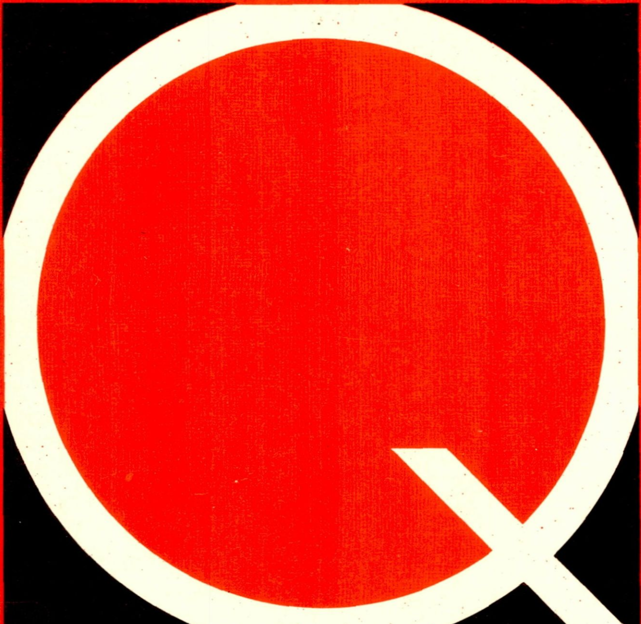
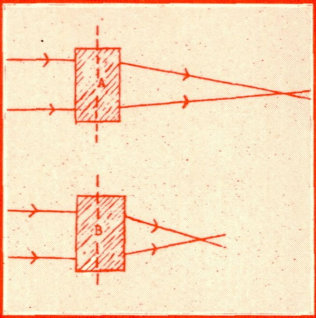
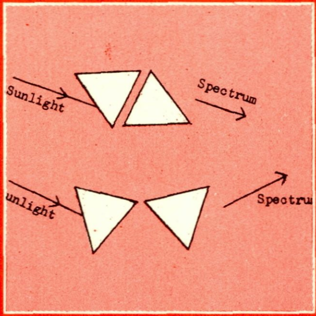
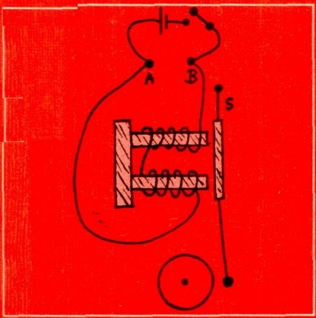
PHYSICS

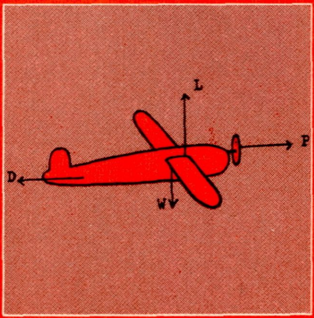
Questions book III

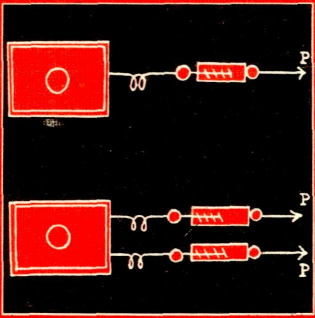












Nuffield Physics
Questions Book III

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Nuffield Physics Questions Book III

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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.

In some places you will come across Uncle George and Freddie Jones. Most of you will think they are awful nuisances. Some of you will think that they ought not to be introduced into anything so solemn as physics questions. They have their uses!

Uncle George is intelligent and interested, and has time to spare, but he knows very little physics. He certainly didn't do any physics at school; he was on the classics side, and when he was a boy the classics side did no science. So, you see, he is *not* an examiner who knows all the answers and is waiting to trip you up. He understands what you say if you tell him simply and shortly, and don't lead him astray with 'red herrings'. He is also quite willing – perhaps rather too willing! – to suggest new ideas of his own, sometimes rather 'off-beat'.

Freddie is your own age. He is ingenious and moderately sensible, though you will often be able to put him right about things. He also is liable to have off-beat ideas.

1 Introduction to waves

1 One example (A) of wave motion (moving waves) is given in the table below, together with:

the way it is started,
what it is that oscillates,
whether it oscillates *at right angles to* the direction of wave travel or *along* the direction of wave travel.

Copy Example A and add two other examples, B and C. Do *not* include sound or light.

	Example A	*Example B*	*Example C*
Wave:	stretched string		
How set up:	plucked sideways		
What oscillates:	particles of string		
Oscillation direction:	at right angles		

2 There are two ways by which you can communicate with another person; two ways of sending him a 'signal'. Either you can use a material object which travels between you, e.g. you can touch him, or attract his attention by throwing a stone at him, or send him a letter. Or you can communicate by means of some form of wave-motion.

Suggest some means by which you could communicate with someone else by using, in turn, the two wave-motions (Examples B and C) you mentioned in answer to question 1. (Note that these do *not* include sound and light.) Your answer should give an indication of the apparatus you would use (however crude) and how you would send a message (however simple).

3 You make a small cork, floating on water, bob up and down so that ripples (small waves) are started. The cork is a material substance and so is the water. Are the waves material objects? Answer yes or no, and write a sentence or two in defence of your answer.

4 A *pulse* is a wave of very short duration, for example, you slam the door and the window curtains flutter, or a vase falls off the mantelpiece.

a. How could the driver of a shunting engine demonstrate a pulse along a train of goods wagons? Say what happens to the wagons.
b. How could you demonstrate a pulse, given a flat table and a number of pennies? Say what happens to the pennies.
c. How would you demonstrate a pulse in which the wave-movement is *at right angles* to the direction the pulse travels?

5 *a.* How would you show that two water waves or ripples can cross each other, or pass through each other?
b. How would you show the same thing happening in a stretched spring, such as a 'slinky'? You may assume that another person is available to hold the other end.

6 What happens when two balls are rolled in opposite directions along a grooved plank so that they meet head-on? How does this differ from two waves meeting head-on, as in question 5?

7 You hold one end of a slinky spring, and the other end is fixed in a support. You send a pulse down the spring; what happens when the pulse reaches the fixed end, and afterwards?

How would you show the same thing happening when a stone is thrown into still water? Give a diagram of what would be seen.

8 A stone is dropped in water. Ripples spread farther and farther, get smaller and smaller in height, and finally vanish. Why do they get smaller (two reasons)?

9 A slinky spring hangs vertically with the lower end fixed to the bench. A pulse sent down it from the top is reflected and goes back up. What difference would it make if the lower end were loose and immersed in water? What if it was immersed in thick treacle?

2 Time intervals

10 Let us find how good you are at estimating a time interval of half a minute. Check your time sense by using the following procedure in estimating an interval of 30 seconds – you will need a watch or clock with a seconds hand.

Look at the seconds hand while 30 seconds go by, so that you get a preliminary idea of what 30 seconds 'feels like'. Now shut your eyes and open them when you think that 30 seconds have passed. Notice the time on the seconds hand as you close and open your eyes. How many seconds were you in error?

Repeat this six times more, and make a list of the errors you made in the seven estimates.

a. Do you think the results show that you are getting better, or getting worse, at estimating 30 seconds?
b. What was your *average* error in the last five estimates you made?

11 Seconds of time may be counted by saying 'Mississippi 1, Mississippi 2', . . . each syllable being clearly said at normal speed.

Use this method to count 30 seconds. Do it five times, and compare the average error in the five counts with the average error you found in question 10 (*b*) above. Is this method an improvement?

12 A simple pendulum consists of a small bob attached to a light thread about a metre long. The other end of the thread is clamped between two pieces of wood. The time for 100 complete swings is found to be 184 seconds (one swing is from one extreme position to the other *and back again*). What is the time taken for 1 swing? For $\frac{1}{2}$ a swing? For $\frac{1}{4}$ of a swing? Why would the time for one-eighth of a swing *not* be half that for one-quarter?

13 A stick of wood, about a metre long, has a hole near one end. The stick is suspended through the hole and allowed to swing. Suggest a method of finding by experiment the length of the simple pendulum (see question 12) which has the same time of swing as the stick. Give a sketch of the apparatus you suggest.

14 Here is a way of making a simple water-clock for measuring short time intervals. Obtain a tin can (e.g. a fruit tin) and, if necessary, remove the top of the can completely with a tin-opener. Punch a small hole in the bottom of the can with a nail and hammer. Fasten the can over a sink so that the water in the can can be kept up to a fixed mark scratched inside the can near the top. You can pour in water from a jug, or use a tap over the sink. There must be room under the can for a measuring cylinder to be held underneath.

a. How could this arrangement be used to measure time intervals of a few seconds?
b. Keeping the water level up to the mark is an awful nuisance. Suggest a modification which would avoid this trouble.

Note: A large number of questions on stroboscopes, etc., follow (15–28 below) *not* in order to make stroboscopes seem very important but only to offer a choice of questions.

15 You have a disk which can rotate on a handle (a stroboscope disk), and the disk has just *one* slit in it.

a. What do you see if you rotate the disk *twice* per second and look 'through it' at a car travelling along a straight road some distance away?
b. If the car travels at 30 mph (which is 44 feet per second), how far does it travel between each 'glimpse' that you get?
c. Suppose the disk is speeded up so that it rotates *four* times per second, what is the time interval between each glimpse, and how far does the car travel between each glimpse?
d. If you have *two* slits in the disk, at opposite ends of a diameter, and still rotate it *twice* per second, the result is just the same as in (*c*). Why is this?

16 A spoked wheel has *eight* spokes, and it rotates *once* per second. It is viewed through a stroboscope disk that has *one* slit and rotates *once* per second. The wheel appears to be stationary.

a. Why does the wheel appear stationary?
b. If the stroboscope disk rotates *eight* times per second, the wheel also appears stationary. Why?
c. Difficult. The wheel also appears stationary for disk rotations of *twice* and *four times* per second. Why is this?

17 A stroboscope disk has twelve slits and rotates 75 times in 15 seconds.

a. How many times does it rotate in 1 second?
b. How many glimpses through the slits does it give in 1 second?
c. What is the time interval between each glimpse?

18 Suppose you want to use the same stroboscope disk (question 17) to give a time interval *twice* as long as that in 17 (*c*). What alteration would you make to the *disk*? How could you double the time interval without altering the disk in any way?

19 A ball rolls in a straight line along a level table with a speed of 120 centimetres per second. It is viewed through a stroboscope disk having 10 slits and rotating 3 times per second.

a. How many glimpses of the ball do you see in 1 second?
b. What is the time interval between each glimpse?
c. How far does the ball travel in this time?

20 Suppose that, instead of looking at the rolling ball (question 19), you took a camera photograph of it through the stroboscope disk. You leave the shutter of the camera open while the ball rolls. Draw a diagram showing what the picture looks like, and explain briefly why it looks like that.

21 The distance the ball moves between successive glimpses is observed, in another experiment, to get smaller and smaller from one to the next. This might be due to:

1. the ball slowing down,
2. the ball speeding up,
3. the disk slowing down,
4. the disk speeding up.

Which of these statements, 1, 2, 3 and 4, could be correct? Explain why (two sentences).

22 A wheel has eight identical spokes. It is viewed through a stroboscope disk with 10 slits. When the disk rotates 4 times a second, the wheel appears to be at rest.

a. How many glimpses of the wheel are seen in 1 second?
b. What is the time interval between each glimpse?
c. What is the *longest time* the wheel can be taking to make one complete rotation?
d. What is, therefore, the *least rate* of rotation of the wheel? (Answer in rotations per second.)

23 Suppose the wheel (question 22) continues to turn at the same speed, but the stroboscope disk is slowed down slightly, what do you see now? Explain why.

What do you see if the stroboscope disk is slightly speeded up from the rate of turning which kept the wheel apparently stationary? Explain why.

24 If the wheel (question 22) rotates at *twice* the 'least rate' the spokes again appear stationary, why is this?

25 Suppose the wheel (question 22) had a single white mark on the rim. The stroboscope is rotating at the least speed which makes the spokes look at rest. The white mark is *not* visible. Why not?

What is the least rate of rotation of the stroboscope disk if the white mark is seen, and appears stationary?

26 Each wheel of a motor-car has four similar spaces or gaps between the centre part of the wheel and the rim which carries the tyre. These four gaps look exactly the same, and are equally spaced round the wheel.

A cinematograph film is taken of the car as it moves away from rest. When the film is projected the car wheels appear first to turn normally, but then, as the car speeds up, the wheels seem to be turning backwards, then they come to rest and stop. As the car moves faster, the wheels appear to turn slowly forward again. This curious appearance is something you must have noticed frequently if you see many cinema films.

a. How do you explain this 'curious appearance'?
b. If the film runs through the camera so that 24 pictures are taken every second ('24 frames per second'), what is the actual speed of rotation of the wheel when it first appears to be stationary, though the car is moving?

27 The games master at a school wishes to take 'slow motion' pictures of pupils while they are batting, bowling, jumping, running, diving, etc., in order to help them to correct faults. He has a film projector which runs at 16 frames per second, and a film camera whose speed can be varied. He says that he wants to show pictures at half actual speed, and to do this he proposes to set his camera for 8 frames a second instead of 16. Is he right? If not, what would you tell him to do? Explain why you are right and he is wrong. What would happen if he did it his way?

28 An astronomer is making a special study of the surface of the Sun, and he wishes to make a film showing changes in the Sun's corona – that is, the region outside the surface which may contain great quantities of red-hot gases, ejected from the surface, rising many thousands of miles, and falling back. One particular sequence will show in three minutes changes that actually take three days. The film will be projected at the rate of 16 frames per second. How frequently must photographs be taken in order to compress three days into three minutes?

3 Ripple tanks

29 *a.* Ripples formed by water drops dropped into the ripple tank are 'emitted' in all directions and appear to be circular. Suggest some way of testing whether they really are circular to an accuracy slightly higher than that possible simply by looking at them.

b. Ripples are formed by a 6-inch ruler held horizontally and dipped into the surface. Are these ripples circular? Are they straight? Draw a diagram of their shape as seen from above.

30 *a.* How would you show, by using a ripple rank, that two waves pass through each other without change?
b. What happens when ripples arrive at a sloping 'beach' in the tank? What would be a similar effect with waves in 'slinky'?

31 The sloping line from A in figure 31 (*i*) represents a part of a straight ripple produced by a straight vibrator. The left-hand side of this part of the ripple has just reached a point A on a straight reflecting surface in figure (*i*). A little later the right-hand side will reach B. The angle between the ripple crest and the reflector is 25°.

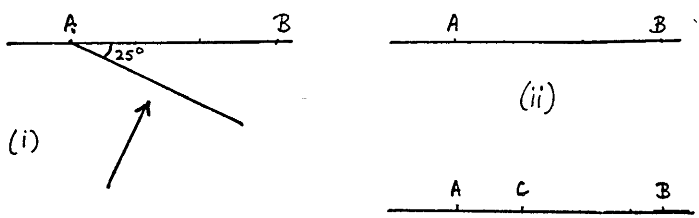


Figure 31

(iii)

Draw another diagram, (*ii*), showing the position of the ripple crest when the right-hand side has reached B, and mark on it an angle which you know is equal to 25°.

Lastly, draw a third diagram, (*iii*), showing the position of the ripple crest when it has just reached C, that is, before it has got as far as B.

32 There is, in figure 31 (*i*), a dotted line representing the direction in which the wave front travels. Draw another diagram, figure 32, showing this line and a line at right angles to the reflecting surface. Add to it the line showing the direction of travel of the reflected ripple, and mark in *two* angles on the diagram which each equal 25°.

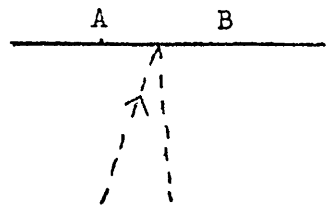


Figure 32

33 Figure 33 (*i*) represents a circular ripple diverging from a source at O. It has just reached a reflecting surface MM.

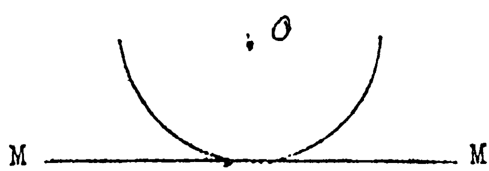


Figure 33 (*i*)

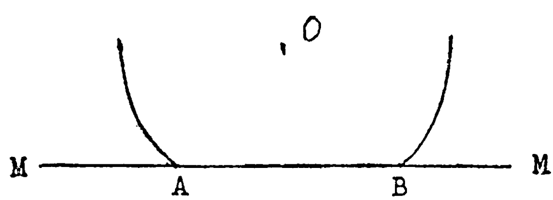


Figure 33 (*ii*)

A little later the ripple has reached the position shown in figure 33 (*ii*). Copy this diagram and draw in the position of that part of the ripple which has already been reflected between A and B.

If you think that this reflected part is circular, on what point would you expect the circle to be centred? Mark in this point on your diagram. What can you say about the distance of this point from MM, and the distance of O from MM?

34 A boy set up a vertical flat 'wall' across a ripple tank, and then, by dropping in drops of water at *two* places, x and y, at the same time, he made the ripple pattern shown in figure 34.

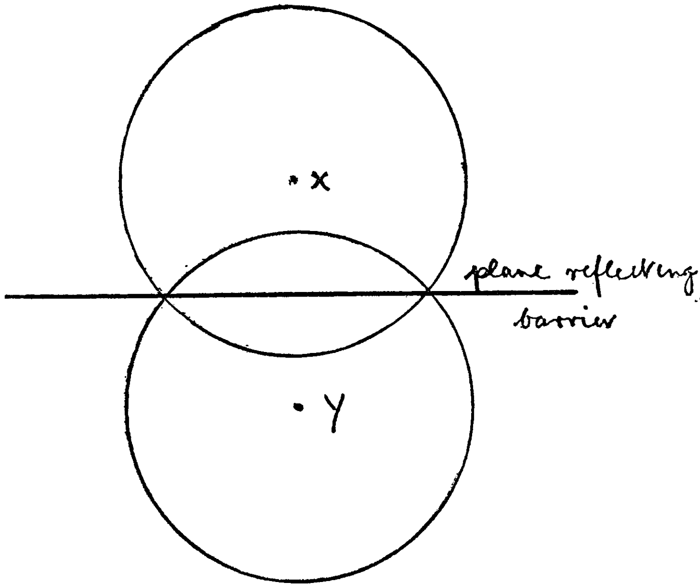


Figure 34

a. What can you say about the distances of x and y from the wall?
b. Copy figure 34, then draw over it with a coloured pencil (or ink) the ripple that came from x. If you have another colour, colour differently the ripple that came from y.

35 *a.* If x (figure 34) is the 'object' point, that is, the place from which a wave started, why may y be called the 'image' point?
b. If y (figure 34) is the 'object' point, why may x be called the 'image' point?

36 *a.* Describe a simple stroboscope such as you have used with a ripple tank.
b. Explain how it is that ripples seen through a stroboscope can be made to appear to be at rest.
c. A stroboscope is rotating at the correct 'no motion' speed. What would be seen if the rotation is (*i*) speeded up slightly, (*ii*) slowed down slightly?

37 'The distance between the crests of the two neighbouring ripples (or between the troughs) is the ——— of the ripples.'

'The number of ripples passing a given point in a given time is the ——— of the ripples.'

Write out the above sentences, filling in the two blanks. If we use a centimetre rule and a watch measuring seconds, in what units would these quantities be measured?

38 *a.* Given a stroboscope, a centimetre rule and a seconds watch, how could you find the wavelength and the frequency of ripples in a ripple tank?
b. How would you *calculate* the velocity of the ripples?
c. How would you *measure* the velocity of the ripples, if they travel fairly slowly?

39 Figure 39 is a diagram of a set of straight ripples in a tank.

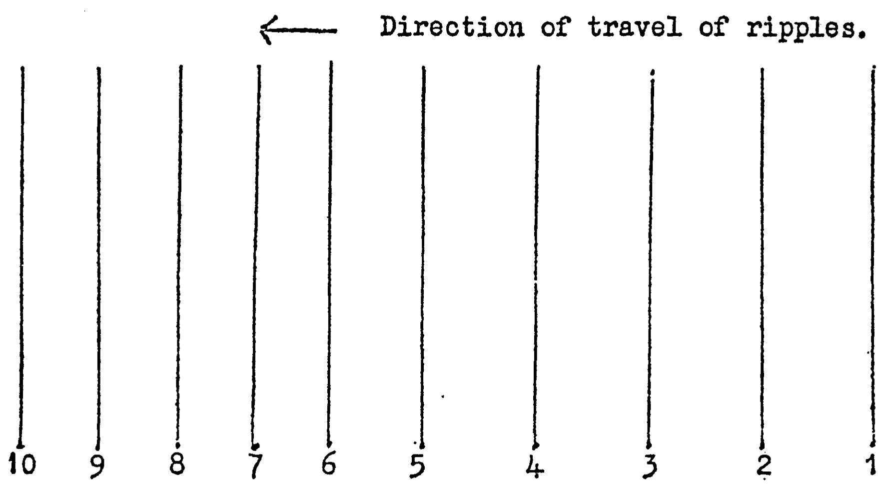


Figure 39

The ripples came from a vibrator on the right of the diagram. They appear in the positions shown when a stroboscope is used to make the ripples appear to be stationary. A flat glass plate rests on the bottom of the tank and makes the water above the plate shallower; the ripples are parallel to the edge of the plate.

a. Where is the edge of the plate situated? (I.e. is it between positions two and three, or eight and nine, or between which two positions?)
b. Is the plate on the right or the left side of the diagram?
c. What can you say about the frequency of the ripples on the right and on the left (remember that the stroboscope holds all the ripples apparently stationary at *the same time*)?
d. What is the wavelength on the right? (Measure on the diagram.)
e. What is the wavelength on the left? (Measure on the diagram.)
f. If the velocity of the ripples is 21 cm per second on the right, what is the velocity on the left?

40 Figure 40 shows, in diagrammatic form, a straight series of ripples proceeding from a vibrator at the lower edge of the paper. The tank contains a straight-sided plate which causes the water above it to be shallower.

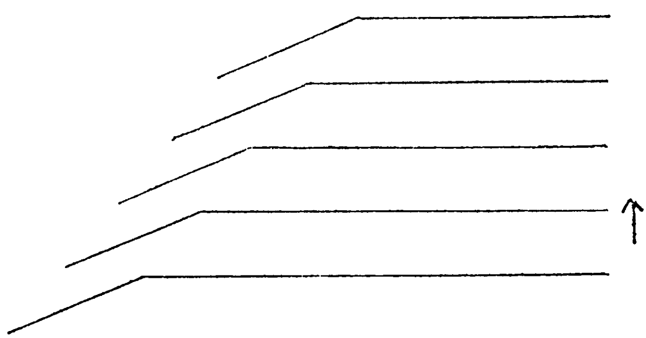


Figure 40

a. Where is the edge of the plate situated?
b. Find, by measurement on the diagram, the wavelength in the shallow part.
c. Find by measurement the angle through which the ripples have turned when they entered the shallower medium.
d. Draw lines showing the direction of travel of the ripples in each part of the tank.
e. What is the angle between the direction of travel of the ripples in the deeper water and the direction in the shallower water?

41 The diagrams on the next page represent three kinds of obstacles placed, one at a time, in a ripple tank. In each case a straight vibrator is situated towards the bottom of the paper, and a series of straight ripples arrive at an obstacle.

a. Figure 41 (*a*) shows an obstacle with a single very small hole. A ripple falls on the obstacle and the hole. A little later it has travelled a further distance of 3 cm. Sketch in the position of this ripple (use compasses if you like).

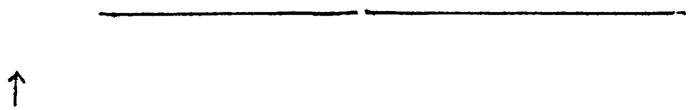


Figure 41 (*a*)
one small hole

b. is a hole 5 cm wide. Sketch in roughly what you think would be the approximate shape of a ripple which has travelled 3 cm from the hole.

Figure 41 (*b*)
one large hole

c. is a series of 11 holes, the two furthest being 5 cm apart. Treat each one as a single small hole, as in (*a*), and show how the ripples are situated when they have travelled 3 cm.

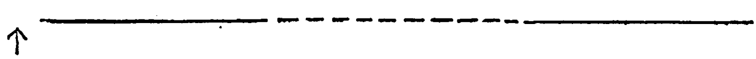


Figure 41 (*c*)
eleven small holes

d. Is there any conclusion, or new idea, that can be drawn from this exercise? Explain (in one or two sentences).

42 A single vibrator has the vibrating tip immersed in a ripple tank, and circular ripples are formed in the usual way. A second vibrator is then added, about 5 cm from the first. The two vibrators move up and down together, that is, they are 'in phase'. Describe briefly (adding a diagram if you can) the ripple pattern produced by the two vibrators together.

43 *a*. Supposing the same thing (question 42) happened with light, in exactly the same way, what would be the effect observed? (For example, if the two vibrators were replaced by two flash-lamp bulbs, and if the tank were replaced by a sheet of white paper.)
b. Would you expect that any such effect, with the bulbs and the paper, would actually be observed? Why not? (Give a practical answer, e.g. 'I've tried it and . . .', or 'I've seen something similar and . . .', or give a theoretical reason, or give both.)

4 Cameras: pinhole and lens

44 The diagram shows a candle placed in front of a sheet of metal with a very small pinhole P. At an equal distance on the other side of P is a waxed-paper screen W.

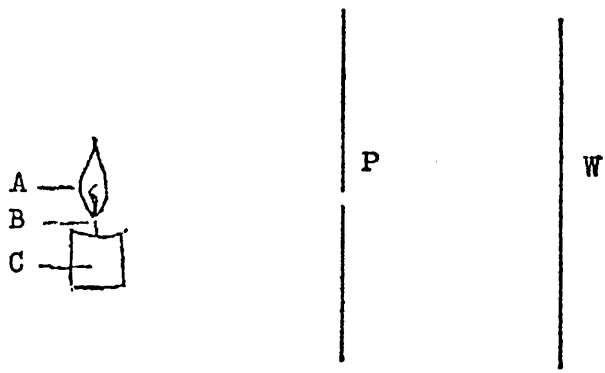


Figure 44

A is a bright yellow point in the flame; B is an almost dark point on the wick, emitting very little light; C is a fairly bright point on the white wax. Copy the diagram and draw single lines from A, B and C to represent rays coming from these points, passing through P, and arriving at A′, B′ and C′ on the screen.

a. In drawing this diagram, what have you assumed about rays of light?
b. What does the diagram lead you to predict about the image on the screen (i.e. what would it look like, and what size)?
c. Does this prediction agree with the observations you have made when doing pinhole camera experiments?

45 Refer back to the diagram, figure 44. What difference in the image on the screen would you expect if:

a. the screen W is moved closer to P,
b. W is moved farther from P,
c. there are *two* pinholes instead of one,
d. there is a single pinhole, but it is twice as wide?

46 You walk under trees on a sunny summer day; the leaves are sharp and angular in shape. There are light patches on the ground where sunshine gets through chinks between the leaves. These patches are round and blurred at the edges. Why is this?
b. During an eclipse of the Sun the light patches under trees are different in shape. What shape would you expect them to be for an eclipse that cut the Sun from a full circle to a crescent like a new moon? Why?

Note about lenses: You should look through several *lenses* – those that make close-up things look bigger, and those that make things look smaller. Feel them, feel their shapes (then clean them again with something soft and don't feel them any more; it's not good for lenses!) The *magnifying* lenses are thicker in the middle than at the edges; they are called CONVEX or POSITIVE lenses. The diminishing ones are called CONCAVE or NEGATIVE lenses. Later we shall find that the real reason for this is that when the 'power' (or 'strength') of the first kind of lens is measured it is given a PLUS sign, while the other sort is given a MINUS sign. (We could just as well have arranged it the other way round, but this seems more sensible.)

A piece of flat glass does not magnify or diminish, it is equally thick at all places, and its 'power' is zero.
We shall also find that a positive lens *converges* light, that is, bends it inwards, while a negative lens *diverges* light, that is, bends it outwards. So we have,
POSITIVE LENS also called CONVEX or CONVERGING
NEGATIVE LENS also called CONCAVE or DIVERGING.

So you may find three different names in use for each kind of lens. In this book we shall usually say POSITIVE or NEGATIVE, though the other names may sometimes be used.

47 *a.* A pinhole camera has five pinholes in a line, instead of one. Draw a diagram like figure 44, but with five pinholes, and draw rays from the point A, through each of the pinholes, to show the five positions of images of A on the screen.
b. Now suppose you have a positive lens placed in front on the five pinholes in (*a*) above, with its centre opposite the central pinhole of the five. Draw rays from A, through the lens, and through the pinholes, to show what is now seen on the screen. How does the appearance with the lens differ from the appearance without it?
c. What difference does it make if, keeping the lens in position, we poke a finger through the pinholes so as to make a round hole of diameter equal to the distance between the first and fifth pinholes?

Note: You may suppose, if you like, that the convex lens is of exactly the right strength to 'focus the images' of the pinholes on the screen. However, the questions can equally well be answered for *any* convex lens.

48 Arithmetic and Geometry department:

a. An electric-light bulb is 7·5 cm in diameter. It is placed 100 cm from the pinhole of a pinhole camera, and the distance from the pinhole to the screen is 20 cm. How wide is the image on the screen? (Work it out from a diagram.)
b. Suppose you had a large pinhole camera 100 cm long, and the bulb was only 20 cm from the pinhole; how wide would the image be then?

49 Let us repeat question 48 with a lens camera instead of a pinhole.

a. An electric-light bulb is 7·5 cm in diameter. It is placed 100 cm from the lens, and the distance from the lens to the film is 20 cm. How wide is the image on the film?
b. Suppose you had a camera 100 cm long with the bulb only 20 cm from the lens; how wide is the image?

Also
c. A camera like that supposed in (*b*) might be used for enlarged copying, but the arrangement is beginning to look like a quite different instrument. What instrument has the distance from object to lens only a few inches, while the distance from lens to screen is many feet? What does the object usually consist of, and which way up is it?

50 Algebra department: (*a*) and (*b*) in questions 49 and 48 are special cases of a general result. If:

O = height (or width) of object,
I = height (or width) of image,
u = distance from object to lens or pinhole,
v = distance from image to lens or pinhole,

write an equation relating the four quantities O, I, u, v (and no others). Now write down, in words, a problem your equation will solve, and solve your own problem.

What advantage is there (if any) in knowing this equation? (Questions 48 and 49 can be solved without it.)

51 A boy in a school laboratory holds a lens so that it gives a sharp image on a screen, of a laboratory window.

a. The headmaster walks across the window, just outside, walking from left to right. What does the boy see on the screen?
b. The boy then notices the image of a tree which is at some distance outside the window. The image is blurred. Which way must he move the lens to get the image 'in focus'?
c. Fill in the blanks in the following: 'The ——— the object is ——— the lens, the farther away the image. The ——— ——— the object is ——— the lens, the ——— the image.'

52 You go to a lesson which includes the showing of a film, but when the projector is switched on and focused the picture is too large for the screen and overlaps it all round. The screen cannot be made bigger. What *two* adjustments must be made before the film can be satisfactorily shown?

53 'Light travels in straight lines.' Use this observation to answer the following questions about shadows.

a. In figure 53 (*a*) A is a small flashlamp bulb, B is a tennis ball and C is a screen. What sort of shadow appears on the screen?

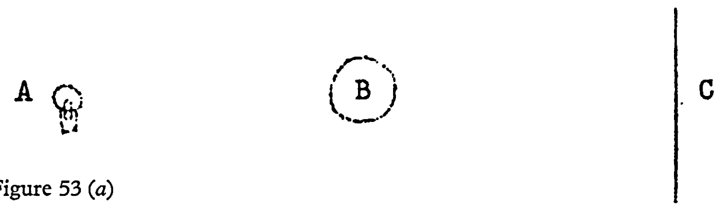


Figure 53 (*a*)

b. In figure 53 (*b*) A is an electric-light bulb made of glass 'frosted' outside. What sort of shadow do you expect on the screen?

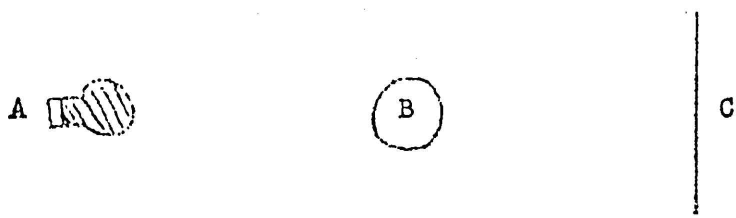


Figure 53 (*b*)

c. In figure 53 (*c*) A_1 is a flashlamp bulb with transparent red material, R, around it. A_2 has transparent green material, G, around it. B is a small object, e.g. a marble. What sort of shadows are cast on the screen? (*Note:* This is a tricky question and you are only asked about the *shadows*. You will probably ask what happens on the screen outside the shadows. The only answer for the moment is 'Try it and see'.)

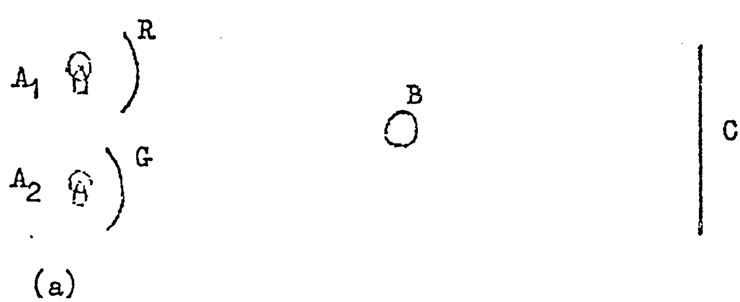


Figure 53 (*c*)

5 Lenses

54 B (figure 54) is a small, very bright, lamp bulb which emits light rays in all directions. Lines showing five of these rays are drawn in the diagram. L is a thin positive lens and S is a screen. S has been placed in a position which gives a sharp image of B.

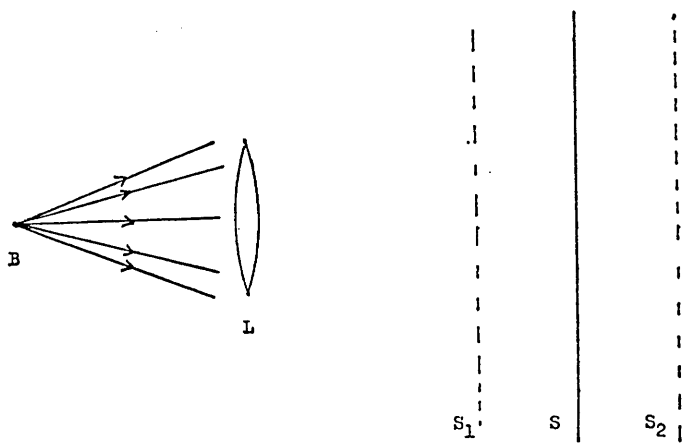


Figure 54

a. Draw the diagram (no exact measurements needed) and draw the five rays onwards till they reach the screen S, or the screen extended top and bottom. (Leave out S_1 and S_2. Do not try to draw the rays *inside* the lens, which is supposed to be thin anyhow.)
b. Suppose the screen is moved from S to S_1, nearer to L, what do you expect to see on it now? What would you expect to see if the screen is moved to S_2, an equal distance the other way? (i.e. $SS_2 = SS_1$).

55 Still referring to figure 54:

a. What would you see on the screen if it is moved only a millimetre or two from S towards the lens? Away from the lens?
b. What is meant by 'depth of focus'?

56 Figure 56 (*a*) shows a lens, L, and a small lamp, X. Five rays of light are drawn from X to the lens. In (*b*) and (*c*), X is farther and farther away from the lens. Copy these two diagrams and add, on each, five rays from X to the lens, just like diagram (*a*).

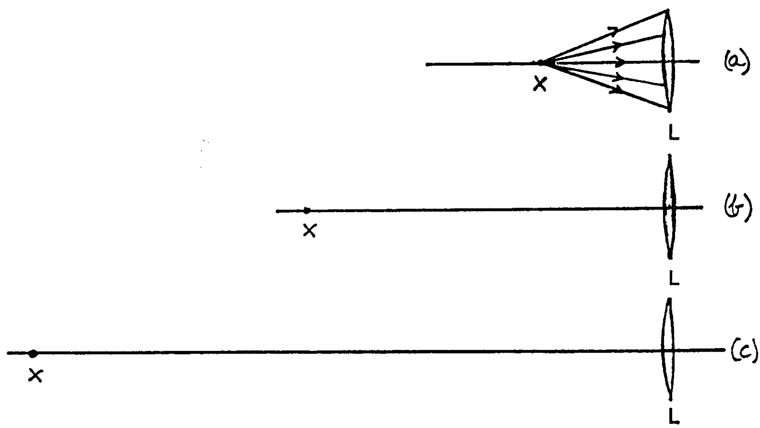


Figure 56

In diagram (*d*) X is right off the paper, ever so far away, like a street lamp, or the Sun or a star. Guess, and then draw, what the rays look like in (*d*). Write underneath your diagram (*d*) the sentence, 'For all practical purposes, these rays are ———', filling in the blank with one word (hope you can spell it!).

Figure 56

57 In figure 57, L is a thin positive lens and A is a screen with a large hole in it that lets through light from an object a long way off, such as a street lamp 100 yards away, or even a star. Five rays entering the hole are shown in the diagram.

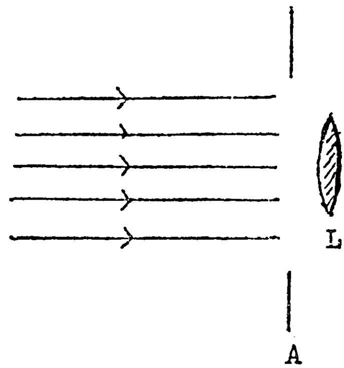


Figure 57

a. Why have these rays been drawn parallel?
b. Copy the diagram, and produce the rays onwards to the right, to just beyond the position where a sharp image of the street lamp or star is formed.
c. If instead of the distant lamp or star we used a lamp a few feet from the lens, would the image be nearer the lens than before, or farther away?

58 Why do you think a real image is called a *real* image? You have often seen an image of yourself in an ordinary plane mirror. In what sense is it true that this image is less 'real' than an image of you formed by a lens when you have your photograph taken?

How would you demonstrate the difference between the image of an electric-light bulb formed by a lens and the image of the same bulb formed by a plane mirror?

59 The teacher says, 'Use the convex lens to form an image on the paper of that end window. Now take the paper away and look at the image.' Freddie Jones tries this, but immediately says, 'Please, sir, I can't see any image.' You notice that he has put his head where the paper was. 'No,' says the teacher, 'hold the lens at arm's length.' 'No use,' says Freddie, 'I still can't see any image, whether I look at the lens or at the window.'

Why cannot he see an image? Where ought he to look?

60 In figure 60 A and B are two boxes which look alike. Each contains a lens, which is fitted into the middle of the box, along the dotted line. The sides of the boxes are open so that light can enter and come out. Parallel light from a distant object passes into each box and comes to a focus as shown in the diagram.

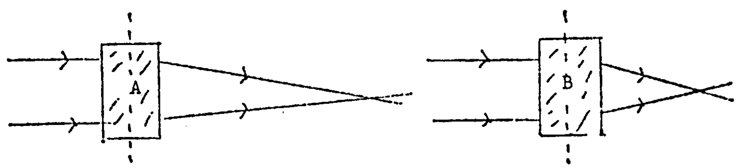


Figure 60

a. Are these lenses thicker in the middle than at their edges, or thinner? Do we call them 'positive' or 'negative'? Do they converge light, or diverge light?
b. Which has the greater focal length, A or B?
c. Which is the 'stronger'?
d. Which would make the better magnifying glass?

61 Figure 61 shows two more boxes, each containing a lens, at the position of the dotted line. When parallel rays from a ray box pass into the boxes, the rays emerge as shown in the diagram.

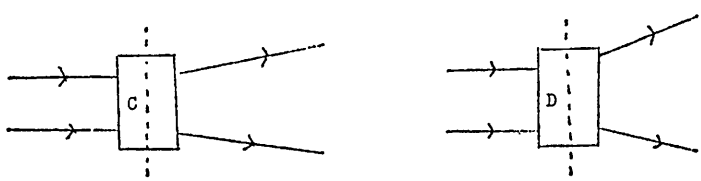


Figure 61

a. If we call the lenses in figure 60 'positive' lenses, what sort of lenses are these?
b. Are they thicker in the middle than at the edges, or thinner? Do we call them 'convex', or 'concave'? Are they 'converging' lenses or 'diverging' lenses?
c. Which is the stronger, C or D?
d. By comparison with your answers to question 60, which of the lenses in figure 61 has the longer focal length, C or D?
e. Copy the diagrams, omitting the boxes and drawing the rays up to and from the dotted lines. Now mark in each diagram a length which, you think, might be called the 'focal length'. This focal

length corresponds to the focal length of the positive lenses in question 60, but you could not measure it so simply; you could not measure it with a window and a wall or a sheet of paper.

62 This is a puzzle question of no particular importance. Try it if you have finished the other questions.

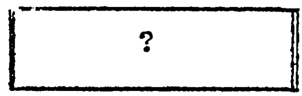


Figure 62

Figure 62 shows a cardboard tube about 15 cm long, closed at each end with pieces of flat glass. Somewhere inside, you do not know where, is a single positive lens fitted across the tube. You do not know the focal length of the lens, but it is at least 15 cm. The only 'apparatus' provided is a bright window at one end of the room, a piece of white paper and a ruler. How would you find the focal length of the lens and the position of the lens in the box without taking the box to pieces?
(*Hint:* Light can go *either way* through the box!)

Note: The 'focal length' of a lens is useful because it provides a measure of the way in which the lens converges light (plus) or diverges light (minus). All the same, it has the disadvantage that the 'stronger' or 'more powerful' the lens (that is, the more it converges or diverges), the less is the focal length, which, for a measure of strength, is the wrong way round. So we take $\frac{1}{\text{focal-length}}$ and call this quantity the *power* of the lens.

$$\text{power (in dioptres)} = \frac{1}{\text{focal length (in metres)}}$$

This is the way opticians measure lens powers, but remember to divide by focal length in *metres*, not centimetres, or you will get a result which is only $\frac{1}{100}$ of the correct result.

A positive power means a positive, converging, convex lens, and a negative power means a negative, diverging, concave lens.

63 *a.* focal length = +25 cm, what is the power of this lens? Is the lens convex or concave?
b. power = +3, what is the focal length, and is the lens convex or concave?
c. power = −5, what is the focal length, and is the lens convex or concave?
d. focal length = −2 metres, what is the power, and is the lens convex or concave?
e. What is the power of a piece of flat window glass?

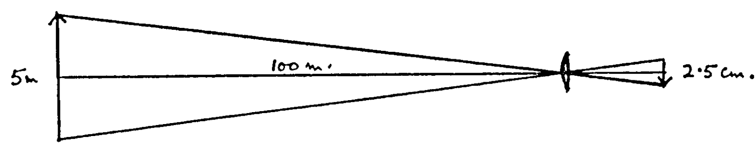


Figure 64

64 *a.* Figure 64 (not to scale!) shows a positive lens forming an image 2·5 cm high of a flagpole 5 metres high 100 metres away. (This is sufficiently far away for us to suppose that the image is at the principal focus of the lens.) Find the power of the lens.
b. You are given a combination of several lenses mounted close together, like a camera lens, for example. You cannot measure the focal length, *f*, of the combination, and then find the power $1/f$, in the usual way, by means of a distant window, because you do not know where to measure from, among the set of lenses. How could you find the power of this lens combination?

6 Rays

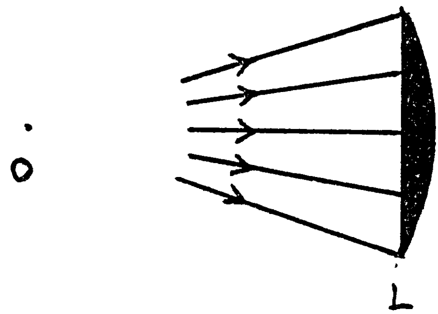


Figure 65

65 *a*. Figure 65 shows rays diverging from a lamp and arriving at a positive lens L. The lamp is not drawn, but it is situated at the point marked O. Copy the diagram and show what is likely to happen to the rays after they have passed through the lens.
b. Now make a similar diagram for rays from a lamp arriving at (*i*) a *more* powerful positive lens, then (*ii*) for a *less* powerful positive lens.
c. Next make a diagram for *two* positive lenses placed a few centimetres apart.
d. Lastly, make a diagram which shows what happens to the rays when they pass through a negative (concave) lens.

66 Repeat parts (*a*) and (*d*) of question 65, using a drawing in which the lamp, at O, is farther away from the lens than it is in figure 65 thus making the rays arriving at the lens more nearly parallel to each other.

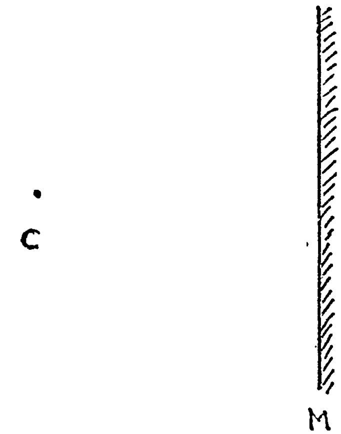


Figure 67

67 *a.* A candle, at C, is placed in front of a flat (plane) mirror M. Many rays of light from the candle fall on the mirror. Copy the diagram, figure 67, and mark on it the point C – which the reflected light seems to come from – that is, where the image of the candle is.
b. Now draw several rays from the original candle to the mirror and use your knowledge of the image position to continue the rays after reflection.

68 Think of the real images formed by lenses. How would you show that the images formed by a plane mirror are *not* real images? What name is given to this type of image?

69 Your diagram in answer to question 67 shows how light appears to spread from a point behind the mirror. Briefly describe an experiment with a ripple tank in which a similar result was obtained.

7 Magnifying glass. Telescope. Microscope

70 Sometimes scientists use instruments in order to provide senses with which the human body is not equipped, e.g. apparatus for detecting and measuring radio waves. Sometimes instruments are used to add in some way to the range and sensitivity of the senses we already possess. The *telescope* is an instrument of the second kind.

a. Obviously a telescope is useful because it makes distant things look bigger and we see greater detail. What other useful job does a telescope do besides making things look bigger?
b. Why can it perform this second function? (*Hint:* Think of the size of a telescope lens and the size of the human eye.)

(Look up the word 'telescope' in a dictionary and find out what 'tele-' and '-scope' mean. The name tele-scope seems to refer more to the 'other useful job' than to 'making distant things look bigger'. Incidentally, if we hadn't used 'telescope' to mean telescope, wouldn't we have used 'telescope' to mean a television set?)

71 You have lenses of powers about +3 and +20, and a means of mounting them and sliding them up and down on a metal rod. You also have a piece of tissue paper. In order to make a telescope:

a. Which lens would you take first, and whereabouts on the rod would you mount it?
b. What would you do with the tissue paper?
c. Where would you put the second lens?
d. At what position would you expect to have your eye when looking through the telescope – up against the lens? 25 cm from the lens? or where?

72 Copy out the following sentences, including only the correct alternative of two offered.

'A positive/negative lens can be used as a simple magnifying glass. Used in this way it forms a magnified real/virtual image through/from which the light actually passes,/appears to come, but does not actually do so. The image is on the same side as/the opposite side to the object; and the object is placed closer to/farther from the lens than the focal length.'

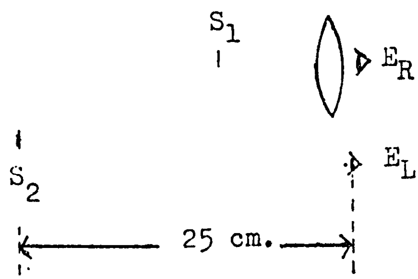


Figure 73

73 A boy looks at a millimetre scale S_1 through a convex lens placed close up to his right eye, E_R. At the same time he looks with his left eye, E_L, at an exactly similar scale S_2, which is 25 cm away. With both eyes open, he sees a large scale with a small scale on top of it. He can see both scales in focus comfortably at the same time.

a. Which eye sees the large scale and which the small?
b. How far from his right eye is the image of S_1 situated? (Assume both eyes to be normal, and that S_1 is placed to give the best and largest image.)
c. How can he estimate the magnification the lens produces?
d. *Difficult*. What would be the effect on what he sees if he moves his head and the lens: (*i*) nearer to S_1; (*ii*) farther from S_1?

74 A scale is drawn vertically on the blackboard, with regularly spaced marks 0–10. A boy makes a telescope from two convex lenses, and goes to the far end of the room to look at the blackboard, which is 30 ft away. He keeps his left eye open and looks at the board directly. He looks through the telescope with his right eye and adjusts the lenses so as to give the sharpest image. He then sees something resembling the diagram below.

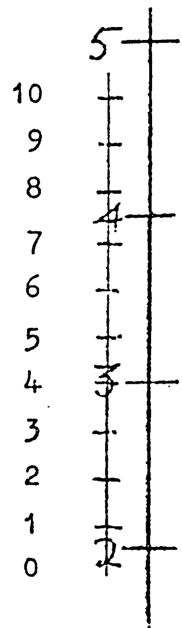


Figure 74

a. How far away from him is the image he sees through the telescope? Why do you say it is at that distance?
b. What is the magnification that the telescope produces?
c. There is something badly wrong with this diagram. If the telescope were really made from two convex lenses, then he could not have seen this through it. Redraw the diagram to show something he *could* have seen – assume that the markings are in the right place but that the *figures* are wrong.

75 *a.* What part of a telescope acts as a magnifying glass, and what 'object' is it that it magnifies?
b. A telescope magnifies 4·8 times and the eyepiece has a focal length of 5·0 cm. What, approximately, is (*i*) the focal length of the objective, and (*ii*) the distance between the lenses?

76 *a.* The ordinary, so-called 'astronomical', telescope gives a final image that is upside-down, yet it is a virtual image, and we usually say 'virtual images are upright'. How do you account for this?
b. How could a third convex lens be used in a telescope in order to give an upright final image? Where would you put the lens in order to give a final image that is the same size as it is without the third lens?
c. If you are offered a choice of two lenses, 5 cm or 25 cm focal length, for use as the third 'inverting' lens, which would you choose and why?
d. Have you seen any other form of telescope which uses only two lenses and yet gives a final upright image? If so, what is the difference between this 'telescope' and the one with two convex lenses that you have been using?

77 *a.* Why do you think a compound microscope is called *compound*? What would a 'simple' microscope be?
b. Which part of a compound microscope is basically the same as in a telescope? What job does it do in both cases?
c. In the compound microscope which you made you almost certainly noticed faults (apart from low magnification) which you would not find in a microscope of the kind used in the biological laboratory. What were these faults?

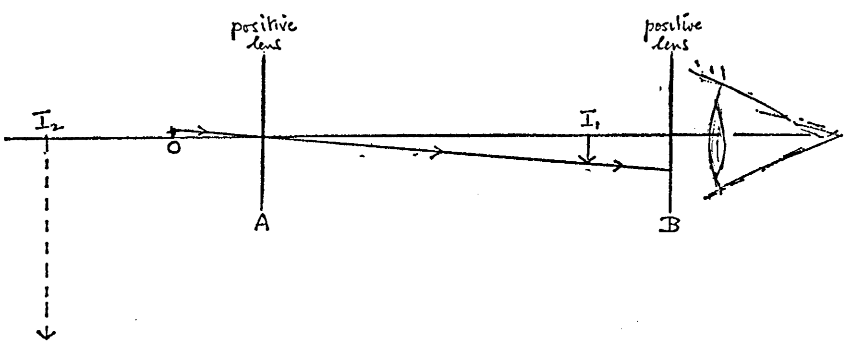


Figure 78

78 Figure 78 shows the positions of the images in a compound microscope (distances drawn about half-scale). A is the objective lens, and B the eyepiece; O is the small object, I_1 is the image formed by the objective, and I_2 is the final image formed by the eyepiece. I_2 to the eyepiece is 25 cm.

a. Copy the diagram and use it to explain (e.g. to Uncle George) how a compound microscope works.
b. Is image I_1 real or virtual? Is I_2 real or virtual?
c. One ray, through the centre of lens A, is drawn on the diagram. Draw this ray onwards, from B to the eye.
d. Find, by measuring the height of O, and the height of I_2, the magnification that the microscope produces. (You can take O to be $1\frac{1}{2}$ mm high in the diagram, that is, 3 mm high in reality.)

8 The eye

79 *a.* Write out and complete the following sentences, inserting the correct alternative where necessary:

'The optical system of the human eye is similar to that of a———. A convex lens, formed of the ——— and eye-lens acting together, forms a $\begin{array}{ccc}\text{real} & \text{upright} & \text{magnified}\\ \text{virtual} & \text{inverted} & \text{diminished}\end{array}$ image on the ———, which is the light-sensitive surface on the back of the eye. The ——— is the hole through which light enters, and corresponds to the ——— of the camera.

However, there are important differences. In the camera focusing is performed by ———. In the eye the distance between lens and retina is kept fixed, but the convexity of the lens can be varied by ———. This action, which enables us to focus objects at different distances, is called ———. Another difference is that the inside of a camera is filled with ———, but the eye contains———. Also the eye is able to adjust itself for different brightnesses of light falling on it, so that we are able to see without discomfort in all conditions, from bright sunlight to nearly complete darkness.'

b. The last sentence above: what are the two ways in which the eye can adjust for different brightnesses of light?

80 How do you account for the fact that, although 'we see everything upside-down', this causes us no inconvenience? Describe an experiment to show what happens when the image of an object formed on the retina is the same way up as the object.

81 A person who needs to wear glasses for reading cannot read small print without his glasses under normal conditions. However, he stands a better chance of being able to read, say, a telephone directory, without his glasses if he looks at it in a very bright light, and he finds no difficulty at all in reading it if he peers at the print with one eye, through a pinhole in a piece of card. How do you account for this? Something similar occurs when a person wishes to take close-up pictures with a cheap box camera: explain what he has to do to get a satisfactory picture.

82 A chicken has its eyes on opposite sides of its face, obviously a sensible arrangement. Why is it sensible for a chicken?

A cat, or the driver of a car, has both eyes the same side of the face.

This seems a silly waste of two eyes, but it is not; in fact it is very fortunate for the cat or car-driver that it is so. Why is it fortunate?

83 A cinema film normally runs through the projector at the rate of '24 frames per second'. This means that 24 separate pictures are presented on the screen in one second: if, for example, the subject shown is a man walking, then, on the screen, he 'walks' in jerks $\frac{1}{24}$ second apart. In between each picture the screen is dark. Yet we see no jerkiness and no darkness. How do you account for this?

Of course, to get the right speed on the screen, the pictures in the film camera were taken at the same rate at which they are projected on the screen, in this case, 24 per second. What do you think would be the appearance on the screen if both camera and projector were run at: (*i*) 10 frames per second; (*ii*) 4 frames per second; (*iii*) 48 frames per second?

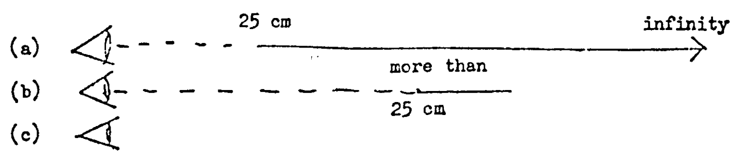


Figure 84

84 The normal eye is said to have a range of accommodation of from 25 cm to infinity (younger people may have a greater range, older people may have less or none – i.e. they can focus clearly at one distance only). Diagram (*a*) represents 'normal range'. Diagram (*b*) is for a long-sighted person, and (*c*) for a short-sighted person. Copy the three diagrams, completing (*b*) and (*c*).

85 A certain long-sighted person has to hold a book at arm's length to be able to read it without glasses; for him, the 'near point' is 60 cm instead of 25 cm.

Explain, with the aid of the diagram below (which you should copy), why he sees only a blurred image of an object 25 cm away. Draw a second, similar, diagram for a normal eye looking at an object 25 cm away.

Assuming that, with a nearpoint of 60 cm he has the same *range* of accommodation as a normal person, would you expect him to be able to see clearly without glasses an object a great distance away? Write a sentence in explanation.

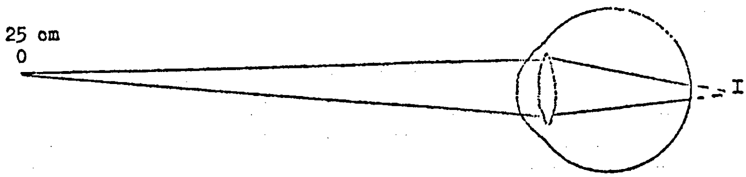


Figure 85
long-sighted eye

86 Write out and complete the following sentences, inserting the correct alternative where necessary:

'The right eye of a certain long-sighted person has a nearpoint of 60 cm instead of 25 cm. To correct this defect he needs a spectacle lens which will form, at —— cm, the image of an object which is actually at —— cm. He will then be able to see the image clearly. The spectacle lens must be convex concave and it forms a real virtual image which is the right way up upside down. His trouble is that the eye lens is not sufficiently too convex, and therefore he has to have an additional convex a concave lens to correct the fault. Alternatively, we could say that his eyeball is too long too short for his eye lens.'

Note: (not to be copied): He probably needs a lens to correct his *left* eye as well, but it is unlikely that the same focal length will be required for both eyes – probably slightly different for the best result. It is possible for one eye to be slightly long-sighted and the other to be slightly short-sighted; this also can easily be corrected by the proper lenses.

87 *Difficult*. Draw another diagram like figure 85, but this time include the correcting spectacle lens. Show what happens now when the eye looks through the lens at an object 25 cm away.

88 A certain short-sighted person cannot see clearly objects which are a great distance away; for him, the 'far point' is 1 metre instead of infinity.

Explain, with the aid of the diagram below (which you should copy), why he sees only a blurred image of an object at infinity. Draw a second, similar, diagram for a normal eye looking at an object at infinity.

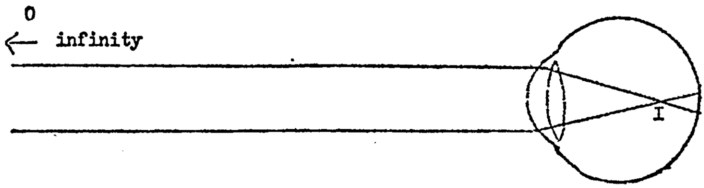


Figure 88
short-sighted eye

Assuming that, with a far point of 1 metre, he has the same range of accommodation as a normal person, would you expect him to be able to see clearly without glasses an object at 25 cm from the eye? Write a sentence in explanation.

89 Write out and complete the following sentences, inserting the correct alternative where necessary:

'The right eye of a certain short-sighted person has a far-point of 1 metre instead of infinity. To correct this defect he needs a spectacle lens which will form, at ———, the image of an object which is actually at ———. He will then be able to see the image clearly. The spectacle lens must be convex concave and it forms a real virtual image which is the right way up upside down. His trouble is that the eye lens is not sufficiently too convex, and therefore he has to have an additional convex a concave lens to correct the fault. Alternatively, we could say that his eyeball is too long too short for his eye lens.'

Note: The note at the end of question 86 also applies here.

90 *Difficult*. Draw another diagram like figure 88, but this time include the correcting spectacle lens. Show what happens now when the eye looks through the lens at a very distant object.

9 Ray diagrams and measurements

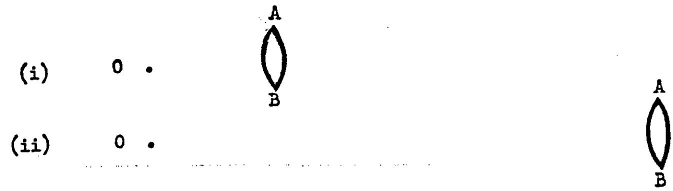


Figure 91

91 In diagram (*i*) above a lens AB (which may be the lens of an eye, or the object glass of an optical instrument) is 25 cm away from an object O. In diagram (*ii*) the lens is 100 cm away. The scale of the diagram is 1 inch equivalent to 25 cm and the lens AB has been drawn $\frac{1}{2}$ inch wide.

a. Copy the diagrams and draw cones of rays from O to AB in each case.
b. Which diagram has the cone with the narrower angle?
c. In which diagram are the rays entering the lens more nearly parallel?
d. Draw another diagram showing a 'cone' of rays from a very distant object ('at infinity') arriving at a lens.
e. One of the following statements is right and one is wrong. Write out the correct statement.

'Rays from a distant object arriving at a lens are nearly parallel because the farther the rays go, the more nearly parallel they become.'

'Rays from a distant object arriving at a lens are nearly parallel because the cone of rays from the distant object has such a very small angle.'

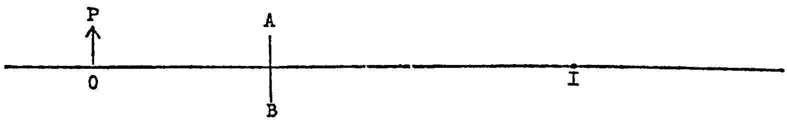


Figure 92

92 An object OP, as shown in the diagram above, is 10 cm high and is placed 35 cm from a positive lens. The point O gives rise to an image at I 60 cm from the lens. Copy the diagram (one-tenth scale, i.e. 35 cm is represented by 3·5 cm) and find the point Q which is the image of P. Draw a cone of rays from P to the lens, and then to Q and produce it on beyond Q. Draw an eye looking at Q and with the cone of rays entering the eye. (Remember that the eye has, we assume, a least distance of distinct vision of 25 cm.)

How big is IQ, the image of OP?

Note: It does not matter how big you draw the lens, so long as it is not unreasonably large.

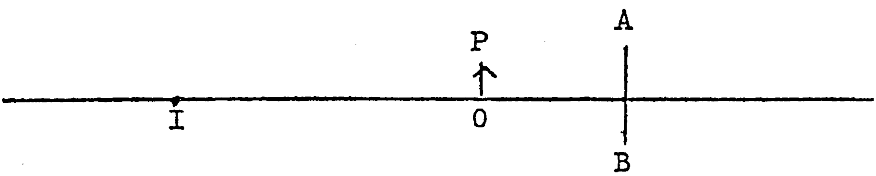


Figure 93

93 OP is an object 5 cm high placed 10 cm from a magnifying glass AB. The point O gives a virtual image at I, 30 cm from AB. Copy the diagram (scale one-fifth) and find the point Q which is the image of P. Draw a cone of rays from P to the lens AB, and then draw it on, through the lens. Draw an eye (least distance of distinct vision = 25 cm) looking at Q, and with the cone of rays entering the eye. How high is IQ?

Note: Remember to draw dotted line to represent construction lines along which rays do not actually pass. Virtual images, such as IQ in this question, should also be drawn in dotted lines. The lens AB should be drawn not too large, but larger than OP.

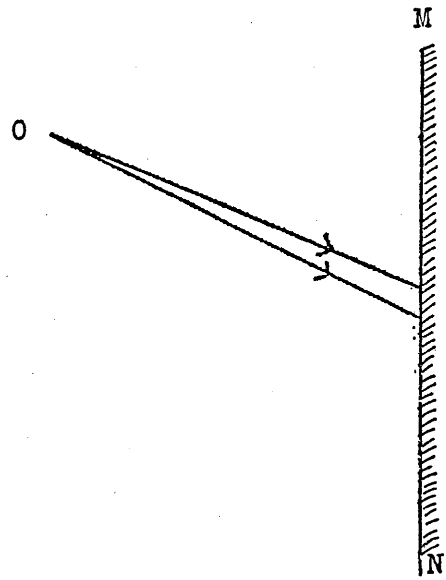


Figure 94

94 The diagram shows an object O placed 50 cm (5 cm on a one-tenth scale drawing) from a plane mirror MN. Two rays, representing a narrow cone from O to the mirror, are also shown. Mark in I, the image of O. Then draw the paths of the rays after reflection at the mirror. Draw them so that they enter an eye (draw the eye too!) placed about 40 cm (4 cm to scale) from the mirror. Draw construction lines as dotted lines.

Is the image real or virtual? Same size, magnified or diminished? Can it be seen on a screen placed at I?

95 In figure 95 you are shown the mirror MN, the object O and the position of an eye viewing the object in the mirror. Draw the paths of two rays that leave the object, are reflected by the mirror and enter the eye, one at x the other at y. (*Hint:* First mark in I, then draw the rays *backwards* from xy, remembering, however, to add arrows to the rays, pointing in the right direction.)

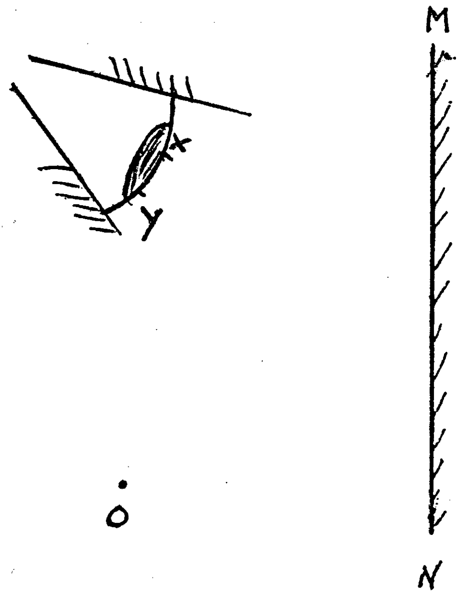


Figure 95

96 Copy the diagram below, which represents an astronomical telescope in which X is the position of the objective lens. It is being used to look at a very distant object. The real image formed by the objective is at I_1. Y is the position of the eyepiece, which forms a magnified image at I_2 of the real image at I_1. The dotted line is a construction line drawn from the tip of the image at I_1 through the centre of the eyepiece.

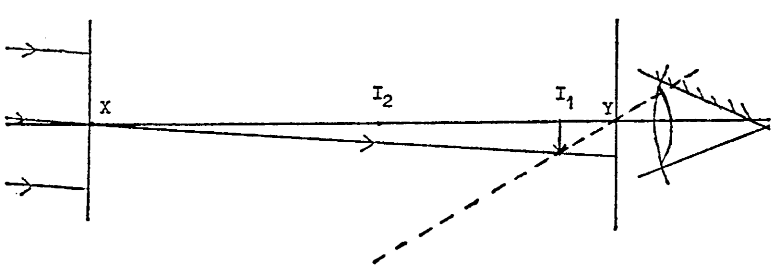


Figure 96

The distance XI_1 is 50 cm, represented by 10 cm on the diagram. I_1Y is 5 cm, represented by 1 cm (scale one-fifth). I_2, the position of the final image, is 25 cm from the eyepiece (represented by 5 cm).

Three parallel rays are shown on the left. They come from the distant object. Only the centre ray is produced on to the eyepiece.

a. Draw the other two rays from the objective to the eyepiece.
b. Draw (dotted line) the final image at I_2.
c. Now draw the three rays, showing their path from the eyepiece to the eye (draw construction lines dotted).
d. What is the focal length of the objective?
e. I_1Y is 5 cm, but the focal length of the eyepiece is not 5 cm, it is over 6 cm. Why is there this difference?
f. What is the length of this telescope, i.e. the distance XY from objective to eyepiece?

97 Draw the diagram of question 96, but this time I_1Y is $6\frac{1}{4}$ cm, which on one-fifth scale will be $1\frac{1}{4}$ cm. The eyepiece is the same lens as before, and the final image I_2 is now at infinity.

a. Trace the three rays through to the eyepiece, as in 96 (*a*).
b. The final image I_2 is at infinity and cannot be drawn.
c. Draw the three rays on through the eyepiece to the eye.
d. What is the focal length of the objective?
e. What is the focal length of the eyepiece?
f. What is the distance XY from objective to eyepiece?
g. These are the same lenses as were used in question 96; the only difference is that the telescope is slightly larger. Is the magnification slightly more or slightly less than it was previously? Explain the reason for your answer.

10 Reflection (plane mirrors)

98 Freddie Jones picked up an old examination paper and read 'Question 1. State the laws of reflection . . .'. 'I can do that,' said Freddie, and he wrote down the following:

'Law 1. When light is reflected the angles are equal.

'Law 2. The reflected ray does not come off in a cockeyed direction.'

These 'laws' are both correct, but they are unlikely to be given full marks by the examiner who set the question. What did Freddie mean by the two statements? Explain with the help of diagrams.

99 *a.* Describe briefly the experiment which led you to make an 'equal angles' statement about reflection of light.
b. Describe one observation which leads to the 'not cockeyed' statement in question 98.

100 A ray of light falls on a plane mirror. The mirror is then turned through an angle of 1°. The reflected ray is found to turn through 2°. How do you explain this?

In some sensitive electrical instruments for measuring small currents the moving part is attached to a tiny mirror instead of a pointer. A beam of light is shone from a fixed lamp on to the mirror. It is reflected from the mirror on to a scale 1 metre away from the mirror. The light beam is like a weightless pointer whose length is – how long? $\frac{1}{2}$ metre? 1 metre? 2 metres? Which is correct, and why?

101 'This table doesn't bend when I sit on it,' says Freddie. 'Yes it does,' you say, 'the bending is too small to see, but it happens all the same.'

You have a small mirror and a lamp arranged to give a narrow light beam – also a nice white ceiling over the table. How would you demonstrate to Freddie that the table bends when he sits on it? Draw a rough diagram showing where you would put the mirror, relative to the table leg and the position of Freddie. (You need not draw Freddie very beautifully, a round lump will do for him!)

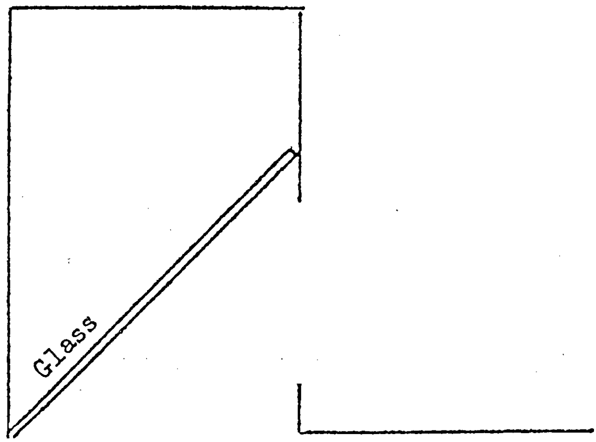


Figure 102

102 The diagram shows a large cardboard box which has had the lid removed. One end is cut open and bent back on the right, as shown. A hole is cut in the right-hand side. A sheet of transparent glass is put at 45°, as you see in the diagram.

The idea is to show (perhaps at a school 'open day' or 'parents' evening') the optical illusion of a candle, burning in the middle of a beaker full of water. Copy the diagram and show on it where you would put the beaker, and where you would put the candle, and where you would tell people to look. For the beaker (seen from above) put a circle with a diameter about one-third the width of the box. For the candle put ' – candle'. The candle has to appear to be exactly in the middle of the beaker. Draw a ray of light from the candle to the observer and another from the beaker to the observer.

103 *a.* A man walks towards a plane mirror with a speed of 4 feet per second. With what speed does his image approach the mirror? With what speed do the man and his image approach each other? *b.* The man stands still and the mirror is moved towards him at 4 feet per second. Does the mirror move away from the image? Or do they approach each other? With what speed?

11 Refraction (plane surfaces)

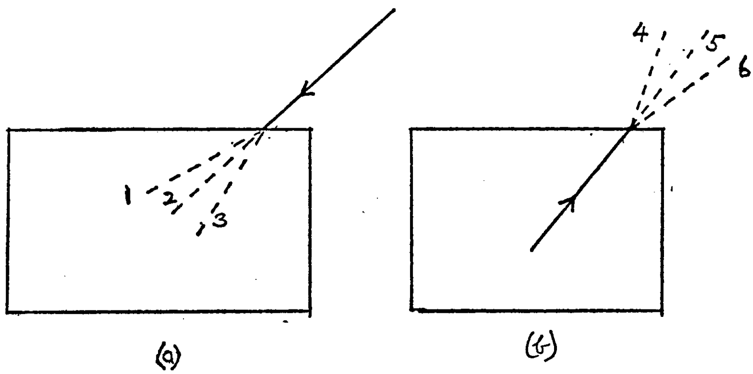


Figure 104

104 *a.* A ray of light falls, as shown in diagram (*a*) on a parallel-sided block of glass. The path which it then follows depends upon the optical properties of the glass, but two of the three (1, 2 and 3) shown in the diagram are clearly impossible. Draw the diagram but include only the possible path, as a full line. Omit the other two. Then draw the ray onwards to show what happens to it on emerging from the block. (Make the block longer if you wish.)
b. Draw diagram (*b*) showing, as a full line, the one path (out of 4, 5 and 6) which is possible, and omitting the other two. Then draw the path of the ray as it entered the block.
c. Copy the following sentences, filling in the blanks with suitable words: 'When rays of light pass from air to glass they are bent ——— the normal; when rays of light pass from glass to air they are bent ——— the normal. By "normal" we mean ———.'
d. There is one exception to the first statement in inverted commas in (*c*), or rather, there is one case for which the statement is meaningless. What is the exception?

105 A boy takes a piece of wooden plank about 20 cm square and draws two lines, AB, MN, on it at right angles to each other. He sticks in a pin at R, and two more at P and Q. He made the angle PRN less than 45°. He then immersed the wood vertically in a sink of water and fastened it so that AB was along the water surface. He then looked from above at the pins P,Q,R, and got his head so that P,Q,R, and his eye seemed to be in a straight line. Then he stuck two more pins S and T so that P,Q,R,S,T and his eye all seemed in one straight line. He then removed the wood from the water, marked the pins' positions and removed them, and drew the lines PQR and RST. The result looked like the diagram above, with angle TRM more than 45°. PQRST is not a straight line.

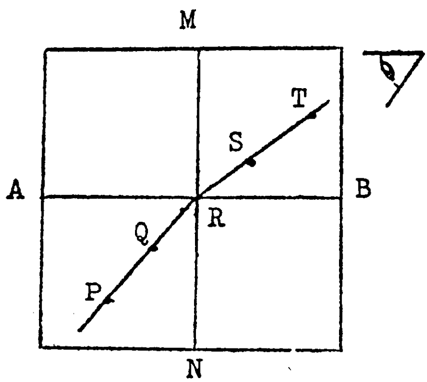


Figure 105

Has he simply placed the pins badly? Or is this what you would have expected? If so, give some explanation of why you would have expected PQRST *not* to be a straight line.

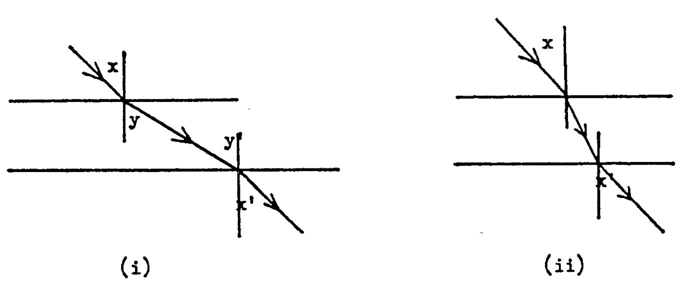


Figure 106

106 *a.* One of the two diagrams (*i*) and (*ii*) shows a ray of light passing from air into and out of a parallel-sided glass block, and the other

shows light passing into and out of an air space between two parallel-sided glass blocks. Which is which?
b. How would you show by experiment that, for light being refracted, if the direction of the path of the light is reversed then the light exactly retraces its path. Say what you would do and what you expect to see.
c. What reason is there for supposing that angle y = angle y′ in the above diagrams?
d. (*This is more difficult.*) How do we know x = x′ in the above diagrams?

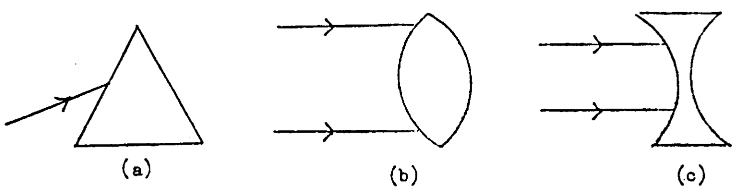


Figure 107

107 *a.* This diagram shows a ray of light falling on a glass prism. Copy the diagram and complete it by sketching in a possible path for the ray after entering the prism and after emerging from it.
A term sometimes used is 'angle of deviation'. Mark on your diagram what you think is the angle of deviation of the ray in your drawing. (Just commonsense. Deviation means bending. The ray goes in one direction when it arrives at the prism, and when it comes out it goes in a different direction. Mark in your diagram the angle through which it is 'deviated'.)
b. This is a 'thick' lens, i.e. not like the ones you have used for laboratory experiments, which were 'thin'. Two parallel rays fall on it as shown: copy diagram (*b*) and show possible paths for the rays in the lens, and after emerging from it.
c. A 'thick' concave lens. Copy diagram (*c*) and again show possible paths for the rays into and out of the lens.
d. What happens to a ray along the axis (centre line) of (*b*) and (*c*) above? And why?

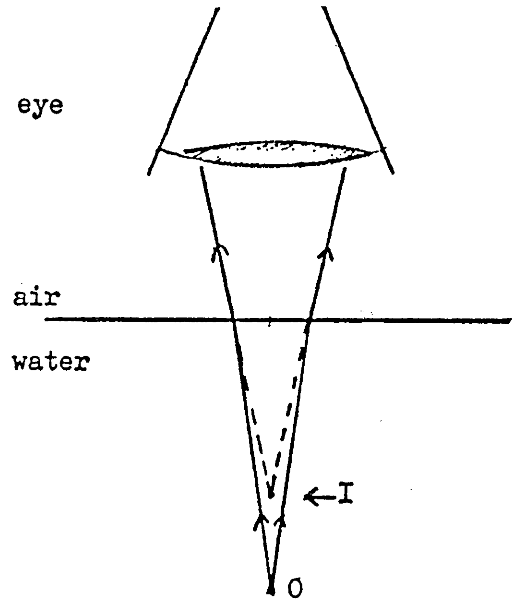


Figure 108

108 *a.* Copy the diagram shown and use it to explain why an object seen under water appears to be nearer the surface than it actually is.
b. Notice the meaning of 'explanation' in your answer to (*a*): you 'explain why' apparent depth is less than real depth by making reference to another happening ('phenomenon') that you already know about. What phenomenon? Write a sentence or two in answer.

109 *a.* Describe a simple experiment to show that real and apparent depth in water are not the same.
b. It is said that, during the siege of Paris in 1870, hungry soldiers tried to kill fish in ponds by shooting at them. Why is a soldier on the bank of a pond unlikely (if he knows no physics) to hit a fish a few yards out?
c. Your face is a metre away from a tank with a vertical side of plane glass. In the tank is water, and in the water is a fish. The fish looks out and sees you. Would you appear to be a metre away from the glass? or more? or less? Explain.

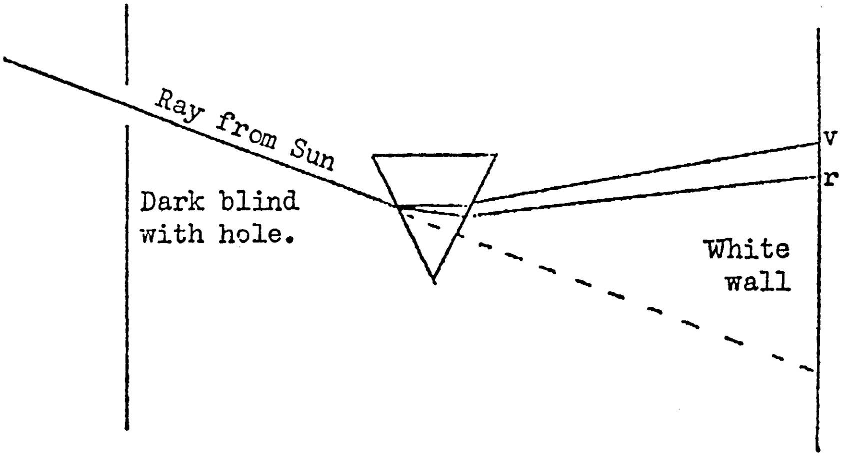


Figure 110

110 *a.* Copy the diagram above and use it to explain Newton's original 'colours of the rainbow' experiment.
b. When did Newton perform this experiment, 100 years ago? 200? 300? 400? or more?

111 Newton performed other experiments following upon that shown in question 110 including (*a*) and (*b*) below.

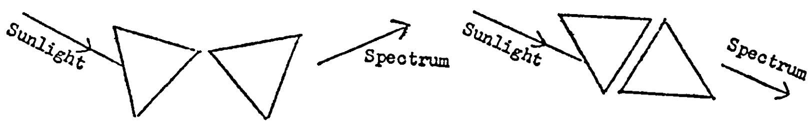


Figure 111 (*i*) (*ii*)

a. He picked out the red colour from the light emerging from the prism, and passed it through a second prism. Draw a simple line diagram showing how this was done, and say, briefly, what result he observed.
b. He passed the *whole* spectrum of rays from a prism through a second prism. What was the result
(*i*) if the prisms were placed as in figure 111 (*i*).
(*ii*) if the prisms were placed as in figure 111 (*ii*)?

112 As a result of the experiments in the previous two questions, and other experiments, Newton arrived at certain conclusions about white light and about prisms.

a. What did he decide about the nature of white light?
b. And what action does a prism have on white light?

113 *a.* If you know what is meant by 'refractive index', what can you say, simply by looking at the diagram of question 110, about the refractive index of glass for red light and its refractive index for violet light?
b. Have you ever noticed coloured edges round images produced by a simple convex lens? Without going into great detail, explain, with a diagram, how these coloured edges are produced.

12 Light particles

114 *a.* Uncle George says, 'I've never thought about it before, but I suppose the idea of light being particles, rather like bullets, does explain some things. It explains why light travels in straight lines so that that electric-light bulb is where I see it, and not somewhere round a corner. But what else does it explain?'

Write a few sentences telling Uncle George how the particle theory explains: (*a*) reflection, and (*b*) refraction of light.

b. Uncle George then says, 'We can have a very bright light or a very dim light, and anything in between. How do particles explain that?' What is your answer?

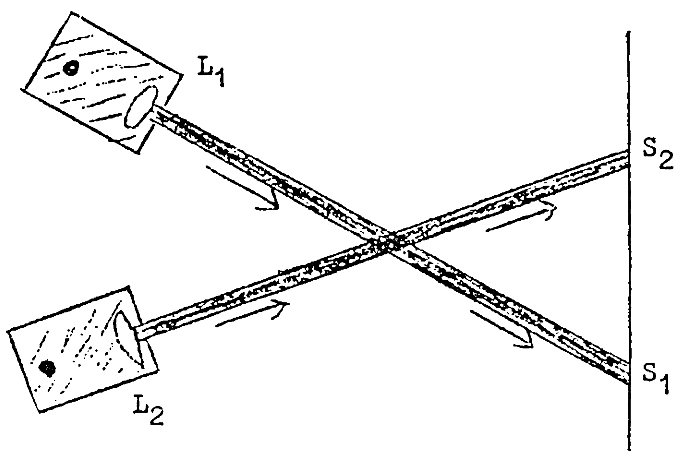


Figure 115

115 Two boxes L_1 and L_2 contain lamps and lenses, and they produce beams of parallel light which shine on a screen and make spots of light S_1 and S_2. The beams are arranged to cross (pass through) each other. Absolutely no difference is noticed in spot S_2 when L_1 is switched off, nor in S_1 when L_2 is switched off.

Assuming light to consist of particles, what conclusion do you draw from this experiment?

116 *a*. Obviously light particles (if we assume a particle theory) are not *strongly* attracted by matter, otherwise we should see rays passing near benches, tables, etc., being bent out of a straight line. However, it might be that a more exact and delicate experiment done under laboratory conditions would detect something.

Imagine you have a 'massive object' in the form of a large ball of lead, say 1 foot in diameter, also a 'light box' that gives a narrow parallel pencil of light, and any other ordinary apparatus you want. How would you do your best to detect a bending of light by the lead ball?

b Your experiment in (*a*) gives an entirely negative result. What conclusion about light particles would you draw?

117 A light-meter measures the 'strength' or 'intensity' of light falling on it. The light-meter is placed first 1 metre from a small light source and then 2 metres. At the 2 metres distance the strength of the light is only one-quarter of what it is at 1 metre. How is this observation explained by a 'bullet' theory of light?

13 Interference

118 You have seen 'Young's fringes' (if not, you had better omit this question). Imagine you are now asked to set up the apparatus in order to show the fringes to two or three members of your class who were previously absent. You have an electric lamp with a straight filament, a 'double slit', and a sheet of ground glass, with, of course, the means of supporting them.

a. Roughly how far apart would you mount: (*a*) the lamp and double slits, (*b*) the double slits and the ground glass?
b. Would you start by placing the double slits so that they are parallel to the filament? Or at right angles? Or some other angle?
c. What, roughly, would you say is the spacing between the slits? 0·5 cm? 0·5 mm? 0·05 mm? 0·005 mm?
d. After showing the 'white light' fringes you put green glass or green celluloid in front of the lamp. Someone then asks, 'Why is it I can now see *more* fringes than before?' What would you say to this, and how would you use a red filter (red glass) to support your explanation?

119 (Proceeding from question 118.) You would point out to your 'pupils' that here we have 'light + light = no light'. You ask them what other experiment they have seen in which something plus something could give nothing.

What would you want them to reply? Describe briefly the experiment you would now want them to repeat.

120 *a.* Instead of

light + light = no light

it would be better to say

crest + trough = level

But this is not just a remark about the behaviour of light. What have we now taken for granted about the nature of light?
b. Draw a diagram illustrating how waves of the same frequency and wavelength, but from two sources, can produce this effect. Illustrate on the same diagram how, at some other place, waves from two sources can produce a much greater effect than waves from one only, i.e.

crest + crest = twice as high a crest

trough + trough = twice as low a trough

121 Having set up a Young's fringes arrangement, you are then given a second 'double slits' in which the spacing of the slits is half what it is in the first. You take out the first 'double slits' and put the second in its place. What difference would this make to the pattern you see on the screen? What explanation of this difference can you give?

122 The double slits each act as an independent light source and interference is produced. Freddie Jones says, 'Why not use two straight filament bulbs placed next to each other?' You say, 'Well, for one reason, the filaments would still be so far apart that the interference fringes would be much too close together to see.' 'All right,' says Freddie, 'get someone to put two filaments very close together in the same bulb.' 'That still wouldn't work,' you say. Why wouldn't it?

123 A short length of transparent centimetre scale is put in place of a slide in a slide (or film-strip) projector and the distance of the projector from the screen is adjusted so that, when in focus, 1 cm on the scale appears as 20 cm on the screen. The scale is removed and a 'double slits' is put in its place. The best value for the distance between the images of the slits on the screen is 1·2 cm centre to centre. What is the actual slit spacing?

124 *a*. White light is used to produce Young's fringes with double slits having a slit separation of 0·4 cm. The distance between the slits and the screen on which the fringes are formed is 140 cm, and the distance between successive dark spaces (or bright spaces) in the fringes is 1·7 mm. Find the average wavelength of white light.
b. Why 'average'?

14 Waves and rays. Speed of light

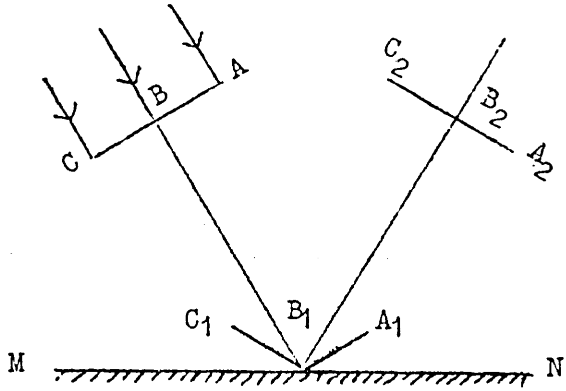


Figure 125

125 In the above diagram, ABC is a wave-front approaching a reflecting mirror MN. A little later the wave-front has travelled on so that B has reached B_1, on the mirror. A has reached A_1, and the part of the wave-front AB has reached A_1B_1. C has reached C_1 and the part BC has been reflected and has reached B_1C_1. A little later still and the whole wave-front has been reflected and has reached $A_2B_2C_2$. Three rays, at right angles to the wave-front ABC, have been drawn at the top of the diagram.

a. Copy the diagram and produce these rays on, through $A_1B_1C_1$ to $A_2B_2C_2$ and just beyond.
b. Notice how the rays have become reversed after reflection; ABC becomes $C_2B_2A_2$. What everyday observation, with the mirror, does this remind you of?
c. Suppose, instead of being a wave-front, ABC is a rank of three marching soldiers who *wheel* left at a wall MN. Then A would still be on the *left* after the wheeling had taken place. How would they have to march to produce the result $C_2B_2A_2$, with A on the right? (Some armies on ceremonial parade do turn corners like this, in Spain for example. It looks confusing and very smart at the same time!)

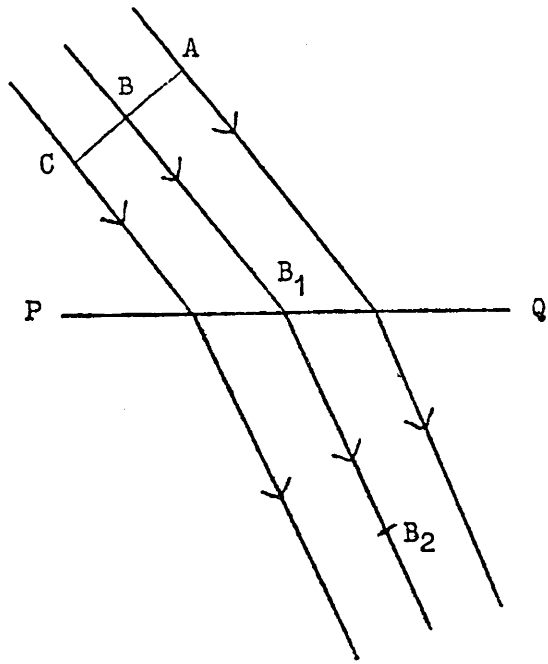


Figure 126

126 In this diagram ABC is a wave-front, and three rays are drawn showing the path of the wave-front up to and through a refracting surface PQ. Copy the diagram and draw in the wave-front $A_1B_1C_1$ when the centre ray has reached B_1. Also draw the wave-front $A_2B_2C_2$ when the centre ray has reached B_2.

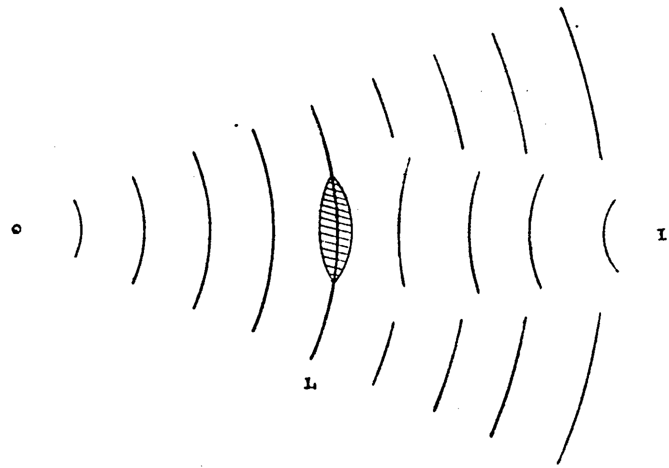


Figure 127

127 In the above diagram O is a point source of waves and L is a convex lens. Spherical waves are sent out from O, and parts of these waves meet and pass through the lens L. As a result, they curve towards a point I.

a. Copy the diagram and draw three rays from O to I through the lens.
b. What rule about the angle between rays and wave-fronts did you follow in drawing the rays?

128 Draw a diagram similar to that of question 127 for a plane wave-front falling on a convex lens. This is partly done for you in the diagram below.
Draw a wave-front *inside* the lens as well, if you can.

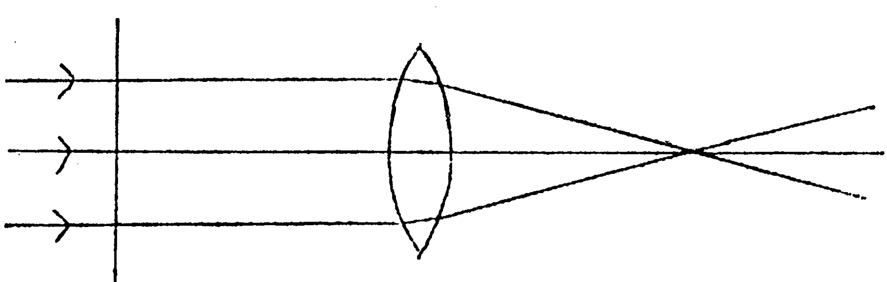


Figure 128

129 Many years ago, before anything was known about how fast light travels, two men tried to find the speed of light in a manner very similar to that already used to find the speed of sound. They arranged to stand several miles apart, each on a small elevation. Each man (we will call them Mr X and Mr Y) had a lantern fitted with a dark shutter that could be open or closed. One man, X, had a watch that would measure in quarter seconds.

After preliminary signals to show that all was ready, X opened his lantern, sending a flash of light to Y. At the same time he noted the reading of the watch. As soon as Y saw the flash, he opened his lantern and sent a flash back. X noted the time when he saw the flash. In the time interval, t, measured on the watch, light had travelled $2d$, twice the distance between the hills, so (they thought) they could easily calculate the speed, namely $2d/t$.

They *did* measure a very small time interval t, half to one second, but the trouble was that changing the distance d seemed to make no difference to the time t. Whether they were close together or far apart, t remained about the same.

a. How do you account for the fact that there *was* a time interval, but that it did not seem to depend on the distance?
b. It would be better to replace the man Y by – what?
c. *Difficult*. The man X must also be replaced by something that can open and close shutters much more quickly than he can. You have used something that would be suitable in principle at any rate: that is, a stroboscope disk with slits. Suppose you now suggest a way of finding the speed of light?

130 The trouble (Sir Isaac Newton thought) about the wave theory of light is that it does not account for light travelling in straight lines (e.g. pinhole camera, formation of sharp shadows). Later, when the facts about 'interference' of light were understood, it was seen that the wave theory could explain interference, but the particle theory could not. Both could explain reflection and refraction.

a. However, the two theories led to different conclusions in their explanation of refraction. What was this difference and how were the two different conclusions tested by experiment. With what result?
b. If we agree to a wave theory of light we are still faced with the 'straight-line' difficulty: ripples (for example) bend round

obstacles, but light casts sharp shadows, at any rate in ordinary scale experiments. What can you say about this?

15 Introductory questions about force and motion

Some questions NOT TO BE ANSWERED, not in writing at any rate. These are for you to wonder about and to discuss with other people.

It takes an exceptional athlete to run a mile in 4 minutes, and nobody in the world could do it while carrying a weight equal to the weight of a bicycle. Yet any active boy or girl could ride a good bicycle one mile in 4 minutes. How does this happen?

If you get a bicycle going at, say, 15 mph on a straight level road, and then stop pedalling, you go a long way before stopping. Why do you ever stop? If the bicycle was well oiled and perfectly frictionless would you ever stop? If you were in a vacuum (wearing a space suit!) would you ever stop?

How does an earth satellite keep going without using up fuel?

What does a space ship do far out in space: travel more and more slowly, travel at the same speed as time goes on, travel in a circle or a straight line or what?

When a policeman starting out on a motor cycle speeds up to 20, to 40, to 60 mph it takes him some time and some petrol to reach 60 mph. What is it that stops him reaching that speed at once? Is it air-resistance, is it road friction, or something else?

If a rocket has a downward blast just strong enough to keep it hovering a few yards above the ground without rising or falling, what will that rocket do with the same blast if it is aimed horizontally? What would the force-measuring machine on a test bench show if the same rocket was fired horizontally but kept tied up to the machine?

Can a rocket go faster and faster in a vacuum?

Does a railway diesel engine need friction on the rails?

If a diesel engine pulling ten carriages takes $\frac{1}{2}$ minute to speed up to 40 mph, how long would a diesel engine pulling twenty carriages take?

Is there any force pulling or pushing the Moon, as a whole?

Some radioactive atoms shoot out a small particle from their nucleus, an alpha particle, which turns out itself to be a helium nucleus. When that happens, the remainder of the original atoms is quite a different atom with different chemical properties. When an atom at rest shoots out a high speed alpha particle like that, does the rest of the atom recoil faster than the alpha particle or slower or not move at all?

16 Vibrators and tickertape

131 *a.* Two pupils, who have a stopwatch as well as the vibrator and tape apparatus, want to find 'How many ticks in 10 seconds?' What advice would you give them about how to do this?
b. They make five 'runs' and count the number of dots in each 10 second run. The five countings are:

498, 554, 513, 476, 504

How should they find the number of ticks in 10 seconds; and what result should they get?

c. Suggest three important reasons why these numbers are not all the same.
d. You are told that the vibrator is supposed to be making 50 ticks in a second. Do you think the pupils' results agree with this? Write a sentence or two of explanation.

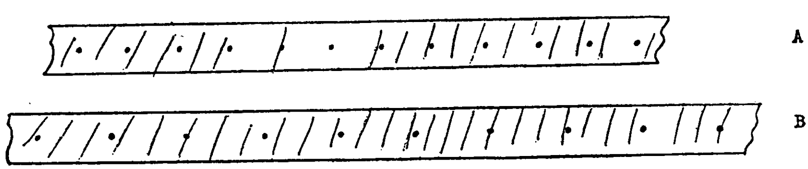


Figure 132

132 A and B above are diagrams of torn-off pieces of tape. Both of these represent the same kind of motion, though with differing speeds. The vibrator makes 50 ticks per second.

a. What kind of motion do they represent?
b. What speed does A show? (Use a ruler.)
c. What speed does B show?

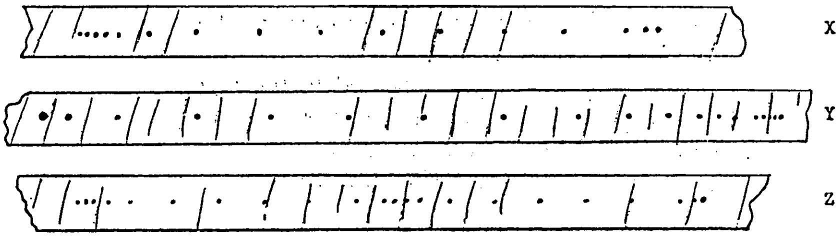


Figure 133

133 Which of the above tapes shows motion that:

a. Slowed down then speeded up again?
b. Reached the fastest speed?
Give the reason for each answer.

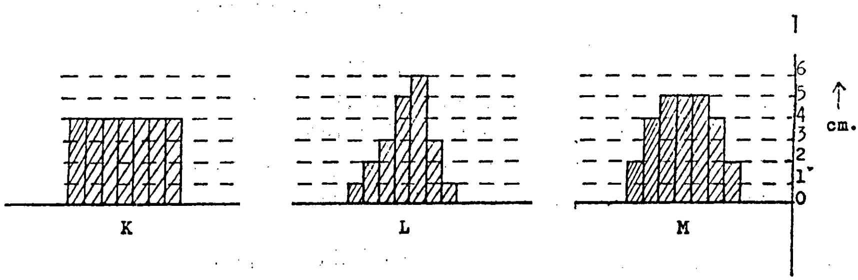


Figure 134

134 Diagrams K,L,M show pieces of tickertape cut off 'every ten ticks' and pasted side by side. In each case there are seven pieces, and the heights are shown in cm. The dots at the start and the end of each run were too close to count properly, so only the middle sets of ten ticks (70 in all) are shown.

a. Describe briefly the kind of motion followed by the person or object pulling the tape through if the result is (*i*) like K; (*ii*) like L; (*iii*) like M.
b. So far as you can tell from the diagrams which tape showed the fastest speed, and what was that speed: (*i*) in cm per ten ticks (remember that each length of tape corresponds to a time of ten ticks); (*ii*) in cm per second, if the vibrator used tapped out 50 dots in one second?
c. Actually it seems likely that the fastest speed reached was more than that calculated in (*b*), though for a shorter time than ten ticks. Why is this?

135 Look again at diagrams K,L,M of question 134.

a. How far did the object attached to the tape move in 70 ticks ($\frac{7}{5}$ seconds) for the motion shown in K?
b. How far for the motion shown in L?
c. How far for the motion shown in M?

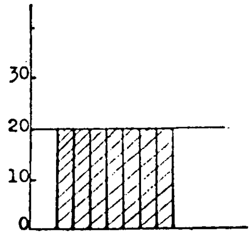
136 *Difficult*
a. Calculate the *average speed* for the 70 ticks shown in diagram K, question 134. To do this, use answer 135 (*a*); remember that the time is 70 ticks = $\frac{7}{5}$ seconds; and calculate by using:

$$\text{average speed} = \frac{\text{total distance moved}}{\text{total time taken}}$$

b. In the same way, calculate the average speed for the 70 ticks shown in diagram L.
c. Then do the same for diagram M.
d. The average speed you found in (*a*) is, of course, the actual speed of tape K throughout the time of 70 ticks. This is *not* true for tape L. Did tape L *ever* have the actual speed you found in (*b*)? If so, how many times did it have that speed?

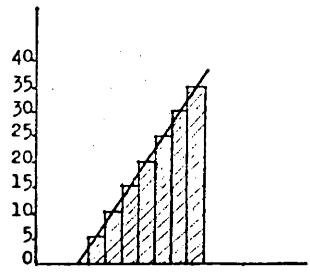
Note: The same question could be asked about tape M, and the answer would be the same.

137 P,Q,R,S (page 63) are tickertape diagrams showing four different motions. The length of each piece of tape corresponds to ten ticks.



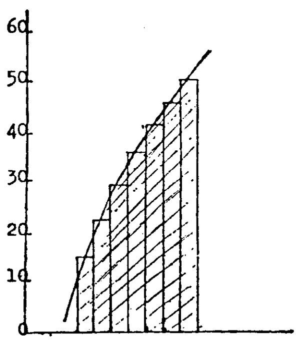
P

Figure 137



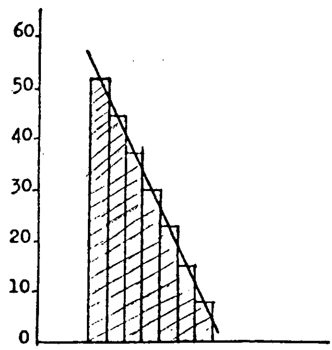
Q

Figure 138



R

Figure 139



S

Figure 140

The numbers represent velocities in centimetres per tenticks.

a. Which two of these show an increase of speed?
b. Which one of these shows a *steady* rate of increase of speed (called a 'constant acceleration')?
c. Which one of these shows a *steady* rate of decrease of speed (called a constant 'deceleration' or 'negative acceleration')?
d. Which one of these shows zero acceleration (i.e. neither acceleration nor deceleration)? In this case, what can you say about the speed (or velocity)?

Note: From now on, the word 'velocity', rather than 'speed', will usually be used. For things moving in straight lines, for example the paper tapes in these questions, there is no need to distinguish between speed and velocity; but we shall see later that 'velocity' conveys two ideas, the idea of speed *and* the idea of *direction* of motion. After all, the speed at which you are moving is not the only thing that matters; which way you are going is also important!

138 *a.* What is the value of the constant velocity represented by diagram P? Give the answer in *cm per tenticks.*
b. If the paper strips, diagram P, had been for 50 ticks instead of 10, how tall would they have been for the same velocity?
c. If 50 ticks take one second, what is the value of the constant velocity represented by diagram P in *cm per second,* and in metres per second?

139 *a. Diagram Q:* by how much does the velocity increase in every tenticks interval of time? Give the answer in cm per tenticks.
b. How much is this increase of velocity in cm per second and in metres per second? (50 ticks = 1 second.)
c. Answer (*b*) is the *acceleration* in cm per second in every tenticks. What is the acceleration in cm per second in every second, and in metres per second in every second?

140 *More difficult.* Use diagram S instead of diagram Q, and find the (negative) acceleration represented by S. You can use exactly the same method as you used for question 139. Don't forget the minus sign.

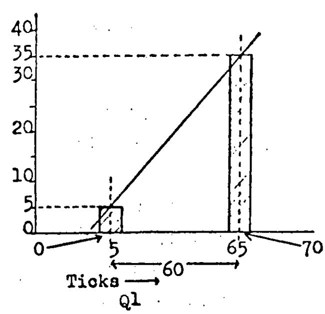


Figure 141

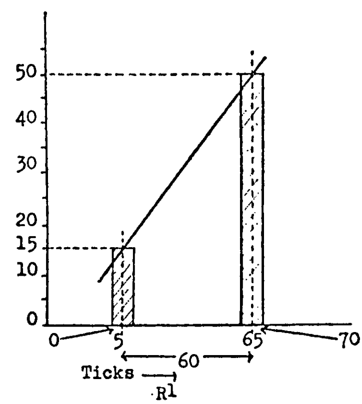


Figure 142

Diagrams Q^1 and R^1 are the same as the previous diagrams Q and R, question 137, except that the five strips of paper between the first and last have been left out; only the first and last have been pasted on. We see that the *centre* of the first strip is 'tick 5', and the *centre* of the last strip is 'tick 65', and there is a time interval of 60 ticks between the centres. The numbers at the side still represent centimetres length of tape.

141 Diagram Q^1. Find the acceleration represented by this diagram:

a. in cm per tenticks in every tenticks.
b. in cm per second in every ten ticks (50 ticks = 1 second).
c. in cm per second every second.

Do not use any information which is not on diagram Q^1. If you are right your answers are the same as for question 139. We did not need all seven strips; only the first and last (or indeed, *any* two) are necessary.

142 Diagram R^1. Find the acceleration this diagram represents:

a. in cm per tentick in every ten ticks.
b. in cm per second in every ten ticks (50 ticks = 1 second).
c. in cm per second per second.

You should now wonder what exactly it is that you have found in these answers. R^1 is a simplified diagram showing only two tapes. R is a 'better' (more correct) diagram showing seven tapes. The answers you have found are for the *average* acceleration between tick 5 and tick 65. The straight slanting line in R^1 represents the *average* acceleration, but the *actual* acceleration at various times is shown by the curved line in R.

If the acceleration is constant (same all the time), then by using the first and last strips we get the actual acceleration. But if the acceleration changes (as in diagram R), by using the first and last strips we get the *average* acceleration.

143 Sixty ticks (questions 141, 142) is rather an awkward number to take; 50 or 100 or 200, etc., would be better. The diagram shows two lengths of tape. One includes dots 0 to 10, then we count on another 90 dots, and cut off a length of tape including dots 100 to 110. So these tapes are '100 dots apart'. And 100 dots = 2 seconds. Find the acceleration in (*a*) cm per 10 dots per second, and (*b*) cm per second per second.

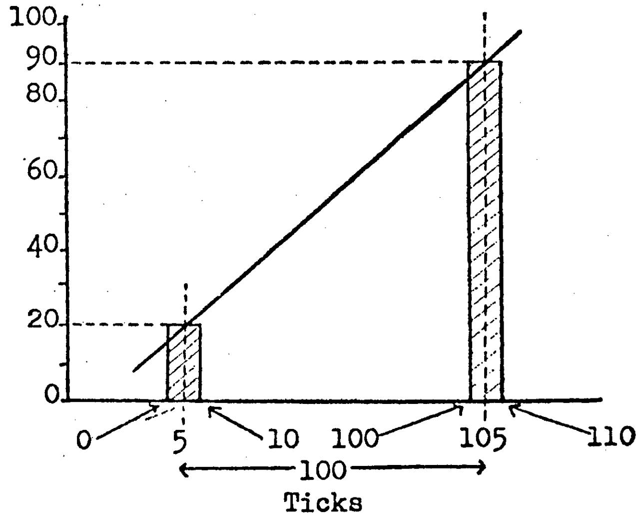


Figure 143

144 You have probably noticed that we need not stick the tapes on paper, though, of course, doing so does make it easier to see what is happening. We need not even cut off the tapes, all we need to do is to measure the distances between suitable pairs of dots. The following question shows this:

Two boys are using a vibrator and tape to measure the acceleration of a trolley running down a sloping plank. They count 110 dots, and measure a length of 22·5 cm between dot 0 and dot 10, and 94·5 cm between dot 100 and dot 110.

a. What is the speed of the trolley at the time of dot 105, in cm per 10 dots?
b. What is the speed of the trolley at the time of dot 5?
c. What is the trolley's acceleration in cm per 10 dots? per 100 dots?

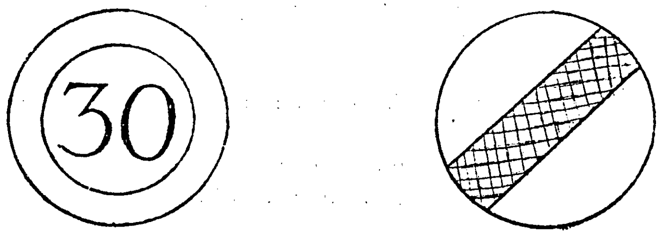
d. What is the acceleration in cm per 10 dots per second?
e. What is the acceleration in cm per second per second? (50 dots = 1 second.)

145 *Distance covered*. Look back to diagrams P,Q,R of question 137. Remember that each piece of tape represents the distances moved in a time of 10 ticks.

a. In P, how far did the object attached to the tape move in 70 ticks?
b. In Q, how far did it move in 70 ticks?
c. In R, how far did it move in 70 ticks?

17 Speed and velocity, acceleration

146 *a.* You are in a car approaching a town, and you see sign A. Later you see sign B. What do these signs mean?



A B

Figure 146

b. Suppose that, between sign A and sign B, you travel at a steady speed of 30 miles an hour. How far do you go in one minute?
c. Beyond sign B you speed up to 60 mph. How far do you go in one minute now?
d. An overseas driver has his speedometer marked in kph. What do you think kph means? And if 1 k = $\frac{5}{8}$ mile, what is the maximum his speedometer should read in a built-up area in England?*

147 *a.* If 1 mile = 3 × 1760 feet, what is 30 mph in feet per second? What is 60 mph in feet per second?
b. How much is a speed of 10 metres per second in kph? How much is this in miles per hour (1 k = $\frac{5}{8}$ mile)?

148 *a.* The 'reaction time' of a certain driver is one-fifth of a second – that is, the shortest time interval between when he notices something and when he can carry out some muscular action in consequence. This time interval is one-fifth second. When he is driving at 25 metres per second he suddenly sees the road blocked ahead and 'instantly' (so he says) applies the brakes. How far did he travel between noticing the obstacle and starting to apply the brakes?
b. Actually the car travels considerably farther than your answer to (*a*) before it comes to a stop. Why is this?

* The proper abbreviation is 'km', not 'k', but Continental speedometers are usually marked 'kph'.

149 *a.* A good sprinter can run 100 yards in 10 seconds. What is his speed in miles per hour? (Nearest whole number will do.)
b. If 10 seconds for the 100 yards is a good time, what is a good time for the 100 metres? (Nearest tenth of a second. Yes, you need to know how many yards in a metre. *You* find that out somehow.)

150 In (*a*) and (*b*) below you are asked to calculate two speeds, one small, one large. For each calculation you need to know that the circumference of a circle is 2π times the radius, where $\pi = 3{\cdot}14\ldots$ However, for these calculations it will be sufficient to put $\pi = 3$, $2\pi = 6$, and so avoid awkward arithmetic.

a. A wrist-watch has an hour hand of radius 1 cm. What is the speed of the tip of the hand in metres per second?
b. The radius of the Earth is 6400 kilometres. What is the speed of a point on the equator in metres per second?

151 *a.* Suppose we work out answers to question 150 (*b*) for places *not* on the equator – the British Isles for example. Are we moving faster or more slowly? Explain your answer with the help of a diagram.
b. What about a man at the North Pole? How fast is he moving?

152 How fast is a '4-minute mile' in miles per hour? ('4-minute mile' means one mile run in a time of 4 minutes.) Would you expect the runner to run all the time with exactly the speed you calculate? Is it possible he could have done? Why must he at some time have been running faster than the result you give?

Would you call your result the runner's fastest speed, or maximum speed, or slowest speed, or steady speed, or average speed – or what?

153 Describe something you have noticed (not something you have read about or been told) which leads you to think that light travels more quickly than sound.

Note: If you have never noticed anything of the kind, then describe some observation you might make which would enable you to decide which travels more quickly, light or sound.

154 A car has a speed of 20 mph. Two seconds later its speed is 23 mph. Two seconds after that, 26 mph. We can tabulate this:

time, seconds	0	2	4
speed, mph	20	23	26

a. If it continues to accelerate like this, what is its speed at time 6 seconds? 7 seconds? 10 seconds?
b. What would you think its speed was at time -2 seconds, that is, 2 seconds *before* its speed was 20 mph?
c. How much increase of speed is there in two seconds?
d. How much increase of speed is there in one second?
e. Which of the above answers is the *acceleration*?
f. What is meant by 'acceleration'?

155 Readings of the speedometers of three cars, A, B and C, are taken every five seconds:

time, seconds	0	5	10	15	20
A's speed, mph	30	30	30	30	30
B's speed, mph	30	34	38	42	46
C's speed, mph	30	$22\frac{1}{2}$	15	$7\frac{1}{2}$	0

a. How much does A increase in speed every 5 seconds? What is A's acceleration?
b. How much does B increase in speed every 5 seconds? What is B's acceleration?
c. How much does C increase in speed every 5 seconds? What is C's acceleration? (Remember to get your signs, $+$ or $-$, correct.)
d. What does '0' mean, for C's speed at time 20 seconds?
e. It is unlikely that car C would continue after 20 seconds with the same acceleration, but if it did, what would its speed be at time 25 seconds? Explain what your answer means.

156 *a*. A train increases its speed steadily from 40 km per hour to 50 km per hour in 5 seconds. What acceleration is this?
b. The same train might also increase in speed from 12 metres per second to 15 metres per second in 5 seconds. What is its acceleration?

157 A friend of yours sees your answer to 156 (*b*) and says, 'What a silly thing to write, "metres per second per second"; either it means nothing, or it means the same as metres per second.' Write a few sentences explaining to him: (*a*) what is meant by (for example) '2 metres per second per second' and what quantity is measured in these units, and (*b*) what '2 metres per second' means, and what it is that is measured in metres per second.

158 *a*. You are riding a bicycle at a steady speed of 6 metres per second. How far do you go in one minute?
b. You are riding a bicycle at a speed of 6 metres per second when you stop pedalling. The bicycle takes 1 minute to stop, and *it has a steady deceleration* (negative acceleration) all the time. How far does it go before stopping? *Note:* The answer to this question is half the answer to (*a*). Why?

159 *Not* difficult. *Easy*, if you can do question 158 (*b*).

A train is $1\frac{3}{4}$ kilometres from a station when the guard operates a lever which disconnects the last coach from the rest of the train. The train continues with the same *constant speed* (60 mph if you like) and the coach is braked so that it has a *constant deceleration* and comes to a stop at the station. How far away is the train when the coach stops?
Yes, very easy! But now, explain in two or three sentences why your answer is correct.

18 More experiments with tapes and vibrators

160 Find a small stone or other small heavy object. Stand on a stool or chair or bench and drop it from a height of about 2 metres (6 feet 6 inches near enough).

a. Make a guess at how long (seconds) it took to reach the ground.
b. You cannot tell, simply by watching the stone, exactly what its motion is like – it could be a steady increase of velocity, or it could be that first it speeds up, then reaches a steady velocity.
But it cannot be a motion with a constant steady velocity all the time from when you released it until it reached the ground. Why not?

161 You can count quarter-seconds by saying 'nought, one, two, three, four' (0, 1, 2, 3, 4) quickly and distinctly. Try this while looking at the seconds hand of a watch or clock, and then, when you have the timing about right, repeat the stone-dropping described in question 160, still from a height of 2 metres. Find the time taken – is it nearer $\frac{1}{4}$ second, or $\frac{1}{2}$ second, or $\frac{3}{4}$ second, or 1 second?

a. Exactly how did you do this?
b. Find the *average* velocity of the falling stone in metres per second.
c. *More difficult.* (No need to finish this unless you wish.) Let us *assume* (we don't yet know) that the stone accelerated (increased its speed) in a steady uniform manner (i.e. a constant acceleration). Write down:

(*i*) The average velocity (your answer (*b*)).
(*ii*) The final velocity (remember that the velocity at the start, when you released the stone, was zero).
(*iii*) Your answer (ii) is also the increase of velocity, because the starting velocity was zero. This increase took place in the time you counted.

Now find the increase of velocity *in one second*, which is the acceleration.

Note: This experiment is, of course, highly inaccurate, but it does show the 'order of magnitude' of the acceleration, that is, give us some idea of how big the acceleration is.

d. Why is (*c*) a highly inaccurate experiment?

162 Two boys set out to find whether a stone falling a distance of about 2 metres was being accelerated all the time. They chose a rather heavy stone and attached it to paper tape which could be run through a vibrator. After a few attempts they obtained a clearly marked piece of tape about $1\frac{1}{2}$ metres long. As usual, the tape showed a bit of a 'fuzz' at the beginning, and the first clearly marked dot was about 3 cm from the start. They marked this dot '0'. Then they counted and marked all the rest of the dots, about 23 in all. Three pieces of the tape are shown below.

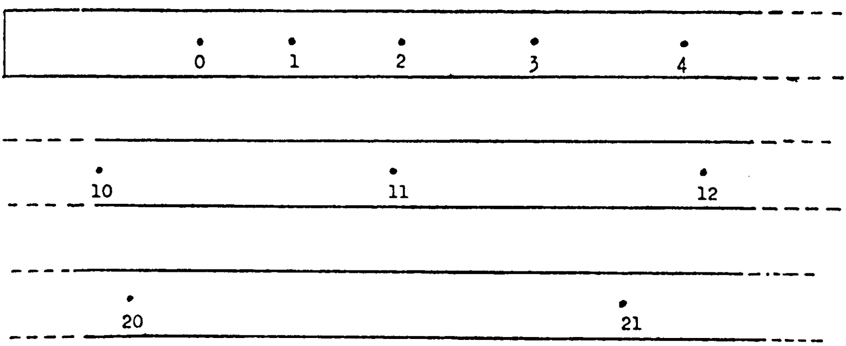


Figure 162

a. Say briefly how you would do this experiment; that is, say how the vibrator is placed, how you get the readings, and what is the chief source of possible error you have to guard against.
b. Do the results shown in the diagram agree with the idea that the stone reaches a constant velocity? OR, do they show that the stone was accelerating all the time? Give the reason for your answer.
c. Difficult (omit if you like). The boys measured the distance along the tape from dot 0 to dot 10, and then from dot 10 to dot 20:

distance from dot 0 to dot 10 = 35·3 cm (in tenticks)
distance from dot 10 to dot 20 = 73·3 cm (in tenticks)

Notice that the middle dot between 0 and 10 is dot 5; and the middle dot between 10 and 20 is dot 15. Now write down answers to the following:

(*i*) The velocity at dot 5 in cm per tentick.
(*ii*) The velocity at dot 15 in cm per tentick.

(*iii*) The increase of velocity between dot 5 and dot 15 (5 to 15 is, of course, also tenticks).
(*iv*) The answer to (*iii*) is the *acceleration* in cm. per tentick in every tentick. If 50 ticks take 1 second, how long do ten ticks take?
(*v*) Now write down the acceleration in cm per second in every second. (Which is it you multiply by? Is it 5? $\frac{1}{5}$? 25? $\frac{1}{25}$?)

Note: In answering (*c*) you assume that the stone is accelerating all the time – we know it is from result (*b*). We also assume that it has a constant, steady acceleration. This also could be shown from the paper tape, though we did not do so in this question.

163 'Diluted fall'
A trolley runs down a sloping plank. As it goes, it drags paper tape through a vibrator. Two pupils then cut up six lengths of the tape, the first from 'dot 0' to 'dot 10', the next from 'dot 10' to 'dot 20' and so on. 'Dot 0' is the first of the clearly marked dots – not, of course, the actual beginning of the trolley's movement because the dots are too close together at the start. The six lengths of tape are then stuck next to each other, as in figure 163, which is drawn half-size.

a. What does this chart, figure 163, tell you about the motion of the trolley?
b. Give the reason for your answer to (*a*).
c. If you can, find the acceleration of the trolley,
(*i*) in cm per tentick in every ten ticks
(*ii*) in cm per second in every second.

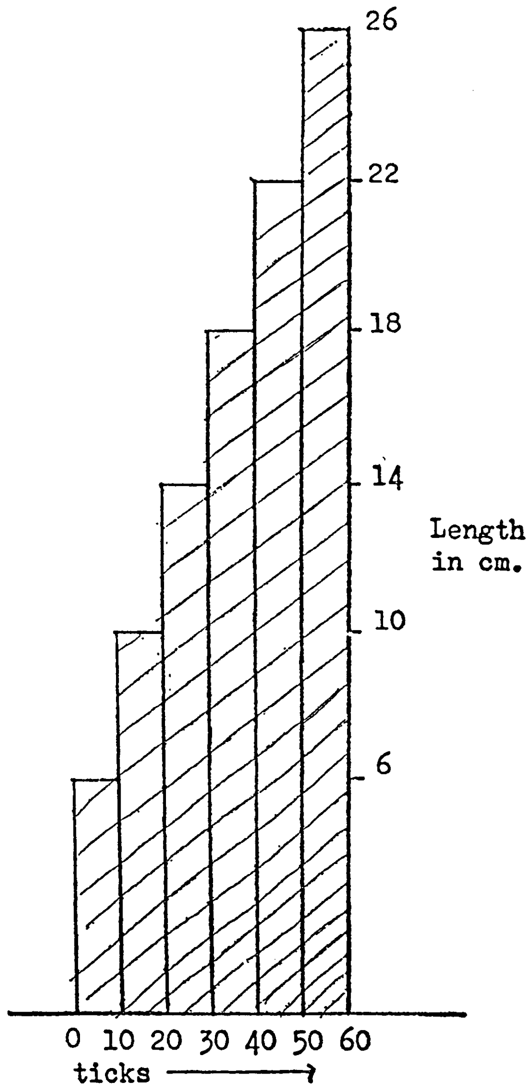


Figure 163

164 A boy stands at the top of a flight of stairs and holds a string which is fastened to the floor below, or to a small heavy object. Small weights are attached to the string at points 1 foot, 4 feet and 9 feet above the floor. The boy lets go of the string and listens to the timing of the 'clonks' as the weights hit the floor.

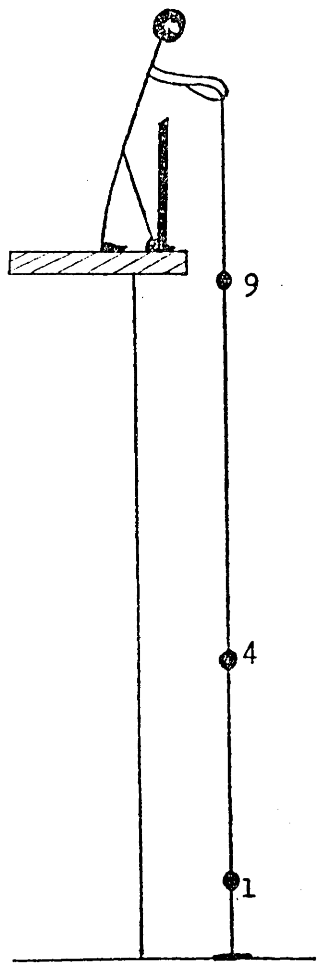


Figure 164

a. What would he notice about the timing of the noises he hears?
b. If he were able to have a string going up *two* flights of stairs, where should he tie a *fourth* weight on the string?
c. Suppose, instead, he tied the weights at heights of 3, 6, 9, 12 feet above the floor, what would he now notice about the timing of the noises made when he drops the string?

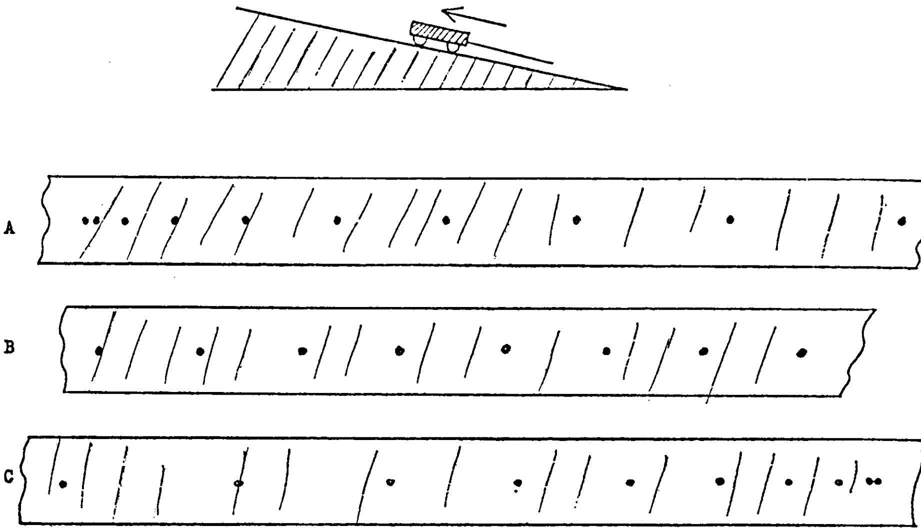


Figure 165

165 A trolley is given a push *up* a hill from right to left (figure 165) so that it travels some way up before stopping. It drags tape through a vibrator.

a. Which looks like the result you would expect to get, A, B or C? If none of them look right, draw a fourth tape, D, which does look right.
b. Give the reason for your choice (or for your new tape D) in answer (*a*).

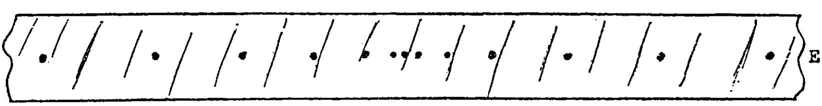


Figure 166

166 You pick up a piece of paper tape which looks like E above. Draw a sketch (like figure 165) showing the sort of slanting plank or planks upon which the trolley that made this has been travelling.

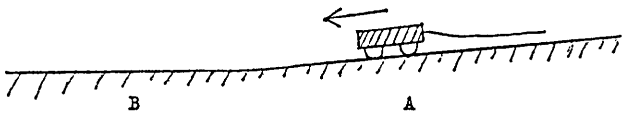


Figure 167

167 A trolley pulling tape through a vibrator runs down a sloping plank (figure 167) and on to a flat horizontal plank. Make a rough sketch of a piece of the tape with dots showing what happens when the trolley passes from somewhere near point A to somewhere near point B.

19 Motion under balanced forces (or no force)

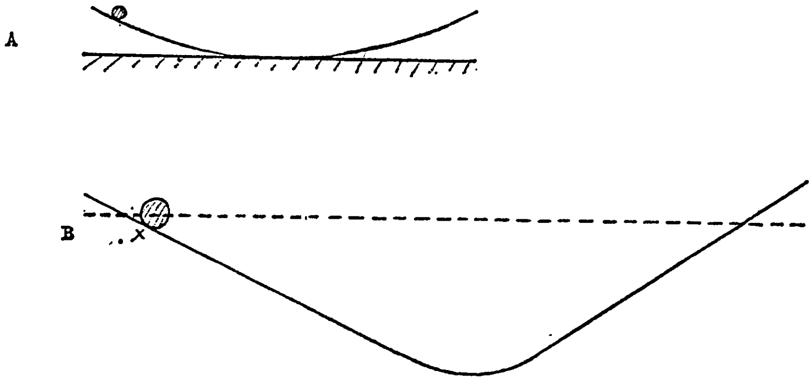


Figure 168

168 *a.* Figure A shows a curved glass surface – a large 'watch-glass' from the chemistry lab, or a large curved mirror. It is placed on the bench and a small ball-bearing is held as shown, and is then released.

What happens to the ball bearing?

b. Figure B shows a length of curtain rail, bent as shown. A ball is placed at position x and is let go. How far does it go up the other side? What happens then?

Figure 169 (*a*)

169 *a.* Figure 169 (*a*) shows a small hill followed by a higher hill. A ball is rolled up and over the first hill. Describe what happens:
(*i*) if the ball has only *just* enough velocity to get over the small hill;
(*ii*) if it has enough velocity to shoot over the small hill with plenty to spare.

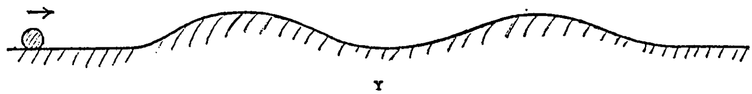


Figure 169 (*b*)

b. Figure Y shows the surface of a lawn which has two ridges and a dip in between; otherwise it is flat. What would you have to do in order to roll a ball so that it came to rest in the dip?

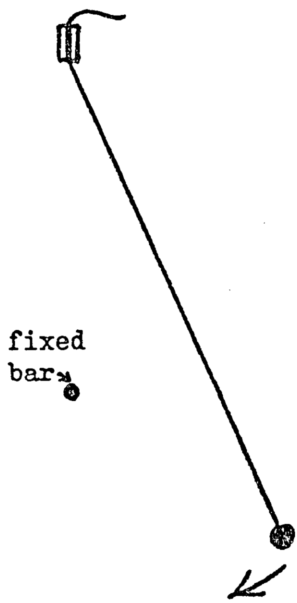


Figure 170

170 *a.* The pendulum bob, figure 170, is released from the position shown. Copy the diagram and show on it the position that the bob swings to.
b. Draw a curved 'hill' down (and up) which a ball could roll and follow a path just like the path of the bob.

Note: Use a pair of compasses.

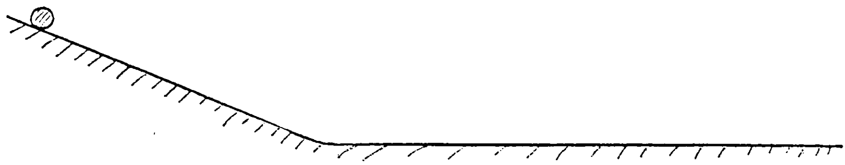


Figure 171

171 Figure 171 shows a hill down which a ball rolls on to a flat horizontal surface which goes on as far as you like.

a. What happens to a real ball on a real surface?
b. What would happen if there were no friction or air resistance at all?

172 You have seen an experiment in which a 'carbon dioxide puck' is placed on a sheet of glass with a frame round it, and is given a gentle push. Describe what happens, and explain what happens by referring to 'friction', for

a. a puck properly filled with solid CO_2,
b. a puck containing no CO_2.

Also:

c. Say what you think 'friction' is. (Don't look in books – make up an answer of your own.)

173 *a.* A space ship is moving far out in space, away from any large bodies like the Earth or the Sun or the planets. Its jets are shut off; what happens to it?
b. What similarity is there between the motion of the space ship, and the motion of the CO_2 puck in question 172 (*a*)? Also, what differences are there?

174 *a.* Suppose you have, on a glass surface, a CO_2 puck which works perfectly, so that there is no friction at all. There are still *two* forces acting in the puck, what are they? Which is the larger? Or, are they equal?
b. A locomotive pulls a train along a flat horizontal track with a pull (force) which exactly equals the retarding force of friction, air resistance, etc., on the train. What can you say about the motion of the train?

175 You can now draw a general conclusion from the experiments and observations you have seen, and heard about.

a. If all the forces acting on a moving body exactly balance each other, OR if there are no forces at all acting on the body, what can you say about the motion of the body?
b. What difference does it make if the body we were talking about in (*a*) is not in motion, if it is at rest?

176 *a.* Give one different example (not in these questions) of a moving body for which all the forces acting on it are exactly balanced, and say what happens to it.
b. Give one example of a body at rest, with all the forces acting on it exactly balanced, and say what happens.

177 Lastly – and this is important – if you see a body *either* at rest *or* moving at a steady speed in a straight line (e.g. a car moving at a steady 30 mph), what can you say about the forces acting on it?

20 Inertia

The last question of the last section was: 'If you see a body *either* at rest *or* moving at a steady speed in a straight line, what can you say about the forces acting on it?' The answer: 'The forces acting on it balance out so that there is no resulting force; or, of course, there are no forces acting on it at all.'

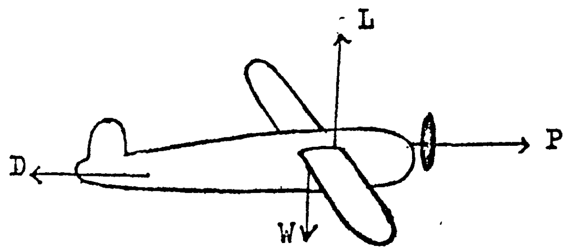


Figure 178

178 A small aircraft is flying 'straight and level' and at a constant speed. The forces acting on it can be represented by four arrows, as in figure 178. These are:

P, the forwards push of air on the propellor;
W, the weight of the aircraft;
D, the 'drag', that is, frictional resistance due to the air;
L, the 'lift' provided by the wings.

a. The aircraft is flying horizontally with constant speed. What two things can you say about the four forces acting on it (or two equations if you prefer)?
b. Difficult (do not answer unless you wish). In figure 178, which pair of forces are trying to turn the aircraft nose downwards? And which pair are trying to turn it nose upwards? If the aircraft continues to fly straight and level, what can you say about the turning effects of these pairs of forces?

179 A fat boy is sitting on a toboggan (a small sled) on a very gradual, only slightly inclined, ice slope. The inclination is just sufficient for him to slide at a steady slow speed; that is to say, just sufficient to allow for friction. Suppose another boy comes up behind and pushes steadily for a few seconds.

a. Uncle George says that the slope already 'overcomes friction', so the slightest extra force will immediately produce a very large increase of speed.
b. Freddie Jones agrees that the slope has already allowed for friction, 'but', he says, 'that only means that any extra force will make no difference'.

Is either answer right? If not, what do you say would happen?

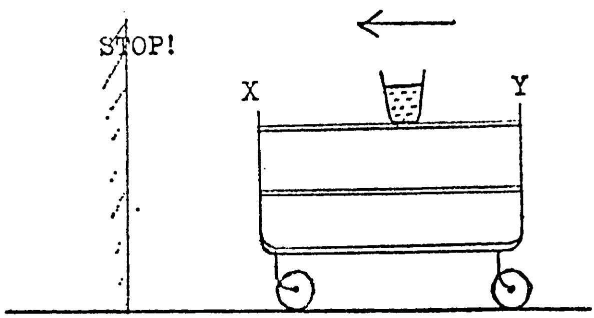


Figure 180

180 Figure 180 shows a tea-trolley, dinner-wagon, 'dumb-waiter' or whatever you call it! A tumbler of water (shown rather larger than life size) is standing on it. The trolley is moving to the left when it suddenly hits a wall and stops.

a. If the tumbler slides, which way does it slide?
b. If the tumbler topples over, which way does it topple over?
c. If the water slops out, without the tumbler falling, which way does it slop out?
d. Suppose the tea-trolley is at rest and you want to make the water slop out of the tumbler towards X (without tilting the trolley). What can you do to the trolley?

181 A man's hat blew on to a path. A mischievous boy, who was passing, gave it a good kick, and then ran away.

The man knew the boy would come back soon, and decided to 'get his own back'. He put the hat on the path with a large brick underneath. The boy kicked the hat, and squealed because he hurt his foot. Freddie Jones said it served the boy right. Freddie tried pushing the hat and brick with his foot; it moved quite easily along the smooth ground. Why was it that the boy hurt his foot?

182 When answering question 181 we can, if we like, say that the brick possesses 'inertia' (though saying this does not answer the question!). The tumbler of water in question 180 has inertia, and so has the fat boy and toboggan in question 179 and the aircraft in question 178. The word INERTIA is simply the name given to a property which is possessed by bricks, fat boys (and thin ones, though the thin ones have less), toboggans, water, aeroplanes and a lot of other things – in fact *all* material objects.

a. What do you think is meant by the word *inert* in everyday life (not particularly in Physics)?
b. What are 'inert gases' in Chemistry? Why are they called inert?
c. Difficult (but make an attempt!). What do you think is meant in Physics when we say an object has inertia?
d. Again *difficult* (but have a try). What difference is there in the meanings of 'inert' and 'inertia' used in (*i*) Physics, (*ii*) everyday life?

183 Describe briefly two experiments or observations, different from those in the previous questions of this section, which show that material objects possess inertia.

21 Movement and forces

184 Describe *one* interesting experiment you (perhaps with assistance of other boys or girls) may have done, using a large trolley and spring balances. What result did you obtain, or what conclusion did you draw, from the experiment?

185 In the experiment you described in answer to question 184 did you make any allowance or compensation for friction? If you did, how did you do so? If you did not, how might you have done so?

186 You have done acceleration experiments with small trolleys pulled by elastic. First you had to pull a trolley along with a steady force *F*, unchanging over most of the trolley's run from start to stop. This was done by using a piece of elastic. Then you pulled it with a force of 2F, then perhaps, 3F.

a. How did you make sure that a *steady* force F was being exerted? (Give details of exactly how you did this.)
b. How did you get forces of 2F and 3F?
c. You also inclined the trolley board slightly in order to compensate for friction – how did you find the correct angle of inclination?

187 Two pupils did a trolley and tape experiment in which they pulled the trolley, first with one elastic thread, and then with two threads kept extended to the same extent as before.

They took the first tape and cut the middle part of it into six lengths, 'tenticks' each, 0–10, 10–20, 20–30, 30–40, 40–50 and 50–60. These were pasted at regular intervals on graph paper, with the result shown, one-quarter real size, in figure 187 (*i*). They then did the same thing with the second tape, result as in figure 187 (*ii*), also one-quarter actual size.

197 Figure 197 represents a 'multiflash' photograph of a ball falling after being held and released.

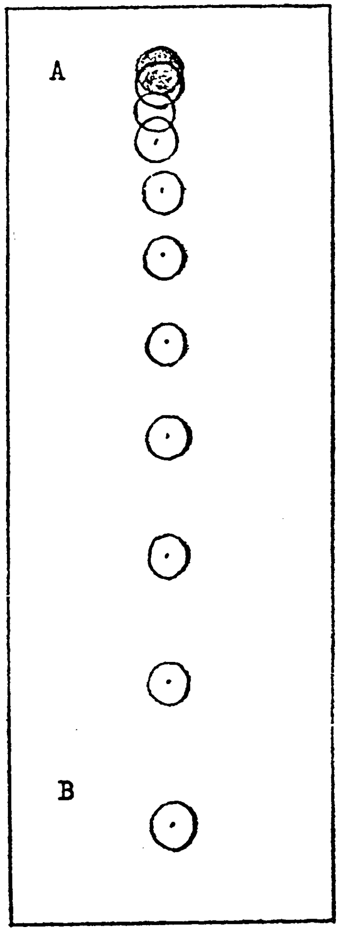


Figure 197

a. What can you say about the motion of the falling ball, simply by looking at a picture like this?
b. Why is the picture likely to be somewhat blurred at the beginning, A?
c. Why is the picture likely to be somewhat blurred at the end, B?
d. Suppose a multiflash picture had been taken of something moving with constant velocity, what would it have looked like? (Make a sketch.)

e. These pictures are taken with a white or polished ball and a black background. Freddie Jones tried to take a picture with a black ball against a white background. Result: no sign of the ball on the picture at all. How do you explain this?

198 Take a penny and cut a circle of not-too-flimsy paper the same size as the penny, or preferably, slightly smaller so that it does not overlap anywhere.

a. Drop the penny and the paper circle simultaneously. What happens? Which reaches the floor first? How do you explain this?
b. Place the paper *under* the penny, hold them horizontally and drop them. Does this show that paper falls as fast as pennies? Give the reason for your answer.
c. Place the paper *on top of* the penny, hold them horizontally and drop them. Does this show that paper falls as fast as pennies? Give the reason for your answer.
d. If you feel you cannot say 'yes' to (*b*) or (*c*), what experiment would you prefer to do with the penny and the paper, which might show without doubt that paper falls as fast as pennies?

199 Figure 199 is a multiflash photograph of a ball which rolled off the edge of a table at T and then fell to the floor.

a. Give what explanation you can of the motion of this ball.
b. Draw a sketch the same size as figure 199 and show on it the picture which the camera would have taken if the table had extended to the right, and the ball had rolled on, without slowing down, until it went outside the picture. (Leave a little space beneath your sketch and to the right of it.)

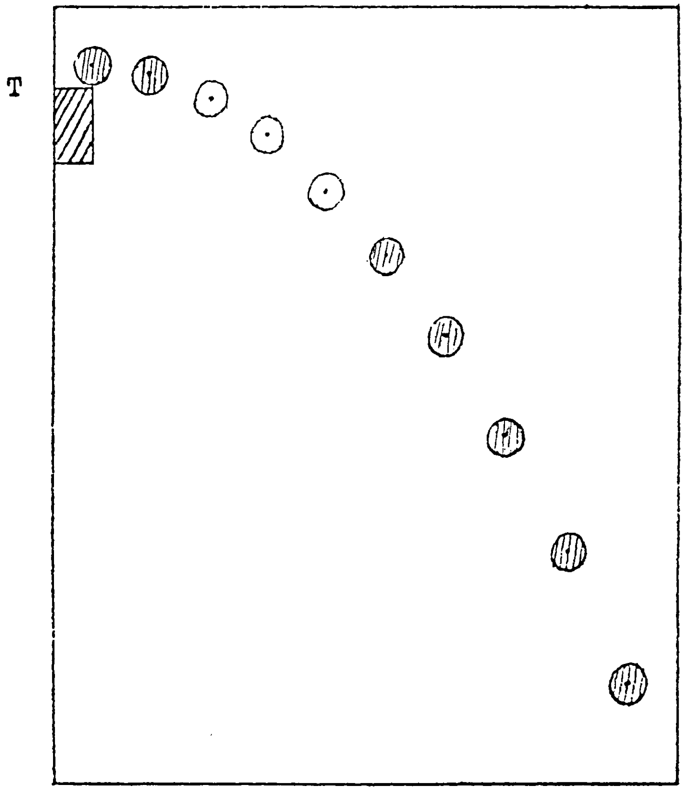


Figure 199

c. On this same sketch (*b*) draw the positions the ball would have had if it fell straight downwards from its first position, without any horizontal velocity. Which other sketch in this section, 22, looks like this?

d. Difficult. In figure 199 there are *ten* pictures of the ball. If the paper had been larger, and the ball did not reach the ground, we would have seen an eleventh and twelfth picture besides the ten in figure 199. Draw on your paper (but of course, outside the rectangle) the positions of the eleventh and twelfth pictures of the ball.

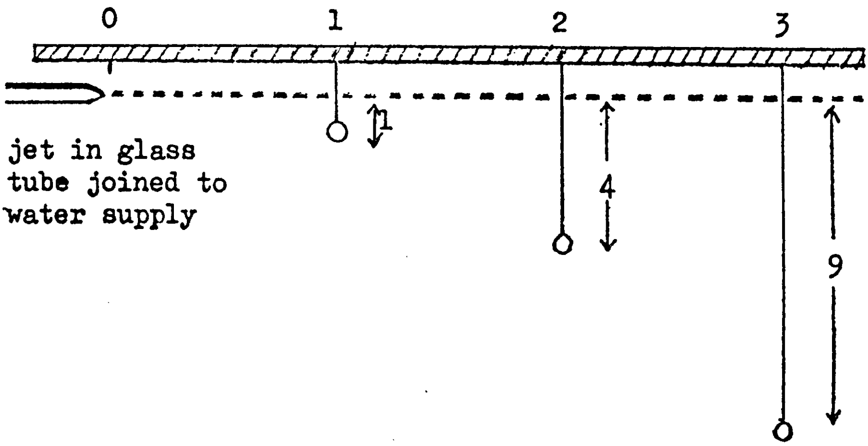


Figure 200

200 Copy figure 200 and then tell a story about an experiment which it illustrates.

201 If you have seen it done, describe the 'Monkey and Hunter' experiment under the following headings.

a. Give a sketch.
b. Say what was done.
c. Say what happened.
d. What conclusion about falling bodies can you draw from this experiment?

Sound travels at 1100 feet per second. Suppose the bullet also travelled at 1100 feet per second, and the monkey waited till *he heard the gun fire* before he let go. Would the bullet hit him?

202 (Just a puzzle – not important.) In actual fact, the sights on a real hunter's gun (question 201) are arranged *so as to allow for* the falling of the bullet under gravity, during its travel. This means that the monkey gets hit if he stays on the branch because the hunter is, in fact, aiming above the branch.

Sound travels at 1100 feet per second. Suppose the monkey waits *till he hears the gun fired* before letting go. The bullet is fired from the properly sighted gun which allows for the bullet falling. Would the bullet hit him: (*a*) if it travels at 1100 feet per second; (*b*) if it travels at 3000 feet per second; (*c*) if it travels at 500 feet per second?

203 *a.* An 80-kg man goes from England, where he was in a gravitational field of 9·81 newtons per kilogram, to the equator, where he is in a gravitational field of 9·78 newtons per kilogram. By how much does the force of gravity acting on him change (answer in newtons)?

b. What is it that is measured in kilograms (e.g. an 80-kg man)?

Note: The answer is *not* the weight (of the man). Weight is measured in newtons or in *kilograms–weight.*

204 A space traveller, complete in his space suit, weighs 882 newtons on a spring balance on Earth. In the same suit on the same balance on a smaller planet he weighs 126 newtons. On a larger planet he weighs 1350 newtons. The gravitational field on Earth is 9·8 newtons per kilogram. What is the gravitational field on:

a. the smaller planet;

b. the larger planet?

23 Molecules in motion: Revision of Year I topics

205 *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 1/10,000th 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?

206 *a.* How does a particle-in-motion theory explain the fact that gases can exert pressure?
b. How does a particle-in-motion theory explain the fact that a gas exerts a bigger pressure when you squeeze it to a smaller volume?

207 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 any apparent diminution of pressure from one year to the next – fortunately for ourselves. How do you explain this?

208 *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. Is the distance between the molecules in the tube less than the distance between the molecules in the air outside? Or greater? Or the same?
b. The picture is made by a stream of 'electrons' which shoot across the tube and fall on the coated screen, thus making it luminous. Explain what would happen if the pressure in the tube were not very low.

24 Ball in motion in tubes: marbles in motion in trays

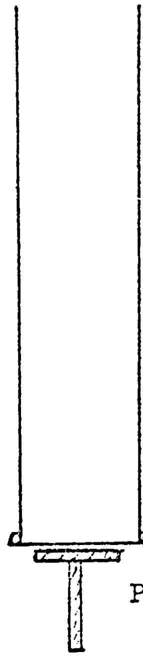


Figure 209

209 Figure 209 shows a wide plastic tube with a base made of sheet rubber. The rubber can be kept in up-and-down motion by a piston fixed to a vibrating rod. A number of small balls are dropped into the tube.

a. Draw a sketch of the tube showing what the balls inside look like when the vibrator is in motion.
b. Describe in words (not more than two or three sentences) the position of the balls in your sketch.
c. In what way do the balls in the tube resemble the molecules of air in the atmosphere? Mention also some differences between this 'atmosphere model' and the real atmosphere.

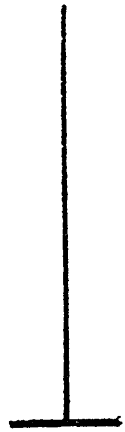


Figure 210

210 Figure 210 shows a paper disk with a thin wire handle. The disk can be put in the large plastic tube, figure 209. First the vibrator is stopped and the balls are at rest on the rubber, then the disk is put in so that it rests on top of the balls.

a. What happens when the vibrator is switched on?
b. What happens when the agitation of the vibrator is increased?
c. What happens when an extra little weight is put on the disk?
d. The balls in the experiment, question 209, *without* the disk, resembled molecules in the atmosphere – in fact, it was a model of the atmosphere. What is this apparatus, *with* the disk, a model of?

211 We use again the apparatus of figure 209, this time including a larger sphere among the ball bearings. What happens to this sphere?

212 You are given a number of marbles and a suitable metal tray; how would you use them:

a. To illustrate what happens when molecules of a gas are enclosed in a certain space, and the space is suddenly doubled? *Hint:* Imagine you start with the marbles in one half of the tray, kept there by a suitable stick or ruler.
b. To illustrate an 'atmosphere' of molecules?

213 Imagine you have a tray, which you keep agitated, containing 24 white marbles, and one other marble which is exactly the same size and weight but coloured red.

a. Draw a rectangle with a 'long' side about 10 cm long (or 4 inches) to represent the tray, and then draw a line in the rectangle to represent a likely path you might see the red marble following. (You need not draw the other marbles, and you need not draw the red marble either – just draw lines to show a likely path for it.)
b. Would one of the white marbles follow a path similar to the red marble, or would you expect it to be different? Give a reason for your answer.
c. Suppose you take out the red marble and put in instead a larger green marble having about twice the weight of the other marbles. How would the path of the green marble differ (if at all) from what you drew for the red marble in (*a*)?

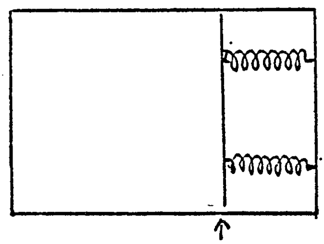


Figure 214

214 The experiment described here is a 'thought-experiment' which you are not likely to have done, but you can easily suggest what would happen if you did do it.

Figure 214 shows a tray into which marbles can be put. The marbles are enclosed at the right-hand end, not by the side of the tray but by a 'movable side' held in position by two suitable springs. The diagram shows the position of the movable side when the tray and marbles (not shown) are being moderately agitated.

a. What happens if the agitation is increased by shaking more quickly?
b. What happens if the agitation is slowed down? Stopped altogether?
c. What happens to gas molecules if the temperature of the gas is increased?
d. What happens to the pressure which a gas exerts on the walls of the vessel holding it if its temperature is increased?

25 Molecules in motion in gases

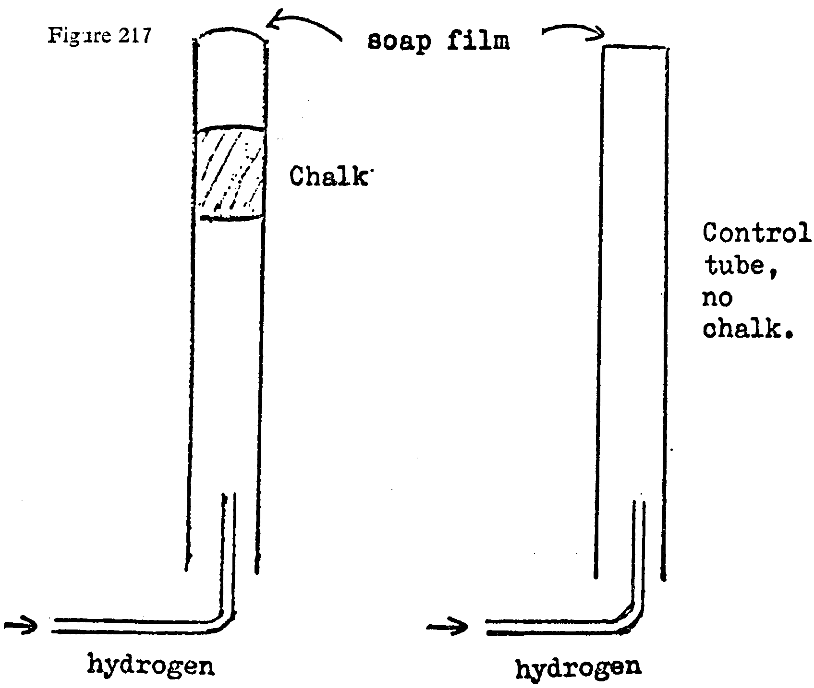
215 You have used a microscope to see the 'Brownian motions' of smoke particles in a small box.

a. Describe (*i*) in words, (*ii*) by a diagram, the motion of a smoke particle.
b. Explain why the motion of the smoke particles suggests that air molecules are also in motion, with much greater speeds.

216 This is another question on Brownian motion of smoke particles.

a. Particles *larger* than smoke particles would be easier to see. What *two* disadvantages would there be in using larger particles?
b. A ping-pong ball is suspended on a fine thread in a closed and entirely draught-free room. Would the ball be completely at rest? Write a sentence or two explaining your answer.

Figure 217



217 Describe the experiment that figure 217 illustrates. Say what happens, and say what conclusion we arrive at from this experiment. Why use the 'control tube'?

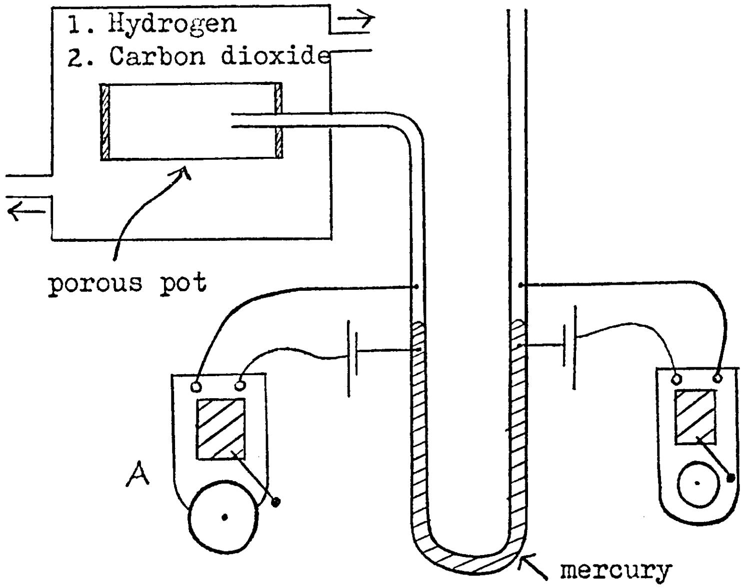


Figure 218

218 The diagram, figure 218, shows a rather complicated apparatus including two electric bells A and B. Each bell, with its battery, is joined to two wires sealed into a side of a U-tube, which contains mercury. A is a big bell with a low-pitched gong; B is a little bell making a high-pitched ring.

One side of the U-tube is open to the air. The other side can be joined to a porous pot also containing air. At first there is air outside the porous pot as well.

a. When the porous pot is thrust on to the tube, bell B rings. Why?
b. After some time bell B stops ringing, and the mercury comes to the same level both sides. Why?
c. Hydrogen is now passed in a very slow stream through a vessel surrounding the porous pot. What happens, and why?
d. The vessel containing the hydrogen is removed and the porous pot allowed to stand in air. What happens, and why?
e. The vessel surrounding the porous pot is replaced (after the hydrogen has been emptied from it) and carbon dioxide is slowly passed into it. What happens, and why?

219 *a.* The lid of a clean and empty 2-lb golden-syrup tin is firmly replaced, and the tin is placed in an oven. What happens? (As usual, an 'empty' tin contains air.) What, therefore, can we say about the pressure of air in an enclosed space, when the air is heated?
b. At 9 a.m. in the morning before setting off on a long drive a man tests the pressure in the tyres of his car, and they all show 25 lb per square inch. He drives for three hours, then tests the pressure again; it is 28 lb per square inch. How do you explain this?

220 In question 219 (*a*) the lid is blown off and we conclude the pressure of the air increases when the air is heated. In question 214 we concluded that the 'pressure' of the marbles increased when they were more greatly agitated.

a. How do we explain the fact that a gas exerts pressure?
b. What, then, do we think happens to the motion of molecules of a gas when the temperature is raised?
c. What happens to molecular motion if the temperature of the gas falls?

221 *a.* Following from 220 (*c*), what is meant by 'absolute zero of temperature' for a gas?
b. Why is the idea of absolute zero, applied to real gases, a complete fiction, something that does not really happen?
c. Difficult. Yet the idea of 'absolute zero' of temperature, applied to gases, is a useful one – why is it useful?

26 Temperature, pressure and volume of gases

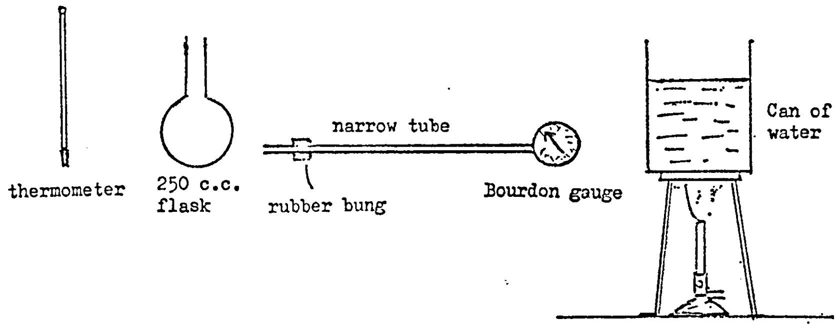


Figure 222

222 The diagrams above show a collection of apparatus you could use to find how the pressure of air varies with its temperature.

a. Draw a sketch showing the apparatus properly assembled for this experiment.
b. Say how you would take a set of readings like those below.
c. Here is a possible set of readings:

Thermometer reading	*Gauge reading*
0° C	14·2 lb per square inch
25° C	15·4 lb per square inch
50° C	16·8 lb per square inch
75° C	18·1 lb per square inch
100° C	19·5 lb per square inch

Plot these readings on a graph, and find from the graph the temperature at which the pressure of the air would be nothing at all. (You may *either* plot a graph which goes, horizontally, from −300° C to +100° C, and then produce the graph backwards till it cuts the horizontal axis, *or* you may draw a graph from 0° C to 100° C and calculate the termperature for no pressure.)

This temperature is called 'Absolute Zero'.

223 The following questions refer to the 'pressure and temperature' apparatus of question 222.

a. Why have a *narrow* tube between the flask and the gauge? Why should it not be a wide tube?
b. What difference would it make to the readings obtained if the flask held 500 cc instead of 250 cc? (Assume that it can still be properly immersed in the water.)
c. Suppose we had compressed the air so that the pressure at 0° C was 28·4 lb per square inch, instead of 14·2 (see Table, question 222). What would be the pressure at 100° C? Would using air at double the pressure make any difference to the value found for absolute zero of temperature?
d. Suppose the flask had been rinsed out with water and emptied, but not dried. What difference would this make to the readings obtained?

224 Given the apparatus of question 222, *but no mercury thermometer*, how would you use it to find (*a*) the boiling point of a saturated solution of salt, (*b*) the temperature of a 'freezing mixture' of ice and salt? You may assume that a plain ice–water mixture is at 0° C and that the water boils at 100° C.

225 In the answer to question 224 you were using the flask and gauge apparatus as an 'air thermometer', which is one kind of 'gas thermometer'. Actually, gas thermometers are used as 'standard' thermometers, and we test mercury and other types of thermometer by comparing them with gas thermometers.

a. What are two advantages a gas thermometer has over a mercury thermometer for use as a standard of temperature measurement?
b. Why not scrap mercury thermometers and use only gas thermometers? (Give any one good reason.)

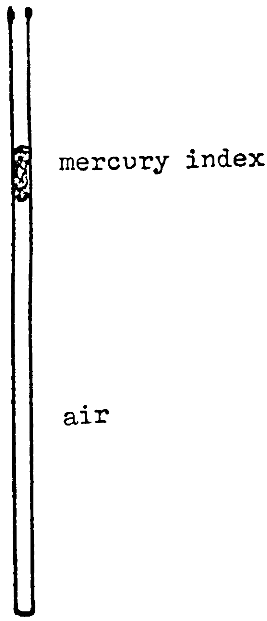


Figure 226

226 *a.* With the capillary tube apparatus shown in Fig. 226 you could carry out an experiment. The title of the experiment would be:

'To find how the ——— of air increases with ——— when the ——— is kept constant.'

Write the above sentence and fill in, in their correct positions, the words TEMPERATURE, PRESSURE, VOLUME.

b. Draw a rough sketch of the *complete* apparatus as you would use it.

c. The following set of readings were obtained in one experiment.

Temperature	*Length of air column*
0° C	12·2 cm
25° C	13·3 cm
50° C	14·4 cm
75° C	15·7 cm
100° C	16·7 cm

Plot these readings on a graph and find the temperature at which the volume of the air would be nothing at all. (Again, this is the absolute zero of temperature.)

227 *a.* How would you use the capillary tube apparatus of question 226 to find the temperature outside, in the playground? You are not to use a mercury thermometer at all.
b. Why would the capillary tube air thermometer be no use for finding the temperature of liquid air? (Neither would a mercury thermometer!)

228 *a.* Draw a sketch of the apparatus you have used to show how the volume of an enclosed quantity of air varies with its pressure, provided the ——— remains the same.
b. What word should be inserted in the blank space above?

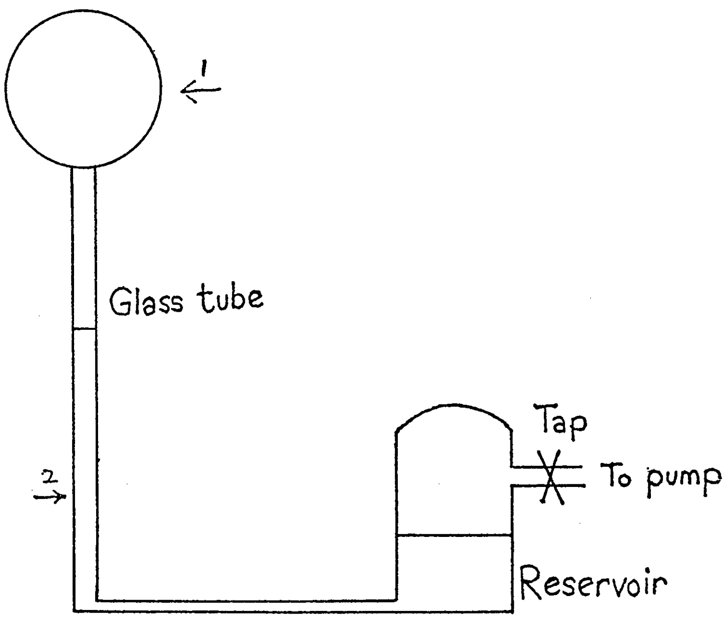


Figure 229

229 Figure 229 is a simplified diagram of an apparatus you have used for finding out how the volume of air changes with its pressure. Copy the diagram, and answer (*a*) and (*b*) by writing on your diagram.

a. What is it that arrow 1 is pointing at?
b. What liquid is in the glass tube (arrow 2)?
c. Say what was done with this apparatus, and how the readings were taken, in order to get a table of values of pressure and volume.

d. When the pressure is doubled (e.g. from 15 lb per sq inch to 30 lb per sq inch) is the volume doubled? Or halved? Or does the volume remain the same?
e. If the pressure is trebled, what happens to the volume?
f. When the pressure is doubled, what happens to:

$$\text{pressure} \times \text{volume}, PV.$$

Is PV doubled? Or halved? Or does PV remain the same?

230 We refer again to figure 229 and the experiment to find how the volume of air changes when its pressure changes. The final conclusion of experiments like this is the equation,

$$\text{pressure} \times \text{volume, or } PV, = \text{constant.}$$

a. Uncle George was never very good at algebra. Explain to him what is meant by 'PV = constant'.
b. This equation can only be true if we keep the same amount of air all the time, that is, the same *mass* of air. How could you find out, at the end of the experiment, whether any air had leaked out during the experiment?
c. Another necessary thing is that the *temperature* should not change from one reading to the next. What would happen to the quantity PV (pressure × volume) if the temperature *increased* during the experiment? Do you guess that PV would increase, decrease, or stay the same?
d. Yes, PV would increase, in (*c*). Why? (This is *difficult.* Do not bother too much about it.)

231 *Difficult.* If a spring follows Hooke's law, equal *increases* of pull produce equal stretches in the spring ('as the force so the extension'). Similarly, for a compression spring, equal loads on the spring produce equal compressions. Thus, if a 1-kg load compresses the spring by 0·5 cm a 2-kg load compresses it by 1·0 cm, 3 kg by 1·5 cm, and so on, so long as it follows the simple law.

Does a gas, when it is compressed, also follow Hooke's law? If you increase the pressure from 1 atmosphere, to 2 atmospheres, to 3 atmospheres, does the volume diminish by the same amount each time? Think carefully before answering, and give the reason for your answer.

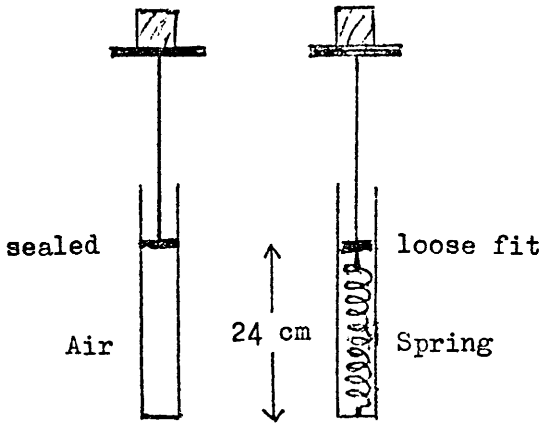


Figure 232 (*i*) Figure 232 (*ii*)

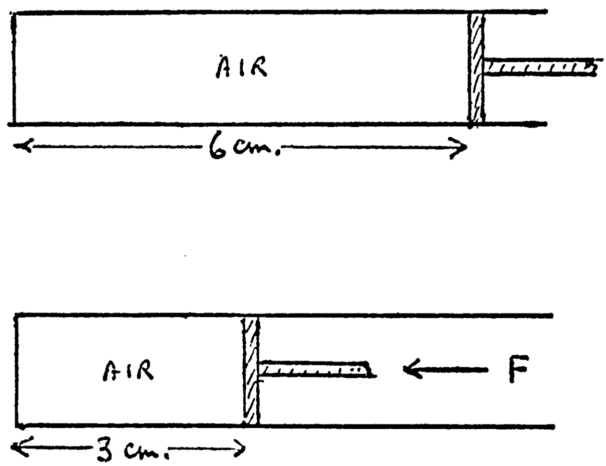
232 Two long tubes, closed at the lower ends, are each fitted with a piston and a platform on which weights may be placed (see figure 232). One has a well-fitting non-leaky piston, and contains air. The other has a loose leaky piston, but there is a coiled spring underneath. The length between the bottom of each tube and the piston is 24 cm for each. *Extra* loads, in steps of 2 kilograms, are then placed on each platform, and the length between the bottom end of the tube and the piston is measured in each case. Results:

	Length	
Extra load	*for A*	*for B*
0	24 cm	24 cm
2 kg	21 cm	20 cm
4 kg	18 cm	17 cm
6 kg	15 cm	15 cm

a. Which of the above columns, A or B, shows figures for a compression which follows Hooke's law? And which follows Boyle's law? Give the reason for your answer.
b. Does column A of the table refer to the air in figure (*i*) or the spring in figure (*ii*)? Which does column B belong to? Give the reason for your answer.
c. If 2 kilograms is *taken off* the platform when the length beneath the piston is 24 cm, what will be the new length for the air in figure (*i*)? What will be the new length for the spring in figure (*ii*)?

One of these two answers is 27 cm and the other is 30 cm. Which is which? Say why.

(See note at end of book. This note is *difficult* and is put in only for those who are worried by the 30 cm answer.)



Figures 233 (*i*) & (*ii*)

233 Figure 233 (*i*) shows air inside a cylinder fitted with an air-tight piston; inside and outside the cylinder the pressure is atmospheric, and, with no extra force applied, the piston stays where it is.

In figure 233 (*ii*) the piston has been pushed in so that the enclosed air occupies half the length. The temperature has returned to the same value as before. A force F is now required to hold the piston in place.

We shall compare figure 233 (*ii*) with figure 233 (*i*). When you give each answer, give the reason for your answer as well. What can we say about:

a. The total number of molecules enclosed after the piston was pushed in, compared with the number before? (Is it the same, twice, one-third or what?)

b. The volume of the air in the cylinder?
c. The number of molecules per cubic centimetre?
d. The average speed of a molecule?
e. The pressure exerted by the air in the cylinder?
f. Which *two* of the following equations correctly express the changes that take place?

$$\frac{p_1}{v_1} = \frac{p_2}{v_2};\ \frac{p_1}{p_2} = \frac{v_2}{v_1};\ \frac{p_1}{p_2} = \frac{v_1}{v_2};\ p_1v_1 = p_2v_2$$

p_1 and v_1 are the pressure and volume in figure (*i*). p_2 and v_2 are the pressure and volume in figure (*ii*).

234 'The height of the water barometer is 10 metres, approximately.' This means that the pressure of the atmosphere is equal to the pressure of a column of water 10 metres high.

A lake is 30 metres deep. A bubble of gas rises from the bottom of the lake to the top. When it reaches the top, its volume is 10 cubic centimetres. What was its volume at the bottom?

235 This is not a numerical question; answer (*a*) to (*h*) below by writing 'greater', or 'less', or 'the same'.

A motor-car type is pumped up to a pressure of 30 lb per square inch at midday, when the temperature is 15° C. That night the temperature falls to 5° C. The tyre does not leak, and its volume remains the same. What happens to:

a. the number of molecules in the tyre:
b. the average speed at which a molecule moves;
c. the average distance a molecule moves between one collision and the next;
d. the average time between one collision and the next;
e. the pressure in the tyre? Give the reason for this answer.

The motorist pumps up the tyre to 30 lb per square inch again, the temperature still being 5° C. Compared with the original condition, when the pressure was 30 lb per square inch at 15° C, what happens to:

f. the number of molecules in the tyre;
g. the average speed at which a molecule moves;
h. the average distance a molecule moves between one collision and the next?

27 Currents, compasses and filings

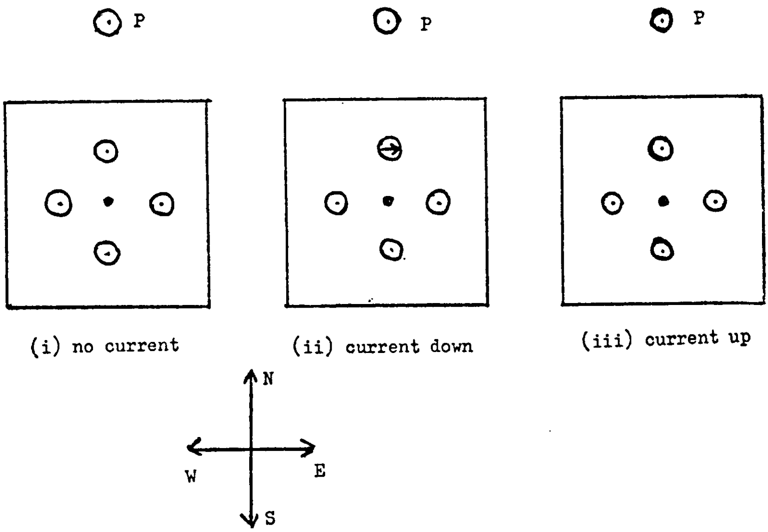


Figure 236

236 A piece of wire which can be connected to a battery goes straight up and down through the centre of a piece of cardboard and at right angles to it. Four compass needles are placed on the board, as shown in figure 236. A fifth compass is placed farther away, at P. When the current goes downwards into the board, as in diagram (*ii*), the needle *north* of the board points to the *east*, as shown. In diagram (*iii*) the current is reversed so that it goes upwards. In (*i*) the current is switched off altogether.

Draw three diagrams showing how all five of the needles point in each case. You need not draw them very beautifully.

237 The compasses in figure 236 are removed and now the pattern of the magnetic field round the wire is shown by sprinkling iron filings on the board (do not trouble about what happens out at P).

a. What advice would you give about how to get the best result from this experiment?
b. What would the filings show in each of the experiments drawn in figure 236? (*Suggestion;* draw a sketch for (*ii*). (*i*) and (*iii*) can be briefly answered in words. And remember to draw what you have *seen*, not what the filings would show if they were as sensitive as compass needles.)

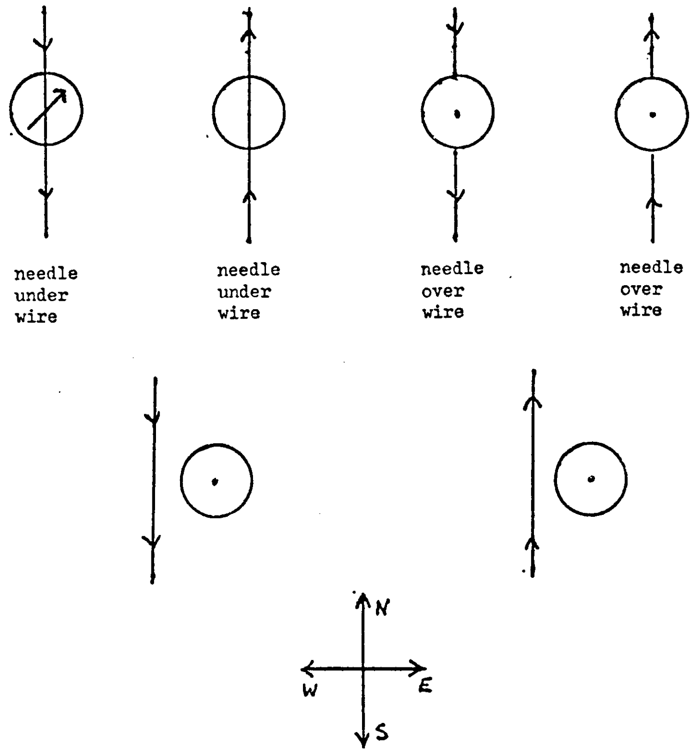


Figure 238

238 (Oersted's experiment.) Copy the above six diagrams of wire and compass needle. The needle direction is given you for the first diagram; put in the rest correctly. In the last two diagrams the wire and the needle are on the same level with each other.

Important note: You will *not* be asked to remember, for examinations, any rule at all about directions in which compass needles turn and directions of electric currents. You are expected to know that magnetic fields are at right angles to electric currents in straight wires, and that reversing the current reverses the field. Be careful about the last two diagrams!

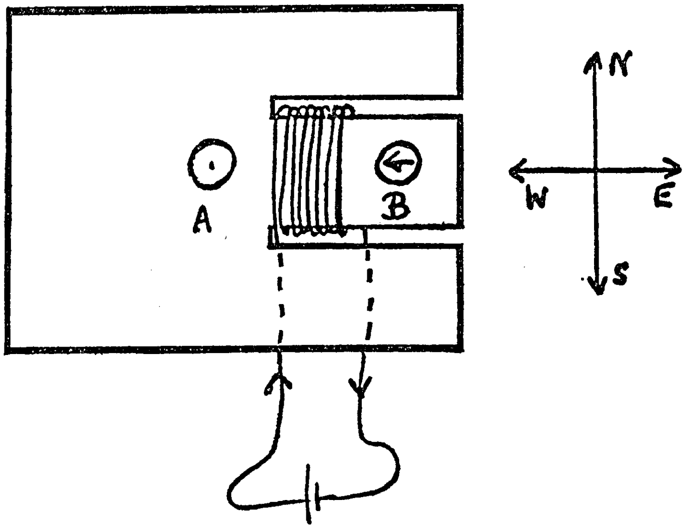


Figure 239

239 In figure 239 the compass needle B, east of the coil, points west. Which way does A point? If the current direction is reversed, which way does A point? Which way does B point?

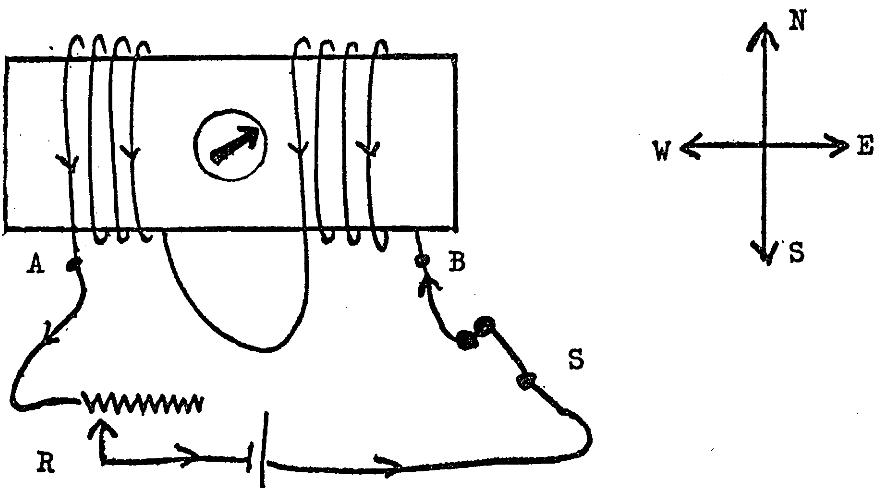


Figure 240

240 In the apparatus shown above:

a. What happens to the needle when the slider of the rheostat R is moved to the right?

b. What happens when the switch S is raised so as to stop the current?
c. What happens when the battery is reversed?
d. Suppose *one only* of the two coils is taken off and put back the other way round, what difference does this make, if any?

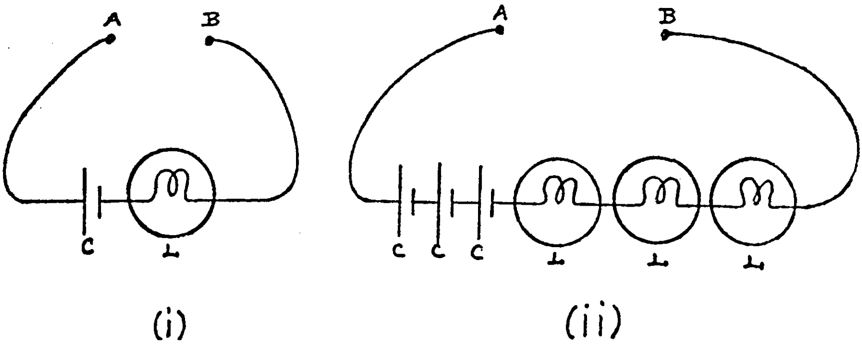


Figure 241

241 In figure 241 A and B are the ends of the wires from the 'simple galvanometer' shown in figure 240 (previous question). In (*i*) the galvanometer is joined in series with a single cell C and a single small lamp L. In (*ii*) it is joined to three similar cells and three similar lamps.

a. In the arrangement (*i*) the deflection of the needle is 45° from the north. Will it be more than 45°, or less, or the same in figure (*ii*)? Give the reason for your answer. *Note:* there are two answers; one will be counted good, the other *very* good, but you must give your 'reason'.
b. If you reverse *two* of the cells, what will happen to the deflection?
c. If you reverse two of the lamps, what will happen to the deflection? ('Everyone knows the answer to *that,*' says Freddie Jones.)

242 Explain, with the help of a diagram, how you have found out what the magnetic field *inside* a long coil ('solenoid') is like: (*a*) by using iron filings; (*b*) by using compass needles. What did you find out about the field?

28 Permanent magnets and electromagnets

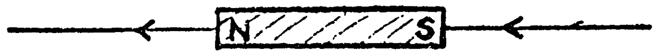


Figure 243

243 In figure 243, NS is a strong bar magnet, and part of a central magnetic field line has been drawn. You need not worry about any effects due to the magnetic field of the Earth.
a. What do the arrows represent? (Your answer should mention a compass needle.)
b. Copy the little sketch, figure 243, and add to it two magnetic field lines in the top half (give yourself enough space in the diagram) and two in the lower half. Put two or three arrows on each line to show its direction.
c. The magnet in the diagram lies east–west. Mention *two* places in the diagram where you could put a compass needle so that it points west, and two places where it would point east.
d. Draw (as a separate diagram, but close to the first) a solenoid coil which would give as nearly as possible *exactly the same* sort of magnetic field as the bar magnet gives. (You have to think of *size* as well as *shape.*)

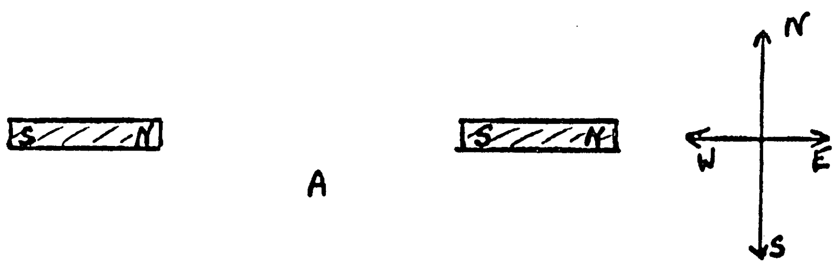


Figure 244

244 *a.* Copy figure 244 and draw a compass needle at A, showing the direction in which it would be deflected. Imagine that the two bar magnets are *not* very strong, so that the magnetic field of the Earth still has an appreciable effect on the needle.
b. If the magnets are *equally* strong, and A is mid-way between them, where does the needle point if you reverse one magnet through 180°?
c. What happens if you reverse both?
d. Draw a diagram showing two coils that could produce the same effect as the two magnets in figure 244. (Just draw the coils; you need not bother with current directions.)

245 Two powerful horseshoe magnets are mounted one on each of two small trolleys, with the open ends of the magnets facing each other.

a. The trolleys are pushed in a straight line towards each other. Two alternative happenings may occur as the magnets approach each other, depending on how the magnets are placed. Describe one possibility. One magnet is then turned over and refixed on its trolley, what difference does this make when the trolleys are pushed together?
b. How would you use pieces of sponge rubber and a length of elastic (instead of the magnets) to show a similar effect with the trolleys?

246 *a.* Draw a sketch to show what happens when a bar magnet is dipped in iron filings, and then taken out and shaken. Write a sentence, or two, in explanation.
b. Say how you would find which is the north-seeking pole of a magnet and which the south, without making use of any other artificial magnet.

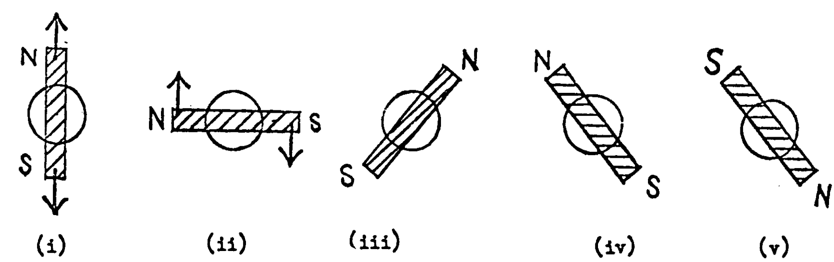


Figure 247

247 The five diagrams in figure 247 show five positions of a short bar magnet which is placed on a flat piece of cork and then floated on water in a glass trough. The arrows in (*i*) and (*ii*) show the forces, due to the Earth's magnetism, which act on the magnet when it is placed in these two positions.

a. Copy the diagrams and add suitable arrows to (*iii*), (*iv*) and (*v*).
b. The magnet in figure (*i*) stays in this position and does not move in any way. What does this tell us about the poles of the magnet?
c. Give the reason for your answer to (*b*).
d. Write against your diagrams (*ii*), (*iii*), (*iv*) and (*v*) the words 'clockwise' or 'anticlockwise', according to whether you think the magnet will turn in the same direction as the hands of a clock, or in the opposite direction.

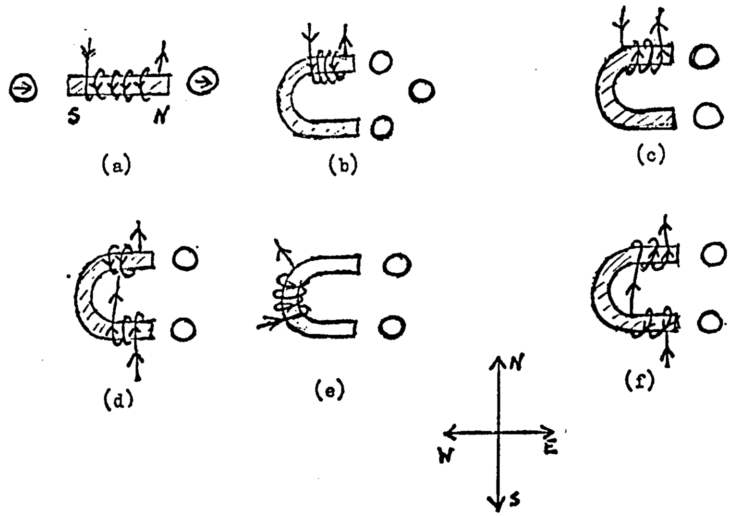


Figure 248

248 The first diagram shows an iron bar with a coil surrounding it. When a current flows in the direction shown, the needles point east.

a. How do we know, therefore, that the N and S poles of the bar are as shown?
b. Copy diagram (*b*) and show the needles of the compass needles pointing in the correct directions. Mark the N and S poles of the 'horseshoe' magnet.
c. Copy and complete the other diagrams, (*c*) to (*f*), in the same way.

Important note: You are *not* expected to remember any rules about current directions and compass needle directions. All the answers can be worked out from what you are shown in diagram (*a*). The only slight difficulty is the centre compass in (*b*); this you can decide by common sense.

249 An iron C-core (or 'horseshoe') has coils wound on its limbs, and is suspended as shown in figure 249. A current is passed through the coils and a second C-core, without coils, is easily held, together with an extra load as shown.

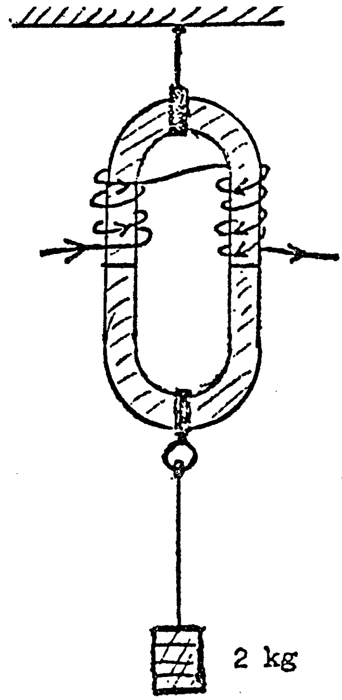
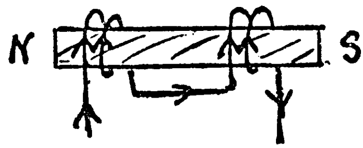


Figure 249

a. What happens when the current is switched off?
b. In a particular case the *least* current which will hold the lower core plus a 2-kilogram load is $2\frac{1}{2}$ amperes. A current of 3 amperes holds a bigger load, and 4 amperes hold a bigger load still. Will the magnet hold *any* load provided we have enough current? What do you say, and why?
c. Reversing the current or reversing *both* coils makes no difference to the lifting power. What would happen if you reversed only *one* coil? Why?

(a)



(b)

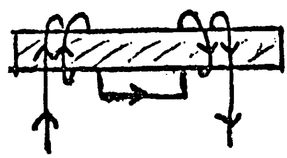
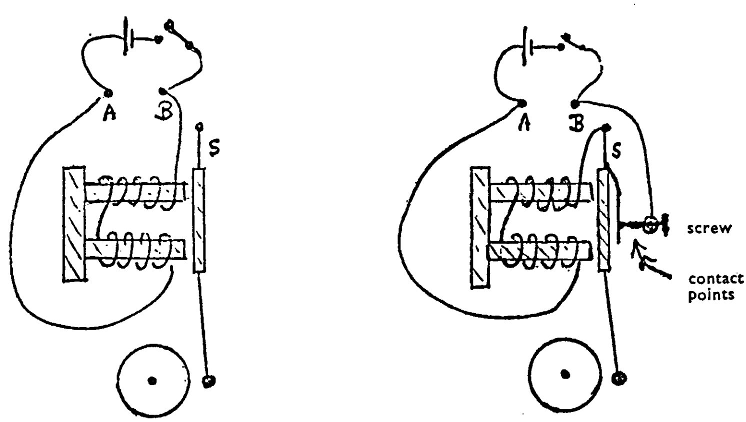


Figure 250

250 Sketch (*a*) of figure 250 shows the poles that appear on an iron bar when the current is passed as shown through the two coils. How would you use a compass needle to discover what happens with the arrangement shown in sketch (*b*), and what positions of poles would you expect to find?



(a) (b)

Figure 251

251 Sketch (*a*) in figure 251 shows a primitive form of electric bell. The shaded parts represent iron. S is a piece of steel spring; A and B are terminals to which a battery and a switch can be connected.

a. What happens when the switch is closed, and why?
b. In sketch (*b*) some extra parts have been added, as shown. What happens now when the switch is closed and why?
c. The 'contact points' are covered in silver or platinum. What would happen if this covering was omitted?

252 *a*. What difference in construction is there between an electric bell and a buzzer? Where does the noise come from in a buzzer?
b. Mention some other piece of machinery you, perhaps, make use of quite often, which has platinum points in it. If you can, write a few sentences explaining what would happen if the platinum points got covered with dirt or oil.

29 Electric currents in magnetic fields, the motor effect

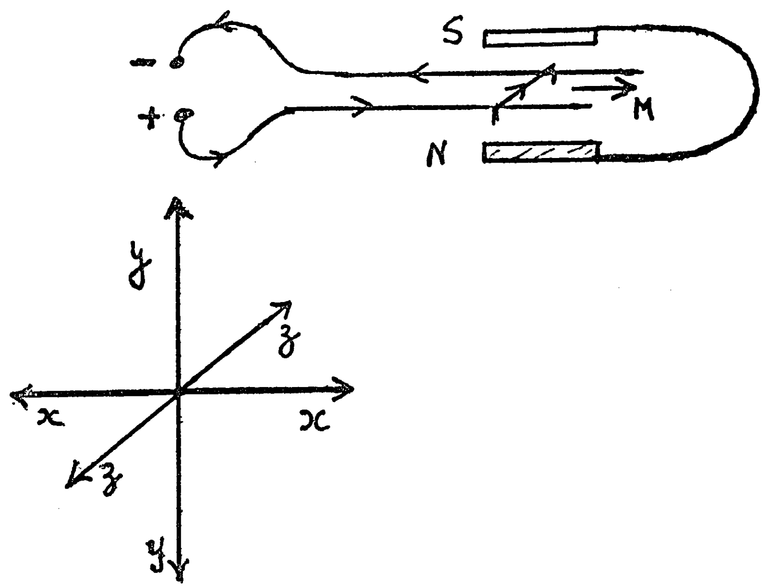


Figure 253

253 *a.* Give a brief description of the apparatus drawn in the top diagram of figure 253, and say what happens when the current is switched on. (The arrows on the wires give the current direction. The field direction is upwards, from north pole to south pole. The direction of motion is to the right, shown by the arrow marked M.)
b. What happens to the direction of motion: (*i*) if the magnet is reversed so that the N pole is at the top; (*ii*) if the current direction is reversed; (*iii*) if *both* are reversed?
c. The small '*xyz*' diagram shows, in perspective, *three* directions at right angles to each other. The x direction is horizontal, y is vertical, and z (in perspective) is meant to be horizontally *into* the paper. Look now at *both* diagrams in figure 253. (*i*) Which is along x: the field direction, the current direction or the direction of motion. (*ii*) Which is along y? (*iii*) Which is along z?
d. Draw your own '*xyz* diagram', but instead of x and y and z, label it (correctly!) 'field', 'current', 'motion'.

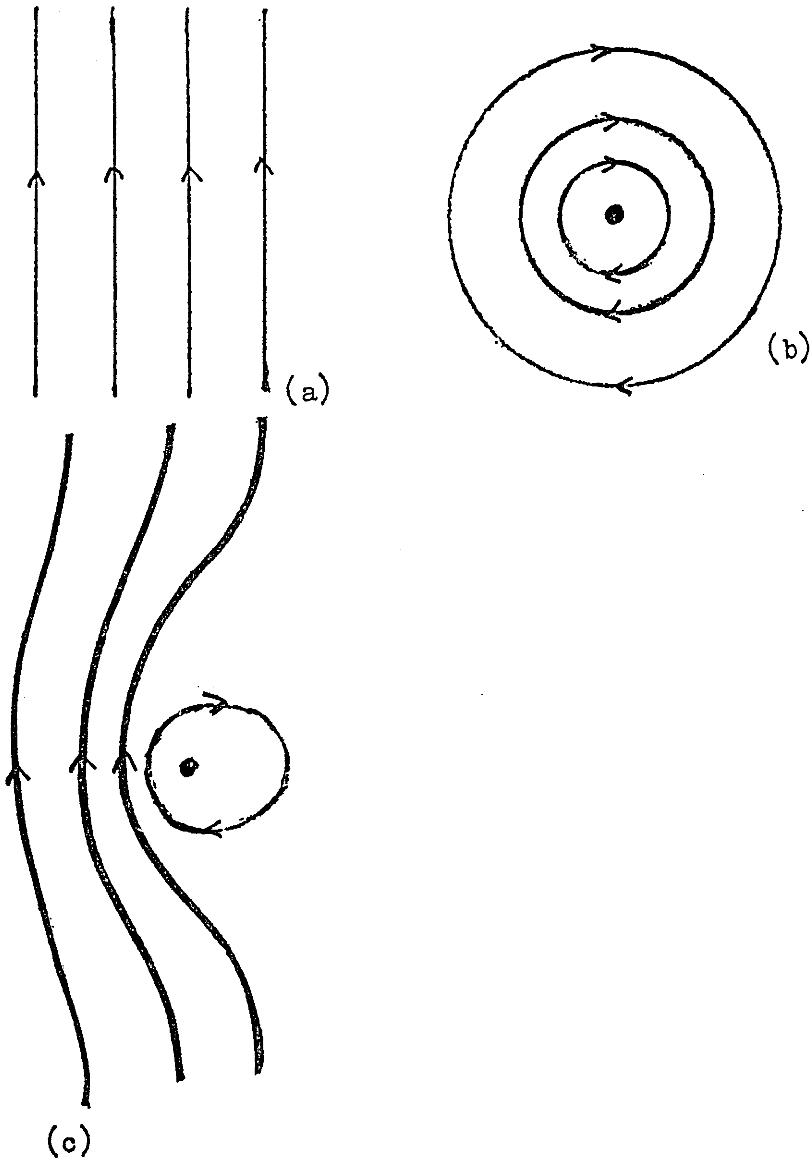


Figure 254

254 What sort of arrangement of magnets or currents give magnetic field lines? Answer by diagrams if you prefer.

a. like those in sketch (*a*)?
b. like those in sketch (*b*)?
c. like those in sketch (*c*)?

255 *a*. The dots (·) in figure 254 (*b*) and (*c*) represent a wire carrying a current down *into* the paper. Suppose, in figure 254 (*c*), the lines had been pieces of stretched elastic, instead of magnetic field lines, the · still representing a wire, what would happen to the wire?
b. Suppose you reversed the magnetic field so that the lines went *down* the paper, instead of up the paper as in figure 254 (*a*) above, but the current direction was still the same as in figure 254 (*b*). What would figure 254 (*c*) look like now (give a diagram)? What happens to the wire now?

256 Here is a list of the parts you used when you made a moving-coil ammeter:

Wooden base with holes for split pins and rivets.
2 split pins, 4 rivets.
Wooden armature with aluminium tube pushed through it.
Knitting needle.
Insulated copper wire.
2 'magnadur' magnets with steel yoke piece.
Drinking straw.

a. Describe, with diagrams if you like, how you made the ammeter.
b. What would be the effect of using thinner wire (but with the same number of turns) for the spiral springs?

257 Figure 257 is a diagram showing essential parts of a moving-coil ammeter.

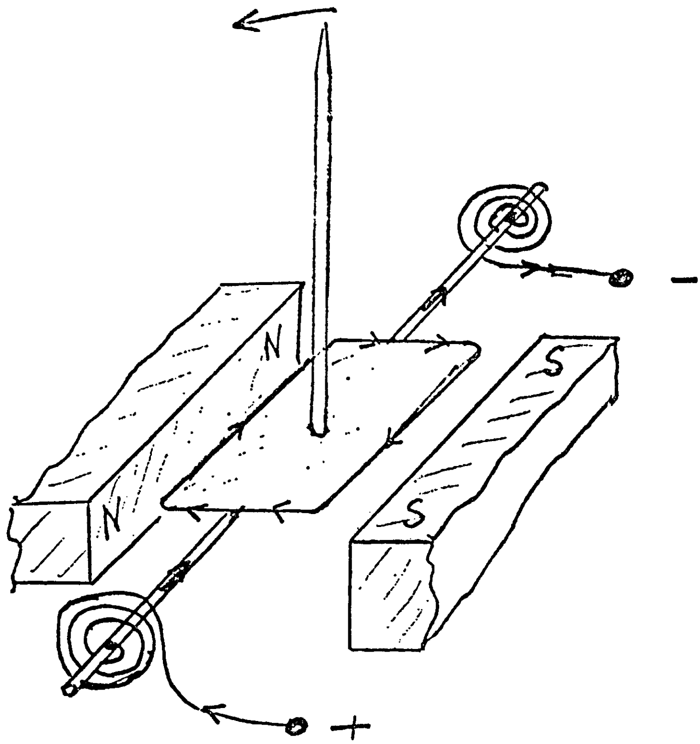


Figure 257

a. Copy this diagram.
b. Label the following parts, using arrows to show clearly which part each name refers to.

the moving coil
the magnets (2)
the controlling springs (2)
the pointer

258 Explain the working of the moving-coil ammeter you have drawn in answer to question 257.

259 What will happen, when you are using a moving coil ammeter, if

a. you reverse the current;
b. you use alternating current in which the direction changes take place very slowly, for example, current from a slowly turning bicycle dynamo;
c. you use rapidly alternating current, for example, from the a.c. mains.

260 You have seen inside a commercially made type of moving-coil ammeter – mention *two* ways in which it has been made more sensitive than the one you constructed. ('More sensitive' means giving a larger deflection for a certain current, or the same deflection for a smaller current.)

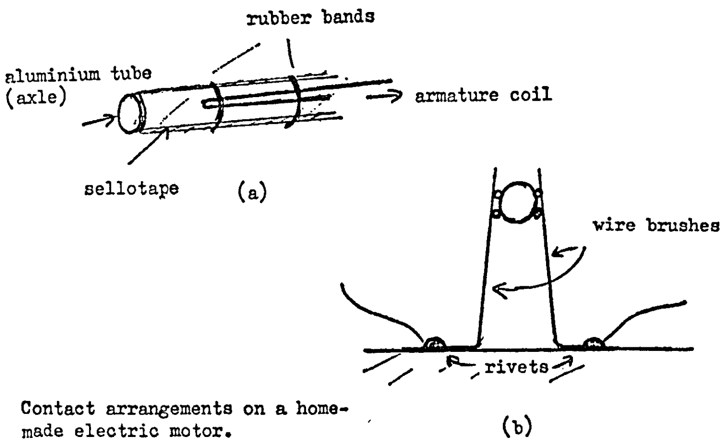


Figure 261

261 Figure 261 (*a*) and (*b*) illustrate the only difference between the moving coil ammeter you made, and the motor. Use these diagrams (copy them) to explain the difference in construction.

Why put the Sellotape on the tube? What would happen if you omitted it?

262 *Difficult.*

Freddie Jones suggested the following method of making the motor which, he said, would be easier. Don't bother with the Sellotape and the wires on opposite side of the axle. Simply cut the aluminium axle in the middle and separate the two parts so that they are insulated from each other. Then connect one half-axle to one end of the armature coil, and the other half-axle to the other end (see figure 262). Then use wire brushes bearing straight on to the axles.

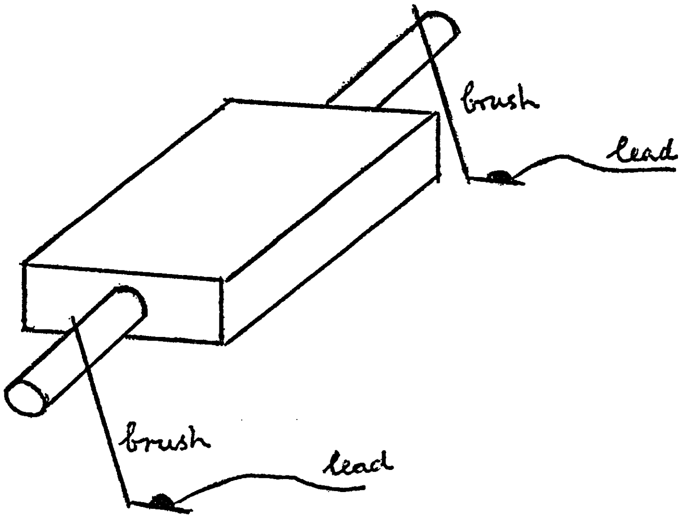


Figure 262

a. He tried this, and the motor did not work. Why not?
b. He did find that the coil made little jerky movements, sometimes as much as half a turn. Why was this?

263 *Difficult.* Explain how the motor you made works. Draw a diagram like figure 257 *without* the coiled-spring connexions. Draw again, or make use of, figure 261 (*a*) and (*b*) in order to make your explanation clear.

264 You take your model motor home, and show it to your younger brother, who is very interested. You use a battery to make it turn, and you explain how it is made. You then take it to pieces so that he can put it together again.

He puts it together and, at a quick glance, it looks all right. But nothing happens when you join up the battery to it.

Mention three things that might have gone wrong, and say what you would do to put them right.

30 Wires moved in magnetic fields, the electric generator

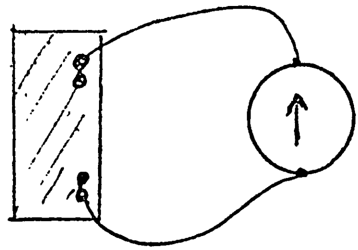


Figure 265 (*a*)

265 *a.* You join the electric motor you made, section 29, to a sensitive galvanometer, figure 265. You then spin the armature coil round with your fingers (no battery in the circuit). What happens to the pointer of the galvanometer? What difference does it make if you spin the armature in the reverse direction?

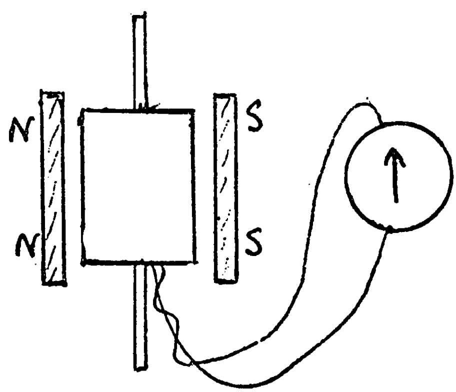


Figure 265 (*b*)

b. Next, you simplify the experiment by holding a coil between the poles of the magnadur magnets (with their yoke piece) and rotating the coil in the magnetic field. The ends of the coil are joined by loose leads to the galvanometer. What does the galvanometer pointer do now, as you rotate the coil?

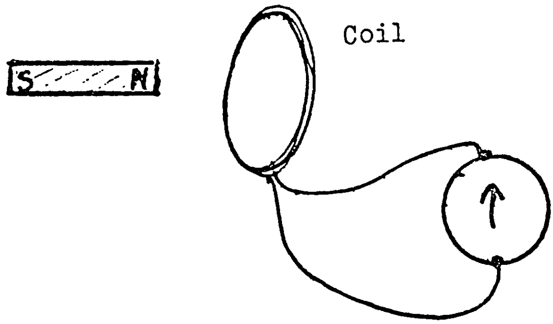


Figure 266

266 Clearly, as you rotate the coil (question 265) you are changing the magnetic field passing through it. This can be done more simply by holding the coil still and moving a magnet near it. So you come to the arrangement of figure 266, which shows a coil of about 20 turns, and a bar magnet.

What experiments did you try with this apparatus, and what did you find out?

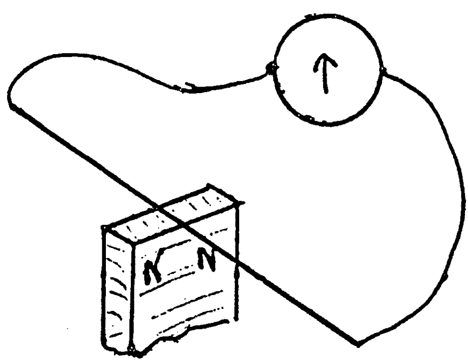


Figure 267

267 Lastly, you may have gone further still with the simplification of the apparatus, doing away with the coil and having only a magnet and a wire, figure 267. (You find out things by making them more simple, NOT by making complications.)

What did you find out with this apparatus?

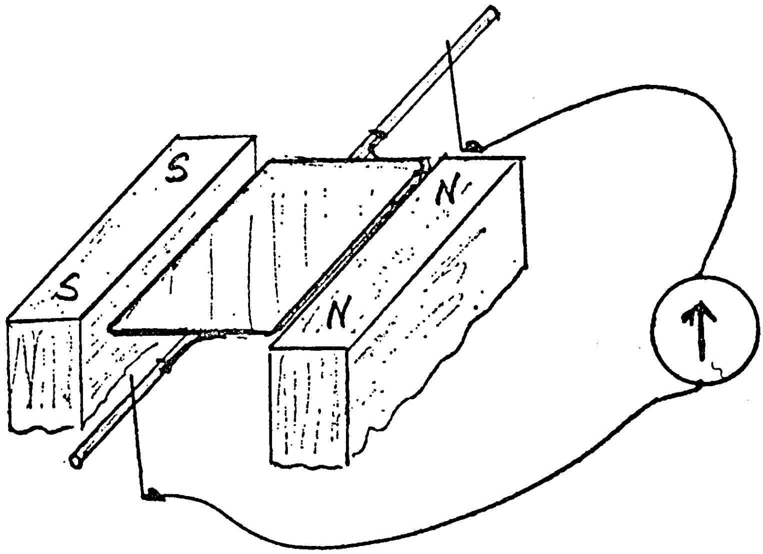


Figure 268

268 We now return to the *generator* of electric current; this time illustrated by figure 268 and called an *alternator.*

If you have made an alternator resembling figure 268, copy the diagram (or draw one similar if it is not the same), explain how it was constructed (briefly, but give special attention to the slip rings-and-brushes part), and say what happens when the alternator is spun round.

269 *a.* What would happen if you kept the coil in figure 268 fixed, and *rotated the magnet* round the coil?
b. Supposing that, instead of rotating the coil clockwise and keeping the magnet fixed, you rotated the magnet clockwise and kept the coil fixed. Would this give *exactly* the same result? Why not?
c. A bicycle dynamo is of the 'fixed coil' type. What advantage is there in this, as compared with a 'fixed magnet' type?

270 *a.* What sort of pattern (draw it) do you see on an oscilloscope screen when the output from an alternator (question 268) or from a bicycle dynamo is joined to a suitably arranged oscilloscope?
b. Write two or three sentences explaining how alternating current differs from direct current.

c. Which sort of current do you get from a dry battery? Draw what you would see on a suitably set up oscilloscope if you replace a '6-volt' bicycle dynamo by a '6-volt' battery.

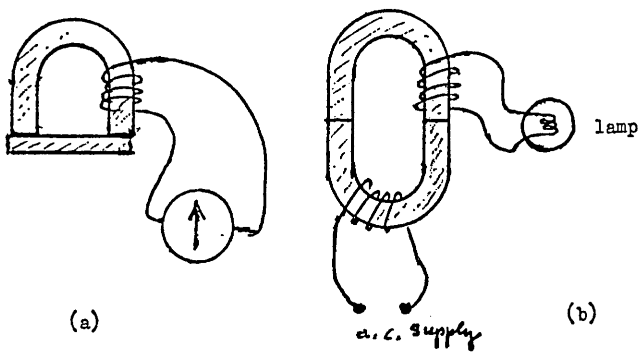


Figure 271

271 *a*. Figure 271 (*a*) shows a ∩-core of iron with a coil wound on it. The ends of the coil are joined to a galvanometer. What would you see in the galvanometer if you put a bar magnet on the core, take it off again, put it on again, and so on?
b. Figure 271 (*b*) shows the same ∩-core with the four-turn coil joined to a lamp instead of a galvanometer. A second ∩-core is now attached to the first; this second core also has a four-turn coil, which is joined to a 1-volt a.c. supply.

The lamp is found to light up just as brightly as if it were joined to the a.c. supply, yet it has no direct electrical connexion at all. How do you explain this?

272 *a*. Suppose, in figure 271 (*b*), you had only two turns in the coil joined to the lamp, still having four on the coil joined to the a.c. supply. What difference would this make to the brightness of the lamp?
b. Suppose you had six turns on the coil joined to the lamp, what then? And what would happen to the lamp if you had eight turns or more?

31 A theory of magnetism

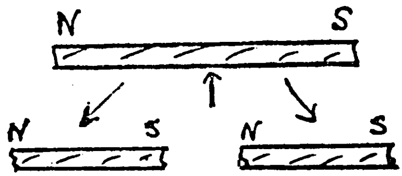


Figure 273

273 A piece of magnetized hacksaw blade is broken in two, with the result shown in figure 273.

a. How would you show that there are two, and only two, poles on the hacksaw blade at the start?
b. How would you show that each of the broken pieces has a north and a south pole (not *two* norths, or *two* souths) as in figure 273?

274 Explain, with diagrams if you like, a 'little magnets' theory which accounts for what happens in the experiment illustrated by figure 273.

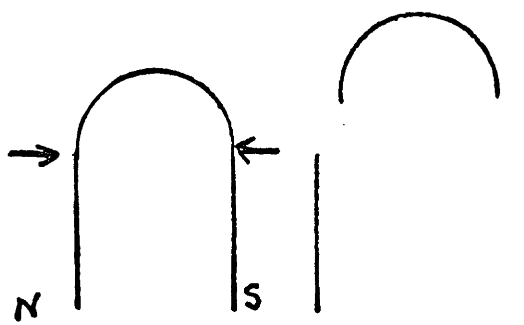


Figure 275 (*a*)

275 *a.* Figure 275 (*a*) above shows a U-shaped piece of hardened steel spring which is magnetized with poles at the ends in the usual way, as shown. It is then cut at places shown by the arrows. Draw the broken pieces as shown on the right, and mark the poles on your diagram.
b. Figure (*b*) shows a three-pole magnet with one pole in the middle. It is then cut in the middle. Draw the two parts and show the poles on them. (See next page.)
c. A similar magnet is cut into three parts, figure (*c*). Draw the parts and show the poles on them. (See next page.)

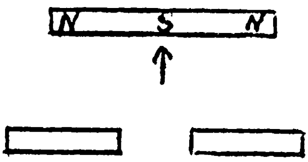


Figure 275 (*b*)

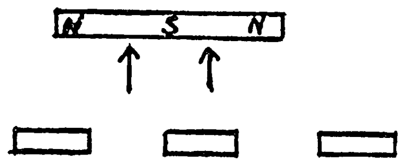


Figure 275 (*c*)

276 *Difficult.* Suggest some way of magnetizing a steel bar so that it has poles like those shown in the top part of figure 275 (*b*).

277 *a.* How does the magnetism theory you described in question 274 explain the fact that there is definitely a limit to the strength of the strongest bar magnet we can make?

Figure 277 (*i*)
wrong

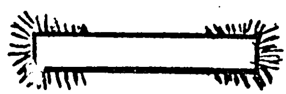


Figure 277 (*ii*)
right

b. If a bar magnet is dipped in iron filings it looks like figure (*ii*), not like figure (*i*). How does the theory explain this?
c. How does the theory explain the fact that some magnets lose their strength as a result of: (*i*) rough treatment, such as hammering; (*ii*) heating and cooling?

278 *a.* A magnet can have two poles, or three, or more. Can it have just *one* pole? Give the reason for your answer.

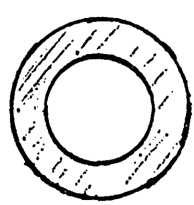


Figure 278

b. A ring of thin steel (figure 278) is stated to be magnetized, but a compass needle placed against it is not deflected at all. How could you discover whether it was magnetized or not? Answer by saying: (*i*) what you would do; (*ii*) what would be the result if the ring is *not* magnetized; (*iii*) what would be the result if it is magnetized. Give a diagram for (*iii*).

279 How would you magnetize a ring like that in figure 278?

Note on question 232 (c): the new length for the spring in figure (*ii*) is 27 cm, and you can say why. So the new length for the air in figure (*i*) is 30 cm. But how would you have found this if you had not been told it? The difficulty is that you do not know the *actual* load when there was no *extra* load. The actual load consists of the piston, plus any load on it before the 'extra' load was added, plus the force due to the pressure of the atmosphere on the piston. There are two ways of finding the answer, 30 cm.

(*i*) By drawing a graph. You could, for the spring, plot a graph of lengths against extra loads, 0 – 6 kg, and then produce the graph back to find the length for —2 (minus two) kg. This answer would be 27 cm. You can do the same for the air, but the graph would not be a straight line; however, you could draw it back and find (rather inaccurately) the value 30 cm. (You may know a way of plotting a graph which is a straight line and gives an accurate result, but if not, don't trouble with it.)
(*ii*) By algebra. Let $x =$ the (unknown) load when the length is 24 cm. Then $(x + 6)$ is the load when the length is 15 cm. Boyle's law then gives: $24x = 15\ (x + 6)$, so we find x.

Let $y =$ new length for load $x - 2$ kg. Then
$y\ (x - 2) = 24x$
We know x, so we now find y, which is 30 cm.

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