Trees as structures

Contents: Reading, questions, data analysis and practical work about trees as physical structures.

Time: 2 to 4 periods, depending on the time spent doing experimental work.

Intended use: GCSE Physics, Technology, and Science courses. Links with work on forces and elasticity.

Aims:

- To complement work on forces and elasticity
- To encourage an awareness of trees with their natural and commercial importance
- To provide opportunities to practise the skills involved in plotting and interpreting graphs
- To provide opportunities to use practical skills to investigate the properties of wood.

Requirements: Students' worksheets No.1009, graph paper and the apparatus for the investigations listed below.

Author: Anabel Curry

The unit views trees as systems for harnessing solar energy and considers their strategies for doing so. It also considers the importance of trees as a resource.

There are two experimental investigations. The first one is relatively quick and simple. The second is open-ended and proved popular in trials.

Part 1 Structures for harnessing the sun's energy

Notes on selected questions

Q.1 This activity gives the students practice in drawing to scale.

Q.4 Students will probably be able to apply intuitive notions of wind loading (wind resistance), centre of gravity and turning moment.

Q.5 The cherry has a higher centre of gravity and needs to be more strongly anchored by its root system.

Q.6 The result of plotting the data on height and girth of trees is shown on page iv. The pattern is that the deciduous trees with large canopies fall on the lower right-hand side. They experience a larger wind loading and tend to have a large girth for their height. The evergreen (coniferous) trees tend to be taller for their girth and fall on the upper left-hand side of the paper. Many conifers grow in regions where snow loading would snap branches if the trees were not conical in form. Note that the examples have been selected from common trees to exemplify the pattern. Deciduous trees with less dense canopies (such as ash or birch) lie closer to the conifers.

The ratio of elasticity of the wood to its density is also an important factor in determining the safe height of a tall structure. It gives a measure of the energy that can be stored per kilogram when the material is stressed.

$$(\text{height})^3 \text{ is proportional to } \frac{(\text{modulus of elasticity})}{(\text{density})} \times (\text{diameter})^2$$

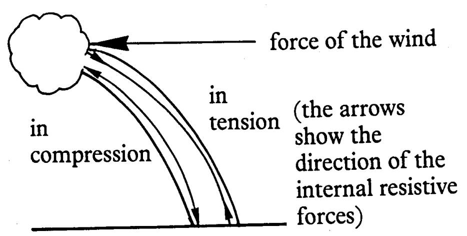
If time permits students might go outside and measure the heights and girths of mature trees in the school grounds, to add to the data in the table.

Q.8 Half the world's timber is burnt for fuel, but this tends to be in the developing nations. Methanol can be used as a fuel and is produced from wood, but the low efficiency of the process gives no overall energy yield. Timber as a material resource is used in buildings. (Its structural properties rival those of steel.) Pulped wood is used for paper making, manufacture of viscose fabrics, cellophane, etc. Turpentine, natural rubber and even maple syrup are obtained from tapping the sap of trees.

Part 2 Investigating the design of trees

Requirements for investigation A

Wooden dowelling about 50 cm long and 8 mm in diameter
1 kg mass
2 stands with bosses and clamps
ruler
sharp knife or saw to cut a notch
pencil sharpener to give a pointed end to the dowelling



The concepts of force and moment are essential to an understanding of how structures resist deformation and failure.

The experimental instructions ignore the slight reduction in perpendicular distance from the support to the weight as the deflection increases. Sharpening the end of the dowelling produces a useful pointer.

The bending moment applied by the wind increases rapidly as the tree gets taller.

When a tree bends in the wind, it experiences both tensile and compressive forces. A tree which is exposed to a prevailing wind lays down special tension or compression wood in response.

Specimen results:

length/cm	10	15	20	25	30	35	40
deflection/mm	2.5	16	14	23	36	53	76

These results are plotted on the graph shown on page iv.

Requirements for investigation B

4 or 5 pieces of dowelling with diameters in the range 5 – 12 mm
slotted masses, 10 × 100 g
2 stands with bosses and clamps
ruler
sharp knife or saw

The dowelling must be of circular cross section (because cross-sectional shape affects the stiffness — try bending a ruler). With four or five different samples, students should be able to obtain a curve relating diameter to deflection.

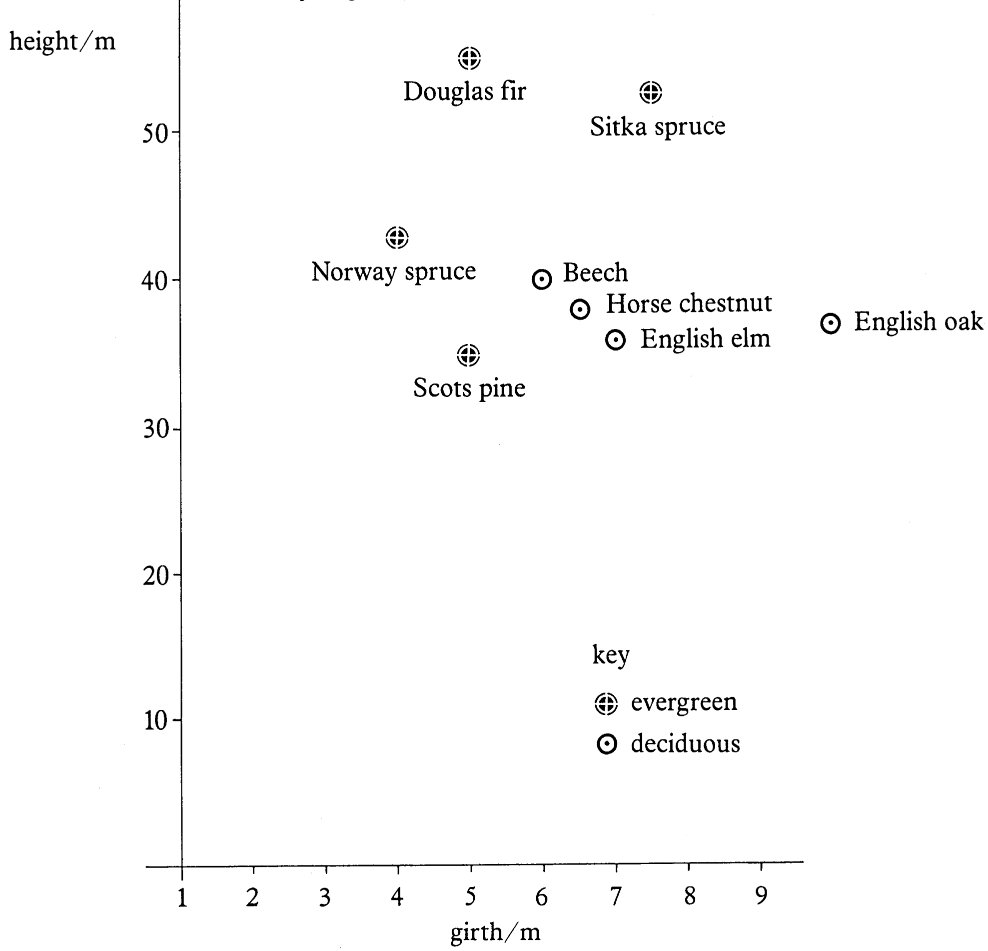
Specimen results:

Length: 20cm
Load: 0.50 kg

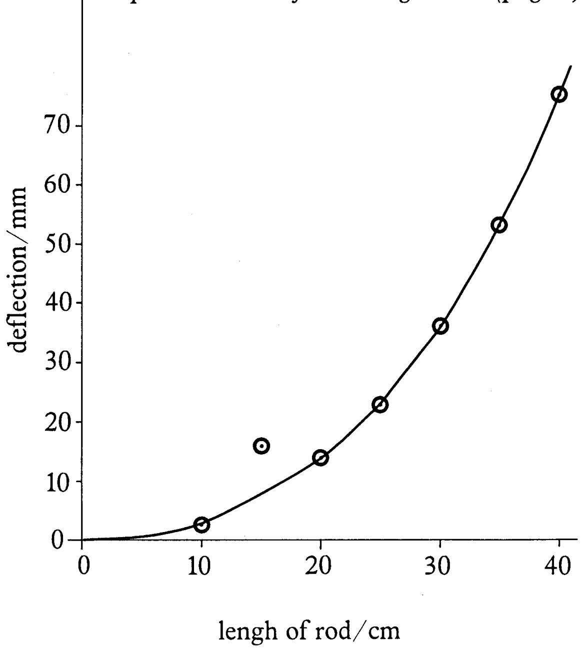
diameter/mm	5	6.15	8	10.15
cross-sectional area/mm^2	20	30	50	80
deflection/mm	28	15	6	5

These results are plotted on the graph shown on page iv.

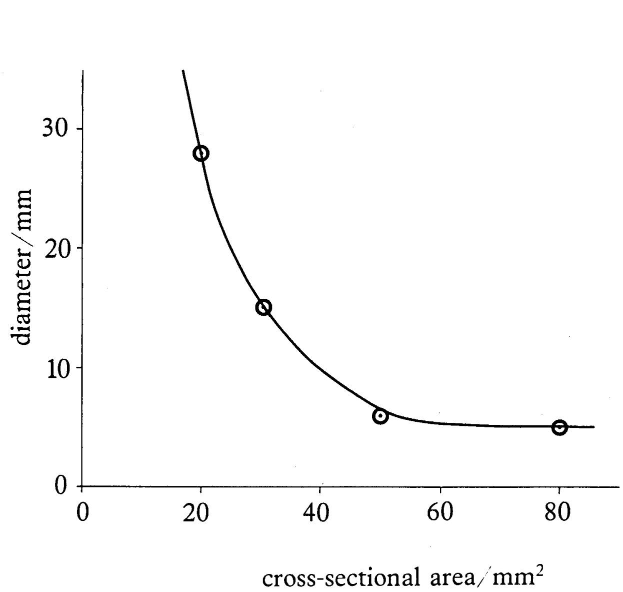
Plot of height against girth for trees (Question 6, page 2)



Specimen results for Investigation A (page 3)



Specimen results for Investigation B (page 3)



TREES AS STRUCTURES

Part 1 Structures for harnessing the sun's energy

The largest organisms that have ever existed are not elephants, whales or dinosaurs. They are trees.

Being big is a biological problem. Large organisms need more energy to survive. On land they have to be supported by very strong structures.

But being big can have benefits too. Size can help in the struggle for survival. Plants live and grow using energy from the sun. This is called photosynthesis. Tall trees capture the light before it reaches smaller plants growing in their shade.

Deciduous and evergreen trees have different strategies for harnessing the sunshine.

Question

1 How big can they grow?

Man (approximate height)	*2 m*
Elephant (height)	*4 m*
Blue whale (length) (the largest mammal)	*30 m*
Diplodocus (the longest dinosaur)	*30 m*
Giant Sequoia tree	*110 m*

Use a scale of 1 cm to represent 10 m. Draw and label lines to represent the height or length of these organisms (Scale 1:1000)

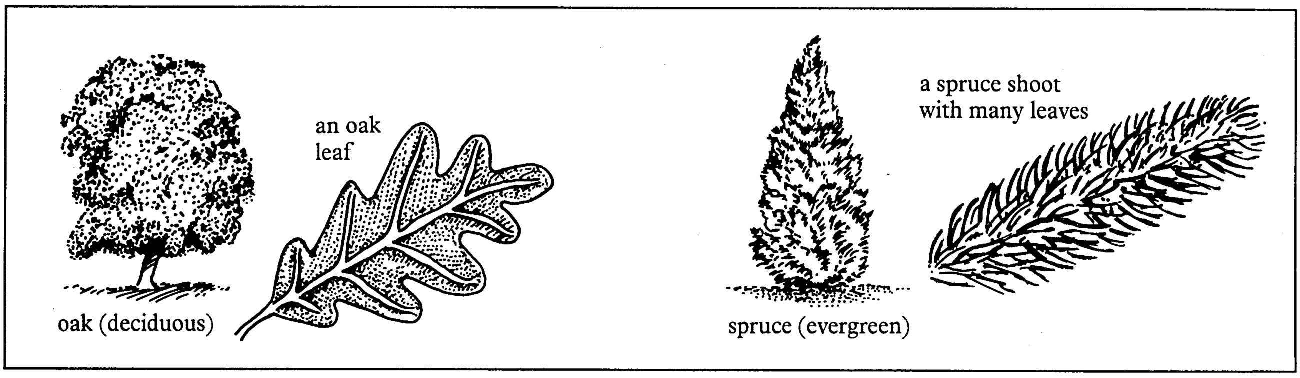


Figure 1 Deciduous and evergreen trees

In Britain deciduous trees lose their leaves in winter. They have to collect as much of the summer sunshine as possible. Their leaves have a large surface area. In windy weather, such trees suffer what engineers call a large wind loading. Their large leaves have a high wind resistance. A deciduous tree needs a strong trunk and branches together with well-anchored root systems so that it does not blow over in high winds.

Evergreen trees photosynthesise all year round. Their leaves are usually smaller and give less resistance to the wind, but they have to be able to survive storms in winter.

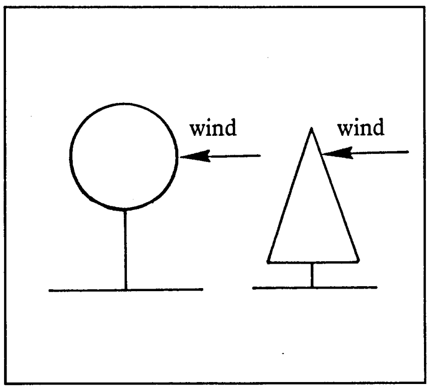


Figure 2 Tree shapes

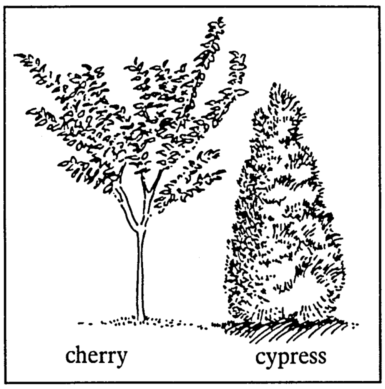


Figure 3 Cherry and cypress trees

Questions

2 What is the strong structure which supports each of these large living things:
(a) a giraffe
(b) an oak tree

3 (a) Why do plants need sunlight?
(b) Why do deciduous trees only grow during the summer?

4 Look at Figure 2. Which shape of tree is more likely to topple over in the wind?

5 Which garden trees need to be anchored more strongly by their roots: deciduous trees like cherries or evergreens like cypresses?

The figures in the table below compare the height and girth of evergreen and deciduous trees. The girth of a tree is the circumference of its trunk.

Table 1

Species of tree	*Deciduous or evergreen*	*Height (in m)*	*Girth (in m)*
Beech	deciduous	40	6
Douglas fir	evergreen	55	5
English elm	deciduous	36	7
English oak	deciduous	37	10
Horse chestnut	deciduous	38	6
Norway spruce	evergreen	43	4
Scots pine	evergreen	35	5
Sitka spruce	evergreen	53	7

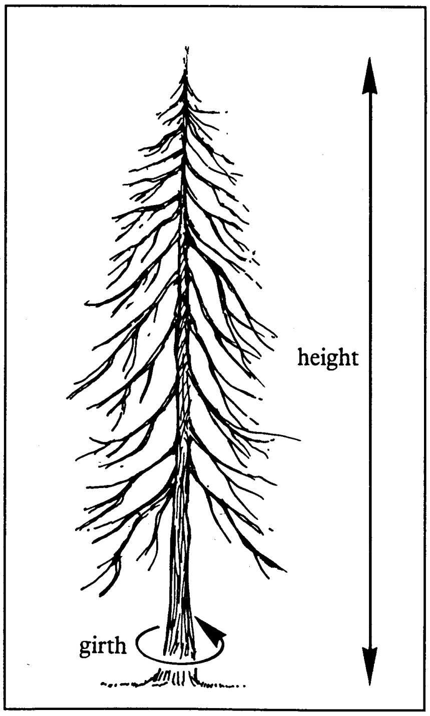


Figure 4

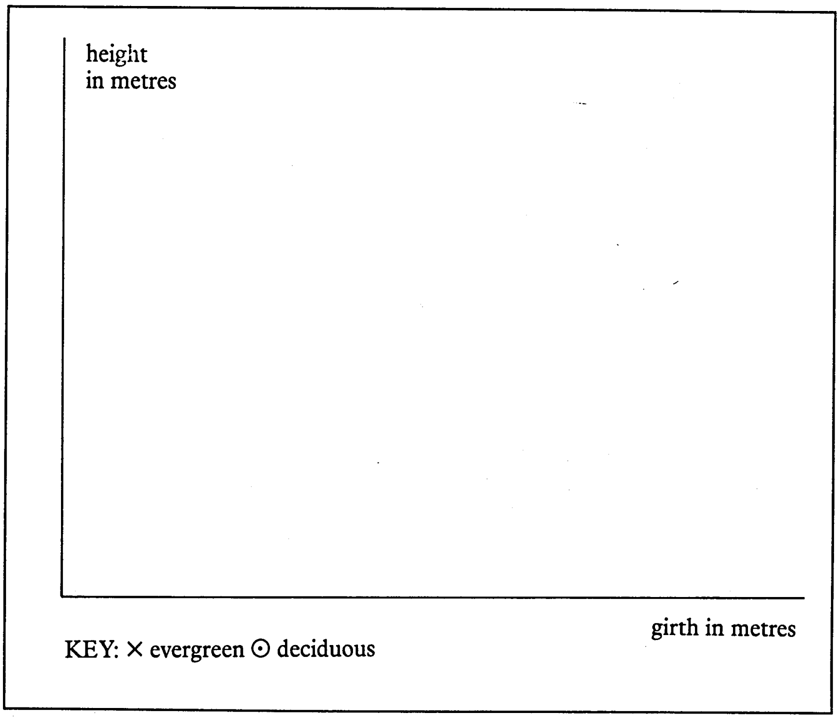


Figure 5

The tallest trees in the world are evergreens. The giant sequoias in California have reached a height of 110 metres. The oldest have been growing for 4000 years.

Deciduous trees are not so big. The tallest deciduous trees reach a maximum height of 60 metres.

Trees still dominate the landscape in many parts of the world. They provide us with a versatile building material as well as a renewable source of fuel. Many of Britain's native forests were felled for firewood, for building homes and ships, and to make charcoal for industry. This process continues in some parts of the world.

Now answer questions 6 to 8.

Questions

6 *(a) Plot height (y axis) against girth (x axis) for each tree in Table 1. Use the axes shown in Figure 5. Use crosses (×) to plot the values for evergreen trees and dots (⊙) for deciduous ones.*
(b) Can you see any patterns when you look at the points you have plotted? Can you suggest reasons for any patterns you may have noticed?

7 *How many trees can you see if you look out of the windows of the room you are in? How many different types of tree can you see?*

8 *How much do you depend on the wood from trees? Do you use wood as a fuel? Do you use things made from wood? How much wood is there in your home and what is it used for?*

Part 2 Investigating the design of trees

You can study some of the factors affecting the design of trees with these investigations.

The structure of a tree must support its own weight. It must also resist the turning force of the wind. Increasing height increases the wind's turning moment. So higher trees tend to bend more.

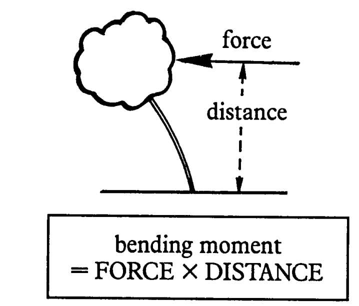


Figure 6

Investigation A How does the height of a tree affect how much the wind bends it?

Assume that the wind produces a force acting near the top of the tree. With ordinary apparatus, it is easier to experiment with the 'tree' on its side and hang weights on it to simulate the force of the wind.

You can use a length of wooden dowelling as your 'tree trunk'. Vary the height of the 'tree' by clamping the dowelling in different places.

Method

Start by using an arrangement similar to that in Figure 7. You can make your own improvements later.

Make a small notch in a wooden rod about 4 cm from one end. This will stop the mass sliding off the end.

Clamp the dowel horizontally at a point 10 cm from the notch.

Try hanging a 1kg mass from the notch. Remember that the pull of the Earth on 1 kilogram is 10 newtons (N). This will only bend the rod slightly. Decide how you can measure the deflection of the rod as accurately as possible. Change your apparatus if you find it necessary to get better results.

Obtain a set of values for the deflection of the rod for lengths between 10 cm and 40 cm.

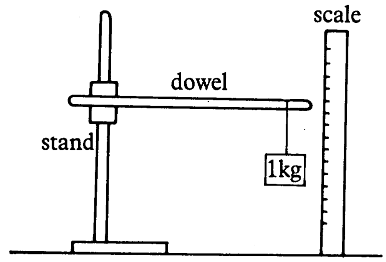


Figure 7

Question

9 (a) Plot a graph of the deflection (y axis) against the length of rod (x axis).
(b) The results should show that there is a pattern but it is not a simple one. What does the graph tell you?

Investigation B How does the girth of a tree affect how much the wind bends it?

Use pieces of dowelling of different diameters, a set of slotted masses (10 × 100g) and any other laboratory apparatus you need.

Method

Use a similar method to that used in investigation A. Beware! Thin dowelling will break if you hang too large a mass on it.

Question

10 What patterns can you find in your results?

Contents: Opinion survey concerning the feasibility and desirability of a number of suggested scientific and technological developments.

Time: 1 period (more if follow-up work is undertaken).

Intended use: Could be used in conjunction with a range of scientific and general courses. May be particularly appropriate for use at the end of a course of study which has included a number of SATIS units.

Aims:

- To help students assess their own awareness and knowledge of developments in science and technology
- To increase awareness of the power and limitations of science and technology for solving problems
- To develop awareness that scientific and technological innovations can have both beneficial and detrimental results for society
- To encourage students to express their opinions, and listen to the opinions of others.

Requirements Students' worksheets No.1010

Author: Jim Teasdale

Suggested use

There are several ways to use the unit. One possibility might be:

1 Introduce the unit and explain the activity
2 Give each student the list of suggestions and an answer grid
3 Get them to complete the answer grid, working individually
4 After completion, ask them to compare their answers with other students, working in small groups and discussing any differences.
5 Finally, have a plenary discussion involving the whole class and focusing on any especially controversial points.

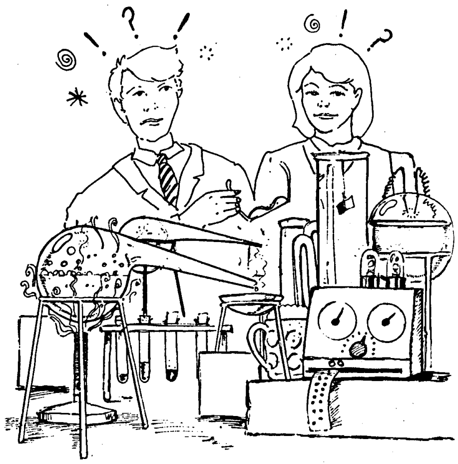
Students need not work through **all** the suggestions. The teacher could choose a selection for them to do. It may help to take the suggestions in batches, working on a small number at a time.

Further activities

1 The list of suggestions can be extended (or completely replaced) by the teacher's own suggestions, or those of students.

2 The responses could be analysed by groups, to examine whether they vary significantly, for example:
(a) betweeen boys and girls
(b) between age groups
(c) between teachers and students
(d) according to subject options (for example, whether students have opted to study science subjects)

CAN IT BE DONE? SHOULD IT BE DONE?



Science and technology can solve many of our problems, but not all of them. Sometimes we make a scientific or technological discovery, then decide we would have been better off without it.

In this unit you will look at a number of suggested scientific or technological developments. For each one, give your opinion on each of the following:

A Is it possible?

Is the suggestion:
1 possible in everyday life
2 possible in the laboratory
3 possible in theory
4 impossible

B How sure are you of your answer to A?

Are you:
1 certain
2 fairly sure
3 unsure
4 blind guess

C Is it desirable?

Do you believe:
1 this suggestion should be put into practice
2 it depends on the balance of advantages and disadvantages
3 this suggestion should not be put into practice

(If you have decided the suggestion is impossible, leave **C** unanswered.)

Put your responses to the suggestions on the answer grid provided.

When you have finished, compare your responses with those of other students. Discuss any differences.

Here is the list of suggestions. Can these things be done? Should they be done?

1 Making food from waste plastic
2 Making electricity directly from sunlight
3 Using non-pedigree cows to produce pedigree calves
4 Powering a car by sunlight
5 Producing a chemical which allows you to drink as much as you like without getting a hangover

6 Producing a chemical which stops the police detecting alcohol on your breath
7 Using radiation to sterilize food to stop it going off
8 Freezing a person's body so they can be kept alive in cold storage
9 Making an artifical heart
10 Making a medicine that will cure all forms of cancer

11 Making a car engine that will use water as a fuel
12 Heating homes using waste heat from power stations
13 Replacing all Britain's nuclear power stations by tidal power stations
14 Putting a chemical into the drinking water that will stop people wanting to smoke cigarettes
15 Recycling 80 per cent of all glass containers

16 Recycling 90 per cent of all the aluminium we use
17 Producing a completely safe insecticide
18 Making a synthetic fibre that has exactly the same properties as wool
19 Making artificial eyes for blind people
20 Building a bridge between Britain and America

21 Building a car in which you could survive a head-on collision at 100 mph
22 Replacing doctors with computers
23 Extracting minerals without causing damage to the environment
24 Producing a chemical which could be added to sweets so they do not cause tooth decay
25 Building a defensive system which would destroy all incoming nuclear weapons before they could hit Britain

26 Running a car factory with no humans at all, just robots
27 Feeding the world's population on plant products alone, using no food produced by animals
28 Making a refrigerator that will work where there is no electricity
29 Using bacteria to get metals from ores
30 Growing bananas on a large scale in Britain

31 Making a medicine that stops people feeling depressed, without any side-effects
32 Predicting when a volcano will erupt
33 Cutting down people's average dose of low-level radiation by half
34 Providing mains household electricity without any danger of electrocution
35 Finding a cure for AIDS

36 Preventing acid rain
37 Disposing of nuclear waste in space
38 Choosing the sex of a baby
39 Performing a brain transplant operation
40 Treating the waste from chemical factories to remove all poisonous chemicals
41 Making computers which are more intelligent than humans
42 Using nuclear fusion to produce practically unlimited energy supplies

Can it be done? Should it be done?

Put a tick in the appropriate column

Suggestion	A Is it possible?				B How sure are you of A?				C Is it desirable?		
	1	2	3	4	1	2	3	4	Yes	Depends	No
1											
2											
3											
4											
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Index

This index includes, in a single list, references to science syllabus topics (eg acceleration, acids), to social and technological topics (eg advertising, agriculture) and to types of activity (eg data analysis, discussion).

Entries give unit and page numbers (eg 801/1). A list of unit titles can be found at the front of this book.

Where the reference is to the whole unit, the number is given in italics (eg *901*).

References to the Teachers' Notes are in small roman numerals as in the units (eg 809/ii). In a few units the Teachers' Notes only cover one unnumbered page. These pages are indexed as 't' (eg 1010/t).

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SATIS 10 and Index

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