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INTERNATIONAL ADVANCED LEVEL

PHYSICS

PRACTICAL GUIDE STUDENTS

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Pearson

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Introduction

Practical skills in physics at International Advanced level

Physics is a practical subject, which means that whatever anybody thinks – hypothesis – it is only by testing the idea – carrying out an investigation – that we can come to conclusion about whether the idea might be a reasonable explanation of the world (or universe) around us. Practical skills are central to the work of a physicist and the IAL course is built around the development of those skills.

At International GCSE/GCSE you might have seen a Geiger counter measuring the emissions from a radioactive source, by putting different materials between source and detector you were able to tell whether the radiation was alpha, beta or gamma. All the ideas and principles in physics have been tested like this and this early investigation of the nucleus led, over a hundred years, to the investigations at CERN.

It is really important to remember that the term 'practical skills' covers a very wide range of requirements at A level. It does not mean just the ability to handle equipment or know how to use some particular piece of apparatus. It ranges from using mathematics in a practical context to understanding how scientists investigate ideas, how they analyse their data and how they use that data when drawing conclusions. This guide will explain each of these in more detail.

By carrying out a programme of practical work you will develop the skills that a student must have if he or she is to be regarded as a competent practical physicist. You will have to be able to work safely and to manage your time so as to complete your work. Normally you will be given written instructions so you must be able to follow these carefully.

Over the two years of your IAL course you should carry out 16 core practicals (8 for IAS). The knowledge and understanding you gain from completing these practicals will be assessed in the relevant unit examination. In addition, the knowledge and understanding of experimental procedures and techniques you gain will be assessed in Practical Skills papers.

How is this different from International GCSE/GCSE?

First of all, you will be doing most of the practical work, occasionally working with one or more other people. Doing this will ensure that you develop a wide range of practical skills. You will need to keep asking 'How do we know that?' You will also realise that, even at this level, you will only have part of the story and that science is constantly changing. It is not a pile of 'facts' it is just the best model we have at the present, in as far as we can test it.

By the end of the course you will have a mastery of practical work which means you will be consistently and routinely competent, and therefore happy to have a go at a huge range of physics experiments and investigations. These skills will be invaluable if you go on to study Physics further, pursue a career in engineering or work in a laboratory setting.

Developing independent thinking

An investigation is more than simply finding a value for something or verifying the behaviour of a system. In the same way a practical mastery is more than the sum of the parts, more than all the practical skills lumped together. The 'extra ingredient' is independent thinking. For example, knowing which instruments to use and knowing how to use them is a key part of planning. Using them correctly and being able to get accurate and precise readings is carrying out your investigation. Completing the work is to present your data and your conclusions supported by some analysis. Thinking independently means being able to make the right decisions about what you know and making them at the right time. Perhaps there is more to an investigation, there is the 'I wonder...', 'what would happen if I did this?' and 'how do we know that?' – an enquiring mind.

All of this makes a good physicist but physicists seldom work alone. Modern projects such as CERN or the Very Large Telescope in Atacama require literally thousands of highly trained specialists to make them work. So although the spark of an idea starts in one head – think of Peter Higgs and his boson – the investigation is usually a collaboration.

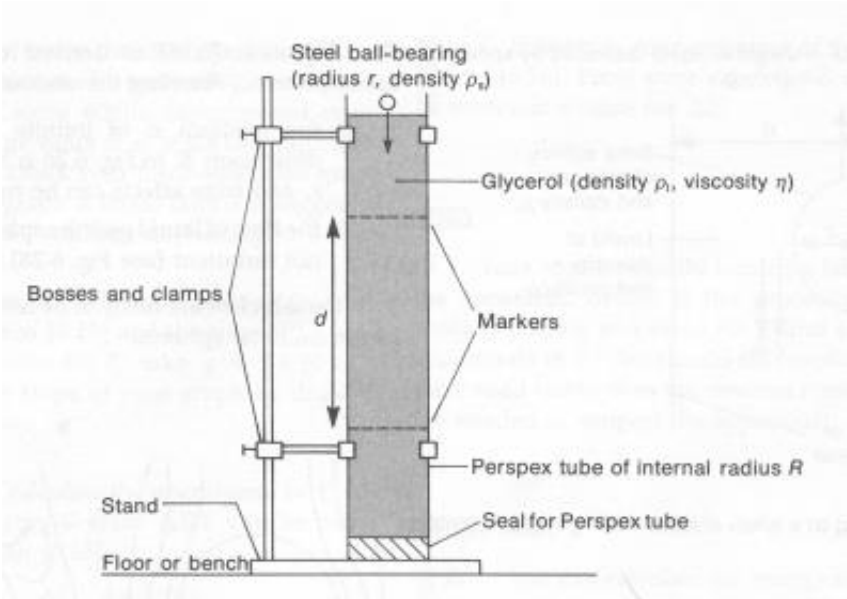
Physics is about describing the world around us, perhaps predicting what it might do next but not really explaining it. That is left for the philosophers. Creating models and then testing them is the way physicists do this and the models evolve all the time. Communicating that spreading understanding is then another aspect of the work.

Finally, physicists are very careful about claiming to have proved something and they are more likely to talk of developing the current model.

Thinking independently is about the creativity of the individual working within the framework of the subject and its other skilled practitioners.

Developing practical skills in Physics

The specification includes 16 core practicals that you will be expected to complete during the two-year IAL course (8 for IAS). These are included in some, but not all, topics. For example it is not a surprise that the Unit 4 topic *Nuclear and Particle Physics* does not include a core practical but most topics do, for example, the Unit 1 *Materials* topic has two. One of these is Core Practical 2 in which you will use a falling ball, perhaps a steel ball bearing, to determine the velocity of a liquid – probably washing-up liquid or glycerol.



During the practical you will measure the diameter and mass of the ball so that you can calculate its radius and its density. You will put markers around the tube and time the descent of the ball over a measured distance. From this you can calculate the viscosity of the liquid.

By carrying out this single core practical you will be using practical techniques associated with measuring small distances and increasing the accuracy of timing. You will also be using and applying some scientific methods such as:

- obtaining accurate, precise and sufficient data using appropriate units,
- performing calculations using the correct number of significant figures,
- determining the percentage uncertainty in measurements.

How will practical skills be tested?

There are likely to be questions all of the six IAL papers (and on the three IAS papers, if you are taking IAS Physics) that test your knowledge and understanding of practical work. Success in these questions will come more naturally if you have carried out practical work on a regular basis and have a thorough understanding of practical techniques. Therefore, you should also conduct additional experiments to the core practical activities.

Units 1, 2, 4 and 5

There are four written papers for IAL (two for IAS) that test knowledge and understanding of Physics.

IAS Unit 1: 1h 30mins. This paper tests Mechanics and Materials.

IAS Unit 2: 1h 30mins. This paper tests Waves and Electricity.

IA2 Unit 4: 1h 45mins. This paper tests Further Mechanics, Fields and Particles.

IA2 Unit 5: 1h 45mins. This paper tests Thermodynamics, Radiation, Oscillations and Cosmology.

These will contain questions which test your knowledge and understanding of the topics listed above but they can be presented in many different forms which are linked to your practical skills e.g. topic questions may well contain data tables or graphs which you might be asked to interpret and explain - in which case, you will need to use the skills you have developed throughout the whole course. There may also be questions directly linked to the relevant core practical activities.

Units 3 and 6: Practical Physics I and II

The papers for these units focus entirely your understanding of experimental methods. These will draw on your experience of experimental methods and, in particular, will draw on your experience of the core practicals. In general, the Physics contained in these papers will based on the IAS content for the Unit 3 paper, or the IA2 content for the Unit 6 paper. Where the Physics content may be unfamiliar there will be enough information in the question to help you answer it.

Both of these papers are 1h 20mins in length and will test your ability to plan an experiment, comment on measurements, and process data in both familiar and unfamiliar contexts. The details for what you will be expected to do for each unit are given in the specification.

When planning an experiment, you will be expected to be able to consider risk management and the select appropriate apparatus and methods, with reasons. You may also be given the results of an experiment which you may need to complete, either by reading scales or giving appropriate units, or criticise the results and suggest how they could be improved.

Processing data will involve using significant figures appropriately in calculations and plotting graphs. For Unit 6 you will need to be able to form a straight-line graph from non-linear data, for example by calculating logs. In analysing outcomes and drawing valid conclusions, you should critically consider methods and data, including assessing measurement uncertainties and errors. *Appendix 10: Uncertainties and practical work* in in the specification provides more guidance on this.

An example of the type of question that uses uncertainties is shown below.

(c) The mass of the microscope slide is recorded as 4.82 g with an uncertainty of 0.03 g.

(i) Calculate a value for the density of the slide.

(2)

Density = ...

(ii) Estimate the percentage uncertainty in your value for the density.
You may assume the uncertainty in the measurement for the width is negligible.

(2)

Percentage uncertainty = ... %

(iii) The student researched the density of different types of glass and found a value for 'Crown glass' of 2600 ± 100 kg m^{-3}.

Use this information to decide if the slide is made from Crown glass.

(2)

....

In this part of the question the candidate performs a reasonably easy calculation but the data, seen in an earlier part, is to 3 significant figures so the answer is expected to be the same and the unit must be appropriate.

Using earlier data the candidate calculates a percentage uncertainty and uses their answer to decide whether the glass is 'Crown' or not.

This is an example of using uncertainties to help support conclusions which is a key part of practical work.

Physics practical skills

This section of the Guide will consider a number of key skills and practices that you develop and use as you progress through your studies.

Designing investigations

Some of the core practicals offer you the opportunity to go beyond simply learning a technique by applying your knowledge to the design of an investigation. You will have met some of the requirements at GCSE level but during the two years of your IAL course you will be expected to gain a deeper understanding of the details. You might start as follows.

Is the hypothesis clear?

Exactly what is to be measured? Is this the correct dependent variable, does it match the hypothesis and how can it be measured as accurately as possible?

Are there any other variables that I need to control? What can I do about ones I cannot control?

How much data will be needed to come to some meaningful conclusions?

For example, in core practical 5 you will investigate the effect of length, tension and mass per unit length on the frequency of vibration of a string or wire. You might think of a guitar, adjusting the frequency means tuning it or playing it – and each of the six strings has a different composition. How will you plan your investigation? You must start with your own hypothesis and run through the questions above. You will need a framework for your practical investigation. You can probably add questions to the list – but don't make it too complicated, you are aiming to test your hypothesis.

Planning

Instruments

You will choose which instruments you are going to use for each of your measurements and explain why they are appropriate; this is probably due to their resolution – the smallest measuring division – but also their range. If the instruments are electrical then it is the range that you must specify, for example a voltmeter on its 20 V range. You should also detail any additional apparatus you will need such as retort stands, beakers or perhaps a bench pulley.

It is a really good idea to draw a diagram of how you will set up your apparatus. This should be labelled, large and drawn with a pencil and ruler. This process will help you think more clearly about what you are about to do. Key dimensions should be indicated on your diagram, such as the lengths you will measure.

Question A
You are given two samples of a metal and told that they might both be aluminium. One is in the form of a sheet of kitchen foil and one is a cylindrical block with a mass of approximately 1 kg. In order to test the suggestion, you decide to measure the density of the metal of each.

What instruments would you use? Justify your choices.

Method

This can be bullet points but should include everything you will need to do including a risk analysis of your activity based on the equipment and other people in the room. You should discuss repeat readings, why they are appropriate or not, and the range you are expecting to cover.

Techniques

You should also describe any techniques you will employ to improve accuracy. For example, a timing marker if the experiment concerns oscillations or zero errors on almost any instrument. This helps you to think more clearly about what you will actually do. You might think about holding your head perpendicular to the scale to get a more accurate reading, on a thermometer for instance.

Question B

Describe how you would use the micrometer in Question A to measure the thickness of the foil with as good a resolution as possible.

Planning should be detailed but concise, in an investigation it is to help you test the right thing in the right way.

Presenting data

Recording

When recording data you should always use a table with headings which include the quantity and its unit. Write the unit that you read from the instrument. You might read a metre rule in centimetres, so head the column of length L say as L/cm. You should also record the resolution of the instrument, as ±0.1 cm in the case of the rule.

Use the number of significant figures that the instrument gives, so a small length might be 6.4 cm and a longer one 25.6 cm. Recording to the resolution of the instrument is more important than having the same number of significant figures.

Be careful that your recorded figure represents what you think you measured. For example, if you record values for mass and write down M = 1.00 kg you are recording the mass to the nearest 10 g. The resolution of the balance is much nearer 1 g so you should write M = 1.000 kg.

When you record the period of 10 oscillations using a timer with a resolution of 0.01 s you might record $10T$ = 14.52 s. This gives you T = 1.452 s so the resolution of your measurement has improved because you recorded a longer time interval.

Make sure you record enough data but not too much. If the dependent variable is changing slowly increase the increments in the independent variable. You should be flexible and not stick rigidly to your plan if nothing much is changing. Write your readings straight into your table and record everything you measure.

Question C
A student records the following values for the diameter of a piece of wire *d*/mm   0.27, 0.29, 0.27, 0.77, 0.26 Calculate a mean value for the diameter and explain your answer.

Graphs

Almost every physics experiment will display data in graphical form and physicists always use a form of their data that produces a straight line – if all goes well with the data. There is usually a mathematical model for the data and it is this that can be manipulated to give a straight line on the graph. This will happen when the model has been manipulated to be similar to $y = mx + c$.

Some examples are shown in the table.

Mathematical Model	*x*-axis	*y*-axis	gradient	intercept
$V = IR$	I	V	R	Zero
$v^2 = u^2 + 2as$	s	v^2	$2a$	u^2
$I = I_0 \exp^{(\frac{-t}{RC})}$	t	$\ln I$	$\frac{-1}{RC}$	$\ln I_0$
$T = kx^p$	$\ln x$	$\ln T$	p	$\ln k$
$I = I_0 \exp^{(\frac{b}{T})}$				
$T = f^2\lambda^2\mu$				

Question D
Complete the bottom two lines in order to determine a value for b in the first one where the variables are I and T, and a value for μ in the bottom line where the variables are T and f.

The axes should be labelled with a quantity and unit such as s/m or ln(T/s) – in this way the plots have no units. The scale should stretch the plots over at last half the graph paper in each direction and should be easy to read, i.e. in 1s, 2s or 5s and their multiples of 10. Take care when plotting time in seconds. The plots should be accurate to 1 mm. It is helpful to tabulate the numbers you are going to use for your graph alongside your data. A graph in physics is always a scatter graph with a line of best fit shown. A good line of best fit should have an even number of plots above it and below

Analysing

Investigations might be to verify the behaviour of a system or to calculate a value for some aspect of it. In the first case you will be commenting on the goodness of fit of your best fit line. In the second you will be doing further numerical analysis, for example, calculating the gradient. In both cases you should record what was easy and what was difficult about your practical work. If your method was easy to carry out you might expect plots close to a straight line whereas difficulties might explain a spread of readings, i.e. there were sources of random error in the experiment. If you were expecting the line to go through the origin but it doesn't then there may be a source of systematic error you did not account for.

If you were expecting a straight line but got a curve there might be a reason for that too. For example, if you are measuring the period of a pendulum and varying the length then plotting T^2 against l should give a straight line from

$$T = 2\pi\left(\frac{l}{g}\right)^{\frac{1}{2}}$$

But if your oscillations are too large then this is not the correct mathematical model which explains the curve you might get on your graph.

You may use the graph to calculate a known value. In Core Practical 1 you will determine a value for *g*. But how can you tell if your result is accurate? If your experimental value turns out to be 9.25 N kg^{-1} then you can calculate a percentage difference to gauge the error.

Percentage difference = 100 × (your value − accepted value) ÷ accepted value

Here that gives %D = 100 × (9.81 − 9.25) ÷ 9.81 = 5.7% − not a bad result but not accurate either. In general, a percentage difference less than 5% would indicate an accurate result.

A properly plotted graph can tell you a very great deal about your experiment.

Question E

You measure a value for Young modulus of copper and obtain a value of 1.32×10^{11} Pa. The accepted value is 1.17×10^{11} Pa. Calculate the percentage difference between the two values.

Use of mathematics

At least 40% of the marks on the written papers will be for applications of mathematics. Full details of all the maths required is in *Appendix 6* of the specification.

These skills come under the five headings: Arithmetic and Numerical Computation, Handling data, Algebra, Graphs, Geometry and trigonometry.

This does not represent much of a change in quantity from previous specifications but the range of skills requires is more carefully detailed without being any larger.

Nearly all the mathematical requirements are those GCSE Higher Tier. But of course at top marks, the topics are relatively easy but the precision is 100% - in other words you have to get Maths right when you use it. Although this might sound worrying you should find that as you practise over the course and keep ticking over with the maths you improve, just as you do with everything else. The only difference is the use of logarithms and exponentials at IA2. All this represents very little change from previous specifications and you will find it very easy to look up what you need to know.

Evaluating uncertainties

There is a great deal of information about uncertainties in *Appendix 10* of the specification, this includes combining uncertainties.

Uncertainties give you a degree of confidence in your results so that if your uncertainties are large, say 25%, then you might find little confidence in your conclusion. But if they are small, say 2%, then you might think your results are valid i.e. you have measured what you were supposed to be measuring.

In your investigation you will want to derive an uncertainty in your final value, this will depend on the difficulty you experienced taking the readings, the spread in your repeated readings and other factors too.

In some experiments you will be comparing your final value to an accepted value as in Core Practical 1 above where the value for *g* was 5.7% different from he accepted value. If the percentage uncertainty resulting from your measurements can be calculated then this should be used to find an upper and lower limit for the final value. If the accepted value falls within this range then the final value can be considered as accurate.

When evaluating the result of your investigation as well as considering percentage uncertainties, as above, you should consider your graph and the readings it shows as well as the difficulties you felt you had in taking accurate readings. As part of this you might consider whether a different method would produce a better result.

You should end with a conclusion supported by numbers and an evaluation based on the evidence you have assembled.

Question F

A wave crosses a tray, reflects off the far side and returns after a time *t*. A student measures the distance *d* across the tray as 33.4 cm with an uncertainty of 0.2 cm.

She then measures *t* = 0.92 s with an uncertainty of 0.03 s.

(i) Use these measurements to calculate *v*, the velocity of the wave.

(ii) Estimate the percentage uncertainty in your value for *v*.

Question G

A student measures the dimensions of a metre rule. She repeats these from several positions along the rule.

Width/mm 28.2, 29.3, 28.9, 29.0, 29.1

Thickness/mm 6.04, 5.94, 5.97, 6.01, 5.99

Mass/g = 106.4

(i) Use these measurements to calculate a value for the density of the rule.

(ii) Calculate the uncertainty in your value for the density.

Question H

A student takes measurements to determine the resistivity of constantan in the form of a wire. He measures the diameter and the resistance of a length of wire. He records:

Diameter = 0.559 ±0.010 mm

Resistance 1.15 ±0.02 Ω

Length = 0.600 ±0.003 m

(i) Calculate the resistivity of the constantan.

(ii) Calculate the percentage uncertainty in your value for the resistivity

(iii) The accepted value for the resistivity of constantan is 4.9×10^{-7} Ω m. Comment on the result of using the student's measurements.

Terminology in practical physics

Appendix 10 of the specification gives some detail about some of the terminology used in practical physics. The list below is a slightly simplified version which you might find useful as a vocabulary list or glossary.

Term	Meaning and notes
Validity	A measurement is valid if it measures what it is supposed to be measuring – this depends both on the method and the instruments.
True value	The value that would have been obtained in an ideal measurement.
Accuracy	A measurement result is considered accurate if it is judged to be close to the true value. It is influenced by random and systematic errors.
Precision	A quality denoting the closeness of agreement (consistency) between values obtained by repeated measurement. It is influenced by random effects and can be expressed numerically. A measurement is precise if the values 'cluster' closely together.
Resolution	The smallest change in the quantity being measured that causes a perceptible change in the output of the measuring device. This is usually the smallest measuring interval.
Repeatability	A measurement is repeatable when similar results are obtained by students from the same group using the same method. Students can use the precision of their measurement results to judge this.
Reproducibility	A measurement is reproducible when similar results are obtained by students from different groups using different methods or apparatus.
Uncertainty	Any measurement will have some uncertainty about the result. This will come from variation in the data obtained and be subject to systematic or random effects. This can be estimated by considering the instruments and the method and will usually be expressed as a range such as 20 ± 2 °C.
Error	The difference between the measurement result and the true value if a true value is thought to exist. This is not a mistake in the measurement. The error can be due to both systematic and random effects and an error of unknown size is a source of uncertainty.

Core practicals

The core practicals are an integral part of your course. They are not there to get you to demonstrate some text book 'fact' or recall some simple information. They are there to help you develop the whole range of practical and mathematical skills which are essential to physicists and which will be tested in the written assessments.

List of core practicals

1. Determine the acceleration of a freely-falling object
2. Use a falling-ball method to determine the viscosity of a liquid
3. Determine the Young modulus of a material
4. Determine the speed of sound in air using a 2-beam oscilloscope, signal generator, speaker and microphone
5. Investigate the effects of length, tension and mass per unit length on the frequency of a vibrating string or wire
6. Determine the wavelength of light from a laser or other light source using a diffraction grating
7. Determine the electrical resistivity of a material
8. Determine the e.m.f. and internal resistance of an electrical cell
9. Investigate the relationship between the force exerted on an object and its change of momentum
10. Use ICT to analyse collisions between small spheres, e.g. ball bearings on a table top
11. Use an oscilloscope or data logger to display and analyse the potential difference (p.d.) across a capacitor as it charges and discharges through a resistor
12. Calibrate a thermistor in a potential divider circuit as a thermostat
13. Determine the specific latent heat of a phase change
14. Investigate the relationship between pressure and volume of a gas at fixed temperature
15. Investigate the absorption of gamma radiation by lead
16. Determine the value of an unknown mass using the resonant frequencies of the oscillation of known masses

Questions on core practicals

1. Determine the acceleration of a freely-falling object

This experiment can be done in two different ways but both involve dropping an object and measuring its fall.

In one method you can use a trapdoor connected to a timer and you measure the distance fallen and the time taken. In the other method you can use light gate to determine the velocity of an object that has fallen through a measured distance. Although the two methods use different mathematical models they will both give you the acceleration.

A student uses a trapdoor and measures the height and time of fall and produces the following readings.

h = 1.200 m t = 0.51 s

h = 0.900 m t = 0.43 s

(a) Use these readings to calculate a value for g.

(b) Criticise these readings.

2. Use a falling-ball method to determine the viscosity of a liquid

In this practical we are looking a terminal velocity and a graphical aspect is missing, unless you have a wide variety of ball bearings. The viscosity of a liquid will fall as its temperature increases.

(a) Research a simple explanation.

(b) This means that as a car engine heats up the oil becomes less viscous. Describe the effect this has.

3. Determine the Young modulus of a material

A different way of measuring the Young modulus of a wire is to hang two identical wires side by side. Weights are hung on one of the wires and their lengths are compared using a cradle at the bottom ends of the wires which measures the extension directly.

One student carried out such an experiment and plotted a graph of load against extension; the gradient of this graph was 11.9 kN m^{-1}. The original length of the wire was 1.300 m and the diameter was 0.315 mm.

(a) Calculate a value for the Young modulus of steel using the student's results.

(b) Give a reason why the second wire improves the experiment.

(c) Give two reasons why a graphical method gives better results.

4. Determine the speed of sound in air using a 2-beam oscilloscope, signal generator, speaker and microphone

The oscilloscope takes some getting used to but when you understand how it works it can be a very powerful tool for analysis and it shows, in effect, a voltage time graph. The scale on the horizontal axis is called the timebase and is calibrated in units of ms/cm or milliseconds per centimetre. The frequency generator is connected to the loudspeaker.

The signal from the frequency generator is first displayed on its own.

(a) Explain what the distance from one peak to the next represents.

(b) Describe what you would see on the screen if you changed the timebase from 0.1 ms/cm to 0.5 ms/cm – in the case ms stands for millisecond.

(c) Now the trace from the microphone is displayed as well. Explain why the traces look different as you move the microphone away from the loudspeaker.

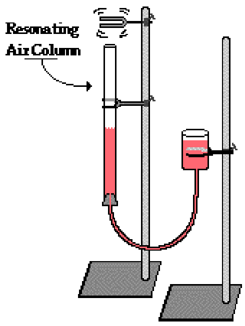
(d) Give one reason why repeating the experiment at a different frequency improves the accuracy.

5. Investigate the effects of length, tension and mass per unit length on the frequency of a vibrating string or wire

If you first carry out this practical with a string with a mass per unit length of 3 g m^{-1} (grams/metre) and then, keeping the same frequencies, use a different string with line density of 4 g m^{-1} would you expect the corresponding wavelengths to be larger or smaller.

(a) Explain your answer.

(b) In a different resonance experiment the speed of sound in air is being investigated using a small loudspeaker (or tuning fork) held over a column of air.



Tuning fork forcing air coumn into resonance

At a given frequency the first resonance occurs when there is a node at the top of the water and an antinode at the top of the tube. The water is then lowered and the next resonance occurs when there is again an antinode at the top of the tube. Explain why the air column is now half a wavelength longer.

6. Determine the wavelength of light from a laser or other light source using a diffraction grating

In this experiment laser light passes through a diffraction grating and on to wall. The distance between adjacent maxima is measured. Explain why the uncertainties in this experiment will be reduced if the grating is moved further away from the wall.

7. Determine the electrical resistivity of a material

This practical is a standard one that is relatively straightforward to carry out and the physics is quite easy too, the more metal the current passes through the greater the resistance. The resistivity is a property of the material and is the same everywhere. The ohmmeter applies a potential difference to the sample and from the current that passes shows the resistance between the probes.

A slice of silicon is 0.50 mm thick and is square with each side measuring 20 mm and it has a resistance of 1.28 MΩ.

(a) Calculate the resistivity of silicon.

(b) Explain why the resistivity of silicon is so much higher than that for a metal.

(c) Calculate the resistance of a square of silicon that is 0.50 mm thick but measures 15 mm on each side.

(d) Explain why in practice, it might be difficult to get an accurate reading using an ohmmeter.

8. Determine the e.m.f. and internal resistance of an electrical cell

This practical gives a graph with a negative slope and it should be a straight line. Designing an electric circuit is a skill that could be assessed so this practical is a chance to practise.

When a car battery, which has an emf of 12 V, starts a car there is a huge current flowing, probably around 150 A. The battery is connected to the starter motor which is usually close to it.

(a) Explain the why the battery must have a very, very low internal resistance.

(b) Explain why the connections to the starter motor must also have a very, very low resistance.

(c) Explain how this can be achieved in practice.

9. Investigate the relationship between the force exerted on an object and its change of momentum

As the title suggests this is intended as an investigation in which you decide what you are going to look at and come up with a plan to do that. You will also do some analysis, an important part of which are the uncertainties. There is some guidance on the student sheet to help you improve your competence with uncertainties.

In this experiment you will have had masses on the hanger and on the trolley. In order to change the number of masses on the hanger you move them from the trolley. Explain why this is an important part of the technique in the experiment.

10. Use ICT to analyse collisions between small spheres, e.g. ball bearings on a table top

This investigation is an opportunity to use some digital equipment and capture some really good physics. Once you have understood and mastered the software you might try analysing the motion of things other than marbles. If you can determine the initial velocity and the time of contact from the image then by finding the mass you can calculate the force on an object. This might be useful on video clips of other impacts – you might even try the famous golf ball shot but footballs are just as good.

11. Use an oscilloscope or data logger to display and analyse the potential difference (p.d.) across a capacitor as it charges and discharges through a resistor

In this experiment you were using the oscilloscope again to measure potential difference. In the two experiments one changed slowly but the other was changing quite quickly.

This question is about the use of a datalogger.

(a) Draw the circuit you would use to record the potential difference across a capacitor as it charges – include the ICT equipment in your diagram.

(b) Describe the advantages of using ICT to monitor this circuit for both experiments. Suggest any disadvantages.

12. Calibrate a thermistor in a potential divider circuit as a thermostat

A thermometric property is a property of a material or device that changes with temperature, in this case it is the resistance of a thermistor. As the temperature changes the change in the thermometric property can be recorded. This change over a known temperature range can be used to calibrate a thermometer.

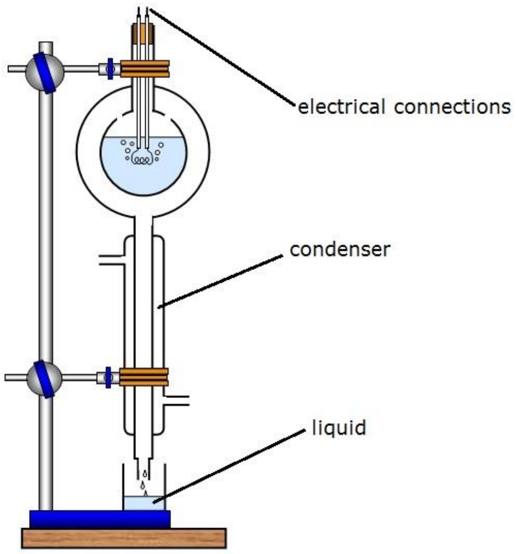
The expansion of a liquid in a tube is another such property and this forms the basis for most thermometers used in the laboratory.

Carry out some research to find another thermometric property and describe how it is used to make a thermometer. Include information about its range and use. Find out also how very high temperatures (>2000°C) are measured.

13. Determine the specific latent heat of a phase change

In this experiment you determined a value for the specific latent heat of fusion (solid/liquid) of water. The specific latent heat of vaporisation is the same thing for the liquid/vapour phase change.

The diagram shows some apparatus that can be used to measure specific latent heat of vaporisation.



The energy supplied electrically changes liquid water into steam which passes out of the bottom of the condenser as a liquid again and is collected, as shown above.

(a) Write a plan to use this apparatus to determine a value for the specific latent heat of vaporisation of water. Your plan should include details of any additional apparatus needed and the measurements you will need to make. Describe one part of your method that improves accuracy. Explain how you will use your readings to obtain a result.

(b) Explain why the apparatus does not have a thermometer.

14. Investigate the relationship between pressure and volume of a gas at fixed temperature

The experiment to investigate Boyle's law is another standard experiment.

(a) Use the ideal gas equation $pV = NkT$ to explain why the amount of gas in the apparatus must remain the same throughout the experiment.

(b) Another law, similar to Boyle's, is Charles' law relating the volume and temperature of a gas. Research the apparatus used for Charles' law, draw a diagram of it and write a plan for its use. Your plan should include any additional apparatus needed and the measurements you will need to make. Describe one part of your method that improves accuracy. Explain how you will present your readings.

15. Investigate the absorption of gamma radiation by lead

In this experiment the gamma radiation is absorbed by different thickness of lead. The count rate will decrease exponentially as the thickness of the lead increases. This is similar to the decay over time of any radioactive source. Both models lend themselves to the idea of a constant in which the count rate halves – a half life in the case of decay and a half thickness in the case of absorption.

Explain how the frequency of the gamma radiation affects the half thickness required by lead.

16. Determine the value of an unknown mass using the resonant frequencies of the oscillation of known masses

Log graphs are useful ways to verify a relationship that has a power. When a mass oscillates on a spring the mathematical model we use is

$$T = 2\pi\left(\frac{m}{k}\right)^{\frac{1}{2}}$$

The following data was recorded.

m/kg	T/s
0.100	0.397
0.200	0.477
0.300	0.551
0.400	0.619
0.500	0.676
0.600	0.729
0.700	0.776

(a) Plot a graph of ln T against ln m and measure the gradient.

(Notice that if you ignore the smallest value you are able to draw a much better line of fit.)

(b) Use your analysis to comment on the results.