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# Getting Started

## GCE Physics

## Edexcel Advanced Subsidiary GCE in Physics (8PH01)

First examination 2009

## Edexcel Advanced GCE in Physics (9PH01)

First examination 2010

Issue 2

This specification includes e-Spec

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# Edexcel GCE e-Spec

## Your free e-Spec

This specification comes with a free e-Spec, Edexcel's electronic version of the specification. You will find the e-Spec disc inside the Specification book for this qualification.

## Everything you need in one CD

The e-Spec provides a range of useful resources including:

- A Senior Examiner explaining the changes to the new specification
- A customisable student guide to help recruit students
- A course planner to make it easy to plan delivery
- Links to sample assessment materials so you can see what is expected
- Student exemplars to show the standards required
- Information on the products and services provided by Edexcel to support the specification.

## Easy-to-use

Just click on the walkthrough to see how easy and useful the e-Spec is and get more out of this specification today.

# Contents

## Getting started for teachers



## Getting started for students

# Introduction

This *Getting Started* book will give you an overview of the GCE in Physics course and what it means for you and your students. The guidance in this book is intended to help you plan the course in outline and give you further insight into the principles behind the content, to help you and your students succeed in the course.

## Key principles

The key principles of the new GCE Physics specification are summarised below.

### An innovative specification

Edexcel's Physics specification has been designed to engage and inspire students who have different needs and abilities by providing two distinct and flexible approaches:

- a concept led approach
- a context led topic approach based on the Salters Horners Advanced Physics Project.

These approaches can be mixed to allow variety in course delivery. Teachers may select the approach that best meets the needs of their students.

### A motivating specification

This specification enables motivating, up-to-date, contemporary contexts to be included in the teaching and learning programme, and opportunities for practical work are identified throughout the specification. It has a realistic, manageable level of content and assessment and therefore provides an enjoyable teaching and learning experience.

### A supported specification

Support is available from both Edexcel and the Salters Horners Advanced Physics project team at York University. Teachers will also find that many of their current resources will be applicable to this specification.

## Assessment overview

The course will be assessed by both examination and internal assessment. A more detailed guide to the internally assessed units can be found later in this book in the section entitled 'Internal assessment guide'.

### AS units

| Unit 1: Physics on the go | Unit 2: Physics at work | Unit 3: Exploring physics |
|---|---|---|
| External assessment: written examination paper (80 mins) | External assessment: written examination paper (80 mins) | Internal assessment: carry out an experiment based on a visit or a case-study |

### A2 units

| Unit 4: Physics on the move | Unit 5: Physics from creation to collapse | Unit 6: Experimental physics |
|---|---|---|
| External assessment: written examination paper (95 mins) | External assessment: written examination paper (95 mins) | Internal assessment: plan and carry out an experiment |

# Course overviews

One of the key features of the GCE Physics specification is that you can approach each unit in this course in one of two ways:

- the concept approach
- the context approach.

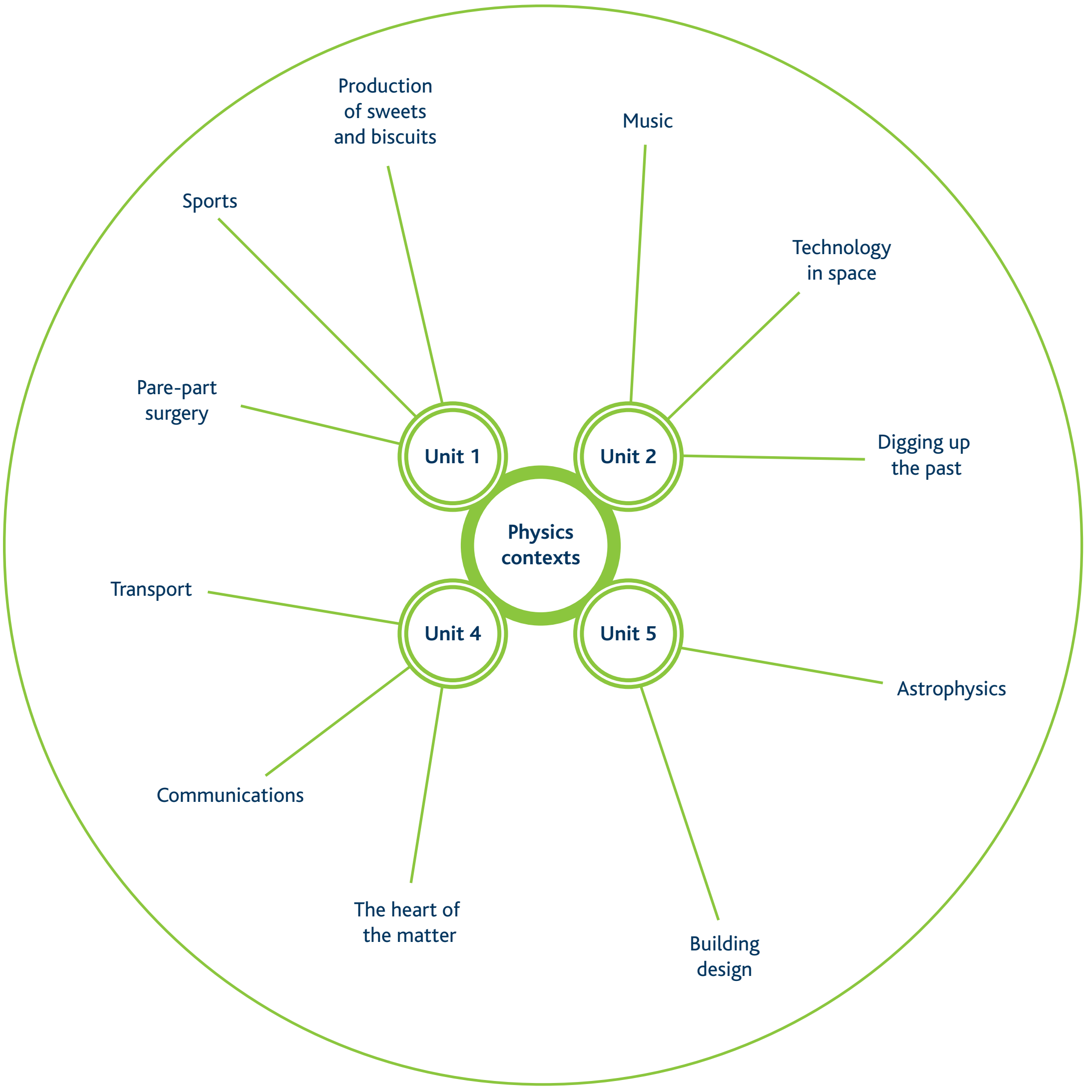
The following diagrams provide an overview of the themes of each approach so you can see at a glance the different options you have for delivering the course.

## Concept approach overview

This diagram shows all the concepts covered in the course.

## Context approach overview

This diagram shows all the contexts you can use to teach the course.



# Unit overviews

These tables give an overview of the content of each unit, allowing you to choose the approach that is most appropriate for your students.

## AS units

### Unit 1

Two approaches, one exam

| Concept approach | Context approach |
|---|---|
| Mechanics<br>• velocity<br>• acceleration<br>• forces<br>• equilibrium<br>• energy<br>• power<br><br>Materials<br>• fluid flow<br>• elastic/plastic deformation<br>• properties<br>• compression | Mechanics and sport<br>• speed and acceleration in sprinting and jogging<br>• work and power in weightlifting<br>• forces and equilibrium in rock-climbing<br>• forces and projectiles in tennis<br>• force and energy in bungee jumping<br><br>Materials<br>• measuring and controlling the flow of a viscous liquid for producing sweets<br>• mechanical testing of products<br>• mechanical properties of bone and replacement materials for spare part surgery<br>• 'designer' materials for medical uses |

### Unit 2

Two approaches, one exam

| Concept approach | Context approach |
|---|---|
| Waves<br>• characteristics<br>• standing waves<br>• refraction<br>• diffraction<br>• polarisation<br><br>Electricity<br>• series/parallel circuits<br>• Ohms law<br>• resistivity<br>• potential divider<br>• emf and internal resistance<br>• negative coefficient temperature thermistors<br><br>Nature of light<br>• photons<br>• Einstein's photoelectric equation<br>• efficiency | The sound of music<br>• synthesised and 'live' sounds<br>• standing waves in string and wind instruments<br>• reading a CD by laser<br><br>Satellites<br>• illuminating solar cells<br>• operation of solar cells<br>• combining sources of emf<br>• radar imaging<br><br>Archaeology<br>• resistivity surveying<br>• artefact analysis by X-ray diffraction<br>• artefact analysis by electron microscopy |

## A2 units

### Unit 4

Two approaches, one exam

**Concept approach**

Further mechanics
- momentum
- circular motion

Electric and magnetic fields
- electric field strength
- potential
- capacitance
- resistor-capacitor circuits
- magnetic flux
- flux linkage
- Fleming's left hand rule
- Faraday's law
- Lenz's law

Particle physics
- the nuclear atom
- thermionic emission
- particle accelerators
- particle tracks
- quark-lepton model
- De Broglie's equation

**Context approach**

Transport system
- track circuits and signalling
- sensing speed
- mechanical braking
- regenerative and eddy current braking
- crash-proofing

Communication and display techniques
- fibre optics and exponential attenuation
- CCD imaging
- cathode-ray tube
- liquid crystal and LED displays

Probing the heart of matter
- alpha scattering and the nuclear model of the atom
- accelerating particles to high energies
- detecting and interpreting interactions between particles
- the quark-lepton model

### Unit 5

Two approaches, one exam

**Concept approach**

Thermal energy
- specific heat capacity
- ideal gas equation
- internal energy

Nuclear decay
- types of radiation
- penetrating power
- ionising ability
- half life

Oscillations
- simple harmonic motion
- free, damped and forced oscillations

Astrophysics and cosmology
- gravitational fields
- Hertsprung-Russell diagram
- Stefan-Boltzmann law
- fate of the universe

**Context approach**

Reach for the stars
- distances of stars
- masses of stars
- energy sources in stars
- star formation
- star death and the creation of chemical elements
- the history and future of the universe

Building design
- earthquake detection
- vibration and resonance in structures
- damping vibration using ductile materials

# What's new?

This section provides key information on the new Edexcel GCE in Physics specification for both new and current Edexcel centres.

## The new specification

The new Edexcel GCE in Physics specification provides a flexible but clearly structured and supported course with manageable levels of content and assessment. In particular, it has been designed to inspire students and develop their enthusiasm for physics by providing one specification which has:

- **two** teaching approaches: concept led and context led
- **one** common set of assessments for both approaches.

This means that teachers may select an approach to meet their students' needs and learning styles that is based on a common assessment model.

The content of the new Edexcel specification has been devised in consultation with practising teachers, the Project Director for Salters Horners Advanced Physics and professional bodies to ensure that it is both attractive to students and can be studied in satisfying depth in the time available. In line with QCA requirements, the course features a range of contemporary physics contexts. As specific contexts will not be examined, they can be kept up to date with new developments in physics, and chosen for local interest or the specific interests of different groups of students.

## Guide to *How Science Works*

An important requirement of the QCA's GCE Science criteria is that *How Science Works* should be embedded within the programme of study. To help you meet this requirement when teaching the new Edexcel GCE in Physics specification, the *How Science Works* content has been integrated into the main course content. This means that you will deliver much of *How Science Works* without noticing, as you teach the course.

A brief summary of the new criteria for GCE Science subjects is given below. Students must:

- be able to use their knowledge and understanding to pose scientific questions, define scientific problems, and to present scientific arguments and ideas
- consider ethical issues and appreciate the ways in which society uses science to inform decision-making
- use theories, models and ideas to develop and modify scientific explanations, and use appropriate methodology to answer scientific questions
- appreciate the tentative nature of scientific knowledge and appreciate how society uses science in decision-making
- communicate their ideas well, use appropriate terminology and consider applications and implications of science (together with risks and benefits).

A document showing in detail how the *How Science Works* content has been integrated into the new GCE in Physics specification can be found at www.edexcel.com.

## Information for current Edexcel GCE in Physics (9540) centres

Here is a summary of the differences between the new Edexcel GCE in Physics specification and the Edexcel GCE in Physics (9540) specification. While providing you with an at-a-glance overview of the key differences, this summary also demonstrates that there is much similarity of content between the expiring and the new specification.

1. QCA will not allow optional topics to be included in the specification. Consequently some of the material that was in the topics has been included in the main part of the specification.
2. The new specification incorporates *How Science Works* as required by the new QCA criteria for GCE Science.
3. The following material has not been specified in the new specification. This allows time for including *How Science Works* in the teaching programme.

| AS material | A2 material |
|---|---|
| Moments<br>Change of state and specific latent heat<br>Pressure transmitted by fluids<br>First law of thermodynamics<br>The heat engine and its efficiency; the heat pump<br><br>**Topic: Astrophysics**<br>Recording star images<br>Benefits of observing from above the Earth's atmosphere<br>Planck distribution of energy<br>The whole section *Lives of stars* has been deleted<br><br>**Topic: Solid materials**<br>The whole section *Engineering materials* has been deleted<br><br>**Topic: Stable and unstable nuclei**<br>Nuclear matter<br>N-Z curves for nuclides, stability, radioactive dating<br>Nuclear decays – energy spectra, neutrino and antineutrino<br>Classification of particles<br>The four fundamental interactions<br>Forces described in terms of exchange particles<br><br>**Topic: Medical physics**<br>Although this topic is not specifically mentioned in the new specification, some of the outcomes of the new specification can be taught using a medical physics context | Mechanical oscillations of a pendulum and spring<br>Two slit interference patterns<br>Electrostatics – charging by contact (friction): two kinds of charge; conductors and insulators<br>Measurement of charge<br>Capacitors in series and parallel<br>Permanent magnets<br>Magnetic effect of a steady current ($B = \mu_0 nI$ and $B = \mu_0 I/2\pi r$)<br>The transformer<br>Comparison of springs and capacitors |

4. Some material has been moved from the AS to the A2 section of the specification in order to meet the new QCA criteria for GCE Science. This includes momentum, molecular kinetic theory, nuclear physics and specific heat capacity.
5. The six written examinations will be replaced with four written examinations.
6. In order to comply with the new QCA criteria for GCE Science, the two externally assessed practical examinations will be replaced with two internally assessed practical examinations. Further guidance on the internally assessed units of the course can be found later in this book in the section entitled 'Internal assessment guide'.

A detailed mapping document showing how the content of the expiring 9540 specification maps to the new specification can be found at *www.edexcel.com*.

## Information for current Edexcel GCE in Physics (Salters Horners) (9552) centres

Here is a summary of the differences between the new Edexcel GCE in Physics specification and the Edexcel GCE in Physics (Salters Horners) (9552) specification. While providing you with an at-a-glance overview of the key differences, this summary also demonstrates that there is much similarity of content between the expiring and the new specification.

1. Specific heat capacity has been moved from the AS to the A2 section of the specification in order to meet the new QCA criteria for GCE Science.
2. The new specification incorporates *How Science Works* as required by the new QCA criteria for GCE Science.
3. The following material has not been included in the new specification. This allows time for including *How Science Works* in the teaching programme.

| AS material | A2 material |
|---|---|
| Speed of waves on strings and wires | Transformers |
| Physical factors affecting the pitch of a note produced by a string or pipe | Digital signals – their use in situations incorporating feedback and control |
| Analogue and digital signals | Companding, quantisation and sampling |
| Ray diagrams for optical systems and the lens equation | Digital and analogue transmission systems |
| Maximum power transfer | Modulation (AM, FM and PCM) |
| Continuous flow calorimetry | Principles of encoding/decoding waveforms; sampling rates |
| Variation of potential difference with distance in a non-uniform medium | Multiplexing (FDM and TDM) |
| Thermoluminescence | Optic fibres and attenuation |
| Electron diffraction images to deduce ordered structure, or lack of it | Active noise control |
| Polymers | Speed of longitudinal waves in a solid |

4. There will be four written examination papers.
5. In order to comply with the new QCA criteria for GCE Science, there are two internally assessed practical assessments, one at AS and one at A2. At AS, centres may base the practical assessment on either a physics-based visit or a case study of a practical application of physics. At A2, the two-week coursework requirement has been replaced by a practical component that can be done in two sessions. One session involves a planning exercise and the other session involves doing an experiment and analysing experimental results. Further guidance on the internally assessed units of the course can be found later in this book in the section entitled 'Internal assessment guide'.

A detailed mapping document showing how the content of the expiring 9552 specification maps to the new specification can be found at www.edexcel.com.

# Course planner

This course planner gives you an overview of the course content and an idea of how to organise your delivery, for AS and for A2. In particular, it shows you how you can deliver each unit using either the concept approach or the context approach.

## AS

**Concept approach**

| Week | Lesson content |
|---|---|
| 1–7 | Unit 1: Mechanics |
| 8–14 | Unit 1: Materials |
| 15 | Unit 1 revision |
| | *January examinations* |

OR

**Context approach**

| Week | Lesson content |
|---|---|
| 1–7 | Unit 1: Higher, faster, stronger |
| 8–10 | Unit 1: Spare-part surgery |
| 11–14 | Unit 1: Good enough to eat? |
| 15 | Unit 1 revision |
| | *January examinations* |

**Concept approach**

| Week | Lesson content |
|---|---|
| 16–21 | Unit 2: DC electricity |
| 22–29 | Unit 2: Waves |
| 30 | Unit 2 revision |
| | *Summer examinations* |

OR

**Context approach**

| Week | Lesson content |
|---|---|
| 16–19 | Unit 2: The sound of music |
| 20–27 | Unit 2: Technology in space |
| 28–29 | Unit 2: Digging up the past |
| 30 | Unit 2 revision |
| | *Summer examinations* |

Internal assessment can be incorporated into your AS course planner at any time that is convenient for you and your students.

## A2

**Concept approach**

| Week | Lesson content |
|---|---|
| 1 | Unit 4: Further mechanics |
| 2 | |
| 3 | |
| 4 | |
| 5 | Unit 4: Electric and magnetic fields |
| 6 | |
| 7 | |
| 8 | |
| 9 | Unit 4: Particle physics |
| 10 | |
| 11 | |
| 12 | |
| 13 | |
| 14 | |
| 15 | Unit 4 revision |
| *January examinations* | |

**OR**

**Context approach**

| Week | Lesson content |
|---|---|
| 1 | Unit 4: Transport on track |
| 2 | |
| 3 | |
| 4 | |
| 5 | Unit 4: The medium is the message |
| 6 | |
| 7 | |
| 8 | Unit 4: Probing the heart of the matter |
| 9 | |
| 10 | |
| 11 | |
| 12 | |
| 13 | |
| 14 | |
| 15 | Unit 4 revision |
| *January examinations* | |

**Concept approach**

| Week | Lesson content |
|---|---|
| 16 | Unit 5: Oscillations |
| 17 | |
| 18 | |
| 19 | Unit 5: Nuclear decay |
| 20 | |
| 21 | Unit 5: Thermal physics |
| 22 | |
| 23 | Unit 5: Astrophysics and cosmology |
| 24 | |
| 25 | |
| 26 | |
| 27 | |
| 28 | |
| 29 | |
| 30 | Unit 5 revision |
| *Summer examinations* | |

**OR**

**Context approach**

| Week | Lesson content |
|---|---|
| 16 | Unit 5: Build or bust |
| 17 | |
| 18 | |
| 19 | |
| 20 | Unit 5: Reach for the stars |
| 21 | |
| 22 | |
| 23 | |
| 24 | |
| 25 | |
| 26 | |
| 27 | |
| 28 | |
| 29 | |
| 30 | Unit 5 revision |
| *Summer examinations* | |

Internal assessment can be incorporated into your A2 course planner at any time that is convenient for you and your students.

# Internal Assessment Guide

## Introduction

This section provides you with advice and guidance on the two internally assessed units of the specification, Unit 3 and Unit 6. It is organised as follows:

- **Unit 3 guidance** A brief overview of the assessment requirements followed by some suggested case studies and associated practicals, and some suggested visits and associated practicals.
- **Unit 3 exemplars** Four pieces of exemplar student work, with examiners' comments.
- **Unit 6 guidance** A brief overview of the assessment requirements.
- **Unit 6 exemplars** Two examples of student work based on the same experiment, at two different grade levels, with examiners' comments.

## Unit 3 guidance

### Unit overview

This summary outlines what students are required to do for Unit 3:

- Students must undertake either a case study involving an application of physics and a related practical, **or** a physics-based visit and a related practical.
- All students can do the same case study or the same visit; however, it is vital that students are able to demonstrate that the assessed work they produce is entirely their own.
- Students must produce a report on their case study or visit; the overall length of this report should be between 1,200 and 1,400 words, including a summary of the case study or visit that is between 500 and 600 words.
- Unit 3 can be completed at any time during the AS course, although you may find it most appropriate to conduct the assessment towards the end of the AS year.

## Suggested case studies and associated practical work

Here are five suggested case studies involving an application of physics and a related practical that you can use with your students. Alternatively, you can choose one of your own.

### 1 Investigate quantum tunnelling composite materials

*Case study brief:* Find out what sort of material a quantum tunnelling composite is. Why is its behaviour interesting and what is the significance of the phrase 'quantum tunnelling'? What uses could it be put to and what are its current limitations?

*Practical:* Candidates could do experiments such as investigating the relationship between the applied stress to a strip of material and its electrical resistance/resistivity. Specimens of QTC material can be purchased from www.mutr.co.uk. The material comes with a booklet with a number of interesting possibilities for experiments.

### 2 Investigate the physics of a 'tyrolean' traverse

*Case study brief:* A tyrolean traverse is a rock-climbing term. Find out what it is and the circumstances in which this manoeuvre is used. What are the mechanics of this process? Discuss the forces acting on the climber and in the rope and justify them using your knowledge of resultant forces. Would you expect these forces to remain the same during the traverse?

*Practical:* Model a tyrolean traverse using two pulleys, cord and three weights. One of these weights is used to model the 'body'. Measure the distance from one pulley to the 'body' and the 'sag'. The sag is the distance of the position of the weight on the cord from the horizontal. Can you find an equation relating sag with distance by 'trying' various graphs? Does this experiment verify your research and findings for the case study?

### 3 Investigate electroplaques and suggest why an electric eel can kill its prey without injuring itself

*Case study brief:* Electroplaques are cells within animals like the electric eel. They are stacked in series and parallel and this arrangement can generate large voltages and currents that can be used to kill or stun prey. Candidates can find out about the chemical processes which lead to the generation of an emf in these biological cells, revise ideas on parallel and series, consolidate ideas about internal resistance and explain why the electric eel doesn't injure itself.

*Practical:* Determine the internal resistance of a biological 'lemon' cell. What happens if you connect three lemon cells in series then in parallel? The electric eel has many electroplaques in series to produce a large voltage — why does it have many chains of electroplaques in parallel?

Students can create a lemon cell from a lemon, copper coin and zinc-coated screw. Three of these in series will create a battery with a reasonable emf. They should connect the battery to a variable load resistor and measure the terminal potential difference and current for an appropriate number of load resistor values. The load resistors need to be chosen so that their range reflects the internal resistance of the battery.

### 4 Investigate the properties of spider silk

*Case study brief:* Candidates can find out the properties of spider silk. They should specifically research typical breaking stresses and strains. They should then go on to compare the typical breaking forces for steel and spider silk, being careful to state the parameters for this comparison. Why is spider silk so strong?

*Practical:* How much energy is stored in an elastic band at full stretch? Compare the energy stored in an elastic band per unit volume at breaking point with that of spider silk at breaking point.

Students can use a typical elastic band. Use weights to establish a force–extension graph then determine the area under it. They test their answer by releasing the band and seeing how high it flies. They can revise ideas on gravitational potential and kinetic energy.

### 5 Investigate the viscosity of ketchup

*Case study brief:* Ketchup is more interesting than you might think. It needs to be treated so that it 'pours' in just the right way — not too runny and not too solid. It is known as a thixotropic material — what does this mean and how is it achieved?

*Practical:* Determine the viscosity of a material such as golden syrup.

Students can use the falling ball technique with a measuring cylinder of liquid (a 3mm-diameter ball bearing should suffice). Elastic bands make useful markers over which to determine terminal velocity. The change in viscosity with temperature of oil used in various machines could provide a different case study.

## Suggested visits and associated practical work

Here are five examples of a physics-based visit and a related practical that you can use with your students. Alternatively, you can choose one of your own.

### 1 A visit to a sweet factory

***Introduction***

Topics that may be covered by a visit to a sweet factory include viscosity, refractometry or polarimetry. The topic that you cover will depend on the part(s) of the factory you will be shown around.

*Viscosity:* Students should note that viscosity is an important property of some ingredients in sweets, considering that fluids that are used to make sweets need to be pumped around the factory. These fluids are often kept at relatively high temperatures — ask students why.

*Sugar content may need to be measured*. Two different techniques can be used to do this. The first technique, refractometry, uses the concept of critical angle. The second technique, polarimetry, uses the rotation of polarised light.

Students should make notes on the principals of these techniques and why they are important for the factory. They may also find it useful to note any relevant numerical values.

***Suggestions for practical work***

*Determine viscosity of a liquid such as golden syrup.* A straightforward method uses the falling ball technique with a measuring cylinder of liquid. A 3mm-diameter ball bearing should suffice. Elastic bands make useful markers over which to determine terminal velocity.

*How does the refractive index of a sugared water solution/Perspex vary with sugar content?* Prepare sugar solutions of different known concentrations. Students soak strips of sugar paper in these solutions to coat them and then stick each of the coated papers in turn onto the flat back of a semicircular Perspex prism. Students can find the critical angle for each sugar concentration by tracing rays of light through the prism from a light box (a good blackout will be essential). The refractive index for each of the different sugar concentrations can be calculated. Students could be asked to determine the concentration of a sugar solution prepared by the technician.

*How does the concentration of sugared water solution affect the angle of rotation of the plane of polarisation?* Students can make a simple polarimeter from a LED source, polarising filters and a plastic cell to contain the liquid which can be placed above the polarised light source.

## 2 A visit to a car maintenance garage or an 'exhausts, tyres and batteries' centre to explore sensor technology

***Introduction***

Sensor technology is now very significant on most cars with light sensing, pressure sensing, temperature sensing, position sensing, etc. Students should note what a basic sensing circuit consists of and the quantity (in each case) that is being monitored by microprocessor. Numerical values should be noted if relevant.

***Suggestions for practical work***

Calibrate a position sensor using a rotary linear potentiometer. This is likely to involve the use of a linear potentiometer, some way of measuring angle, eg with a protractor and needle (through the arm of the potentiometer), a voltmeter and a power supply.

A nice extension is to ask candidates to decrease its sensitivity: full-scale rotation for 1V rather than, say, 5V.

## 3 A visit to any environmentally friendly ('green') site, eg an alternative energy centre or most modern building projects

***Introduction***

A number of sites now profess to be 'green'. Students could discuss what this actually means in small groups and then each group could present their ideas to the whole class. At the 'green' site students may look for:

- features that reduce waste products, eg solar cells
- design features that reduce energy costs, eg insulation.

### *Suggestions for practical work*

*Investigating a solar cell.* The efficiency of a solar battery depends, to some extent, on its internal resistance. Students could determine the internal resistance of a solar cell. These may be purchased cheaply from surplus suppliers. The internal resistance of a solar cell increases with light intensity, so students may not obtain the same values of internal resistance as each other for the same type of solar cell. Students will need to ensure illumination remains constant during their experiment and will need to use a sensible range of variable load resistance values.

*How does the thickness of insulating material change the rate of cooling?* Candidates will need a hot beaker of water, different thicknesses of material to wrap around the beaker, and a thermometer. They obtain a cooling curve for each thickness and then find the gradient at a particular temperature for each thickness.

## 4 A visit to a medical physics department at a hospital

### *Introduction*

Most medical physics departments have three main applications of physics: X-ray imaging, nuclear medicine and ultrasound. It is probably best to concentrate on two of these during a visit.

- *X-ray imaging* Students should be able to explain: How are X-rays produced? How are images formed and what are X-rays typically used for? What are the risks? What safety precautions must be used? They should note any relevant numerical values.
- *Nuclear medicine* Students should be able to list medical applications that use radiation and explain: What radiation is used for and why? How is the radiation detected and an image produced? What are the risks?
- *Ultrasound* Students should be able to explain: What is it used for? What are the principles of ultrasound imaging?

### *Suggestions for practical work*

While exploring the safety precautions involved with the use of ionising radiation, students could consider the importance of the inverse square law that relates the intensity of the radiation with distance from its source. Students could investigate this relationship using a light bulb to simulate a non-collimated source of ionising radiation. This will require a small 6V lamp and a light-intensity sensor, eg an ORP 12 light-dependent resistor.

An interesting variation is to use a 12V ('camping') strip light rather than a bulb — this tends to act as a line source and give more of a $1/r$ variation.

## 5 A visit involving an audio shop or stage production to investigate matching impedances, eg an amplifier with a speaker or an electric guitar with an amplifier

*Introduction*

The impedance of discrete systems have to be 'matched', eg an amplifier with a speaker or an electric guitar with an amplifier.

Students should be able to explain: What does this mean? Why is this important? What are the principles? Students should make a note of relevant numerical values.

*Suggestions for practical work*

Students could do an experiment to find the internal resistance of a power supply by investigating how the electrical power delivered to a load varies with resistance.

Apparatus that students will need include a low-voltage supply or dry cell or solar cell and a variable resistance box which includes values either side of the internal resistance of the supply.

## Unit 3 exemplars of marked student work

Here are four pieces of student work from Unit 3 with associated marks and examiners' comments. They are designed to show you the level of detail expected of students and how assessment criteria will be applied. The exemplars show a range of grade outcomes so you can see what standards are required.

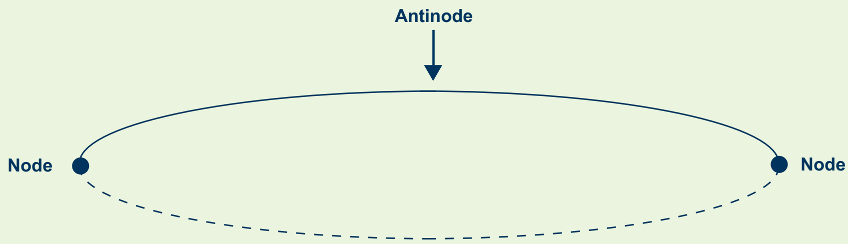
The four pieces of work are as follows:

1. Mid-range grade exemplar: case study and practical.
2. Low grade exemplar: case study and practical.
3. Mid-range grade exemplar: visit and practical.
4. Low grade exemplar: visit and practical.

### Mid-range grade exemplar: case study and practical

**The Physics of Electric Guitars**

When a guitar string is plucked a standing wave is set up on the string. There is an antinode in the middle and nodes at the end as shown in my diagram. This is formed by reflected waves superimposing with incident waves.




The frequency is given by $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

This can be derived from the wave equation $v = f\lambda$
and the equation which relates the speed of a wave on a wire or string $v = \sqrt{\frac{T}{\mu}}$

where $T$ is the tension and $\mu$ is the mass per unit length of the wire.
$f$ is known as the fundamental frequency – this occurs when half a wave 'sits' on the wire.

This theory is the same for acoustic or electric guitars.

Electric guitar strings are made from steel. Beneath each of the wires lies a small magnet. Beneath the magnet lies a coil of wire with as many as 3000 turns.

If the magnet moved a voltage would be induced in the coil of wire due to faraday's law which states that a change in magnetic flux linkage will induce a voltage in a nearby conductor. The magnet and coil are, however, firmly fixed. The steel string does vibrate as it is plucked. This vibration causes a disturbance in the magnetic field around the magnet. This disturbance has the effect of reducing/increasing the magnetic field around the coil. A change in the field induces a voltage which varies at the same frequency as the string is vibrating.

The output from the coil goes to an electric circuit.

The volume can be adjusted by changing the output position of the potentiometer.

This has the effect of feeding a larger/smaller voltage to the jack which is then connected to an amplifier and speaker.

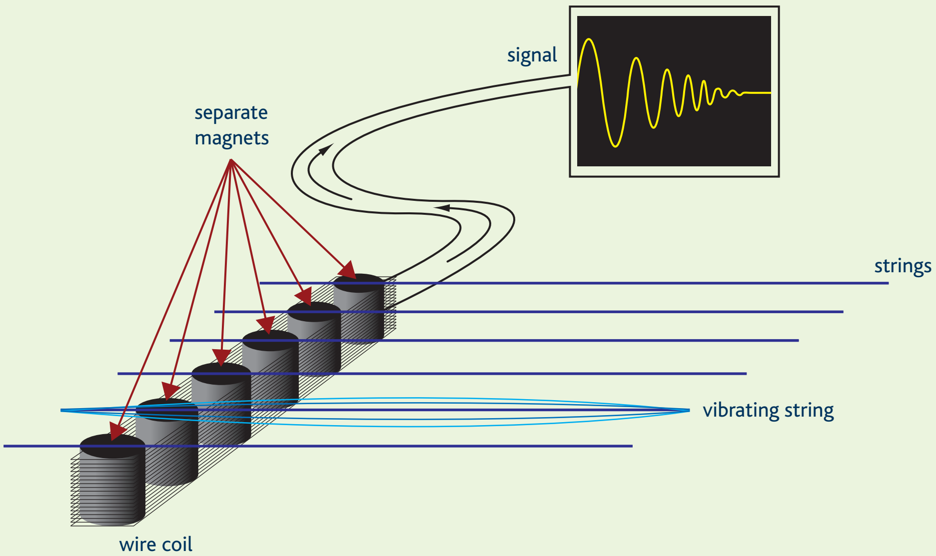
http://physics.bu.edu/py106/notes/Music.html

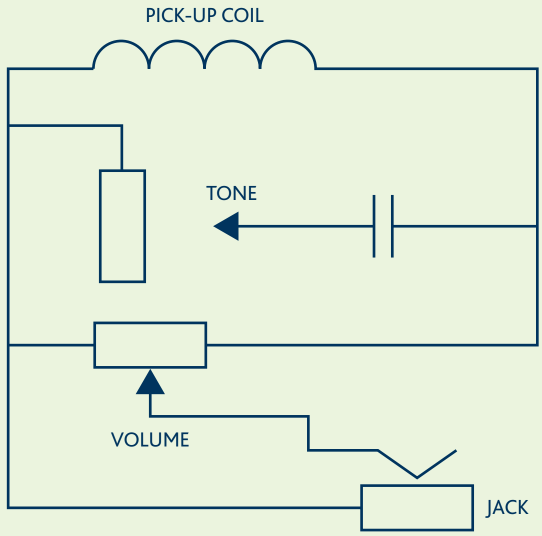
www.homestead.com/dennysguitars/whyopentune1.html

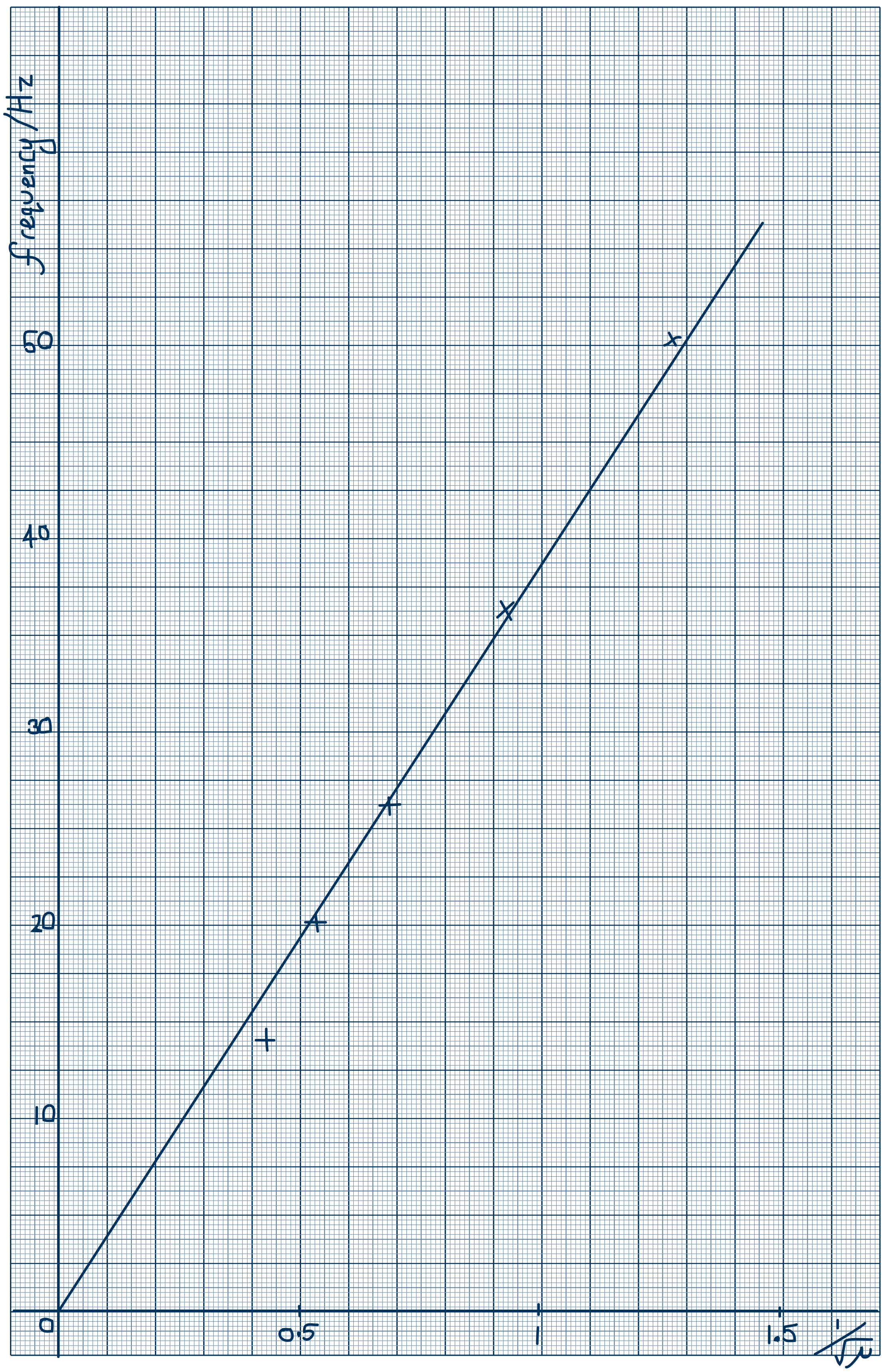
www.howstuffworks.com/electric-guitar1.htm

User's manual: Stagg Universe of Music

Advanced AS Physics Heinemann: P140-142



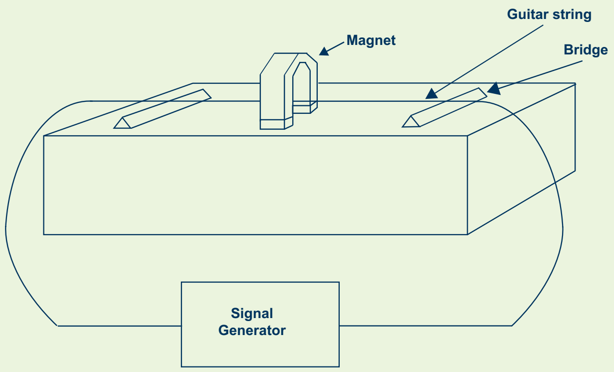

frequency /Hz
50
40
30
20
10
0
0.5
1
1.5
1/√μ

**Experiment to investigate the relation between frequency of fundamental wave on a guitar string with its mass per unit length - μ**

**Apparatus needed:**

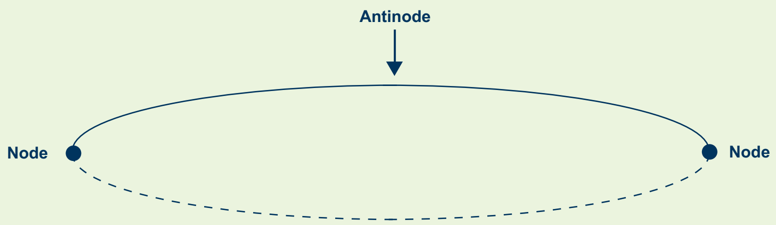
- Guitar strings – different types
- Balance
- Rule
- Sonometer
- Strong magnet
- Signal generator
- Weights
- Weight hangs

The first part of my report above discussed standing waves on the strings. According to background theory the frequency (*f*) of the fundamental wave should be inversely proportional to the square root of $\mu$. I'm going to try and verify this relationship. $\mu$ is the independent variable and *f* is the dependant variable.




I will weigh six different guitar strings and measure their lengths to find $\mu$. The balance I will use is accurate to the nearest 0.01g and the 1m rule I will use will measure to the nearest mm.

I discussed an idea with the teacher which is similar to the magnetic ideas above. If I put a current in the wire and place it between a magnet a force will act on it. If I use an alternating current supplied from a signal generator I can vibrate it at different frequencies. The fundamental frequency *f* is when it vibrates with the largest amplitude with an antinode in the middle as shown in my diagram below.




I can repeat this for each string.

If I plot a graph of *f* against 1/root $\mu$ it should be a straight line and be through the origin.

I will wear goggles in case the string breaks. I will put some masses on the end of the string to hold it taut.

### Results

| wire type | mass / g | length / m | mass per unit length $\mu$ | 1 / sq rt $\mu$ | frequency / Hz |
|---|---|---|---|---|---|
| 11 | 0.68 | 1.12 | 0.607 | 1.28 | 50 |
| 16 | 1.30 | 1.12 | 1.161 | 0.93 | 36 |
| 24 | 2.35 | 1.12 | 2.098 | 0.69 | 26 |
| 32 | 3.88 | 1.12 | 3.464 | 0.54 | 20 |
| 44 | 6.20 | 1.12 | 5.536 | 0.43 | 14 |

### Analysis

The graph shows that the fundamental frequency $f$ is proportional to the reciprocal of the square root of the mass per unit length as it is a straight line and through the origin.

This is directly predicted by the theory.

The gradient of this graph is related to the tension and length of the wire used.

There were errors in the experiment. I had to decide when the vibrations were largest and note the frequency. I tried to judge this as best as I could but realise it was subject to error.

## *Assessment criteria*

### *A Summary of case study or physics-based visit*

| Ref. | Criterion | Mark |
|---|---|---|
| S1 | Carries out a visit OR uses library, consulting a **minimum of three** different sources of information (eg books/websites/journals/magazines/case study provided by Edexcel/manufacturer's data sheets) | 1 |
| S2 | States details of visit venue OR provides **full** details of sources of information | 1 |
| S3 | Provides a brief description of the visit OR case study | 1 |
| S4 | Makes correct statement on relevant physics principles | 1 |
| S5 | Uses relevant specialist terminology correctly | 1 |
| S6 | Provides one piece of relevant information (eg data, graph, diagram) that is not mentioned in the briefing papers for the visit or case study | 1 |
| S7 | Briefly discusses context (eg social/environmental/historical) | 0 |
| S8 | Comments on implication of physics (eg benefits/risks) | 0 |
| S9 | Explains how the practical relates to the visit or case study | 1 |
| | **Marks for this section** | **7** |

### *B Planning*

| Ref. | Criterion | Mark |
|---|---|---|
| P1 | Lists all materials required | 1 |
| P2 | States how to measure one relevant quantity using the most appropriate instrument | 1 |
| P3 | Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P4 | States how to measure a second relevant quantity using the most appropriate instrument | 0 |
| P5 | Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P6 | Demonstrates knowledge of correct measuring techniques | 1 |
| P7 | States which is the independent and which is the dependent variable | 1 |
| P8 | Identifies and states how to control all other relevant variables to make it a fair test | 0 |
| P9 | Comments on whether repeat readings are appropriate in this case | 0 |
| P10 | Comments on safety | 1 |
| P11 | Discusses how the data collected will be used | 1 |
| P12 | Identifies the main sources of uncertainty and/or systematic error | 0 |
| P13 | Draws an appropriately labelled diagram of the apparatus to be used | 1 |
| P14 | Plan is well organised and methodical, using an appropriately sequenced step-by-step procedure | 0 |
| | **Marks for this section** | 7 |

*C Implementation and measurements*

| Ref. | Criterion | Mark |
|---|---|---|
| M1 | Records all measurements using the correct number of significant figures, tabulating measurements where appropriate | 1 |
| M2 | Uses correct units **throughout** | 0 |
| M3 | Obtains an appropriate number of measurements | 0 |
| M4 | Obtains measurements over an appropriate range | 1 |
| | **Marks for this section** | **2** |

*D Analysis*

| Ref. | Criterion | Mark |
|---|---|---|
| A1 | Produces a graph with appropriately labelled axes and with correct units | 1 |
| A2 | Produces a graph with sensible scales | 1 |
| A3 | Plots points accurately | 1 |
| A4 | Draws line of best fit (either a straight line or a smooth curve) | 1 |
| A5 | Comments on the trend/pattern obtained | 1 |
| A6 | Derives relation between two variables or determines constant | 0 |
| A7 | Discusses/uses related physics principles | 1 |
| A8 | Attempts to qualitatively consider sources of error | 0 |
| A9 | Suggests realistic modifications to reduce error/improve experiment | 0 |
| A10 | Calculates uncertainties | 0 |
| A11 | Provides a final conclusion | 1 |
| | **Marks for this section** | **7** |

*E Report*

| Ref. | Criterion | Mark |
|---|---|---|
| R1 | Summary contains few grammatical or spelling errors | 1 |
| R2 | Summary is structured using appropriate subheadings | 1 |
| | **Marks for this section** | **2** |

| | |
|---|---|
| **Total marks** | **25** |

## Examiner's commentary

### A Summary of case study or physics-based visit

The candidate has drawn a diagram showing a wire vibrating in fundamental mode and the nodes and antinodes have been labelled. This scores the mark for *S6: Provides one piece of relevant information (eg data, graph, diagram) that is not mentioned in the briefing papers for the visit or case study.*

Neither a context nor any implications of the physics are mentioned in the report and therefore marks could not be awarded for *S7: Briefly discusses context (eg social/environmental/historical)* or *S8: Comments on implications of physics*.

### B Planning

The candidate clearly describes how to measure the mass per unit length of the wire but only vaguely mentions the frequency and has therefore lost the mark for *P4: States how to measure the second relevant quantity using the most appropriate instrument*.

To obtain the mark for *P8: Identifies and states how to control* ***all*** *other* ***relevant*** *variables to make it a fair test*, the candidate should state that the tension needs to be kept constant for each string and that the same length of string should be used each time.

The candidate should have considered repeat readings to achieve a mark for *P9: Comments on whether repeat readings are appropriate in this case*. The concept of accuracy has been misunderstood and therefore no mark was awarded for *P12: Identifies the main sources of uncertainty and/or systematic error*.

The candidate has included a diagram showing the apparatus used and therefore scores the mark for *P13: Draws an appropriately labelled diagram of the apparatus to be used.*

### C Implementation and measurements

The candidate had the opportunity to test six strings but appears to have collected results for only five. Consequently the student lost the mark for *M3: Obtains an appropriate number of measurements*.

The candidate has omitted the units for mass per unit length and 1/root $\mu$ and therefore the mark for *M2: Uses correct units* ***throughout*** was not achieved.

***D Analysis***

The candidate could have considered the tension in the wire, the length of wire and confirmed one or other of these values using the gradient of the graph. This would have given a good idea of the accuracy of the experiment and consolidated the mark for *A7: Discusses/uses related physics principles*.

The candidate made very little attempt to discuss errors to obtain marks for *A8* to *A10*. The points on the graph did not lie on a perfect straight line. The frequency readings were presumably read from a signal generator dial and would be subject to significant error. The candidate could have checked the calibration using mains frequency or an oscilloscope.

***E Report***

Subheadings should be used in the case study report in order to achieve the mark for *R2: Summary is structured using appropriate subheadings*.

## Low grade exemplar: case study and practical

### Resistivity Surveying

In its simplest form this involves placing two electrodes in the ground. A current is sent through them and both the current and voltage are measured from which resistance can be calculated.

If resistance R is known then the resistivity is related to it by some constant $k \times R$. The constant depends on the length between the electrodes and the area through which the current passes.

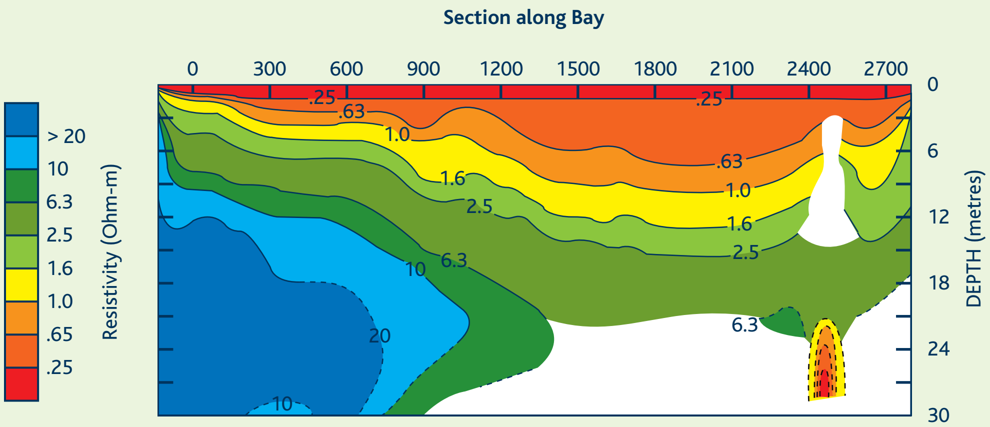
By measuring $R$ in different locations the variation in resistivity can be established. However this change in resistivity is then either due to lateral variations and/or to vertical variations. This simple method cannot determine which.

In practice two terminals are used to provide the current and then two further terminals are used to measure the potential difference across a set distance.

It can be used to determine the porosity of rocks and how fresh the water absorbed in them is. For instance the resistivity of fresh water is approximately 100 Ωm and sea water about 0.1 Ωm.

Contamination of fresh water can also be determined.

2 D surveying also checks whether resistivity varies vertically below the surface.




This example shows the resistivity of water at different depths and at different distances from the shore of this bay.

Note that salty water will have reduced resistivity so the fresh water is coloured blue.

### Sources:

1 www.abem.se/files/res/2Dnotes.pdf

2 water.usgs.gov/ogw/bgas/surface/

3 www.brigantesnation.com/Guide/Research/Resistivity.htm

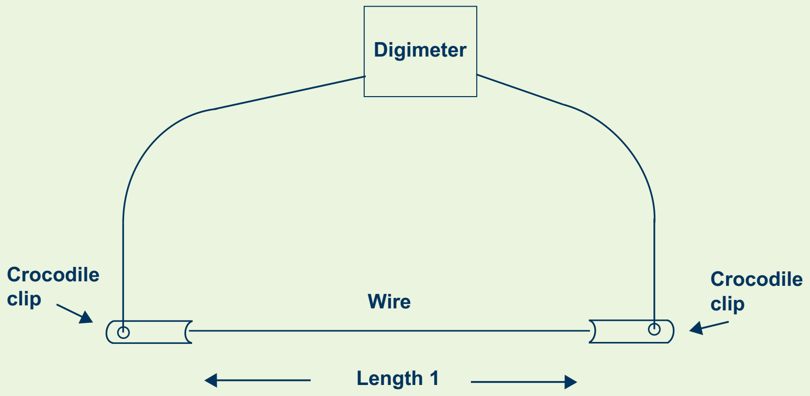
4 http://woodshole.er.usgs.gov/epubs/SAGEEP/SAGEEP_final.pdf

**Experiment to determine the resistivity of a metal.**

### Apparatus

- Digimeter
- Crocodile clips
- Wires
- Micrometer
- 1 m rule

### Plan




I have been given a metal wire. I intend to measure the diameter using a micrometer. I will then measure the resistance of several lengths using croc clips. I will measure the lengths and use a digimeter to find the resistances.

I will repeat each reading of resistance twice.

I will table my results and then calculate the length divided by the area.

I'll plot a graph of resistance against length/area of wire.

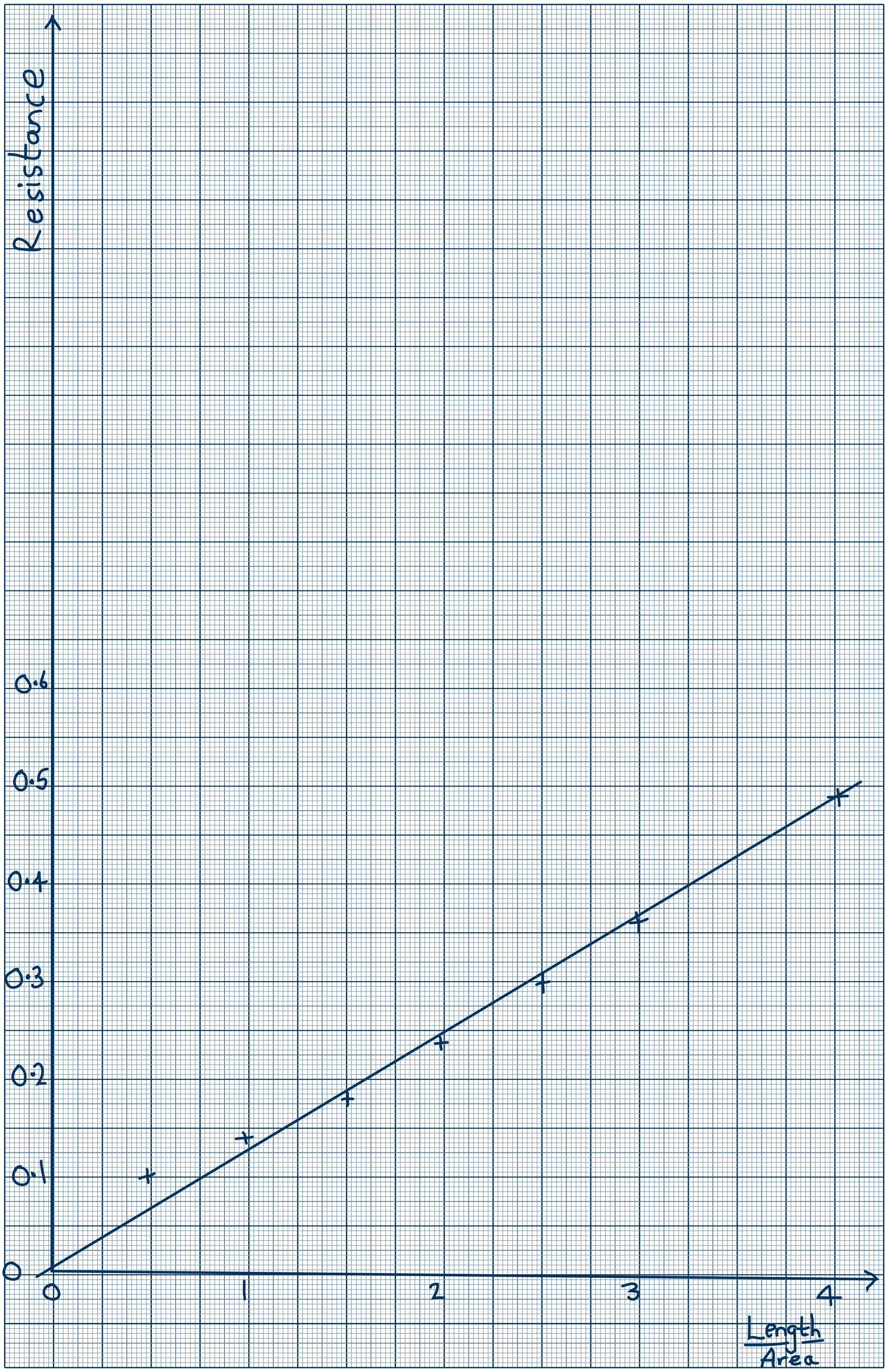
The gradient should give me the resistivity of the metal.

### Results

Diameter of wire = 0.5 mm

Area = 0.196 $mm^2$

| Resistance/Ω | Length/m | Length/area |
|---:|---:|---:|
| 0 | 0 | 0 |
| 0.1 | 0.1 | 0.51020 |
| 0.14 | 0.2 | 1.02040 |
| 0.18 | 0.3 | 1.53061 |
| 0.24 | 0.4 | 2.04081 |
| 0.3 | 0.5 | 2.55102 |
| 0.36 | 0.6 | 3.06122 |
| 0.48 | 0.8 | 4.08163 |



Resistance
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
Length
Area

**Analysis**

My graph is a straight line as expected because R should be proportional to l/A.

The gradient is resistivity which is
= 0.48/4.1 = 0.12 Ω/mm

I think my experiment went well as the points on the graph lie on a straight line.

***Assessment criteria***

*A Summary of case study or physics-based visit*

| Ref. | Criterion | Mark |
|---|---|---|
| S1 | Carries out a visit OR uses library, consulting a **minimum of three** different sources of information (eg books/websites/journals/magazines/case study provided by Edexcel/manufacturer's data sheets) | 0 |
| S2 | States details of visit venue OR provides **full** details of sources of information | 1 |
| S3 | Provides a brief description of the visit OR case study | 1 |
| S4 | Makes correct statement on relevant physics principles | 0 |
| S5 | Uses relevant specialist terminology correctly | 0 |
| S6 | Provides one piece of relevant information (eg data, graph, diagram) that is not mentioned in the briefing papers for the visit or case study | 1 |
| S7 | Briefly discusses context (eg social/environmental/historical) | 1 |
| S8 | Comments on implication of physics (eg benefits/risks) | 0 |
| S9 | Explains how the practical relates to the visit or case study | 0 |
| | **Marks for this section** | **4** |

*B Planning*

| Ref. | Criterion | Mark |
|---|---|---|
| P1 | Lists all materials required | 1 |
| P2 | States how to measure one relevant quantity using the most appropriate instrument | 1 |
| P3 | Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P4 | States how to measure a second relevant quantity using the most appropriate instrument | 0 |
| P5 | Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P6 | Demonstrates knowledge of correct measuring techniques | 1 |
| P7 | States which is the independent and which is the dependent variable | 0 |
| P8 | Identifies and states how to control all other relevant variables to make it a fair test | 0 |
| P9 | Comments on whether repeat readings are appropriate in this case | 0 |
| P10 | Comments on safety | 0 |
| P11 | Discusses how the data collected will be used | 1 |
| P12 | Identifies the main sources of uncertainty and/or systematic error | 0 |
| P13 | Draws an appropriately labelled diagram of the apparatus to be used | 1 |
| P14 | Plan is well organised and methodical, using an appropriately sequenced step-by-step procedure | 0 |
| | **Marks for this section** | 5 |

*C Implementation and measurements*

| Ref. | Criterion | Mark |
|---|---|---|
| M1 | Records all measurements using the correct number of significant figures, tabulating measurements where appropriate | 0 |
| M2 | Uses correct units **throughout** | 0 |
| M3 | Obtains an appropriate number of measurements | 0 |
| M4 | Obtains measurements over an appropriate range | 1 |
| | **Marks for this section** | **1** |

*D Analysis*

| Ref. | Criterion | Mark |
|---|---|---|
| A1 | Produces a graph with appropriately labelled axes and with correct units | 0 |
| A2 | Produces a graph with sensible scales | 0 |
| A3 | Plots points accurately | 1 |
| A4 | Draws line of best fit (either a straight line or a smooth curve) | 0 |
| A5 | Comments on the trend/pattern obtained | 1 |
| A6 | Derives relation between two variables or determines constant | 0 |
| A7 | Discusses/uses related physics principles | 1 |
| A8 | Attempts to qualitatively consider sources of error | 0 |
| A9 | Suggests realistic modifications to reduce error/improve experiment | 0 |
| A10 | Calculates uncertainties | 0 |
| A11 | Provides a final conclusion | 0 |
| | **Marks for this section** | **3** |

*E Report*

| Ref. | Criterion | Mark |
|---|---|---|
| R1 | Summary contains few grammatical or spelling errors | 1 |
| R2 | Summary is structured using appropriate subheadings | 0 |
| | **Marks for this section** | **1** |

| | |
|---|---|
| **Total marks** | **14** |

## Examiner's comments

### *A Summary of case study or physics-based visit*

A mark should not be awarded for *S1: Carries out a visit OR uses library, consulting a minimum of three different sources of information (eg books/websites/journals/ magazines/case study provided by Edexcel/manufacturer's data sheets)* as the candidate has not used three **different** sources of information — all sources use the internet.

The candidate states that 'the resistivity is related to it by some constant k x R'. This relationship is too vague — the full equation expressing the relationship including resistivity is expected and therefore it is not possible to give a mark for *S4: Makes correct statement on relevant physics principles*.

The candidate refers to 'area' when 'cross-sectional area' is more appropriate. Therefore a mark has not been awarded for *S5: Uses relevant specialist terminology correctly*.

Although there is a relationship between the case study of a practical application of physics and the experiment, the candidate has not made this clear in the report and therefore cannot be awarded a mark for *S9: Explains how the practical relates to the visit or case study*.

### *B Planning*

The candidate suggested using a micrometer so he achieved the mark for *P2: States how to measure one relevant quantity using the most appropriate instrument*. He should not loose this mark for failing to state the need to repeat measurements and calculate the average value as P5 penalises him for this.

The candidate needs to state that a ruler will be used to measure the length of the wire in order to get the mark for *P4: States how to measure a second relevant quantity using the most appropriate instrument*.

Other variables have not been mentioned, eg the need to ensure that the temperatures of the wires are the same when each measurement is taken and therefore a mark for *P8: Identifies and states how to control all other relevant variables to make it a fair test* has not been awarded.

Although the candidate states that he will repeat each resistance reading twice he has not commented on why he thinks this is appropriate. Neither has the candidate suggested checking the diameter in more than one place. There is no evidence in the results section that he has repeated any measurements or calculated an average value for the diameter of the wire. He has therefore lost a mark for *P9: Comments on whether repeat readings are appropriate in this case*.

As there are no comments on safety, or possible sources of uncertainty and/or systematic error, the student cannot score a mark for *P10: Comments on safety* or *P12: Identifies the main sources of uncertainty and/or systematic error*. For example, the candidate could have mentioned that current was allowed to flow through the wire for the shortest possible period of time as the heating effect of the current can affect the resistance of the wire and hence the magnitude of the current that flows.

### C Implementation and measurements

There are several reasons for not awarding a mark for *M1: Records all measurements using the correct number of significant figures, tabulating measurements where appropriate*. The candidate has used too many significant figures in the table of results and the diameter of the wire has been stated to the nearest 0.1mm even though a micrometer will measure to the nearest 0.01mm.

Not only has the candidate failed to insert a unit in the last column of the results table, he has used a mixture of units when dividing the length (metres) by the area (millimetres squared). He has, therefore, not scored a mark for *M2: Uses correct units throughout*.

The candidate should have included evidence to show that he had repeated the measurements of the diameter of the wire at different places along the wire to obtain the mark for *M4: Obtains measurements over an appropriate range*.

### D Analysis

The graph is not scaled appropriately (it only occupies a third of the grid) and therefore the candidate failed to achieve the mark for *A2: Produces a graph with sensible scales*. It does not have the correct units on the $x$-axis and the best line of fit should go through the origin; therefore marks were not awarded for *A1: Produces a graph with appropriately labelled axes and with correct units* and *A4: Draws line of best fit (either a straight line or a smooth curve)*. The candidate has not recognised that the first couple of points are anomalies.

A mark was not given for *A6: Derives relationship between two variables or determines constant* as the constant is not correctly determined even though the candidate commented on the trend. The candidate has some idea of the physics principles to apply but has not applied any meaningful error analysis to this experiment and therefore fails to get any marks for *A8* to *A10*.

### E Report

The case study report lacked structure. The use of appropriate subheadings would be advisable to achieve a mark for *R2: Summary is structured using appropriate subheadings*.

## Low grade exemplar: visit and practical

### Visit report to Symphony Hall

In November we visited the Symphony Hall in Birmingham. This concert hall was opened in 1991 and seats about 2600 people. It is multipurpose – it can be used for full scale orchestras to a single electric guitarist.

We were shown a number of aspects of physics. The interior design included the use of beech wood which is a good reflector of sound. Specific use of curtains which absorb sound. The use of a reverberation chamber to extend the length of time for a given note. The use of hydraulics to raise/lower the stage. The aspect of physics I intend to discuss relates to the organ which was added to the symphony hall in 2001.

The organ consists of a set of pipes. Air is pumped through different combinations of pipes at the touch of the keyboard. The keys on the keyboard control 'stops'. When a key is pressed a stop is removed and this allows air to blow through either a single pipe or a mixture of pipes.

The resonance of a pipe produces a note in a similar way to many wind instruments.

The vibrating air inside the pipe produces a standing wave pattern. This has nodes and antinodes.

In the design of an organ some pipes are closed at one end. The air at the closed end cannot vibrate so this must be a node (*N*). The simplest pattern has an antinode at the open end.

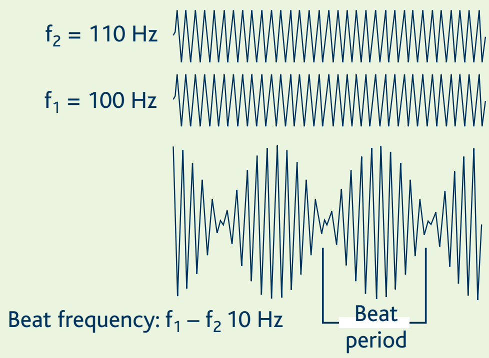
In this case there is a quarter of a wavelength in the length of the pipe. So the frequency of the sound produced should be given by $v/4$.length of pipe where $v$ is the speed of sound in air.

In fact we were told that this formula is not entirely correct. An organ design needs to take this into account and make the length of the pipe accordingly to give a specific frequency.

Some organ pipes are open at both ends. This has the effect of halving the wavelength of the standing wave or doubling the frequency produced.

One interesting aspect we were shown were the tremolo stops. When played these produced a sound which seemed to 'warble' ie the frequency altered slightly periodically. We were told that this is because two sets of almost identical pipes are activated at the same time.

This is a particular example of superposition of sound called beats. When two waves of similar frequency are superimposed the effect can be represented as shown below.



The organ has increased the range of events that can be hosted at the symphony hall. It has also added to the educational benefits that the hall offers to local schools etc. Many visitors are left with a lasting memory of playing a base stop at maximum volume!

**Experiment to determine the relationship between 'length' of recorder and the frequency of the note produced**

**Apparatus**

- Recorder
- Multimedia sound computer
- Microphone and computer interface

**Plan**

I intend to use a standard treble recorder. I can vary the length by closing holes with my fingers. I will measure to the first open hole.

I can measure the frequency, $f$, of the note produced using some software called multimedia sound. This will produce a frequency spectrum for the note. I don't see the point of repeating all my measurements because it should give the right answer as it is a piece of computer software.

I have seven holes on the recorder so I can take seven sets of readings.

On my visit around symphony hall we learnt that frequency (of an organ pipe) was inversely proportional to the length. The constant was the speed of sound divided by 4. My experiment should check some of these ideas.

I will plot a graph of frequency against length.

I should be able to find the speed of sound from the gradient of this graph.

**Results**

The first note was repeated with a value of 1000 Hz. The software seems to give accurate values.

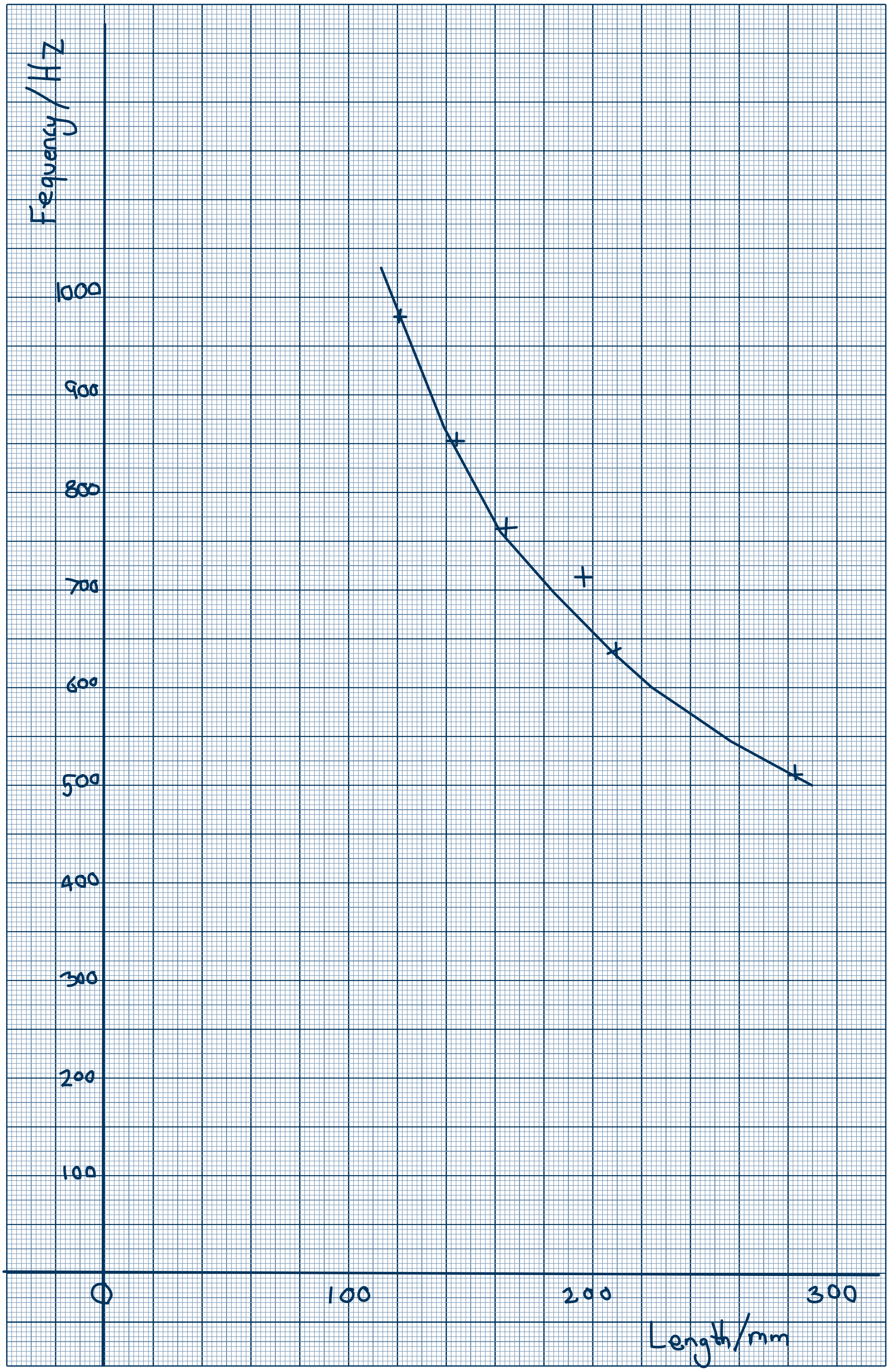
| length /mm | frequency |
|---|---|
| 122 | 990 |
| 145 | 850 |
| 168 | 760 |
| 191 | 690 |
| 211 | 635 |
| 234 | 580 |
| 285 | 517 |

**Analysis**

The graph shows that as the length of the recorder increases the frequency decreases.

The points lie on a smooth curve – this shows my experiment is accurate.

I expected this type of graph because we were told on my visit that frequency was inversely proportional to length. The shape of my graph proves this.


Fequency / Hz
1000
900
800
700
600
500
400
300
200
100
0
100
200
300
Length/mm

### *Assessment criteria*

*A Summary of case study or physics-based visit*

| Ref. | Criterion | Mark |
|---|---|---|
| S1 | Carries out a visit OR uses library, consulting a **minimum of three** different sources of information (eg books/websites/journals/magazines/case study provided by Edexcel/manufacturer's data sheets) | 1 |
| S2 | States details of visit venue OR provides **full** details of sources of information | 1 |
| S3 | Provides a brief description of the visit OR case study | 1 |
| S4 | Makes correct statement on relevant physics principles | 0 |
| S5 | Uses relevant specialist terminology correctly | 0 |
| S6 | Provides one piece of relevant information (eg data, graph, diagram) that is not mentioned in the briefing papers for the visit or case study | 1 |
| S7 | Briefly discusses context (eg social/environmental/historical) | 1 |
| S8 | Comments on implication of physics (eg benefits/risks) | 1 |
| S9 | Explains how the practical relates to the visit or case study | 0 |
| | **Marks for this section** | **6** |

*B Planning*

| Ref. | Criterion | Mark |
|---|---|---|
| P1 | Lists all materials required | 1 |
| P2 | States how to measure one relevant quantity using the most appropriate instrument | 1 |
| P3 | Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P4 | States how to measure a second relevant quantity using the most appropriate instrument | 0 |
| P5 | Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P6 | Demonstrates knowledge of correct measuring techniques | 1 |
| P7 | States which is the independent and which is the dependent variable | 0 |
| P8 | Identifies and states how to control all other relevant variables to make it a fair test | 0 |
| P9 | Comments on whether repeat readings are appropriate in this case | 0 |
| P10 | Comments on safety | 0 |
| P11 | Discusses how the data collected will be used | 0 |
| P12 | Identifies the main sources of uncertainty and/or systematic error | 0 |
| P13 | Draws an appropriately labelled diagram of the apparatus to be used | 0 |
| P14 | Plan is well organised and methodical, using an appropriately sequenced step-by-step procedure | 0 |
| | **Marks for this section** | **3** |

*C Implementation and measurements*

| Ref. | Criterion | Mark |
|---|---|---|
| M1 | Records all measurements using the correct number of significant figures, tabulating measurements where appropriate | 1 |
| M2 | Uses correct units **throughout** | 0 |
| M3 | Obtains an appropriate number of measurements | 1 |
| M4 | Obtains measurements over an appropriate range | 1 |
| | **Marks for this section** | **3** |

*D Analysis*

| Ref. | Criterion | Mark |
|---|---|---|
| A1 | Produces a graph with appropriately labelled axes and with correct units | 1 |
| A2 | Produces a graph with sensible scales | 0 |
| A3 | Plots points accurately | 0 |
| A4 | Draws line of best fit (either a straight line or a smooth curve) | 1 |
| A5 | Comments on the trend/pattern obtained | 1 |
| A6 | Derives relation between two variables or determines constant | 0 |
| A7 | Discusses/uses related physics principles | 0 |
| A8 | Attempts to qualitatively consider sources of error | 0 |
| A9 | Suggests realistic modifications to reduce error/improve experiment | 0 |
| A10 | Calculates uncertainties | 0 |
| A11 | Provides a final conclusion | 1 |
| | **Marks for this section** | **4** |

*E Report*

| Ref. | Criterion | Mark |
|---|---|---|
| R1 | Summary contains few grammatical or spelling errors | 1 |
| R2 | Summary is structured using appropriate subheadings | 0 |
| | **Marks for this section** | **1** |

| | |
|---|---|
| **Total marks** | **17** |

## Examiner's comments

### *General*

It is recommended that candidates include appropriate diagrams to illustrate their report for the visit.

### *A Summary of physics-based visit*

To gain the mark for *S4: Makes correct statement on relevant physics principles* this candidate should have been more specific on the importance of the end correction and how this is taken into account when considering the frequency of oscillation of the air column in a pipe.

The candidate has used some physics terminology such as 'superposition', 'nodes' and 'antinodes'. However, in order to achieve the mark for *S5: Uses relevant specialist terminology correctly*, the candidate is expected to use the word 'fundamental' when describing the 'simplest pattern' for vibrating air. Also, although she has used it in her report, it is not clear whether this candidate understands the meaning of the word 'resonance'.

The candidate has drawn attention to a useful bi-product of the organ at the symphony hall, ie increasing the attraction of the symphony hall to a wider audience, and hence the mark for *S8: Comments on implication of physics (eg benefits/risks)* is awarded in this case.

The candidate has not overtly explained the relationship between the practical and the visit and therefore the mark for *S9: Explains how the practical relates to the visit or case study* has not been awarded.

### *B Planning*

The candidate stated how to measure the frequency of the note produced by a treble recorder and therefore gained a mark for *P2: States how to measure one relevant quantity using the most appropriate instrument*. However, the candidate lost the mark for *P4: States how to measure a second relevant quantity using the most appropriate instrument* because she did not state that she will use a ruler to measure the length of the air column and nor has she stated where distances are being measured from; candidates should be encouraged to include a diagram to show distances that are being measured.

The candidate could have mentioned that it was necessary to ensure that the temperature of the air did not change during the experiment or that the apparatus needed to be used in a draught-free area to get the mark for *P8: Identifies and states how to control all other relevant variables to make it a fair test*.

The candidate said that she could not see the point of repeating measurements, but the reason given for this was inappropriate; therefore a mark for *P9: Comments on whether repeat readings are appropriate* could not be awarded.

There are no realistic comments on safety precautions and so the given mark for *P10: Comments on safety* is zero. The candidate could have mentioned, for example, that contact between the mouth and recorder in a laboratory presents a hazard if the recorder picks up chemicals from a work bench and therefore the recorder must be handled carefully at all times.

Although the candidate has discussed how she intends to use the data, it is not being used in an appropriate manner (the candidate stated that the gradient of the graph of frequency plotted against wavelength would give the speed of sound). For this reason, a mark for *P11: Discusses how the data collected will be used* could not be given.

The candidate was not awarded a mark for *P12: Identifies the main sources of uncertainty and/ or systematic error* as there are no realistic comments on the possible sources of uncertainty or systematic errors. For example, the candidate could have discussed the fact that the holes in the recorder having a finite size and the effect of this on the accuracy of measuring the length of the vibrating air column.

***C Implementation and measurements***

Although this candidate mentioned that the first note was repeated with a frequency of 1000Hz, the unit of frequency is missing from the table. Therefore the candidate lost the mark for *M2: Uses correct units throughout*.

***D Analysis***

The scales do not spread the points above half the grid in the $y$-direction and one of the points is plotted incorrectly; therefore marks for *A2: Produces a graph with sensible scales* and *A3: Plots points accurately* could not be awarded.

The candidate has mentioned that she was expecting the type of graph shown, and as she has given a reason for this expectation she has achieved the mark for *A5: Comments on the trend/pattern obtained*.

In order to achieve the mark for *A6: Derives relation between two variables or determines constant*, the candidate should have either obtained a reasonable value for the speed of sound or shown how the $Y$ and $X$ variables on the graph are related, ie

$$\frac{1}{f} = \frac{4}{c}L + \frac{4e}{c}$$

where $y = \frac{1}{f}$ and $x = L$.

The candidate could have discussed the inverse nature of the relation between the two variables had she plotted the appropriate graph in order to gain the mark for *A6: Derives relationship between two variables or determines constant*.

The candidate made no attempt to consider errors in an appropriate way, eg with the measurements made or with the use of the software, and therefore could not be credited with marks for *A8* to *A10*.

***E Report***

The candidate should have included subheadings in the report of the visit to achieve *R2*.

## Mid-range exemplar: visit and practical

### Visit to Birmingham airport

In November we visited Birmingham airport. We were given a tour by the community liaison officer. He explained that Birmingham is the sixth busiest airport in the UK and deals with about 9 million passengers each year.

We were shown examples of the application of physics:

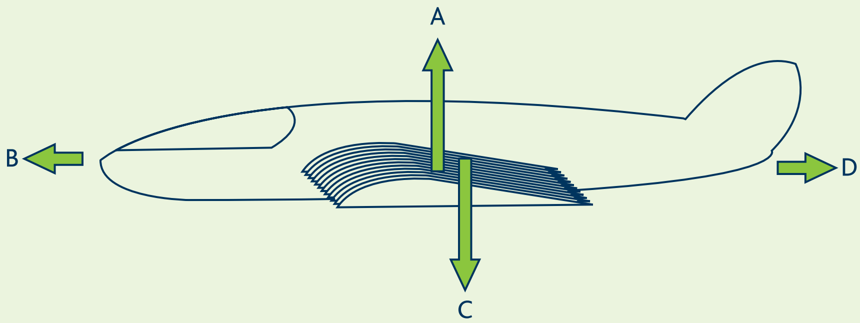
Airport security involving X ray machines

Airport landing guidance – use of radar

and whilst we watched aircraft taking off and landing we were told about the mechanics of flight.

I particularly want to explain the physics of flight and how it relates to landing.

There are four forces acting on a plane in flight as illustrated below.




A is lift caused by the flow of air over the shape and orientation of the wings

B is the thrust provided by propellers or jet turbines

C is the weight

D is drag through the air

At normal cruising speed these forces are balanced.

The thrust force is provided by jet engines propelling air backwards, newton's laws state that there will be a force giving the air a change in momentum and that an equal force must act on the plane forwards.

The lift force is provided by the shape of the wing. Air has to travel further around the top edge of the wing this has the effect of speeding it up compared to the lower edge. As a consequence the pressure is lower above the wing than below.

Another contribution to this lift force is due to the deflected angle of the air flow past the wing (known as angle of attack). If air is deviated from the horizontal then a vertical force is required and an equal and opposite force will apply to the wing of the plane.

Drag force is caused by the viscous nature of air.

The weight includes the craft and its passengers and luggage.

When an airplane approaches an airport it starts a descent – this is usually arranged to be at about 3 degrees to the horizontal. The lift force has to be reduced. This means the speed of the airplane has to be decreased by reducing the thrust. As the cruising speed of a typical passenger jet is about 600 km/h this descent needs to start some way from the airport. As the plane gets close to the airport its speed can be as low as 200 km/h and more lift is usually required than this speed of air over the wings would give. Slats are used to effectively increase the width of the wing and reduce the pressure on the upper side. As the plane nears the ground the swirling air vortices can reduce the lift forces further.

As the plane lands spoilers (vertical plates) reduce the lift further and the airplane is brought to a halt on the runway by brakes in the wheels of the undercarriage.

Reverse thrust can be employed to reduce wear between rubber tyres and the runway or reduce the length of runway use.

The use of reverse thrust is often avoided because it increases noise pollution. However in, say, wet conditions it may have to be employed because water reduces frictional affects.

Bibliography:

1 http://travel.howstuffworks.com/airplane1.htm

2 www.aerospaceweb.org/question/conspiracy/q0274.shtml

3 www.rvs.uni-bielefeld.de/publications/Incidents/DOCS/ComAndRep/Warsaw/leyman/analysis-leyman.html

### An experiment to determine the frictional force acting on a moving trolley

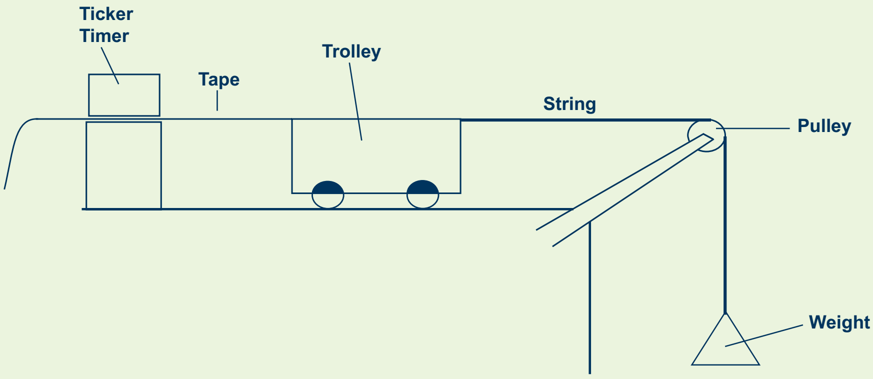
**Apparatus**

- Trolley
- Pulley
- 200g mass
- Ticker tape
- Ticker timer
- 1m rule
- String

**Plan**

I am going to use a mechanics trolley these have a mass of 1.0kg. I'm going to determine the typical frictional forces acting on it whilst it is moving along a bench top. I will connect the trolley to a 200g mass using a length of string. I will place a pulley over the end of the bench to guide the string.




I will then release the 200g mass and it should accelerate the trolley. I will use tickertape timer to determine the acceleration of the trolley *a*.

The forces acting on the trolley are friction F and the weight of 200g = 2N so

$2 - F = ma$

or $F = 2 - 1.2a$ (as the total mass is 1.2 kg).

To find acceleration I will measure every 5 intervals of dots which are punched out every $5 \times 0.02\text{s} = 0.1\text{s}$.

I can calculate the velocity for each 0.1 s interval and plot this against the mid-times. Time is the independent variable and velocity is the dependant variable.

Precision/Accuracy:
A rule is to the nearest mm

**Results**

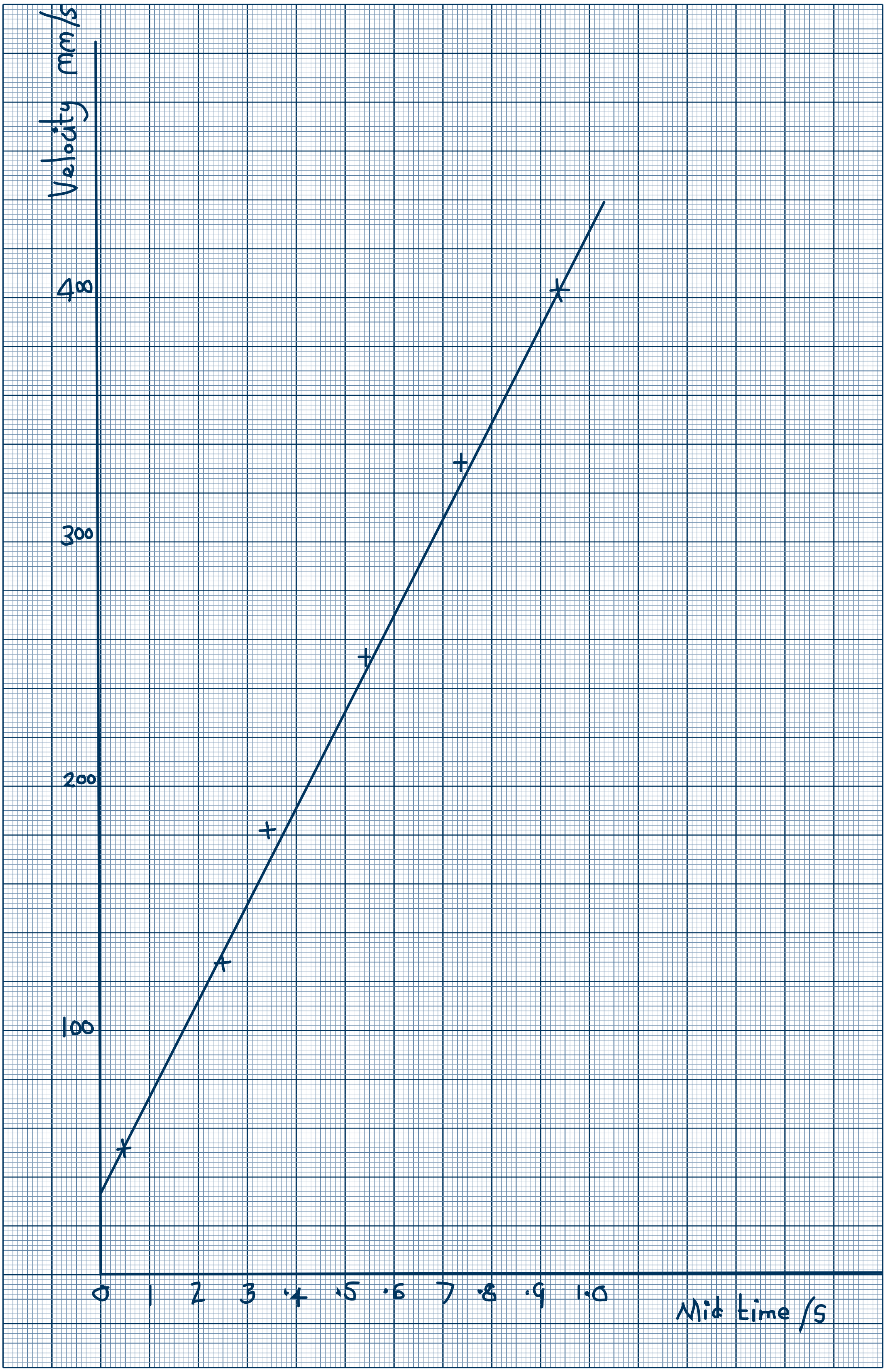
| distance/mm | time/s | velocity mm/s | mid time/s |
|---|---|---|---|
| 5 | 0.1 | 50 | 0.05 |
| 9 | 0.1 | 90 | 0.15 |
| 13 | 0.1 | 130 | 0.25 |
| 18 | 0.1 | 180 | 0.35 |
| 20 | 0.1 | 200 | 0.45 |
| 25 | 0.1 | 250 | 0.55 |
| 28 | 0.1 | 280 | 0.65 |
| 33 | 0.1 | 330 | 0.75 |
| 36 | 0.1 | 360 | 0.85 |
| 40 | 0.1 | 400 | 0.95 |

**Analysis**

The graph is a straight line but not through the origin. I wasn't able to distinguish the first few dots easily so I may have started after the measurements after the 200g had started to move. However the acceleration seems to be constant over this interval of time.

The acceleration is the gradient = 400 – 30 / 0.95 – 0 = $370\text{mm/s}^2 = 0.37\text{m/s}^2$

Now F = 2 – 1.2*a* = 2 – 1.2.0.37 = 1.6N


Velocity mm/s
400
300
200
100
0
·1
·2
·3
·4
·5
·6
·7
·8
·9
1·0
Mid time /s

### *Assessment criteria*

*A Summary of case study or physics-based visit*

| Ref. | Criterion | Mark |
|---|---|---|
| S1 | Carries out a visit OR uses library, consulting a **minimum of three** different sources of information (eg books/websites/journals/magazines/case study provided by Edexcel/manufacturer's data sheets) | 1 |
| S2 | States details of visit venue OR provides **full** details of sources of information | 1 |
| S3 | Provides a brief description of the visit OR case study | 1 |
| S4 | Makes correct statement on relevant physics principles | 0 |
| S5 | Uses relevant specialist terminology correctly | 1 |
| S6 | Provides one piece of relevant information (eg data, graph, diagram) that is not mentioned in the briefing papers for the visit or case study | 0 |
| S7 | Briefly discusses context (eg social/environmental/historical) | 1 |
| S8 | Comments on implication of physics (eg benefits/risks) | 1 |
| S9 | Explains how the practical relates to the visit or case study | 0 |
| | **Marks for this section** | **6** |

*B Planning*

| Ref. | Criterion | Mark |
|---|---|---|
| P1 | Lists all materials required | 1 |
| P2 | States how to measure one relevant quantity using the most appropriate instrument | 1 |
| P3 | Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P4 | States how to measure a second relevant quantity using the most appropriate instrument | 1 |
| P5 | Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P6 | Demonstrates knowledge of correct measuring techniques | 1 |
| P7 | States which is the independent and which is the dependent variable | 1 |
| P8 | Identifies and states how to control all other relevant variables to make it a fair test | 0 |
| P9 | Comments on whether repeat readings are appropriate in this case | 0 |
| P10 | Comments on safety | 0 |
| P11 | Discusses how the data collected will be used | 1 |
| P12 | Identifies the main sources of uncertainty and/or systematic error | 0 |
| P13 | Draws an appropriately labelled diagram of the apparatus to be used | 1 |
| P14 | Plan is well organised and methodical, using an appropriately sequenced step-by-step procedure | 1 |
| | **Marks for this section** | **8** |

*C Implementation and measurements*

| Ref. | Criterion | Mark |
|---|---|---|
| M1 | Records all measurements using the correct number of significant figures, tabulating measurements where appropriate | 1 |
| M2 | Uses correct units **throughout** | 1 |
| M3 | Obtains an appropriate number of measurements | 0 |
| M4 | Obtains measurements over an appropriate range | 0 |
| | **Marks for this section** | **2** |

*D Analysis*

| Ref. | Criterion | Mark |
|---|---|---|
| A1 | Produces a graph with appropriately labelled axes and with correct units | 1 |
| A2 | Produces a graph with sensible scales | 1 |
| A3 | Plots points accurately | 1 |
| A4 | Draws line of best fit (either a straight line or a smooth curve) | 1 |
| A5 | Comments on the trend/pattern obtained | 1 |
| A6 | Derives relation between two variables or determines constant | 1 |
| A7 | Discusses/uses related physics principles | 1 |
| A8 | Attempts to qualitatively consider sources of error | 0 |
| A9 | Suggests realistic modifications to reduce error/improve experiment | 0 |
| A10 | Calculates uncertainties | 0 |
| A11 | Provides a final conclusion | 1 |
| | **Marks for this section** | **8** |

*E Report*

| Ref. | Criterion | Mark |
|---|---|---|
| R1 | Summary contains few grammatical or spelling errors | 1 |
| R2 | Summary is structured using appropriate subheadings | 0 |
| | **Marks for this section** | **1** |

| | |
|---|---|
| **Total marks** | **25** |

## Examiner's comments

### *General*

It is recommended that candidates include appropriate numerical quantities/arguments when appropriate in their reports.

### *A Summary of physics-based visit*

The candidate could have quoted the Bernoulli principle or some appropriate figures to have obtained a mark for *S4: Makes correct statement on relevant physics principles*. Further illustrations to accompany some of the arguments would have gained *S6: Provides one piece of relevant information (eg data, graph, diagram) that is not mentioned in the briefing papers for the visit or case study*. There is no attempt to relate the practical to the visit and therefore a mark for *S9: Explains how the practical relates to the visit or case study* was not given.

### *B Planning*

This candidate did not consider other variables (*P8: Identifies and states how to control* ***all*** *other* ***relevant*** *variables to make it a fair test*) that may have affected the experiment and, more crucially, did not consider repeating the experiment at least once (*P9: Comments on whether repeat readings are appropriate in this case*). Although the candidate makes some attempt to consider precision, she did not comment on possible sources of error such as measurements of short lengths at the start of the tickertape (*P12: Identifies the main sources of uncertainty and/or systematic error*).

### *C Implementation and measurements*

The candidate actually obtained significantly more results (dots) than those used to plot the graph but chose to ignore the rest and therefore marks for *M3: Obtains an appropriate number of measurements* and *M4: Obtains measurements over an appropriate range* could not be awarded.

### *D Analysis*

Although this candidate seems to have a good idea of how to interpret the graph to calculate acceleration and hence friction, there is a lack of appreciation for sources of error (*A8* to *A10*). The distances for the initial dots is small and the initial values are difficult to determine — the initial velocity is probably the value some time after the 200g mass has been released, as this candidate rather vaguely tries to point out.

### *E Report*

Subheadings were not used in the visit report.

# Unit 6 guidance

## Unit overview

This summary outlines what students are required to do for Unit 6:

- Students must plan an experiment, carry out an experiment, record measurements, analyse their own results and draw conclusions.
- All students are allowed to produce a plan for the same experiment and do the same practical work; however, it is vital that students are able to demonstrate that the assessed work they produce is entirely their own.
- Where students are unable to carry out the experiment detailed in their plan, they are permitted to conduct a different experiment; however, their original plan can still be submitted for assessment.
- Students’ work can be based either on briefing material provided by Edexcel or on briefing material devised by your centre.
- The assessment itself should take about two hours to complete.
- Unit 6 can be completed at any time during the A2 course, although you may find it most appropriate to conduct the assessment towards the end of the A2 year.

## Unit 6 exemplars of marked students' work

Here are two examples of student work for the Unit 6 assessment based on the same experiment. They are at two different grade levels, so you can see the standards required and how the assessment criteria are applied. The first example is a mid-range grade exemplar, and the second a low grade exemplar.

### Mid-range grade exemplar

**Nanotechnology and Prostate Cancer Detection**

Nanotechnology is a growing area of research which has already produced many useful applications. For example, in medical physics protein markers that are characteristic of prostate cancer can be made to stick to a microscopic cantilever. The proteins are detected via an electrical measurement of a change in the resonant frequency of the cantilever.

A metre rule clamped to a bench at one end and loaded at the other end is an example of a cantilever.

Displacing the mass vertically from its equilibrium position will result in simple harmonic oscillations.

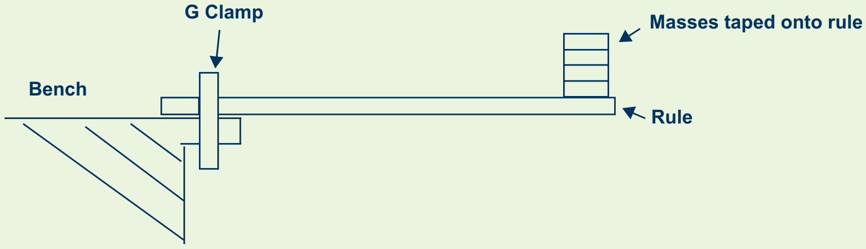
Plan and carry out an experiment to investigate how the period of vertical oscillation of a cantilever, $T$, depends upon the attached mass, $m$.

## Experimental procedure

### List of apparatus

- Metre rule
- G clamp
- Stopwatch capable of reading to ± 0.1s
- Masses from 100g to 800g in 50g increments
- Clamp and stand to identify centre point of oscillation

### Method




Before starting the experiment I will make sure that I have a clear working area, and that all books and bags are packed away under the bench.

I will clamp the metre rule to the edge of the bench with a large overhang. I will keep this overhang distance constant throughout the rest of the experiment. I will then add a mass to the free end of the metre rule, using tape to keep it firmly in place.

I will displace the loaded end of the ruler through a few centimetres so that it is set into oscillation. Using the stopwatch I will record the time for 30 oscillations, timing from the centre of the oscillation. I will repeat this measurement twice and take an average. This will help to reduce the effect of random error in my experiment.

I will increase the mass on the end of the ruler and repeat the timing measurements. I will collect data for 6 different masses in total.

### Recording results

I will record all of my data in a table like the one below.

| Mass at free end, $m$ / g | Time for 30 Oscillations | | | | Time period, $T$ / s |
|---|---|---|---|---|---|
| | $t_1$ / s | $t_2$ / s | $t_3$ / s | $t_{av}$ / s | |
| | | | | | |

$T = t_{av} / 30$

### Analysis of results

Assume that there is a simple power relationship between the time period and the mass at the loaded end of the ruler.

$\therefore \log(T) = \log(km^n)$

$\therefore \log(T) = \log(k) + \log(m^n)$

$\therefore \log(T) = \log(k) + n\log(m)$

$\therefore \quad y \quad = \quad c \quad + \quad mx$

So a graph of $\log(T)$ against $\log(m)$ should be a straight line with gradient $n$.

**Implementation**

When I measured the time period I used the second clamp and stand to act as a pointer so that I knew where the centre of the oscillation was. This allowed me to time from the centre of the oscillation and hence obtain a more accurate value for the time. This is because the mass will be moving fastest at the centre of the oscillation.

**Results:**

| Mass at free end, $m$ / g | Time for 30 Oscillations | | | | Time period, $T$ / s |
|---|---|---|---|---|---|
| | $t_1$ / s | $t_2$ / s | $t_3$ / s | $t_{av}$ / s | |
| 150 | 14.7 | 14.9 | 14.9 | 14.8 | 0.494 |
| 250 | 20.1 | 20.4 | 19.5 | 20.0 | 0.667 |
| 350 | 24.6 | 24.0 | 23.7 | 24.1 | 0.803 |
| 450 | 26.7 | 26.4 | 27.0 | 26.7 | 0.890 |
| 550 | 30.3 | 30.6 | 29.4 | 30.1 | 1.003 |
| 650 | 32.1 | 32.7 | 32.4 | 32.4 | 1.080 |

| Log($T$) | Log($m$) |
|---|---|
| -0.306 | 2.18 |
| -0.176 | 2.40 |
| -0.095 | 2.54 |
| -0.051 | 2.65 |
| 0.001 | 2.74 |
| 0.033 | 2.81 |

$$gradient = \frac{0.1 - (-0.35)}{2.93 - 2.08} = \frac{0.45}{0.85} = 0.53$$

From my graph I have found the gradient to be 0.53. This is very close to 0.5 and I feel reasonably confident that the value of $n$ is 0.5.

So I can write an expression for the time period variation with mass: $T = km^{0.5}$

$\therefore\ T = k\sqrt{m}$ or $T^2 \propto m$

**Error analysis**

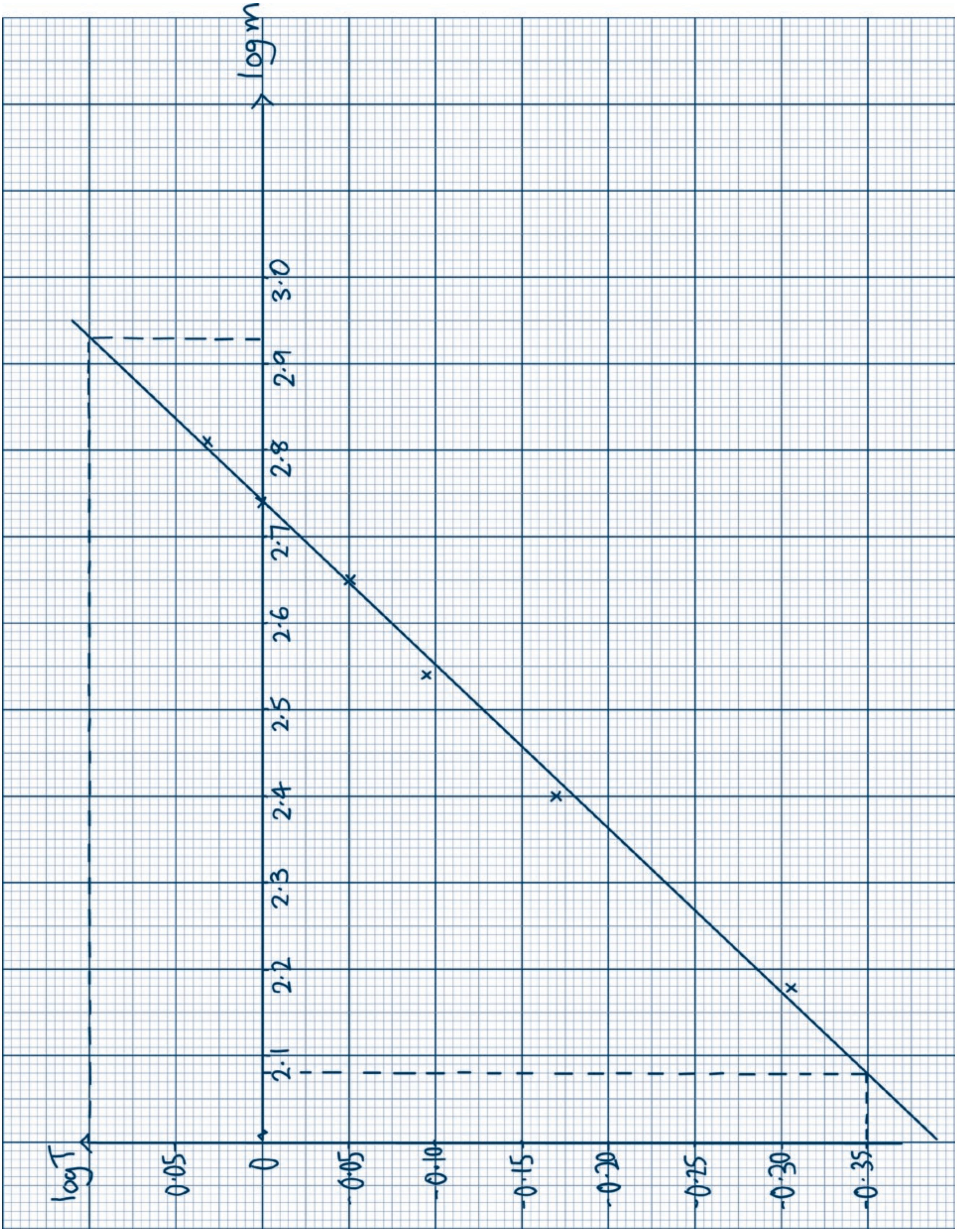
When timing the oscillations the precision of the stopwatch was 0.01s. However, there would have starting and stopping errors in these timings and so I decided to quote my times to ± 0.1s. In order to improve the accuracy of the times I timed a large number of oscillations three times to find an average value for the time period of each different loaded ruler. I used standard masses for loading the free end of the metre ruler.

If I were to repeat the experiment I would increase the total number of oscillations timed.

**Conclusion**

My results clearly show that $T = k\sqrt{m}$


log m
3·0
2·9
2·8
2·7
2·6
2·5
2·4
2·3
2·2
2·1
log T
0·05
0
-0·05
-0·10
-0·15
-0·20
-0·25
-0·30
-0·35

## *Assessment criteria*

*A Planning*

| Ref. | Criterion | Mark |
|---|---|---|
| P1 | Identifies the most appropriate apparatus required for the practical in advance | 1 |
| P2 | Provides clear details of apparatus required including approximate dimensions and/or component values (for example, dimensions of items such as card or string, value of resistor) | 1 |
| P3 | Draws an appropriately labelled diagram of the apparatus to be used | 1 |
| P4 | States how to measure one quantity using the most appropriate instrument | 0 |
| P5 | Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P6 | States how to measure a second quantity using the most appropriate instrument | 0 |
| P7 | Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P8 | Demonstrates knowledge of correct measuring techniques | 1 |
| P9 | Identifies and states how to control all other relevant quantities to make it a fair test | 1 |
| P10 | Comments on whether repeat readings are appropriate for this experiment | 1 |
| P11 | Comments on all relevant safety aspects of the experiment | 1 |
| P12 | Discusses how the data collected will be used | 1 |
| P13 | Identifies the main sources of uncertainty and/or systematic error | 0 |
| P14 | Plan contains few grammatical or spelling errors | 1 |
| P15 | Plan is structured using appropriate subheadings | 1 |
| P16 | Plan is clear on first reading | 1 |
| | **Marks for this section** | **11** |

*B Implementation and measurements*

| Ref. | Criterion | Mark |
|---|---|---|
| M1 | Records all measurements with appropriate precision, using a table where appropriate | 1 |
| M2 | Readings show appreciation of uncertainty | 0 |
| M3 | Uses correct units throughout | 1 |
| M4 | Refers to initial plan while working and modifies if appropriate | 0 |
| M5 | Obtains an appropriate number of measurements | 1 |
| M6 | Obtains measurements over an appropriate range | 1 |
| | **Marks for this section** | **4** |

*C Analysis*

| Ref. | Criterion | Mark |
|---|---|---|
| A1 | Produces a graph with appropriate axes (including units) | 1 |
| A2 | Produces a graph using appropriate scales | 1 |
| A3 | Plots points accurately | 1 |
| A4 | Draws line of best fit (either a straight line or a smooth curve) | 1 |
| A5 | Derives relation between two variables or determines constant | 1 |
| A6 | Processes and displays data appropriately to obtain a straight line where possible, for example, using a log/log graph | 1 |
| A7 | Determines gradient using large triangle | 1 |
| A8 | Uses gradient with correct units | 1 |
| A9 | Uses appropriate number of significant figures throughout | 0 |
| A10 | Uses relevant physics principles correctly | 1 |
| A11 | Uses the terms precision and either accuracy or sensitivity appropriately | 0 |
| A12 | Discusses more than one source of error qualitatively | 1 |
| A13 | Calculates errors quantitatively | 0 |
| A14 | Compounds errors correctly | 0 |
| A15 | Discusses realistic modifications to reduce error/improve experiment | 0 |
| A16 | States a valid conclusion clearly | 1 |
| A17 | Discusses final conclusion in relation to original aim of experiment | 0 |
| A18 | Suggests relevant further work | 0 |
| | **Marks for this section** | **11** |

| | |
|---|---|
| **Total marks** | **26** |

## Examiner's comments

### *A Planning*

Marks for *P1: Identifies the most appropriate apparatus required for the practical in advance* and *P2: Provides clear details of apparatus required including approximate dimensions and/or component values (eg dimensions of items such as card or string, value or resistor)* are awarded, as all necessary apparatus has been listed, and the stopwatch sensitivity and range of masses has been identified. *Marks for P4: States how to measure one quantity using the most appropriate instrument* and *P5: States how to measure a second quantity using the most appropriate instrument* would have been gained if the student had explained how the time period would be found and how the masses were known. The student has referred to timing from the centre of the oscillation, and so the mark for *P8: Demonstrates knowledge of correct measuring techniques* is awarded.

The student stated his intention to keep the overhang distance constant throughout the rest of the experiment and increase the mass on the end of the rule. Hence he achieved the mark for *P9: Identifies and states how to control all other relevant variables to make it a fair test*.

Reference to repeat measurements is made, as is a reference to safety, and so *P10: Comments on whether repeat readings are appropriate for this experiment* and *P11: Comments on all relevant safety aspects of the experiment* are awarded. The student correctly identifies that a graph of log($T$) against log($m$) should be plotted and so a mark for *P12: Discusses how the data collected will be used* is awarded, but there is no reference to errors/uncertainties in the plan and so a mark for *P13: Identify the main sources of uncertainty and/or systematic error* is not given. The plan is well structured and there are no grammatical/spelling errors and so marks for *P14: Plan contains few grammatical or spelling errors* and *P15: Plan is structured using appropriate subheadings* are awarded.

### B Implementation and measurements

The results were tabulated with appropriate precision and appropriate units were given for all quantities, so marks for *M1: Records all measurements with appropriate precision, using a table where appropriate* and *M3: Uses correct units throughout* were awarded. The student has not modified the original plan, eg he could have drawn a rough graph as the experiment was carried out, and so *M4: Refers to initial plan while working, and modifies if appropriate* is not awarded. The range and number of points are suitable and so marks for *M5: Obtains an appropriate number of measurements* and *M6: Obtains measurements over an appropriate range* are awarded.

### C Analysis

The graph scales are suitable, points are accurately plotted with a line of best fit drawn and the student has used the equation of a straight line ($y = mx + c$) to derive an expression, hence marks for *A1* to *A4* are awarded. The student has used a log-log graph and determined the gradient correctly using a large triangle and so marks for *A5* to *A7* are awarded. The use of two few significant figures in the calculation of the gradient loses the mark for *A9: Uses appropriate number of significant figures throughout*. The gradient is correctly interpreted, and so the mark for *A10: Uses relevant physics principles correctly* is awarded.

There is some confusion in the use of the terms 'sensitivity', 'precision' and 'accuracy' and so the mark for *A11: Uses the terms precision and either accuracy or sensitivity appropriately* could not be awarded. There is a discussion of starting and stopping errors in timing the oscillations and so the mark for *A12: Discusses more than one source of error qualitatively* is awarded. There is no attempt to carry out a simple error analysis (eg work out the fractional error in each quantity measured) so errors cannot be combined and hence the marks for *A13: Calculates errors quantitatively* and *A14: Compounds errors correctly* cannot be awarded.

A modification is suggested but no indication is given as to how this would improve the experiment and so a mark for *A15: Discusses realistic modifications to reduce error/improve experiment* is not awarded. The final conclusion is valid and so a mark for *A16: States a valid conclusion clearly* is awarded. However, there is no attempt to relate the conclusion to the original aim of the experiment and so a mark for *A17: Discusses final conclusion in relation to original aim of experiment* is not awarded. The student makes no suggestion for further work (eg to investigate whether the length of the cantilever has any impact on the results obtained) and so a mark for *A18: Suggests relevant further work* is not awarded.

## Points for improvement

### *Planning*

The candidate has produced a workable plan, although if the candidate had given more detail on how the measurements were to be made and included some discussion of errors, then up to four marks could have been added to this section.

### *Analysis*

There is little attempt to carry out any quantitative error analysis. The candidate has suggested a modification, but has not discussed how this would improve the experiment. Nor has there been any indication of any further work that could be carried out (eg repeating the experiment with a different overhang). If these points had been addressed, then the candidate could have gained at least an additional four marks.

The combined effect of making the improvements to planning and analysis suggested above would have been to take the candidate from a mid-range grade to a high grade.

## Low-range grade exemplar

### Plan

Before starting the experiment I will clear the bench space so that I can set up the apparatus safely.

I will clamp the metre rule to the edge of the bench. I will then use tape to fix a mass to the free end of the metre rule to load the cantilever.

I will set the cantilever into oscillation and using the stopwatch I will record the time for 20 oscillations. I will repeat this measurement and find an average.

I will increase the mass on the end of the ruler and repeat the timing measurements. I will collect data for 5 different masses in total.

I will record all of my data in a table like the one below.

| Mass at free end, $m$ / g | Time for 20 Oscillations | | | | Time Period, $T$ / s |
|---|---|---|---|---|---|
| | $t_1$ / s | $t_2$ / s | $t_3$ / s | $t_{av}$ / s | |
| | | | | | |

I will plot a graph of time period against mass to see if there is a linear relationship between the quantities.

### Implementation

When I measured the time period I set the cantilever into oscillation and let it oscillate a couple of times before I started timing. This was to allow the cantilever to settle into harmonic oscillation.

### Results

| Mass at free end, $m$ / g | Time for 20 Oscillations | | | | Time Period, $T$ / s |
|---|---|---|---|---|---|
| | $t_1$ / s | $t_2$ / s | $t_3$ / s | $t_{av}$ / s | |
| 0.2 | 12.12 | 12.24 | 12.18 | 0.609 | 0.494 |
| 0.3 | 14.9 | 14.82 | 14.86 | 0.743 | 0.667 |
| 0.4 | 17.38 | 17.48 | 17.43 | 0.8715 | 0.803 |
| 0.5 | 19.63 | 19.32 | 19.475 | 0.9738 | 0.890 |
| 0.6 | 21.26 | 21.4 | 21.33 | 1.0665 | 1.003 |

$$\text{gradient} = \frac{1.15 - 0.4}{0.650} = 1.15$$

intercept = 0.4

**Discussion**

From my graph I have found that my points lie on a straight line of gradient 1.15. The line cuts the $y$-axis at 0.4.

The equation of a straight line is $y = mx + c$, so I can write for the cantilever

$$T = 1.15m + 0.4$$

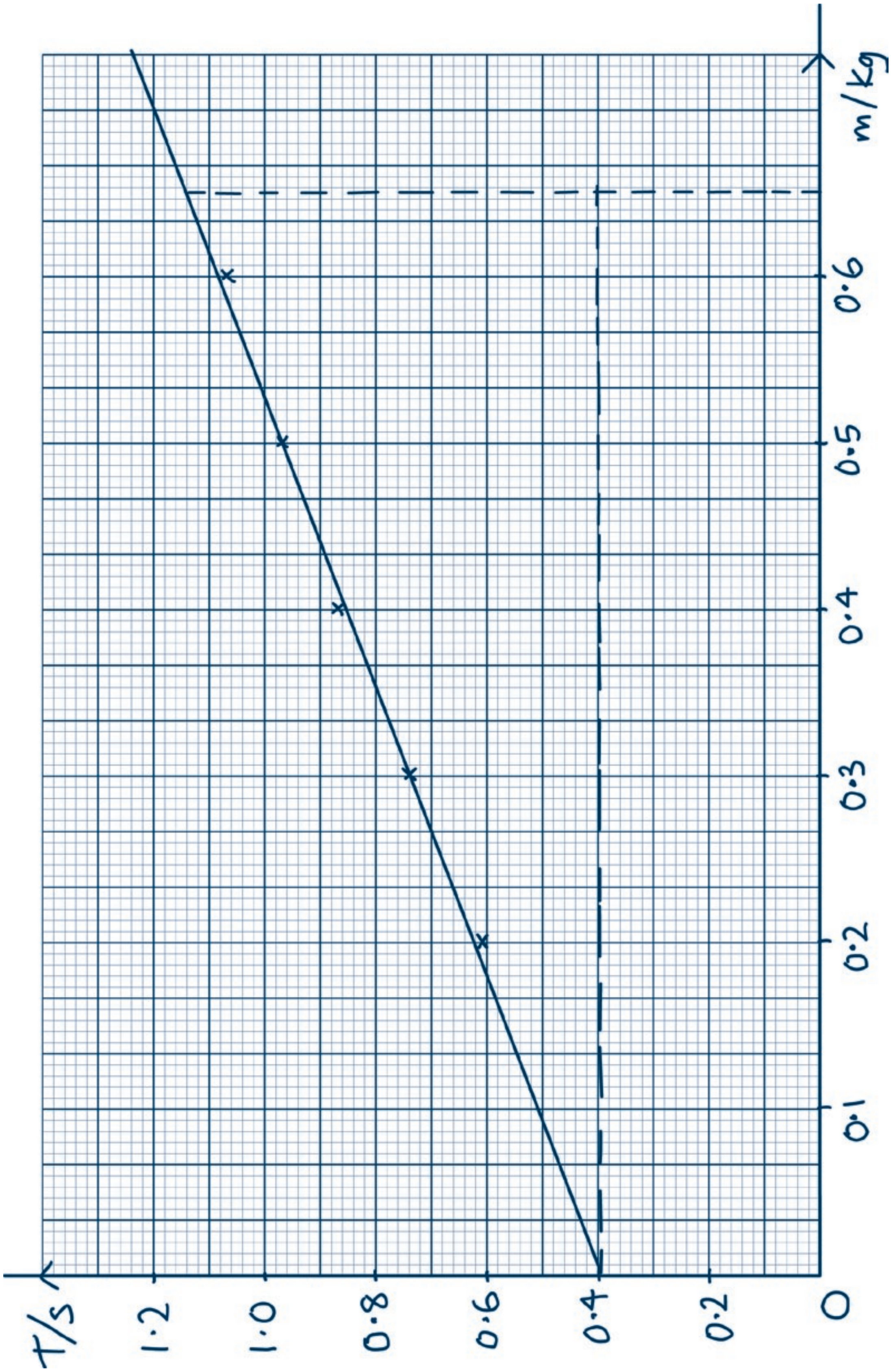
**Error analysis**

When timing the oscillations the precision of the stopwatch was 0.01s. To improve the accuracy I repeated the timing for each added mass twice and took an average value for the time period.

Manually starting and stopping the stopwatch leads to errors in the timings. To make the experiment more accurate I would use an electronic timer connected to a data logger to measure the time period.

**Conclusion**

The time period of a cantilever varies in proportion with the added mass.


T/s
1·2
1·0
0·8
0·6
0·4
0·2
O
m/Kg
0·1
0·2
0·3
0·4
0·5
0·6

## *Assessment criteria*

### *A Planning*

| Ref. | Criterion | Mark |
|---|---|---|
| P1 | Identifies the most appropriate apparatus required for the practical in advance | 0 |
| P2 | Provides clear details of apparatus required including approximate dimensions and/or component values (for example, dimensions of items such as card or string, value of resistor) | 0 |
| P3 | Draws an appropriately labelled diagram of the apparatus to be used | 0 |
| P4 | States how to measure one quantity using the most appropriate instrument | 0 |
| P5 | Explains the choice of the measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P6 | States how to measure a second quantity using the most appropriate instrument | 0 |
| P7 | Explains the choice of the second measuring instrument with reference to the scale of the instrument as appropriate and/or the number of measurements to be taken | 0 |
| P8 | Demonstrates knowledge of correct measuring techniques | 0 |
| P9 | Identifies and states how to control all other relevant quantities to make it a fair test | 0 |
| P10 | Comments on whether repeat readings are appropriate for this experiment | 1 |
| P11 | Comments on all relevant safety aspects of the experiment | 1 |
| P12 | Discusses how the data collected will be used | 1 |
| P13 | Identifies the main sources of uncertainty and/or systematic error | 0 |
| P14 | Plan contains few grammatical or spelling errors | 1 |
| P15 | Plan is structured using appropriate subheadings | 1 |
| P16 | Plan is clear on first reading | 1 |
| | **Marks for this section** | **6** |

### *B Implementation and measurements*

| Ref. | Criterion | Mark |
|---|---|---|
| M1 | Records all measurements with appropriate precision, using a table where appropriate | 0 |
| M2 | Readings show appreciation of uncertainty | 0 |
| M3 | Uses correct units throughout | 1 |
| M4 | Refers to initial plan while working and modifies if appropriate | 0 |
| M5 | Obtains an appropriate number of measurements | 0 |
| M6 | Obtains measurements over an appropriate range | 1 |
| | **Marks for this section** | **2** |

*C Analysis*

| Ref. | Criterion | Mark |
|---|---|---|
| A1 | Produces a graph with appropriate axes (including units) | 1 |
| A2 | Produces a graph using appropriate scales | 0 |
| A3 | Plots points accurately | 1 |
| A4 | Draws line of best fit (either a straight line or a smooth curve) | 1 |
| A5 | Derives relation between two variables or determines constant | 1 |
| A6 | Processes and displays data appropriately to obtain a straight line where possible, for example, using a log/log graph | 0 |
| A7 | Determines gradient using large triangle | 1 |
| A8 | Uses gradient with correct units | 0 |
| A9 | Uses appropriate number of significant figures throughout | 0 |
| A10 | Uses relevant physics principles correctly | 0 |
| A11 | Uses the terms precision and either accuracy or sensitivity appropriately | 0 |
| A12 | Discusses more than one source of error qualitatively | 1 |
| A13 | Calculates errors quantitatively | 0 |
| A14 | Compounds errors correctly | 0 |
| A15 | Discusses realistic modifications to reduce error/improve experiment | 0 |
| A16 | States a valid conclusion clearly | 0 |
| A17 | Discusses final conclusion in relation to original aim of experiment | 0 |
| A18 | Suggests relevant further work | 0 |
| | **Marks for this section** | **6** |

| | |
|---|---|
| **Total marks** | **14** |

## Examiner's comments

### *A Planning*

To obtain the mark for *P1: Identifies the most appropriate apparatus required for the practical in advance* the student would have needed to refer to a pin in a cork held in a clamp-stand or some other suitable fiducial marker. There is no indication of the type and range of masses required to perform the experiment and so *P2: Provides clear details of apparatus required including approximate dimensions and/or component values (eg dimensions of items such as card or string value of resistor)* is not awarded.

Marks for *P4: States how to measure one quantity using the most appropriate instrument* and *P6: States how to measure a second quantity using the most appropriate instrument* would have been gained if the student had explained how the time period would be found and how the masses were known. Good practice in timing oscillations is to time from the centre of the oscillation (as the mass will be travelling fastest at this point reducing the error in determining the starting and stopping times). Since the student has not referred to this, then the mark for *P8: Demonstrates knowledge of correct measuring techniques* is lost. In order to gain the mark for *P9: Identifies and states how to control all other relevant variables to make it a fair test*, the student should make it clear that the length of the oscillating ruler should be the same for each oscillation period measured, eg by stating that the metre rule is firmly clamped at the same point throughout the experiment and the masses are all attached at the same point throughout.

Reference to repeat measurements is made, as is a reference to safety, and so marks for *P10: Comments on whether repeat readings are appropriate for this experiment* and *P11: Comments on all relevant safety aspects of the experiment* are awarded. The student identifies that a graph of $T$ against $m$ should be plotted (although this is not useful, nonetheless the student has indicated how they intend to process their data) and so the mark for *P12: Discusses how the data collected will be used* is awarded. However, there is no reference to errors/uncertainties at all and so the mark for *P13: Identifies the main sources of uncertainty and/or systematic error* is not given.

There are no grammatical/spelling errors and so a mark for *P14: Plan contains few grammatical or spelling errors* has been awarded. The plan is reasonably well structured so a mark for *P15: Plan is structured using appropriate subheadings* was awarded.

### B Implementation and measurements

The results were tabulated, but variable precision in the data table means that the mark for *M1: Records all measurements with appropriate precision, using a table where appropriate* cannot be awarded. Raw data should be recorded to a consistent number of decimal places (normally to the precision of the instrument). Appropriate units were given for all quantities and so the mark for *M3: Uses correct units throughout* was awarded.

The student should have realised that 20 oscillations was giving too short a time for accurate results and so the mark for *M4: Refers to initial plan while working, and modifies if appropriate* is lost. Although the range is suitable (the mark for *M6: Obtains measurements over an appropriate range* was awarded), six good points is the minimum acceptable for a straight line and so the mark for *M5: Obtains an appropriate number of measurements* is not awarded.

### C Analysis

The $x$-axis has a difficult scale and therefore the mark for *A2* has not been awarded. Points are accurately plotted with a line of best fit drawn and the student has used the equation of a straight line ($y = mx + c$) to derive an expression, hence the marks for *A3* to *A4* are awarded.

The student has not processed and plotted the data appropriately for this experiment; a log-log graph is expected so the candidate loses the mark for *A6: Processes and displays data appropriately, eg use of log/log graph*. Even though their straight line is incorrect for the relationship given, they have determined the gradient correctly using a large triangle and so marks for *A7: Determines gradient using large triangle* is awarded. The use of varying numbers of significant figures in the calculation of the time period loses the mark for *A9: Uses appropriate number of significant figures throughout* (processed data should be quoted to a consistent number of significant figures, taking into account the number of significant figures in the raw data). The erroneous assumption of a linear relationship loses the mark for *A10: Uses relevant physics principles correctly*.

There is some confusion in the use of the terms 'sensitivity', 'precision' and 'accuracy' and so the mark for *A11: Uses the terms precision and either accuracy or sensitivity appropriately* is not awarded. There is a reasonable discussion of starting and stopping errors in timing the oscillations and so the mark for *A12: Discusses more than one source of error qualitatively* is awarded. There is no attempt to carry out a simple error analysis (eg work out the fractional error in each quantity measured) and so errors cannot be combined and the marks for *A13: Calculates errors quantitatively* and *A14: Compounds errors correctly* cannot be awarded.

The modifications suggested are not realistic (a realistic modification would have identified absolute error in the timing as the most significant error and suggested timing more oscillations to reduce the impact of this) and so the mark for *A15: Discusses realistic modifications to reduce error/ improve experiment* is not awarded. The final conclusion is not valid as the relationship obtained is not a proportional one (as well as the fact that power relationship has been mistaken for a linear relationship). For this reason the marks for neither *A16: States a valid conclusion clearly* nor *A17: Discusses final conclusion in relation to original aim of experiment* are awarded. The student makes no suggestion for further work (eg to investigate whether the length of the cantilever has any impact on the results obtained) and so the mark for *A18: Suggests relevant further work* is not awarded.

## Points for improvement

### *Planning*

The candidate has produced a workable plan, although a number of key details are missing. If the candidate had thought more about the apparatus in terms of sensitivity, ranges, etc and had given more detail on how the measurements were to be made, then up to four marks could have been added to this section.

### *Analysis*

The graph is deficient, as the scale is difficult and so it is hard to take readings from the graph for in-between points. A major problem with the candidate's analysis is the assumption that there would be a linear relationship between the two variables. This also affected the marks awarded for the conclusion. There is no attempt to carry out any quantitative error analysis; the candidate is satisfied with a gradient that is close to a half. If these points had been addressed, then the candidate could have added at least four marks.

The combined effect of making the improvements to planning and analysis suggested above would have been to take the candidate from a low grade to a mid-range grade.

# Student Guide

## What do I need to know, or be able to do, before taking this course?

The qualification builds on the knowledge, understanding and process skills that you achieved in GCSE Science. You will need at least a GCSE grade C in Physics or Additional Science (or equivalent). You should also have at least a grade C in GCSE Mathematics (or equivalent) as numerical and mathematical skills are important in physics. Communication is also important as you will need to be able to communicate effectively, carry out research and critically think about problems.

## What will I learn?

**Unit 1: Physics on the go**

This unit leads on from your GCSE studies.

You will learn about motion, forces, energy, power, flow of liquids, viscosity and properties of materials. Applications that use these concepts include sports, the production of sweets and biscuits, and spare-part surgery.

**Unit 2: Physics at work**

The physics content of this unit is related to applications that include medical physics, music, technology in space and solar cells.

You will learn about waves including standing waves, refraction, polarisation, diffraction and the nature of light. You will also learn about electric circuits, resistivity, thermistors, emf and internal resistance.

**Unit 4: Physics on the move**

The physics content of this unit is related to applications that include transport, communications and display techniques. It is also related to exciting, current research in the field of particle physics.

You will learn about momentum, circular motion, electric and magnetic fields, evidence for a nuclear atom, particle accelerators, particle detectors and different types of sub-atomic particles.

**Unit 5: Physics from creation to collapse**

The physics content of this unit is related to applications that include the construction of buildings in earthquake zones and a detailed exploration of astrophysics and cosmology.

You will learn about thermal energy, radioactive decay, simple harmonic motion, resonance, gravitation, the life cycle of stars, fission, fusion and the fate of the universe.

While studying these units you will develop practical skills that include planning experiments, collecting data, analysing experimental results and making conclusions. You will also gain an appreciation of how scientific models are developed and evolve, the applications and implications of science, the benefits and risks that science brings, and the ways in which society uses science to make decisions.

Two other units (**3: Exploring physics** and **6: Experimental physics**) are not shown in the above table because they are practical assessments that are based on the skills you will develop while you are studying the above units.

## Is this the right subject for me?

**AS Physics** is suitable if you:

- want to progress to the full A-level
- want a grounding in a relevant worthwhile qualification of recognised value
- want to broaden your educational experience before making a decision about which A-levels to take
- are taking A-levels in the other Sciences and/or Mathematics or other relevant courses such as Design and Technology and want to take another course that will support your studies.

**A2 Physics** is suitable if you:

- have an interest in, and enjoy, physics
- want to find out about how things work in the physical world
- enjoy applying your mind to solving problems
- enjoy carrying out investigations by the application of imaginative, logical thinking
- want to use physics to move on to further studies in Higher Education, support other qualifications or enter physics-based employment.

## How will I be assessed?

**AS** For Units 1 and 2 you will do a written paper that lasts for 80 minutes. The papers will contain objective questions, short questions and longer questions. For Unit 3 you will do an experiment that is based on either a physics-based visit or a case study of a practical application of physics. You will use the skills that you have gained while studying the AS to plan an experiment, do the experiment to obtain data, analyse the data and produce conclusions.

**A2** For Units 4 and 5 you will do a written paper that lasts for 95 minutes. The papers will contain objective questions, short questions and longer questions. For Unit 6 you will use the skills that you have gained to plan an experiment, do an experiment to obtain data, analyse the data and produce conclusions.

## What can I do after I've completed the course?

Physics leads on to a wide range of courses and careers. You could use Physics to support other qualifications or move on to further studies or employment, including:

- a BTEC Higher National (HNC and HND) or a degree course such as Physics, the Sciences, Medicine, Metrology, Engineering (including Chemical Engineering) and related programmes
- employment in the area of, for example, radiography or biotechnology.

In fact, Physics is recognised as an entry qualification for a wide range of Higher Education courses and employment opportunities.

## Next steps!

You could:

- visit *http://learningphysics.iop.org/beyond_school/careers/index.html* for further information on careers in physics
- discuss the possibility of studying this subject with your Physics or Science teacher(s)
- visit your careers office to find out more about careers and Higher Education courses that need GCE Physics
- order free physics careers booklets from the Institute of Physics website: *www.iop.org/activity/education/Promoting_Physics/Career_Resources/page_5893.html*
- visit the Edexcel website, *www.edexcel.com*, to obtain a full copy of the Edexcel GCE in Physics specification.

# Unit overviews for students

## Introduction

Each overview provides you with a summary of the content and assessment for each unit, making it clear what you need to know, and how you will be expected to demonstrate what you know.

While studying these units, you will develop practical skills that include planning experiments, collecting data, analysing experimental results and making conclusions. You will also gain an appreciation of how scientific models are developed and evolve, the applications and implications of science, the benefits and risks that science brings, and the ways in which society uses science to make decisions.

## AS units

| Unit 1: Physics on the go | |
|---|---|
| Content | This unit leads on from your GCSE studies.<br>You will learn about motion, forces, energy, power, flow of liquids, viscosity and properties of materials. Applications that use these concepts include sports, the production of sweets and biscuits, and spare-part surgery. |
| Assessment | You will do a written paper that lasts for 80 minutes. The paper will contain objective questions, short questions and longer questions. |

| Unit 2: Physics at work | |
|---|---|
| Content | The physics content of this unit is related to applications that include medical physics, music, technology in space and solar cells.<br>You will learn about waves including standing waves, refraction, polarisation, diffraction and the nature of light. You will also learn about electric circuits, resistivity, thermistors, emf and internal resistance. |
| Assessment | You will do a written paper that lasts for 80 minutes. The paper will contain objective questions, short questions and longer questions. |

| Unit 3: Exploring physics | |
|---|---|
| Content | This unit is based on the practical skills that you develop while studying Units 1 and 2. |
| Assessment | You will do an experiment that is based on either a physics-based visit or a case study of a practical application of physics. You will use the skills that you have gained while studying the AS to plan an experiment, do the experiment to obtain data, analyse the data and produce conclusions. |

## A2 units

| Unit 4: Physics on the move | |
|---|---|
| Content | The physics content of this unit is related to applications that include transport, communications and display techniques. It is also related to exciting, current research in the field of particle physics.<br>You will learn about momentum, circular motion, electric and magnetic fields, evidence for a nuclear atom, particle accelerators, particle detectors and different types of sub-atomic particles. |
| Assessment | You will do a written paper that lasts for 95 minutes. The paper will contain objective questions, short questions and longer questions. |

| Unit 5: Physics from creation to collapse | |
|---|---|
| Content | The physics content of this unit is related to applications that include space technology, medical physics and construction of buildings in earthquake zones. It also includes a detailed exploration of astrophysics and cosmology.<br>You will learn about thermal energy, radioactive decay, simple harmonic motion, resonance, gravitation, the life cycle of stars, fission, fusion and the fate of the universe. |
| Assessment | You will do a written paper that lasts for 95 minutes. The paper will contain objective questions, short questions and longer questions. |

| Unit 6: Experimental physics | |
|---|---|
| Content | This unit is based on the practical skills that you develop while studying Units 1, 2 4 and 5. |
| Assessment | You will plan an experiment, do an experiment to obtain data, analyse the data and produce conclusions. |

This document is Issue 2. We will inform centres of any changes to this issue. The latest issue can be found on the Edexcel website: www.edexcel.com.

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