Science lessons for Grade 9

Lessons in this section

Life science

1 Antibiotic action

Materials

2 Energy resources

Physical processes

3 Ohm's law

4 Waves

Resource sheets for the lessons

Using these lesson plans

These sample lessons for Grade 9 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 9. The relevant standards are shown in the lesson plans.

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 9.1 'Antibiotics' involves growing cultures of bacteria for 24 hours, so it needs to extend over two lessons on consecutive days.

Lesson plan 9.2 'Energy resources' is for extended individual or group research work involving the use of the library and the Internet. Several periods should be allowed for it.

9.1 Antibiotic action

Objectives

- Know that antibiotics are effective against bacterial illness.
- Grow and handle micro-organisms with safety.

Preparation

You will need to prepare cultures of a bacterium for use in this activity. Suitable species are *Escherichia coli*, *Bacilliu subtilis* and *Micrococcus luteus.* Each group of students will need a culture from which they will inoculate Petri plates of nutrient agar. You will also need to prepare a bottle of sterile nutrient agar for each student. Before the lesson, the agar should be melted and kept molten by placing it in a water bath at 45 to 50°C. Bacterial cultures must be obtained from an approved source.

You should also make a collection of packets that have contained antibiotics, advertisements for antibiotics or other materials that will allow you to build up a reference list of antibiotics and the conditions they are used to treat.

Safety

In addition to standard laboratory safety precautions, special attention must be given to safe working practices for handling micro-organisms and for the safe disposal of materials after the lesson. Once Petri plates have been inoculated and the antibiotic discs added, they should be sealed with tape and not opened again. Cultures should not be incubated at temperatures approaching body temperature. At the end of the activity the Petri plates of bacteria should be autoclaved before disposal. If the starter cultures are not to be used again, they too should be autoclaved and disposed of. If retained, they should be labelled clearly and stored in a fridge; the fridge should not be used for foods. Anyone handling bacteria should wash their hands thoroughly beforehand and afterwards. Inoculation is best done in a transfer hood; if this is not available, the activity should be contained on a designated area of bench that should be washed with antiseptic solution before and after use.

Introduction

Vocabulary
antibiotic

What are antibiotics?

Start this lesson by writing the word *antibiotic* on the board. This should be the starter for engaging the class in oral questioning:

Q Who has seen this word before?

Q Where have you seen the word used?

Q What does the word mean?

Q What are antibiotics used for?

Q Do you know the names of any antibiotics.

You should try to involve as many students as possible in answering these questions and discuss their answers. It is likely that several students will have heard of the word, some will recognise its use in a medical context, a few will know that antibiotics are used as medicines and others may know the names of antibiotics such as streptomycin and penicillin. Some will have been treated with these antibiotics. It would be appropriate to refer to the information on packets that have contained antibiotics and/or to promotional materials. Having established the knowledge and experience base of the class, you should explain that the lesson aims to illustrate the action of antibiotics against bacteria and also to provide the class with practice in handling bacteria. You should make clear that in this lesson they will set up an experiment and that they will observe the outcomes in a later lesson.

Main activity

Vocabulary

agar
antibiotic
contamination
inoculate
Petri plate
sterile

Resources

per class

Water bath

per group

Bacterial cultures
Antibiotic discs
Inoculating loop
Forceps
Bunsen burner

per student

2 sterile Petri plates
2 bottles molten nutrient agar

Pouring agar plates

Students should work in groups of four.

In this part of the lesson students should work in groups but each student should prepare their own Petri plates of agar. You will have to instruct the class on safe working practices. It is advisable to demonstrate how to pour a plate before asking the pupils to do their own. Remember to warn them that molten agar is hot. Students should prepare plates of agar and label these with their names in a way that does not obscure much of the plate. The plates should be left to cool for 5 to 10 minutes. This might be a good time to demonstrate how to spread bacteria across the surface of the agar in a Petri plate. The students will do this in the next part of the lesson. You will need to stress the use of good practice to avoid contaminating the bacteria with organisms entering from the air, from the laboratory bench or from their bodies and clothes. You should similarly stress the need for students to avoid being contaminated by bacteria and the necessity to wash their hands after practical work with bacteria.

Inoculating with bacteria

Each student should now inoculate their Petri plate with a culture of bacteria, ensuring that the culture is spread evenly over the surface of the plate. The next step is for each student to use sterile forceps to place antibiotic discs on the surface of their plate along with one control disc of sterile water. Some students in a group should use discs of the same antibiotic but in different concentrations while others should use different antibiotics of the same concentration. Students should record what they have done. You should set up some demonstration plates to show the normal growth of the bacteria. The plates should now be sealed and placed in an incubator for 24 hours. They should be examined in the next lesson and the observations recorded.

Consolidation

Ask some questions to check that students have understood the important aspects of the lesson. For example:

Q Why did the agar need to be sterile?

Q Why did the agar need to be nutrient agar?

Q Why are we incubating the plates at about 25°C and not about 35°C?

Q Why did we spread the bacteria over the plates?

Q Why did we wash our hands before and after working with the bacteria.

You should also get students to think about what might happen and why by asking questions such as:

Q What do you predict you will see on the plates with just bacteria?

Q What do you predict you will see on the plates with antibiotic discs?

Q What do you predict you will see on the plates with discs with different concentrations of antibiotic?

Q What is the basis of your predictions?

You should end by telling students that in the next lesson they will examine their plates and will be able to determine whether their predictions are correct.

Other tasks

If time allows, students could be asked to design an experiment to determine the concentration of a common liquid antiseptic that is most effective against bacteria.

As a homework activity students could be asked to find out the names of some common antibiotics and the bacterial illnesses against which they are effective. Another possibility would be to ask them to use books or the Internet to find out about the discovery of penicillin and/or antibiotic resistance.

Summary for students

- Antibiotics are common medications.
- Bacteria can be cultured on plates of nutrient agar.
- When working with bacteria you must be careful to prevent contamination.
- You should not incubate plates of bacteria at close to human body temperature to avoid encouraging the growth of organisms harmful to humans.

Notes

In the next lesson students will observe the inoculated Petri plates. Plates with no antibiotic discs or with discs of sterile water should show an even growth of bacterial colonies. Plates with antibiotic discs should show clear areas with no bacterial colonies around the discs. The larger the diameter of the clear area the more effective the antibiotic at killing the bacteria.

9.2 Energy resources

Objectives

- List the main sources of energy available to us and classify them as renewable and non-renewable.
- Name the common fossil fuels and explain their origin.
- Describe the different ways in which we can harness energy from the Sun, either directly or indirectly through wind energy and hydropower.
- Know that scientific work may be affected by the context in which it is undertaken.

Preparation

Search the Internet for useful websites yielding up-to-date information and pictures related to different energy sources.

A class visit to Doha power station would provide very useful background information for students. This may have been organised when electricity generation was taught earlier in the year.

Introduction

Vocabulary

finite
non-renewable
renewable

Resources

Pictures or diagrams of ways of generating electricity from renewable energy sources
Information on the costs of generating electricity from different energy sources
Resource 8.3

This section must be taught *after* the students have studied electricity generation. Students should also have had an opportunity to work on data display and interpretation before starting this lesson (see, for example, Lesson 8.4).

No practical work is suggested for this lesson. Students will be asked to find information from various sources and interpret the information and answer questions using it. A possible output of the lesson is a presentation on energy resources, which could take the form of a classroom display, a portfolio in students' books or an ICT presentation using software such as PowerPoint.

Start the lesson by asking about energy supply, cost and use in Qatar:

Q What fuel is used to make our electricity here in Qatar?

Q How much do we pay for our electrical energy?

Look at world energy costs in **Resource 8.3** and discuss the cost of energy in Qatar. Question the class to ensure they understand that Qatar has cheap energy because there is a large gas field under the country and the nearby sea:

Q Why is energy in Qatar so cheap?

Q Where do we get our energy from in Qatar?

Ask questions that recall what students have learned of the process in Doha power station:

Q How is electricity made in Doha?

The answers will probably be general, such as 'from gas'. Ask more questions to get the details of the process, which involves large gas turbines that drive generators. Draw a flow diagram of the process on the board, showing the energy transformations at each stage.

Q How is the gas burnt in the power station?

Q What energy transformation happens in the gas turbine?

Q How is the kinetic energy from the gas turbine transformed into electricity?

Q What happens to the waste heat energy from the turbine?

Make sure that students know what gas turbines are (see the notes at the end of this lesson plan). Emphasise that gas turbines are not usually used alone to generate electricity; they are too inefficient because they waste a lot of energy in the form of heat. Remind them that using gas to generate steam to drive a steam turbine is more efficient. Note that in Doha, however, the waste heat from the gas turbine is needed to distil seawater to produce water for drinking.

In the next part of the lesson, distinguish between *chemical* energy sources, which use burning to generate the energy that is used, and sources that use other forms of energy, such as *kinetic* (wind, tide), *potential* (hydro) and *light* (solar). Have pictures of windmills, hydroelectric dams and solar panels as examples of other ways or generating electricity.

For each picture, ask one student to draw an energy transformation flow chart. This can be done individually in their books or on the board in front of the class.

Q Of all the processes mentioned, which involve the conversion of chemical energy?

Q Where does this chemical energy come from?

Some students will recall the origins of the gas field in the Carboniferous era and be able to describe the processes that have converted living material in that era to gas in the Qatar field today.

Q Where did the plants and animals living in the Carboniferous era get the energy that is now stored as chemical energy in the gas?

The answer is from the Sun through photosynthesis.

Construct a flow chart that shows the energy transformations that have taken place in all the processes, from the origins of the gas field in the Carboniferous era to using it today.

Emphasis that the Qatar gas field is a *finite* resource. It is not being continuously replenished as it is used. It is *non-renewable*.

Discuss briefly the ethical question of whether we have the right to use it all or whether we should use it slowly and save as much as possible for future generations. Note that much of the benefit from Qatar gas goes to people in other countries.

Q Who does the Qatar gas field belong to?

The class will probably respond that it belongs to the state and all the people of Qatar.

Q Who is getting the benefit from the gas? Is it only Qatar?

Q How long will there be gas in the gas field?

Q Where will Qatar get its energy and its water from when the gas field is used up?

Q Should we save some of the gas for future generations to use?

Then ask the first question again and see if the class gives a different answer – that it also belongs to future generations of Qataris.

Main activity

Resources

Access to a library and the Internet

Resource 9.1

Renewable and non-renewable sources of energy

Students should work individually or in small groups. Time: around 2–3 hours over several lessons.

Students should conduct research work and prepare a display on one or more of the following aspects of energy resources:

- How the world is using energy – where does the energy come from and what is it being used for?
- A comparison of the different sources of energy (see **Resource 9.1**).
- Why we should gradually move from using non-renewable sources to renewable ones.

The display can be in the form of a portfolio, a wall display or an ICT presentation using software such as PowerPoint.

This research topic will take several lessons and you must agree on a timetable with students. As well as ensuring that students are busy working you will be the research supervisor. This will mean scheduled interviews with each research group at which they will report progress and problems. You should assist with problems and help students find relevant material and information. Much use will be made of the Internet, so you need to make sure that students are not visiting inappropriate websites (if the school is using a proxy server, suitable filtering software should be installed to help prevent this).

Encourage students to present data in a graphical or diagrammatic form rather than using a lot of text.

Consolidation

Resources

Cooking timer or wall clock

Paper or card

Warn the groups before the final lesson in this sequence that they must make a short presentation of their work. They should be asked to limit the time of their presentation to a maximum of 3 minutes. Ask them to think carefully about how they are going to manage this; they should practise and time themselves before the lesson.

Control the presentation times very strictly using a clock that everyone can see or a timer with a bell. Allow time for questions and comments after three or four presentations.

On two sheets of paper or card on a display board, make two, two-column summary tables, one headed ‘Renewable energy resources such as …’ and one headed ‘Non-renewable energy resources such as …’. Leave a space after the titles. The columns in each table should be headed ‘Advantages’ and ‘Disadvantages’. You (or some appointed students) should add information to the tables as it is raised during the presentations.

At the end of the presentations, discuss the summary tables with the class, asking them if there are any points that have been missed. If necessary, rewrite the tables neatly. Leave the tables on display in the classroom for a few weeks.

Summary for students

- We need energy for almost everything we do.
- We use a variety of energy resources to meet our energy needs.
- Some of these resources are finite and non-renewable and others are renewable.
- The energy in almost all renewable energy sources came originally from the Sun.
- Most finite energy resources were created many millions of years ago by living things that obtained their energy from the Sun.
- The use of finite energy resources causes atmospheric pollution.
- We should conserve finite energy resources so that some is available for future generations.
- There are many ways of displaying data and the way data are displayed should depend on who the display is intended for.

Notes

Making electricity using a gas turbine

Gas turbines are very large jet engines in which burning gas causes a large expansion in the volume of the air sucked into the turbine. The air expands through turbine blades, causing them to rotate. This rotation drives a shaft that drives a generator.

Gas turbines are inefficient because the exhaust gases that emerge are very hot, which means that much of the chemical energy in the original fuel is converted into heat and not electricity. In Doha power station this waste heat is used to distil seawater to make drinking water.

Making electricity using a steam turbine

In this process the fuel (such as natural gas) is burnt in a furnace and the heat produced is used to boil water to make steam under pressure at around 600°C. This steam expands through steam turbines and the turbine drives an electrical generator. The steam goes through several turbines, each designed to operate at a different temperature and pressure. The steam emerging at the end can be at a temperature as low as 60°C, under reduced pressure. In this system much more of the chemical energy in the gas is captured in the form of electrical energy than in the case of a gas turbine.

'Combined cycle' electricity generation

This process uses both a gas turbine and steam to generate electricity. The hot gases from the turbine are used to make steam under pressure, which is used to make more electricity. An overall efficiency of up to 40% can be obtained in this way. In Doha, however, this heat is used to distil seawater.

9.3 Ohm's law

Objectives

- Calculate the resistance of a component knowing the current passing through it and the potential difference between its ends.
- Know how the resistance of a wire depends on its diameter, length and the material from which it is made.

Preparation

Have a good supply of thin resistance wire, especially nichrome.

Check that all components are in working order and carry out the experiment beforehand to determine the optimum length of resistance wire to give readings on the scales of both meters.

Introduction

Vocabulary

circuit
current
potential difference
resistance
voltage

Question the class to recall previous work on current and voltage:

Q What do we mean by 'current' and 'potential difference'?

Q Why does the current change when we change the components in the circuit?

Q What happens to the current in the bulb when the number of cells is increased?

Q What happens to the voltage across the bulb when the number of cells is increased?

Remind students that a bulb contains a thin wire called a resistance wire that resists the flow of electricity.

Discuss how they could design a circuit that will show how the current flowing through a resistance wire changes as the voltage across the wire is changed.

Main activity

Resources

per group

6 cells and holders
Length of resistance wire
Ammeter
Voltmeter
Connectors

per student

Resource 9.2

Work in groups of up to four. Time: around 30 minutes.

Hand out **Resource 9.2**. Ask students to complete the activity and record their results in the table. Give help where needed, particularly with setting up the circuit correctly and connecting the resistance wire without shorting it. Allow sufficient time for each group to get several results.

Assist with the calculations if necessary. The value of the resistance should be corrected to two significant figures; some students may need help with this.

Ask questions that point towards the conclusion that voltage is proportional to current:

Q What happens to the current when you increase the voltage?

Q What happens to the current when you double the voltage?

The last part of the activity is to plot a graph of V against I. Allow those who finish early to start this.

Consolidation

When all groups have completed the table, bring the class together and invite some of them to present and discuss their results. They may need help with questions such as:

Q What happened to the current when you increased the voltage?

Q What do you notice about the numbers in the last column?

The significant point that should emerge is that the value for voltage over current (V/I in the last column) is almost constant.

This value will differ slightly from group to group. Discuss why.

The ratio voltage/current is called *resistance*. Students should be able to use and manipulate the formula $V = IR$; questions at the end of Resource 9.2 will help them with this. Ask them to complete it for homework. The answers to the questions are:

1 15 volts and 6 ohms.

2 3 amps.

3 0.5 amps.

Plotting the graph of *V* against *I*

Instruction 7 of Resource 9.2 asks students to plot a graph of voltage against current (x-axis). Help them with this, either on the board for the whole class or with individual groups, so that they know they should draw a straight line that need not pass through all the points. They should know that if a point was off the line, it was probably due to errors in reading the instruments. Any point that is far off could be checked experimentally.

When students have done this, some time should be spent interpreting it. Ask questions of increasing difficulty:

Q What is the shape of the graph?

Q What happens to the current as the voltage increases?

Q What happens to the current when the voltage doubles?

Q What is the current when the voltage is zero?

Introduce the concept of proportionality: the current is directly proportional to the voltage. This always gives a straight-line graph that passes through the origin.

Ask them to work out the gradient of the line, if they have done gradients in mathematics. The gradient is the same as the resistance. Faster groups can be shown how to do this if they have not met it in mathematics.

Summary for students

- The resistance of a wire is given by the ratio of the voltage between its ends to the current it takes.
- The resistance of a wire depends on its length.
- A graph showing a straight line through the origin indicates that the variables are proportional to each other.

9.4 Waves

Objectives

- Know that energy can be transmitted through water in the form of waves.
- Understand the relationship between velocity, frequency and wavelength, and perform calculations using the relationship.
- Explain the refraction of water waves in terms of the change in velocity of waves.
- Use mathematical relationships routinely to calculate physical quantities.

Preparation

Check that the overhead projector is in working order. Ensure that the ripple tank accessories include a triangular sheet of glass or, preferably, Perspex that is about 4 mm or more thick and a piece of dowel about 20 cm long and 1 cm in diameter. The other ripple tank accessories are optional but may be used. As with all demonstrations, you should try it out beforehand so that no unforeseen problems arise (for example, refraction of water waves is not at all obvious unless the shallow water is much shallower than the deep water).

Introduction

This will probably be the second lesson in the unit on waves. It follows an introductory lesson on the transmission of energy by waves through different media. It is a demonstration lesson using a ripple tank on top of an overhead projector.

Question the class to remind them what they learned in the previous lesson. The questions can be in linked pairs (or longer sequences) that start by recalling something concrete and then lead quickly to a more abstract interpretation or explanation.

Q Can you give an example of a transverse wave?

Q Who can explain what a transverse wave is?

Q What was the shape of the waves in the rope?

Q Can you explain what we mean by wavelength / amplitude of the wave in the rope?

Q How far away from your ear could you hear a watch?

Q Why can you hear a watch on a bench much better and from further away if you put your ear against the bench?

Ask questions to recall experiences of water waves:

Q Where have you all seen waves in Doha?

Q What causes waves on the sea?

If nobody answers this by mentioning the wind, ask questions such as:

Q When are the waves in the sea big / small?

Ask questions that focus on waves as a means by which energy can travel through a medium:

Q Where does the energy in the water waves come from?

Most students will say the wind. Ask them what the wind is and how it can hold energy (kinetic energy of the air particles that make up the wind) and remind them that energy cannot be created from nothing but it can be transformed from one form to another. A few students might also observe that water waves can be produced by ships. Again, talk about the transformation of energy in the ship to the propellers and to the water.

Ask a further question, given below; it does not require an answer at this stage but tell the class that you will be asking the question again at the end of the lesson. Challenge them to come up with a correct answer then.

Q Why do waves in the sea always travel towards the shore?

They will probably say that the wind blows them that way but logic should tell them that this is not so; off-shore winds are quite common in Qatar in the mornings and the waves do not travel *away* from the shore when these are blowing.

Main activity

Resources

Ripple tank and accessories
Overhead projector
Hand-held stroboscopes for the whole class (optional)
Clear plastic ruler with markings clearly visible when placed on the OHP

Set up the ripple tank on top of the overhead projector so that the ripples are focused on the screen. The depth of water in the tank should be such that when the glass (or Perspex) sheet is placed in it, the water depth on top of the sheet should be as shallow as possible without the plate being exposed when waves flow over the top of it.

Students should be sitting in a group at the front of the class so they can all see the demonstration, but not too close to the equipment: you need unimpeded access all around it.

As in all demonstrations, involve individual students as volunteer helpers as much as you can. You should be conducting a continuous dialogue with the class that explains at all times what you are doing. Where possible, ask students for suggestions on how to proceed whenever a problem arises. Some examples of this are suggested in the form of questions below.

1 Demonstrating waves

Demonstrate the production of a single straight wave using a rolling dowel in the tank. Ask a student to demonstrate a similar wave so that you can then stand next to the screen to explain what is happening. Define the term *wavefront* and show that what is produced by the dowel is straight wavefront. Ask the student helper to make a circular wavefront by dipping his or her finger quickly in and out of the water.

2 Measuring wavelength, frequency and velocity, and demonstrating the relationship between them

Now get a student to create a series of wavefronts by rolling the dowel evenly backwards and forwards. Ask another student to come to the screen and show what is meant by *wavelength*. Question the class:

Q What is meant by the frequency of the waves?

Q How could you measure the frequency of the waves?

Many methods will be suggested and can be tried. One idea for measuring the frequency accurately is as follows:

- the person who makes the wave calls out loud each time a wave is created;
- the number of waves created in (say) 10 seconds is counted and from this the frequency is calculated;
- several results are taken and an average calculated.

Question the class further about the velocity of the waves:

Q Can anyone suggest how we can find out how fast the waves are moving?

Some will suggest measuring the time taken for a wave to travel a particular distance.

Q How can we show the distance on the screen.

Some students will mention the use of a ruler; show how a plastic ruler can be used on an OHP.

Q What distance should we measure?

Agree on, say, 25 cm as an appropriate distance to use. Many students can measure the time for a single wave to travel 25 cm and the average can be taken.

The relationship $v = f\lambda$ can be used to calculate the wavelength of the multiple waves made when the frequency was calculated. The result can be checked by direct measurement.

3 Showing the reflection of water waves by a straight barrier

A straight barrier placed at an angle to the direction of a series of parallel wavefronts will show reflection of the wavefronts (see Figure 1 in the notes at the end of this lesson plan). It is easy to see that the angle of incidence is the same as the angle of reflection, particularly if the experiment is repeated several times with different angles of incidence.

This activity can be repeated with a circular wavefront to show how the waves continue to spread out after reflection.

4 Showing the refraction of water waves by changing the depth of the water

An area of (much) shallower water is made by putting a glass plate in the water such that a series of parallel wavefronts hits the plate at an angle (see Figure 2 in the notes at the end of this lesson plan). Ask a student to generate the waves. Ask what is happening to the waves on the screen. It can readily be seen that:

- the direction of travel changes towards the shallow water;
- the wavelength of the waves decreases;
- the frequency remains the same (it is determined by the person making the waves).

Question students on the observations:

Q What is happening to the velocity of the waves as they enter the shallow water?

It should be clear from the relationship $v = f\lambda$ that the velocity decreases.

Q Can anyone tell us why the direction of the wave changes in shallow water?

This is not an easy question to answer. Split the question up into parts:

Q Which end of the wavefront reaches the shallow water first?

Q What happens to the velocity of that end of the wave?

Q What is the velocity of the other end of the wave?

Q Which end of the wave will move the greatest distance in one second?

Q What must happen to the wave if one end moves a greater distance than the other end?

This last question is the key one. If students cannot get the right answer, the situation can be demonstrated by the class. Six members should be asked to act as a wavefront and to hold hands and march in step towards a line that indicates the shallow water. The line should be at an angle to the marching students so that they reach it one at a time. As they step over the line they should halve the length of their step. It will immediately be seen that the wavefront turns towards the shallow water.

Ask again the question you posed at the end of the introduction:

Q Why do waves in the sea always travel towards the shore?

The answer is that no matter which direction waves are travelling in the open water, they will move more slowly when they move into shallower water near the shore and this will cause them to turn into the shore.

Consolidation

Summarise on the board the three main points that have been shown in the demonstration (these are given in the box below). Ask students to draw the movement of the waves, showing reflection and refraction, in their books. Help them, if necessary, by drawing them on the board (see the notes below).

Summary for students

- Wavefronts in water can be reflected by a barrier.
- Water waves travel more slowly in shallower water.
- Wavefronts bend towards shallower water.

Notes

Wave diagrams

The paths of successive parallel wavefronts as the wave is reflected at a barrier or moves from deep to shallow water are shown in the figures below. The arrows represent the direction of movement of the wave. Diagrams like these appear in all good textbooks but they are included here as examples that can be put on the board. They are key to the understanding of the two processes of reflection and refraction and you will return to them when teaching light.

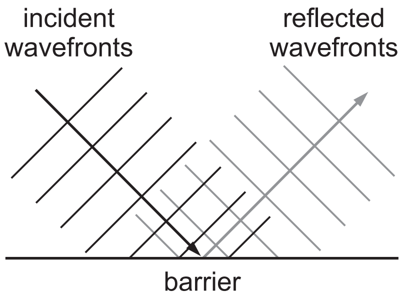

Figure 1

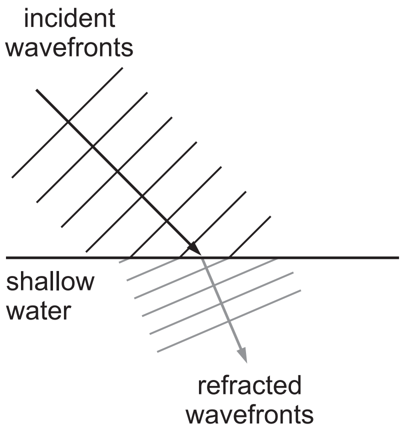

Figure 2

Java applets

Many websites carry interactive examples, in the form of Java applets, of the movement of waves between and around objects. These are particularly useful for showing more advanced topics, such as interference and diffraction. A search for the key words such as ‘reflection + applet’ will find them.

