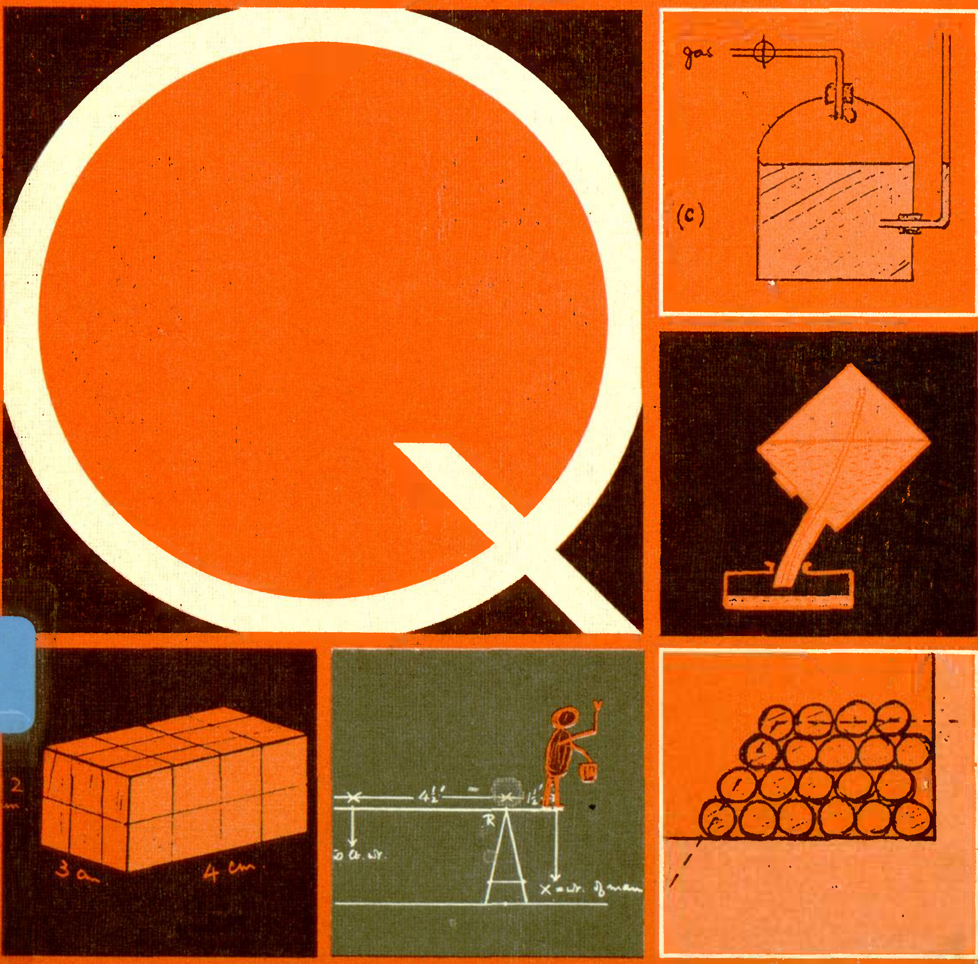
PHYSICS

Questions book I



Nuffield Physics
Questions Book I

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Nuffield Physics Questions
Book I

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FOREWORD

This volume is one of the first to be produced by the Nuffield Science Teaching Project, whose work began early in 1962. At that time many individual schoolteachers and a number of organizations in Britain (among whom the Scottish Education Department and the Association for Science Education, as it now is, were conspicuous) had drawn attention to the need for a renewal of the science curriculum and for a wider study of imaginative ways of teaching scientific subjects. The Trustees of the Nuffield Foundation considered that there were great opportunities here. They therefore set up a science teaching project and allocated large resources to its work.

The first problems to be tackled were concerned with the teaching of O-Level physics, chemistry, and biology in secondary schools. The programme has since been extended to the teaching of science in sixth forms, in primary schools, and in secondary school classes which are not studying for O-Level examinations. In all these programmes the principal aim is to develop materials that will help teachers to present science in a lively, exciting, and intelligible way. Since the work has been done by teachers, this volume and its companions belong to the teaching profession as a whole.

The production of the materials would not have been possible without the wholehearted and unstinting collaboration of the team members (mostly teachers on secondment from schools); the consultative committees who helped to give the work direction and purpose; the teachers in the 170 schools who participated in the trials of these and other materials; the headmasters, local authorities, and boards of governors who agreed that their schools should accept extra burdens in order to further the work of the project; and the many other people and organizations that have contributed good advice, practical assistance, or generous gifts of material and money.

To the extent that this initiative in curriculum development is already the common property of the science teaching profession, it is important that the current volumes should be thought of as contributions to a continuing process. The revision and renewal that will be necessary in the future, will be greatly helped by the interest and the comments of those who use the full Nuffield programme and of those who follow only some of its suggestions. By their interest in the project, the trustees of the Nuffield Foundation have sought to demonstrate that the continuing renewal of the curriculum—in all subjects—should be a major educational objective.

Brian Young
Director of the Nuffield Foundation

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To those on whom these problems are inflicted

First of all, don't worry.

You will probably be able to answer some of the problems. Others you will find too difficult. Some, you will find, have no simple answer: this is intentional, but see what you can do. And some problems are simply meant to start discussion – they ask 'What do you think?'

Some problems will involve things you have already covered in your physics. Others will bring in new topics. And some problems will be concerned with things which are unfamiliar but which are linked with what you have already heard about. Some questions are just problems to test your ingenuity. A good scientist tests what he can, and what he has time for, but he cannot test everything, he cannot find all the answers. All the same, he enjoys speculating about – wondering about – a lot of other things.

Altogether there are far too many problems for you to be able to tackle all of them. You will have to pick and choose. Some problems will be more interesting, or provoking, than others. Do them. With luck, you will enjoy them.

Above all, don't worry.

1 Discovering the variety of things

1 *Experiment.* Put on a tray about ten different solid substances; e.g. a stone, a cork, a piece of iron, a piece of aluminium, an india-rubber, a piece of sponge rubber, a ball-bearing, a piece of plasticine, some sugar, salt, sand and a piece of chalk. Feel their shape, weight, texture, temperature, squeeze them between your fingers, smell them. Now shut your eyes while someone turns the tray and moves some of the things. Keep your eyes shut, and try to identify each by feel or smell. Open your eyes, make a list of all the objects and write against each one the property or properties by which you identified it.

2 *a.* A small stoppered bottle is half-filled with water, a second bottle is half-filled with bicycle oil and a third with golden syrup (or treacle). What difference would you expect to notice when each bottle is slowly turned upside down?
b. What meaning can you give to the remark of the garage mechanic who says, 'Motor oil is thicker than bicycle oil'?

3 *a.* Is it correct to say that each of the bottles in question 2 is half-empty? If not, why not?
b. Each bottle is half-full of the same substance. What substance?

4 A can of lemonade has *two* places marked on the top where you should make holes to pour out the lemonade. Why two?

5 *a.* Here are four substances: glass, diamond, putty, one's finger-nails. Write them in a 'scratch order', that is, so that the first scratches the second but is not scratched by it, the second scratches the third but is not scratched by it and similarly for the third and fourth. Would the first scratch the third and fourth?
b. A steel pin scratches wood, but a sharpened wooden stick does not scratch steel. So we say 'steel is harder than wood'. Which is the hardest of the four substances mentioned in (*a*), and which is the softest?
c. Write out and complete the following sentence, which explains what is meant by 'harder'.

'A substance X is harder than a substance Y if X ...., but Y ....

6 You are given two tightly stoppered lemonade bottles. Both look

alike and both look empty. One is labelled 'air' and the other is labelled 'vacuum'.

a. When you weigh them you find that the bottle marked vacuum weighs $\frac{1}{2}$ gram *more* than the other. How do you explain this? (You may take it that the labels are *correct.*)
b. How could you show to a younger brother or sister the difference between the contents of the two bottles? (You may now open them.)
c. How would you show that your explanation in (*a*) was correct?

7 You open a bottle which has nothing inside (a vacuum) and air comes in. Does this mean that there is less air somewhere else? Where has the air become less?

Compare this with what happens when a bottle with no water in it is opened underneath the surface of the sea.

8 Three blown-up balloons look alike, but one is known to be filled with air, one with carbon dioxide and one with hydrogen. The material of the balloons is very light, and they do not carry strings. They are released and pushed over the edge of the bench at the same time. Two fall slowly to the floor, one reaching the floor before the other. The third goes upward and has to be pulled down from the ceiling. Which is which? And how do you know?

9 Scouts sometimes, when they are being funny, talk about 'sky-hooks'. Nowadays we have useful 'sky-hooks', that is helicopters.

What other sort of sky-hook can you suggest? And what would be its disadvantages compared with a helicopter?

10 *a.* You are given two dice that look exactly the same, but one is loaded with a lead plug under the face marked 6. When placed in water, both sink. You gently drop each die into a glass of water several times. Do you think you could tell by watching them carefully which was the loaded one? How would you tell?
b. Suppose one die is 'loaded' just under the face marked 6 and the other has an equal lead plug at the centre. How could you tell which is which, using a glass of water?
c. How could you tell which is which of the dice in (*b*) without water or any other liquid?

11 It rained heavily last night – one-tenth of an inch. How many raindrops must have fallen on each square inch if each raindrop had a volume of $\frac{1}{2000}$ cubic inch? How many fell on each square foot?

2 Forces felt with fingers

Do *not* write answers to all these questions. Just think what the answers are; you can usually be fairly sure you are right. Jot down answers to any you are *not* sure about and, later on, see whether you are right.

The question is the same for every one of the diagrams, 12–24. The small circle represents a brass ring, small and light, but large enough for you to put one finger into it. The other slightly larger ring, shaded, which appears in *some* diagrams, means a pulley over which a strong thread passes. The pulley turns freely on its axle. Imagine you have a bandage over your eyes. Someone takes your hand and puts one finger into the ring; then you try the following small experiments:

A you hold your finger still,
B you move your finger *slowly* upwards,
C you move your finger *slowly* downwards.
What do you think you would feel for A? for B? for C?

Lastly, does it make much difference if:
D you move your finger *quickly* up, or *quickly* down? (though not so quickly as to hurt your finger or damage the apparatus).

Figure 12

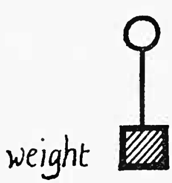


Figure 13

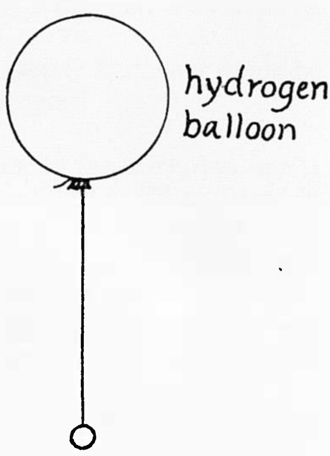


Figure 14

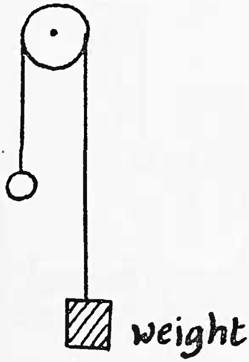
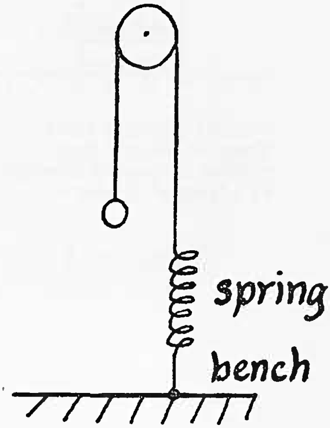


Figure 15



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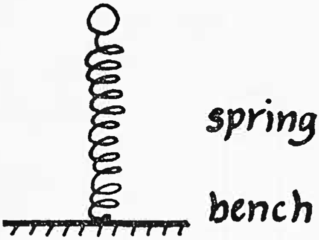
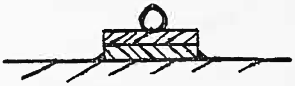


Figure 17



flat magnets placed to attract – lower magnets fixed to bench

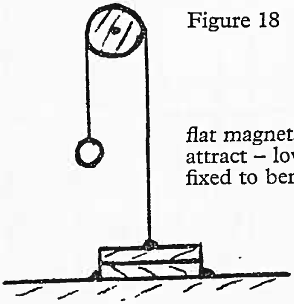
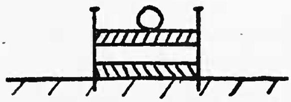


Figure 18

flat magnets placed to attract – lower magnets fixed to bench

Figure 19



magnets placed to repel.
They are stopped from
twisting or moving sideways
by a 'cradle' of pine –

Figure 20

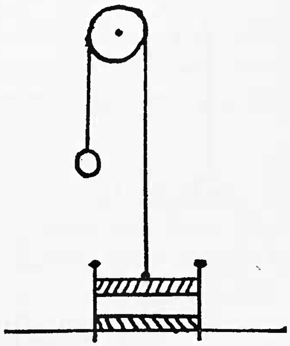


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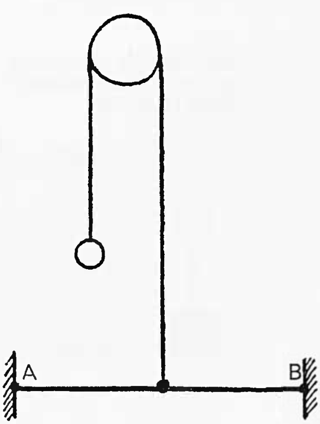
Figure 21



elastic held firmly at A and
B

Figure 22

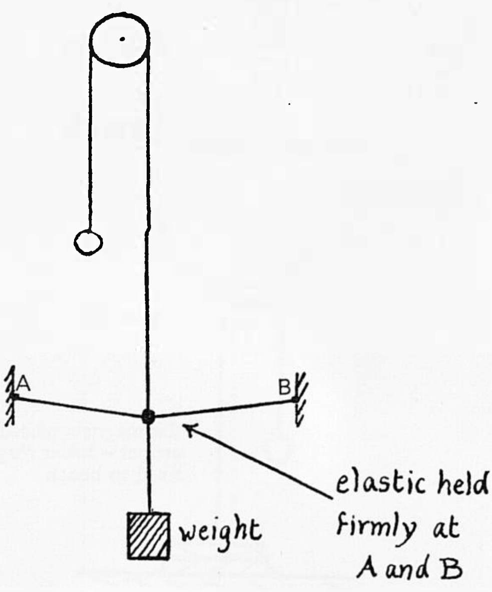


Figure 23

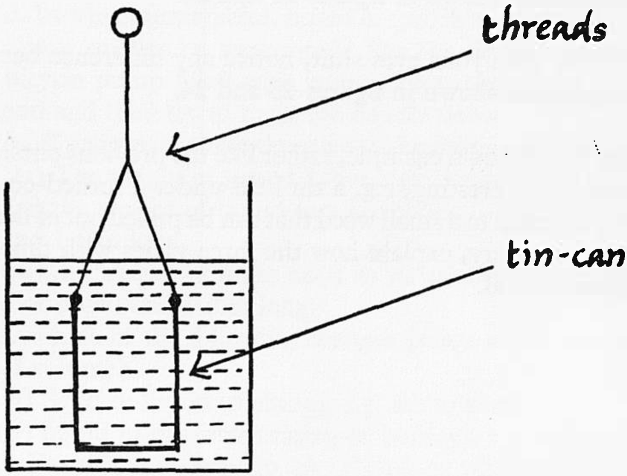
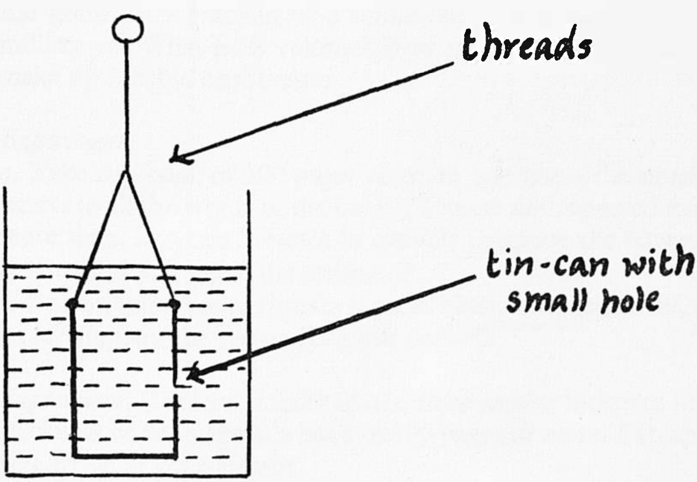


Figure 24



25 Will you, with your eyes shut, notice any difference between the arrangements shown in figures 21 and 22.

26 Will you, with your eyes shut, notice any difference between the arrangements shown in figures 23 and 24.

27 Make up your own example, rather like the previous ones. Let it be something interesting, e.g. a tin held under a turned-on tap, or a string attached to a small weed that can be pulled out of the ground. Where necessary, explain how the force varies with time, or with distance moved.

3 Thinking about things packed together

28 *a.* In which form (solid, liquid or gas) is matter easiest to compress (make smaller by squeezing)? For the liquid and gas, think of a bicycle pump filled with water or air; you put a finger over the end and then try to push the handle down.

b. Which two of these three would be more nearly the same weight?

(*i*) The weight of a solid 1 foot high, 1 foot broad and 1 foot long,

(*ii*) the weight of liquid in a container, 1 foot high, 1 foot broad and 1 foot long,

(*iii*) the weight of a gas such as air in a container 1 foot high, 1 foot broad and 1 foot long.

c. Which of the following changes brings about the larger change of volume?

(*i*) Solid to liquid (melting), e.g. ice to water,

(*ii*) liquid to gas (evaporating or boiling), e.g. water to steam.

d. From your answers to (*a*), (*b*) and (*c*), which two forms of matter would seem to be most like each other?

e. If matter is made up of tiny particles pressed together, how closely would you expect the particles to be packed in (*i*) a solid, (*ii*) a liquid, (*iii*) a gas? (Write either 'tightly' or 'loosely' for each answer.)

29 *Experiment.* Drop a few grains of household salt on a clean flat surface and look at them carefully through a magnifying glass. What is their shape? Put a clean ruler, marked in millimetres, against a salt grain, and make a guess at the length of the side of the grain (as a fraction of a millimetre). Is it $\frac{1}{10}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, or 1 millimetre? What is its volume? How many of these grains would make up 1 cubic centimetre?

30 *Experiment.*

a. Take any book of 100 pages or more and guess the number of letters in all the words in the book. (You are not expected to spend more than, say, two minutes in actually counting the letters.)

b. How did you make the estimate?

c. Do you think your estimate is more likely to be too small, or too large? Explain the reason for your answer.

31 *Experiment.* Use a ruler marked in centimetres or inches to find the thickness of one page of a book of 100 pages or more. Explain how you arrive at your answer.

32 Two square-shaped glass jars A and B are exactly alike. A is filled with very small marbles and B with larger marbles, though still quite small. Draw diagrams, viewed from the side, of A and B filled with marbles. Answer the following:

a. which jar has the greater number of marbles?
b. which jar has the greater number of spaces between the marbles?
c. which jar has the larger spaces between the marbles?
d. when water is poured into each jar (still filled to the top with marbles) about the same volume of water goes into each. Is this what you would expect? Give a reason for your answer.

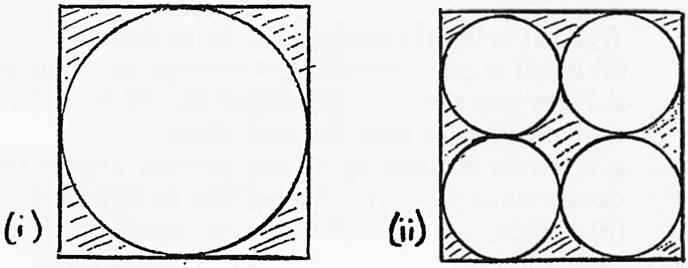


Figure 33

33 Figure (*i*) shows a glass marble, of radius 2 cm, inside a cubical box that just fits round it. Figure (*ii*) is an exactly similar cubical box filled with a number of smaller marbles inside, each of radius 1 cm.

a. How many 1-cm marbles are there in the box? (The answer is *not* four.)
The volume of a completely round marble is,

$$\tfrac{4}{3} \times \tfrac{22}{7} \text{ (radius)} \times \text{(radius)} \times \text{(radius)}$$

The number $\frac{22}{7}$ is an approximate value of π, the ratio of the circumference of a circle to its radius. In the questions below you need not actually do the multiplication by $\frac{22}{7}$; in your answers to (*b*) and (*c*) just leave it as $\frac{22}{7}$.
b. Find the volume of the marble in figure (*i*).
c. Find the volume of all the marbles together in figure (*ii*).
d. What can you say now about the answers to (*b*) and (*c*)?
e. What can you say about the amount of water you could pour into the box in figure (*i*) and the box in figure (*ii*)?

f. What connection has this with the answer to part (*d*) of the previous question?

34 *Experiment*. This is something you can try at home.

a. Fill a large cup or can exactly to the brim with clean, perfectly dry, sand. Tip the sand into a basin, add about $\frac{1}{10}$ cup of water, and stir it up so that all the sand is evenly damp. Return the sand to the original cup. Can you get it all in? Examine the sand with a magnifying glass. Can you suggest anything which might explain your discovery?
b. Try making the sand *very* wet by adding a lot more water. Will it go into the cup now? What has happened this time?
c. What is sand used for in building houses? Might the results of this experiment be of importance to a builder?

35 A box is nearly, but not quite, cubical in shape. Its base measures 30 cm × 28 cm inside, and its height is 28 cm (instead of 28 × 28 × 28). You have a large number of spheres (balls) each 4 cm in diameter.

a. How many of these spheres can you fit along a 28-cm side? How many along a 30-cm side?
b. How many can you fit inside the bottom of the box, so as to form a layer one sphere thick?

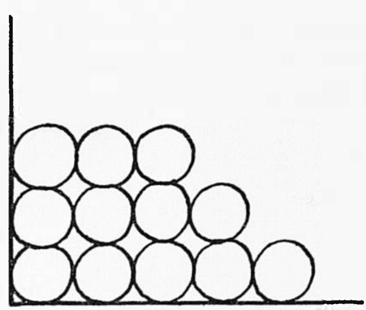


Figure 35

c. If layers are fitted on top of each other as in figure 35, how many layers fit in the box?
d. Packed like this, how many spheres go in the box?
e. Is any space wasted? If so, where?

36 The answer to question 35 (*d*) is *not* the *largest* number of spheres that can be fitted into the box. How would they be packed so as to get more in? Give a diagram. (You need not draw large numbers of spheres; a diagram like figure 35 but showing a different arrangement will do.)

37 Suppose you have a large number of small spheres, beads, for example, which you pour into a box or bag. Would they be more likely to settle down in an arrangement like figure 35, or would they settle so that they were more like your answer to question 36? Give a reason for your answer.

4 Things that show orderly arrangement

38 What happens when you cleave a calcite crystal 'in the right way'? Explain what you do, and draw a diagram showing what is meant by 'in the right way'. (It would be better to say 'with the right orientation'.)

39 (*Following question 38*). What happens if you have the 'wrong' orientation, though you are using the 'right' tool (razor-blade, knife, etc.)? What happens if you have the right orientation but the wrong tool, that is, something blunt? Draw a diagram illustrating one of the two answers above.

40 What do your answers to questions 38 and 39 suggest about the nature of crystals; that is, how do they differ from something else, such as glass, plastic, or stone?
Do you know any other kind of crystal besides calcite which can be easily cleaved? If so, name the crystal and say how you would cleave it.

41 One pupil following this course (we will call him Freddie Jones, though that is not his real name) tried cleaving cubes of sugar with a knife. The results were unsatisfactory; in whatever way he held the knife the sugar lump broke, sometimes into two pieces, sometimes into many pieces. So, he said, clearly sugar is not crystals. What do you say to this?

42 Freddie then found a small cube of wood. He tried two sides with a knife but only made a small cut or dent. Then he tried another side, and the wood split easily, 'therefore,' he said, 'wood consists of crystals'. What do you say?

43 Threads in linen;
seats in a cinema;
steps on stairs;
ripples on water;
fruit trees in an orchard;
a crystal.

What do all these have in common? What, in a crystal, corresponds to threads, seats, steps, ripples, trees? Suggest two more to add to this list.
Actually, there is one way in which the crystal differs from the

other five, though it resembles the arrangements of spheres in questions 35 and 36. In what way does the crystal 'differ from the other five'?

44 You have seen crystals (of hypo) form quickly in a tube.

a. What did you do to make this happen? (one sentence)
b. What did you *see* happening? Did you *feel* anything happening, and if so, what?
c. Draw two diagrams of the tube, 'before' and 'after'.

45 You have also grown crystals, allowing them to form slowly.

a. How did you do this? (about three sentences)
b. What happened? Draw a picture of the crystal you grew, or if you made several, draw a picture of the one you liked best.

46 *Difficult*. Give the best explanation you can of why the final result is so different when crystals grow quickly and when they grow slowly.

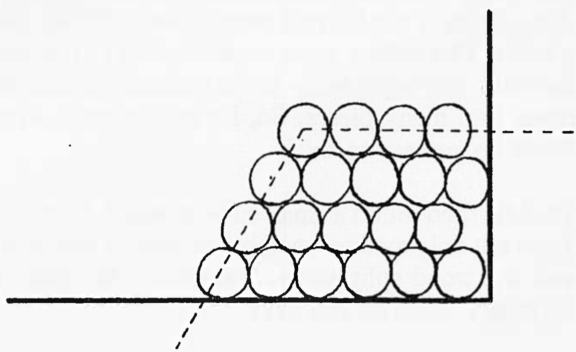


Figure 47

47 *a*. The diagram shows one corner of a square wooden tray like the one in which you put marbles. Twenty marbles are shown in this corner. Suppose you add nine or ten more, where are they likely to go? Answer this by copying figure 47 and adding nine or ten marbles.
b. In figure 47 two lines are drawn joining the centres of the outer rows of marbles. You do the same for *your* diagram, which has extra marbles added.

c. What can you say about *your* lines (with the extra marbles) and the original lines in figure 47.

48 This is an extension into three dimensions (length, breadth, height) of the two dimensions (length and breadth) of question 47. Therefore it is more like a crystal because, of course, a crystal exists in three dimensions.

a. You make a pyramid out of 14 balls in 3 layers. How many balls in each layer?
b. You then add more balls in order to make a 4-layer pyramid with a 4×4 base. How many balls does this need *altogether*?
c. Next you make the pyramid into one with a 5×5 base. How many balls altogether?

49 *a*. What can you say about the angles between the faces of the 3×3 base pyramid, the 4×4 base pyramid, and the 5×5 base pyramid in question 48?
b. What resemblance is there between a crystal and the pyramid you have built up with balls?

50 Building up a pyramid of balls is like growing a crystal in a saturated solution. Suppose you take balls away from the pyramid; what is this like doing to a crystal? Describe (two or three sentences) an experiment which shows this happening to a crystal.

51 What is the most interesting thing, *except crystals*, you have seen through a microscope? Draw a diagram of what you saw, and label it. (Do not spend too much time on this.)

52 You have seen, through a microscope, crystals growing on a microscope slide. Draw two sketches to show:

a. the appearance when about one-third of the liquid has crystallized,
b. the appearance of the same crystals and liquid a few instants later, when about one-half has crystallized.

Note: If you have seen both, answer this for *either* salt *or* salol, whichever you think is the more interesting.

53 *Difficult*. Crystals do not grow into balls or circles; they grow more in some places than in others. Suggest a reason for the way crystals grow.

Note: The next question is an 'Uncle George' question. Uncle George is intelligent and interested and has time to spare to try out new ideas, but he did not do any physics when he was at school, so you have to explain things to him.

54 You have told Uncle George a lot about your work on crystals and you showed him some cooking salt under a lens, and he agreed that the salt consisted of small cubical crystals. 'Sugar is the same', you say, 'look at some through the lens.' 'Right,' he says, and fetches *icing sugar* from the cupboard. Under the lens it still looks like a powder.

'All right,' you say, and next day you borrow a microscope so that he can look through that. The icing sugar still looks like nothing but powder. You cannot borrow a more powerful microscope.

Uncle George is willing to be convinced by any reasonable experiment and argument. How would you convince him that icing sugar consists of crystals? (In addition to icing sugar, the cupboard contains granulated sugar, castor sugar, and demerara.)

55 *Difficult.* You have seen many crystals through a microscope, but even with the most powerful magnification you had, you never saw any *atoms* of the crystals. Therefore atoms, if they exist, must be smaller than the smallest thing you can see, as a separate thing, in the microscope. Make the best estimate you can of the size, in a fraction of a centimetre, of the smallest thing you can see in your microscope. Explain how you arrived at this estimate of size. Atoms must be *smaller* than this.

5 Counting in powers of 10. Making rough guesses

56 *a.* How much is $10 \times 10 \times 10$? Write it in words.
b. Write $10 \times 10 \times 10$ in numbers, in two different ways that are each of them quicker to write than $10 \times 10 \times 10$.
c. Write $10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10$ in numbers in the quickest way you know.
d. Atoms are extremely small, so small that people can hardly picture how small they are. But we can do experiments to find out how small atoms are. Then, knowing their size, we can work out how many atoms there are in some object of ordinary size that we can see. For example, a small aluminium saucepan is made up of about 10,000,000,000,000,000,000,000,000 atoms of aluminium. Write that in numbers in the quickest way you can.
e. In the question about the aluminium saucepan just above, the number you were given was only a very rough estimate. (It was not a wild guess, but was worked out roughly from real experiments.)
Explain in your own words why you think it would be silly to give a value like 12,356,419,000,000,000,000,000,000, and claim that it was more 'accurate'.

57 Some astronomers who have collected a great deal of information about the stars think that they can estimate how many atoms there are in the whole universe – the stars and the planets all put together.
Of course, that is only a very rough guess. They do not count just atoms, but electrons and the other small pieces which we think are inside atoms.
They say that they guess the total for the whole universe of all those little 'particles' is about 10^{80}.
a. Time yourself while you write out 10^{80} fully in ordinary figures. How may seconds did it take you?
b. Time yourself when you write 10^{80} in this short form, 10^{80}. How many seconds does that take you?
c. Suppose your clock was only marked every five seconds, and did not show separate seconds or fractions of seconds. Describe a simple way in which you could find the time taken to write 10^{80} with a rough clock.
d. How many times quicker is the short way of writing this big number than the long way, in actual time of writing? (Remember that 'how many times' asks you to divide and not just to subtract and find how much quicker it is.)

58 The speed of light is 186,000 miles per second.

a. If the speed of light were only 100,000 miles per second, how could you write it quickly?
b. You can say $186{,}000 = 10{,}000 \times x$. What should you write instead of the x?
c. Making use of both your answers (a) and (b), what can you write instead of 186,000?
d. The Earth's radius is $6{\cdot}4 \times 10^6$ metres. Write this as a number in ordinary figures.

59 In scientific standard form we always write the number in the form of a power of 10 (like the 10^6 in the Earth's radius) multiplied by another number which has one figure, just one figure, in front of the decimal point. And then we carry on as many figures as we think our accuracy deserves after the decimal point. Try doing that yourself with the following examples. If you like, use your own measurements instead of those that are given you for the imaginary person called Freddie Jones.

a. He is 4 feet 7 inches tall. That is the same as 1397 millimetres. Write down his height in millimetres in standard form. (If you use your own height you will have to turn it into millimetres by multiplying your height in inches by 25·40, because that is the number of millimetres in one inch.)
b. Say, in standard form, how far you would advise him to carry his statement of his height. What figure should he stop at? Give a short, clear reason for your advice.
c. Suppose today is his birthday and his age is just 12 years. Write that in standard form in months. Suppose his school writes to him now and says, 'Let us know how old you will be *next term*, in months.' Write down the most sensible answer for him to give in standard form in months.
d. Now turn his age into days. (Reckon $365\frac{1}{4}$ days in a year.) Express his age in days in standard form. Suppose just after his birthday he writes to a friend in America and says, 'When you get this letter, I shall be just so many days old'. Put that number 'so many' in standard form and end it where you think is sensible. Give a short reason for your choice of how far to carry the numbers in this case.

60 Choose any *two* out of the following things, and in each case make the best quick rough guess you can – which is something

a good scientist often has to do. Put your guess in standard form and carry the figures of the standard form as far as you think wise.

(*i*) The number of eggs a good hen lays in one year.
(*ii*) The number of gallons of milk an average cow gives in one year.
(*iii*) The number of quart milk bottles a family of two parents and two children take in one year.
(*iv*) The number of letters one postman delivers in one year.
(*v*) The number of chemist's shops in the nearest big city: Birmingham, Bristol, or whatever is nearest to you.
(*vi*) The number of grains of sand in a handful.
(*vii*) The number of hairs on your head.
(*viii*) The number of sewing-needles sold in England in one year.
(*ix*) The number of stars that you can see on a clear night outside your home with your eyes alone.
(*x*) The distance in yards between your bedroom and your Physics classroom.
(*xi*) The amount of potatoes in pounds that your family eats in a year.
(*xii*) The amount of potatoes in pounds that you are likely to eat in the first twenty years of your life.
(*xiii*) The number of robins in England.
(*xiv*) The number of golden eagles in England.
(*xv*) Height in inches of the tallest tree or building within one mile of your school (say where it is, and what it is).
(*xvi*) The number of dogs in your county (not counting puppies).

6 Comparing the weights of things

61 The names of seven substances are written in the table on the right. Rewrite this table, putting the heaviest at the top, and arranging in order with the lightest at the bottom. What do we mean by 'heaviest' if we make a fair comparison, and what would be a better word to use?

aluminium
candle wax
iron
glass
polystyrene
marble
lead

Note: Three of these substances can be bracketed together in the table, which three?

62 'Lead is heavier than feathers'. Is this statement true? Which is the heavier, 1 ton of lead or 1 ton of feathers? If you were the manager of a storage firm which of the two would you rather store, and why?

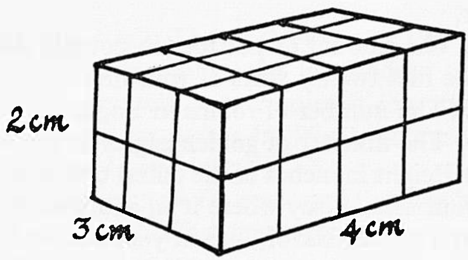


Figure 63

63 A small block of marble measures 2 cm × 3 cm × 4 cm and weighs 60 gm. (Figure 63.)

a. How many cubical blocks 1 cm × 1 cm × 1 cm can you count in this block?
b. What is the weight of one of these 1 cm × 1 cm × 1 cm blocks?

64 *Following from question 63:* (*i*) A sculptor who wants to cut a statue out of marble orders a marble block 40 cm long by 30 cm wide by 20 cm thick. How much will it weigh?
(*ii*) After the sculptor has chopped away a lot of marble he has an irregular shape that weighs 40 kilograms. How many cubic centimetres has he got left?

65 *The problem of the apples.* A farmer who grows apples in his orchard packs them and sends them to a big shop in London. To make quite sure the apples are not harmed by being packed and transported, he packs them in a big box with sheets of cardboard between each apple and the next so that each apple is inside a small box of cardboard. The little cardboard box that holds each apple is 2 inches wide, 2 inches deep and 2 inches high. (The cardboard used to keep the apples apart is too thin for its thickness to matter.)

a. Suppose instead of his big packing box the farmer had only a little box 4″ long × 2″ wide × 2″ high. How many apples would that hold?
b. Suppose he sent apples in a little box 6″ long × 2″ wide × 2″ high? Suppose he sent them in a box 6″ × 4″ × 2″? Or, in a box 6″ × 4″ × 10″? How many apples does each box hold?
c. Now suppose the farmer measures his big packing box and finds it is 40″ long inside, 20″ wide and 10″ high. How many apples?

66 Did you get the right answer to the last question? How did you get it? Suppose you were going to work for that farmer and had to find out how many apples could go into each packing box and you had many different sizes of packing box. Would you have to think out very carefully for each box how many apples fit into the length, how many apples fit into the width, how many apples fit into the height, and then would you have to think out very carefully how many rows and layers that would make? Or could you give yourself the simple rule that you could use for every box? There is such a rule. What is it?

67 *The problem of the atoms.* Scientists can measure the size of a single atom. An atom of iron is so small that if you put it into a small cubical box that would just hold it the box would be about $\frac{2}{100{,}000{,}000}$ cm wide, and the same thick and the same high. Think of the iron block that you handled, and which measures 5 cm × 4 cm × 3 cm. Suppose that the atoms are arranged very simply in it in a cubic crystal pattern. (See, for example, figure 35 of Section 3.)

a. How many atoms would there be in the length of your iron block and how many in the width and how many in the height?
b. How many atoms would there be in the whole block?
c. Suppose the weight of your block is 450 gm. How much would one single atom of iron weigh?

7 Weighing things

68 *a.* A glass block measures 10 cm × 6 cm × 2 cm. How many cubical blocks 1 cm × 1 cm × 1 cm are there in this block?
b. What name is given to the volume of a 1 cm × 1 cm × 1 cm block? What is the volume of the 10 × 6 × 2 centimetre block?
c. A block of glass 1 cm × 1 cm × 1 cm weighs $2\frac{1}{2}$ gm. What is the weight of the 10 × 6 × 2 centimetre block?

69 *a.* A block of ice measures 5 cm × 4 cm × 2 cm. What is its volume?
b. If it weighs 36 gm, what is the weight of 1 cubic centimetre of ice?
c. What is the area of the smallest face of the 5 × 4 × 2 centimetre block? ...... of the middle-sized face? ...... of the largest face?

(If this puzzles you, draw a sketch of the block.)

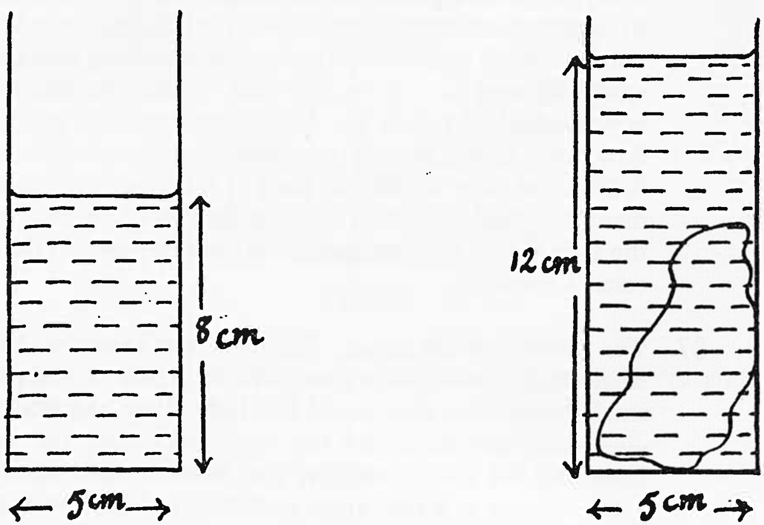


Figure 70
the base of the tray is 5 cm × 5 cm

70 A piece of marble which weighs 270 gm is gently lowered into a plastic box 5 cm square which contained 8 cm height of water. When the marble is completely covered the water rises to a height of 12 cm (figure 70).

a. What is the volume of the piece of marble?
b. What is the weight of a volume of water equal to the volume of the piece of marble? (1 cubic centimetre of water weighs 1 gm.)
c. If you compare equal volumes, how many times heavier than water is marble?

71 You are given 50 steel balls, all alike and all very small. The only balance available is not sufficiently sensitive to weigh a single ball accurately.

a. How would you find the weight of one ball?
b. You are now given an egg-cup full of the same size of balls. How would you find the number of balls in the egg-cup without counting them?

72 Suggest a way of finding the volume of one of the 50 balls mentioned in question 71. A single ball is too small to be measured with a ruler.

73 How would you find the volume and weight of an egg if the only measuring apparatus you have is a balance and a measuring cylinder which is too small for the egg to go into? (You may use the things you would find in a kitchen or in a laboratory, but no other *measuring* apparatus is to be used.)

The egg becomes hard inside if you leave it in boiling water for ten minutes. Does this mean that its weight has increased? Give the reason for your answer.

74 *a.* Suggest some possible way by which you might find your own volume. You may assume that you can be provided with a special kind of bath made for the purpose according to your instructions.
b. Suppose you breathe in, and out again, every 4 seconds. What effect on your volume does this have?
c. It is popularly supposed that a drowning man comes up three times, shouts for help three times, and sinks. This might well happen – why?

75 *a.* What is your weight in pounds (1 stone = 14 lb)? How many kilograms weight is that (1 kilogram = 2·2 lb)?
b. Suppose you can just lift another boy or girl whose weight is the same as yours. Would you be able to lift a cube of cork if the length of one side of the cube is 0·6 metre? (1 cubic metre of cork weighs 250 kilograms. 0·6 metre is $\frac{6}{10}$ metre or 60 centimetres.)

76 *a.* 1 cubic centimetre of glass weighs 2·5 gm. How much does a glass slab 10 cm × 20 cm × 4 cm weigh?
b. A box of the same dimensions, 10 cm × 20 cm × 4 cm is filled with small round glass beads. We know from geometry that the volume of the spaces between the beads equals the volume of the beads themselves. What is the weight of all the beads in the box?
c. Water in then poured into the box until it is completely filled with beads and water. 1 cubic centimetre of water weighs 1 gm. What weight of water is there in the box?

77 *This question is for those who know fully about 'density'.*

The density of water is 1 gm per cubic centimetre.

a. The box in question 76 is emptied of glass beads and completely filled with water. What weight of water does it now hold?
b. If we suppose water to consist of very small round particles which touch each other, what could we say about the particles and the spaces between the particles?
c. What would the density of the particles be (as distinct from the density of the water as a whole)?
d. Suppose instead that there are just as many water particles as in (*b*), but they are much smaller still and are kept apart from each other in some way, what can we say about the 'density' of the actual particles, as compared with our answer to (*b*)?

78 *a.* Given a hollow rectangular plastic box and a ruler, how would you check the accuracy of a measuring cylinder marked in cubic centimetres?
b. Which is likely to be more accurate, your measurements of volume with the box or your readings of the height of the water in the cylinder and the manufacturer's markings of the measuring cylinder?
c. Suppose you had a balance and could weigh the box. How could you find the volume of the box very accurately?
d. Suppose you need to know the volume of a box that has an uneven shape – a teapot, for example. Suggest two quite different, easy, ways of measuring the volume it holds.

79 100 cubic centimetres of water, weighing 100 gm, is thoroughly mixed with 100 cubic centimetres of alcohol, which weighs 82 gm.

a. What is the total weight of the mixture?

b. If there is *no* change of volume on mixing the liquids, so that the total volume is 200 cubic centimetres, what would be the weight of 100 cubic centimetres of the mixture?
c. In fact, experiment shows that the volume of the mixture is rather less than 200 cubic centimetres. What does this fact suggest about the particles of water and of alcohol when they are put together?

80 *a.* Complete the following table:

Object	Volume	Mass (weight)	Density
A.	100 c.c.	800 gm	
B.	3·0 c.c.	2·4 gm	
C.		400 gm	0·25 gm per c.c.
D.	60 c.c.		8·0 gm per c.c.

b. Answer the following:
(*i*) Which *two*, out of A, B, C and D, could be the same material?
(*ii*) Which *one* takes up the most space?
(*iii*) Which *one* would be the heaviest to lift?
(*iv*) Which *two* would float when placed in water?

8 Air and how to weigh it

81 If we open a box and see nothing inside it we immediately say that the box is empty, but, of course, it is not empty; it is full of air.

Write three sentences giving three reasons for supposing air exists (that is, that air is really there).

82 *a.* What volume of air do you think comes into and out of your lungs each time you breathe, when you are breathing normally? Is it near to 10 c.c.? 100 c.c.? 1 litre (1000 c.c.)? 10 litres?
b. What would the volume be for a 'forced' respiration, that is, when you breathe in and out as deeply as you can? (Guess.)

83 *Experiment,* which might be done at home. You can measure how much your lungs can take (which is what you have been guessing) by the following method. *Apparatus needed:* large bottle (e.g. 'Winchester quart'), sink or bowl, water, measuring cylinder or plastic box, piece of plastic or rubber tubing.

Fill the bottle with water and have the sink or bowl half-full too. With your hand over the opening, up-end the bottle so that at least the neck is immersed; the bottle stays full of water. Drop the tubing into the bowl and let it also get full of water. Put one end of the tubing into the bottle through the neck. Blow into the tube with, as nearly as you can, one normal breath. Remove the tube, put your hand over the neck and turn the bottle the right way up. Now use the measuring cylinder or plastic box to find the volume of water needed to fill the bottle again; this is one normal breath. Do it again to find the volume of a forced breath, that is, the volume which is, more or less, your total lung capacity. (This could be done at home if you can find a large enough bottle and piece of tubing, and the kitchen measure your mother uses for liquids. A gallon oil can or a 14-lb syrup tin, might be used. The tubing could then be a short piece of garden hose. Or you can use several milk bottles. You know their volume in pints: 1000 c.c. = about $1\frac{3}{4}$ pints.)

84 Describe how you would do the experiment in 83 in reverse, that is, to find how much you breathe in, instead of exhale, at every breath. Try it. *Note:* Blow the water out of the tubing before you start, or else you will have a surprise!

Figure 85
milk bottle full of water at the bottom of the sea. Problem: get the water out

85 *Easily answered puzzle.* Imagine you are standing in shallow water on a gently sloping beach. The water is, let us say, 3 feet deep. On the sand at the bottom is a milk bottle full of water. It has a cork and a tube, also a second hole in the cork (Figure 85). You are *not* allowed to bring the bottle anywhere near the surface of the water. You have no other apparatus.

a. How could you get some of the water out of the bottle?
b. Why have *two* holes in the cork, when only *one* hole is needed for the tube?

86 *Following from question 85.* Suppose that, instead of a pint milk bottle you have, under the water (still 3 feet deep), a 2-gallon 'petrol' can which is full of water. It has no cork. You have a piece of rubber tubing but nothing else. How would you get all the water out of the can without bringing it near the surface?

87 *Difficult puzzle.* You cannot answer this question, but you can think about it. Suppose that, instead of being a girl or boy, you are a mermaid or merman, and you don't breathe air. You are deep down beneath the sea, and you have a bottle full of water. How would you get the water out, leaving *nothing* inside the bottle? Think about it; do not write anything.

But you are not a mermaid or a merman.

Yet you *do* live at the bottom of an ocean, 'an ocean of air.' You have a bottle full of air. Your laboratory has a piece of apparatus for getting the air out, leaving nothing inside.

a. What do you call this piece of apparatus?
b. What do you call the 'nothing' which the apparatus leaves inside?

Note: It is still nothing, even if you do give it a special name!

c. How do you think this apparatus works?

88 *a.* A polythene 'squeeze' bottle is joined to a vacuum pump and the pump is set working. What happens to the bottle?

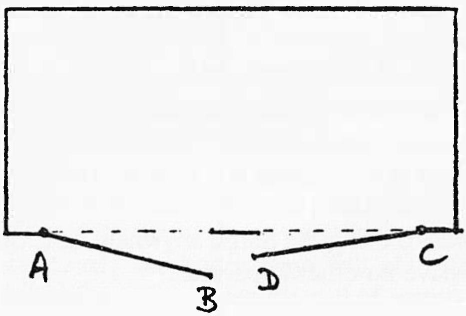


Figure 88

b. Figure 88 is a top view (or 'plan') of a cupboard with two doors, AB hinged at A, and CD hinged at C. This cupboard is a bit of a nuisance.

(*i*) When AB is pushed shut, CD opens. Why?
(*ii*) When AB is pulled open, CD shuts with a bang. Why?

89 Did you succeed in showing that air has weight? How did you do it? Give a diagram and write a brief account, explaining to Uncle George how it was done.

90 How would you measure the 'ordinary' volume of the extra air you weighed (question 89)? How would you calculate the weight of 1 cubic metre of air?

91 One cubic centimetre of water weighs 1 gm and 1 cubic centimetre of air weighs $\frac{12}{10000}$ gm. What weight of *a.* water, *b.* air, is enclosed in a box 10 cm × 20 cm × 5 cm?

92 *a.* If air and water consist of particles of about the same size and weight, what can you say about the distance apart of the particles in air and water?
b. What other knowledge about air and water (apart from their weights) supports what you have said in answer to (*a*)?

93 The box (question 91) measuring 10 cm × 20 cm × 5 cm has a strongly fastened lid fitted to it. Air is then pumped in until the weight of air inside is three times what it was before. If the air is now released under water and is then measured at the same pressure as the air in the room, how many cubic centimetres will be found,

a. if *all* the air in the box is measured,
b. if only the *extra* air is measured, that is the air which entered the box as the result of pumping?

94 One cubic metre of water weighs 1000 kilograms, and 1 cubic metre of air weighs only $\frac{12}{10000}$ times as much.

a. What is the weight in kilograms of 1 cubic metre of air?
b. What weight of air is there in a room 6 metres long, 5 metres wide and 3 metres high?
c. If, on a particular day, 1% of this air is in fact water vapour, what weight of water is there in the air of the room? (1% = one-hundredth part.)

95 *Difficult.* As we go higher up in the Earth's atmosphere, so the density of the air gets less. However, if this did not happen, and instead the density remained at all heights the same as it is at sea-level, then the atmosphere would be 8 kilometres high. Also, for the same volume, air weighs $\frac{12}{10000}$ times as much as water.

a. How many metres of water is equivalent to 8 kilometres of air (about 27,000 feet)? (This is the height of water which produces the same pressure as the air does. We call this pressure '1 atmosphere'.)
b. How far down in a lake would we have to go to find a pressure of (*i*) 2 atmospheres? (*ii*) 3 atmospheres?

9 Weighing with a micro-balance

96 Twenty sheets of thick foolscap paper, each 30 cm × 20 cm together weigh 240 grams.

a. How much does 1 square centimetre of foolscap paper weigh?
b. If you cut a strip of this paper 0·5 cm wide, how long must it be to weigh 10 milligrams?
c. If the deflection of your straw balance is 5 divisions (5 spaces on your scale) when 10 milligrams is added, how many milligrams does each division correspond to?
d. Balance makers tell their customers how delicate a balance is by stating its 'sensitivity'. This is a number that tells the customer how many spaces on the scale the pointer moves when an extra milligram weight is put on one pan. Each space on the scale is called one 'division'. What is the sensitivity of the balance in (*c*) in divisions per milligram?

97 What would be the effect on the sensitivity of your balance of:

a. Using a shorter straw?
b. Using a wooden skewer instead of a straw (with a larger counterweight if one is used)?

How could you be sure that your answers to (*a*) and (*b*) were right? Did you try some experiments that helped you to give those answers, or were you just guessing? (A scientist often makes sensible guesses, but he always says very clearly that he is guessing.)

98 Suppose you wished to use your straw balance outside, in the open air; what difficulty would you expect? How would you overcome the trouble?

99 Suppose you had a piece of paper of a suitable known weight.

a. How would you use your straw balance to find how much a centimetre length of hair from your head weighs? (Be as clever as you can in thinking of any things that you can do to make this experiment as easy and reliable as possible.)
b. Have a look at your own head in a mirror and make a sensible guess as to the number of hairs on it. Say very roughly how much you think all the hair on your head would weigh.

c. From (*b*), make a very rough guess at the weight of hair a barber has to get rid of every week.

100 If you wanted to weigh an 8-cm length of hair on the straw balance you might do this in several ways.

(*i*) Slip the hair down the straw until the end of the hair was level with the end of the straw.
(*ii*) Cut the hair into 8 lengths of 1 cm each and place all of these on the end of the straw.
(*iii*) Slip the hair into the straw so that 4 cm is inside the straw and 4 cm overhangs beyond the end of the straw.

a. Do you think all three ways would give the same deflection? If not, would any two of them give the same deflection? Which two? Or would all three give different deflections?
b. Can you say which one way gives the 'right' deflection?
c. Experiment. Try this out for yourselves and see how much difference (if any) there is.
d. Can you think of another way of placing the 8-cm hair that will give the 'right' deflection?

101 *a. Experiment.* You can find out something about the heavy gas carbon dioxide (CO_2) with your micro-balance. Make a tiny cup or box of paper that will hold, say, 10 cubic centimetres. Hang it on your micro-balance and add something to counterpoise it. Then pour carbon dioxide gas into the cup.
b. Puzzle. The weighing does *not* tell you the full weight of carbon dioxide you poured in, why? (Hint, was there anything in the box which came out when you poured in the carbon dioxide?)

10 Measuring things in metres

102 *a.* How many centimetres are there in 1 metre?
b. How many metres are there in 1 cm?
c. Is 1 cm longer or shorter than 1 inch? How many inches (roughly) in 1 cm?
d. What is 1 kilometre (1 km)? How many cm in 1 km?
e. What is a millimetre (1 mm)? How many millimetres in a kilometre?
f. Name some common thing which has (roughly) each of the following sizes (the first is answered as an example).
1 cm .... finger breadth
1 mm ....
1 metre ....
g. How many miles in 1 km? (8 km = 5 miles).

103 About 1 inch from the left-hand side of a sheet of paper draw a long thin, vertical 'ladder' with 22 rungs.

Count up to the sixth rung from the bottom, and label it '1 metre'.

Label the rungs above '1 metre', going upwards, 10^1 metres (meaning 10 metres), 10^2 (meaning 100), 10^3, . . . up to 10^{16} metres. Label the rungs below '1 metre', going downwards, 10^{-1} metre (meaning 0·1 metre), 10^{-2} (meaning 0·01), 10^{-3}, . . . down to 10^{-5} metre.

Each rung of this ladder represents a length 10 times the rung below and one-tenth of the rung above. Now write in the following names by the side of the ladder, marking with arrows the correct places where they should come on the ladder:

Nearest star	10^{13} km	$= 10^{16}$ metres
Sun to planet Pluto	6×10^9 km	$= 6 \times 10^{12}$ metres
Sun to Earth	$1{\cdot}5 \times 10^8$ km	=
Earth to Moon	400,000 km	=
Earth's diameter	13,000 km	=
London to Edinburgh	640 km	=
1 kilometre	1 km	=
Height of Salisbury Cathedral	120 metres	=
Tall man	? (Guess)	=
Baby	50 cm	$= 5 \times 10^{-1}$ metres

Length of your little finger	? (Measure it)	=
Diameter of a pencil	? (Measure it)	=
Thickness of paper	10^{-2} cm	= 10^{-5} metres

104

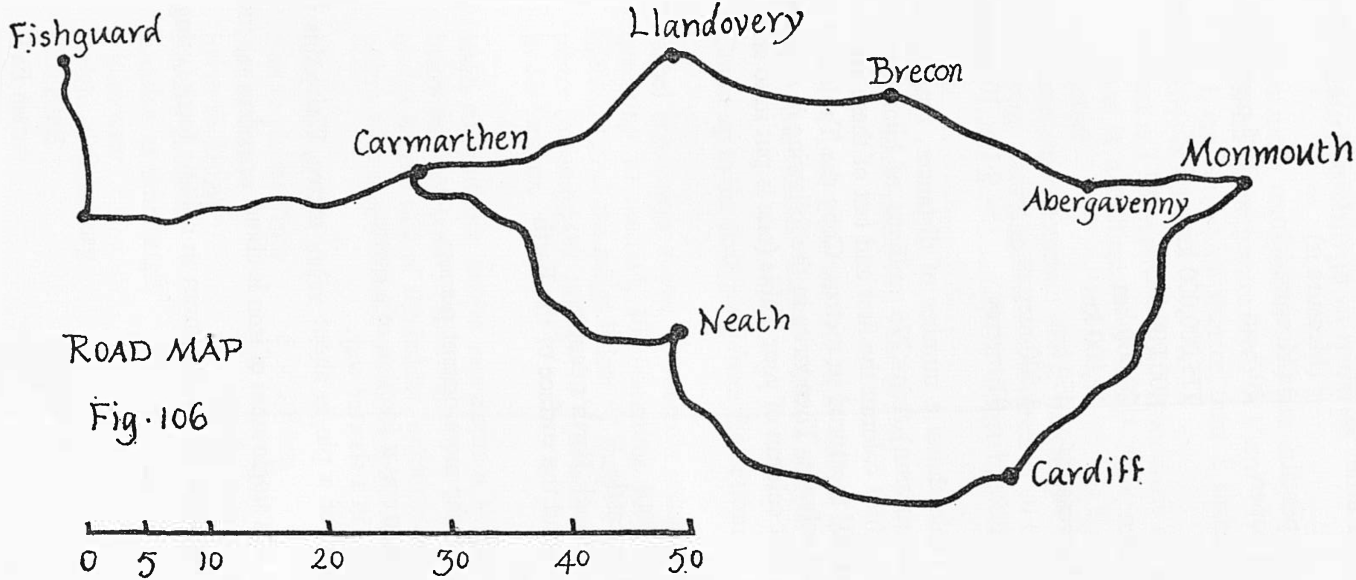
	775,000,000 km	= $7{\cdot}75 \times 10^{11}$ metres
	400,000 km	=
	20,000 km	=
	12,800 km	=
London to Newcastle	450 km	=
	1,600 metres	=
	91 metres	= $9{\cdot}1 \times 10$ metres

The above Table shows a number of distances, ranging downwards (second column) from 775 millions of kilometres to 91 metres. In the third column the first and last of these are written in 'powers of 10' measured in metres. Copy the Table and complete the third column. Then write in the following *in their correct places* in the first column of your Table (one is put in to show the idea).

Earth to Moon
One mile
London to Newcastle
Pole to Pole through Earth's centre
Pole to Pole round the surface of the Earth
100 yards race
Sun to Jupiter

Note: Jupiter is one of the more distant planets.

105 *a*. Write 10^{-4} metre as a fraction of a metre.
b. Write 100,000 in a shorter way.
c. The diameter of a pin is about $\frac{1}{10000}$ metre. Write this in a power of ten.
d. The radius of a single atom of iron is about $\frac{1}{10{,}000{,}000{,}000}$ metre. Write this as a power of 10.
e. Write the diameter of an iron atom in a short form (using (*d*) above).



ROAD MAP

Fig. 106

Scale: 16 miles to 1 inch, or 1,000,000 to 1

11 Guessing, estimating, measuring

106 *a.* Estimate, first by guessing, then with a piece of cotton, the road-miles between Carmarthen and Fishguard.
b. Which is shorter, Monmouth to Carmarthen via Cardiff, or Monmouth to Carmarthen via Brecon? Guess first, then check with cotton.
c. What does a scale of 16 miles to 1 inch mean? What does a scale of 1,000,000 to 1 mean?
d. 16 miles $= 16 \times 1760 \times 36$ inches, which is 1,013,760 inches. Is this correct? Where do the figures 36 and 1760 come from?
e. The man who drew the maps said it is 16 miles to 1 inch, and also that it is 1,000,000 to 1. Both these statements cannot be exactly correct. Why not?
f. Difficult. Suppose the map is exactly 1,000,000 to 1, and that '16 miles to 1 inch' is approximate. You measure the distance on the map between two towns X and Y, and find it to be exactly 6 inches.

(*i*) Is the real distance between X and Y more nearly 95 miles, 96 miles or 97 miles?
(*ii*) Give the reason for your answer to (*i*).

107 *a.* Use a metre ruler or measuring tape to find your height, the length of your average pace as you walk, and the length of your foot (in a shoe), all in centimetres.
b. Use your measurements to estimate;

(*i*) the height of the laboratory, or of a room at home, in metres,
(*ii*) its floor area, in square metres,
(*iii*) its volume, in cubic metres.

c. In the same way, estimate the area of a playground or sports field.

108 Measure your hand span in centimetres, i.e. distance across from tip of little finger to tip of thumb when farthest apart. Use this to estimate the length and width of the table or desk-top at which you are sitting, then check with a ruler.

109 Guess the thickness of a playing-card (or postcard or visiting card), putting it against a millimetre scale if you like. Then see how near your guess was by measuring the thickness of a counted number of cards (10, 20, 50 or 100).

110 Given 1 inch = 2·54 cm, find which is the longer race, 220 yards or 200 metres. How much longer? Give the answer to the nearest centimetre.

111 Seconds of time may be counted by saying 'Mississippi 1, Mississippi 2', etc.* each syllable being clearly said at normal speed. Test this by counting up to 'Mississippi 10' while watching a clock which has a seconds hand. Then try your skill at counting seconds up to a minute in this way.

Suppose you were in a train one day, and you started counting like this just as your compartment passed a quarter-mile post. You find that you pass the next quarter-mile post just as you count 'Mississippi 15'. How fast is the train travelling?

112 Make a simple weighing balance as follows: Find a six-sided (hexagonally) shaped pencil and balance a foot rule on it. Collect a number of halfpennies. We will call the weight of a halfpenny one 'unit' of weight. Find, to the nearest whole number of 'units', the weight of a half-crown and of other small objects, heavier than a halfpenny, that you can put on the ruler.

Can you suggest any way of using this balance to find the weight, in 'units', of a sixpence? How?

* If you prefer, say 'one little second, two little seconds, etc.'

12 Taking averages

113 Twelve boys weighed the same piece of metal on the same balance (which weighs to the nearest gram). The twelve results were:

173	173	174	173	173	172	grams
173	171	173	173	174	172	grams

One of the boys, Freddie Jones, added up all these, and got 2074. He then divided 2074 by 12 and got to one decimal place, 172·8 gm.

a. This is correct, but how would you have got the same result much more quickly, without nearly as much arithmetic?
b. What is the 'best' value for the weight of the metal *to the nearest gram*?

114 *Following from 113.* Freddie wonders whether the balance is really correct, and to test this, he puts on to it the following weights taken from a weight box – these weights have been tested and are known to be accurate to much less than 1 gm. They are:

100 gm   50 gm   20 gm

They are put on together, and the balance reads 168 gm. Several people agree about this.

What do you now think is the 'best' value (to the nearest gram) for the piece of metal weighed in question 113?

115 *a.* Take any book and count the number of words in any three lines of print. Is there the same number in each line? What is the *average* number of words per line?

Did any of the three lines you chose start or finish a paragraph? Did any of them have a part of a word on one line and part on the next? Would it be better, if we want to find the average number of words per line, to avoid counting 'special' lines such as the above? Begin again if you think you ought to.
How did you count figures if there were any? Did you count words with hyphens, such as 'see-saw' and 'co-operative', as one word or two words?

b. Now take two other sets of three lines each and find the average

number of words per line for each set. Do you get the same average for each of the three sets? Does your answer seem reasonable?
c. Without doing any more counting, what would you give as the best average for the number of words per line?
d. Suppose you found 73 words in 10 lines. Is it sensible to say the average is 7·3 words in a line, or is 7 more sensible? (We do not use fractions of a word in talking or writing.) Which should a printer use for estimating cost of type-setting, 7·3 or 7? Explain why.

116 A tape measure, which is marked in inches up to 60 inches, is suspected to have stretched. Six boys use an accurate boxwood rule to measure the length which is marked as 36 inches on the tape. They obtain the following six readings:

36·4 36·5 36·2 24·2 36·4

a. What is the most likely value for the real length between the 0 and the 36-inch marks on the tape?
b. Did you leave out the 24·2 value in finding the answer to (*a*)? If so, why do you think it right to leave it out?
c. What would you suggest the boy who took the 24·2 reading should do? (Actually the tape was marked in inches on both sides, but from opposite ends; can you suggest what happened?)
d. Some people think that by taking more and more readings (measurements) of the same thing with the same ruler or tape, and then taking the average of all the readings, you will get a more and more accurate result. Would this be true for measurements made with this tape? Why not?

117 *Experiment.* Try this at home. Take a pack of playing cards and shuffle it well. Then make ten small cuts exposing ten cards. How many of these belong to the suit of Hearts? Make a note of the number. Collect the cards, reshuffle and try again, making twelve tries in all.

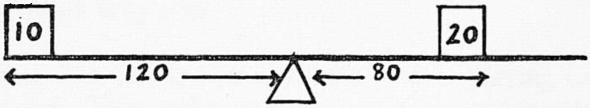
a. Are there always the same number of Hearts exposed in each try?
b. What was the maximum number of Hearts exposed in a single try? What was the minimum number?
c. Your twelve tries will have exposed 120 cards. How many of these were Hearts? Does this seem reasonable?
d. What is the average number of Hearts exposed per try? (Work to one decimal place.)

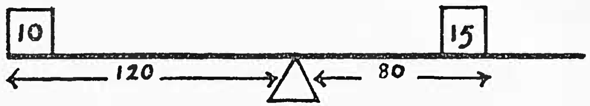
e. What is the average number of Hearts exposed per cut? (Remember you make 10 cuts at each try.)
f. Does the answer to (*e*) mean anything? What would this answer have been if you had been given a 'conjuror's pack' in which all the cards were Hearts?

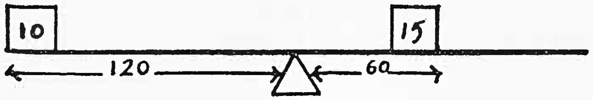
13 Balancing things on see-saws

118 *a.* Tommy, weight 5 stones, sits at one end of a see-saw 12 feet long, supported at the mid-point. Where must Uncle John, weight 15 stones, sit to produce a balance?
Uncle John says: 'I don't like this. I want to sit at one end too.' Tommy says: 'All right, it's perfectly possible to have you at one end and me at the other, and still balance the see-saw.' Tommy is right, but they will have to shift the balance-point (fulcrum) of the plank.
b. Draw a rough diagram of the see-saw in the new position, marking in the fulcrum.
c. Draw arrows on your rough picture of the see-saw to show Uncle John's weight pulling downwards and Tommy's weight pulling downwards.
d. If you can, add one more arrow pointing downwards to show the weight of the see-saw itself. The see-saw is quite a light plank compared with Tommy or Uncle John. You can pretend that the whole pull of the Earth on the plank is a pull at the mid-point of the plank.
e. The plank does not fall down because the support (fulcrum) pushes it up. Draw an upward arrow for that push.

119 Here are six diagrams showing a plank resting across a support; the support is at the mid-point of the plank. Two loads rest on the plank, and their value in kilograms is shown on them. Their distance from the support in centimetres is shown beneath the plank.







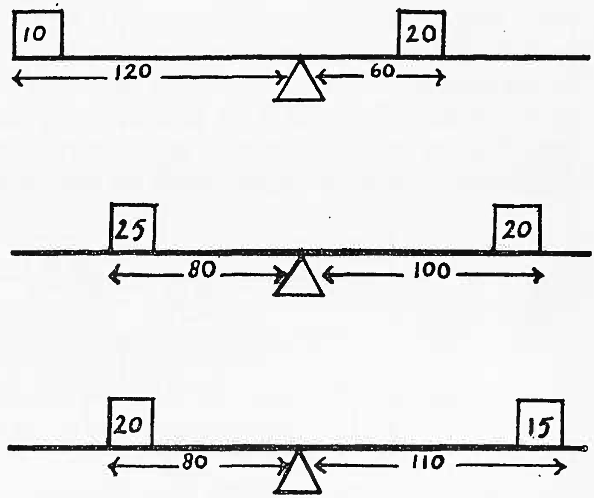


Figure 119

a. Copy the diagrams in your exercise book and draw arrows to represent the weights, including the weight of the plank, which is 10 kg. Add another arrow for the upward push of the support.
b. Write at the side of each diagram either BALANCED or UNBALANCED.
c. Add in the unbalanced cases a note such as 'left-hand end tips downwards' to explain what you think will happen.

120 Here are four more diagrams similar to those in question 119. The plank is always supported at its mid-point. This time the value of either one of the weights or one of the distances has been marked as X. *All the planks balance.*

Put a heading in your notebook FOUR BALANCED PLANKS and beneath it copy the diagrams to scale, with arrows of suitable lengths, for the weights and pushes which you know, as before. One weight or one distance is left as X in your diagram, and at the side of each diagram write X = putting in the correct figure – and don't forget to say whether the figure stands for kilograms or centimetres.

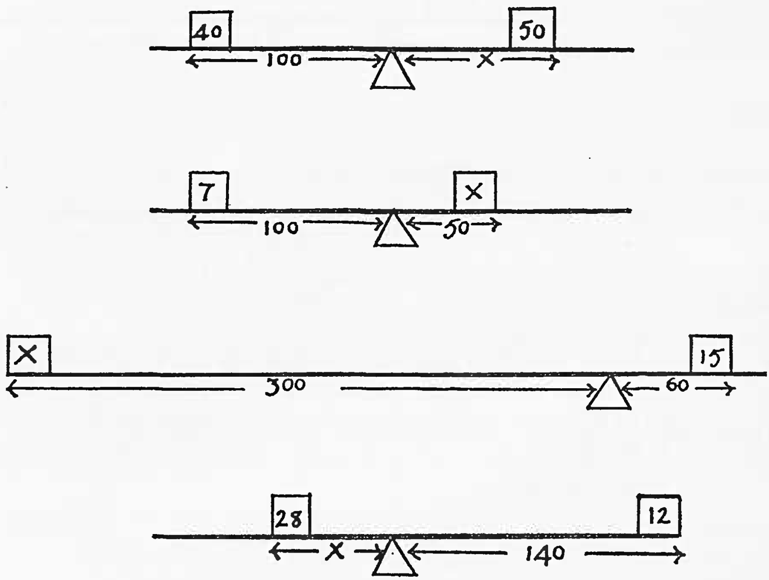


Figure 120

121 A man who is painting a ceiling stands on a plank 12 feet long stretched across two trestles L and R as shown. The plank is (foolishly) allowed to overlap the trestles by $1\frac{1}{2}$ feet at each end. It weighs 50 lb. The plank *just* begins to tip as the man gets to one end, the end near R in the drawing.

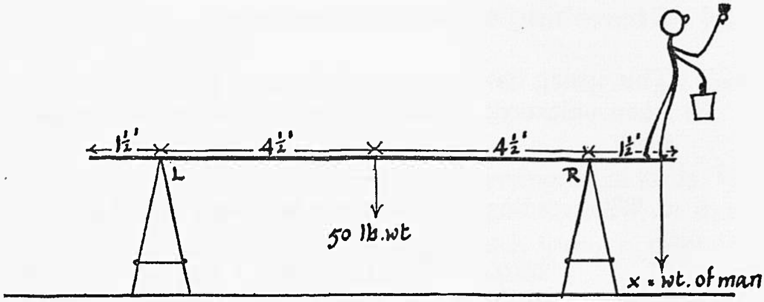


Figure 121

a. What is the weight of the man? (We can take the weight of the plank to act at its middle point.)
b. You could stop the plank tipping by tying it to the trestle at L, provided the trestles are heavy enough, but tying it to R would have little or no effect in stopping the plank tipping. Why not?

122 Tommy weighs 100 lb and wants to find the weight of a plank which, he knows, has a weight of something between 20 and 30 lb. He also has a foot or so of old broom handle, and two trestles like those in figure 121.

a. Draw a sketch showing how Tommy could find the weight of the plank.
b. Invent some reasonable measurements and put these on the diagram.
c. Work out the weight of the plank.

14 Stretching springs and wires

123 This spring has its free end B opposite the 0 mark on the scale when unloaded. When 100 gm is attached B is opposite the 20 mark.

a. What reading do you expect for a load of 150 gm? For 50 gm?

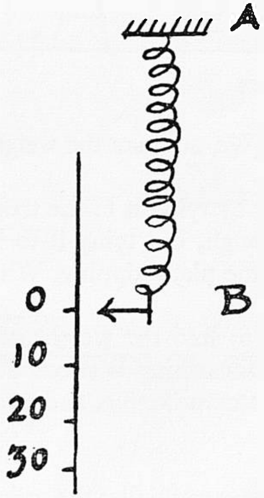


Figure 123

Figure 124(*b*)

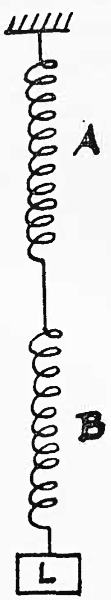
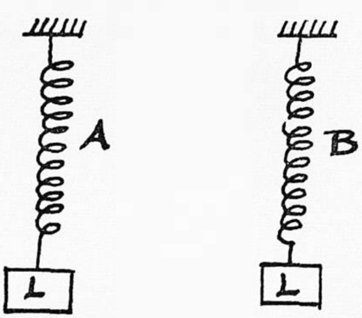


Figure 124(*a*)



b. If the reading is 15, what is the load? How did you get your answer?
c. What is the load when the reading is 22? Did you get your answer in the same way as for (*b*)? If not, how did you get it?

124 A and B are two exactly similar springs carrying equal loads. We can forget about the weight of the springs because it is so small compared with the weight of the loads. Each spring is extended by 6 cm by the load L (figure 124(*a*)).

a. The load on A is removed and the spring B is attached to A, figure 124(*b*).

(*i*) How much does A stretch when the load L is hung on B?
(*ii*) How much does B stretch?
(*iii*) How far will the bottom end of spring B go up if the load L is removed?

b. Think about your answers to (*a*) when you answer the following questions. Two springs P and Q are identical in every respect, except that P is twice as long and therefore has twice as many 'turns' as Q. If a load of 1 kg stretches Q by 3 cm, how much will a load of 1 kg stretch P?

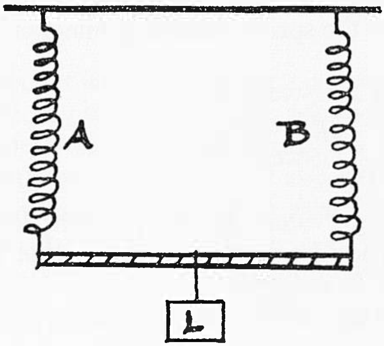


Figure 125

125 The same springs A and B, used in question 124, are now joined side by side as in figure 125 to a very light lath. (A lath is a flat wooden stick.)

a. What is the stretch in A and B when a load L is attached to the centre of the lath?
b. What difference would it make to the stretch in each spring if the load L were attached at some point other than the centre? (This is not a numerical question; just say in words what difference it makes if L is nearer A, and if L is nearer B.)

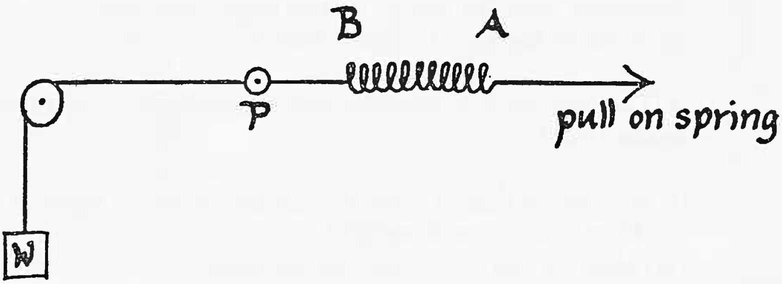


Figure 126

126 In the diagram one end, B, of a spring balance is fastened to a small ring. The ring is also attached to a string passing over a pulley and carrying a weight W. P is a removable peg which keeps the ring in place. The end A of the spring balance is now pulled to the right so that the reading of the spring is 3 kg. The peg P is then removed. What happens to the ring, and what is the final reading of the spring balance in kilograms-weight,

a. if W = 2 kg-weight,
b. if W = 3 kg-weight,
c. if W = 4 kg-weight?

Note: There is no 'catch' in this question; it really is as simple as it seems. The idea is to give you a little practice with 'pulls' or 'tensions' in strings. If W = 4 kg-weight, then the tension in the string is 4 kg-weight. The pulley is supposed to turn freely without friction.

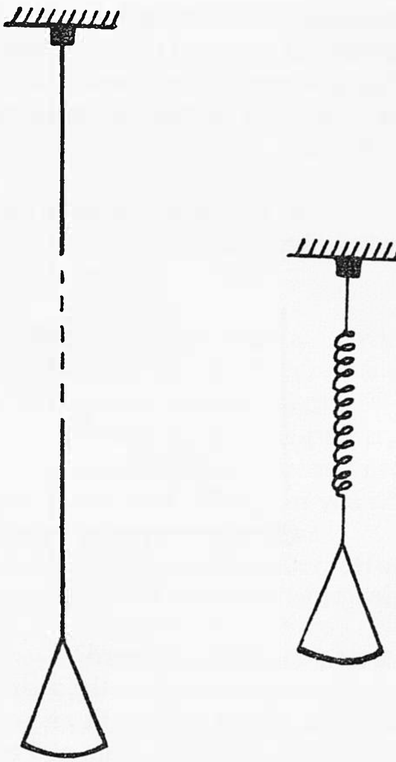


Figure 127

127 A piece of thin copper wire 2 metres long is fixed to the ceiling so that it hangs vertically with a light scale pan at the lower end. An exactly similar piece of thin copper wire, also 2 metres long, is coiled into a tightly wound spring, and also has a light scale pan attached to it (see diagrams). A load is then put on the pan attached to the *wire*, and the wire stretches by an extra 1 cm; we will call this load P. A different load Q, when put on the pan attached to the *spring*, stretches the spring by 1 cm.

a. Which do you think will be the larger, P or Q?
b. What is likely to happen when P is taken off again?
c. What is likely to happen when Q is taken off?

128 *a.* When a load is put on a spring the distance between the coils of the spring is increased. What is it that will be increased when a load is put on a copper wire, as in question 127? (We suppose that the wire is made up of atoms.)

b. A wire carries a load which is not quite big enough to break it. When the load is removed the wire shortens a little, but most of the stretch produced is not recovered; the wire is permanently stretched. Write one or two sentences explaining what has happened to the wire.

129 When you did an experiment with springs you plotted a graph, which looked like this:

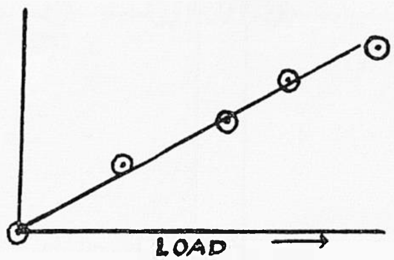


Figure 129

a. What were you plotting upward?
b. When you put bigger loads on the spring and it began to stretch permanently the points did not fit on your simple graph; where were they? Sketch the graph again and add more points to show what happened.

130 *Difficult puzzle.* Suppose you have a spring of steel wire like this:

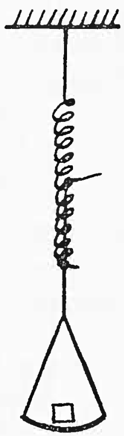


Figure 130

A piece of strong thread is tied to one end and to the spring at its mid-point. The thread is loose, but when the spring is loaded up to about $\frac{1}{3}$ of its limit for elastic behaviour the thread is pulled taut. You continue loading beyond that up to the safe limit. What graph would you get? Sketch it and explain.

131 If we suppose that solid substances are made up of atoms, then some very simple observations tell us quite a lot about the forces atoms exert on each other.

a. You take a piece of metal or wood or almost anything, even india-rubber, and try to pull it into two pieces. It resists your pull. What does this tell you about forces between atoms?
b. You take two pieces of metal, or india-rubber, and put them near each other. They do not fly together, and even if you touch them together they do not stick. What can you now add to what you said in (*a*) about forces between atoms?
c. You take a piece of metal, or india-rubber, between fingers and thumb and try to squash it. It resists being squashed. What does this tell you about forces between atoms?
d. Difficult. Put together the observations and your conclusions in (*a*), (*b*) and (*c*) in order to make a general statement about how forces between atoms vary, in a solid, with the distance apart of the atoms.

132 *Difficult.* Freddie Jones says that question 131 'proves that solids are made up of atoms', because, 'you can't explain what happens in any other way except by talking about atoms'.

Is he right? What do you say?

15 Force divided by area

133 You stand with bare feet on smooth concrete. Then someone sprinkles gravel on the concrete and you stand on the gravel. Why does the gravel hurt while the concrete did not? Answer, because the gravel sticks into your feet. Let's think a little more about that.

a. Compare the force your weight makes you exert on the gravel (and therefore the gravel on you) with the force on the smooth concrete. Is the force greater, or less, or the same?
b. Compare the area of gravel in contact with your feet, and the area of smooth concrete touching your feet. Is the area greater, or less, or the same?
c. Compare (force divided by area) for the gravel with (force divided by area) for the concrete. Is it greater, or less, or the same?
d. What is another, one word, name for (force divided by area)?

134 *a.* You take a drawing pin between your fingers by the pointed end, and press the head of the pin against the palm of your other hand, with let us say, a force of $\frac{1}{10}$ kg (100 gm). Suppose now you reverse the pin, and push the sharp end against your palm with the same force, $\frac{1}{10}$ kg. Not the same thing at all! Why not?

b. You take a magnifying glass and look at the pin. You decide that the area of the point is 1 square millimetre (rather blunt!), while the area of the head is 1 square centimetre.

Then, when the head is pressed against your palm,

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{\frac{1}{10}\text{ kg}}{1\text{ sq cm}} = 0{\cdot}1\text{ kg per square centimetre.}$$

What is the pressure on your palm if you pressed the pointed end of the pin against it? Give the answer in kg per square centimetre as before. (Remember that, 1 sq mm $= \frac{1}{100}$ of 1 sq cm)

135 It is said that a girl in stiletto heels (heels having a very small area of contact with the ground) makes a bigger dent in a polished wood floor than an elephant would. Why is this? After all, it would take very many girls to make the weight of one elephant.

136 Copy the table below and fill in the blanks. Notice that, in all lines except the first, there are *two* blanks, one for the number and one for the unit.

force	area	pressure
20 lb	4 sq in	... lb per sq in
... ...	30 sq cm	4 kg per sq cm
10 kg	... .	2 kg per sq metre
75 lb	5 sq in	... .
12 kg	0·3 sq metre	... .

137 *To be done at home.*

(*i*) Weigh yourself, or make a good guess at your weight in pounds. Write it down.
(*ii*) Take your shoes off and stand on a sheet of paper, or two sheets. Draw round your feet. You could also do this with chalk on the floor. Make the best estimate you can of the area of each foot in square inches. Another way is to wet your bare feet and measure the wet mark on the floor.
(*iii*) Now work out the pressure of your feet on the floor, in lb per sq in,

a. when you stand on two feet,
b. when you stand on one foot.

138 *a*. Why are skis so long? Why not have short ones, the size of one's boots? Much more handy!
b. Freddie has fallen through thin ice. In order to reach him, Uncle George crawls across the unbroken ice and lies flat when he gets near. Why lie flat?

139 A car weighs 1 ton and is supported on four tyres, each pumped up to what the makers say is the correct pressure, 25 lb per sq in. A fortnight later the pressure has fallen to 20 lb per sq in, but the car still runs well, and of course, it still weighs 1 ton. How is it that the same car can be supported by a pressure of 25 lb per sq in and also by 20 lb per sq in? What has happened?

140 You have a bicycle pump with a well-fitting piston. You put one finger over the nozzle and press the handle in.

a. What do you feel on your finger?
b. You use the whole hand and arm to push the handle and piston, which pushes the air; but you can hold back the same air with one finger. Why is this?
c. If you let go of the handle, what happens?

141 *a.* What difference would it make if the pump (question 140) had been filled with water instead of air?
b. Things that have to stand high pressures, gas cylinders for example, are tried out with much greater pressures than they will have to withstand. But the cylinders are filled with *water* when they are tested, not air. Why is it much safer to use water for the test, rather than air?

142 A bicycle pump is sealed up at the nozzle end, and the handle is pushed down, so that the air inside is compressed. It is a very good pump, and no air leaks away. Write down each of the following, (*a*) to (*e*), and add to each the correct words: increased (got greater), diminished (got less), or stayed the same.

a. The volume of the air has ....
b. The number of air particles in the pump has ....
c. The weight of the air has ....
d. The pressure of the air has ....
e. The distance (on average) between one air particle and the next has ....

143 *a.* How would you use a water pressure gauge (a U-tube containing water) to find the pressure your lungs can exert? Give a diagram. Say how you would make sure you find the 'best', or maximum possible, pressure.
b. Do you think the result you find has anything to do with the *capacity* of your lungs, that is, the maximum amount of air the lungs can hold? Explain the reason for your answer.

144 The drawings opposite are all *one-tenth actual size.*

Figure (*a*) shows an ordinary U-tube pressure gauge joined to the gas supply. What is the pressure of the gas? (Measure it on the diagram, and remember about the one-tenth size.)
Figure (*b*) is a manometer with unequal arms. It is joined to the same gas supply, but the gas tap has not yet been turned on. Make a drawing showing what it looks like when the tap is turned on.

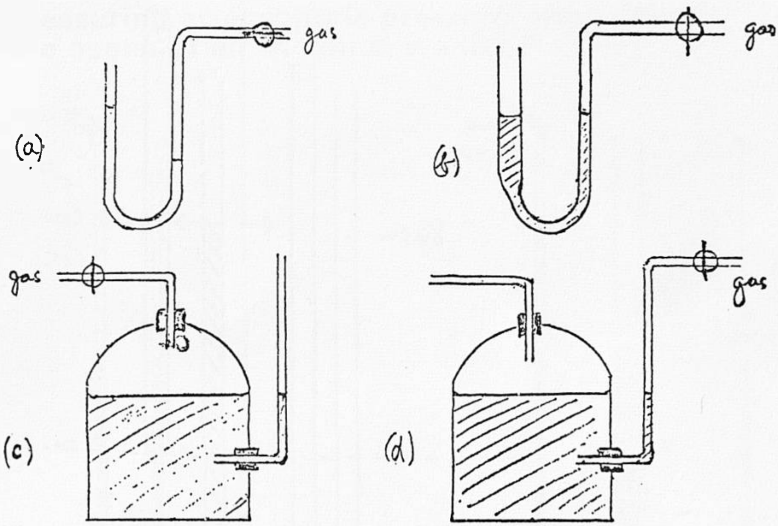


Figure 144

Now do the same for figure (*c*) and figure (*d*), that is, make drawings showing what each looks like when its tap is turned on.

Remember to make the level differences right for the gas pressure you mentioned in (*a*). The same gas supply is used all the time. Remember, too, that no water is lost from, or put into, the manometers.

145 *An unexpected result.* The diagram overleaf shows a pressure gauge made from one piece of plastic tubing. At first the levels were the same both sides, and a boy fixed a half-metre scale X with the O mark against the water level. Then he blew down one side, and sealed off the tubing on that side. The water level on one side was now at the 40-cm mark on X (see diagram). 'The other side must have gone down 40 cm, so the difference of level is 80 cm,' he said. But when he measured it directly, on another scale Y, the difference of level was 86 cm.

Which of these two, 80 cm or 86 cm, is correct? Would it make any difference if the manometer was made of glass instead of plastic? Give the reasons for your answers.

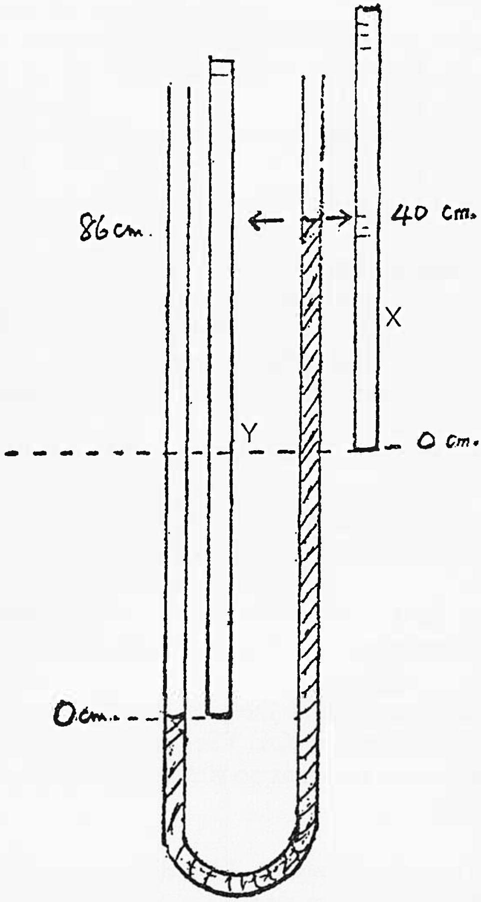


Figure 145

146 A manometer containing water, when joined to a gas supply, showed a difference of levels of 13·6 cm.

A manometer containing mercury, joined to the same gas supply, showed 1·0 cm.

A manometer containing oil, joined to the same gas supply, showed 17·0 cm.

1 cubic centimetre of water weighs 1 gm. What does 1 cubic centimetre of mercury weigh? Explain the reason for your answer. What does 1 cubic centimetre of oil weigh?

16 Measuring atmospheric pressure. How deep is the ocean of air in which we live?

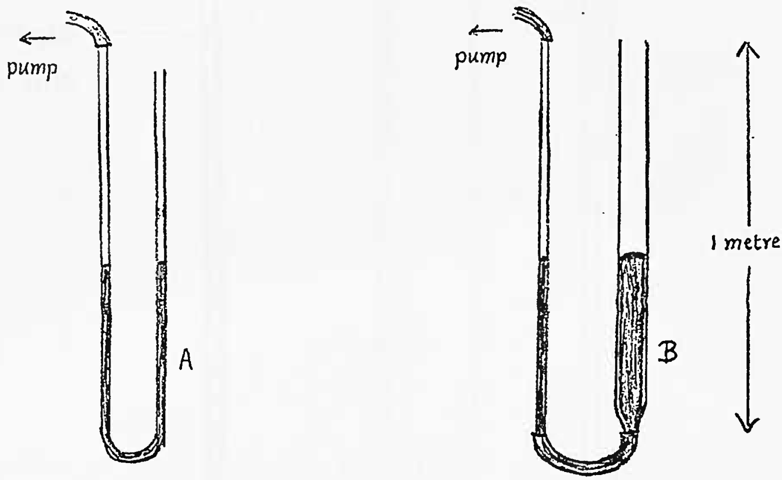


Figure 147

147 A and B are two U-tubes, each of height 1 metre. They can be joined to a good vacuum pump. A has the same width both sides; B is narrow on the left, wide on the right. The tubes are half-filled with mercury, as shown on the diagrams. Atmospheric pressure is equal to the pressure of 76 cm height of mercury. 76 cm is about 30 inches.

a. Draw a diagram of A, after the pump has been working, and mark in the height which is 76 cm.
b. What happens to B when the pump is set working? Why would the owner of the pump not be pleased?
c. What difference would it make if A and B had been filled to the same levels with water instead of mercury?

148 In figure 148 we have a single open tube dipping into mercury. The pump is a good vacuum pump.
a. Draw a diagram of this tube after the pump has been operating for some time, and mark in a distance, which if you measured it you would find to be about 76 cm.
b. What difference would it make if the tube were twice as wide?
c. What difference would it make if we had water in the apparatus instead of mercury?

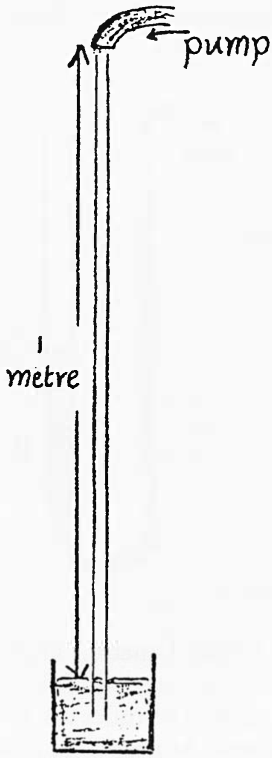


Figure 148

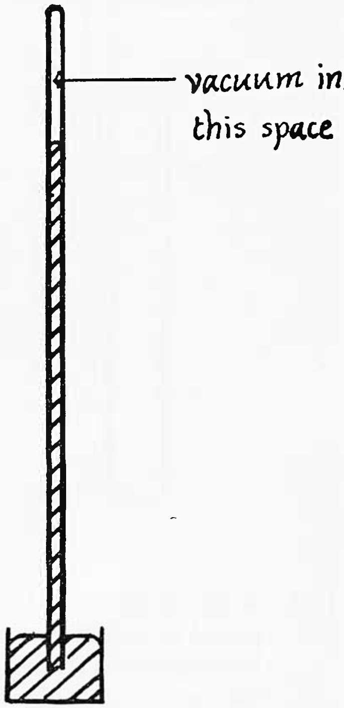


Figure 149

149 *a*. Copy the diagram, figure 149, and mark in the height that represents atmospheric pressure.
b. What is this instrument called?
c. How is it made? (No air-pump is available. The tube is closed at the top.)

150 Figure 150 is just like 149, except that we have a much deeper lower container, holding mercury. The total height of the tube is 100 cm. Atmospheric pressure is 76 cm of mercury. There is 4 cm of vacuum above the mercury in the tube.

a. What happens if the tube is pulled 10 cm farther out of the jar? How much 'vacuum-space' is there above the mercury?
b. What happens if the tube is pushed 10 cm farther down?
c. What is the pressure at C? (i.e. how many cm of mercury is the pressure at C equal to?)
d. What is the pressure at D?

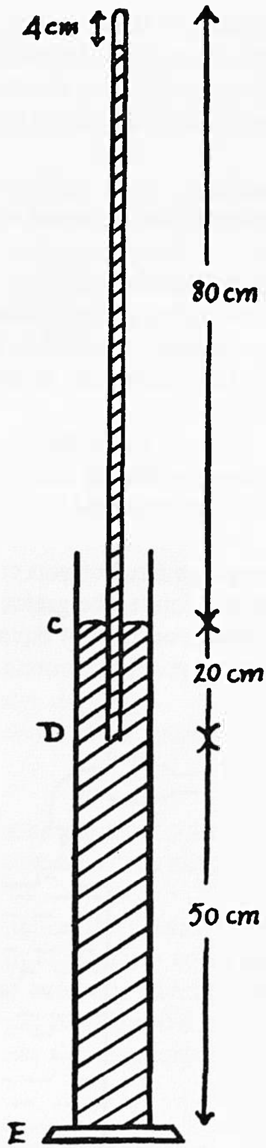


Figure 150

e. What is the pressure at E?
f. Does the position of the tube make any difference to the pressures at C, at D or at E? Give the reason for your answer. (*Note:* D marks the position of the lower end of the narrow tube.)

151 *Three Experiments:*
a. Hold your thumb on the spout of a tap and turn the tap on. What happens?
b. An old tennis-ball has four or five holes punctured in it; then it is held under water and squeezed. What happens?
c. After being squeezed, the ball is released under water so that it fills up. It is now taken out of the water and squeezed. What happens?

152 The experiments in question 151 show the truth of which *two* of the following true statements?

A. You can compress air, but you cannot compress water.
B. The greater the depth, the greater the pressure.
C. Pressure in water or air acts equally in all directions.
D. Experiments on water pressure are likely to be messy.

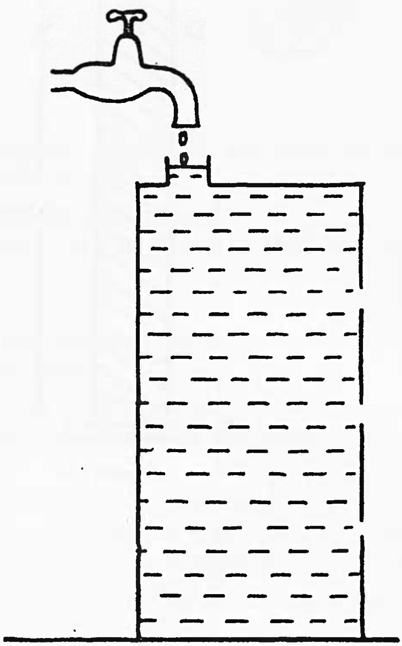


Figure 153

153 A gallon oil-can has three small holes made in one side, at $\frac{1}{4}$ its height from the *top*, half-way down and $\frac{1}{4}$ its height from the *bottom*. It is filled with water and, of course, water comes out of the holes. Water is run into the can from a tap to keep it full.

a. Draw a diagram showing what you think the water jets would look like. Try the experiment if possible. It shows that 'the greater the depth, the greater the pressure'.
b. Now think of the sea with the atmosphere above it; an ocean of water with an ocean of air on top. How will the pressure change as we go (*i*) deeper down in the sea, and (*ii*) higher up in the atmosphere?

154 There is an important difference between pressure in water and pressure in air. Think of a bicycle pump filled *first* with air, *then* with water.

a. What happens if you put your finger over the nozzle and try to push the handle when the pump is filled with air?
b. What happens when it is filled with water?
c. What can you say about the densities of water near the surface of the sea and at greater depths?
d. What can you say about the densities of the air at sea-level and at greater heights?

Note: The next three questions are DIFFICULT and should be attempted only by those who are GOOD AT ARITHMETIC.

155 To the nearest single figure, the pressure of the atmosphere equals the pressure of a height of mercury equal to 0·8 metre ($\frac{8}{10}$ metre). So an 'atmosphere' of mercury having the same pressure as the actual atmosphere would be about 0·8 metre high. Mercury is $13\frac{1}{2}$ times denser than water; also mercury is 10,000 times denser than air.

a. How high would an atmosphere of water be?
b. Using the same method as you used for (*a*), say how high an atmosphere of air is. Give the answer first in metres, then in kilometres, then in miles. 1 kilometre = $\frac{5}{8}$ mile.

156 The answer you should get in question 155(*b*) is 8 kilometres. This is a silly answer, because we know the atmosphere goes much higher than 8 kilometres.

a. If you know of any reasons for supposing that there is air higher than 8 km up, say what these reasons are.
b. Why is it wrong to use the same method for 155(*b*) as for 155(*a*)?

157 After answering questions 155 and 156, give the best answer you can to the question at the head of this Section, 'How deep is the ocean of air in which we live?'

17 Some consequences of living at the bottom of an air ocean

Note: The first three questions, 158–160, are DIFFICULT and should be attempted only by those who are GOOD AT ARITHMETIC.

158 The pressure of the atmosphere is about 76 cm of mercury, which is about 30 inches. Thirty inches of mercury pressure equals about 15 lb weight on each square inch, or 15 lb per square inch. (If you disbelieve this, see question 160.)

a. Measure the table or desk at which you are working (length and breadth to the nearest inch will do). Find its area in square inches. Now find the force, due to the weight of the atmosphere, pressing down on the whole table top – put it into tons weight if you like.
b. Why doesn't the table collapse under this enormous load? (*Hint:* Look at question 152, statement C.)

159 Not only the table, but you yourself have to withstand the pressure of 15 lb on each square inch. Measure the size of your chest if you like, and calculate the load on it.

How is it that you not only bear this load, but do not even feel it?

160 This is how to show that a pressure of 30 inches of mercury is the same as 15 lb per square inch. The figures are in simple numbers, and the result, though good enough, is approximate (14·7 lb per square inch is more nearly the *average* atmospheric pressure, which varies slightly from one day to another).

Data: Mercury is $13\frac{1}{2}$ times denser than water, and 1 cubic inch of water weighs $\frac{1}{27}$ lb.
Imagine a column of mercury 1 square inch in cross-section and 30 inches high (figure 160A).

1 cubic inch water weighs $\frac{1}{27}$ lb
1 cubic inch mercury weighs $\frac{1}{27} \times 13\frac{1}{2}$ lb
30 cubic inches mercury weigh $\frac{1}{27} \times 13\frac{1}{2} \times 30$ lb
which is
$\frac{1}{27} \times \frac{27}{2} \times 30 = 15$ lb
This stands on 1 square inch.

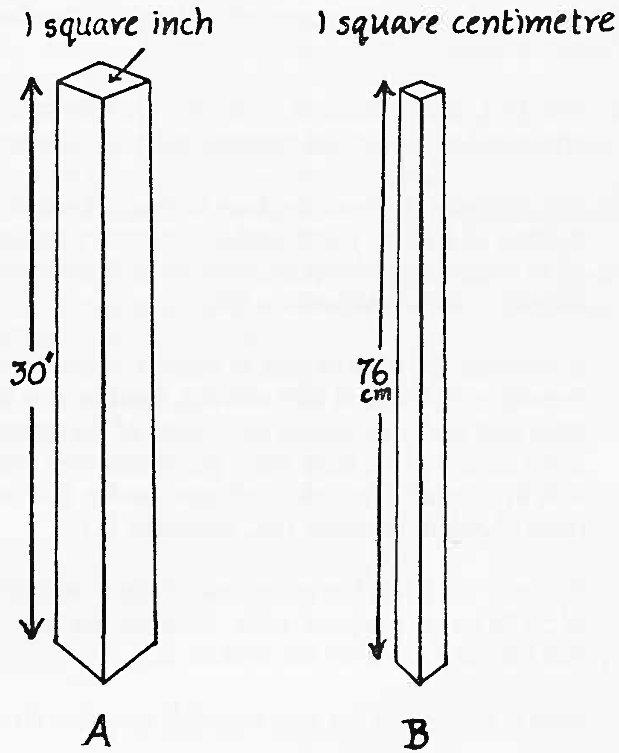


Figure 160
(length and breadth measurements
not to scale!)

Therefore pressure = 15 lb per square inch. You work out the same thing in scientific measurements. Copy out and complete the following:

Data: Mercury is $13\frac{1}{2}$ times denser than water, and 1 cubic centimetre of water weighs 1 gram.

Imagine a column of mercury 1 square centimetre in cross-section and 76 cm high (figure 160B).

1 c.c. of water weighs 1 gm.

Now complete it. Your result should be slightly more than 1 kilogram-weight (1000 grams-weight) on each square centimetre.

161 Take a glass tumbler or beaker or milk bottle (a tin can would do, only it is better if you can see inside). Completely immerse it in a bowl of water so that it is full of water. Turn it mouth down and remove it slowly from the bowl. Describe what happens. Why does the water stay inside? And why does the water *not* stay inside when the tumbler, still upside down, is lifted clear of the water in the bowl?

How tall would the tumbler have to be for some water to come out while the rim is still immersed? Explain. (It would be rather a tall tumbler!)

162 Let us follow up a consequence of the answer to the last question. Take a piece of ordinary laboratory glass-tubing and put it in the bowl so that it gets full of water (if necessary, clear all the air out by sucking water through it). Put a finger over one end and lift the tube clear of the water, with the open end downwards. Does the water come out? Why not? When you remove your finger the water does come out. Why does removing your finger make a difference?

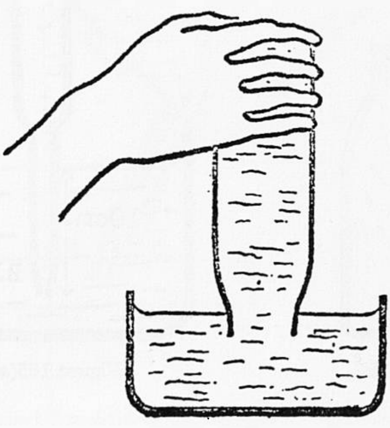


Figure 163

163 A milk bottle (or glass tumbler, beaker or any open container) is fully immersed in water. You hold the bottom end and raise it as shown in the sketch.

a. What stops the water coming out?
b. Do you have to support the weight of the bottle alone, or the weight of the bottle plus the water in it? Give reasons for your answer.
c. What difference, if any, would it make to this experiment if you were a giant with a giant milk bottle 40 feet tall?

164 *a*. Following from question 163, you now lift the bottle (figure 163) clear of the water. What happens?
b. Next you fit a cork with a narrow open tube into the bottle mouth, as in figure 164. (The tube is not really necessary, just a hole in the cork will do.) The cork is removed, the bottle is filled with water and the cork is replaced. The bottle and the cork are turned upside down. The water stays in the bottle. Why?
c. Suppose you turn upside down a bottle, full of water, and fitted with a cork having *two* holes. Perhaps the water might still stay in, but perhaps something else would happen – what?

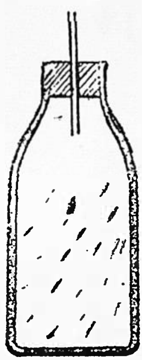


Figure 164

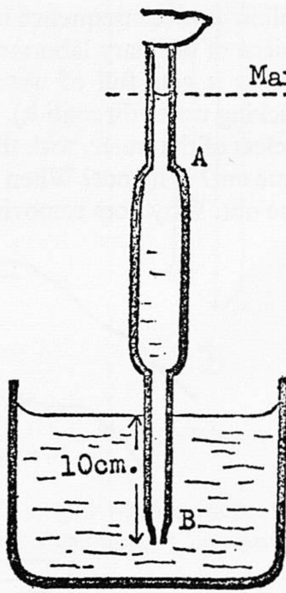


Figure 165(*a*)

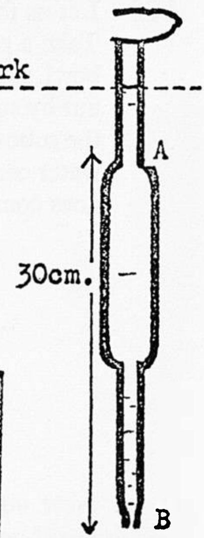


Figure 165(*b*)

165 Explain what in fact happens when you 'suck up' milk or fruit juice through a straw.

A is a point inside a pipette below the mark to which the pipette is filled. B is the 'nozzle' of the pipette (AB = 30 cm). The pipette is filled with water as shown.

a. Figure 165(*a*) shows the pipette vertical and immersed 10 cm in water.

(*i*) By how much, in cm of water, is the pressure at B above (+) or below (—) atmospheric pressure?
(*ii*) By how much is the pressure at A above or below atmospheric pressure?

b. (*i*) How much is B above or below atmospheric pressure when the pipette is outside the water and is vertical as in figure 165(*b*)?
(*ii*) By how much is the pressure at A above or below atmospheric pressure?

c. If the pipette is now turned into a horizontal position, what is the pressure at A?

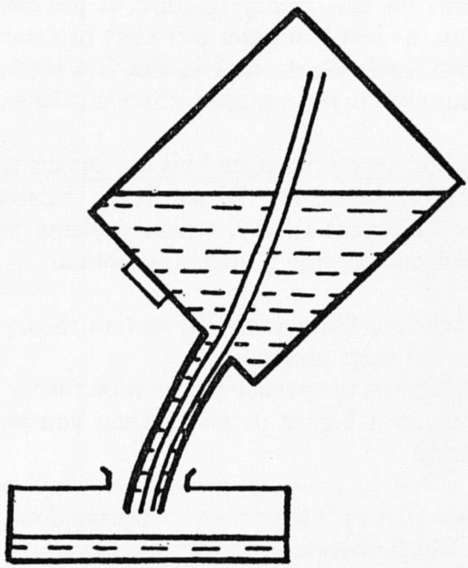


Figure 166

166 A paraffin can used for filling an oil stove has a spout with a thin tube running through it as shown in the sketch. This tube is a safety device which stops the oil container being overfilled. Why, when the can is used, as shown in the sketch, is it impossible to overfill the oil container in the stove?

167 Consider the glass bottle in question 163. This time we simply push the empty bottle upside down into the water in the bowl.

a. Why does the water not fill up the bottle?
b. All the same, a *little* water does enter the bottle. Why?

18 Particles in rapid random motion

168 Robert Boyle, who lived 300 years ago, carried out many experiments on the pressure of gases, and discovered a famous law that bears his name. In 1661 he read a paper to the Royal Society of London, entitled 'Touching the Spring of Air'.

He supposed that air is made up of tiny particles in contact with each other and surrounded by springs – perhaps nowadays we might think of particles made of foam rubber, or springy steel wool.

a. How, on this theory (picture of gas particles), would Boyle explain the fact that gases can exert pressure?
b. How would Boyle explain the fact that a gas exerts a bigger pressure when you squeeze it to a smaller volume?

Boyle did experiments, and his law came straight from the experiments, but his theory did not fit the facts very well, and we now have a different theory, which explains pressure by supposing there are many tiny particles in motion.

c. How does the particles-in-motion theory explain the fact that gases can exert pressure?
d. How does the particles-in-motion theory explain the fact that a gas exerts a bigger pressure when you squeeze it to a smaller volume?

169 *a.* Describe an 'experiment' you have done with a trayful of marbles which provides a simple working model of particles in gases in motion.
b.
The rectangle, figure 169, represents at ray containing marbles, drawn about one-quarter size. All the marbles are the same size and weight. All are coloured white, except one, which is red. Only the red marble is shown in the diagram. The tray is being shaken. The red marble moves a distance in the direction shown by the little line before it hits another marble. Copy the diagram and draw about twelve more little lines, showing how the marble is likely to move between collisions. Should all these little lines be the same length? Does the colour of the marble make any difference? Or might we equally well be talking about one of the white marbles?

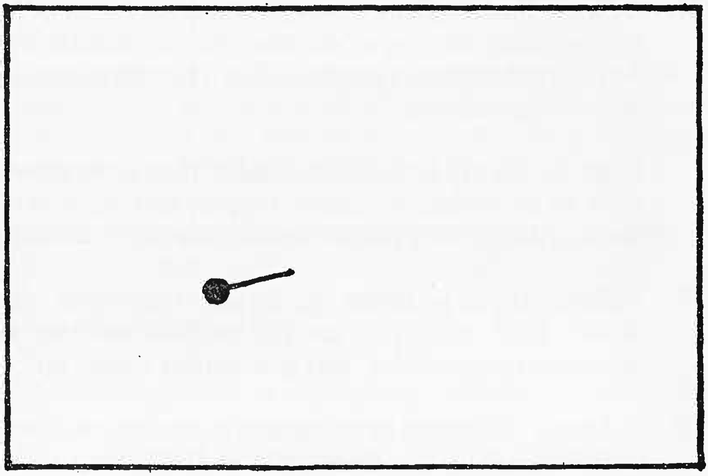


Figure 169

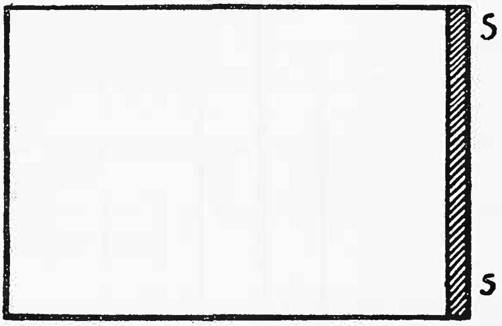


Figure 170
tray with one loosely wedged side SS.
The other sides are firm

170 *a*. Figure 170 shows a tray with one loose side, SS, which has been wedged in, but not very tightly. You put marbles in the tray and shake it gently; nothing much happens. You then shake it more violently; what is likely to happen now?
b. You have an empty can, like a golden syrup tin, with a lid that wedges on, also a gas or electric oven. How would you do an experiment which is just like (*a*), except that you are using air particles instead of marbles, and heating instead of shaking?

171 *Difficult.* Freddie Jones is worried because, he says, 'You have to keep agitating the tray of marbles, else the marbles stop. But you don't have to agitate air squashed in a bicycle pump for it to keep on exerting pressure.'

What do you say to this? (Remember that, if we suppose air particles are in motion, we usually suppose that particles of solids are moving, though they cannot move right away from their positions.)

172 *Difficult.* As you go higher up, the atmosphere gets 'thinner' (less dense). How could you use the marbles and tray to show an 'atmosphere of marbles' that gets thinner higher up?

173 *a.* Among the twenty or so marbles in the tray, you put one larger marble weighing, say, three times as much. How will the motion

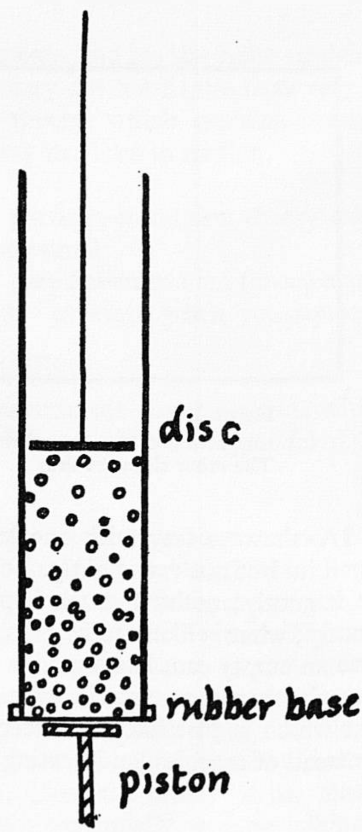


Figure 174

of the large marble differ from the motion of one of the small marbles?

b. Suppose you were looking at an agitated tray which might contain marbles, and you were so far off that you couldn't see the small marbles, but could see a large marble, like that in (*a*). What would the movements of the large marble look like if,

(*i*) as well as the large marble there were small marbles in the tray,
(*ii*) if only the large marble were in the tray?

174 Look at the diagram, 174.

a. When the apparatus is set working, what is the 'rubber base' doing?
b. What, in actual fact, are the black blobs in the diagram?
c. Why does the cardboard disk stay where it is? What is supporting its weight?
d. What happens if a small extra cardboard 'weight' is put on top of the disk?
e. Explain (perhaps to Uncle George) why we bother with this apparatus – that is, what is it meant to show us?

175 *a.* How would we use the apparatus of figure 174 to show a 'model of an atmosphere'?
b. How would we use it to show the motion of a large particle among smaller particles?

176 The experiments with marbles and little balls show that a particles-in-motion explanation of how gases behave *could* be true; but if Freddie or anyone else says that playing with marbles and balls doesn't really prove anything about gas particles you have to agree.

Describe briefly one experiment you did (using a microscope) which really does give support to a 'particles-in-motion' theory of gases, but not to 'sponge-rubber particles-at-rest' theory. Say what you did and what you saw.

177 *Continuing 176.* Why does 'what you saw' lead you to suppose,

a. that air particles (we will now call them 'molecules') are very small,
b. that they are in constant rapid motion?

19 More about molecules in motion

178 Observation (a). Copper sulphate crystals are dropped into water and the water is stirred. Soon the blue colour is spread throughout the liquid.

Observation (b). Someone cooks sausages and chips in the basement of a tall house and leaves the kitchen door open. Soon the smell of cooking is clearly noticeable on the top floor.

Do these observations show that gas and liquid particles are in constant rapid motion? Write two or three sentences in explanation.

Note: Answer questions 179 and 180 *without* saying anything about theories of molecules or particles in motion, in fact, without mentioning molecules or particles at all.

179 *a.* Give a diagram, and a brief description, of an experiment you have done which shows the 'diffusion' of one liquid into another liquid.
b. You could mix the liquids much more quickly by stirring them, but this would not be 'diffusion'. Try to explain what you mean by diffusion of liquids.

180 *a.* Give a diagram, and a brief description, of an experiment you have done which shows the 'diffusion' of one gas into another gas.
b. You could mix the gases much more quickly by stirring them, but this would not be 'diffusion'. Try to explain what you mean by diffusion of gases.

181 Now for the theory!

a. Explain, by using the theory of 'molecules in motion', why liquids can diffuse into each other (question 179).
b. Explain why gases can diffuse into each other (question 180).

182 Even the best of toy balloons 'goes down'. A few days after it has been blown up there is no pressure inside, and most of the gas has escaped ('no pressure' means that the pressure is not above atmospheric pressure). This is because the skin of the balloon has tiny pores through which the gas escapes.

a. Even if the balloon has been blown up with air, it still goes down. Why does not air from outside diffuse in as fast as air from inside diffuses out, thereby keeping the balloon blown up?
b. Three similar balloons are blown up, one with air, one with hydrogen and one with carbon dioxide (hydrogen is less dense than air, and carbon dioxide is denser). Which one would you expect to go down the fastest, and which one the slowest? Try to make up a sensible reason for your answer.
c. (Don't worry about this if you cannot answer it.) Is what you expect, in (*b*), the same as what actually happens?

183 Answer this question only if you have seen the bromine experiment.

Bromine vapour, set free in *air*, slowly diffuses into the air. But bromine vapour, liberated in a *vacuum*, fills the available space so quickly that our eyes cannot follow the movement.

How do you explain this difference?

184 Marbles, dried peas, dry sand and water are poured, in turn, into an empty tin can. We use about the same volume of each, and pour at about the same rate.

a. Describe the kind of noise you hear each time.
b. What (if anything) does this experiment show?

185 Unless a gas is kept in a closed container it spreads out until it occupies (mixed perhaps with other gases) all the space available to it – this is a fact of common observation. There is no container round the Earth's atmosphere, and yet the atmosphere remains without losing pressure from one year to the next – fortunately for ourselves. How do you explain this?

186 *a.* You probably have a very good vacuum in your house – inside a television picture tube. Air has been removed from this tube until a very low pressure is reached. How does the distance between the molecules in the tube compare with the distance between the molecules in the air outside?
b. The picture is made by a stream of 'electrons' which shoot across the tube and fall on the coated screen, thus making it glow brightly. What do you think would happen if a little air leaked into the tube? Give the reason for your answer.

187 *Just for amusement*. This is to find out what being a gas molecule feels like. Go out of your front door, taking a penny with you. Toss the penny; if it is heads, turn right, if tails, turn left. When you get to a place where there is a choice of paths, toss the coin again to decide which to take. If there are more than two alternative paths, at a crossroads, for example, you will have to toss the coin twice in order to make a decision. Notice how you get further from home, but not so far as you would if you walked in a straight line. You are behaving rather like a molecule; each street corner corresponds to a collision with another molecule which may change your direction. The varying distances between one street corner and the next correspond to varying distances travelled by one molecule between collisions with other molecules.

Note: To make a better comparison you ought to include, at each road junction, the possibility of returning the way you came – but this makes it too boring! You will probably decide that being a molecule is not very interesting anyhow.

188 What is 'Brownian Motion' a name for? What experiment have you done which shows real Brownian motion? (Just mention it – do not describe.)

Who was Brown? What was he doing when he discovered Brownian motion? How did he (wrongly) explain what he saw? (This is the sort of question you can answer from books or an encyclopaedia. Answer briefly, and don't spend much time on it.)

189 As a rough model of Brownian motion along one line only, toss a coin and draw a line on paper to the right if it comes down heads, and to the left if it comes down tails. Toss the coin ten times and draw equal lines each time. Go through this procedure several times, and write down how many lines you have moved to the right or to the left each time. (Two examples taken in this way are shown below.)

However, you should make, say, six of your own.
Now answer the following:

a. What is the least distance that could be moved in one set of 10 tosses?
b. What is the greatest distance that could be moved in one set?
c. What is the *average* distance moved in each of *your* sets of 10

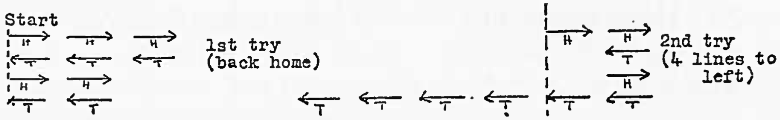


Figure 189

tosses? (e.g. in my set of six, the distances were: 0, 4L, 6R, 2L, 2L, 4R, and the average of 0, 4, 6, 2, 2 and 4 is $\frac{18}{6}$ or 3).
d. Write down and complete the following sentence: 'In this comparison, tossing coins in order to decide which way to go, represents chance bombardment by . . ., which are hitting a larger particle.'

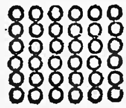
Notice that a 'big jump', corresponding to 8 or 10 moves to the left or right, is very rare, but smaller moves of two or four are common. So it is with particles in Brownian motion.

(There are clearly some important differences between this kind of imitation 'Brownian motion' by coin-tossing, and real Brownian motion. The real motion is along any direction, but this is all along one line. Particles moving with real Brownian motion move all sorts of different distances between one change of direction and the next direction, but in this imitation each 'step' or distance equals every other step.)

190 A 1-kilogram brick is hung on a string in a glass box which is completely closed so that no draughts of air can reach it. The brick is a 'particle' which is being bombarded from all sides by air molecules. Explain in not more than three sentences why we do not observe the brick moving with Brownian motion.

20 How small are atoms (or molecules)?

191

Figure 191 

A small room is 3 metres cube. A ping-pong ball is 3 cm diameter. If the balls are packed as in figure 191 but touching each other:

a. How many balls are required to cover the whole floor with a single layer?
b. How many are required to fill the room?
c. A larger room, which is also square in plan, requires a quarter of a million balls to form a 'mono-layer' as in (*a*). How many balls could be laid along one side of the floor?
d. What is the length of one side of the floor in centimetres? What is the length in metres?

192 Is the method of packing shown in figure 191 (but with the balls touching) the closest method of packing ping-pong balls? Try with coins such as pennies, on a flat surface. What do you find?

Look again at question 191 (*b*): is your answer the *largest* number of balls you could get into the room?

193 One-tenth of a cubic centimetre of gold can be beaten into gold leaf so fine that it occupies a surface 5 metres by 1 metre.

1 cubic centimetre = $\frac{1}{1,000,000}$ cubic metre.

a. What is the thickness of the foil in metres?
b. What is its thickness in centimetres?
c. Is it safe to say that the length of a gold molecule equals our answers in (*a*) and (*b*)? If not, what statement about the gold molecule could we make?

Note: Ordinary commercial 'gold leaf' is about five times thicker than this.

194 *a.* What do you think is the length of the side of the smallest square which, when you see it with the naked eye, still looks like a square? Make a sensible estimate in fractions of a centimetre.

b. With a good microscope you could see a square whose side is only $\frac{1}{1000}$ as long as that in (*a*). If 100,000,000 (10^8) atoms side by side stretch 1 cm, how many atoms are there along the side of the smallest square you can just see through the microscope?

195 What is meant by 'skin effect' in liquids? (Answer in one sentence.) Describe something you have seen which shows 'skin effect'.

196 Here are four sentences saying how the idea, that matter consists of molecules, shows why water behaves as if it had an elastic skin. Copy out the sentences filling in the blanks.

Sentence A. A molecule in a drop of water is
(*i*) . . . by neighbouring molecules close to it, and it is
(*ii*) . . . by neighbouring molecules *very* close to it.

Sentence B. If the molecule is well inside the drop, the effect of the attractions of all its neighbours together is . . .

Sentence C. If the molecule is at the surface of the drop, the effect of the attractions of all its neighbours is to pull . . .

Sentence D. Since the surface molecules are being pulled . . ., the effect is the same as if the water were held in a thin stretched rubber bag or skin.

197 Draw diagrams to show,

a. A water patch on glass. (Water wets glass.)
b. A large water drop and a small water drop standing on wax. (Water does not wet wax.)
c. Why is the shape of the large drop different from that of the small drop?
d. Why is it that raindrops are round, although they are nearer in size to the 'large drop' than to the 'small drop' in question (*b*)?

198 *a.* What happens when a large drop of water standing on wax is given a small 'dose' of wetting agent?
b. A girl brushes her hair with some kind of oil to make it brighter, or lacquers it with stuff to make the hair waterproof. What happens if she holds her head in a shower of clear water? What would happen if the shower already had a little wetting agent added to it?
c. If you try to paint a picture on a toy balloon with ordinary

water-colour paints, the paint will not 'go on' the balloon surface. What could you do to make it go on?

199 Lord Rayleigh found that if he put a drop of olive oil of volume $\frac{16}{10000}$ c.c. on a clean water surface it spread out to a patch of area 1 square metre. He made use of these figures to estimate the length of a molecule of olive oil, but in order to do so he had to make one big assumption.

a. What was this assumption?
b. Make this assumption yourself and calculate the length of the molecule.
c. Chemists tell us that the oil molecule is a long chain of about 12 'atoms'. If we think of the 'atoms' as little spheres, can you now estimate the diameter of a single 'atom'? What value do you find?

Note: To calculate (*b*) remember:
volume = area × height (or length), and that 1 square metre = 100 × 100 = 10,000 square centimetres.
If you work in cubic centimetres and square centimetres your answer will be in centimetres.

200 Tell Uncle George how you found the length of an oil molecule. Tell him first, how you did the experiment. Then give your own measurements or make up some possible measurements – and show how, from them, you calculate the molecular size.

21 Fuels, foodstuffs, and energy changes

201 Here is a list of ten 'jobs' done by living and non-living things. Which of these is a 'fuel-using' job, and which requires no fuel?

a. A man hoisting a sack of potatoes off the ground on to his back.
b. Pillars holding up a roof.
c. Air molecules in motion, in the room where you are sitting.
d. A piston moving in and compressing air.
e. A man winding a clock spring.
f. A clamp tightly holding a piece of wood.
g. A refrigerator keeping things cold on a hot day.
h. Water keeping a boat afloat.
i. A bus moving along a horizontal road on a windy day.
j. A man or a computer doing sums.

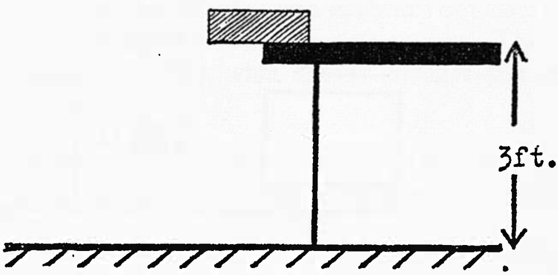


Figure 202

202 A 5-lb brick (figure 202) rests on the edge of a table 3 feet above floor-level. Because it is above the floor it can do a job as it falls to the floor: we say it possesses energy-due-to-being-higher-up, or more simply, uphill-energy.

a. Could the brick do a bigger job if it were resting on the top of a 6-foot-high bookcase? How much bigger? What would you say about its uphill-energy?
b. Suppose there were a hole in the floor, exactly beneath the brick which is 6 ft up, as in (*a*), and that the room beneath was 9 ft high. How would the energy which the brick loses, in falling to the floor of the room beneath, compare with the uphill-energy it had on the table in figure 202?
c. Do you think you could increase the uphill-energy of the brick by cutting a hole in the floor? Answer 'yes' or 'no' and give the reason for your answer.

203 An engine pumps water from a lake to a high reservoir. To raise 200 gallons of water 300 feet above the lake the engine uses up (burns) one pint of diesel oil.

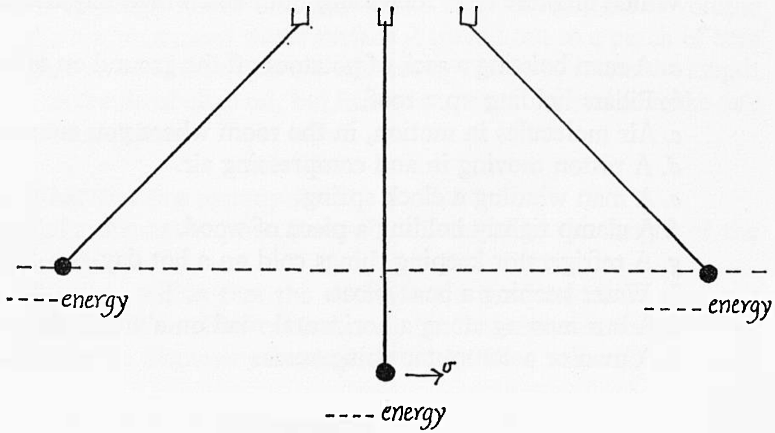


Figure 204(a)

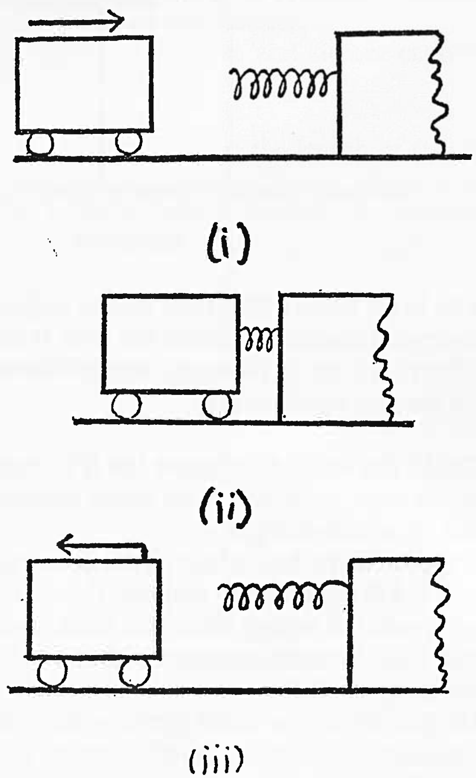


Figure 204(b)

a. How many pints of oil would be required to pump 400 gallons to a height of 300 feet?
b. How many pints to pump 200 gallons to 600 feet?
c. How many pints to pump 400 gallons to 600 feet?
d. How many pints to pump 600 gallons to 450 feet?
e. If 1 gallon of water weighs 10 lb, how many foot-pounds of energy does the engine provide when it uses 1 pint of fuel?
f. Not *all* the energy of the fuel goes into raising water. Suggest two or three ways in which energy is 'wasted'.
g. In what form does wasted energy finally appear?

204 *a*. The diagrams show three positions of a swinging pendulum bob, the two extreme positions on either side, and the central position where it is moving with the maximum speed v. Each diagram is drawn to represent either motion-energy or uphill-energy. Copy the diagrams and write in the correct word in each case.
b. Similarly, copy each of the three diagrams opposite and label it either 'motion-energy' or 'compression energy'. Then write two or three sentences telling what energy changes take place when 'truck hits buffers'.

205 What has happened to the man and the rope and the weight is clear enough. You are asked to write four sentences explaining the *energy changes* that have taken place.

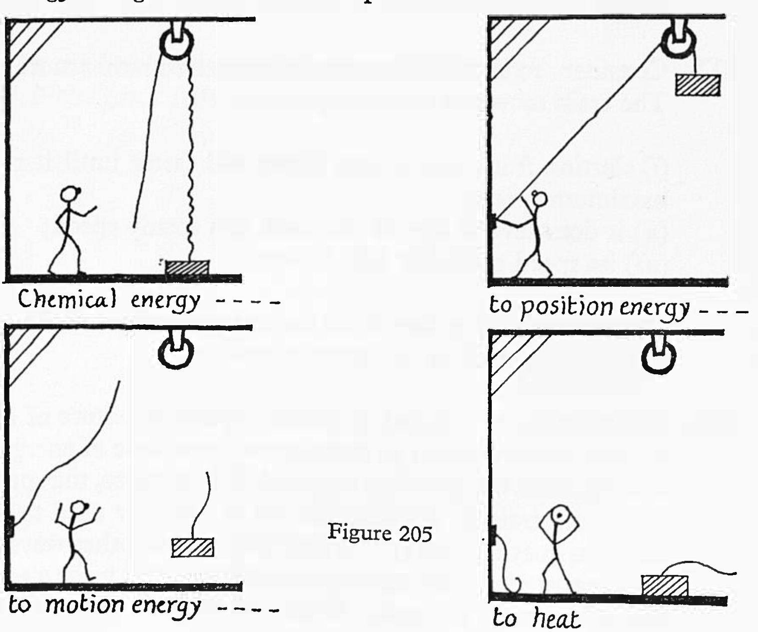


Figure 205

206 When jobs are done, energy is converted from one form to another. Often there is a sequence of several changes. As an example, when an electric bell works from a battery:

Chemical energy in the battery ⟶ electrical energy ⟶ mechanical energy in the vibrator ⟶ sound energy (and heat energy in the gong).

Copy out the following 'jobs' and underneath write the corresponding energy changes.

a. A match is burnt in air.
b. A falling weight spins a dynamo which lights a lamp.
c. Methylated spirits burns in a model steam engine, which drives a generator, which lights a flash-lamp bulb.
d. A fast-moving car is brought to rest on a level road by use of the brakes.
e. You wind up a clockwork train and then allow it to run round the track until it comes to rest.
f. An archer shoots an arrow into a distant target.
g. A cricketer in the outfield throws in the ball, which is caught by the wicket-keeper without it bouncing.
h. Light falls on a photographer's exposure-meter and the needle moves across the scale.

207 Consider section (*e*) of the previous question rather more carefully. The train moves in three stages:

(*i*) starting from rest it goes faster and faster until it reaches its maximum speed;
(*ii*) it does several laps of the track at a steady speed;
(*iii*) its speed gradually falls to zero.

Write a sentence or two about the energy changes which are taking place during each of the three stages.

208 Ordinary fuels, like coal or petrol, represent a store of energy. It is often convenient for us to make our own store of energy in some suitable form for use when required. For instance, the spring of the clockwork train in question 206 (*e*) or the bow used to shoot the arrow in question 206 (*f*). Try to think of two other ways in which we store up energy for our own convenience, and write a sentence or two about each example. There are at least two very common

examples, and other less well-known ones which are becoming very important. (If you cannot think of examples, you can choose from four given at the end of this Book, after question 218.)

209 Write out the following statements, filling in the blanks with the words 'work' or 'energy' according to which you think is correct.

a. 'Fuels are stores of usable . . . which men and machines use when they do some kinds of useful jobs, e.g. lifting weights.'
b. 'The product (force) $\times$ (distance moved) is called . . .'.
c. '. . . shows the amount of . . . transferred from one form to another form or from one place to another place'.

210 *Difficult.* Imagine a hole has been made right down through the centre of the Earth and out to the other side. What do you think would happen if you released a brick and allowed it to fall down the hole? Give two answers, saying what would happen:

a. if the Earth were like the Moon and had no atmosphere (air) at all,
b. if the hole is full of atmospheric air.

(You can assume that the brick does not touch the sides of the hole.)

Also say what *energy changes* take place;

c. if the brick falls into an empty hole as in (*a*),
d. if the brick falls into a hole full of air as in (*b*).

22 Measuring energy transferred

211 You pick up a book, which weighs 2 lb, from the floor and lift it on to a shelf 5 feet above the floor. By accident, the book is gently nudged off the shelf and falls back on the floor again. Copy the following statement, describing the energy changes that take place, and fill in each blank with a correct choice of one of the following words:

'Chemical-energy, heat, foot-pounds, motion-energy, uphill-energy'.

Some of the words are used twice.

'When I lift the book on to the shelf I transfer 10 .... of .... into .... When the book falls down again, the energy is changed from .... to .... After the book hits the ground, the .... has been changed into ....

212 Freddie drags a 56-lb sack of potatoes across the floor, and to do this he pulls the sack with a horizontal force of 22 lb. He moves the sack 15 feet. How much energy does he transfer into heat? Where does he get this energy from?

Uncle George then lifts this same sack on to a shelf 6 feet above the floor. How much energy does he transfer when he lifts the sack? What name do we give to the final form of this energy, that is, when the sack is on the shelf?

How is it that Uncle George needs to transfer more energy in moving the sack 6 feet than Freddie does in moving it 15 feet?

213 WORK is the name we give to the quantity of energy transferred from one energy form to another. In question 212 it is easier to ask, 'How much work does Uncle George do in lifting a 56-lb sack up a height of 6 feet?'

a. Suppose Uncle George lifts 60 sacks each weighing 55 lb (*not* 56) up a ladder 10 feet high, how much work would he do altogether?
b. A strong horse is supposed to be able to do 550 foot-pounds of work in a second, when it is working at the fastest rate it could keep up for a short time. In fact, 550 foot-pounds is a rate of working we call '1 horse-power'.

Suppose the horse is used by Uncle George to lift the sacks, how long would it take to lift 60 sacks? Give the reason for your answer. (You may assume that the horse is used to operate some suitable piece of 'sack-lifting-machinery' and that no energy is wasted in the machinery. In actual fact it would be difficult to devise such machinery, and energy would certainly be wasted in using it.)

c. Of course, Uncle George does not buy a horse, he buys a 'fork-lift truck'. Now he does not get so tired, and might save something on food, but he has to pay for something else – what else? (That is, in addition to the money he paid for the truck itself.)

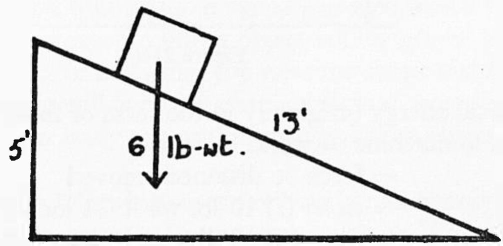


Figure 214(*a*)

214 Energy transferred, or work, is calculated from (force) × (distance moved). But we must be careful about 'distance moved'. Here are two problems with two answers, one right and one wrong. Show that you understand what is meant by 'distance moved' by writing down the *right* answer to (*a*) below – is it 78 or 30 foot-pounds? Then say why it is right and why the other answer is wrong. Then do the same for (*b*).

a. A boy pushes a 6-lb block to the top of a very smooth slope 5′ high and 13′ up the incline (figure 214 (*a*)). He then lets it slide down the full 13′.

Uphill-energy transferred to motion energy = work
= force × distance moved
= *either* (*i*) 6 lb. wt × 13′ = 78 ft. lb. wt.
or (*ii*) 6 lb. wt × 5′ = 30 ft. lb. wt.

Now do the same for (*b*): say which answer is *right*, and say why it is *right* and why the other answer is *wrong*.

b. The rider of a bicycle pushes the pedal from 'top dead centre' to 'bottom dead centre' with a steady push of 10 lb. wt all the time. The length of the pedal crank is 7 inches.

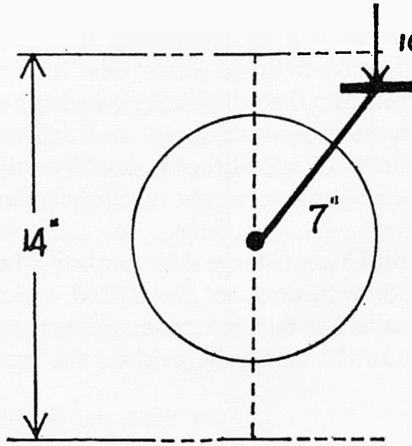


Figure 214(*b*)

Chemical energy (originally in the form of food) transferred from cyclist to machine = work.

= force × distanced moved
= *either* (*i*) 10 lb. wt × 14 inches = 140 in. lb. wt
or (*ii*) 10 lb. wt × semicircular distance through which the pedal moves
= 10 lb. wt × $\frac{1}{2}$ (2 × $\frac{22}{7}$ × 7) in
= 220 in. lb. wt.

Now write the following sentence and add a few words at the end in order to make quite clear what is meant: 'Work (energy-transfer) is equal to the product of force and the distance moved . . .'

215 A man uses a long plank to lift a heavy load. He arranges the plank across a pivot (as in the diagram).
By pushing downwards with an effort of F, he can just lift a load of 200 lb. wt.

a. How big must the effort F be?
b. How many times bigger than the effort is the load?
c. If the plank swings on the pivot so that the effort moves down

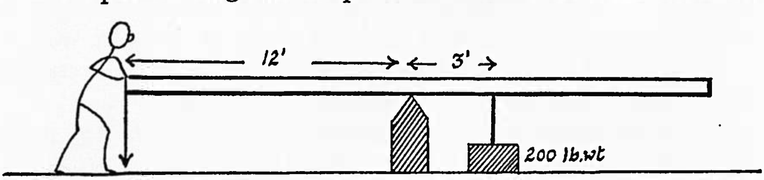


Figure 215

1 foot, how much energy is transferred from the man to the plank?
d. How far is the load raised?
e. How much energy is transferred from the plank to the load?
f. A gain of force is found in (*b*). Is there any gain or loss in energy?

216 If the pivot of the plank (in question 215) were in the form of a rather rusty steel rod fixed to the plank and running in holes in two rusty steel plates, what difference would it make to the above answers? Take each answer in turn and guess some suitable figures. What is now your answer to (*f*)?

217 Scientists use a unit of force called a *newton* which is roughly the force you must exert to lift an object which weighs 100 gm. If, by exerting a force of 1 newton, you raise the object through a distance of 1 metre, you will have *transferred 1 joule of energy* from chemical energy in your body to position-energy in the object.

In each of the following cases say how big an energy change takes place and what happens in sentences, such as, '25 joules of uphill-energy are transferred to motion-energy'.

a. An object which the Earth pulls with a force of 7 newtons falls through a vertical distance of 3 metres.
b. A man lifts an encyclopaedia (force acting on it 50 newtons) from a table of height 0·8 metre ($\frac{8}{10}$ metre) to the top shelf of a bookcase at height 2 metres.
c. A man pushes a car with a force of 300 newtons causing it to move steadily along a horizontal road for a distance of 50 metres.
d. A 110-lb boy falls from a height of 12 feet on to a trampoline (a kind of spring mattress) and rebounds to a height of 6 feet. In this case make estimates of the energy changes (in joules) using rough equivalents between the English and the scientific units.

218 A 70-kilogram man climbing a mountain can climb 500 metres vertically in one hour.

a. How much uphill-energy (in joules) does he gain in four hours' climbing?
b. Assuming that the human body is capable of changing one-quarter of the chemical energy drawn from a man's own supply into useful mechanical energy delivered by the muscles, how much chemical energy does he use up in four hours' climbing?

c. How much extra heat energy does he have to get rid of in four hours, as a result of climbing? (This is in addition to the heat energy he would have lost had he stayed still all the time.)
d. He will have to make up for the chemical energy used up (answer *b*) by eating more food. Yet, when he walks down the mountain he loses all the uphill-energy he gained. Why, then, does he need extra food for mountain climbing?

Note : *Suggested 'examples' for question 208*

Winding up the mainspring of a watch.

Raising the weight of a grandfather clock.

Using energy from an accumulator battery to turn the starter-motor of a car.

Operating a pile-driver, i.e. using a diesel engine to raise the weight used to drive in the 'pile'.

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