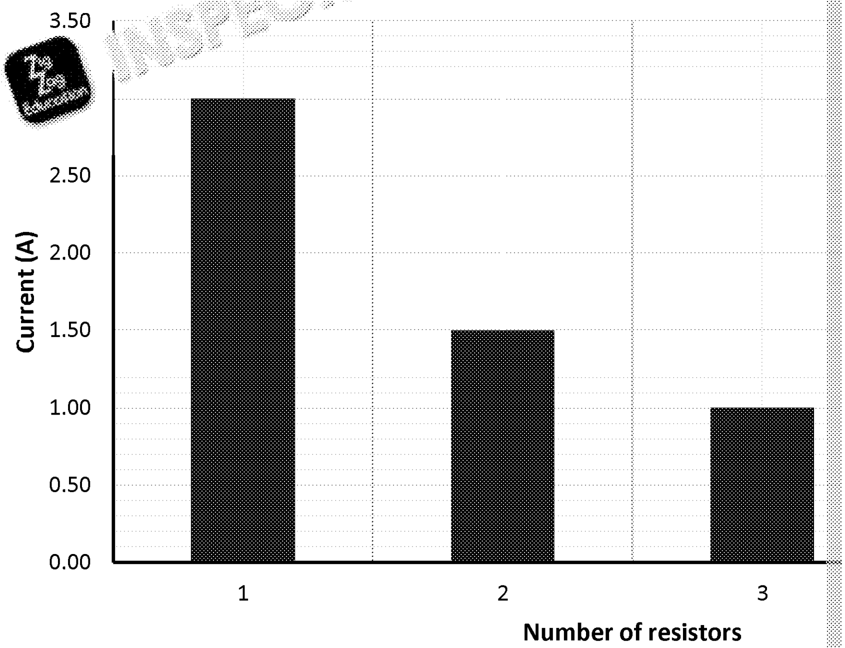
Resistance required practical: exam-style questions

1. A student sets up a simple series circuit with one resistor, as shown in the ci



They record the current flowing through the circuit before adding another ide record the new current and continue to add a further two resistors, recording

Their results are presented in a graph.



a. Assuming that the student used a 6.0 V supply, and that this did not var the resistance of the individual resistors.
Use the formula: *potential difference = current × resistance*

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b. What would be the value of the current in this circuit with five identica

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2. The current and potential difference of a circuit are measured as the curren of wire. The table presents the results of the practical.

Length of wire (cm)	Potential difference (V)	Current (A)	Resis
20	0.60	0.15	
40	0.80	0.10	
60	0.75	0.07	
80	0.84		
100		0.04	

a. Calculate the missing values from the table above and complete the tab

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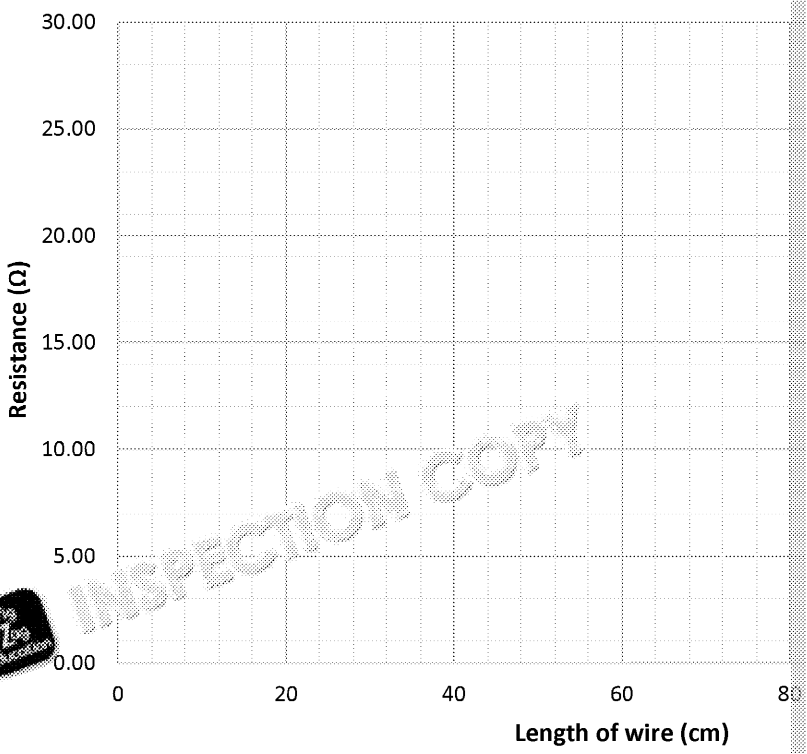
b. Plot a graph to show how the resistance changes with the length of the for this data.



c. To check the repeatability of the data, the investigation was carried out

Length of wire (cm)	Resistance (Ω)			
	1	2	3	Averag
20	2.95	3.15	2.98	3.03
40	5.80	4.30	5.90	
60	9.87	9.67	10.05	9.86
80	12.05	11.97	12.04	
100	19.65	19.78	18.99	19.47

i. Calculate the missing aver[illegible] d [illegible]nplete the table above.

....

....

....

....

ii. Comment on the repeatability of the data and identify any anomalous

....

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Resistance required practical: answer sheet

Pre-lab task

1. • Switch off the power supply or disconnect the batteries when assembling circu
   • Do not touch circuits with wet hands.
   • Never exceed the maximum voltage recommended or set by the teacher.
   • Do not touch bare wires when the power is turned on.
   • Any of the above answers are acceptable.

2. resistance = potential difference ÷ current (or R = V ÷ I)

3. a. R = V ÷ I
   R = 2.5 ÷ 0.25
   R = 10 .0 Ω
   b. i. The reading on the ammeter will decrease
   A higher-level response might include that the reading will halve, or stat
   b. ii. 20 Ω (There is no requirement for any explanation or mathematics.)

Analysis

The values for resistances in both parts of the practical will depend on individual stud

The graph should place the length of wire as the x-axis and the resistance as the y-axis.

Note that the line of best fit may not pass through the origin; this is an acceptable error f students to note this and possibly explain why during a class discussion.

Evaluation

1. The resistance of the conductor increases with the length; resistance is proportiona relationship between the variables.
2. The degree of error will depend on the individual student's data. However, they sh degree to which the data points lie on the line of best fit. The further a data point i is likely to be.
3. Errors often occur in this experiment due to the difficulty of placing the clip at an ex by having a thinner connection, such as a single wire. Allow comments on the possi the wire. Difficult to make sure wire is exactly lying along ruler, causing an error in t
4. Adding resistors in series leads to a direct increase in the resistance. Students shou that the increase is simply a matter of adding the resistances together to get the ov Adding them in parallel decreases the resistance. Students are neither expected no mathematical relationship for the addition of resistors.
5. The current will decrease by a third of the original value; some students might sugg

Exam-style questions

1. a. potential difference = current × resistance
   resistance = potential difference ÷ current (1)
   resistance = 6.0 ÷ 3.0 (1)
   resistance = 2.0 Ω (1)
   b. current = voltage ÷ resistance
   current = 6 ÷ (2 × 5) (1)
   current = 0.60 A (1)
   Allow alter[illegible]

2. a.

Length of wire (cm)	Potential difference (V)	Current (A)	Resistan
20	0.60	0.15	**4.0**
40	0.80	0.10	**8.0**
60	0.75	0.07	10.7
80	0.84	**0.05**	16.8
100	**0.96**	0.04	24.0

   1 mark for the two resistances; 1 mark each for the missing current and poten
   b.

1 ... r c... plotting the data points; 0 marks if two or more are incorr
1 ... a line of best fit, which should be a straight line passing close to the

c. i.

Length of wire (cm)	Resistance (Ω)			
	1	2	3	Average
20	2.95	3.15	2.98	3.03
40	5.80	4.30	5.90	**5.33**
60	9.87	9.67	10.05	9.86
80	12.05	11.97	12.04	**12.02**
100	19.65	19.78	18.99	19.47

ii. There is a narrow range of results around the averages (1); the exception reading at 40 cm, 4.30 Ω (1)

Appendix: Sample Results

Results for use in the event of practical problems or if a student is away during the less

Part A:

Length of wire (cm)	Current (A)	Potential difference (V)	
10	0.19	0.35	
20	0.16	0.47	
30	0.14	0.65	
40	0.11	0.68	
50	0.09	[illegible]	
60	0.07	[illegible]	
70	0.06	0.80	
80	[illegible]	0.84	
90	[illegible]	0.87	

Part B:

Ci	Current (A)	Potential difference (V)	
Series	0.28	4.51	
Parallel	0.90	3.82	

Required Practical 4
I–V Characteristics: Filament Lamp, Re

Teacher's notes

Before the required practical

		Trilogy	Synergy
Specification reference		6.2.1.4 Resistors	4.7.2.2 Current, resistance and potential difference
AT criteria		AT 6 and AT 7	

The purpose of this practical is to investigate the relationship between the curren individual components as the potential difference across each component is vari filament lamp, a fixed resistor and a diode in this practical.

Students should be familiar with common circuit diagram symbols and the constr before beginning this practical. The students should have completed required pr work. If not, then it is suggested that some additional time is given to students t circuit diagrams and the construction of simple series circuits.

Suggested questions

- Is an ammeter wired in series or in parallel with a component in a series circ circuit?
- To find the potential difference across a lamp in a circuit, should the voltme parallel with the lamp?
- What would you expect to happen to the current flowing in a series circuit a increased?
- Thinking back to required practical 3, what safety considerations are there w

Practical considerations

Although the students will have had practice at assembling circuits from diagram advisable to remind students that they should check with the teacher or a techni data to ensure that the circuit is wired together correctly.

The lamp and the resistor circuits can use a standard digital ammeter; the sectio will require a meter that can read in milliamps.

All components can vary in specification from one supplier to another; as such, t **does not** specify a voltage to use from the power supply. Instead, it asks the stu suggested by the teacher. Please check the correct voltages for the componen

The three parts of this practical can be completed in any order; to this end, each presented on a separate page and with full instructions that do not require any r the practical. These could also be reproduced, laminated and used as part of a ci

A key skill for students (AT 7) is to be able to assemble circuits from a diagram pr recommended that students should complete this task for themselves without as

Included sheets

- Pre-lab task – work for the students prior to the start of the practical
- Student instructions – apparatus list and method
- Analysis and evaluation – student instructions for completing calculations, g
- Exam-style questions – GCSE-style questions focused on the practical

Apparatus

- Batteries or low voltage supply
- Connecting wires
- Filament lamp (6 V or 12 V)
- Diode with protecting resistor (normally a 10 Ω resist... ...ut this will depend
- Fixed resistor
- Ammeter (ideally capable of readin... ...an... milliamps)
- Voltmeter
- Variable resistor

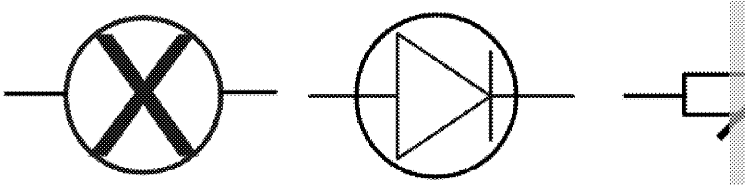
Each studer... ...eed access to all the apparatus for this practical, but the lamp, shared within the class. These can be used in any order to complete the three se

Timings

- **Pre-lab task plus starter questions: 10 minutes**
- **Practical activity** will require **20–25 minutes**
- **Analysis: 20 minutes** to draw graphs
- **Evaluation: 20 minutes**, plus discussion time if desired. Sheets can be collec holding a class discussion.
- **Exam questions: 15 minutes** should be allowed for this exercise

I–V characteristics required practical: pre-lab task

1. Identify each of the common electrical components from their symbols.



2. Draw a simple electrical circuit diagram to show a filament lamp in series wit
ammeter and a voltmeter in the circuit to measure the potential differenc

3. How is the resistance of a variable resistor different from that of a fixed resis

4. What is a diode, and how does it affect the flow of current in a circuit?

I–V characteristics required practical: student instructions

Part A: I–V characteristics of a filament lam

CAUTION

Do not exceed the maximum voltages recommended by your teacher

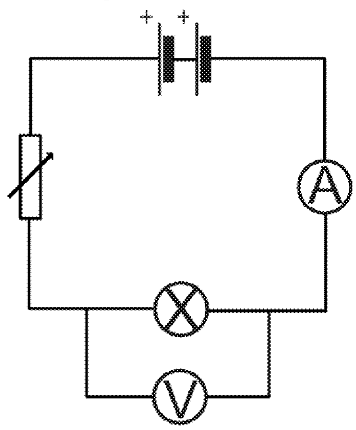
In this part of the practical you will investigate how the current flowing through a potential difference of the circuit is changed.

Apparatus

- Power supply or battery
- Ammeter
- Voltmeter
- Variable resistor
- Filament lamp
- Connecting wires

Method

1. Draw a results table for your data. You will vary the potential difference and space for 10 sets of data.
2. Assemble the circuit illustrated in the circuit diagram below.



Note: your teacher may ask you to use either a power pa

3. Adjust the variable resistor to give a dim glow from the bulb.
4. Record the readings on both the ammeter and the voltmeter.
5. Increase the reading on the voltmeter by adjusting the variable resistor. Rec voltmeter and the ammeter.
6. Repeat step 5 a further three times, increasing the reading on the voltmeter
7. Reverse the wires connected to the battery or power supply so that the pola Both meters should now have negative values showing on their displays.
8. Gradually reduce the potential difference by adjusting the variable resistor. difference and current each time you adjust the variable resistor.

Do not exceed the maximum voltage for the lamp pro

Part B: I–V characteristics of a fixed resist

CAUTION

Do not exceed the maximum voltages recommended by your teacher

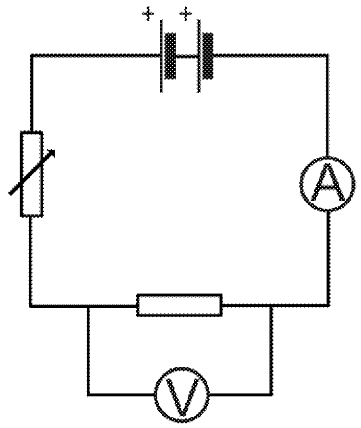
In this part of the practical you will investigate how the current flowing through a potential difference of the circuit is changed.

Apparatus

- Power supply or battery
- Ammeter
- Voltmeter
- Variable resistor
- Fixed resistor
- Connecting wires

Method

1. Draw a results table for your data. You will vary the potential difference and space for 10 sets of data.
2. Assemble the circuit illustrated in the circuit diagram below.



Note: your teacher may ask you to use either a power pack

3. Adjust the variable resistor to give a low reading on the voltmeter.
4. Record the readings on both the ammeter and the voltmeter.
5. Increase the reading on the voltmeter by adjusting the variable resistor. Re voltmeter and the ammeter.
6. Repeat step 5 a further three times, increasing the reading on the voltmeter
7. Reverse the wires connected to the battery or power supply so that the pola Both meters should now have negative values showing on their displays.
8. Gradually reduce the potential difference by adjusting the variable resistor. difference and current each time you adjust the variable resistor.

Do not exceed the maximum voltage for the resistor p

Part C: I–V characteristics of a diode

CAUTION

Do not exceed the maximum voltages recommended by your teacher

In this part of the practical you will investigate how the current flowing through a difference of the circuit is changed.

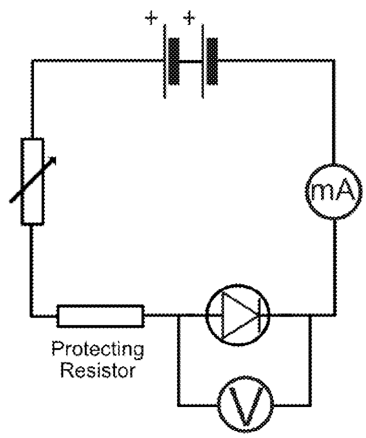
Apparatus

- Power supply or battery
- Ammeter
- Voltmeter
- Variable resistor
- Diode and protecting resistor
- Connecting wires

Method

1. Draw a results table for your data. You will vary the potential difference and space for 10 sets of data.
2. Assemble the circuit illustrated in the circuit diagram below.

Important: there must be a protecting resistor in the circuit in fr



Note: your teacher may ask you to use either a power pack o

3. Adjust the variable resistor to give a low reading on the voltmeter.
4. Record the readings on both the ammeter and the voltmeter.
5. Increase the reading on the voltmeter by adjusting the variable resistor. Re voltmeter and the ammeter.
6. Repeat step 5 a further [illegible] times, increasing the reading on the voltmeter
7. Reverse the wires connected to the battery or power supply so that the pola Both meters should now have negative values showing on their displays.
8. Gradually reduce the potential difference by adjusting the variable resistor. difference and current each time you adjust the variable resistor.

Do not exceed the maximum voltage for the diode pr

I–V characteristics required practical: analysis and evaluat

Analysis

1. Draw a separate graph for each set of data, plotting the current (y-axis) against t
   - As this data contains both positive and negative values for current and p the graph will be in the middle of your graph paper.
   - Label each graph to show which component it represents.

2. Add a t[illegible]ne to each graph.
   Each line of best fit represents the I–V characteristics of the component.

3. For the fixed resistor only, calculate the gradient of the line of best fit.
The resistance is equal to the inverse of the gradient.

   - Use this formula to calculate the resistance:

     resistance = 1 / gradient of the line of best fit

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   - Compare this to the actual value of the resistor used in your practical.

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Evaluation

1. Describe the relationship between the current and the potential difference for components. Describe how this affects the resistance of the component as the difference vary. Write a separate paragraph for each.

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2. Compare the overall patterns shown in your graphs with those of two other reliability of your own data compared to theirs.

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3. Why was it necessary to use a protecting resistor with the diode but not with

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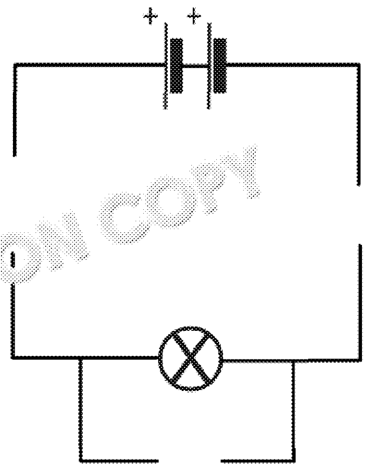
I–V characteristics required practical: exam-style question

1. a. Complete the circuit diagram which can be used to investigate the I–V c a 12 V filament lamp.

   Choose from the following components to fill in the three gaps in the ci

   diode, fixed resistor, voltmeter, variable resistor, amm



   b. Describe how this circuit can be used to collect a set of data for this inv

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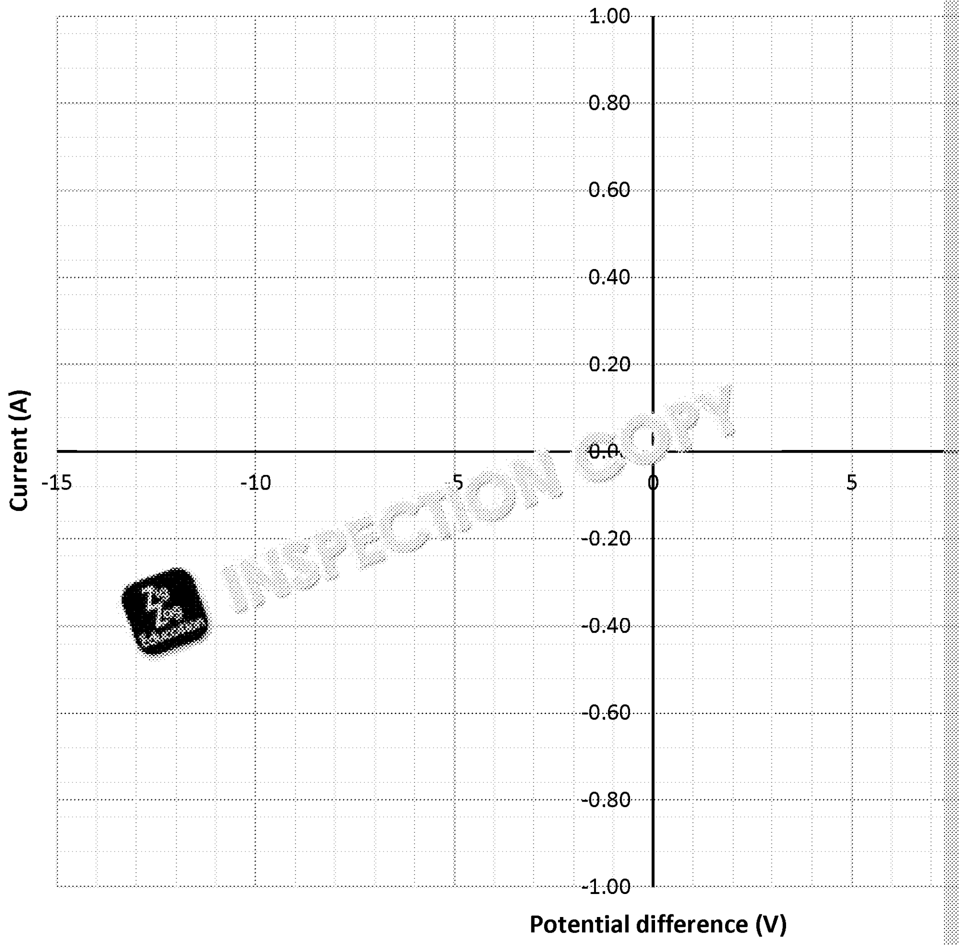
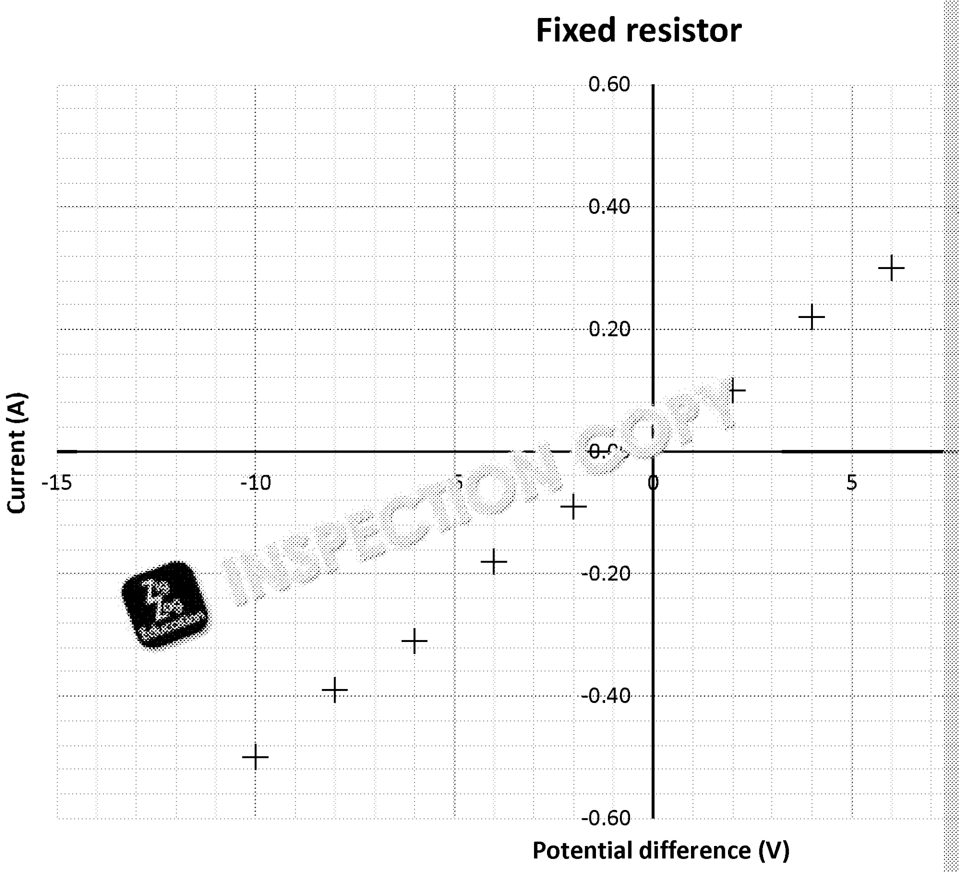
   c. The table below shows a set of data for this investigation. Draw a grap illustrate the I–V characteristics of this filament lamp, including a suitab

Potential difference (V)	Current (A)
10	0.82
8	0.80
6	0.74
4	0.63
2	0.42
0	0.00
-2	-0.40
-4	-0.65
-6	-0.74
-8	-0.82
-10	-0.84



2. The graph below shows the I–V characteristics of a fixed resistor.



a. Draw a line of best fit for this data.

b. Use the graph to calculate the resistance of this component, given the *gradient of the line = 1 ÷ resistance*

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c. Suggest two reasons why errors may occur when collecting this data.

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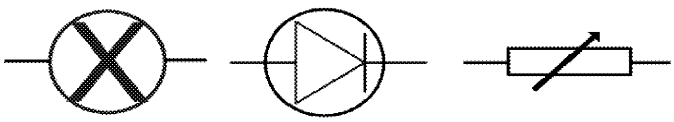
I–V characteristics required practical: answer sheet

Pre-lab task

1.

2.



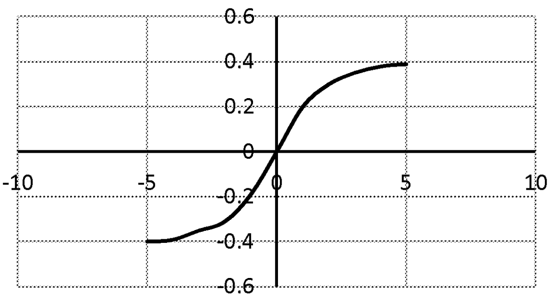
Filament lamp Diode Variable resistor

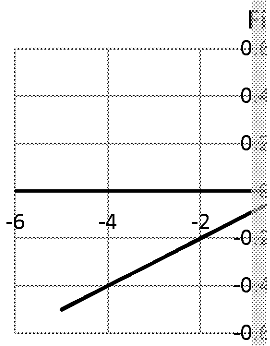
3. The resistance of a variable resistor can be increased or decreased, whereas the resi not change.

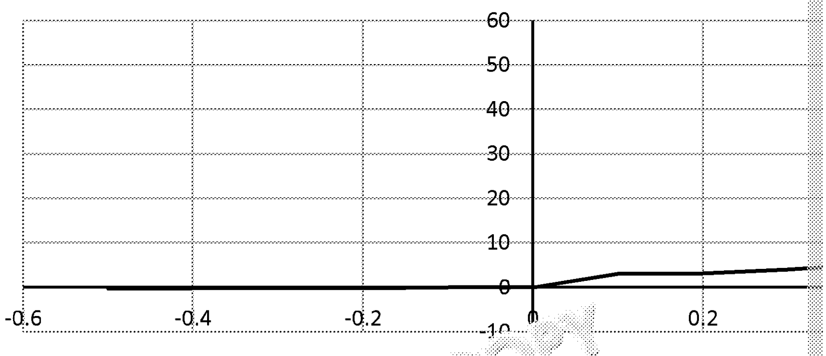
4. A diode is an electrical component that allows electricity to flow in one direction onl it to flow when the polarity is in the forward bias but prevents the flow of current if t

Analysis

1. Students' graphs will vary depending on their data and the components used.
Using the data supplied on the previous page, examples of potential responses from







3. Answers will vary depending upon the student's results, however, the resistance shou the line of best fit from the graph.

Normally, the calculated value of resistance will vary from the actual value stated on t identify this fact and suggest some reasons why, such as, errors in reading the meters in the graph. This might include the judgement made by the student of where to posi

Evaluation

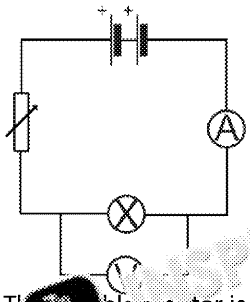
1. All lines of best fit will vary, but they should all go through the origin of the graphs.
   - Filament lamp curve is roughly an 'S' shape through the origin, indicating that t lower potential differences. It is roughly symmetrical either side of the y-axis, i a similar manner irrespective of the polarity.
   - There is a positive correlation (linear relationship) between the current and po resistor. The resistor responds in the same way irrespective of the polarity of t
   - For the diode, little or no current flows when the potential difference is negativ positive potential difference is low, but increases rapidly beyond a trigger value

2. Students should recognise that their data and that of another student have the sam component. They data will vary with the degree of accuracy they used in recording t degree of accuracy in plotting the data, and the scale they used. They should make their data and presentation compare with others, identifying strengths in their own other's data and presentation.

3. A diode is a component that uses only a small current in the order of milliamps, wh larger currents. High currents can quickly damage diodes meaning they fail.

Exam-style questions

1. a.

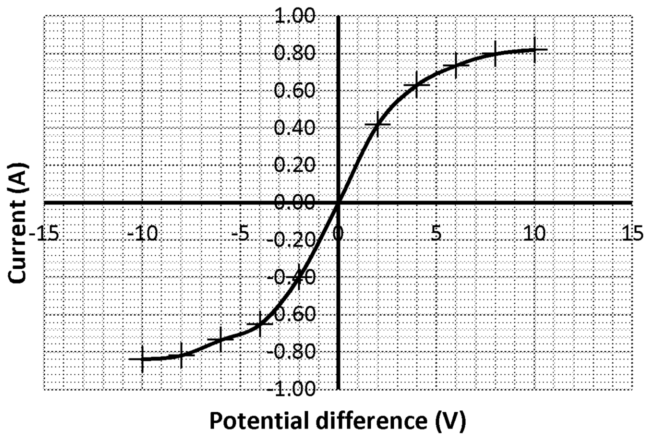


- Voltmeter positioned in parallel with the bulb (
- Inclusion of a variabl[illegible]tor (1)
- Ammeter po[illegible] series with the bulb (1)

Note: the [illegible] the variable resistor and the a

b. Th[illegible] [illegible]sistor is used to set a range of potential differences (1). Readin (fo[illegible]t) and the voltmeter (for potential difference) (1). The polarity of th swapping the connecting wires on the battery / power supply (1).
Note for a and b: Some students might vary the potential difference from the p variable resistor; therefore, full credit can be given for the circuit in 'a' if their r

c.



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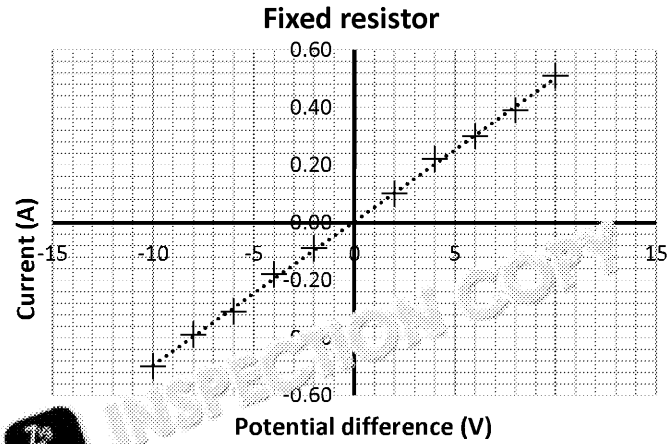
2. a.



- De stra
- De thro

b. - [illegible]ents use the graph to find the gradient (1) – answer 0.05 (± 0.01)
Students do not have to indicate on the graph which data they have chosen.
- Recognition that I/V = 1/R (1)
- Substitution and calculation: answer 20 Ω (allow answer between 25 Ω a

c. Errors might include any of the following for 1 mark each (maximum 2 marks):
- Human error in reading meters (this could be for an analogue meter and
- Using too high a voltage (heating of the resistor can affect its resistance)
- Incorrectly wired meters, i.e. voltmeter in series will produce a reading th
- Allow faulty apparatus, such as a damaged variable resistor

Do not award marks for comments on errors in data manipulation
Note: accept the use of the term voltage instead of potential difference throu

Appendix: Sample Results

Results for use in the event of practical problems or if a student is away during the lesson

Lamp

Potential difference (V)	Current (A)
5	0.39
4	0.38
3	0.35
2	0.3
1	0.2
0	0
-1	-0.19
-2	-0.31
-3	-0.35
-4	[illegible]
-5	-0.4

Resistor

Potential difference (V)	Current (A)
5	0.5
4	0.4
3	0.3
2	0.2
1	0.1
0	0
-1	-0.1
-2	-0.2
-3	-0.3
-4	-0.4
-5	-0.5

Required Practical 5: De

Teacher's notes

Before the required practical

	Trilogy	Synergy
Specification reference	6.3.1.1 Density of materials	4.1.1.2 Density
AT criteria		AT 1

The purpose of this practical is to m[illegible] volume and mass of objects in ord
from the formula:

density = mass ÷ volume **or** ***ρ = m/V***

Students wi[illegible] out the densities of three objects:

1. A regular shaped object, such as a cube, by direct measurements
2. An irregular shaped object, using displacement to find the volume
3. A sample of liquid, by direct measurements

A set of student instructions are included for this practical along with a student p
students to design their own investigation.

Suggested questions

- What is the correct procedure for using a measuring cylinder?
- What happens to the water level in a beaker when an object is placed in it?
- Why should an electric balance be placed on a level surface before using it?
- How can you reset an electric balance to zero when an empty beaker is plac
- What should you do if you spill some liquid onto the floor during a practical?
- What are the SI units of density?
- Name one material with a high density and one with a low density; think ab

Practical considerations

A range of different objects can be used in this investigation; it is, therefore, not p
provide exact answers to any of the calculations.

School suppliers produce a range of standard density cubes in a range of materials th
of this experiment. Any irregular shaped objects will have to be submerged in water
they are of a non-absorbent material and that they will n[illegible] 1p, 2p, 5p and 20p

If you do not have access to a displaceme[illegible] fo[illegible]easuring displacement, it is
displacement in a measuring cylin[illegible] decide to use this method, it is expl
student instructions. No[illegible]se metal objects in glass measuring cylinders.

The measu[illegible]ume by displacement carries with it a high probability of spil
have the me[illegible] mop up spills to hand, and access to plenty of paper towels.

It is important that students measure mass before volume for the irregular shape
been immersed it will have water clinging to it – this will affect the mass, and dry
consuming and unreliable.

Any suitable liquids that are not hazardous can be used for finding the density of l
and easy to prepare. Sugar solutions can be used, but, if spilt, can leave a sticky r
Sugar solutions are prone to attracting insects in summer, and this can be a distr

Included sheets

- Pre-lab task – work for the students prior to the start of the practical
- Student instructions – apparatus list and method
- Student design sheet – an alternative to the student instructions to allow st[illegible] method
- Analysis and evaluation – student instructions for completing calculations, g[illegible]
- Exam-style questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data

Apparatus

- Range of regular shaped objects, such as density blo[illegible]
- Range of irregular shaped objects (non-poro[illegible] [illegible]nk in water)
- Range of measuring cylinders
- Displacement can (if availab[illegible] [illegible]aker
- Ruler with mm divi[illegible]
- Electri[illegible]ce
- Prepar[illegible]d, such as saline
- Paper towels

Each student will need access to all the apparatus.

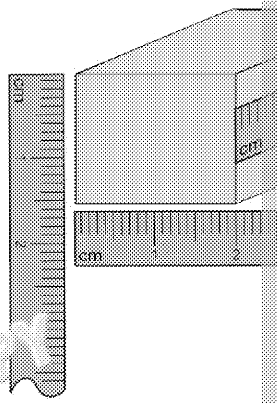
Timings

- **Pre-lab task** plus starter questions: **10 minutes**
- **Practical activities** will require a total of **30 minutes**
- **Analysis: 10 minutes** to complete calculations
- **Evaluation: 10 minutes**, plus discussion time if desired. Sheets can be collec[illegible] holding a class discussion.
- **Exam-style questions: 15 minutes** should be allowed for this exercise

Allow around 20 minutes for the students to design their own methods if using th[illegible]

Density required practical: pre-lab task

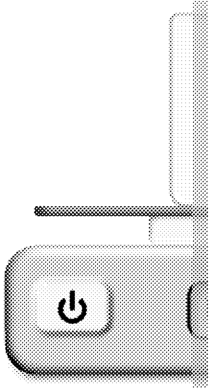
1. What is the volume of the metal block shown to the right? Show your working.



2. a. On the diagram of the measuring cylinder to the right, mark the point o
   where you would look to take an accurate reading of the volume of the

   b. Why is it important to be at eye level with the scale and the level of the cylinder?

3. Describe how you would reset the electric balance below to zero, without removing the beaker.



4. A student spills some water onto the floor while carrying out a practical. W mop up this spillage before carrying out any other work?

5. When an object is submerged in a container of water, the surface level rises tell you about the submerged object?

Density required practical: student instructions

Density of regular shaped objects

In this part of the practical you will measure the three dimensions of a regular sh
mass. You will use this information to calculate the object's density in grams per

Apparatus

- Three or four regular shaped objects of different sizes and/or different mate
- 30 cm ruler with millimetre divisions
- Electric balance

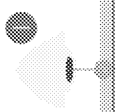
Method

1. Draw a results table for your data. You will need space for each object, alon
   and mass. In addition, you will calculate the object's volume and density.
2. Select your first object and record its 'name' or material in your table.
3. Measure the three dimensions of the object to the nearest $^{1}/_{10}$ (0.1) of a cm
4. Use the electric balance to measure the mass of the object in grams to the n
   Record in your table.
5. Repeat steps 2 to 4 for your other chosen objects.

Density of irregular shaped objects

In this part of the practical you will measure the volume of an irregular shaped o
and then use this value, along with the object's mass, to calculate the object's de

Remember: when using a measuring cylinder, always **measure the volume from the bottom of the meniscus** – the curved surface of the liquid.



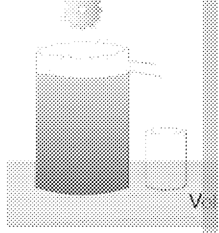
Apparatus

- Three or four irregular shaped objects
- Electric balance
- Measuring cylinders of different sizes
- Displacement can (if available)
- 2 × 250 ml beakers
- Paper towels

Method

(If you are **not** using a displacement, can see the method in appendix A to find th

1. Draw a results table to record the names of the objects and their masses, vo
2. Find the mass of the first object and record this in your table.
3. Place an empty 250 ml beaker below the spout of the displacement can.
4. Fill the displacement can with water up to the spout. Any excess water collecte
5. Place an empty measuring cylinder below the spout of the displacement can
6. Gently lower the object into the displacement can, allowing the displaced wate
   cylinder. Note: if the measuring cylinder is too large to fit below the spout, catc
   beaker first, then transfer it to a measuring cylinder.
7. Measure and record the volume of water displaced; this is equal to the volume of the object. (1 ml = 1 cm^3)
8. Remove the object from the displacement can over a sink or bowl.
9. Repeat the method for each new object.



CAUTION

Water spilt onto the floor can present a slip hazard and must b
before proceeding with any other work.

Appendix A: measuring volumes without a displacement ca

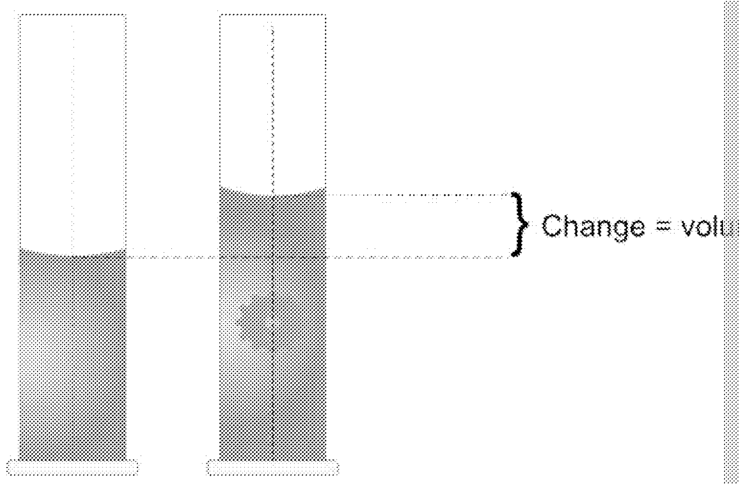
Density of regular shaped objects

Apparatus

- Measuring cylinder with a bore large enough to place the object in

Method

1. Approximately half fill the measuring cylinder with water. Fill it to a round m than 99 ml).
2. Gently lower the object into the measuring cylinder. Do not drop heavy obje cylinders as they might break, causing a hazard.
3. Measure and record the increase in volume; this is equal to the volume of th
4. Carefully remove the object from the measuring cylinder; this is best done o spilt water before proceeding with any other work.



Density of a liquid

In this section of the practical you will measure the density of a liquid, such as salin

Apparatus

- Sample of liquid
- Electric balance
- Measuring cylinder (100 ml or 50 ml)
- Paper towels

Method

1. Draw a results table to record the volume, mass and density of your sample
2. Place the measuring cylinder onto the electric balance.
3. Set the balance to zero.
4. Remove the measuring cylinder from the electric balance. **Do not reset the** anyone else.
5. Add the liquid to the measuring cylinder, filling it to the highest level on the exact amount of liquid in the measuring cylinder.
6. Ensure that the outside of the measuring cylinder is dry.
7. Replace the filled measuring cylinder onto your electric balance and record t
8. Remove the measuring cylinder from the electric balance and reset it to zero

Note: many electric balances are sensitive to any movement of the bench on whi **not lean on the desk next to the balance** as this will affect your results.

Density required practical: analysis and evaluation

Analysis

1. Calculate the **volume** of each of the regular shaped objects in your first table

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2. Calculate the **density** of each regular shaped object, using the formula:

density = mass / volume

Enter these values into your table.

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3. Calculate the densities of the irregular shaped objects using the data collected in your table.

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4. Calculate the density of the sample of liquid, using your data, and enter this i

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5. For one regular shaped object, one irregular shaped object and for the sampl densities to present the answers in the standard SI units for density: kg/m^3.

($1\ cm^3 = 1 \times 10^{-6}\ m^3$)

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Evaluation

1. Compare the density of the liquid with that of one of the solid objects.

   a. Which has the lower density?

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   b. Why, in general, do liquids have lower densiti... solids?

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2. If one of the regular shaped objects were cut in half, how would this affect i

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3. What sources of error can affect the accuracy of finding the density of an irr identify at least two sources of possible error, and, for each, suggest how th

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Density required practical: student design sheet

In this practical you must design a method, with three sections, to find the densit

a) a solid regular shaped object, such as a cube of metal
b) a sold irregular shaped object, such as a coin
c) a sample of salt water

Density is a measure of the mass of material per unit volume, calculated using th

density = mass / volume

Although the standard SI unit for density is kg/m^3 (kilograms per metre cubed), it present your answers in g/cm^3.

For each section of the practical you will need to decide how to measure:

- mass
- volume

To help you with your planning, consider the answers to these questions:

i. How do you calculate the volume of a cube 2 cm wide, 3 cm long and 3 cm h
ii. How do you measure the volume of a liquid? (Hint: what do you use, in che water or 25 ml of hydrochloric acid?)
iii. What did Archimedes discover about the relationship between the amount o object is submerged and the object's physical properties? (His famous eurek

Apparatus you can use

- Measuring cylinders
- Beakers
- Displacement can
- Electric balance
- Rulers with mm divisions
- Water
- Paper towels

You will be given a range of objects by your teacher. Some will be regular in shape; others will be irregular. You should aim to find the density of three of each. You will also be given a sample of a liquid; you must find the density of this liquid.

Density required practical: exam-style questions

1. Describe a method that could be used to accurately measure the volume of

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2. A stude[illegible] comparing the density of three different samples of water from They use a 250 ml sample of each.

Sample	Mass (g)	Density (g/cm^3)
A	257.50	1.03
B	253.75	
C	250.75	1.00

density = mass / volume

a. Calculate the density of sample B. Show your working.

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b. The density of a sample of pure water is 1 g/cm^3. Why are these sampl pure water?

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c. What app[illegible] [illegible]uld the student need to measure the mass accurate sl[illegible] used to ensure the data collected is accurate.

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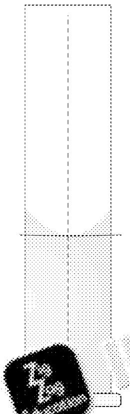
Density required practical: answer sheet

Pre-lab task

1. Volume = width × length × height
   = 2.0 × 2.0 × 1.5
   = 6.0 cm^3

2. a.



   b. This avoids an incorrect reading. Being too high and looking down on the scale gives an over-reading. This type of error is known as a parallax error.

3. Press the 'Tare' button without removing the beaker from the balance.

4. Spilt liquids on the floor present a slip hazard and can lead to serious accidents.

5. The displaced water is equal to the volume of the object submerged.

Analysis and evaluation

Analysis

Responses to sections 1 to 4 will vary according to the objects and liquids used, as well as

5. Example: 20p coin
   Mass = 5 g = 0.005 kg   1.35 cm^3 = 1.35 × 10^{-6} m^3
   Density = mass / volume   = 3703.70 kg/m^3

Evaluation

1. a. The liquid will have a lower density than any of the solids.
   b. The densities of liquids are lower due to the greater distance between the mole compared to those of a solid. This results in less mass per unit volume.

2. This would not affect the density. Halving the volume would also halve the mass. Th unchanged.

3. Common errors:
   - Parallax error in reading the level of the liquid in the measuring cylinder. Solu level with the scale.
   - Reading the volume from the top of the meniscus. Solution – always read the v meniscus.
   - Inaccurate readings on the electric balance. Solution – ensure the read-out is z balance pan. Do not lean on the desk near the electric balance when in use.
   - Inaccurate readings from both can occur if they are not on a level surface. Solu balance and the measuring cylinder on a level surface.

Exam-style questions

1. Credit should be given for describing the use of either a displacement can or a meas
   Level 3: The method would lead to the production of a valid outcome. All key steps sequenced. (4 marks)
   Level 2: The method would not necessarily lead to a valid outcome. Most steps are fully logically sequenced. (2–3 marks)
   Level 1: The method would not lead to a valid outcome. Some relevant steps are ide clear. (1 mark)
   No relevant content: 0 marks

Indicative content

Displacement can

- Identifying the use of a displacement can (allow eureka can/cup)
- Filling the displacement can to the spout
- Collecting the displaced water
- Measuring this volume using a measuring cylinder

Measuring cylinder

- Identifying the use of a measuring cylinder large enough for the object
- Measuring the change in volume
- Recognising that the change in volume is the volume of the object
- Correctly describing how to use a measuring cylinder to avoid a parallax error

2. a. Density of sample B – 1.015 (allow 1.02) (1)
   Substitution of values (1)

   b.
   - Each of the samples contains dissolved chemicals (salt) (1)
   - These solutes increase the mass per volume (i.e. density) (1)

   c.
   - Mass – electronic/digital balance (1)
   - Zero (take into account the mass of the container (1)
     or subtract the mass of the empty container from the mass of the fu
   - Recognition that the balance should be on a level surface (1)

Appendix B: Sample Results

Results for use the event of practical problems or if a student is away during the lesson

Object/material	Width (cm)	Length (cm)	Height (cm)	Volume (cm^3)
Iron	2.0	2.0	2.0	
Copper	1.9	2.1	2.0	
Aluminium	2.1	2.1	1.8	

Object	Mass (g)	Volume (cm^3)
1p coin	3.56	0.35
2p coin	7.12	0.47
20p coin	5.00	0.36

	Volume (cm^3)	Mass (g)
Saline	100	102.30

Required Practical 6: Force and

Teacher's notes

Before the required practical

	Trilogy	Synergy
Specification reference	6.5.3 Forces and elasticity	4.6.1.6 Elastic deformation
AT criteria		AT 1 and AT 2

The purpose of this practical is to i... the relationship between the force a... extension of that spring ... astic limit. Students will collect data for a sp... extension gr... fr... they can calculate the value of the spring constant.

Some stude... ay have time to extend this practical to look at two springs of di... and lower spring constants. This is not a requirement of the practical, but it can e... understanding of the topic.

This practical is an illustration of Hooke's law.

Suggested questions

- What is the difference between the weight of an object and the mass of an o...
- What are the SI units of force?
- Given the gravitational field strength on Earth is 10 N per kg, what is the we...
- During this practical you will be hanging masses from a spring; what are the ... activity?

Practical considerations

In the instructions, the students are asked to add a small pointer to the base of th... of the extension of the spring; it is possible to omit this and measure the spring d... setting up the apparatus, it is important to ensure that the zero line of the ruler is... the spring and not the top of the loop. This is a common source of error.

Students are asked to measure the length of the spring as masses are added to it... of Hooke's law, in the analysis stage they will be asked to calculate the extension... find this a confusing idea. It is, therefore, worth spending a little time ensuring th... between the length of the spring and the extension f... ve... mass. This is cove... understanding and comprehension. However, th... re... will still give the same g... extension or length. (Note: the syll... in... ...ates that the students will measu...

Although there are ... hazards, falling masses can cause harm and it is wo... practices, a... s ...ying attention to the set-up details that require the clamp s... instruction, ... amp is used; G-clamps can normally be borrowed from the Desi... Alternatively, you can counterbalance the set-up with a 1 kg mass. The first optio... to accidents. Overloaded springs can snap, presenting a hazard. The spring may ... spring can have sharp edges. Warn students not to exceed the maximum load fo...

Apparatus

- Spring
- 10 g masses × 9, plus holder
- Metre ruler
- Splint for pointer and sticky tape
- Clamp stand with two clamps
- G-clamp or 1 kg mass as an anchor

Each student will need access to all the apparatus to complete the investigation.

Note: it is often easier to have a technician add the pointers to the bottom of the otherwise this can result in wasting time during the le...

Included sheets

- Pre-lab task – work f... ...ents prior to the start of the practical
- Student ...uc... ...apparatus list and method
- Analys... ...valuation – student instructions for completing calculations, g
- Exam-st... questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data
- Student design sheet – an alternative to the student instructions to allow stu method

Timings

- **Pre-lab task** plus starter questions: **10 minutes**
- **Practical activities: 20 minutes**
- **Analysis: 10–15 minutes** to draw a graph with line of best fit and complete
- **Evaluation: 10–15 minutes**, plus discussion time if desired. Sheets can be co than holding a class discussion.
- **Exam-style questions: 15 minutes** should be allowed for this exercise

Force and extension required practical: pre-lab task

1. A spring is 10 cm long without any force applied to it. When a force of 5 N is is measured again and found to be 12 cm long.

    a. What is the extension of the spring?

    ....

    ....

    b. When an additional 5 N is added, the spring is measured as 14 cm. Wha with this new load applied?

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    ....

    c. P... the length of the spring if a force of 15 N is applied.

    ....

    ....

    d. Use the data provided to find the spring constant for this spring.

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    ....

2. What is the difference between mass and weight?

    ....

    ....

    ....

3. What are the SI units of mass and weight?

    ....

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    ....

4. What is the size of the f... applied to a spring if a 40 g mass is hung on it? You can use th... : *weight = mass × gravitational field strength* (*w = m*

    ....

    ....

5. What are the practical considerations for your safety of hanging masses on a

    ....

    ....

Forces and extension required practical: student instructi

CAUTION

During this practical you will be hanging masses from a spring. It is importa hands or feet in a position where the masses could fall on them. Please ensu secured before adding any masses to the spring.

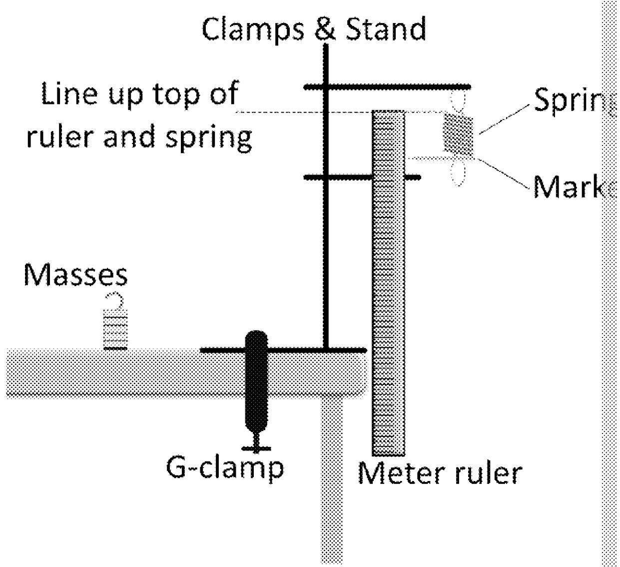
Apparatus

- Spring
- Splint to make a pointer, plus sticky tape
- Metre ruler
- Clamp stand with two sets of cl[illegible]
- G-clamp (or 1 kg mass)
- 9 × 10 g masses [illegible] holder

Method

1. Draw a results table for your data. You will be adding masses to a spring and data you will also need to calculate the extension for each mass added.

   Note: in your table you will need to record the <u>force</u> being applied to the sp
2. Set up the apparatus as shown in the diagram below.



3. Ensure the set-up is stable and will not fall over as masses are added to the s
4. Use the pointer to measure and record the length of the spring with no forc
5. Add a single 10 g mass to the bottom of the spring. Add this gently to preve (bouncing up and down).
6. Allow the spring to [illegible] and use the pointer to record the new leng
7. Repeat steps 5 and 6 until all nine masses have been used.
8. Remove the masses carefully before dismantling the apparatus. Note: your t this exercise using more than one spring.

Forces and extension required practical: analysis and evalu

Analysis

1. Calculate the extension of the spring for each mass added to it. Add these ca

2. Add the force for each mass added to the table. A single 10 g mass has a for

3. Draw a graph of extension over force using your data and calculations.

   Label the x-axis 'Force', and label the y-axis 'Extension'. It is acceptable to use ce

4. Add a line of best fit to your graph; note that this line should go through the

5. If your teacher asks you to use more than one spring in this practical, add th the same axes. This will allow you to compare the springs easily.

Evaluation

1. a. Use the following formula to calculate the spring constant for the sprin

force = spring constant × extension

....

....

....

b. Use the graph to calculate the gradient of the line of best fit.
Find the inverse of the gradient (1 / gradient).
Compare this with the spring constant calculated in a. (above).

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2. Describe the steps you took to ensure that your data was as accurate as pos

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3. How could you improve this practical to test the repeatability of your data?

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4. Measuring the extension of the spring accurately can be difficult with this m
the accuracy of this measurement could be improved, by changing the appa

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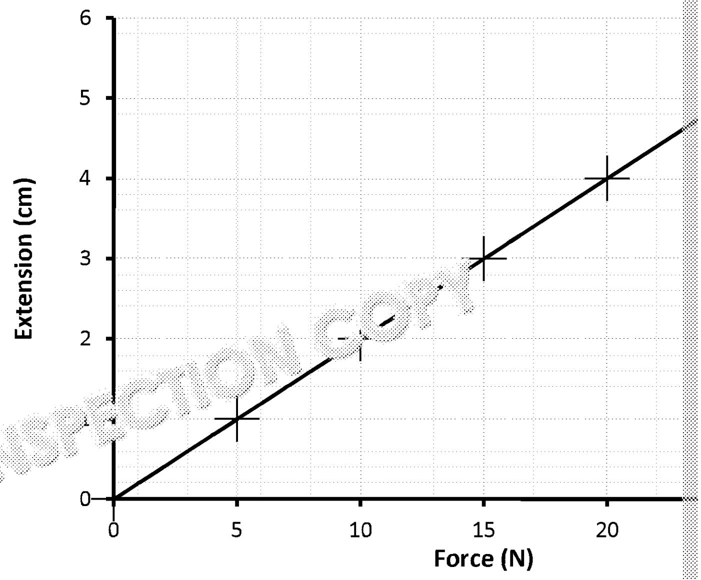
Forces and extension required practical: exam-style questi

1. The graph below shows the extension of a spring as it is subjected to an incr



a. What is the value of the spring constant for this spring? Demonstrate h from the graph. Show your working.

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b. What would be the extension of this spring if a force of 35 N were to be

....

....

c. Given that the spring is 10 cm long with no force applied, what is the le of 19 N is applied to it?

....

....

2. A student is provided with a range of 1 N weights an ... pring to investigate spring will affect the extension of the spring.

Describe a method they might ... conduct this investigation. You should considerations that ... plan. Your method should include at least any additional ... standard apparatus in your plan.

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Continue on a separate sheet if required.

Forces and extension required practical: answer sheet

Pre-lab task

1. a. 12 cm – 10 cm = 2 cm
   b. 14 cm – 10 cm = 4 cm
   NB Extension is the length of the spring with a load, minus the length of the sp
   c. 16 cm
   d. Force = spring constant × extension (F = kx)
   Using data from part a:
   Force = 5 N   Extension = 2 cm ≡ 0.02 m
   F = kx
   k = F / x
   k = 5 / 0.02
   k = 250 N/m
2. Mass is a measure of the amount of matter that makes up an object. Weight is a m pulling on a mass; it is a force.
3. Mass: kilograms
   Weight: newtons
4. weight = mass × gravitational field strength (or w = mg)
   g at Earth's surface is taken as 10 N/kg.
   40 g ≡ 0.04 kg
   w = 0.04 × 10 = 0.4 N (0.392 N if a student has taken *g* as *9.8 N/kg*)
5. i. Ensure the apparatus is stable and will not fall over.
   ii. Do not drop masses.
   iii. Keep hands and feet away from the area below the spring so if anything falls it
   iv. Do not exceed the elastic limit of the spring.

Analysis and evaluation

Analysis

1. Results will vary depending on the student's own data. However, it is important to e calculated the overall extension of the spring for any given load, rather than the inc
2.

Mass (g)	Force (N)
0	0
10	0.1
20	0.2
30	0.3
40	0.4
50	0.5
60	0.6
70	0.7
80	0.8
90	0.9
100	1.0

3. Answers will vary depending on the student's own data. The force should be plotte along the y-axis.
4. Lines of best fit in this practical must go through the origin.
5. If this has been completed, the two lines must be distinguishable from one another have a key.

Evaluation

1. a. force = spring constant × extension ∴ spring constant = force / extension
   Results will depend on student's own data.
   b. The two values are theoretically identical. Given some experimental error, thi student's data and calculations.

2. Answers might include:
   - Used the pointer at the base of the spring to help get an accurate reading from
   - Allowed the spring to come to rest before taking any readings.
   - Used a ruler with mm divisions.
   - Asked more than one person to check the reading from the ruler before recordi
   - Ensured the zero mark on the ruler was level with the top of the spring.

   Accept any other sensible suggestions.

3. Repeat the practical several times with any given spring and generate averages. Cro using similar springs to ensure scale of extension is consistent.

4. Suggestions might include:
   - Use a ruler with finer divisions.
   - Use a laser measuring device.
   - Take pictures of the ruler and pointer, then zoom in on the image to check the

Exam-style questions

1. a. The students could use one of two approaches to answer this question.
   Approach A: calculating the gradient of the line of best fit
   - Evidence on the graph of finding the change in extension against the cha
   - Correct calculation of the gradient from this data. (1)
   - Recognition that the inverse of the gradient is equal to the spring constan

   Approach B: using the formula
   - Extraction of a pair of coordinates from the line of best fit. (1)
   - Use of the formula to find the spring constant. (1)
   - Stating the correct value in N/m. (1)

   Answer: spring constant = 500 N/m

   b. extension = force / spring constant
   extension = 35 / 500 = 0.07 m or 7 cm

   c. From the graph, the extension of the spring can be seen to be 3.8 cm (1)
   Adding this to the original length – 10 + 3.8 = 13.8 cm (1)
   Note: student may use the formula to calculate the extension; answers may be
   1 mark is allocated to a valid method; 1 mark for the correct answer in m or cm

Students can gain full marks for the correct answer only. However, this should be disco to do so.

2. Level 3: The method would lead to the production of a valid outcome. All key steps sequenced. (5–6 marks)
   Level 2: The method would not necessarily lead to a valid outcome. Most steps are fully logically sequenced. (3–4 marks)
   Level 1: The method would not lead to a valid outcome. Some relevant steps are ide clear. (1–2 marks)
   No relevant content: 0 marks

Appendix: Sample Results

Data for use if the practical fails or if a student is absent from the lesson.

Mass (g)	Force (N)	Length of spring (cm)	Extension (cm)
0		3.5	
10		3.8	
20		4.1	
30		4.4	
40		4.7	
50		5.0	
60		5.3	
70		5.6	
80		5.9	
90		6.2	
100		6.5	

Required Practical 7: Accel

Teacher's notes

Before the required practical

	Trilogy	Synergy
Specification reference	6.5.4.2.2 Newton's second law	4.7.1.6 Newton's second law
AT criteria		AT 1, AT 2 and AT 3

This practical investigates Newton's second law of motion, as expressed in the fo

force = mass × acceleration or *F = ma*

The students are asked to investigate this relationship in two sections:

- the effect on the acceleration of an object of a fixed mass when a variable fo
- the effect on the acceleration of an object of a variable mass subjected to a f

The students are thus calculating and investigating acceleration using the rearran

acceleration = force / mass

It is important that the students have a sound understanding of the concepts of b before beginning this work. They will also need to be able to calculate both veloc measuring distances and times.

They should be familiar with the formulae for velocity and acceleration:

velocity = distance travelled / time taken

acceleration = change in velocity / time taken

Suggested questions

- What is speed?
- How is velocity different from speed?
- What units are used to measure both speed and velocity in science?
- How would you define acceleration?
- What units are used to measure acceleration?
- State Newton's second law of motion.

Practical considerations

There are several methods used to investigate Newton's second law of motion in t students are directed to use trolleys or cars running along a track or tracks force from a set of weights hanging from the end of the bench over a pulley. Th video to capture the movement of the trolley along the track. It is advised that th should belong to the school and use a memory card also belonging to the school. card before and after use. It is not recommended to use camera equipment, mem the teacher or the students in class. If you decide to do so, please check your scho school recording devices, and be aware of the potential issues of allowing person

Many institutions may have more elaborate apparatus, including air tracks and co These may be used in place of the suggested set-up if desired. However, it is imp the data themselves, rather than using graphs or precalculated tables from a com requirements of AT 1.

Care should be taken to ensure the falling weights, that provide the force, do not to the floor or to people. Placing a blanket or folded towel below the masses can The trolley can easily be pulled off the bench; therefore, care should be taken to and to instruct them to catch or stop the trolley before this happens.

Using this method, the average velocity over the length of the track/run is calcula acceleration from rest. Although this introduces some error, it is accurate enough between force, mass and acceleration.

Students should take all their measurements over a set distance as this will make the analysis section of this practical.

This practical includes optional sheets for the stud ... t... esign their own investi sheets has been included for this purpos... se ... eets are intended to replace students have not previously seen ... y and track in operation, a brief demo lesson, before they begin ... will aid their understanding and help highlight consider in the design.

Apparatus

- Stop clock / stopwatch
- Metre ruler
- Track or length of bench around 1.5 m to 2 m
- Trolley or toy car large enough to attach the string to
- String
- Pulley and clamp
- 1 × 1 N stack of weights with holders (holder plus 9 × 10 g masses)
- 4 × 100 g masses plus holder
- Blu-Tack
- Electric balance
- If available, something soft to place on the floor below the falling weights to or to the floor. Note: this is not listed in the students' set of instructions as it teacher's own discretion.
- Video camera

Each student or group of students will need a complete set of apparatus.

Included sheets

- Pre-lab task – work for the students prior to the start of the practical
- Student instructions – apparatus list and method
- Student design sheet – an alternative to the student instructions to allow stu method
- Analysis and evaluation – student instructions for completing calculations, gr
- Exam-style questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data

Timings

- **Pre-lab task** plus starter questions: **10 minutes**
- **Practical activities:** parts A and B will require a total of **30 minutes**
- **Student design sheet**: allow **15 minutes** for this activity
- **Analysis: 20 minutes** to draw the graphs with lines of best fit and complete t
- **Evaluation: 15 minutes**, plus discussion time if desired. Sheets can be collec holding a class discussion.
- **Exam questions: 15 minutes** should be allowed for this exercise

Acceleration required practical: pre-lab task

Useful formulae for this practical:

- resultant force = mass × acceleration: $F = ma$
- velocity = distance travelled ÷ time taken: $v = s \div t$
- acceleration = change in velocity ÷ time taken: $a = \Delta v \div t$

The symbol 'Δ' is used in formulae to mean 'a change in'. So Δv mean
'Δ' is pronounced 'delta'.

1. If a car travels a distance of 15 metres in three seconds, what is its average v

   ....

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   ....

2. What is the difference between velocity and acceleration?

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3. A toy car starts at rest and is pushed by a 10 N force so that it moves forwar reached a velocity of 1.6 m/s. What was its acceleration over these four sec

   ....

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   ....

4. Two shopping trolleys are pushed with the same force. The first trolley is em second trolley is full of shopping and has a mass of 15 kg. Which trolley will

   ....

   ....

   ....

5. If a person is cycling along a flat road at a velocity of 2 m/s and then accelera their new velocity after the five seconds?

   ....

   ....

   ....

Acceleration required practical: student instructions

CAUTION

Be aware of falling weights and moving trolleys in this practical. Do not let th
floor. Do not place hands or feet in the way of falling weights o

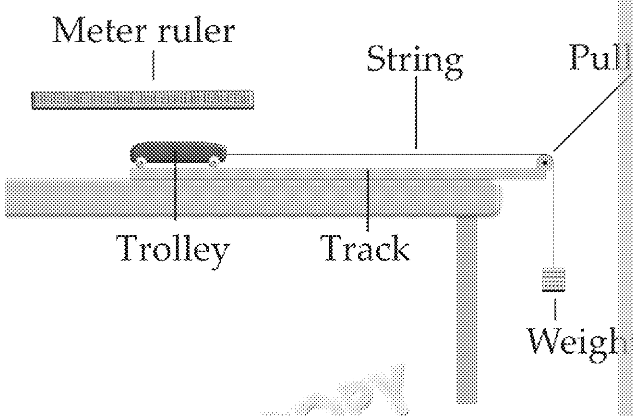
Apparatus

- Stop clock / stopwatch
- Metre ruler
- Track or length of bench around 1.5 m to 2 m
- Trolley or toy car large enough to attach the string to
- String
- Pulley and clamp
- 1 × 1 N sets of weights with holders (holder plus 9 × 10 g masses)
- 4 × 100 g masses plus mass holder
- Blu-Tack
- Electric balance
- Video camera

Part A: Investigating the effect of force on the accelera

Method

1. Draw a results table to record the time taken for the trolley to move along e use this to calculate the velocities and acceleration of the trolley for the five
2. Set up the apparatus as shown in the diagram below.

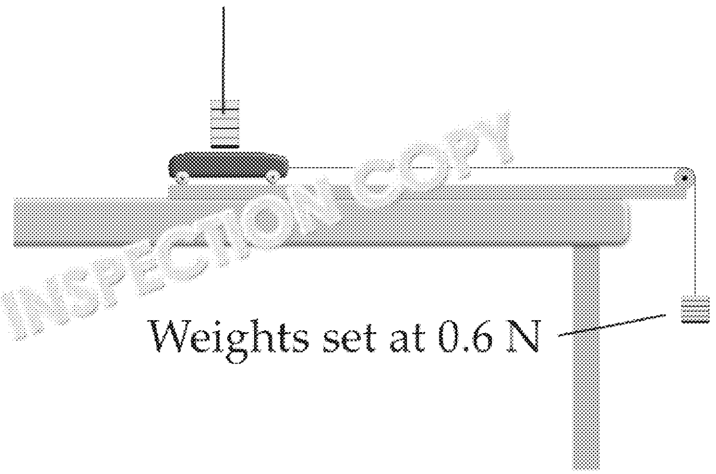


3. Use the metre ruler to mark along the side of the track at 10 cm divisions.
4. Place the trolley at the far end of the track from the pulley. Set up the came length of the track; ensure that the divisions are visible.
5. Place the weight holder and one additional weight on the end of the string; th
6. Start the video recording and then release the trolley. **Remember to catch t the table**. Stop the video recording.
7. Review the video on slow motion if possible. Using either the built-in timer c record how long it took the trolley to move between each of the 10 cm divis table of results.
8. Add two more weights to the stack, adding an additional 0.2 N of force. Rep this process until you have reached 1 N of force.

Part B: Investigating the effect of mass on the accelera

1. Draw a new results table with enough space to record the effect on the troll different magnitudes of mass.
2. Measure the mass of the trolley and record this next to your table of results
3. Change the set-up of the apparatus as shown.

Additional masses blu-tacked to troll



4. Run the trolley along the track with **no** additional masses added. You **do no** run. Adjust the 0.6 N pulling force so that the trolley runs slowly along the t this should not be changed for the rest of the practical.
5. Run the trolley with no additional masses added and record the times in you trolley, using the video as described in the previous method.
6. Add 100 g to the top of the trolley and secure with Blu-Tack. Record the ne table, before measuring the times taken to travel along the track.
7. Repeat step 6 adding 100 g each time until you have 500 g additional mass o maximum mass used. Note: the masses do not have to be stacked one on to placed along the trolley for increased stability and safety.
8. Remove the masses from the top of the trolley and from the end of the strin the apparatus.

Acceleration required practical: analysis and evaluation

Analysis

Part A: Investigating the effect of force on the acceleration of a trolley

1. Use the data to calculate the average velocity for each section of the journey

velocity = distance travelled ÷ time taken

Distances must be in metres not centimetres.

Repeat this for each level of force used.

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2. Calculate the average acceleration for each section of the journey along the r velocity as 0 m/s for the first section. For each subsequent section, the start from the previous section of the journey.

acceleration = change in velocity ÷ time taken

Repeat this for each section force used.

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3. On one graph, plot the acceleration along the ramp for each 10 cm of the jou forces used. Add a key so that each force can be clearly identified.

Part B: Investigating the effect of mass on the acceleration of a trolley

Repeat the calculations of the velocities and acceleration for this part of the investiga graph showing the change in acceleration over distance for the range of masses u investigation.

Evaluation

1. For each of the two graphs, write a paragraph to describe the relationships betw

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2. Newton's second law of motio... be expressed by the formula: *force = ma*
Use your data and you... to explain whether your investigation agrees
(Force in newtons, mass in kg)

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3. Using the data for your trolley with no additional mass and a force of 0.6 N,
acceleration using the formula above.

   a. Compare this with the average acceleration over the length of the ramp

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   ....

   b. Suggest reasons why these two values are not identical.

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4. Write an evaluation of the method used for this practical to identify any sou
assumptions that might affect the repeatability or accuracy of your data. Yo
suggestion to improve either of the methods used.

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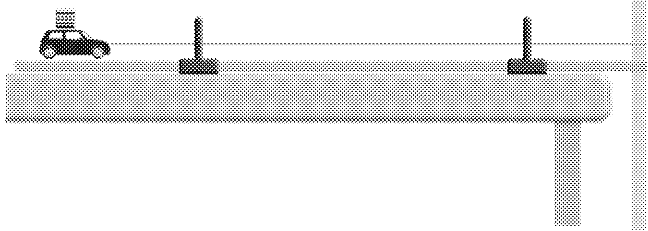
Acceleration required practical: exam-style questions

1. A toy car of mass 250 g was timed as it passed between two light gates. The
to a computer that calculated the acceleration of the toy car.



The measurements were repeated, and each time additional mass was adde
effect this would have on the acceleration of the to

The data from the computer is presented below.

Mass (g)	Mass (kg)	Acceleration (m/s^2)
1500	1.50	0.68
1250		1.05
1000	1.00	1.41
750	0.75	1.78
500	0.50	
250	0.25	2.33

a. Complete the data table by adding the missing values for mass (in kg) a

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b. Give one hazard in this practical method and suggest how the risk of inj

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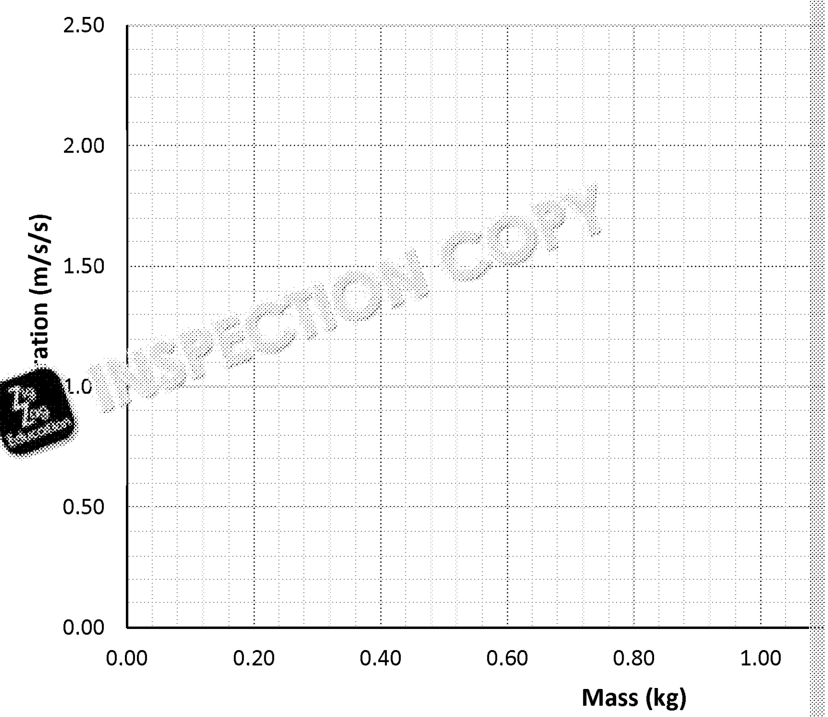
....

c. Use the axes provided to plot the acceleration against the mass in kg. I



d. Describe the pattern shown in the graph.

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2. An empty carriage for a new roller-coaster ride is tested with different level acceleration is measured using an accelerometer from a smartphone attach repeated three times for each force. The results are shown in the table belo

	Acceleration (m/s^2)			
Force (N)	**1**	**2**	**3**	**Average**
1000	8.34	8.[illegible]	8.45	8.33
2000	[illegible].53	16.76	16.72	
3000	24.97	25.06	24.97	
4000	33.00	33.28	33.71	33.33

a. C[illegible] the table by calculating the missing average accelerations.

....

....

b. Use the data from the table to calculate the mass of the carriage to the

....

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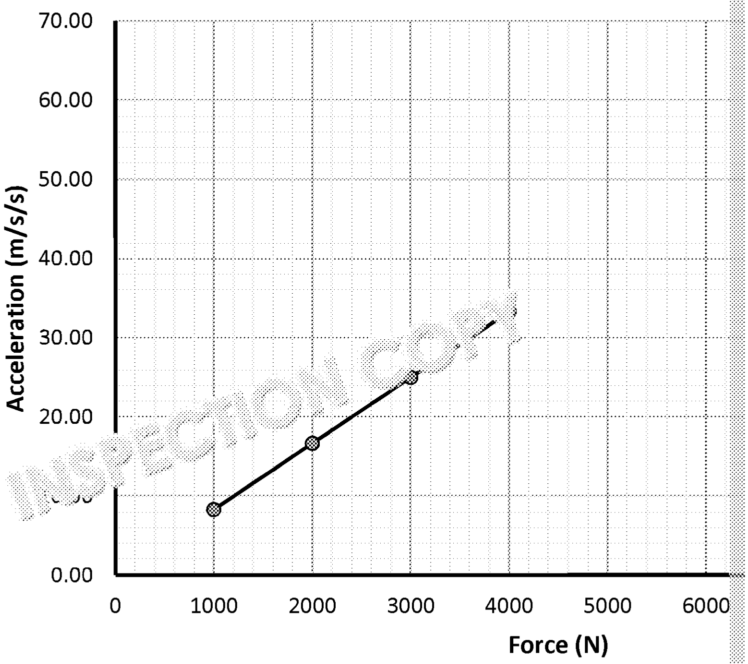
c. The higher the acceleration on the ride, the more exciting people find t above 5 G (approx. 50 m/s^2) there is a risk that the passengers will lose graph of the data below, suggest the maximum force that could be use your answer.



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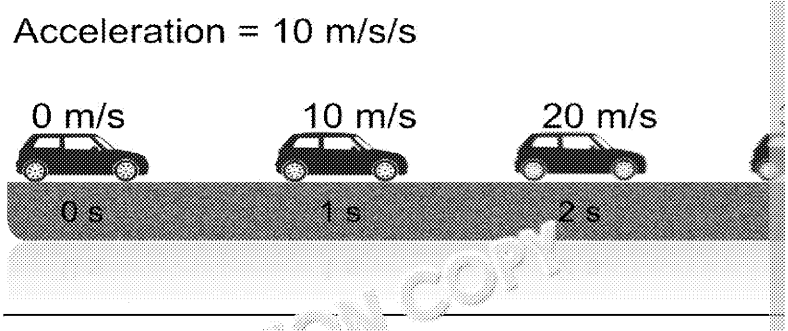
Acceleration required practical: student design sheet

Your task is to design and carry out a practical to investigate the effects of mass a
acceleration of a toy car or trolley. This should be done in two separate stages.



- Stage 1: investigate th... changing the force applied to the trolley on
- Stage 2: i...sti... ...effect of changing the mass of the trolley on its acce

It is importa... carry out each stage separately so that you are changing **<u>either</u>**
<u>both</u> at the same time; this would not be a fair test.

Apparatus available for this practical

- Stop clock / stopwatch
- Metre rulers
- Track or length of flat bench
- Trolley or toy cars
- String
- Pulley and clamp
- 10 g masses and mass holders
- 100 g masses and mass holders
- Blu-Tack
- Sellotape
- Electric balances
- Video camera

You may use any other apparatus available in your lab, <u>with your teacher's perm</u>

Your plan must include the following:

1. A complete list of the apparatus to be used.
2. A clear method that provides step-by-step instructions, either as a list or in
3. A clear statement of any hazards and how you w... ...ge these to reduce t or damage to the apparatus.
4. A diagram for the set-up of ea... ...e ...the practical. Each diagram must b
5. A results table for each ... of the practical.
6. An indica...n o... ...will process your data to find the acceleration, and final d... yo... analysis and evaluation.

Do not set up your apparatus or begin collecting data until your teacher has s

Acceleration required practical: answer sheet

Pre-lab task

1. velocity = distance travelled ÷ time taken
   velocity = 15 ÷ 3 = <u>5 m/s</u>

2. Velocity is the rate of change of displacement (distance) with respect to time, or ho
   given direction.
   Acceleration is the rate of change of velocity with respect to time, or how quickly a
   Students may also express this as how quickly an object is speeding up (slowing do
   changing direction.

3. acceleration = change in velocity ÷ time
   acceleration = (1.6 – 0) ÷ 4 = 0.4 m/s^2

4. The trolley with the lower mass will have the higher acceleration. In accordance wi
   acceleration is inversely proportional to mass for a fixed force (a = f ÷ m).

5. acceleration = change in velocity ÷ time
   acceleration = (final velocity – initial velocity) ÷ time
   final velocity = (acceleration × time) + initial velocity
   final velocity = (3 × 5) + 2
   final velocity = <u>17 m/s</u>

Analysis

Parts A and B

1 and 2. In both parts of the analysis, the answers will vary according to the student's o
student has converted their distances to metres before carrying out the calcul

3. Each graph should have a clear key so that the change in acceleration for each cond

Evaluation

1. There should be a linear trend line for both sets of data. Students should recognise
   for a fixed mass, and that there is an inversely proportional relationship for mass fo
   Allow some variance to this in light of the data actually collected by the student.

2. Students are expected to link their descriptions (in 1, above) to the formula.

3. a. The answer will depend on the student's own data; however, they will probab
   than that observed.
   b. The actual data is subject to experimental error; the calculation uses average o
   travel along the track; the real data is affected by inertia and friction.

4. Assumptions: the acceleration is constant from being to end of the journey; there is
   release of the trolley should happen at the same time as starting the stop clock, but
   Use of light gates or other data-logging solutions would improve the accuracy of the
   attaching a smartphone to the trolley and using the inbuilt accelerometers.

Exam-style questions

1. a.

Mass (g)	Mass (kg)	Acceleration (m/s^2)
1500	1[illegible]	0.68
[illegible]0	[illegible]25	1.05
[illegible]	1.00	1.41
[illegible]0	0.75	1.78
500	0.50	**2.13**
250	0.25	2.33

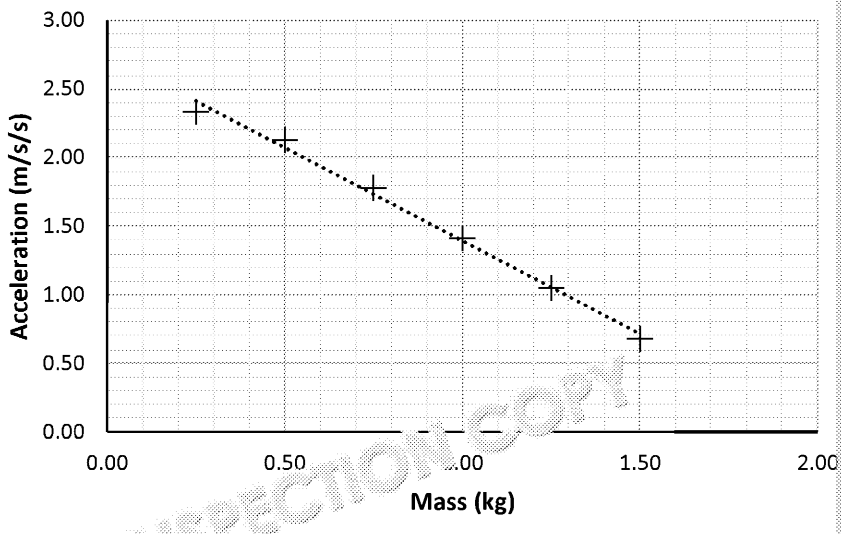
2 marks for correctly calculating all four averages; 1 mark only if two or more a
more are incorrect.

b. Possible answers include

- Injury from the falling masses. Solution: do not place hands, etc. in the way o
- Injury from the moving car. Solution do not place hands, etc. in the way o

1 mark for identifying any reasonable hazard; 1 mark for suggesting how to re

c.



- All data correctly plotted (2). Deduct 1 mark if two or more data points are … up to three data points incorrectly plotted.
- Line of best fit – as shown; straight line fitting close to the data points. (1)

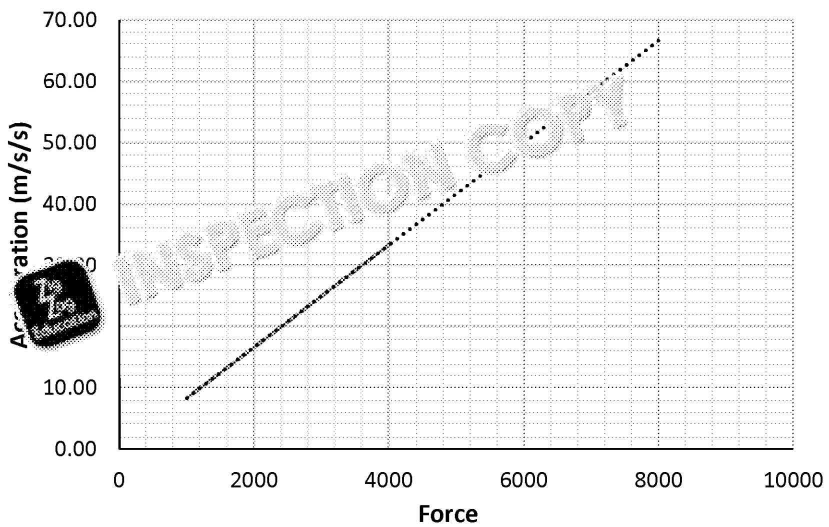
d.
- Recognition that as the mass increases the acceleration decreases. (1)
- Use data to provide examples of this. (1)
- An attempt to quantify the relationship by describing the angle of the line line of best fit. (1)

2. a.

	Acceleration (m/s²)			
Force (N)	**1**	**2**	**3**	**Average**
1000	8.34	8.20	8.45	8.33
2000	16.53	16.76	16.72	**16.67**
3000	24.97	25.06	24.97	**25.00**
4000	33.00	33.28	33.71	33.33

b. Any pair of data points from the table, using the average acceleration (1)
force = mass × acceleration
∴ mass = force ÷ acceleration (1)
mass = 1000 ÷ 8.33 (1)
mass = <u>120 kg</u> (1)

c.



Extrapolation of the line past the 50 m/s² point on the y-axis (1)
Maximum force = 6000 N (1)
Justification based on maximum force relating to this acceleration (1)

Appendix: Sample Results

Data in case the experiment does not work or a student is absent from the lesson.

Time (s)	Force (N)				
Distance (cm)	**0.2**	**0.4**	**0.6**	**0.8**	**1**
0	0	0	0	0	0
10	0.27	0.19	0.15	0.13	0.12
20	0.53	0.37	0.31	0.26	0.24
30	0.80	0.56	0.46	0.40	0.35
40	1.06	0.75	0.61	0.53	0.47
50	1.33	0.94	0.77	0.66	0.59
60	1.59	1.12	0.92	[illegible]	0.71
70	1.86	1.31	[illegible]	0.92	0.83
80	2.12	1.50	1.22	1.06	0.94
90	2.39	[illegible]	1.38	1.19	1.06
100	[illegible]	1.87	1.53	1.32	1.18

Time (s)	Mass (kg)				
Distance (cm)	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**
0	0.00	0.00	0.00	0.00	0.00
10	0.15	0.17	0.19	0.22	0.24
20	0.30	0.34	0.38	0.44	0.48
30	0.45	0.51	0.57	0.66	0.72
40	0.60	0.68	0.76	0.88	0.96
50	0.75	0.85	0.95	1.10	1.20
60	0.90	1.02	1.14	1.32	1.44
70	1.05	1.19	1.33	1.54	1.68
80	1.20	1.36	1.52	1.76	1.92
90	1.35	1.53	1.71	1.98	2.16
100	1.50	1.70	1.90	2.20	2.40

Required Practical 8: W

Teacher's notes

Before the required practical

	Trilogy	Synergy
Specification reference	6.6.1.2 Properties of waves	4.1.4.1 Longitudinal and transverse waves
AT criteria		AT 4

The purpose of this practical is fo[illegible] to measure both frequency and w
waves: one from a water [illegible] ripple tank, and the other from the standing w
measureme[illegible] used to calculate the speed of each wave.

Unlike othe[illegible]icals, it is not anticipated that the students will set up the appa
will need access to all the apparatus individually. It is suggested that the appara
class, so they gain an understanding of the equipment in use. The key aspect is t
gather the data and complete the calculations in order to satisfy AT4: *'make obse
solids to identify the suitability of apparatus to measure speed, frequency and wa*
encouraged to use the apparatus with help so they can judge its '*suitability*'.

Students should be familiar with longitudinal waves, transverse waves and the ke
formula: wave speed = frequency × wavelength → $v = f\lambda$

Included sheets

- Pre-lab task – work for the students prior to the start of the practical
- Student instructions – apparatus list and method
- Analysis and evaluation – student instructions for completing calculations, g
- Exam-style questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data

Suggested questions

- Give an example of a longitudinal wave and a transverse wave.
- What do we mean by the frequency of a wave, and what SI units are used to
- What is the amplitude of a wave?
- What units do we use to measure the wavelength of a wave?
- How do we calculate the speed of a longitudinal wa[illegible]m its wavelength a

Practical considerations

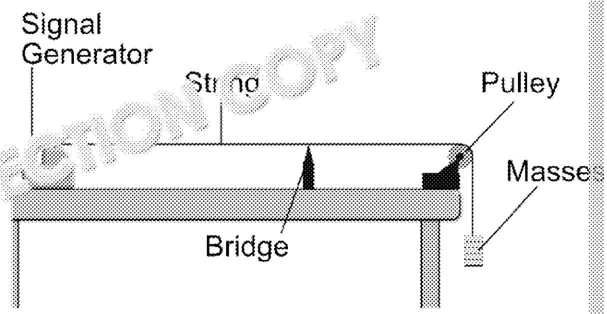
This practical is carried out in [illegible] sec[illegible]ns. Firstly, measurements are taken of a
from standing waves [illegible] string or cord attached to a signal generator. The sp
tank will de[illegible]n [illegible] version owned by the institution. It is important to be fa
prior to the [illegible]. This is also true of the standing wave in the string. It is advis
assistance of a technician in the lab for this lesson.

Given the variable designs for ripple tanks, only general instructions are provided
procedure will need to be demonstrated in class. However, it is important to allo
apparatus in order for them to be in a position to achieve AT4, as stated above.

The set-up for a standing wave machine is shown on the following page. Student
the lesson. However, they should be able to adjust the set-up to obtain a standi
teacher or the technician is acceptable.

Apparatus

- Ripple tank
- Metre rulers
- Stopwatches
- Power supply and signal/wave generator
- Masses and holder – variable as required to provide tension
- Pulley with clamp
- String/cord
- Wooden bridge/rest



The set-up needs to be adjusted to form a standing wave. This should be practis requires adjustments to the wave generated, the tension provided by the masse or rest. It can be explained to students as an analogy of tuning a guitar string to note. There is no requirement in this practical for students to understand any of waves or resonance, etc.

Timings

- **Pre-lab task** plus starter questions: **10 minutes**
- **Practical activities**: both sections will require a total of around **30 minutes**
- **Analysis: 10 minutes** to complete the calculations
- **Evaluation: 15 minutes**, plus discussion time if desired. Sheets can be colle holding a class discussion.
- **Exam questions: 15 minutes** should be allowed for this exercise

Waves required practical: pre-lab task

1. a. Draw a simple longitudinal wave, such as a string being oscillated vertic the side. Include at least two peaks and two troughs.

   b. Ac is diagram labels to indicate the following:
   - wavelength
   - amplitude

2. A girl throws a stone into a pond and it creates a series of waves heading ou She counts 10 waves reaching the edge over a period of two seconds. What in hertz (Hz)?

   ....

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   ....

3. A wave from a simple ripple tank is measured as having a distance of 25 cm students count 30 waves over a period of one minute.

   a. What is the wavelength of the wave in metres?

   ....

   b. What is the frequency of the wave? Give your answer in standard SI un

   ....

   ....

   c. Calculate the speed of the wave. Give your answer in standard SI units.

   wave speed = frequency × wavelength

   ....

   ....

   ....

4. How could you verify the measurement of the wavelength of a wave in a rip

   ....

   ....

   ....

Waves required practical: student instructions

During this practical you will measure some properties of simple longitudinal wav wave in a ripple tank, and then standing waves in a solid string or elastic cord. Yo how to measure the wavelength of these waves and determine their frequencies. asked to calculate the speed of each wave in metres per second (m/s).

> **Note**: Some of the apparatus used in this practical may be unfamiliar to you, s allowed assistance from your teacher and technicians, but **you must decide h perform your own measurements and calculatio**
>
> Throughout this practical **do not** adjust the apparatus without permission and to give the correct wave patterns can be a time-consumin

Part A: Water waves in a ripple tank

A ripple tank is a shallow basin of water with a bar resting on the water's surface generator that makes the bar vibrate. These vibrations create ripples or waves o then be observed directly or via a projection system.

Your task is to measure the wavelength and frequency of the waves in the ripple

Apparatus

- Ripple tank and projection
- Metre rulers
- Stopwatch

Method

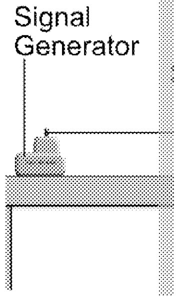
1. Your teacher will set up and turn on the ripple tank, or show you how to do s
2. Observe the wave and decide how to measure the wavelength. The wavele identical sections of the wave, i.e. between two peaks. Hint: you could coun the tank, and then measure the length of the tank.
3. Take your measurement and record the wavelength in metres.
4. Use the stopwatch to count the number of waves passing a fixed point on th minute. Record this number.

Part B: Standing waves in a solid (string)

In this part of the practical you will help set up standing waves in a string, using a task is to measure the wavelength of these waves and determine the frequency f

Apparatus

- Power supply and signal/wave generator
- Masses and holder – variable as required to provide tension
- Pulley with clamp
- String/cord
- Metre rulers
- Wooden bridge/rest



1. With assistance, set up the apparatus as shown.
2. Adjust the string to form a standing wave. This can be achieved by adjusting the masses, the position of the bridge and/or the frequency from the signal generator. A standing wave is a wave that looks as though it is not moving. It is easiest to adjust the bridge position first, then add masses *if required*. **Ask f technician if you are unsure what to do.**
3. Measure the wavelength with the ruler, then record the wavelength in a resul for four sets of data. Your table will be used to record the wavelength, freque
4. The frequency of the wave can be found from the frequency set on the sign recorded in hertz (Hz). Add this to your table of data.
5. Repeat steps 2 to 4 for three additional frequencies.

Waves required practical: analysis and evaluation

Analysis

The speed of a wave can be calculated using the following formula:

wave speed = frequency × wavelength ($v = f\lambda$)

1. Use this relationship to calculate the speed of the water wave. Show your w answer in metres per second. It is important to make sure your wavelength i in hertz, otherwise your answer will be incorrect.

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2. Use the formula to c... ...e table for the standing wave in the string at

Evaluatio

1. Describe the procedure you used to adjust the apparatus in part B of this pr with the string. What did you have to adjust, and how easy was it to do?

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2. What sources of error were there when measuring the wavelength of the w How might these be reduced?

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3. What would happen to th... ...sta... between the top of each wave in the ri remained the sam... ...th wave speed was doubled? Explain your answer

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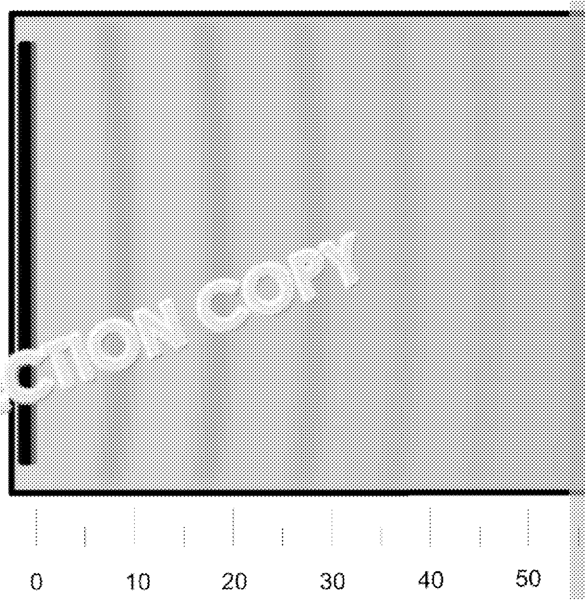
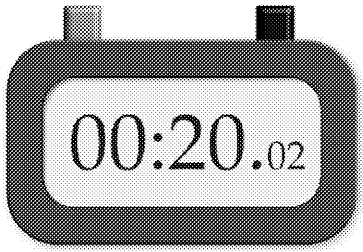
Waves required practical: exam-style questions

1. The diagram below shows the projected surface of a ripple tank with the ba the waves to the left side of the tank and a scale below.



The students observed these waves and timed how long it took for the wave Their stopwatch is shown below.



a. To the nearest second, how long did it take for the first wave to cross t

....

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b. What is the wavelength of the waves shown? Give your answer in met

....

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c. Use the information provided to calculate the speed of the wave. Use t *wave speed = frequency × wavelength*

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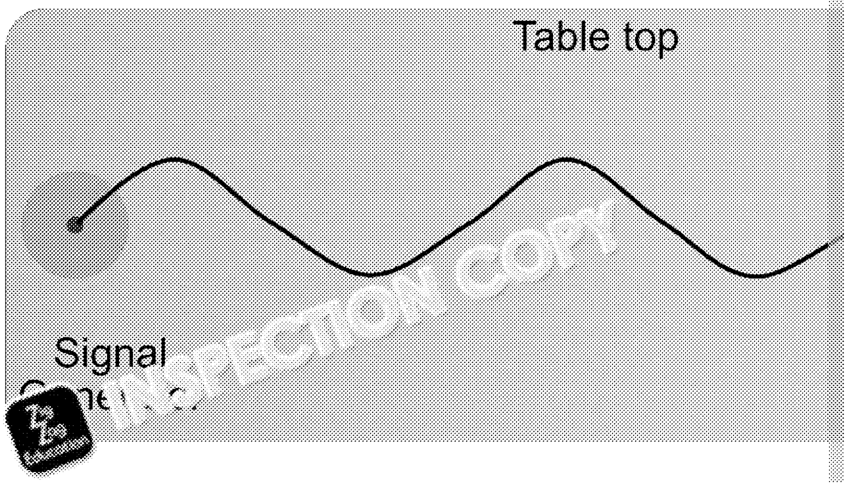
2. A student is investigating the relationship between the wavelength of a wave signal generator connected to a string held taut by weights hanging from the top. The vibration of the string is controlled by a small wooden bridge placed

The diagram below shows a plan view of the set-up with one of the waves ge



a. What apparatus would the student need to use to find the wavelength

....

....

b. Describe how the student could find the speed of the wave in this pract

....

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....

c. During this investigation, the student wishes to change the wavelength generator has a fixed frequency. Describe how they could change the s of the wave.

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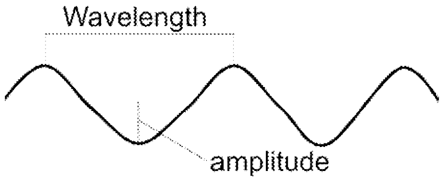
Waves required practical: answer sheet

Pre-lab task

1. a and b.



2. Frequency *(f)* = waves per second
   f = 10 waves ÷ 2 seconds = 5 Hz

3. a. 25 cm = 0.25 m
   b. 1 minute = 60 seconds
   f = 30 waves ÷ 60 s = 0.5 Hz
   c. wave speed = frequency × wavelength
   wave speed = 0.5 [illegible]
   wave speed = [illegible] m/s (ms^{-1})

4. The length of several waves can be measured, and the average found by dividing th
   The measurements could be repeated several times by different people to verify the
   Alternatively, count the number of waves visible in the tank, and then measure the l
   measurement can be repeated several times by different people to verify the meas

Answers using sample results for teacher's reference

Wave	Wavelength (m)	Frequency (Hz)	Speed (m/s)
Water wave (ripple tank)	0.034	4.80	**0.163**
String (1)	3.25	5	**16.250**
String (2)	1.45	10	**14.500**
String (3)	1	15	**15.000**
String (4)	0.6	20	**12.000**

Analysis

1. Answers will vary depending on the set-up and individual students' measurements.
   standard SI units of hertz and metres have been used in the calculations.
2. See note for 1 above.

Evaluation

1. Although the answers will vary depending on the actual set-up, the students should
   following:
   a. Adjusting the signal/vibration generator to change its frequency.
   b. Moving the bridge to change the wave.
   c. Adjusting the tension in the string by changing the masses suspended on the e
   They should make a suitable comment on the difficulties of doing each step they des

2. Common errors might include:
   - The waves are moving so it is harder to determine the exact length of the wav
     measuring several waves to find an average, can help reduce this source of err
   - Accuracy of the ruler can affect the measurements. This can be reduced by usi
     divisions.
   - Knocking the tank disturbs the waves. This can be avoided by projecting the im
     tank before taking any measurements.
   - It can be difficult to count part waves.

3. The distance between the top of each wave is a measure of the wavelength, given t
   formula:
   wave speed = frequency × wavelength
   wavelength = wave speed / frequency
   Therefore, if the frequency remains unchanged and the wave speed doubles the wa

Exam-style questions

1. a. 20 seconds (1)
   b. 0.1 m (1)
   c. frequency = waves per second
      frequency = 6 waves ÷ 20 s
      frequency = 0.3 Hz (1)
      wave speed = frequency × wavelength
      wave speed = 0.3 × 0.1 (1)
      wave speed = 0.03 m/s (1)

2. a A metre ruler (1)
   b. Either
      Find the wavelength by using a ruler and measuring the distance between two
      wave (1)
      Find the frequency from the generator (1)
      Use the formula: wave speed = frequency × wavelength ($v = f\lambda$) (1)
      Or
      Measure the distance from the generator to the bridge (1) and record the time
      distance (1). Use the formula: *speed = distance ÷ time* (1).
   c. Move position of the bridge (1) and adjust the masses (1) to give a stable w

Appendix: Sample Results

Results to use in case the practical does not work or a student is absent from the lesson.

Wave	Wavelength (m)	Frequency (Hz)	Speed (m/s)
Water wave (ripple tank)	0.034	4.80	
String (1)	3.25	5	
String (2)	1.45	10	
String (3)	1	15	
String (4)	0.6	20	

Students should be provided with the above table and asked to calculate the speeds.

Required Practical 9: Li

Teacher's notes

Before the required practical

	Trilogy	Synergy
Specification reference	N/A	N/A
AT criteria		AT 4 and AT 8

The purpose of this practical is to ... the refraction of light through two diff... angles of incidence, refl... refraction. Most commonly this will compare ... However, a... t... ...ent materials can be used.

Suggested questions

- What is the difference between reflection and refraction?
- What are the main hazards when using a ray box for light experiments?
- What is the speed of light in a vacuum?
- What happens to the speed of light as it enters a dense material such as glas
- What is the normal in a ray diagram?

Included sheets

- Pre-lab task – work for the students prior to the start of the practical
- Student instructions – apparatus list and method
- Analysis and evaluation – student instructions for completing calculations, g
- Exam-style questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data

Practical considerations

Ideally, this practical should be carried out using rectangular glass and Perspex bl... lenses for this practical as these will distort the results and make it difficult for th... of the materials on refraction.

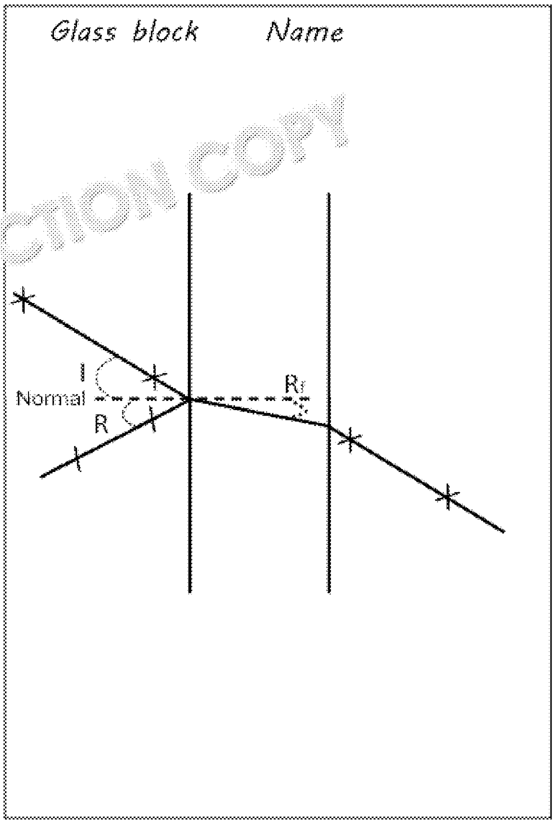
The rays of light can often be very dim on the page; therefore, it is usually necess... conditions, with blinds closed and/or lights turned off. It is, therefore, sensible to... apparatus assembled and that they have marked the ... of the block and th... the lights. Instruct the students that they should not move about the classroom v... student instructions indicate when the lights will be turned off. A general remind... practices in a lab is advisable before the start of this practical.

CAUTION

Remind students that the top of the ray boxes can become hot during use. The... this part of the box when they move it. This, and the considerations of working... conditions than normal, should be covered as part of the introduc...

Students should work in pencil and have access to an eraser for this practical. An
in the instructions and the apparatus list it is suggested that a protractor is used.
can measure to whole degrees.

At the end of the practical, the students should have two ray diagrams. On each
angle of incidence (I), the angle of reflection (R) and the angle of refraction (R_f).
add their names to their work, along with the material of the block. An example
the diagram below.



Apparatus

- Ray box
- Single slit grating
- Pencil
- Eraser
- 2 × A4 sheets of plain paper
- 30 cm ruler
- Protractor
- 2 × transparent blocks of different materials [illegible] glass, plastics, Perspex, etc.

Each student will need access to all the apparatus. Students need only one trans
can be shared.

Timings

- **Pre-lab task** plus starter questions: **10 minutes**
- **Practical activities:** both sections will require a total of around **20 minutes**
- **Analysis: 10 minutes** to complete the measurements
- **Evaluation: 15 minutes**, plus discussion time if desired
- **Exam questions: 15 minutes** should be allowed for this exercise

Light required practical: pre-lab task

1. When a person looks into a plain mirror, they see an image of themselves. W to the light to form this image?

....

....

....

....

....

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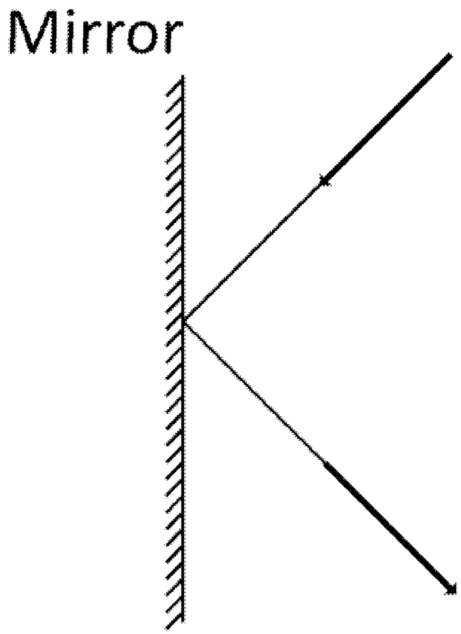
2. The diagram below shows a ray diagram for a plain mirror. Add a normal to th this 'N' ... and the angle of incidence (label this 'I') and the angle of re



3. Glass has a higher refractive index than Perspex. When a ray of light is shon will be refracted. Predict which material will result in the greatest angle of r

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Light required practical: student instructions

During this practical you will shine a ray of light from a ray box into two blocks m
materials. Your task is to measure the angles of incidence, reflection and refract
compare the effect on the light of the two materials.

CAUTION

The ray box will become hot during use. Handle with care and avoid touch

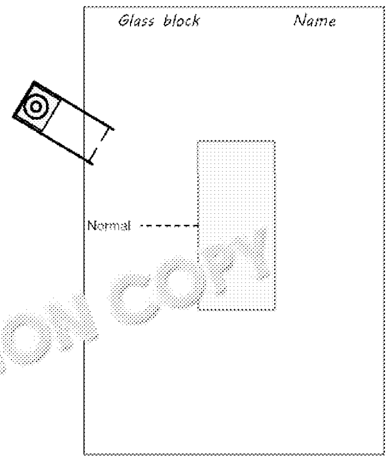
During this practical you will need to work with the lights turned off or turned
class during this time. Work at your own bench with your ow

Apparatus

- Ray box with a single sl... in...
- Pencil
- Eraser
- 2 × A4 ... of plain paper
- 30 cm ruler
- Protractor
- 2 × transparent blocks of different materials – glass, plastic, Perspex, etc.

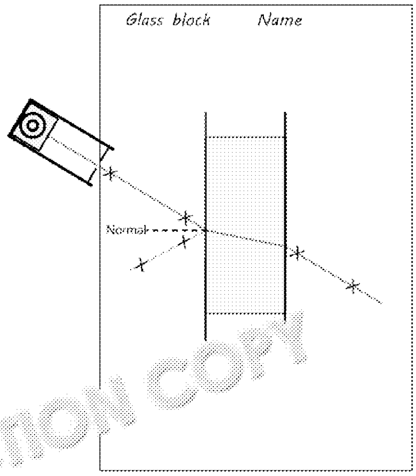
Method

1. Place a piece of plain A4 paper flat on the desk. Write your name at the top
   your first block is made from.
2. Place your block in the centre of the A4 paper. Using a **pencil**, mark the two
   whole block.
3. Draw a *normal* line halfway down the left-hand side of the block. This shoul
   (90°) to the edge of the block.
4. Plug in the ray box and place it near the edge of the paper. Place the single s
   ray box. Aim it so that the ray of light will shine on the point where the nor
   the block. See the diagram below.

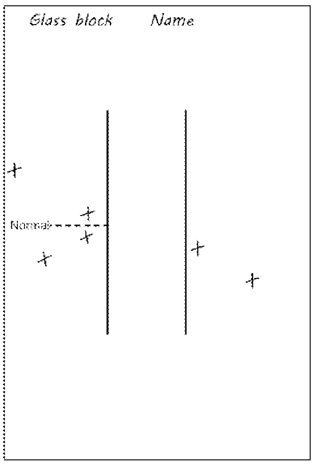


5. Turn on your ray box. Your teacher will now dim the lights to make it easier
   Adjust the ray of light so that it intersects with the normal and the edge of th
   following positions, ensuring that the middle of each cross is in the centre o
   i. Close to the point where the ray exits the ray box
   ii. Close to the edge where the ray enters the block
   iii. Close to the point where the ray exits the block on the opposite side
   iv. About 3 cm or 4 cm along this ray, after it has exited the opposite side o
   Find the pale ray of light that has '<u>reflected</u>' off the surface where the n

v. Add two crosses to the reflected ray, similar to the crosses previously d
See the diagram below as an example of how your work should look.



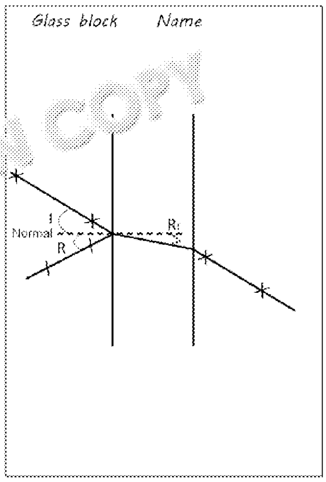
6. Turn off the ray box and carefully move it to one side. Remove the block fro
look similar to the diagram below.



7. Using a ruler and a pencil, join up the crosses to show the path of the rays o
the block area as shown.

Label the following angles:

i. angle of incidence – I
ii. angle of reflection – R
iii. angle of refraction – R_f



8. Repeat the method using the second block of a different material. Use a fre

It is important to keep the angle of incidence the same for b

9. Unplug the ray box and leave it to cool before packing it away.

Light required practical: analysis and evaluation

Analysis

1. Draw a simple table in which to record your results. You will be measuring t the method for each of the two materials.

2. Measure the angles of incidence, reflection and r... ...ic... on both ray diagra are measured between the ray of light ...n...t... ...e ...nal. Add these results to

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Evaluation

1. Compare the angles of **reflection** for both materials. What can you say abou

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2. Compare the angles of **refraction** for the two materials. What can you say a

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3. Comment on the reliability of your measurements. Were there any sources

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4. Compare your results with the resu... ...o ...her students in your class. D results? Comment on how t... ...r ... compare to your own, and what this your own measurem...

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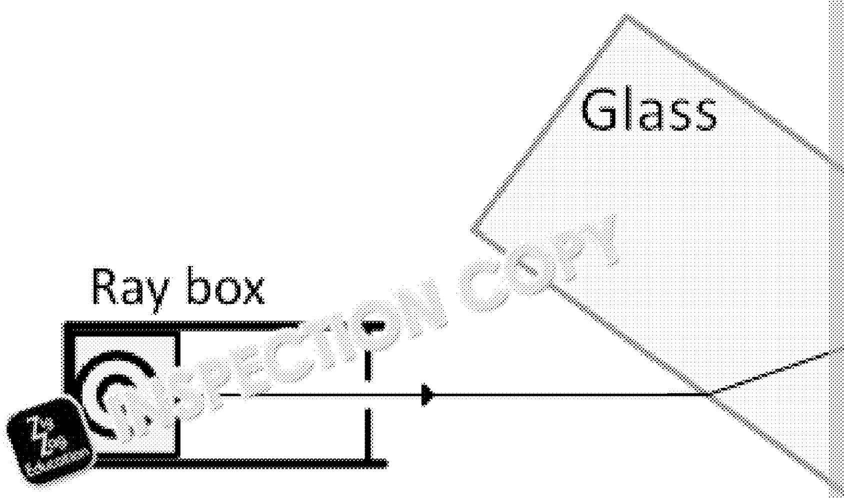
Light required practical: exam-style questions

1. The diagram below shows part of a ray of light incident on a block of clear gl

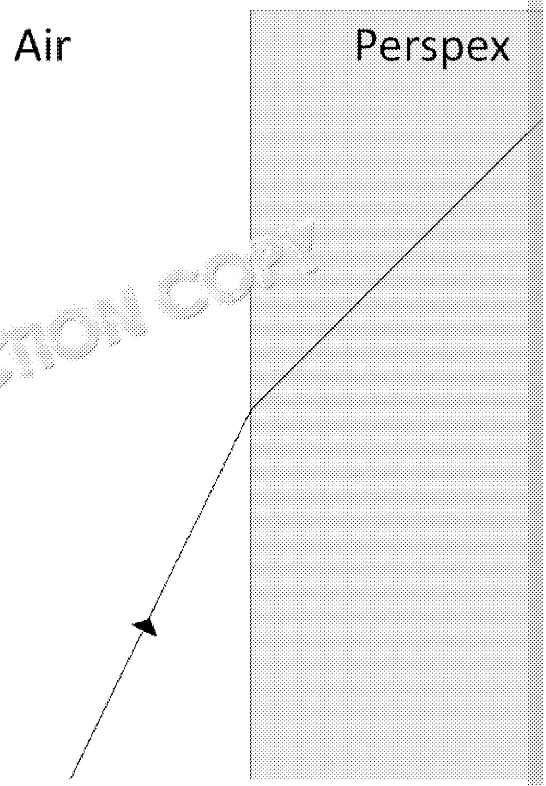


   a. Add a normal to the diagram at the point where the ray of light is incid
   that it can be used to measure the angles of incidence and refraction. L

   b. Add a line to represent the ray of light as it exits the glass block. Label t

   c. Draw in the ray of reflected light. Label this 'RL'.

2. A ray of light is shone from the air into a block of Perspex. The diagram belo
these two materials and the ray of light.



a. Determine the angle of refraction. Show on the diagram how you have

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b. A student wishes to investigate how the angle of refraction changes wit materials. They have access to blocks of Perspex, glass and a clear acryl

Write a method for this investigation, giving a full list of apparatus. You measure the angle of refraction for each material.

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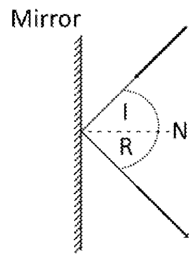
Light required practical: answer sheet

Pre-lab task

1. The light has been reflected from the boundary between the two different materials mirror.
2. 

3. Glass – the greater density results in a greater change in the speed of the light and, t refraction.

Analysis and evaluation

Analysis

1. Suggested table structure is shown on the previous page.
2. Values will vary with the angles of incidence used and the materials. However, the a to the angle of incidence.

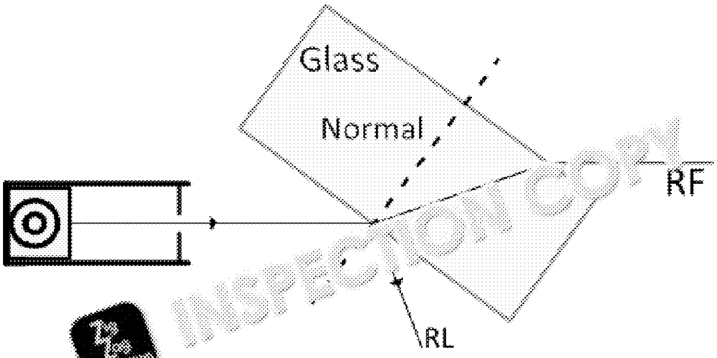
Evaluation

1. The two values should be identical in both materials.
2. One of the angles will be greater than the other. Typically, glass will produce a grea and Perspex, but this can vary.
3. Students must comment on their results and the degree to which they have measur they completed the diagrams. Common sources of error include:
   - not placing the crosses in the centre of the ray of light
   - the ray of light being very dim and hard to map
   - the normal not being at right angles to the medium interface
   - measuring the angles from the ray to the medium interface rather than to the r
4. Students should comment on the degree to which the pattern in the other students' Although the values will differ, they should all see that the angles of incidence and re angle of refraction is different for the two materials. They should make a sensible co work is accurate, based on the similarities in the patterns in the other students' wor

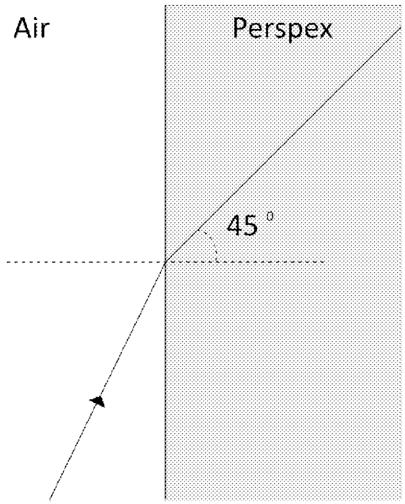
Exam-style questions

1. a. The normal should be drawn at right angles to the glass block surface at the po the glass (1). The normal extends inside the block (1).
   b. The line labelled 'RF' should exit the glass and be parallel to the ray of incidenc
   c. The ray 'RL' should emanate from the point where the ray of incidence touches refraction must be equal to the angle of incidence (1).

   Diagram for a, b and c.



2. a.



   Normal line at right angles to the medium interface (1)
   Angle correctly identified and measured from the normal to the ray (1)
   Angle measured as 45° ± 2° (1)

   b. Level 3: The method would lead to the production of a valid outcome. All key sequenced. (5–6 marks)
   Level 2: The method would not necessarily lead to a valid outcome. Most step not fully logically sequenced. (3–4 marks)
   Level 1: The method would not lead to a valid outcome. Some relevant steps a clear. (1–2 marks)
   No relevant content: 0 marks

   Indicative content

   - Use of a single ray of light from a suitable light source
   - Means by which the rays of light can be marked and recorded for measur
   - Construction of a normal to material at the point of intersection of the ray of li
   - Recognition that the angles are measured from the normal to the ray of li
   - A suitable list of apparatus
   - Same method used for all three materials

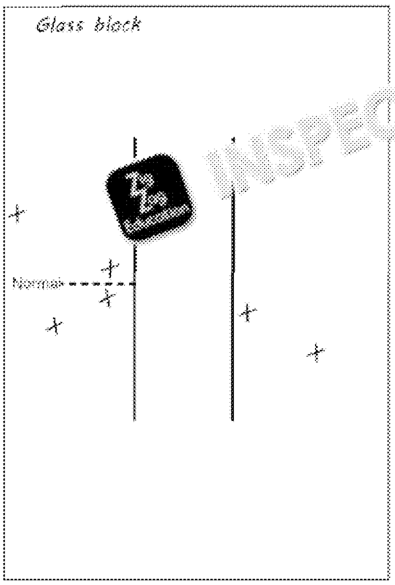
Appendix: Sample Results

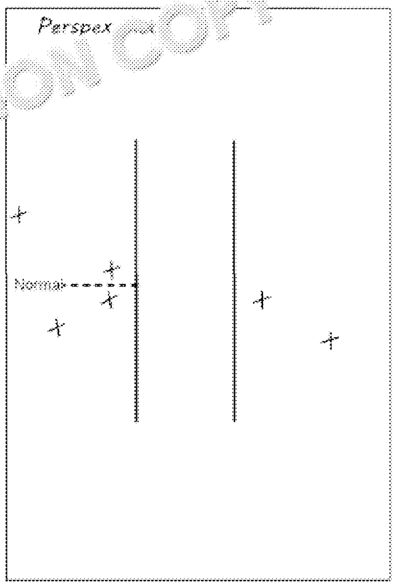
Results in case the practical does not work or a student is absent from the lesson.

	Angles		
Material	**Incident**	**Refraction**	**Reflection**
Glass	20.0	14.5	20.0
Perspex	20.0	12.0	20.0

Alternatively, the student(s) can be given the diagrams below and asked to perform their

Example results for a glass block and a Perspex block





Required Practical 1(
Radiation and Absorption – Le

Teacher's notes

Before the required practical

	Trilogy	Synergy	
Specification reference	6.6.2.2 Properties of electromagnetic waves	4.1.4.3 Electromagnetic waves	
AT skills	AT 1 and AT 4		

The purpose of this practical is to compare the intensity of infrared radiation emi
Leslie cube. This is a metal cube with four different surfaces – usually a matt bla
silvered surface, a matt white surface and a gloss white surface.

Included sheets

- Pre-lab task – work for the students prior to the start of the practical
- Student instructions – apparatus list and method
- Analysis and evaluation – student instructions for completing calculations, g
- Exam-style questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data

Suggested questions

1. Name the parts of the electromagnetic spectrum.
2. How is infrared radiation detected by the human body?
3. What happens to the energy of electromagnetic radiation when it is absorbe
4. Although the human eye cannot detect infrared radiation, what can we use t
5. What happens to the wavelength of an EM wave as the energy carried by th

Practical considerations

It is not a requirement that each student should have individual access to a Leslie
However, it is advisable to allow the students to help collect the data and to mak
should be collected.

Please remind students that the cube will be filled with hot water and should be h
always be kept on a heatproof mat (when filled or empty) as a matter of good

Ideally, the radiation emitted should be measured using an infrared detector wit
possible to measure the radiation emitted from each surface using a standard gl
using this approach, the bulb of the thermometer will need to be painted with m
less reliable and accurate than using a digital infrared detector.

Whichever method is used to measure the level of infrared radiation, it is import
between the surface of the Leslie cube and the detector / thermometer bulb is k
measurements. Although the cube will retain heat for a reasonable amount of ti
the data is protracted it may be necessary to refill the cube with hot water. Plea
of the water is kept constant to ensure that it is a fair comparison.

Apparatus

- Leslie cube
- Kettle
- Infrared detector with meter or suitable alternative
- Heatproof mat
- 30 cm ruler

Although providing these for individuals or small groups would be ideal, this can b
with the students making decisions about how to collect the data.

Timings

- **Pre-lab task** plus starter questions: **10 minute**
- **Practical activities**: around **20 minutes**, including time for the students to h
- **Analysis: 10 minutes** to complete the measurements
- **Evaluation: 10 minutes** plus discussion time if desired
- **Exam questions: minutes** should be allowed for this exercise

Radiation and absorption required practical: pre-lab task

1. During this practical you will be using a metal cube filled with hot water, kno
What are the hazards associated with using this apparatus? How can you e
the class remain safe?

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2. a. L[illegible] he [illegible] e cube you will be using. Which surface do you think w
en[illegible] nd which the least?

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b. Justify your choice. You can refer to scientific explanations and example
help explain your ideas.

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Radiation and absorption required practical: student instr

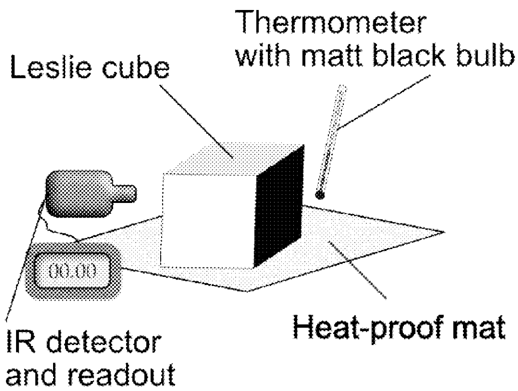
During this practical you will be using a device called a Leslie cube. This is a meta different surfaces. The cube is filled with hot water, and the amount of infrared surface can be measured using an infrared detector or a standard thermometer

Apparatus

- Leslie cube
- Kettle
- Infrared detector with meter or suitable alternative
- 30 cm ruler
- Heatproof mat

Method

1. You will be measurin… of infrared radiation emitted from each o cube. Yo… ill … is process to verify your measurements. Create a ta The ur… w… use will depend on the measuring apparatus, so check thi
2. Place t… e on the heatproof mat. Carefully fill it with boiling water fron
3. It is important to take the readings at the same distance from the surface ea distance for your experiment, take some preliminary readings from one of t Use this data to choose the distance you will use in your investigation.
4. Place the detector in front of the first surface and measure the amount of ra



5. Repeat the process for each of the different surfaces of the cube.
6. Carefully empty and refill the cube to repeat the process to gain a second se temperature is the same each time.

Radiation and absorption required practical: analysis and e

Analysis

1. Calculate an average for the amount of radiation detected for each surface.

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2. Present your data in a suitable chart. (As the input variable is discontinuous simple bar chart.)

Evaluation

1. At what distance did you place the detector from the cube to take your readi referring to your preliminary data in your answer.

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2. Your response to pre-lab question 2 forms a simple hypothesis for this invest comment on your prediction. State whether your original idea is supported has happened?

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3. Use your scientific understanding about radiation, absorption and emission t

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4. Compare the two sets of data that you collected on each surface. What doe reliability of your data?

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5. Suggest an improvement to the method that could increase the accuracy of t

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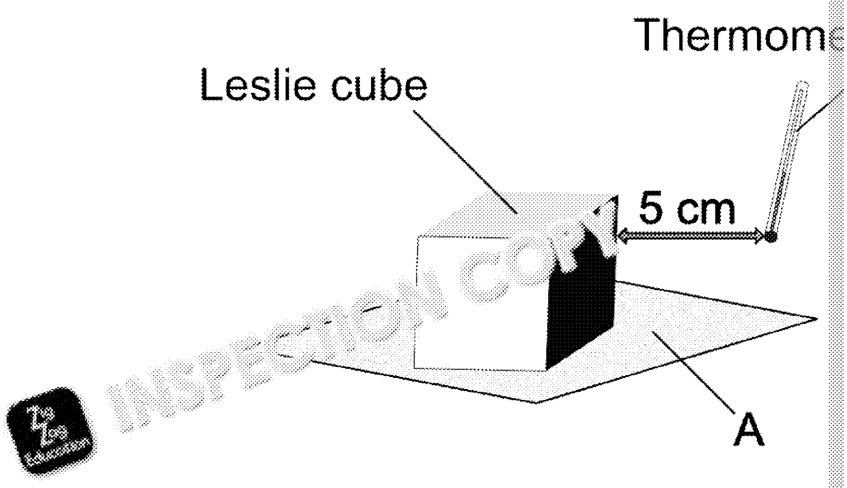
Radiation and absorption required practical: exam style qu

1. A student sets up a Leslie cube as shown in the diagram below. The cube ha different finish: matt black, shiny black, matt white and shiny white. The dia black and the matt white surfaces. The top and bottom of the cube are not



The set-up above shows the thermometer being held at a distance of 5 cm fr

a. What is the name of the item labelled 'A' in the diagram?

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b. When the thermometer is moved to take a measurement from the whi from the surface should the thermometer be placed?

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The student took readings from four of the surfaces, each of which had a dif their readings three times. Their data is shown in the table below.

	Temperature (°C)			
Surface	**1**	**2**	**3**	**A**
Black – Matt	50.5	[illegible]1.0	51.5	
White – Shiny	2[illegible].5	23.5	22.5	
White – Matt	29.0	27.5	26.5	
Black – Shiny	32.5	34.0	33.5	

c. Calculate the missing averages to one decimal place to complete the ta

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d. Draw a graph of the results.

e. Which set of data is the **least** reliable? Justify your answer.

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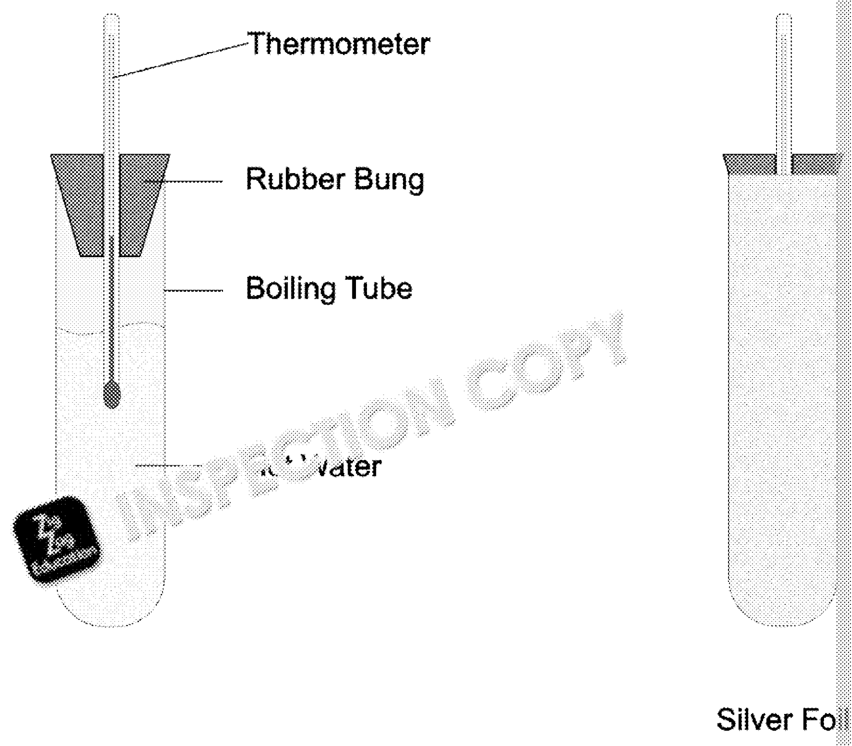
2. Two boiling tubes are set up containing hot water, a thermometer and a bun silver foil and the other with a thin layer of matt black paper. The foil and th



Describe a method that could be used to compare how the two surfaces affe radiation emitted by the two tubes over a given period of time. Your metho ensure this is a fair test and how the results will be collected. You should als considerations. Include a list of any **additional** apparatus your method requ

Radiation and absorption required practical: answer sheet

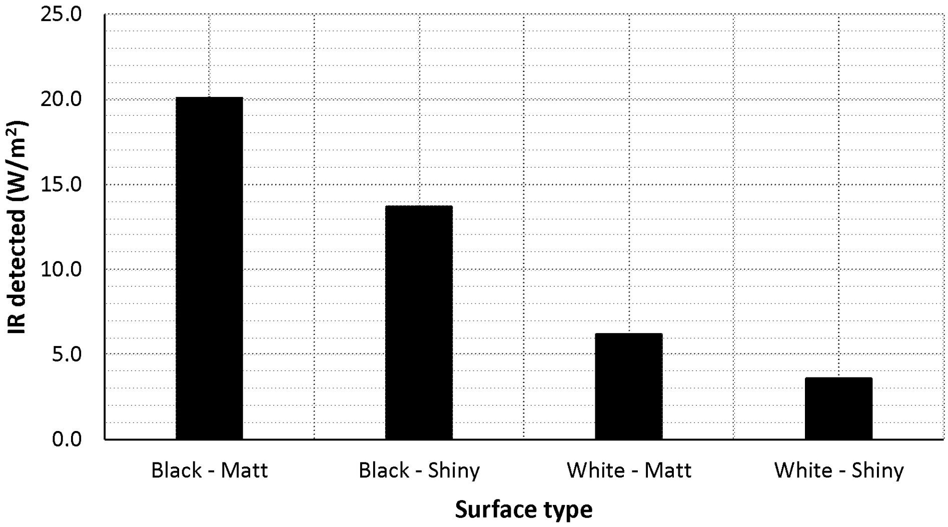
Pre-lab task

1. Hazards – hot water, the cube will become hot
   Handle with care; keep on a heatproof mat; use heatproof gloves when handling

2. a. This will depend on the cube being used and the student's opinion; however, t
   more energy than the paler gloss surfaces.
   b. Students can link their ideas to theory and to ideas from everyday experience,
   hotter than white/shiny ones in the sun. At this stage their ideas do not have t
   based on a reasoned opinion to form a basic hypothesis for the practical.

Answers using sample results for teacher's reference

	Infrared radiation level (W/m^2)		
Surface	**1**	**[illegible]**	**Average**
Black – Matt	[illegible]	20.4	20.1
Black – Shiny	[illegible]	13.2	13.7
White – Matt	6.4	6.0	6.2
White – Shiny	3.1	4.1	3.6



Analysis and evaluation

Analysis

1. Check averages have been calculated correctly; these will vary depending on appara
   measurements.
2. The data should be in the form of a bar chart – see [illegible] below (using data from the

Evaluation

1. The student should re[illegible] preliminary data to justify the distance they choos
2. The stud[illegible] their actual results to their answer to pre-lab 2; their b
   identif[illegible] degree their data supports their prediction, and recognise any varia
3. Black su[illegible] heat up faster than white/shiny surfaces; this results in them reradiat
   surfaces absorb a greater range of the spectrum than white surfaces do. This also le
   of that radiation, including the infrared part of the spectrum.
4. Answers will vary. Students should recognise that the closer in value the readings a
   reliable that set of data is.
5. This might include: using an infrared detector if the thermometer was used; using a
   shielding the cube to reduce the impact of ambient radiation interfering with the re
   distance from the detector to the cube.

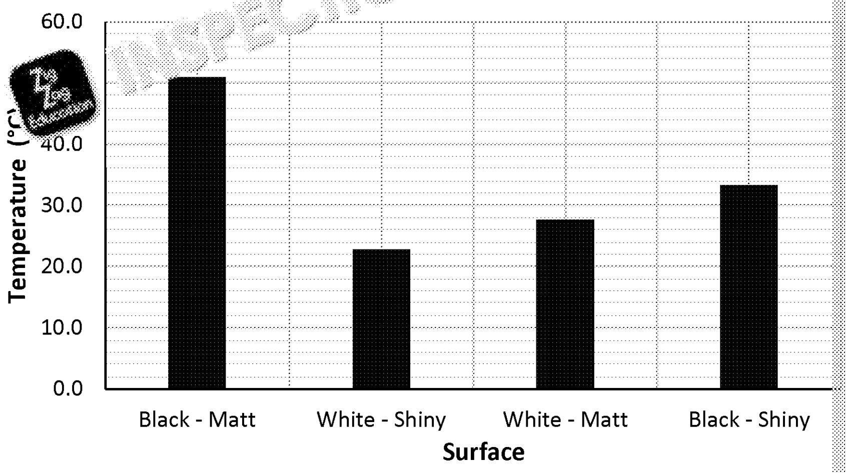
Exam-style questions

1. a. Heatproof mat (1)
   b. 5 cm (1)
   Accept: Same distance as for other reading.
   c.

	Temperature (°C)			
Surface	**1**	**2**	**3**	**Average**
Black – Matt	50.5	51.0	51.5	**51.0**
White – Shiny	22.5	23.5	22.5	22.8
White – Matt	29.0	27.5	26.5	**27.7**
Black – Shiny	32.5	34.0	33.5	33.3

2 marks for both averages correct; 1 mark if one average is incorrect; 0 marks if
is no requirement from the candidate to display the calculations.
Deduct 1 mark if the answers are **not** rounded.

   d.



Correct axes with labels (1)
Even scale on y-axis (1)
Averages correctly plotted (2) – 0 marks if the data is presented as a line chart

   e. Data for the white matt surface (1); this set of data has the greatest variance o

2. Level 3: The method would lead to the production of a valid outcome. All key steps a
sequenced. (5–6 marks)
Level 2: The method would not necessarily lead to a valid outcome. Most steps are i
fully logically sequenced. (3–4 marks)
Level 1: The method would not lead to a valid outcome. Some relevant steps are ide
clear. (1–2 marks)
No relevant content: 0 marks

Indicative content

- States a given volume of water
- States a temperature for the water or that the temperature must be the same
- Measures temperature drop over a stated period of time.
- Includes an instruction to repeat the data collection at least twice
- Safety considerations: handling hot water

Appendix: Sample Results

Data in case the experiment doesn't work or a student is absent from the lesson.

	Infrared radiation levels (W/m^2)		
Surface	**1**	**2**	**Average**
Black – Matt	19.8	20.4	
Black – Shiny	14.2	13.2	
White – Matt	6.4	6.0	
White – Shiny	3.1	4.1	

Additional Practical
Specific Latent Heat – Melti

Teacher's notes

Before the practical

This practical is **not** a requirement of the AQA specification. In this practical, stud change in temperature of ice as it melts. There is no requirement in this part of th of the latent heat of fusion for water. The end product is a temperature–time gra identify the point at which the ice is melting and changing state.

This is a good extension for AQA practical 1 – investigating the specific heat capac

Included sheets

- Pre-lab task – work for students prior to the start of the practical
- Student instructions – apparatus list and method
- Analysis and evaluation – student instructions for completing calculations, g
- Exam-style questions – GCSE-style questions focused on the practical
- Answer sheet – answers to all questions, including a set of example data

Suggested questions

1. What is the melting point of pure water?
2. What happens to the temperature of water as it changes to ice?
3. When using a Bunsen burner, what flame (air hole position) should be used f
    - a safety flame?
    - gentle heating?
    - rapid heating?
4. Name two pieces of apparatus that should always be used with a Bunsen bu
5. What happens to the arrangement of the molecules of water as it melts?

Practical considerations

The normal safety considerations of heating using a Bunsen burner apply to this p specifics of Bunsen burner safety, if required. It is not advisable to heat the conta melt too rapidly, making it harder for the students to collect a clear set of data.

The student instructions suggest the use of a boiling tube, but a 50 ml beaker can be that the ice is crushed prior to the lesson as this helps give a more consistent set of re

Remind students NOT to heat the apparatus with the safety flame.

Apparatus

- Boiling tube
- 250 ml beaker
- Thermometer
- Heatproof mat
- Tripod and gauze
- Clamp stand and clamps
- Stopwatch
- Bunsen burner

Students will require their own graph paper.

Timings

Pre-lab task: minutes
Practical: allow 20 minutes
Analysis: 20 minutes to draw graph, add a trend line and complete calculations
Evaluation: 15 minutes, plus discussion time if desired. Sheets can be collected i holding a class discussion.
Exam-style questions: 15 minutes

Specific latent heat required practical: pre-lab task

1. What happens to the structure of a solid as it melts to form a liquid?

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2. Draw diagrams to represent a particle model for a solid and a liquid.

3. When thermal energy is absorbed by a melting solid, what does this energy d

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Specific latent heat required practical: student instruction

During this practical you will gently heat a sample of ice and record the temperat period of around 10 minutes. This will allow you to produce a graph to see how t changes as it melts.

Apparatus

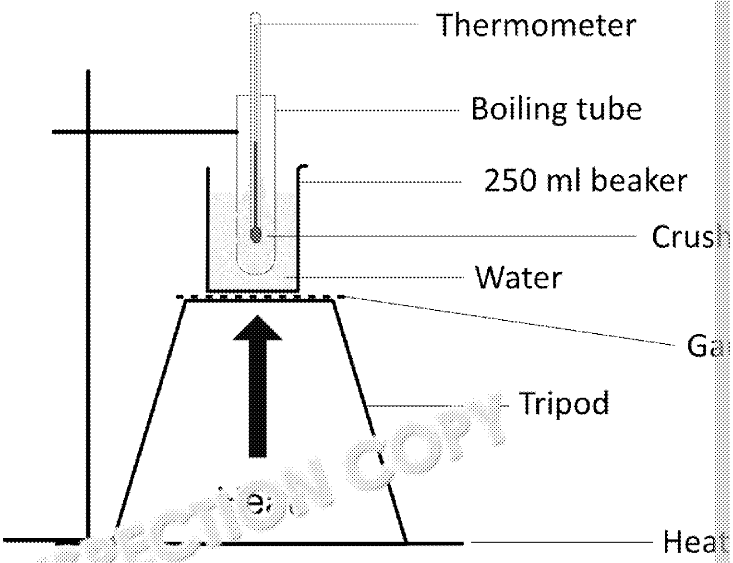
- Boiling tube
- 250 ml beaker
- Thermometer
- Heatproof mat
- Tripod and gauze
- Clamp stand and clamps
- Stop clock
- Bunsen burner
- Goggles

Method

CAUTION!

Always wear goggles when heating. Tie back long h
Place the Bunsen burner and other apparatus on a hea
Do not heat any apparatus using the safety flam

1. Draw a results table in which to record your data. You will be measuring the period of at least 10 minutes.
2. Set up the apparatus as shown in the diagram.



3. Recor[d the te]mperature of the ice at the start of the investigation **before** th
4. Light the Bunsen burner and use a low flame with the air hole half open. St heating the water bath and ice.
5. Record the temperature of the ice every minute for at least 10 minutes, or u
6. Turn off the Bunsen burner and leave to cool before tidying away the appar

Specific latent heat required practical: analysis and evalua

Analysis

1. Draw a graph showing how the temperature of the ice changed over time.

2. Draw a trend line to show the pattern of change in temperature.

Evaluation

1. Mark a coloured line across the graph to show the melting point of pure ice.

2. Describe how the temperature has changed over the period of time illustrat

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3. What happens to the temperature of ice as it melts to form water?

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4. Why was the boiling tube of ice placed in a beaker of water before heating?

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5. The theoretical melting point of pure ice is 0 °C. Did your sample of ice melt suggest a reason why not.

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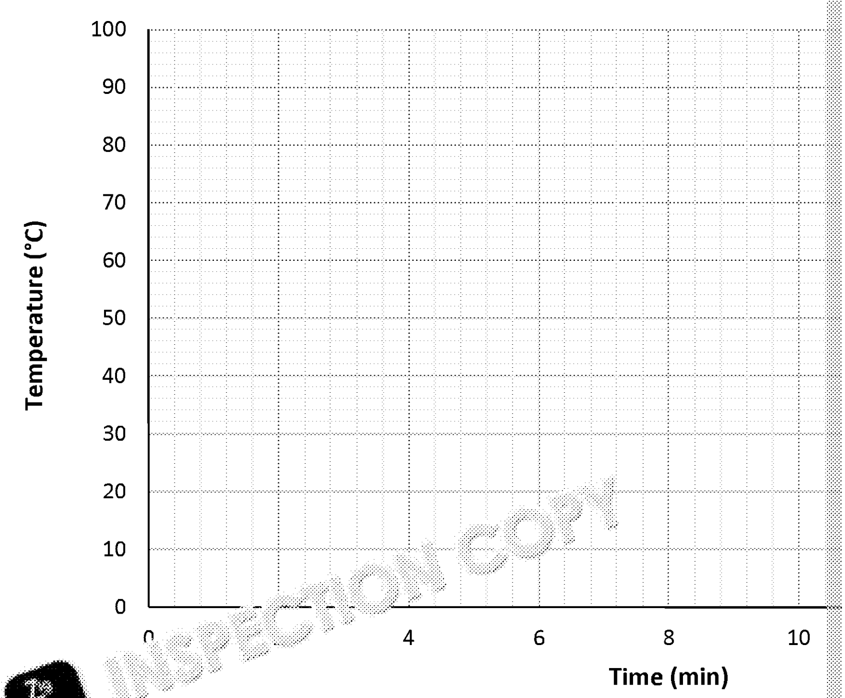
Specific latent heat required practical: exam-style questio

1. A boiling tube containing liquid paraffin wax is allowed to cool until solid. T
temperature changes over a period of 15 minutes.

Time (min)	Temperature
0	90
1	88
2	83
3	80
4	80
5	80
6	80
7	80
8	80
9	78
10	77
11	74
12	68
13	62
14	57
15	51

a. Use the data presented in the table to complete the graph to show the c



b. Draw a trend line on the graph.

c. Use the graph to find the melting point of the sample of paraffin wax.

Melting point of the paraffin wax: ____________________ °C

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d. Name two pieces of safety apparatus required for any practical involving t

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2. A student wishes to investigate the effect of dissolved salt (NaCl) concentrat
of water by observing the effect on the melting point of the samples which h
for the student.

Sample A: Ice made from distilled water ([illegible] % NaCl)
Sample B: Ice made from 1 % NaCl solution
Sample C: Ice made from [illegible] NaCl solution

a. Describe a method the student could use to carry out this investigation.
prepared in advance; you do not need to describe how these are prepa
an apparatus list and a labelled diagram.

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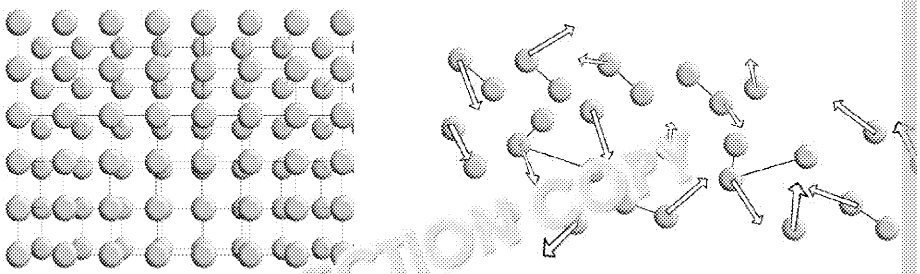
Specific latent heat required practical: answer sheet

Pre-lab task

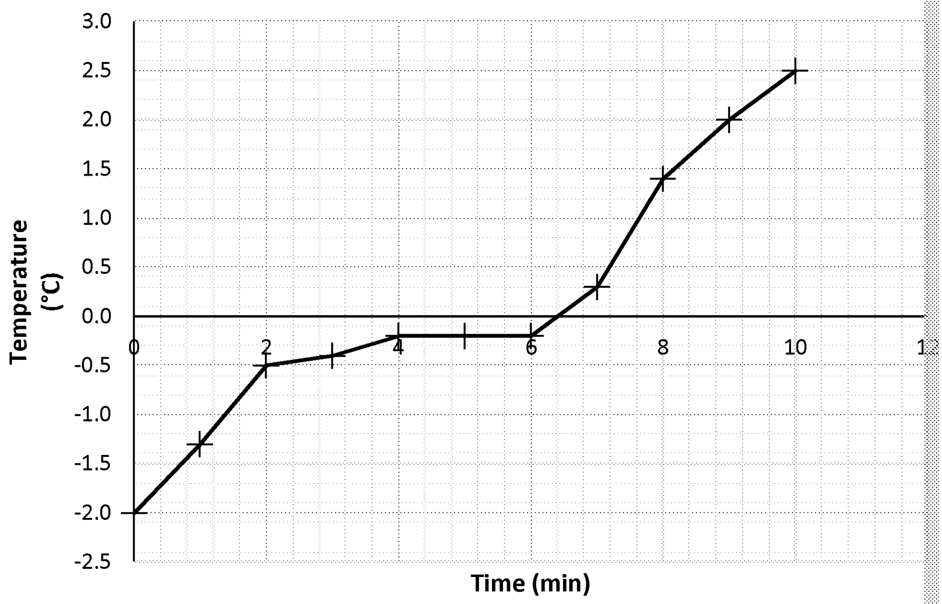
1.
- The bonds between the particles are broken.
- The particles move faster as they absorb thermal energy (their kinetic energy in
- The particles spread out.

2.



Solid (lattice) Liquid

3. The thermal (heat) energy helps to break the bonds between the particles. (During t change in the temperature of the substance; the thermal energy does not result in a the substance – latent heat of fusion.)



Analysis and evaluation

Analysis

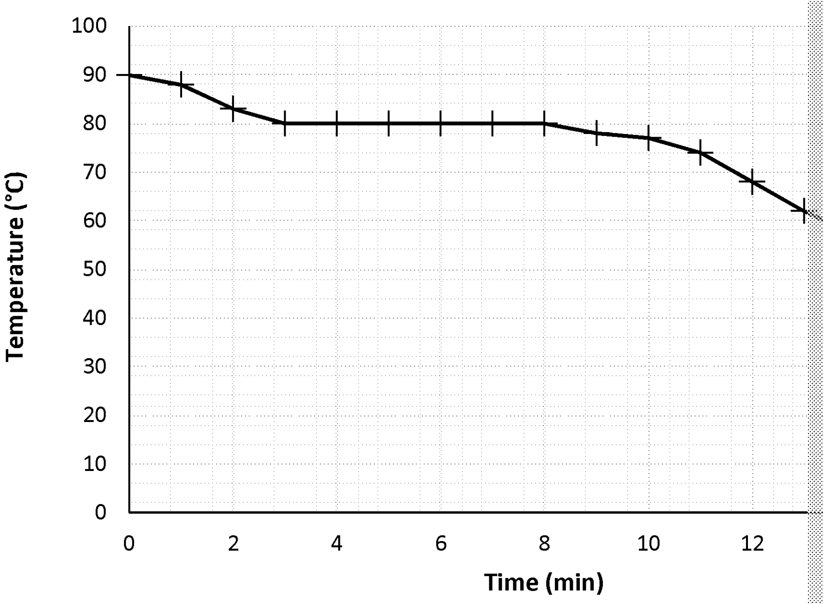
1 and 2. See example above; actual values will differ.

Evaluation

1. The coloured line should run across the graph at 0 °C.
2. The key features for the students to identify are:
   - the gradual rise from the starting temperature to the point at which the ice me
   - the point and value at which the line levels off – the melting point of the samp
   - the gradual rise in temperature after the ice has melted
3. There is no change in temperature as the ice melts.
4. The beaker of water acts as a water bath to allow a more controlled and gradual inc
5. Although it is possible that the melting point of the student's sample of ice was exa from tap water, which is impure. This causes a small change in the melting point – caused by the solutes in the water, for example, putting salt on icy pavements to mel

Exam-style questions

1. a.



   2 marks for all data points correctly plotted; 1 mark if two or more are incorre incorrect.

   b. Line draw as shown above. (1)

   c. Students should draw or mark on the graph the melting point. (1)
   Note: Allow both marks if the student identifies the correct melting point withou
   Value = 80 °C (1)

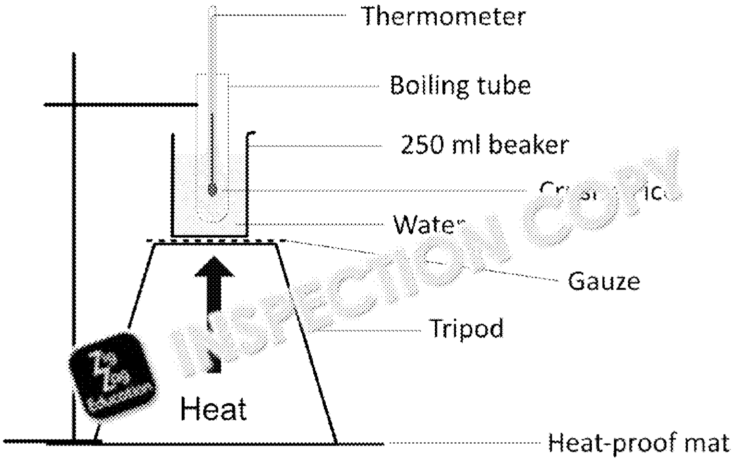
   d. Any from:
   - Heatproof mat
   - Goggles or other eye protection
   - Heatproof gloves

   1 mark per answer. Do not allow any item used to tie up long hair – this is not

2. Level 3: The method would lead to the production of a valid outcome. All key steps sequenced. (5–6 marks)
   Level 2: The method would not necessarily lead to a valid outcome. Most steps are fully logically sequenced. (3–4 marks)
   Level 1: The method would not lead to a valid outcome. Some relevant steps are id clear. (1–2 marks)
   No relevant content: 0 marks

Indicative content

- Labelled diagram
- Apparatus list
- Describes how to monitor the temperature of the ice, using a thermometer or
- Specifies either a reasonable time (10 minutes) or until the ice has fully melted
- A reference is made to safety or risk assessment/management
- Use of a water bath or other means to control the temperature increase



Example of diagram and indication of typical apparatus.

Appendix: Sample Results

Data in case the experiment doesn't work or a student is absent from the lesson.

Time (min)	Temperature
0	-2.0
1	-1.3
2	-0.5
3	-0.4
4	-0.2
5	-0.2
6	-0.2
7	0.3
8	1.4
9	2.0
10	2.5

Data obtained with a digital thermometer.