Science lessons for Grade 10

Lessons in this section

Biology

1 Cell ultrastructure

Chemistry

2 Giant covalent molecules

3 Reaction kinetics

Physics

4 Determining the acceleration due to gravity

Resource sheets for the lessons

Using these lesson plans

These sample lessons for Grade 10 are suitable for use with a whole class. The lessons are single examples to illustrate different teaching and learning activities. They are not intended to be taught as a sequence. They are drawn from different topics and points in the teaching year to show spread rather than sequence.

The objectives for the lessons are drawn from the standards for Grade 10. The relevant standards are shown in the lesson plans. All lessons are suitable for students following the foundation programme. Some incorporate additional material suitable for those who will ultimately study the subjects at the advanced level.

The lesson plans indicate any safety issues relevant to the lessons. They also provide equipment lists and any short- and long-term preparation required by the lessons. Some of the plans include notes that provide additional information relevant to the teaching of the lesson that may not be readily accessible elsewhere.

Most of the lessons are organised in three parts: an introduction to the lesson, a main activity, and a final phase to help students to reflect on the lesson and consolidate their learning. As part of the introduction, you should outline the purpose of the lesson, drawing out for students what they will learn and how this builds on previous work. In the final part of the lesson, you will need to establish the key learning points, what students need to remember and what they will go on to learn next. There is no expectation that students should copy out the key learning points in their exercise books.

The lesson plans do not include homework tasks because the lessons are single examples taken out of sequence. You will need to provide this, since homework is an important part of a lesson.

The lesson plans have enough material to support a minimum of about 60 minutes of teaching. You may need to supplement the activities with simpler or more challenging tasks if the students in your class have a range of attainment. You could choose from activities in textbooks or from your own resources. If you wish, different tasks can be given to different groups of students, according to their needs.

For some classes there may be too much material in the lesson plan for 60 minutes. In this case, you could designate one of the activities in the lesson as homework, or carry it forward to the next lesson. Be selective about which activity to cut – it does not have to be the last one merely because it comes at the end.

Lesson plan 10.2 'Giant covalent molecules' involves making crystals; students will need to examine the experiment every day for about two weeks.

10.1 Cell ultrastructure

Objectives

- Recognise and know the function of a nucleus, mitochondria, chloroplasts, endoplasmic reticulum and ribosomes.
- Know how scientists disseminate their ideas and results to encourage discussion and further development.

This lesson is suitable for both foundation and advanced students.

Preparation

You will need a collection of electron micrographs that illustrate each of the cell structures and organelles to be studied. These may be obtained from a science educational supplier. Suitable pictures also appear in textbooks and images can be downloaded from the Internet. In addition to the pictures of the structures and organelles you should also have created or copied a set of diagrammatic representations or be able to show textbook examples to help students interpret the micrographs. Factual information should also be available. You should create one of more collections of resources on each of the cell structures to be studied. Each set should include at least one picture or diagram of a whole cell.

Introduction

Vocabulary
chloroplasts
endoplasmic reticulum
mitochondria
nucleus
ribosomes

Magnification and resolution

Start this lesson by showing a photograph (or directing the attention of students to a textbook photograph) of a typical cell as seen under the light microscope. Ask students:

Q What does this show?

Q What structures can you see?

Q What is the level of magnification?

Q What would you expect to see if the image was magnified more?

You should expect students to recognise that the picture is of a cell and that the magnification is probably in the region of ×400. They should recognise the main structures. They are likely to tell you that the greater the magnification, the more you will see. It is important that you explain the difference between magnification and resolution and that the wavelength of light limits the resolution of a light microscope and that even if we could make it magnify things more it would not be able to distinguish between small structural features. Explain that electrons behave as waves. The wavelengths of electrons (about 0.01 nm) are many thousands of times smaller than the wavelength of light (about 500 nm), so the limit of resolution of a microscope that uses electrons rather than light is much greater. In other words, electrons allow much smaller objects to be 'seen' than does light. You should also explain that an electron microscope does not allow us actually to see structures in the same way as does a light microscope, but the effects of the electrons create an image that allows us to study the detail of very small objects, including the ultrastructure of cells.

Continue by explaining that this lesson will allow students to study the ultrastructure of a cell and to learn about the functions of various cell organelles.

Main activity

Resources

Collection of materials on cell ultrastructure

Presentation materials

Resource 10.1

Researching cell ultrastructure

Activity 1 Finding out about cell ultrastructure

Students should work in groups of about four.

Divide the class into research teams with about four students in each team. Explain to the class that each research team will be responsible for researching the structure and function of a cell organelle and will have to give an oral presentation of their findings at a class research conference. Their task is to do the research and prepare a presentation to tell the class what they have discovered. When each team has made their presentation, all members of the class should have information on each of the cell organelles. The research could be guided by a worksheet similar to **Resource 10.1**. In a large class more than one team may research the same structure. This is preferable to having larger research groups.

Depending on the resources available and the skills of the students, research groups could enhance their oral presentations by board drawings, posters, photographs, overhead transparencies and PowerPoint slides.

The research is likely to take most of a lesson and preparation of a presentation may be a homework activity or it could be carried over to the next lesson. If it is set for homework, you will need to bear in mind that it is a team activity and students will need to be able to meet to agree their roles, prepare materials and possibly rehearse their presentation.

Activity 2 Class research conference

You should arrange the class conference for the lesson following the research work. Part of the lesson may need to be given over to completion of presentations.

Allocate set times for each research group to make a presentation and for questions and discussion. If more than one team has researched the same cell structure, have them present one after the other and combine the questioning and discussion.

As each research group gives its presentation, encourage the rest of the class to make notes on the key points. If groups have prepared handout summaries or other resources to share with their peers, arrange for these to be made available.

In concluding this section, comment on the quality of the presentations and the questions and discussion, and tell the class that the research conference they have held is not unlike the research conferences that scientists hold to share and discuss their findings.

Consolidation

In the final section, write the names of the structures studied on the board. Ask students to rank these in order of size. Rewrite the structures in this order. Now ask the class to tell you the function of each structure. Write the appropriate function beside each structure. Ask students to record this information.

Other tasks

Students could be asked to make a sketch drawing of each of the cell's structures.

Summary for students

- An electron microscope has a higher resolution than a light microscope and allows the study of cell ultrastructure.
- The endoplasmic reticulum (ER) is found in the cell cytoplasm and is a network of hollow sacs and tubes surrounded by a membrane. There are two forms of ER. The rough ER carries ribosomes. The smooth ER is involved in lipid metabolism
- Ribosomes are involved in the manufacture of proteins.
- Mitochondria are found in almost all eukaryotic cells. They have a double membrane, with the inner one being elaborately folded. They have a role in respiration, in which they are involved in the oxidation of molecules such as glucose to make ATP.
- Chloroplasts are found in the cytoplasm of some plant cells. They are chlorophyll-containing organelles surrounded by a double membrane. They have an elaborate internal membrane system where some of the reactions of photosynthesis are catalysed.
- The nucleus is the largest cell organelle and can be seen by an optical microscope. It is separated from the cytoplasm by a nuclear envelope. The nucleus contains the chromosomal DNA of the cell. The chromosomes are surrounded by nuclear sap (nucleoplasm). Most eukaryotic cells have one or more nucleoli in the nuclear sap.

Notes

These activities are likely to run over two lessons. If you are concerned that students may not be able to provide appropriate information to their peers or if there is any doubt about the ability of students to make comprehensive notes from conference presentations, then you should create an information sheet with key facts and give this out after the class research conference. Alternatively, or in addition, you could refer students to texts, reference books or Internet sites.

10.2 Giant covalent molecules

Objectives

- Know that some covalent compounds, such as the element carbon and the compound silicon(IV) oxide, form giant molecular structures.
- (Advanced) Show an understanding of allotropy.
- Follow instructions accurately but be able to adapt to unforeseen circumstances.

This lesson is suitable for both foundation and advanced students.

Preparation

Search the Internet for good applets of the structure of giant covalent molecules, such as graphite and diamond, that allow the user to rotate them at will.

Carry out the experiment beforehand to determine the most desirable quantities to use and the time taken for rhombic sulfur to crystallise.

Prepare a sample of rhombic sulfur in advance of the lesson as the crystals being prepared by students may not appear during the course of the lesson.

Safety

The solvent most commonly used to dissolve sulfur for recrystallisation is carbon disulfide. However, this is hazardous and poisonous and should not be used in schools. Methylbenzene (toluene) is a much safer alternative but all naked flames should be extinguished before it is warmed in a water bath.

Eye protection should be worn.

Introduction

Vocabulary

allotropes
allotropy
crystallisation
rhombic
monoclinic
metastable

This lesson has two parts: the first is an introduction to allotropy and the second is a consideration of giant covalent structures.

This lesson will follow several sessions on bonding, during which students will have become familiar with ionic crystals. Introduce the lesson by asking if they know of any covalent compounds that form crystals:

Q Do covalent compounds form crystals?

Q Can you think of a covalent compound that is crystalline?

Well-known examples are ice, sugar and diamond, but while students may be aware that ice is a covalent compound, they may not realise that sugar and diamond are too.

Tell students that they are going to make covalent crystals of the element sulfur.

Main activity

Resources (per pair)

- Test-tube
- Bunsen burner
- Access to powdered roll sulfur and methylbenzene
- Filter funnel
- Filter paper
- Beaker
- Stirring rod
- Access to fume cupboard
- Resource 10.2

Making sulfur crystals

Students should work in pairs. Time: around 60 minutes, plus time to examine the experiment daily for two weeks.

Give a copy of **Resource 10.2** to each pair. Each pair will make a sample of monoclinic sulfur and rhombic sulfur or, if you prefer, you can demonstrate the crystallisation of the rhombic form in the fume cupboard.

If students are crystallising rhombic sulfur, warn them of the fire hazard when methylbenzene is heated; all burners must be extinguished before it is given out.

Students follow the instructions and you give advice where necessary. Some pairs will heat the sulfur too strongly and miss the moment when it is a pourable liquid.

Both experiments require students to look at the experiment every day (preferably) over a period of about two weeks.

Consolidation

Bring the class together and ask them to describe the two different crystalline forms of sulfur. If they have not seen the shape of rhombic sulfur, show them the sample you prepared earlier. Explain that the two names are technical names for different classes of crystal shape: rhombic crystals are rhombohedral in shape and monoclinic crystals are needle-shaped.

Q What were the main differences in the conditions under which the crystals formed?

Students will suggest many differences but they may miss the important one – temperature. The monoclinic crystals form at a temperature of over about 80°C and the rhombic shape forms below that. At room temperature, the monoclinic form is unstable, reverting slowly to the rhombic form, as will be observed over the two weeks.

For the advanced students, introduce the concept of a metastable state: a state which is unstable in that there is another state of lower energy that it should decompose into if it could. Often there is no mechanism by which this change can take place and so crystals in the higher energy state persist. They are called metastable.

Other tasks

Resources

- Continuity meter (or continuity testing circuit made from a cell and bulb)
- Pencil
- Diamond (if available)
- OHT 10.3

Explain that the existence of these two crystalline forms of sulfur is known as allotropy. Challenge them with the question:

Q Do you know any other elements that exist in two different forms?

Some may know about the allotropy of carbon. Show **OHT 10.3**. This shows the structure of two allotropes of carbon: diamond and graphite. Ask if they know where diamonds are found:

Q Where do we get diamonds from?

Q How do you think diamonds are formed?

Some students may know that they crystallise from carbon deposits under the high temperature and pressure conditions of Earth's mantle. Now ask about graphite:

Q Where do we get graphite from?

Q How do you think graphite is formed?

They will know how it can be formed as charcoal is an impure form of graphite.

Ask advanced students which they think is metastable – diamond or graphite. They will probably think, incorrectly, that diamond is the stable allotrope, but ask them to compare the formation of the allotropes with the preparation of the sulfur allotropes. Diamond must be the metastable one.

Ask students to look at the bonding in graphite.

Q How many bonds are there to each carbon?

Q How many bonds does carbon normally form?

Because there are fewer bonds in graphite than normal, it means that some electrons are left free to move between the layers of carbon rings, much as they do in metals. Ask students if they can think of a way of testing whether this is the case. Some may suggest that graphite may therefore conduct electricity. Demonstrate that a pencil lead (which is actually made from graphite) conducts electricity. If possible, also demonstrate that diamond is an insulator.

Show, for interest, the third allotrope of carbon, fullerene, which was discovered in 1985. It is a molecule that is constructed like a football out of 60 carbon atoms.

Q What do we use diamonds for as well as jewellery?

Some students will have heard about diamond-tipped drills being used for drilling through rock into gas and oil fields. Others may know that glasscutters use diamonds in their work. Diamonds are extremely hard.

Show students the structure of silicon dioxide and note that it is very similar to diamond. One form of silicon dioxide, flint, is one of the hardest rocks – harder than steel. An important conclusion is that the hardness of a material depends on its crystalline structure and covalent molecules having the diamond structure are always very hard.

Show a picture of a diamond, or show a real diamond, and ask:

Q How many molecules do you think there are in this diamond?

This is a trick question but the faster students may realise that the answer is one. The diamond crystal is one single giant molecule. Likewise, a sand crystal, common in Qatar, is one giant molecule.

Some teachers may prefer to teach the Avogadro constant at this stage. Students with a knowledge of the Avogadro constant can be asked how many carbon atoms are there in the largest known diamond molecule (the Cullinan diamond found in Johannesburg in 1905) which has a mass of 620 g.

Summary for students

- Some covalent compounds form giant molecular structures that are hard and crystalline.
- Some elements form two or more different covalent giant structures; this phenomenon is called allotropy.
- (Advanced) Only one allotrope will be stable at any given temperature and pressure. The others are metastable. Diamond is a metastable form of carbon at room temperature.

Notes

Using test-tubes to heat sulfur

It is not possible to clean test-tubes that have been used for heating sulfur. Keep a set just for this purpose and reuse them with each class doing this experiment each year.

10.3 Reaction kinetics

Objectives

- Know and measure the effect on reaction rates of concentration.
- Know that reaction rates vary considerably and be able to produce, and analyse graphically, data from rate experiments.
- Identify and develop a clearly focused research question.
- Identify and control variables.
- Process raw data by the most appropriate means.

This lesson is suitable for both foundation and advanced students; the activity under ‘other tasks’ is more appropriate for advanced students.

Preparation

This lesson requires access to an electronic top-pan balance reading to an accuracy of at least 100 mg. If several balances are available, groups can be smaller. Try the reaction beforehand to ensure that each experiment goes to completion in a reasonable time. This will depend on how finely divided the solid is. The range of acid concentrations used may have to be adjusted to accommodate this. Aim for conditions that give adequate results in less than 5 minutes.

Preparing the correct volumes of the different concentrations of acid in advance will save students time during the lesson. Weighing out 20 g portions of the calcium carbonate in advance will also save time.

Introduction

This lesson will be the second or third in a unit on reaction kinetics; students will already be familiar with experimental investigations that illustrates the relationship between kinetics and particle size and, possibly, kinetics and temperature. These use broadly the same experimental technique and this will not be repeated here.

Start with a direct question to focus on the experimental method:

Q How did we determine the effect of particle size on the rate of production of carbon dioxide from the reaction between marble chips and hydrochloric acid?

This will permit a discussion of the method using a top-pan balance.

Define the problem to be solved in this lesson, which is to determine the effect of concentration of acid on the same reaction rate.

Ask students to discuss this problem in groups of about four and to produce solutions to it. (This could be assessed if written down.)

They should be able to propose studying, using the top-pan balance (or similar) method, the rate of evolution of carbon dioxide from a volume of hydrochloric acid at room temperature when a fixed mass of calcium carbonate granules (more than is required to neutralise all the acid) is added. The experiment can then be repeated using acids of different concentration but with varying volumes such that the number of moles present is always the same. All other variables are controlled.

Agree on the process through class discussion.

Main activity

Studying the effect of varying acid concentration on the rate of reaction

Resources (per group)

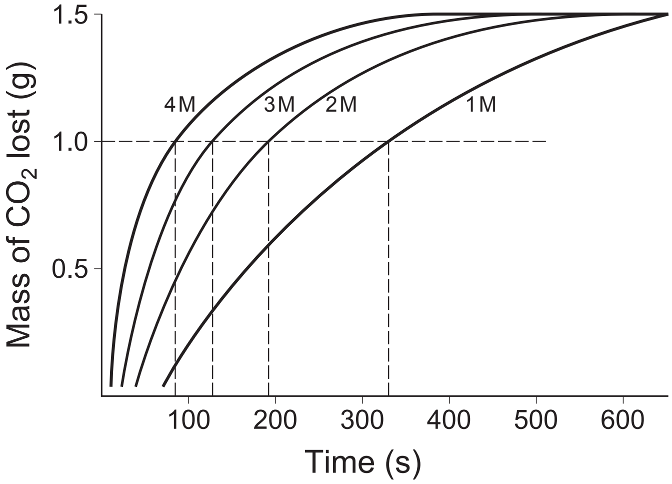
Access to a top-pan balance
Hydrochloric acid in concentrations of 00.1 M, 0.5 M, 1 M, 2 M, etc.
20 g portions of calcium carbonate
Graph paper
Timer or watch with a sweep second hand
Resource 10.4

Students should work in groups of up to four (depending on the number of balances available). Time: about 60 minutes.

Give out **Resource 10.4** and help groups work through part 1. If only one top-pan balance is available, each group could perform a single experiment using a different concentration of acid and the results could be shared.

Help groups with the experiment where necessary.

Students should (individually) obtain a graph similar to the one below expressing rate of reaction in terms of loss of mass of the reactants as the carbon dioxide is evolved. (*Note:* In the interest of time, the measurements could be stopped after a shorter time than the 10 minutes shown on the graph.)



Put a table of typical results on the blackboard. While students are plotting their graphs, draw one like that shown here on the blackboard.

Note that at the end of the evolution of gas, in each case, there was some solid remaining unreacted.

Consolidation

Bring the class together and discuss the results. Ask progressively searching questions to draw out the conclusions:

Q In which sample was the reaction rate fastest / slowest?

Q In (one case) how long did it take for 1 g of carbon dioxide to evolve?

Q Why did the rate of evolution of the gas get lower, in all cases, as the experiment progressed?

Q Why was there some solid left behind at the end of the reaction in each case?

Q Why was the maximum amount of gas evolved the same in each case?

At this point the class will be in a position to draw a number of simple conclusions from the results:

- the reaction rate was fastest when the acid was most concentrated;
- the reaction rate decreased during the experiment as the concentration of acid became less as it was neutralised;
- the reaction stopped when all the acid had been used up;

- the same mass of gas was given off by the end of each experiment because the same number of moles of acid was used in each.

End this section of the lesson by asking for an explanation, in terms of particles, of why a higher concentration of acid should give a faster reaction. Many students should be able to explain that the more particles of acid there were in a given volume of acid, the more likely they were to collide with the calcium carbonate particles and cause a reaction.

Other tasks

Advanced students can take this study further and show that initial reaction rate is directly proportional to acid concentration.

Students should work individually (or in the same groups). Time: 15 minutes.

Ask students to work through part 2 of **Resource 10.4**. This gives instructions for converting results from the graph showing the loss of carbon dioxide over time into a table of results that shows how the average rate of reaction during the loss of the first 1 g of carbon dioxide depends on initial acid concentration.

Move around the class and give assistance to individuals where necessary.

The notes below show how the graph given above leads to a plot of rate against initial acid concentration that is a straight line. These sample results (or similar results drawn from the class) can be used to discuss this extension work. Put a table of results on the board.

Direct the attention of the class to the graph on the board showing how the time taken to lose 1 g of carbon dioxide varies with the initial concentration of acid. This is an exponential curve and its meaning can be explored. Start with simple questions and lead to more complex theoretical ones:

Q Describe how the time taken for 1 g of gas to evolve varies with initial concentration of acid.

Q How long would it take to lose 1 g of gas if the initial concentration was (say) 2.5 M?

Q What is the hypothetical concentration of acid that would cause the *instantaneous* loss of 1 g of the gas?

After most students have got as far as plotting the rate curve, draw their attention to the board and discuss the meaning of *reaction rate*.

Q What do we mean when we talk about the *rate* at which something happens?

Answers will probably refer to how *fast* it happens.

Q How do we measure how fast something happens?

Answers should lead to the idea of measuring the number times something happens *per second*. Remind them of speed, the number of metres travelled *per second*.

Q How do we measure speed?

Answers should show that we measure either the distance that something moves in a second, or we measure the time taken to cover a specific distance and then divide the distance by this time.

Q In this case we are not measuring a fixed distance. What are we measuring?

The answer is that we are measuring a fixed amount (1 g) of carbon dioxide being lost. Our rate (speed) is therefore expressed as 1 g divided by the time taken to lose it (the reciprocal of the time)

Direct the attention of the class to the second graph on the board showing the relationship between rate and initial concentration. Ask students to interpret this straight-line graph:

Q What happens to the rate of reaction if the initial concentration of acid is doubled?

Q How does the rate of reaction depend on the initial concentration of acid?

Q What is the rate of reaction when the initial concentration of acid is zero?

This can lead easily on to the explanation of reaction rate in terms of particle collision: if concentration doubles, so will the number of collisions between particles and hence so will the reaction rate.

Summary for students

- The rate of reaction increases when the concentration of one of the reagents increases.
- In the reaction studied, the rate of reaction was proportional to the concentration of the acid.

Notes

The readings indicated in graph shown above yield the first two columns in the following table of results. The third column, the rate, is the reciprocal of the second.

Acid initial concentration	Time to lose 1 g CO_2 (s)	Rate (1/s)
4 M	80	0.0125
3 M	120	0.0083
2 M	190	0.0060
1 M	325	0.0030

The plot of column 2 against column 1 (Figure 1 below) shows the exponential relationship between the initial acid concentration and the time to lose 1 g of gas. The plot of rate (column 3) against initial acid concentration (Figure 2 below) shows the direct proportionality of the two.

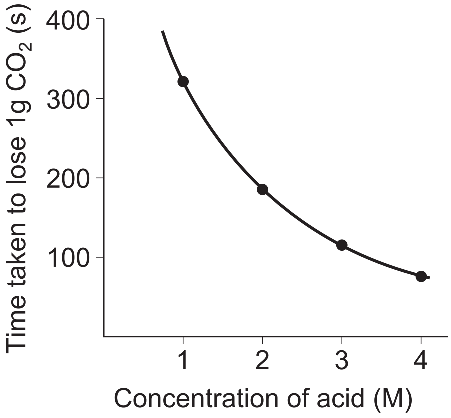


Figure 1

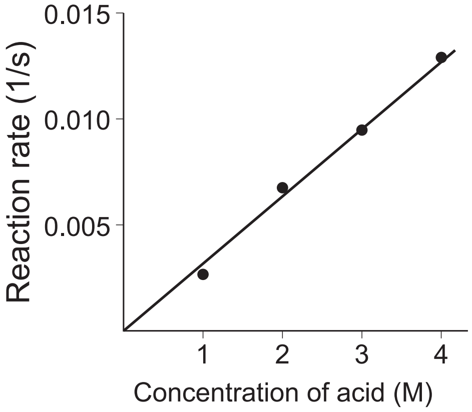


Figure 2

10.4 Determining the acceleration due to gravity

Objectives

- Understand the concepts of displacement, speed, velocity and acceleration, represent them graphically and interpret graphs that represent them.
- Solve problems relating to the motion of objects under uniform acceleration.
- Identify and develop a clearly focused research question.
- Evaluate experimental design, identify weaknesses and develop realistic strategies for improvement.
- Distinguish between systematic and random error.

This lesson is suitable for both foundation and advanced students.

Safety

Students will be using mains electrical equipment, which should be properly wired and earthed. They may also use a strobe light. Anyone with a history of epilepsy should not use a strobe light.

Introduction

Vocabulary

ball-bearing
centisecond timer
multiflash photography
strobe light

This lesson may be allowed to develop, for some students, into a problem-solving exercise which they can work at in their own time. They will need supervised access to the laboratory.

The lesson will be near the end of a series on the equations of motion, so students will be familiar with the concept of the acceleration due to gravity. In this lesson they will be asked to develop ways of measuring it based on two pieces of equipment: the centisecond timer and the strobe light.

Students must first be introduced to each item of equipment and shown what it can do and how it does it. Briefly demonstrated how each one works.

Remind the class, by dropping a ball-bearing (about 1 cm in diameter), of the force of gravity, which generates a constant acceleration in the ball-bearing when it is dropped.

Question the class to recall the equations of motion. Ask volunteers to write one that they can recall on the board. Clarify with them which of the variable s, a, t, u and v could perhaps be measured directly in a laboratory using a falling ball-bearing. Note particularly that $u = 0$ and $a = g$.

Q Which of the other variables (v, s and t) could you measure most easily?

They should realise that v is difficult to measure but that it might be possible to measure s and t.

Q Which of the equations of motion will you use to find g?

The answer is the one that does not contain v, namely $s = ut + \frac{1}{2}at^2$.

Question the class about how the two pieces of equipment might be used to measure the acceleration by giving values of *s* and *t*. Start with general open questions, such as:

Q How could you use the centisecond timer (or the strobe light) to study the movement of the falling ball-bearing?

This may generate ideas that can be developed. The class will certainly realise that the timer can be used to time how long the ball-bearing takes to fall a given distance, but they may not be able to think *how* that can be done. If their ideas are too vague, ask more specific questions, such as:

Q How can the ball-bearing be made to turn the centisecond timer on (or off)?

The aim of this questioning session is not to work out how to do the experiment, but to generate ideas that could be exploited in the experimental design. Some possible ideas are discussed in the notes below.

How the strobe light can be used to determine *g* is not as obvious, but a multiflash picture of a falling ball (most textbooks have one) will suggest ideas. A group familiar with digital photography may wish to develop these ideas.

Main activity

Determining the acceleration of a falling ball-bearing

Resources

per class

Centisecond timer
Strobe light
Digital camera
Access to a dark room

per group

Metre rule
Wire, plugs, magnets, crocodile clips, etc.
Ball-bearing

Students should work in groups of up to four.

Students should be asked to develop ways of measuring *s* and *t* using one of the two methods. The timer and strobe light must be shared between groups. This will be a process of experimental design, trial and evaluation until the group is satisfied that the design will give acceptable results.

The time needed for this process will depend on the practical expertise of the students. The most competent will achieve a result well within a double period, but it is desirable to give a longer time to the slower groups. The faster ones can be asked to solve both the problems or to develop other techniques, such as the use of a ticker-timer.

Your main role will be to ensure that each group has access to the materials they need and, by questioning, to direct the groups to recognise experimental weaknesses and possible solutions. You should not show the students how to solve the problem.

Improving accuracy

Generate discussion within each group on how to improve the accuracy of the experiment. Ask questions such as:

Q What is the main source of inaccuracy? How can this be reduced or eliminated?

Most students will identify the measurement of the time taken for the ball to fall as the main source of inaccuracy and should be able to suggest measures methods for reducing error, such as increasing the distance the ball falls, and taking an average of repeated measurements. (Note that the former will reduce the impact of systematic error, such as a possible mechanical delay in starting the clock, whereas the latter will also reduce random, experimental error. The difference between these two forms of error can be discussed with advanced students.)

Graphical solution

As soon as one or two groups have obtained satisfactory results, call the attention of the class to discuss how a value of g can be calculated. Repeat an earlier question:

Q What equation must we use to calculate g?

Many will recall $s = ut + \frac{1}{2}at^2$. Some will realise that, because $u = 0$, this will simplify to $s = \frac{1}{2}at^2$ and, because $a = g$, this becomes $s = \frac{1}{2}gt^2$.

Ask questions that lead to the use of a graphical method for reducing inaccuracies. Remind them of other examples:

Q How did you calculate the resistance of a wire in Grade 9?

Some will recall plotting a graph and calculating the resistance from measuring the gradient. Ask:

Q What is the main difference between this equation and the equation for calculating resistance?

Some will note that in this case the variable, t, is squared. Recall from mathematics the shape of the curve of s against t in an equation like this. If they do not recall it, ask them to make several measurements of t for different values of s and plot the curve. The result is not a straight line, so the gradient varies.

Recall that the equation for a straight line through the origin is of the form $y = mx$.

Q What variables must we plot that will give a straight line from which we can calculate g?

This is a difficult question and the correct answer may not be obtained. Students must be shown that if one variable is s and the other is not t but t^2, then the gradient will be $\frac{1}{2}g$. Ask them to determine the value of g from such a graph.

Consolidation

Bring the class together and call on two groups to describe briefly what they did, one group using the centisecond timer and the other the multiflash technique. Allow some discussion on experimental techniques that differed and whether the differences contributed to accuracy or not.

Ask all groups to write on the board their values for g and note the variation. Spend some time discussing the accuracy of the individual measurements and hence the accuracy of the value of g, and therefore the number of significant figures that should be used to report it (probably two).

Summary for students

- A value of g can be determined using a free-fall method with suitably accurate equipment for measuring small time intervals.
- The equation used is $s = ut + \frac{1}{2}at^2$, which simplifies to $s = \frac{1}{2}gt^2$ because $a = g$ and $u = 0$. A graph of s against t^2, will give a straight line of gradient $\frac{1}{2}g$.

Notes

The two techniques for determining *g*

These notes are not intended for students. The material covered in them can, however, be brought into the consolidation phase of the lesson if students have not already discussed it.

1 Using a centisecond timer

Most centisecond timers can be set to start and finish counting by making or breaking two DC circuits: the start and stop circuits. This allows a metal ball to trigger the timer at the start of a fall if, for example:

- it is held up by an electromagnet that is switched off;
- the ball itself is part of a circuit and the two pieces of metal supporting it are pulled apart suddenly, allowing the ball to fall.

The timer can be switched off by the falling ball if, for example:

- the ball falls onto a pressure switch (a home-made one could consist of two pieces of thin copper held apart by a piece of paper or card with a hole 2–3 cm in diameter cut in it; if the ball hits the copper above the hole, the copper deforms and touches the lower sheet, making a circuit);
- the ball falls onto the centre of a piece of iron supported underneath at its edges by two magnets, the whole of which is part of a circuit; when the ball hits the iron, it forces it away from the magnets and breaks the circuit.

Pieces of equipment such as these are commercially available but their use turns the practical into a straightforward demonstration and its problem-solving element is lost.

2 Using the strobe light

The ball is allowed to fall against a clearly calibrated ruler (such as a board ruler) placed in front of a dark background. It is illuminated by a strobe light set to flash at 10 flashes per second (or more). The falling ball is photographed using a digital camera set to infinite time exposure such that the shutter is opened just before the ball is released and closed when it hits the ground. The exposure is fixed and set by trial and error. The photograph can be printed using a computer. The distances that the ball falls after $\frac{1}{10}$ s, $\frac{2}{10}$ s, etc., can be measured on the photograph and scaled to the actual value.