PHYSICS

Tests and examinations

per second for air molecules in an ordinary room. Do all t
molecules in this room move with this speed?

....

....

....

Question 4

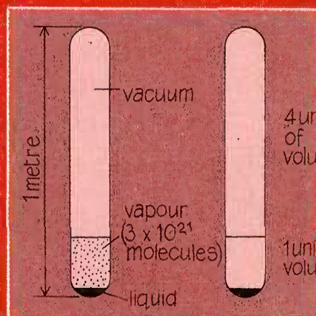
How does the molecular theory account for the following

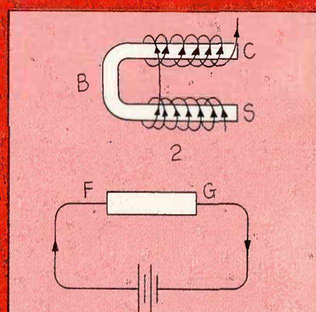
a. When water in a dish is heated, the evaporation of the

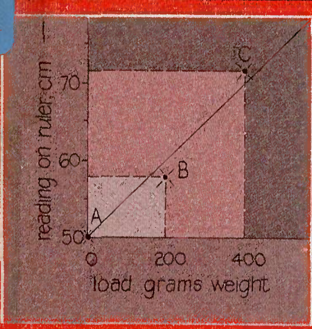
....

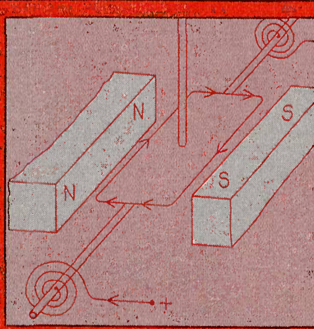
....

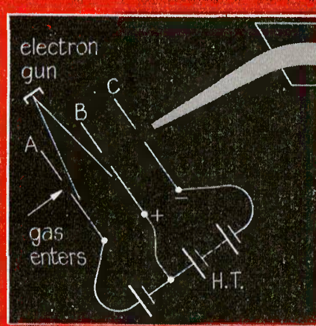
....











Nuffield Physics Tests and Examinations

PTE 04218

Nuffield Physics
Tests and Examinations

Prepared by H. F. Boulind, M.A., Ph.D.

Published for the Nuffield Foundation
by Longmans/Penguin Books

First published 1968

Longmans, Green and Co Ltd,
48 Grosvenor Street, London, W1
Penguin Books Ltd,
Harmondsworth, Middlesex

Made and printed in Great Britain by
Butler & Tanner Ltd, Frome and London

Set in Monotype Plantin

Designed by Ivan and Robin Dodd

Foreword

This volume is one of the O-level Physics publications whose works were among the first to be produced by the Nuffield Science Teaching Project. In 1962 when the Project started, many individual school-teachers 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

Contents

Introduction

The major part of this book, pages 16 to 140, forms a kind of mine or quarry from which examination questions can be extracted, whether in the form of whole papers, or individual items, or even parts of questions. As explained in Chapter II, these were the questions set to the pilot schools which helped to develop the Physics Project during the years 1963 to 1965. They are made available here in order to assist all teachers who are faced with the problem of devising end-of-term tests. At the same time the opportunity has been taken of adding a Chapter I giving some information about the questions in the five years of Question Books, and a Chapter III on the Ordinary-level examinations set to pupils who have followed the Physics Project.

Henry F. Boulind
Cambridge, 1968

Chapter 1

Concerning the Questions Books Years I, II, III, IV, and V

In much of the Physics programme of the Nuffield Project, constructive problems or questions that ask for active thinking take the place of pupils' reading in texts or background books. Direct contact with experiment is provided by work in the laboratory, and most of the reasoning is better done by class discussion or homework problems than by reading, especially since the ability to absorb varies very greatly from pupil to pupil. Five Questions Books, one for each year, span the O-level Physics Project. Altogether they provide something like a thousand questions which teachers may use as they think fit, either for class work, or for homework. The books are intended to be issued to individual pupils. Pupils do not need to write inside the Questions Books themselves: questions may be answered in ordinary exercise books or on loose-leaf paper; consequently the same books can be used by other pupils in subsequent years.

No claim is made that these are the only possible sets of questions, and that nobody can invent better ones. Clearly the best person to set the questions is the teacher himself; he knows the abilities of his pupils and he alone can set the questions which are most suited to them and which are expressed in the form of language familiar to them. All the same, most teachers will not have sufficient time available to do this during the first few years when they are following the Nuffield courses. So these Questions Books fill the gap and provide initial guidance; it is in this spirit that they are offered. At a later stage the books can be used as a source of ideas for sets of questions tailor-made to fit the needs of individual schools and classes.

These questions (or something similar invented by the teacher) are an integral part of the Nuffield Physics scheme, without which the scheme must fail. The *aims* of the scheme, that is, the aims which its designers had in mind, are set out in the Teachers' Guides. They can be variously stated, but clearly the principal aim is '*teaching science for understanding*'. Understanding what? Not only understanding science, but also, and equally important, understanding what it is like *to be a scientist.* Training children to act reasonably and in accordance with common sense, to build knowledge on experiment, to recognize the importance of models and of theories: this is what we mean by 'being a scientist'. It can hardly be done entirely in the laboratory; it cannot be done at all by the type of textbook that provides the answers ready made. The general objects of the Questions Books may be stated: to encourage children to think and wonder about things; to lead them to the more difficult concepts by easy stages: and finally, to replace much of the tedium of note-taking and 'writing up'.

Types of Question

1 Cheap recall

Consider the following question (Year II, number 96):

'Why are the melting point of ice and the boiling point of water good temperatures to take for the "fixed points" (0° and 100°C) of a thermometer scale? What numbers represent these points on the Fahrenheit scale?'

The second part of this is 'cheap recall', that is, recall of memorized information. Whether the first part is cheap recall depends on how, and to what extent, the subject has previously been discussed in class. No conscious attempt has been made to introduce cheap recall questions into the Questions Books – for two reasons, first because the teacher has little need of such questions in a book; if needed he can invent them at a moment's notice as the class is about to leave the laboratory. Secondly, they have little or no effect in causing the pupil to think about anything. Nevertheless pupils should know that 32°F is the melting point of ice; and, as for the first part of II 96, perhaps it is better for the pupil to write an answer for homework than to copy it from the blackboard in class time. Undoubtedly, though, cheap recall is intended to have only a very small place in a Nuffield book of questions.

2 Simple recall

If pupils understand a piece of science, they should be able to use it intelligently. So we offer them a problem requiring the same knowledge as a problem discussed in class but we describe it with a different context and in different words. (For example, class discussion of a rocket accelerating is followed by a test question on a car decelerating.) We may call this 'simple recall' as distinct from 'cheap recall' of a memorized fact. In that way we avoid the danger of a stereotyped question eliciting a memorized answer, whether of definitions or of solving procedure (*Teachers' Guide* III, p. 89).

Two examples follow.

I 137:
'*To be done at home*
a. Weigh yourself, or make a good guess at your weight in pounds. Write it down.

b. Take your shoes off and stand on a sheet of paper, or two sheets. Draw round your feet. You could also do this with chalk on the floor. Make the best estimate you can of the area of each foot in square inches. Another way is to wet your bare feet and measure the wet mark on the floor.

c. Now work out the pressure of your feet on the floor, in pounds to the square inch
when you stand on two feet, and
when you stand on one foot.'

V 71:
'If you had been an observant person *living three thousand years ago* you might have picked out four of the "stars" as behaving differently from the rest. These we now call "planets". Write a page or so explaining in what way they are "different" and describing how they differ. You might write this brief essay under four headings: apparent movement among the stars, position in the sky where seen, brightness, colour. Those planets are, of couse, Venus, Mars, Jupiter, Saturn.'

3 Experimental recall

An example is III 71, which might be set after a practical period on the construction and use of telescopes:

III 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?'

If we ask the 'omnibus' question, 'How did you make a simple telescope?', then the pupil, starting as it were from scratch, has to sort out and write about the whole of a long piece of work, and this is probably beyond the capabilities of most thirteen-year-olds. Instead, leading questions are asked about four separate stages. Answering these questions involves an element of thought and is not the same as note-copying.

Questions such as III 71 are, in fact, another kind of simple recall question, referring back to practical experiences rather than problems on theoretical work. The following is another example of an 'experimental recall' question, this time with a sting in the tail.

III 197:
'Figure 1 represents a "multiflash" photograph of a ball falling after being held and released.

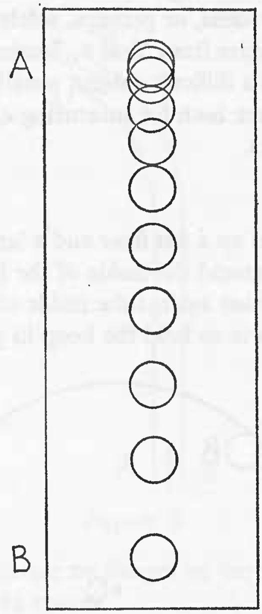


Figure 1

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?'

4 Beginning a new piece of work: questions that look forward

Instead of telling pupils to 'read the next chapter in the book', questions may be set to encourage them to formulate (not necessarily on paper) some preliminary ideas, or perhaps, solely to 'start them wondering'. Consider two examples from Year v, Section 1, 'Introduction to circular motion'. This is a difficult subject usually reserved for the sixth form; but it is needed here both for measuring *e/m*, and for dealing with planets and satellites.

v 1:
'A circular hoop is placed on a flat floor and a large steel ball (or heavy marble), B, is set rolling round the inside of the hoop. So long as it is moving the steel ball presses against the inside of the hoop – try it and see. You will probably have to hold the hoop in position (figure 2).

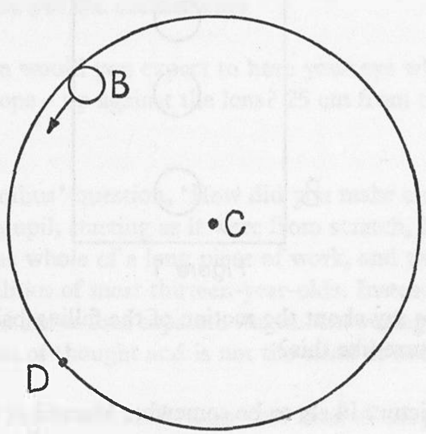


Figure 2

a. Which way is the force exerted *by* the hoop *on* the ball – towards the centre C, or away from it? Which way is the force exerted *on* the hoop *by* the ball?

b. When the ball has reached the position D, the hoop is suddenly lifted off the floor. What happens to the ball? Draw a sketch to illustrate your answer.'

V 2:
'AA′ and BB′ are the two rails of a single flat railway track. A train proceeds from the straight portion at AB towards the lefthand curve at A′B′ (figure 3).

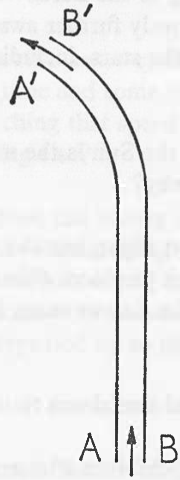


Figure 3

a. Suppose first that there are no flanges on the wheels. What happens when the train reaches the curve?

b. But of course there are flanges on the wheels, and these flanges fit inside the rails. When the train rounds the curve, which rail presses against the wheel flanges? Is it the inner rail, AA′, or the outer, BB′? Give a commonsense reason for your answer, using the word "momentum".'

These questions provide a suitable introduction to circular motion without the pupil having to be 'told' anything. Question V 55 provides a similar introduction to the section on astronomy.

v 55:
'On a clear cloudless day – or night – the sky above us looks like an inverted hemispherical bowl, with ourselves at the centre: a bright blue bowl by day, or a black bowl by night. Inside this bowl but above us we see objects that clearly belong to the Earth – clouds, and man-made things such as aircraft. Obviously further away, part of the bowl perhaps are the Sun, the Moon, and the stars, including the very interesting objects we call planets.

a. Certainly to us, on Earth, the Sun is the most important and necessary of these objects – why?

b. Moonlight may be useful at night, but the most important thing to us here about the Moon is that it produces *tides*: what evidence is there that the Moon, rather than the Sun or stars, is chiefly associated with oceanic rise and fall?

c. Have the stars any practical usefulness to us at all? If so, what?'

In Year III, Section 15 gives children who are going to study force and motion something to think about and wonder about and discuss next day. In the discussion the teacher, though perhaps giving a gentle prod where necessary, would definitely NOT produce a set of answers – the intention is to lead the class to want to find out something about motion under forces *for themselves.*

Year III *section* 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 m.p.h. 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 m.p.h. it takes him some time and some petrol to reach 60 m.p.h. 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 were tried 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 m.p.h., 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 of radioactive gas at rest shoots out a high speed alpha particle like that, does the rest of the atom recoil faster than the alpha particle or more slowly or not move at all?'

5 Teaching questions: saving the teacher's time

III 257:
'Figure 4 is a diagram showing essential parts of a moving-coil ammeter.

a. Copy this diagram.

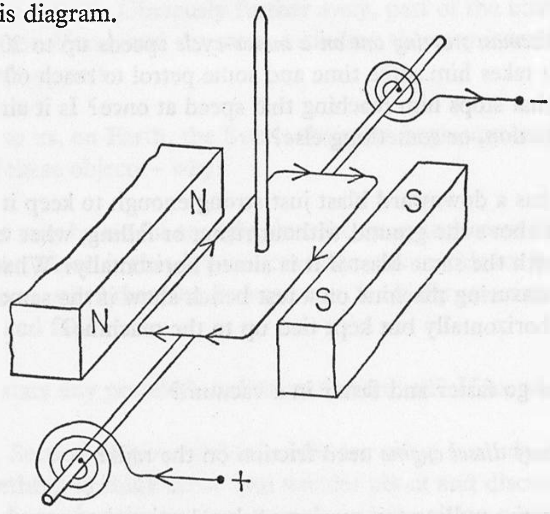


Figure 4

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.'

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

Some part of the straightforward 'bread-and-butter' work of teaching may be avoided or shortened by allowing pupils to answer questions for homework. Teachers constantly use this method, and questions III 257 and 258 could appear in any O-level syllabus. Another example is the whole of Section 5 of Year V, which leads pupils in stages through the measurement of *e/m* for electrons, or V 50 below, which leads towards positive rays and the idea of isotopes.

v 50:

'Figure 5 is a diagram which shows the basic idea of a modern 60° mass spectrometer.

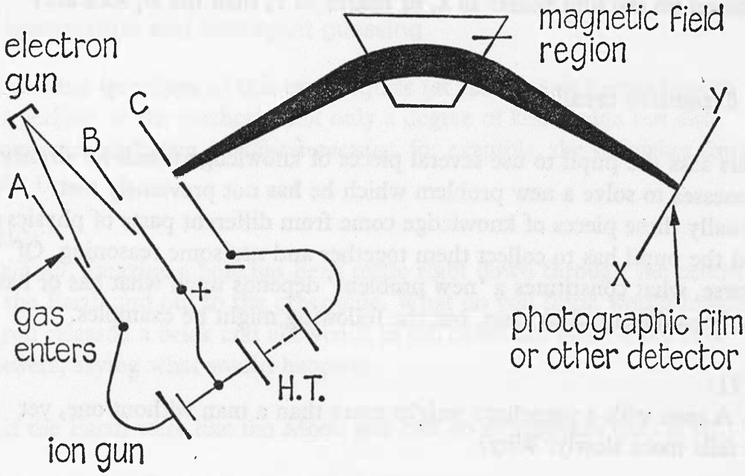


Figure 5

A slow stream of gas at low pressure enters the apparatus through the slit A. The gas is continuously pumped away. Between A and B the gas is "bombarded" by an electron stream from an electron gun. These electrons knock other electrons off the atoms of gas, thus making positive ions. Some of these, under the influence of a weak electric field between A and B, drift through the slit B with only very small velocities. The positive ions are accelerated from B to C by a strong electric field, so that some of them emerge from C with large velocities and large energies (K.E. = $\frac{1}{2}mv^2$). Since they have all been accelerated by the same field between B and C, they all have very nearly the same kinetic energy. Even though a fine slit is used at C, the ion beam splays out through a small angle, and it is focused on a photographic film XY, or some other detector, by a magnetic field whose direction is perpendicular to the paper.

a. Why is it necessary to have ions coming through C all with the same energy? What would be the disadvantage if this were not the case?

b. Why is it necessary to have B negative with respect to A, but only slightly negative?

c. Suppose the gas contains a mixture of atoms of two different masses, m_1 and m_2, m_2 being greater than m_1. Suppose also that *all* the gas ions formed carry equal positive charges (i.e. all have lost the same number – one or more – of electrons). What is going to happen when the ion beam has been focused by the magnetic field? Will the m_2 ions be focused on the film nearer to X, or nearer to Y, than the m_1 ions are?'

6 Expensive recall

This asks the pupil to use several pieces of knowledge which he already possesses to solve a new problem which he has not previously met. Usually these pieces of knowledge come from different parts of physics; and the pupil has to collect them together and use some reasoning. Of course, what constitutes a 'new problem' depends upon what has or has not been discussed in class, but the following might be examples.

II 71:
'*a*. A man with a parachute weighs more than a man without one, yet he falls more slowly. Why?

b. An aircraft dives vertically with its engines off. It reaches a constant speed of 350 m.p.h. What two forces are acting on it when it reaches that terminal velocity? What can you say about these two forces?

c. The aircraft is still diving when the pilot switches on the engines (a "power dive"). What happens now? Assume the plane does not hit the ground or break in pieces. Why, in fact, is it likely that it might break in pieces under this treatment?'

IV 247:
'A new laboratory in a school is to be equipped with a low-voltage d.c. supply and a higher-voltage a.c. supply. The mains input to the laboratory is at 240 volts, but it was decided that this was dangerously high for a bench supply, and that 100 volts would be better. A large step-down transformer was used, and the design was such that 4 turns of wire on the coils were required for each volt input to the primary.

a. How many turns were required on the primary, and how many on the secondary?

b. The secondary had a centre-tapping, "which", said the physics master concerned, "we will 'earth' onto a metal water pipe for the sake of safety". Why is it safer to earth the centre-tapping, rather than one end or the other of the secondary coil?'

7 Imagination and intelligent guessing

Sometimes questions of this type require (at the student's level though not perhaps at the teacher's) not only a degree of knowledge but also *imagination* and even *intelligent guessing*, for example, the following from Year I:

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

a. if the Earth were like the Moon and had no atmosphere (air) at all,

b. if the hole is full of atmospheric air.

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

Also say what *energy changes* take place;

c. if the brick falls into an empty hole as in *a*.,

d. if the brick falls into a hole full of air as in *b*.'

Question V 107 (following a question on Kepler's 'five regular solids' theory) provides another example.

'. . . write about two pages of discussion, explaining why one of Kepler's theoretical schemes is interesting but of no present value, while the other is regarded as completely successful. Your brief essay can be written under three headings:

a. which scheme best fitted the facts known to Kepler;

b. which deals the better with subsequently discovered facts, e.g. newly discovered planets;

c. which scheme best links up with other knowledge in quite different fields, e.g. mechanics?'

8 'Open' or 'loose' questions

Another category of question is the *open or loose question,* for example, 'What would you mean as a scientist if you described an experiment as a good experiment, or a successful one?' Occasional questions of this kind might well appear in test papers, but they have not found much place in the Questions Books, which follow a specific layout of work.

9 'Uncle George' and 'Freddie Jones' questions

These are, perhaps, among the less traditional types of question. 'Uncle George' questions try to fit the pupil into the role of the teacher; he has to explain to Uncle George something he has already learnt, or to help Uncle George to solve some problem. This is an attempt to get the pupil away from the false position of the examinee-examiner relationship, in which the examinee explains to the examiner things with which the examiner is much more familiar already. Uncle George is intelligent but he knows very little physics. He wants to know and is willing to listen; he is also argumentative, and may have ideas of his own.

'Freddie Jones' fulfils a similar function, but not quite the same because he is a contemporary of the pupil's, and is following the same course in physics. He has already appeared in question III 197 (p. 5); here are two further 'Freddie' questions.

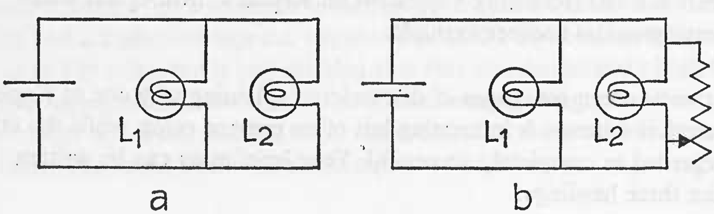


Figure 6

II 25:
'*a.* Draw the circuit of figure 6(a), including a "dimmer" that would dim lamp L_2 without affecting L_1.

b. In answer to part *a*. of this question, Freddie Jones drew circuit *b*. Why is this a "fool's circuit", and what would be the bad results of using it?'

II 9:
'Freddie Jones says there is no advantage in using two engines to pull a train, because you can't get two engines that are equally strong. If used separately one engine must pull the train faster than the other. The addition of the slower engine could then only slow down the train. What do you say?'

And here are two 'Uncle George' questions.

IV 189:
'*Difficult*. You told Uncle George that two good examples of perpetual *movement* are the movement of the Earth round the Sun, and the movement of molecules in a gas.

Now he asks:

a. Why the Earth does not slow down and stop? and

b. Why the molecules do not slow down and stop?

Do your best to explain *a*. and *b*. to him in about three sentences for each.'

IV 190:
'After your chat with Uncle George about perpetual *movement*, you and he talk about perpetual *motion*, and you tell him, with one or two examples, that perpetual-motion machines are impossible. He says "I remember reading about a perpetual-motion machine some time ago. As far as I remember, it consisted of an electric generator joined by wires to an electric motor, which is coupled by a pulley and band to the generator. The generator provides current which drives the motor, which rotates the generator, which gives current for the motor, and so on. Wasn't that a perpetual-motion machine?"

a. Write a few sentences of your subsequent conversation with Uncle George.

b. He then says, "All right, I agree that the generator-motor machine would not provide a continuous supply of energy. But my grandfather – your great grandfather – he was clever, he had a perpetual-motion machine. It was a windmill; it ground corn. If you had seen the large wheels and shafts rotating inside, and the rotating grindstone, you would have had no doubt that it had plenty of energy. Yet he paid nothing for coal, gas, electricity, or anything of the sort."

What do you reply to this?'

Chapter II

Test Papers, Years I–V

This chapter contains complete papers of questions set for those schools which, during the trial period, assisted by trying out Nuffield Schemes in laboratory and classroom. For two reasons, Year V does not find much place here, first, because there were no Year V pupils during the first trial year, and second, because, later, Year V pupils took the O-level examination (see Chapter III). However, a few 'mock O-level' questions set in Year V are included as the last section of this chapter.

Except for the first examination when one paper was set, two papers of different kinds were set for each examination:

Paper A, questions which were called 'quickies', that is, short answer questions to be answered on the question paper itself. This paper gives good coverage of the syllabus for a particular Year or, for the December papers, part of a Year.

Paper B, questions designed to test the pupil's ability to describe something he has seen or done, or to discuss it with some other person, e.g. Uncle George.

The one paper set for the first examination, in December 1963, is really a B-type paper. It must be remembered too, that the papers marked 'December' are set on only about half of the syllabus for a particular year.

The remarks concerning *purpose* of an O-level examination, *types of question*, and *marking*, which will be found at the beginning of Chapter III, are also applicable at the levels of Years I to IV. As explained in Chapter III, the marking of A-type papers is highly objective: answers are mostly right or wrong without gradations. Nevertheless there is frequently room for the 'more than satisfactory' answer that gets more than 100 per cent of the marks (see Chapter III). B-type papers give more latitude for marking on impression. In both papers, much time and care should be given to the setting of the questions; then the marking is in fact accomplished more quickly than for a traditional paper, and certainly with much less boredom.

Use of these papers by teachers

Obviously there are various possibilities:

a. whole papers can be set to pupils,

b. suitable questions from different papers can be chosen to make a new paper,

c. teachers wishing to construct papers of their own can use these questions to suggest ideas for further questions on the same topics.

If the same papers will be set to succeeding classes in future years, then it would be a good idea to collect up the question papers after each examination. However, it is hoped that teachers will not rely too much on setting the same questions year after year since this will have a rather depressing effect on the course!

Year I July Paper Section A

time allowed, 45 minutes

Question 1

Jack and Jill go to a boatyard, and each hires a canoe. The canoes weigh the same, and they have the same size and shape, but Jack's is made of wood and Jill's is made of aluminium. The boatman says, 'Aluminium weighs more than water, and wood weighs less than water.'

a. What do you think he means by 'aluminium weighs more than water'?

....

....

b. Jill says, 'My canoe must be thinner.' How does she know?

....

....

c. Both canoes float well. This surprises Uncle George who had said that Jill's canoe would sink 'because aluminium is heavier than water'.

Why does Jill's canoe float?

....

....

d. What happens to the canoes if both get filled with water?

....

....

Question 2

a. Jill has a balloon filled with hydrogen. When she releases the balloon, it rises upwards. What does this tell her about hydrogen compared with air?

....

....

b. Jack has another balloon filled with a different gas. He releases it and it falls slowly downward. Jill says that this shows that the gas in the balloon is heavier than air. Jack is not sure about it. What do you think?

....

....

c. One day later, both balloons have got smaller, though the 'gas' balloon has not diminished as much as the hydrogen balloon. Why have the balloons got smaller?

....

....

d. What can you say about the size of the 'gas' molecules compared with the size of hydrogen molecules (though, of course, this one experiment does not really prove it)?

....

....

Question 3
Jill suspended a slightly stretched spring and adjusted a ruler against it so that, with no added load, the lower end of the spring was against the 50 cm mark. She then added loads of 200, 400, 600, and 800 grams weight and each time took the reading on the ruler.

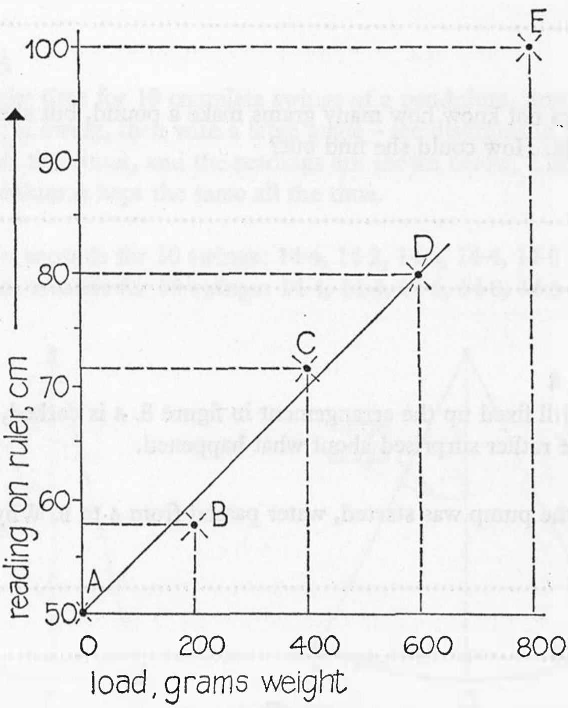


Figure 7

She then plotted a graph, as shown in figure 7. Afterwards, she lost the table of readings from which the graph was plotted. Jack made them up again for her, from her graph.

a. You make them up again too, in the table below. You are to make up the readings she *had*, not the ones you think, perhaps, she ought to have had.

Load, g wt	0	200	400	600	800
Reading, cm					

b. She has drawn a straight line graph from A through D. Is this right or ought she to have drawn it through B, C, and E as well? Give the reasons for your answer.

....

....

c. She does not know how many grams make a pound, but she has a 1 lb weight. How could she find out?

....

....

Question 4

Jack and Jill fixed up the arrangement in figure 8. A is corked, B is not. They were rather surprised about what happened.

a. When the pump was started, water passed from A to B. Why?

....

....

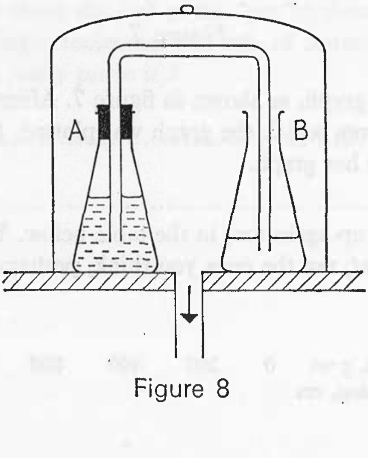


Figure 8

b. When the pump was stopped and air was allowed in, water passed back from B to A. Why? ....

....

....

Question 5

Jack finds the time for 10 complete swings of a pendulum, first with a small angle of swing, then with a large angle – see diagrams in figure 9. He does this five times, and the readings are shown below. The length of the pendulum is kept the same all the time.

Small angle, seconds for 10 swings: 14·4, 14·2, 14·6, 14·4, 14·6
Large angle, seconds for 10 swings: 14·4, 14·4, 14·6, 14·8, 14·6

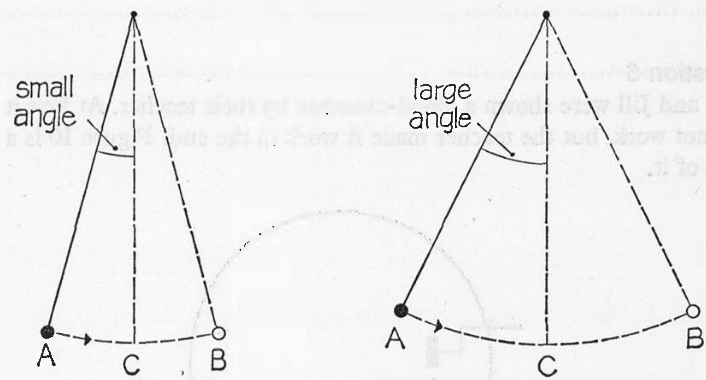


Figure 9

a. Find the best value for the time for *one* swing of the small angle pendulum .... seconds

b. Find the best value for the time for *one* swing of the large angle pendulum .... seconds *c.* Jack says this shows that large angle swings take longer than small angle swings. Jill says, 'That may be so, but your readings don't show it.' Which do you agree with, and why?

....

....

d. Jack and Jill agree that, when the pendulum bob is at the central position C, it is moving *faster* when the angle of the swing is *large* than when it is small. Give a reason why this must be so.

....

....

Question 6

Jack and Jill were shown a cloud-chamber by their teacher. At first it did not work, but the teacher made it work in the end. Figure 10 is a plan of it.

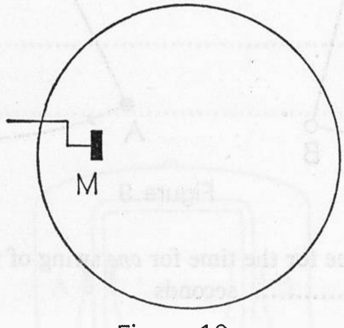


Figure 10

a. Draw in what is seen when it is working.

b. What is there on the piece of metal marked M?

....

c. What do you think the trails are made of?

....

....

d. Explain shortly what you think is happening.

....

....

....

....

....

....

Year I December Paper Section A

These questions were sent to teachers for them to use as they thought fit.

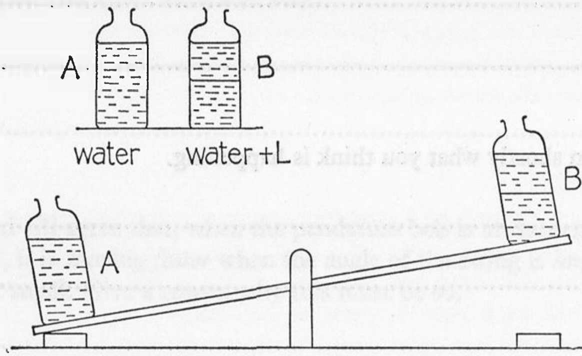


Figure 11

Question 1

Two exactly similar bottles will each hold just over 1 litre. Into one bottle, A, is poured 1 litre of water. Into the other bottle, B, is poured $\frac{1}{2}$ litre of water and $\frac{1}{2}$ litre of a colourless liquid, which we shall call 'L'. Bottle B is shaken, but the water and liquid, L, do not mix.

A and B are then put on a simple balance, and the result is shown in figure 11. Is the liquid, L, at the top, or at the bottom of bottle B?

....

Give, in not more than two sentences, the reason for your answer.

....

....

....

Question 2
One of two bottles, X and Y, is joined to a bicycle pump and valve. The pump handle is pushed in and out for a few strokes, and the tap is then closed. The other bottle is left as it is. The tubes attached to the bottles are placed under water, the taps are opened, and the result is shown in the first two diagrams in figure 12.

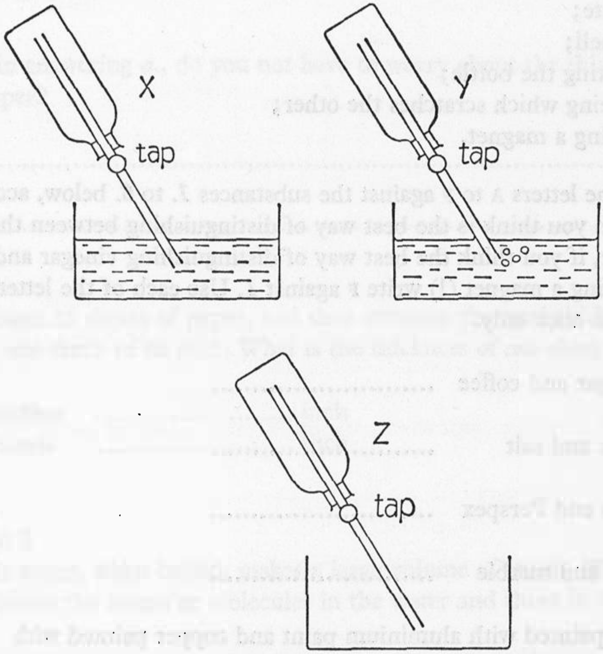


Figure 12

a. Which bottle, X or Y, was attached to the bicycle pump?

....

b. Give the reason for your answer..

....

c. Complete this picture by showing what would happen if a third bottle, Z, were joined to a *vacuum* pump, and the tap were then opened with the tube under water.

Question 3

Listed below are 6 pairs of substances (the liquids are in bottles). Here are six ways in which we might distinguish one of each pair from the other:

A by colour;
B by taste;
C by smell;
D by tilting the bottle;
E by seeing which scratches the other;
F by using a magnet.

Write the letters A to F against the substances *1.* to *6.* below, according to which you think is the best way of distinguishing between them. For example, if you think the best way of distinguishing vinegar and coffee is by using a magnet (!) write F against *1.* Use each of the letters A to F once and once only.

1. Vinegar and coffee ....

2. Sugar and salt ....

3. Glass and Perspex ....

4. Slate and marble ....

5. Iron painted with aluminium paint and copper painted with aluminium paint ....

6. Water and glycerine ....

Question 4

a. A bullet which is $1\frac{1}{2}$ inches long travels 3,000 feet in every second. How long (what fraction of a second) does it take to travel right through a sheet of paper? Work out your answer here.

....

b. Why, in answering *a.*, do you not have to worry about the thickness of the paper?

....

....

c. You count 25 sheets of paper, and then measure the total thickness, which is one-tenth of an inch. What is the thickness of *one* sheet of paper:

1. as a fraction .... inch

2. in decimals .... inch

Question 5

a. A little water, when boiled, makes a large volume of steam. What can you say about the atoms or molecules in the water and those in the steam?

....

b. Very difficult. 1 litre of a certain liquid, when boiled, makes 1,000 litres of the vapour of the liquid. How much further apart are the atoms in the vapour, compared with their distance apart in the liquid? (*Note* 1 – 'distance apart' means distance between the centres of the atoms. *Note* 2 – the answer is not 1,000 times.)

.... times

Question 6

A small watertight cubical box has sides of 1 cm length (figure 13). 27 drops of water from a dripping tap fill it completely. 27 small ball-bearings also fill it completely.

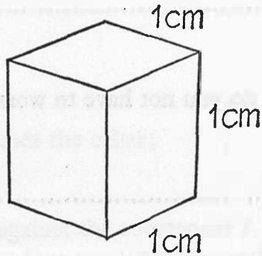


Figure 13
(Not actual size.)

a. What is the volume of *one* drop? (Leave the answer as a fraction of a cubic centimetre.) .... cm^3

b. Is this also the volume of one ballbearing? (Answer *yes* or *no*.) ....

c. If 'No', why not? ....

....

d. What is the diameter of *one* ballbearing? (Leave the answer as a fraction of a centimetre.) .... cm

Year I   July Paper   Section A

time allowed, 45 minutes

Questions 1–2

Three liquids were poured into a glass jar, shaken up, and left to stand. When they had settled down, the appearance was like that shown in figure 14.

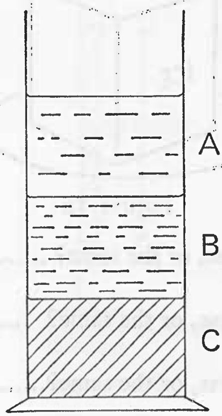


Figure 14

1. Which liquid, A, B, or C, has the greater density? ....
Which liquid has the least density? ....

2. If A is water and C is mercury, why cannot B be a solution of sugar in water? ....

....

Questions 3–8

A cube of ice is put in an open flat-bottomed cylindrical can (figure 15). Soon, all the ice has melted.

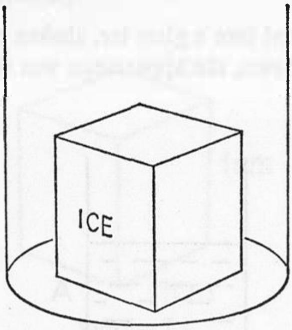


Figure 15

3. Is the weight greater, less, or the same? ....

4. Is the volume greater, less, or the same? ....

5. Is the density greater, less, or the same?.......................................

6. Has the ice changed to: solid, liquid, or gas?..............................

7. Has the melted ice still got the shape of a cube? ....
(Answer *yes* or *no*.)

8. If 'No', what is the shape now? ....

Questions 9–14

An indiarubber band has a small load on it to keep it taut, and its length is then 11·8 cm. When an *extra* 200 grams weight is put on it, its length is 13 cm (figure 16). Two experiments are carried out with this rubber band. In the first experiment loads are added in steps of 50 up to 200 grams weight:

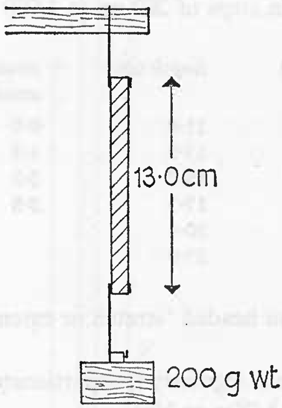


Figure 16

load (g wt)	*length (cm)*	*stretch or extension (cm)*
0	11·8	0·0
50	12·1	0·3
100	12·4	0·6
150	12·7	
200	13·0	

9. Complete the column headed 'stretch or extension'.

10. Calculate the extension (stretch) for 1,000 grams weight, assuming that the rubber continues to extend in the same way.

Extension = ________ ________
number units

A second experiment is then performed with the same rubber band in which loads are added in steps of 200 up to 1,000 grams weight.

load (g wt)	*length (cm)*	*stretch or extension (cm)*
0	11·8	0·0
200	13·0	1·2
400	15·0	3·2
600	17·3	5·5
800	20·4	
1,000	23·9	

11. Complete the column headed 'stretch or extension'.

12. Did extension increase regularly (proportionately) with load between 0 and 200 grams weight? (Yes or No) ....

13. Did extension increase regularly (proportionately) with load between 0 and 1,000 grams weight?......................

14. Which of the three graphs in figure 17, X, Y, or Z, most nearly follows the behaviour of the rubber band between 0 and 1,000 grams weight?......................

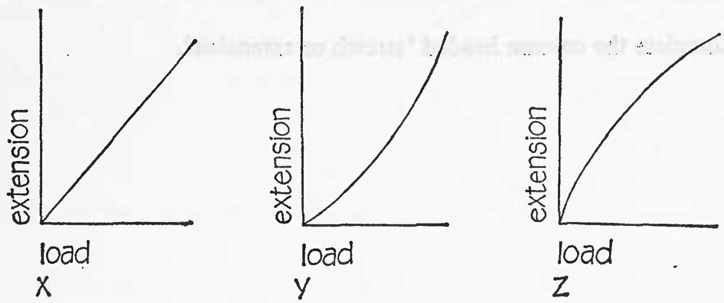


Figure 17

Questions 15–18

The container A, shown at the bottom of figure 18, is open to the atmosphere through the side tube. The liquid is mercury and there is a vacuum at the top of the tall tube. The tube is about 90 cm long.

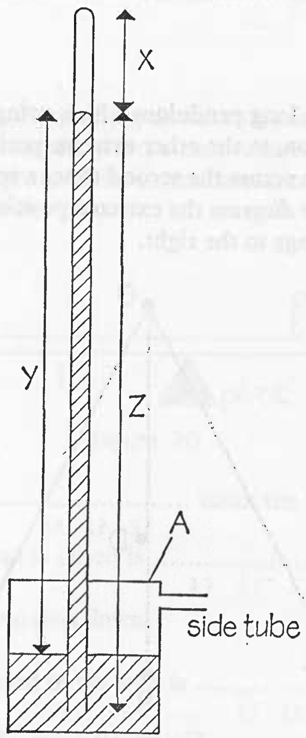


Figure 18

15. What does this instrument measure?

....

16. Which height are you supposed to measure, X, Y, or Z? ....

17. The side tube is then joined to a bicycle pump through a suitable valve, and the pump is operated a few times. What happens in the apparatus?

....

18. The bicycle pump is removed and a vacuum pump is joined on instead. The pump is operated until a very good vacuum is obtained. What happens?

....

Question 19

Figure 19 represents a long pendulum which swings from one extreme position, OA, through OB, to the other extreme position, OC, then back again. But, as it comes across the second time, a round peg is put in its way, at D. Draw *on the diagram* the extreme position the pendulum reaches now, as it swings to the right.

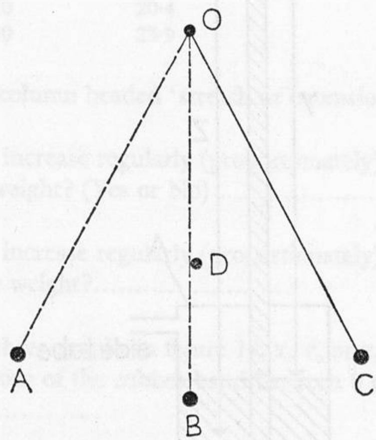


Figure 19

Question 20

A 10 lb block of stone is lifted from the floor to a shelf 6 feet above the floor. How much work is done in lifting the block?

_______ . _______
number unit

Question 21

The block falls off the shelf and into a hole which goes down 2 feet below floor level. How much potential energy is transformed?

P.E. transformed = ______ . ______
number unit

Questions 22–24

Figure 20 shows a lever. By pushing down with a force of 4 pounds weight, applied 3 feet from the pivot, a man raises a load of 12 pounds weight 1 foot from the pivot. Write in the correct answer, $\frac{1}{3}$, or 1, or 3, in the next three questions.

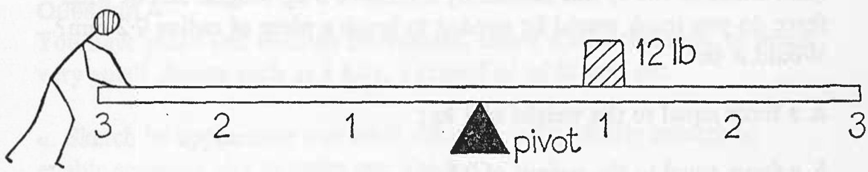


Figure 20

22. The load raised is .... times the force applied.
$\frac{1}{3}$? 1? 3?

23. The distance the load is raised is .... times the
$\frac{1}{3}$? 1? 3?
distance the applied force goes down.

24. The energy transferred to the load is .... times the
$\frac{1}{3}$? 1? 3?
energy supplied from the man's push.

Year 1 July Paper Section B

time allowed, 40 minutes

Teachers were asked to choose TWO out of these four questions. Pupils were then required to answer both of the questions chosen.

Question 1

Explain how you would measure the smallest force needed to break a piece of cotton. Sketch and label the apparatus that you would use.

In an experiment, a piece of thread of radius 0·1 millimetre (mm) was broken by a force of $\frac{1}{2}$ kilogram (kg) weight. A piece of radius 0·4 mm (four times as thick) was broken by a force of 8 kg weight. About what force do you think would be needed to break a piece of radius 0·2 mm? Would it be:

a. a force equal to the weight of 1 kg;

b. a force equal to the weight of 2 kg;

c. a force equal to the weight of 4 kg;

d. a force equal to the weight of $4\frac{1}{2}$ kg?

Give a reason for your answer.

Question 2

Crystals of common salt are shaped like cubes.

a. How would you show a younger brother or sister that this is so? (You have some table salt.)

b. Suppose you had some special kind of microscope that could magnify salt crystals till the atoms were as big as pinheads. Draw and explain what a crystal would look like.

c. Suppose the crystal were heated till it started to melt, and you still looked at it through your special microscope. What do you think you would see:

1. at first, when it had hardly become hot enough to melt;

2. when it was melting very rapidly?

d. Suppose that before the salt had entirely melted, you let it cool. What would you see through your microscope as the liquid salt started to solidify?

Question 3

Explain, using diagrams if you like, how you have found the thickness of a very thin film of oil on water. If you can, make up some simple readings, and show how the thickness was calculated from them.

Why do we think this is an important experiment?

Question 4

You have made and used an instrument, called a microbalance, to weigh very small objects such as a hair, a crystal of table salt, etc.

a. Sketch its appearance and label the main parts clearly enough to enable someone else to make one like it.

b. What would you do if the straw would not balance?

c. What would you do if the straw would not stop swinging?

d. How could you use it to weigh long lengths of things such as hair, cotton, nylon, etc.?

Year 1 December Paper Section B

Teachers were asked to make their own selection from these questions.

In all the questions, use diagrams (drawings) whenever they can help you to explain your answer.

Question 1

a. This question is about eggs.

A lady makes cakes to be sold in a home-made-cake shop. She uses several dozen eggs in a week. She can buy 'large' eggs at 4½d each, or she can buy 'medium' eggs at 3d each. All are fresh; she simply has to decide which gives her the largest amount of eggs for her money. Which is the better buy, 'large' or 'medium'? She doesn't know.

You don't know either, but you can find out. How?

b. You want to find the height of a tall aerial mast set at one side of a level sports field. You are not allowed to climb it, nor to take it down. The only 'instruments' you have are:

1. a metre rule;

2. a piece of thick cardboard cut into a right-angled triangle, the other angles being 45° (figure 21);

3. a drawing pin that can be pushed into the cardboard anywhere you like;

4. a piece of thread and a small stone that can be tied to it.

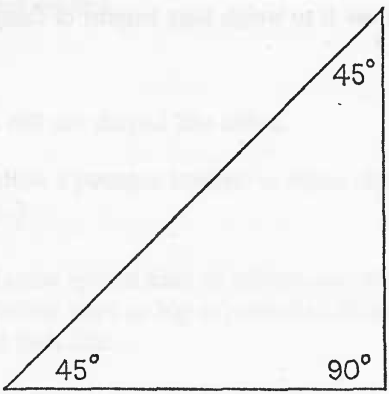


Figure 21

How would you find the height of the mast? You may have the help of another boy or girl to hold the apparatus in any way you want, but you must tell him or her how to hold it.

Question 2

a. 'Children grow, animals grow, plants grow,' says Uncle George, 'but these are alive and that's why they grow. Crystals are not alive, so they cannot grow.'
Describe the experiment you would show Uncle George, in order to convince him that he is wrong.

b. Uncle George is willing to believe that crystals are made up of atoms. How would you use this idea (that is, the idea of atoms) to explain what happens in the experiment you have described?

Question 3

a. Some solid substances are easy to cleave with a razor blade and a hammer, but the blade cannot be placed just anyhow; it must be in the right position. How do you explain these facts?

b. Suppose you take sugar cubes from the kitchen and try to cleave them with a razor blade. You try the blade in all sorts of positions. What do you think would happen? How do you explain what happens?

Question 4

Describe one interesting experiment for which you used a microscope (do not describe the microscope). What did you see that you would not have seen without the microscope? Explain as much as possible about what you noticed, drawing diagrams if you think they will be helpful.

Question 5

A few weeks ago you met a boy or girl of your own age and you talked about the physics you were doing at school. He (or she) lives in another town, and now writes asking about the straw microbalance you made. He (or she) wants to make one like it.

a. Make a sketch of the balance for him.

b. Label the sketch with the names of the parts.

c. Explain how he should put the balance together.

d. Later he (or she) writes saying he has put the balance together, but that it is not sensitive enough. It will not weigh a hair. What advice can you give him about how to make it more sensitive?

Year 1 July Paper Section B

Teachers were asked to choose TWO of these three questions. Pupils were then required to answer both questions.

Question 1

Suggest ways of finding out:

a. the average spacing of neighbouring grooves on a long-playing record (no microscope available);

b. the 'all out' speed on the flat of a model electric locomotive;

c. the percentage (by weight) of moisture contained in a slice of fresh white bread.

Question 2

You have looked through a microscope at smoke particles in a small box. A strong light was shone into the box, and you saw the particles in motion.

a. How did the smoke get in the box?

b. Describe the kind of motion the smoke particles had.

c. Explain why the motion of the smoke particles helps you to believe that air molecules are also in motion, and that their speeds must be greater than that of the smoke particles.

d. Suppose you tried this experiment using particles several times bigger than the smoke particles which were actually used. An advantage of the bigger particles would be that they are easier to see. A disadvantage would be that they would fall, that is, drift slowly downwards – let us imagine, however, that this has been overcome in some way. What difference would you observe between the smoke particles and the larger particles?

Question 3

You have found the thickness of a single oil molecule by dropping oil on water.

a. How did you get an oil drop about $\frac{1}{2}$ mm across?

b. How did you make sure the water surface was clean?

c. How did you make it possible to see the extent of the oil patch?

d. Use the following figures to work out the thickness of an oil molecule. The first stage of the calculation has been put in to help you – copy out the whole 'Calculation' and finish it as far as you can. It will be quite satisfactory to leave the final result as a fraction.

Results

Diameter of oil drop $= \frac{1}{2}$ mm $= \frac{1}{20}$ cm
Diameter of oil patch $= 25$ cm

Calculation

To make the working simple we calculate the volume of the drop as if the drop were a cube, of side $\frac{1}{20}$ cm, and the area of the patch as if the patch were a square of side 25 cm.

Volume of oil 'cube' $= \frac{1}{20} \times \frac{1}{20} \times \frac{1}{20}$ cubic centimetres. (Now carry on as far as you are able.)

Year 1 December Paper Section B

Question 1
Somebody has hidden a lump of metal in a cube of wood, then painted the cube so that it looks exactly like other painted cubes of wood.

a. How would you tell which cube had the metal hidden in it if they are all the same size?

b. How would you tell which cube had the metal hidden in it if they are different sizes?

also
c. How could you tell whether the metal is iron or not, without cutting open the cube?

Question 2
Three bottles, A, B, and C, are correctly labelled: A air, B half air, half vacuum, C vacuum.

a. The bottles are held upside down with the necks just under water and the stoppers removed. What do you notice in each case?

b. Which half of bottle B was the air in? Explain.

c. If we suppose that air is made up of atoms (or molecules), what can you say about the number in bottle B compared with those in A, and their distance apart?

Question 3

a. Here are four substances: glass, diamond, putty, one's fingernails. Write them in a 'scratch order', that is, so that the first scratches the second but is not scratched by it, the second scratches the third but is not scratched by it, and similarly for the third and fourth. Would the first scratch the third and fourth?

b. We know that a steel pin scratches wood, but a sharp wooden stick does not scratch steel. Therefore, we say, steel is harder than wood. Does the statement 'steel is harder than wood' tell us anything about steel and wood that we did not know before? Or does it tell us what is meant by 'harder'?

c. Write a sentence telling a non-scientific friend what you mean by harder. Start the sentence 'A substance X is harder than a substance Y if...'

Question 4

Imagine that a few weeks ago you met a boy (or girl) of your own age and you told him about the physics you were doing at your school. He lives in another town, and now writes asking about the straw micro-balance you made; he wants to make one like it.

a. Make a sketch of the balance for him.

b. List the things he has to have ready in order to make it.

c. Write a sentence or two giving him some tips about how to put the microbalance together.

Question 5

a. Your friend in question 4 will want some weights and you know he is unlikely to have any means of weighing in grams. But you have a gram balance, and so you decide to send him a sheet of paper, and to tell how many milligrams the paper weighs for each square centimetre.
You take 20 sheets of foolscap each 30 cm by 20 cm and weigh them. They weigh 108 grams. How many milligrams does each square centimetre of paper weigh?

b. What area of the paper in *a.* would he have to cut to make a 20 milligram weight?

c. He writes saying his microbalance is not sensitive enough to weigh 1 milligram. What advice would you give him about how to make it more sensitive?

Question 6

Uncle George is intelligent but does not know any science. He says, 'You say the air in this room weighs 40 kilograms, nearly 90 pounds. I don't believe it. I don't believe you can weigh air.' Tell him how you have seen it done. Remember that you need to convince him that it is a sensible piece of work. You need to make him understand. However you need not give any of the numbers that you got in the measurements and you need not do any calculations, but you should give sketches to help him understand.

Question 7

In your science classes you have seen some crystals and you have heard about atoms. Suppose you have an Uncle George who is intelligent but does not know any science. He hears you say that it is easier to understand crystals if you think about atoms. He says, 'I don't understand. What connection is there between crystals and the idea of atoms?' Write an answer, explaining to him in your own words, in half a page or less. Use drawings if you wish.

Year II July Paper Section A
time allowed 40 minutes

Question 1*
Each of the four diagrams in figure 22 shows a pair of trolleys which can run on grooves so that they do not skew sideways. The first pair, (a), carry short powerful magnadur magnets placed as shown. Both trolleys of the second pair, (b), are made of soft wood; and the one on the right has, firmly fixed to it, a pin, with a sharp point sticking out. When the pin sticks into the other trolley, the two become locked together. The third pair, (c), carry small strong balloons filled with air.

Say what you see happening when the trolleys are pushed together so that they start with equal speeds.

a. In figure (a)

....

....

b. In figure (b)

....

....

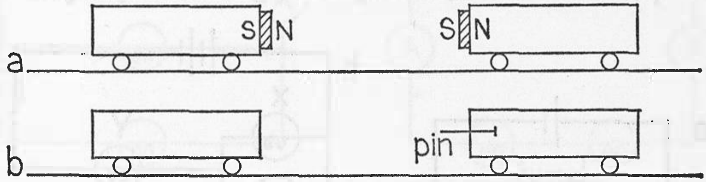


Figure 22*a* and *b*

* Trolleys play only a minor part in Year II, to illustrate energy changes qualitatively.

c. In figure (c)

....

....

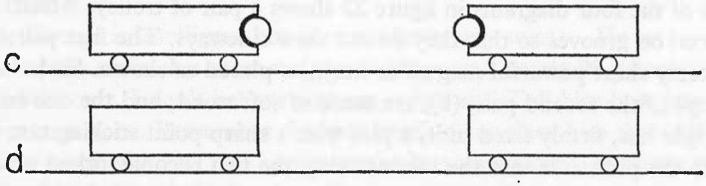


Figure 22*c* and *d*

d. Add to figure 22(d) magnets arranged so that when the trolleys are pushed together, the result is similar to what happens to the trolleys in figure (c).

e. There is, however, an important difference between what happens to the trolleys in figure (c), and what happens in figure (d). What is this difference?

....

....

....

Question 2
One lamp joined to one cell, as in figure 23(a), is 'normally bright'.

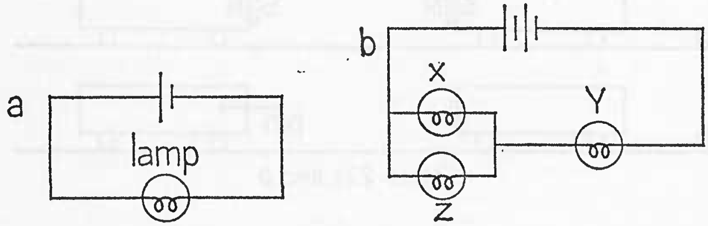


Figure 23

The circuit in figure 23(b) shows *three* lamps, X, Y, and Z, joined in an unusual way to *two* cells. You are asked below to say whether each lamp is very bright, normally bright, dim, or out.

a. How bright is lamp X? ....

b. How bright is lamp Y? ....

c. How bright is lamp Z? ....

Also, if lamp Z is disconnected:

d. How bright is lamp X? ....

e. How bright is lamp Y? ....

Question 3

The circuit on the top lefthand side of figure 24 shows a cell connected to a lamp and an ammeter, A, which indicates a current of 0·3 amperes. Exactly similar lamps and cells are used in the other circuits in this figure. Mark by the side of each ammeter the current you expect it to indicate – you do this by writing '0·3 amp', or 'more', or 'less', or 'nothing', according to what you think is the right answer.

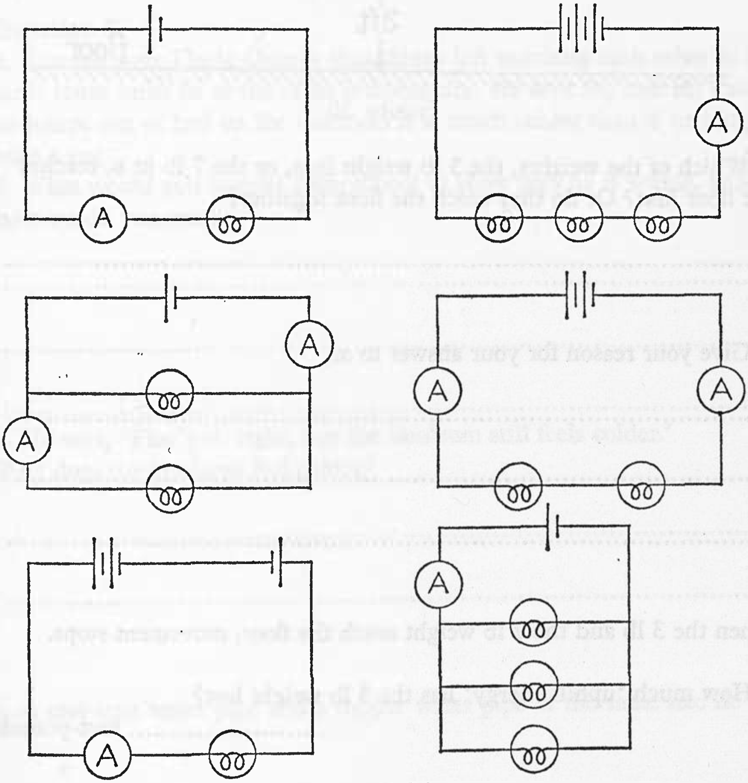


Figure 24

Question 4

Figure 25 shows two exactly similar pulleys and strings. One, marked A, carries a 3 lb load and a 1 lb load. The other, B, carries a 7 lb load and a 5 lb load. They are held steady in the position shown, and are then released at the same instant.

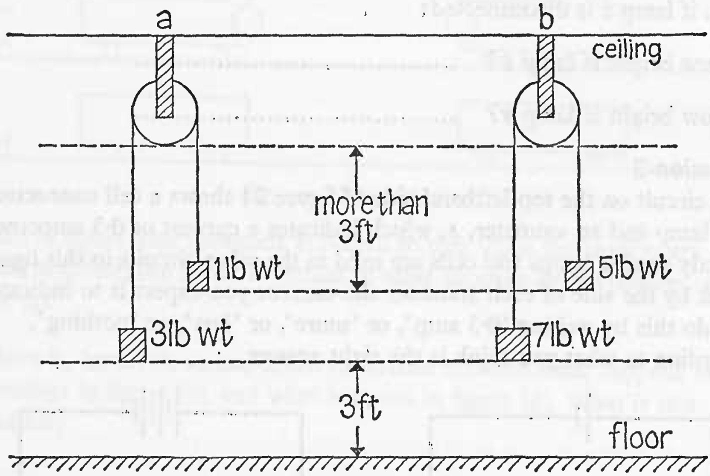


Figure 25

a. Which of the weights, the 3 lb weight in A, or the 7 lb in B, reaches the floor first? Or do they reach the floor together?

....

b. Give your reason for your answer to *a.*

....

....

....

When the 3 lb and the 7 lb weight reach the floor, movement stops.

c. How much 'uphill energy' has the 3 lb weight lost?

.... foot-pounds

d. How much has the 1 lb weight gained?

.... foot-pounds

e. How much has the 7 lb weight lost? ....foot-pounds

f. How much has the 5 lb weight gained?

.... foot-pounds

g. Which system has lost the greater amount of 'uphill energy', A or B? Or have they lost the same?

h. What form of energy was the 'uphill energy' changed into first, just before movement stopped? (*One word*) ....

i. What was this energy converted to when movement stopped? (*One word*) ....

Question 5

a. You tell your Uncle George that things left touching each other in the same room must be at the same temperature. He says no, that isn't so, if he jumps out of bed on the linoleum it is much colder than if he jumps onto a rug.

1. What would you borrow from school to show him he is wrong, and how would you use it?

....

....

....

2. He says, 'That's all right, but the linoleum still feels colder.' Why does the linoleum feel colder?

....

....

b. A cast-iron water pipe and a copper water pipe of the same size lie side by side on a cold winter's night. The iron pipe bursts but the copper does not.

1. Why did the cast-iron pipe burst?

....

....

2. Why didn't the copper pipe burst?

....

....

Year II July Paper Section A
time allowed, 40 minutes

Question 1
WEIGHT: Is it a quantity of matter? A force? The speed of fall of a body? The time for which it falls?
(*Underline the correct answer.*)

Questions 2–7
Figure 26 shows a free-running, practically frictionless arrangement of pulleys. The man pulls the rope down 3 feet.

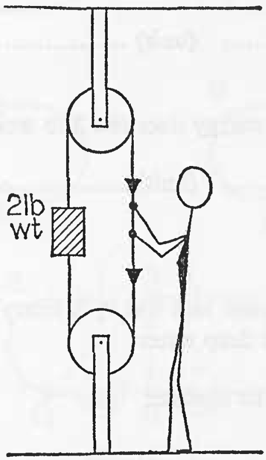


Figure 26

2. What force must he exert?

(number) .... (unit) ....

3. How much work does he do?

(number) .... (unit) ....

4. How much potential energy does the 2 lb weight gain?

(number) .... (unit) ....

Unfortunately the pulley system is left out in a shed, the pulleys and their bearings get rusty, and the rope shrinks and tightens because of the damp. The man finds that the friction is now so great that the 2 lb weight 'stays put' in the position shown, without anyone holding the rope. But the slightest *extra* weight put on the 2 lb weight causes it to fall.

5. What force must the man exert to raise the weight now?

(number) .... (unit) ....

6. How much work does he now do in raising the weight 3 feet?

(number) .... (unit) ....

7. How much potential energy does the 2 lb weight gain?

(number) .... (unit) ....

Questions 8–9

Underline the *correct* answer to 8 and 9. A heavy stone falls vertically down onto the surface of deep water.

8. As soon as it reaches the surface:

a. it comes to a stop;

b. gravity makes it fall faster;

c. it continues with exactly the same speed;

d. it slows down.

9. When it has fallen a long way in water:

a. it is falling at a steady speed;

b. it is 'reaching its level' and coming to a stop;

c. it is accelerating downwards;

d. it begins to turn round and come up again.

Questions 10–15

L, in figure 27(a), is a lamp which is lit with normal brightness by one cell. In answer to questions 10–13 below write: N for 'normal brightness'; B for 'brighter than normal'; D for 'dimmer than normal'.

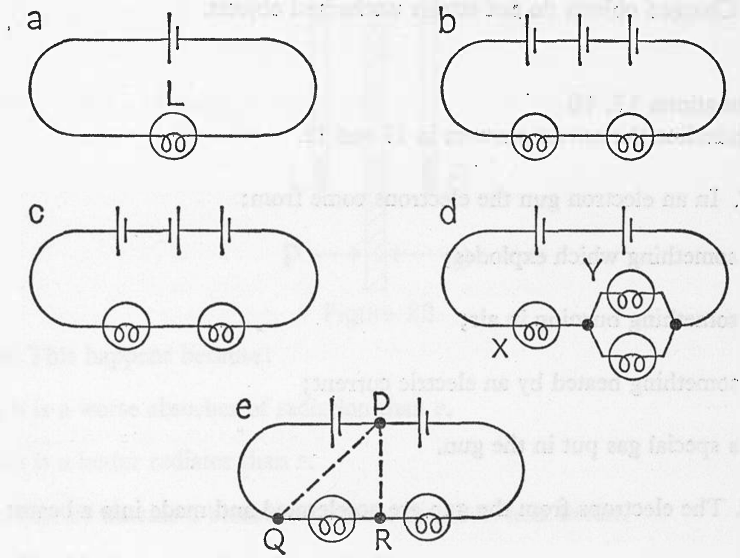


Figure 27

10. In diagram (b), are the lamps N, B, or D? ....

11. In diagram (c), are the lamps N, B, or D? ....

12. Is lamp X in diagram (d) N, B, or D? ....

13. Is lamp Y in diagram (d) N, B, or D? ....

14. Diagram (e) shows two lamps lit by two cells. Unfortunately a piece of wire is joined by accident from P to Q.

Why is this unfortunate?..

15. Diagram (e) again: To join a piece of wire from P to R is useless but not unfortunate; why?

....

Question 16

Underline the *correct* statements among the following:

a. Charged objects exert forces on each other.

b. These forces are always pulls (attractions).

c. There are two kinds of charges.

d. Charged objects do not attract uncharged objects.

Questions 17, 18

Underline the *correct* answers in 17 and 18.

17. In an electron gun the electrons come from:

a. something which explodes;

b. something burning in air;

c. something heated by an electric current;

d. a special gas put in the gun.

18. The electrons from the gun are accelerated and made into a beam:

a. by gravity;

b. by friction;

c. by a powerful magnet suitably placed;

d. by an electric battery (or something similar) suitably joined to the gun.

Questions 19, 20

Underline the *correct* answers in these two questions.

Figure 28 shows a thick copper sheet which has a polished surface, P, and a surface, B, blackened with soot. The sheet is heated well above boiling water temperature and placed as shown, with two similar thermometers, L and R, placed at equal distances from P and from B. R is found to rise in temperature more rapidly than L does.

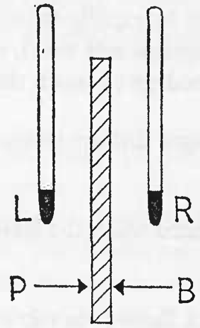


Figure 28

19. This happens because:

a. B is a worse absorber of radiation than P.

b. B is a better radiator than P.

c. The air outside a blackened surface conducts heat better.

d. The blackened surface gives off more electrons.

20. A friend says, 'Ah, yes, the thermometers may look similar, they may even read the same when put touching each other in cold water, but you cannot be sure they are accurate when warmed up.' You can easily show that the difference is not (or not entirely) due to the thermometers by:

a. doing more experiments with the thermometer at different (equal) distances from the copper;

b. putting the thermometers horizontally with the bulbs towards the copper;

c. turning them upside down;

d. reversing their positions, moving L to the right, R to the left.

Year II July Paper Section B

time allowed, 45 minutes

Teachers were asked to choose TWO out of these three questions. Pupils were then required to answer both questions.

Question 1

Some people can make a fire by rapidly twisting a dry stick while one end of the stick is pressed against soft wood, and is covered with dry leaves. The leaves get warmed up so much that they catch fire.

a. Describe the energy changes that are taking place when the leaves are being warmed.

b. Much more heat is produced when the leaves catch fire. Where does this heat come from?

c. An easier way of making a flame is to rub a match on a matchbox. You use much less energy than you do when you make a flame by rubbing a stick on wood. Why is the same result produced with much less energy?

d. You are given a box of matches and a piece of copper wire the same length and size as a match. Using no other apparatus, how would you show, to your own satisfaction, that copper conducts heat better than wood does? Say exactly what you would do and what you would notice.

Question 2

a. How do you know, from common observation in the laboratory and outside, that ordinary air is a bad conductor of electricity?

b. You are given a match with the head cut off, and an iron nail of about the same length and thickness. Using apparatus such as you may have used during the past year, how would you show that iron conducts electric current better than wood does?

c. A friend tries the experiment you described in *b.*, and says, 'This shows that iron does not carry electric current.' You look at his apparatus and see that he has used an old rusty nail he found in the garden. What is it that his experiment really shows? Still using the same nail, what should he do to get the same result as you got?

d. Your friend says that a strong solution of copper sulphate is a better conductor for electricity than a weak solution is. You say that this is meaningless, you might have a metre of solution in a tube a millimetre in diameter, compared with a millimetre of solution in a tube a metre in diameter. What ought he to have said?

e. How would you show that provided you are comparing the solution in the *right way*, strong copper sulphate solution *is* a better electrical conductor than weak copper sulphate solution is?

Question 3
We believe that ice, water, and steam all consist of the same particles, called molecules. Write a page or two, with diagrams if you like, describing the differences between the three forms of water, so far as the molecules are concerned. You should say something about the distances apart of the molecules, the speeds with which they move, whether they are arranged in patterns or not, and anything else you think is worth mentioning. You can refer to, or draw, models that help you to explain what you are describing.

Year II July Paper Section B

time allowed, 45 minutes

Teachers were asked to choose TWO of these three questions. Pupils were then required to answer both questions.

Question 1

Have you noticed what happens when a muddy ball is dropped onto a clean dry floor? A circular patch appears, and the further the ball falls (or the harder it is thrown) the larger the patch. And, of course, if we have a muddy floor and a clean ball, then we get a circular clean patch.

Here is a problem that can be investigated experimentally – the relation between the size (diameter) of the patch and the height from which the ball falls. Imagine you are given a thick glass plate (for the ball to fall on), a soft rubber ball of diameter about 3 cm, two metre rules, a small transparent scale marked in millimetres, a pair of dividers (compasses with two points and no pencil), stands and clamps, a pot of paint and a brush – oh, yes, and plenty of old rags! How would you set about obtaining a number of values of 'size of splodge' for various heights of fall of the ball? How would you present the measurements so as to show the relation between 'size of splodge' and 'height of fall'? And if, subsequently, you measure a certain splodge, and find it to be 1·2 cm diameter, how would you find, from your previous results, how far the ball had fallen to make that 1·2 cm diameter circle? (Assume that '1·2 cm' was *not* one of the results you had previously obtained.)

Question 2

a. A firebrick which has been heated red-hot is taken out of a furnace and placed on an iron slab in a large room. Explain how it loses heat by: *1.* conduction, *2.* convection, *3.* radiation.

b. If you look it up in books or tables, you find that wood is much better than air as a conductor for heat. Yet, if you put an ice-cream brick in an empty box (i.e. full of air), it melts much more quickly than it does if you put it in the same box, but pack the inside of the box, round the ice-cream, with wood shavings. How do you explain this?

Question 3

a. Can an electric current flow through a vacuum? Describe any experiment you have seen which provides an answer to this question.

b. Do electrons (e.g. those from an electron gun) themselves glow so that you can see them? If not, what enables you to see where an electron stream goes?

c. The diagram in figure 29 shows a stream of electrons passing between two parallel metal plates. The whole apparatus is enclosed in an evacuated glass tube which is not shown in the diagram. When the switch S is pressed down, the plates are joined as shown to a battery consisting of very many cells. Draw a diagram showing what happens to the electron stream when the switch is closed. Then draw a second diagram showing what happens if the battery is *reversed*, so that the negative end is joined to the lower plate.

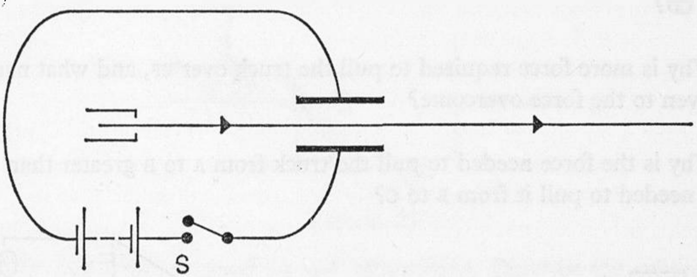


Figure 29

Year II December Paper Section B

Question 1

The top diagram in figure 30 shows a small truck filled with sand or bricks so that it is quite heavy. However, it is fitted with freely running pram wheels, and you can easily pull it by a length of rope attached to the front. You start it from rest at A, and at B reach a speed which you try to keep fairly steady all the way from B to G and beyond. AB, BC, DE, and FG are flat level surfaces. CD is soft earth, like a flower-bed. EF is uphill. The lower diagram shows how the force required to pull the truck changes as you go from A to G.

a. Only a small force is required to pull the truck over parts of the journey. Which parts? What name do we give to the force that has to be overcome during these parts of the journey? What can we say about the part CD?

b. Why is more force required to pull the truck over EF, and what name is given to the force overcome?

c. Why is the force needed to pull the truck from A to B greater than that needed to pull it from B to C?

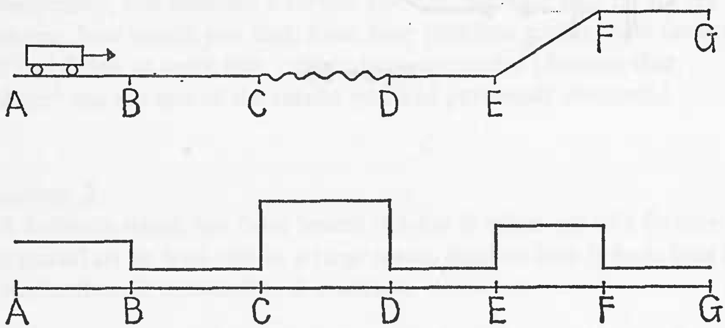


Figure 30

Question 2

The arrangement in figure 31 is rather messy and has been mounted over a sink. P is an empty pail attached by a cord over a pulley to a weight W. W has the same weight as the pail half full of water. T is a water tap, and B is a thick block of wood placed in the sink so that it is just under the lefthand side of the pail.

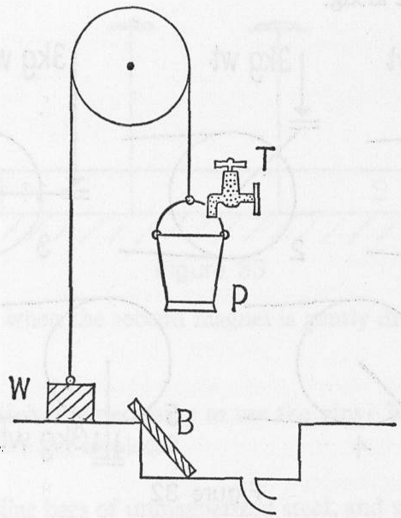


Figure 31

a. The water tap is turned on and left running. Describe the subsequent course of events.

b. Actually, when Freddie Jones (the inventor) tried to set this up he found that, although he had several pulleys, not one of them was wide enough to stop the weight, W, from hitting the pail, P. However, he thought of an arrangement which got round this difficulty. What would you have suggested?

Question 3

A boy riding a bicycle, represented in figure 32, pushes a pedal vertically downwards from the extreme top position of the pedal to the extreme bottom position with a force equal to the weight of three kilograms. In this way he exerts a turning effect which is transmitted through the pedal crank to the chain wheel, the chain, and the back wheel, thus driving the bicycle along.

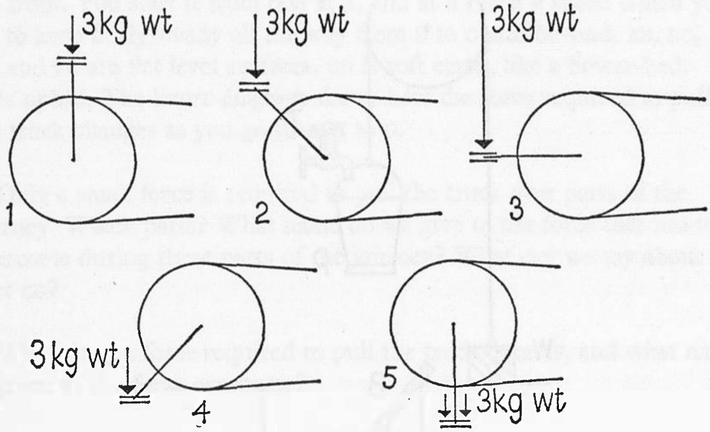


Figure 32

a. Is he exerting the same turning effect all the time as he pushes the pedal from top to bottom? If not, where does he exert maximum turning effect, as represented in diagrams (1), (2), (3), (4), or (5)? And where does he exert least turning effect?

b. The pedal crank is 20 cm long. What number do you think gives the best measure of the maximum turning effect: 20 cm or 3 kg or something else?

c. Suppose the pedal crank is 30 cm long; what force would he have to exert now in order to get the same turning effect as before?

d. If your answer in *c.* is less than 3 kgf, it looks as if there is an advantage in having longer cranks. However, there is a compensating disadvantage; what is it? (*Note:* '3 kgf' means 'a force equal to the weight of 3 kilograms'.)

Question 4

Figure 33 shows a powerful bar magnet with a 'cradle' of tall brass pins round it. Another similar bar magnet can be put into the cradle. It is inserted with its north pole also on the left.

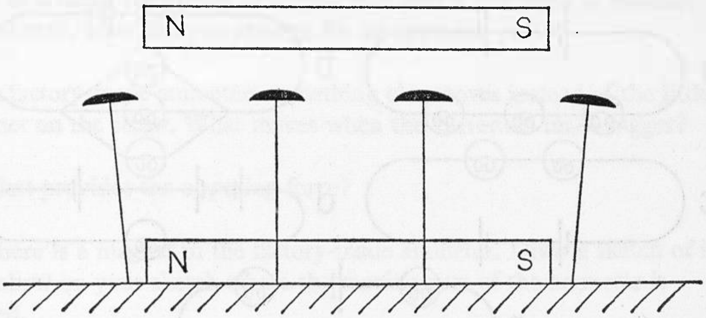


Figure 33

a. What happens when the second magnet is gently dropped into the cradle?

b. Why do you think it is necessary to use the pins? What would happen if they were not in place?

c. Given two similar bars of unmagnetized steel, and suitable springs, how would you demonstrate something similar happening with 'spring forces' instead of 'magnetic forces'?

d. What is meant by the 'north pole' of a magnet?

Question 5

Figure 34 shows five circuits of lamps and cells. All the lamps are alike and all the cells are alike. One cell joined to one lamp lights it with normal brightness.

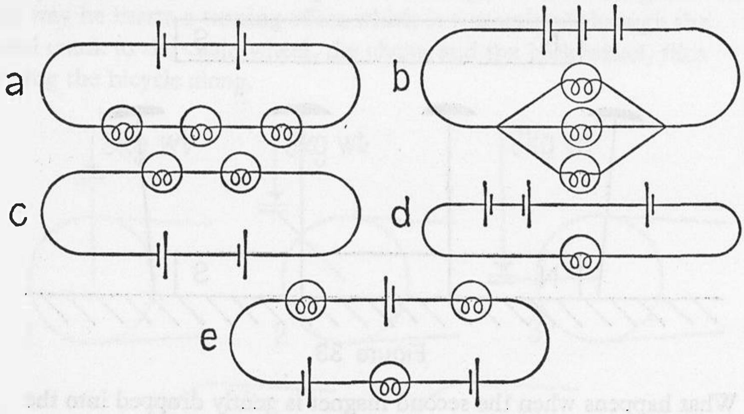


Figure 34

There are five things we might say about these circuits: lamps normally bright; brighter than normal; dimmer than normal; burnt out; not alight at all. Which of these statements would you make about circuit (a)? About (b)? About (c)? About (d)? About (e)?

Question 6

a. You are given two lamps, one cell, two switches, and a piece of resistance wire suitable for dimming one lamp. Draw a circuit that would enable you to switch one lamp on and off without affecting the other *and*, at the same time, allow the other to be either fully bright or dimmed without affecting the first.

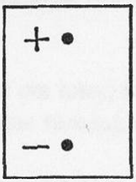


Figure 35

b. You are given a box which may contain any number of cells in series, from one up to four (figure 35). You also have three lamps and a variable resistance, but no voltmeter. One cell lights one lamp. How would you find the number of cells in the box without burning out any lamps?

Question 7

a. You used a very simple ammeter or 'current balance' to measure currents, with a little magnet on a straw. When you send a bigger current through this the magnet is pulled right into the coil and you have to arrange something to oppose that pull if you want to measure the current. How did you arrange for an opposing pull?

b. In factory-made ammeters something else moves instead of the little magnet on the straw. What moves when the current is made bigger?

c. What provides the opposing force?

d. There is a magnet in the factory-made ammeter. Draw a sketch of it and show on your sketch where the moving part of the ammeter is placed.

Year III July Paper Section A

time allowed, 1 hour

Question 1

The three straight lines in each of the diagrams in figure 36 represent ripples produced by a straight vibrator. The arrows represent the directions of travel of the ripples. The diagrams are half actual size, so that any measurement on them must be multiplied by 2.

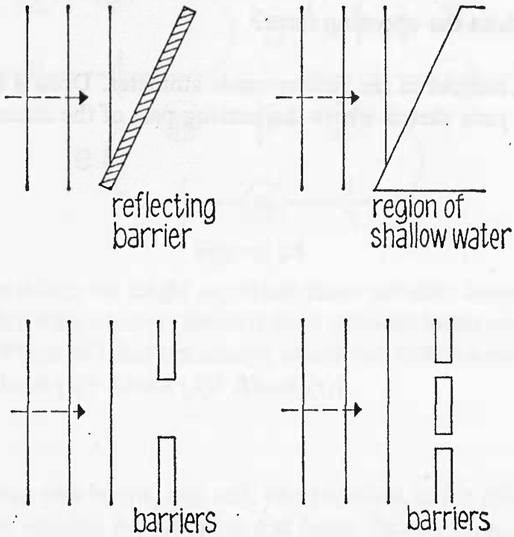


Figure 36

a. If the vibrator moves up and down 12 times a second, what is the velocity of the ripples?

.... number .... unit

b. The diagrams are incomplete; complete them by drawing in the three ripples in front of (that is, to the right of) the ripples shown.

Question 2

A certain stroboscope has 12 slits, and, with it, a pupil can 'stop' the motion of a vibrating reed so that it appears bent to one side and slightly blurred as in figure 37.

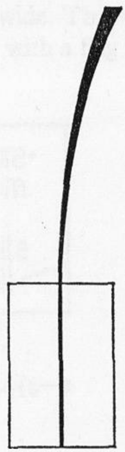


Figure 37

a. How should he alter the slits to make it less blurred?

....

....

b. Why is it more blurred at the top than at the bottom?

....

....

c. If he rotates the stroboscope at *half* the speed, the pupil is again able to 'stop' the reed, and the appearance is similar to figure 37. If he rotates it at *twice* the speed, he sees something different. Draw what you think he might see, in the space provided, marked figure 38.

Figure 38

d. He now blocks out every other slit and rotates the stroboscope at the *doubled* speed. What does the reed look like now?

....

....

e. If the original speed of rotation is 3 times per second (and the doubled speed is 6 times per second), how many complete vibrations per second was the reed making?

.... vibrations per second

Question 3

In figure 39, diagram (1) is a diagram of a small laboratory and storeroom. When the storeroom door is shut, light enters only through a small round hole, about $\frac{1}{4}$ inch across, in the door. At the far end of the laboratory is a window 3 feet wide. This window is drawn, on a different scale, in diagram (2), together with a flag and pole seen outside the window.

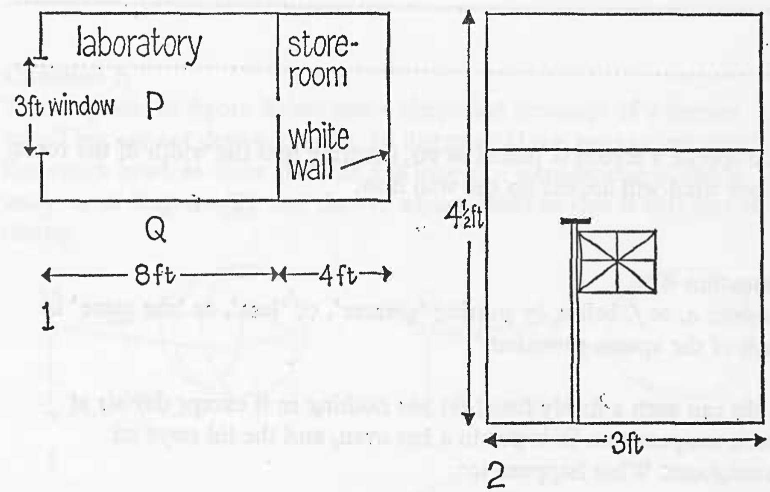


Figure 39

a. Sketch what will be seen on the storeroom wall.* (Draw the sketch to a scale in which 2 in represent 3 ft. Include the flag and pole, but it does not matter about drawing them to scale!)

b. If the hole is square instead of round, will this make any noticeable difference to what is seen on the wall? If so, explain the difference.

....

....

....

* In the actual paper, space for sketches was included in figure 39.

c. If the hole is $\frac{1}{8}$ inch across instead of $\frac{1}{4}$ inch, what differences, if any, will this make to the appearance? Explain.

....

....

....

....

d. Suppose a screen is placed at PQ, covering half the width of the room. Draw what will appear on the wall now.

Question 4

Answer *a.* to *f.* below by putting 'greater', or 'less', or 'the same' in each of the spaces provided.

A tin can with a firmly fitted lid has nothing in it except dry air at room temperature. It is put in a hot oven, and the lid stays on throughout. What happens to:

a. The number of molecules in the can? ....

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 can? ....

f. Give the reason for your answer to *e.*

....

....

....

....

Question 5

The diagrams in figure 40 are much simplified drawings of a human eye. They are *not* drawn to scale. In diagram (1) the eye can see clearly the match head, M. Now the match is moved a considerable distance away, as in diagram (2), and the eye adjusts itself so that it still sees M clearly.

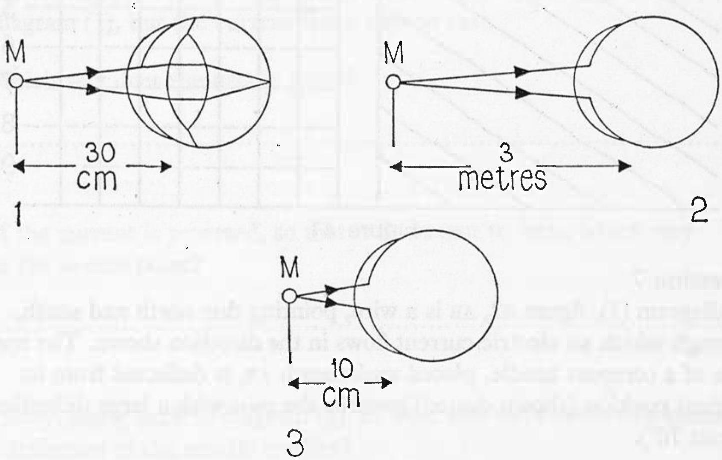


Figure 40

a. Exaggerating if necessary, draw in the details given in diagram (1) but omitted in diagram (2), showing what adjustment the eye would make.

b. In diagram (3) the match has been moved so that it is only 10 cm from the eye, and the eye can no longer focus it clearly. Why not?

....

c. Complete diagram (3), showing the eye doing the best it can (but failing) to focus the match head.

Question 6

Figure 41 represents part of a photograph of a ball, A, rolling towards the edge of a table, illuminated by a flashing lamp. At the instant that A reaches the edge of the table, another ball, B, is released. At the next flash of the lamp, B appears at B_1. Draw in the position A_1 of A at that instant. Draw also the position B_2, B_3 of B at the next two flashes of the lamp. Then draw in the corresponding position A_2, A_3 of A.

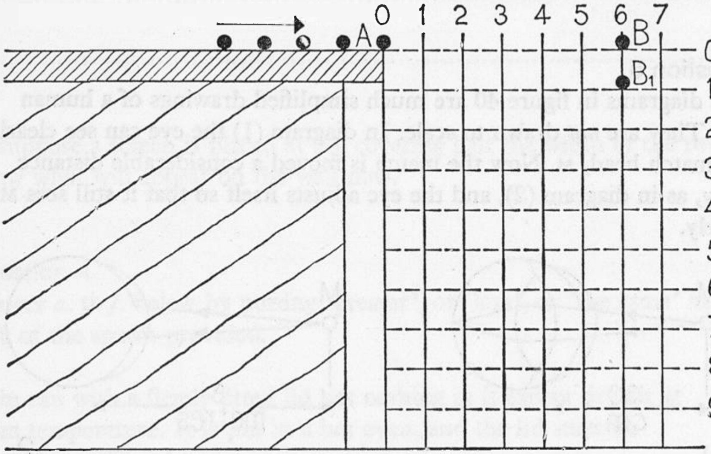


Figure 41

Question 7

In diagram (1), figure 42, AB is a wire, pointing due north and south, through which an electric current flows in the direction shown. The north pole of a compass needle, placed underneath AB, is deflected from its original position (shown dotted) towards the *west* with a large deflection (about 70°).

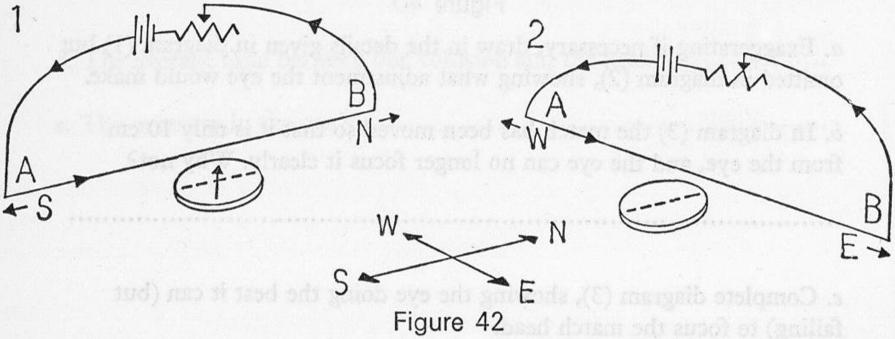


Figure 42

How would you make the needle deflect to the east? (Give two answers.)

Either

a. ....

....

or

b. ....

....

In diagram (2) the compass needle is still as close to the wire as it was in diagram (1), but the current flows west to east.

c. Which way does the needle point?

....

d. If the current is reversed, so that it flows east to west, which way does the needle point?

....

e. Lastly, going back to diagram (1), in what *two* ways could you make the deflection of the needle smaller?

either

c. ....

....

or

d. ....

....

Year III December Paper Section A

These questions were sent to teachers for them to use as they thought fit.

Question 1

A cinema camera is used to take one photograph every minute of an electric stop clock which has a seconds hand, but no minute or hour hands.

The first photograph looks like diagram (z), figure 43.

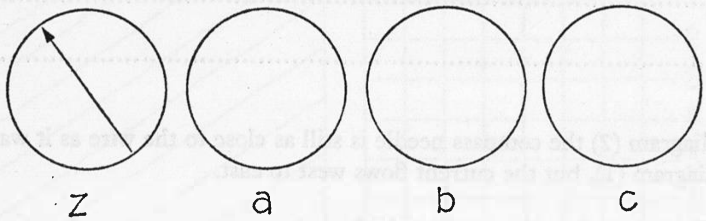


Figure 43

a. Show on diagram (a) what the second photograph looks like.

b. Suppose, instead of one photograph a minute, the camera takes one photograph every *two* minutes. The first is like diagram (z). What does the second look like? Show this on diagram (b).

c. If it takes one every half minute, what does the second look like? Show this on diagram (c).

d. Suppose the three films are put through one projector (16 pictures a second), but the exact speed does not matter. Draw on diagrams (a), (b), (c), of figure 44 what would be seen for film (a), which was taken at 1 per minute, film (b), which was taken at every two minutes, and film (c), which was taken at 1 every half minute.

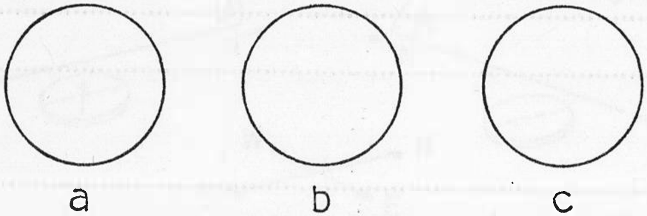


Figure 44

Question 2

This is based on question 1: suppose, instead of taking pictures at exactly 1 minute intervals, the camera took pictures at intervals of 1 minute *plus* a fraction of a second.

a. What would be seen on the screen when the film was projected?

....

b. Suppose the camera took pictures at intervals of 1 minute *less* a fraction of a second; what would be seen on the screen?

....

Question 3

(*Alternative to questions 1 and 2*) A circle of white paper is cut to fit the turntable of a record player. Lines are drawn every 6°, from the centre of the circle to both edges, that is, 60 lines in all. The paper is fixed on so that its centre is at the centre of the turntable.

The turntable is revolved at an unchanging speed of 45 revolutions per minute in a darkened room. A lamp above it flashes first at 45 times per second.

a. What is seen on the revolving paper?

....

b. What is seen if the lamp flashes slightly more than 45 times per second?

....

....

c. What is seen if the lamp flashes slightly less than 45 times per second?

....

....

d. What is seen if the lamp flashes 90 times per second exactly?

....

....

e. What is seen if the lamp flashes slightly less than 135 times per second?

....

....

Question 4

A straight-edged vibrator driven by a constant speed motor produces straight ripples in a ripple tank. These are viewed through a stroboscope having twelve holes in its wheel. When the stroboscope is making two revolutions every three seconds the ripples appear stationary, and this is the fastest rate of spinning for which the ripples are 'stopped'. Measurement then shows that the distance between 'ripple 0' and 'ripple 5' is 8·5.

a. What is the wavelength of the ripples? .... cm

b. What is the frequency (i.e. the number passing in a second)? .... per second.

c. What is the speed at which they are moving? .... cm per second.

d. Why count the first ripple as 'ripple 0'?

....

....

Question 5

Figure 45 shows a ripple tank about one-fifth actual size, but the exact scale does not matter. RR is a ruler, which is moved up and down once, so as to send a single ripple which, a little later, has reached the position AOB. The lower end, B, of the ripple has just reached a flat obstacle XY, which is at 45° to the ripple.

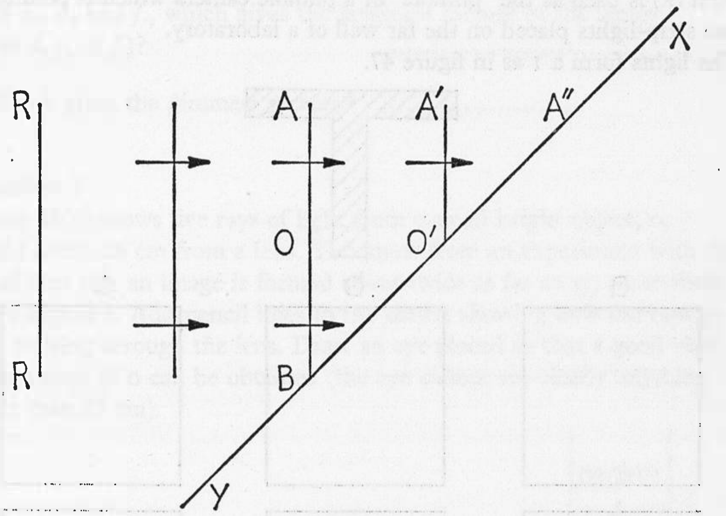


Figure 45

a. The ripple then travels further, so that the centre point, O, has just reached O′. The top half of the ripple, A′O′, is drawn in, but what has happened to the lower half, O′B′? Draw in O′B′ on the diagram.

b. A little later the top point, A, has reached A″. Draw in the ripple A″ O″ B″ now.

c. Small arrows have been put on AO, OB, and A′O′ to show the direction the ripple travels. Put similar arrows on the portions O′B′, A″O″ and O″B″ that you have drawn.

Question 6

In figure 46, (x), (y), and (z) are three pieces of thick black paper. (x) has a single pinhole, (y) has three pinholes, and (z) has a hole the size of a sixpence.

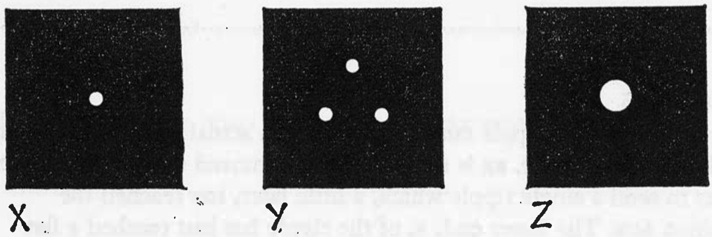


Figure 46

First (x) is used as the 'pinhole' of a pinhole camera which is pointed at two strip-lights placed on the far wall of a laboratory.
The lights form a T as in figure 47.

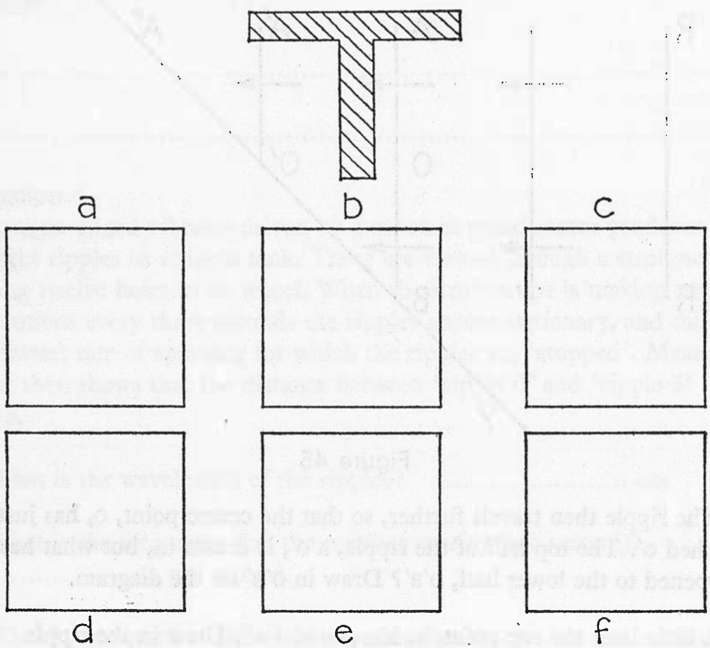


Figure 47

a. Draw in square (a) what would be seen on the screen of the camera (indicate the bright image by a 'T' placed in the correct way).

b. Then (y) is used instead of (x); what is seen now? Use square (b).

c. Then (Z) is used; what is seen on the screen? (Answer in words if you prefer.)

Now a lens is taken which, when it is placed in front of the holes, is exactly right for making a lens camera. Using the appropriate squares, indicate:

d. What is seen when (X) is used with the lens?

e. What is seen when (Y) is used with the lens?

f. What is seen when (Z) is used with the lens?

Lastly:
g. Of *d.*, *e.*, and *f.*, which gives the brightest picture of the lamps (write *d*, *e*, or *f*)? ....

h. Which gives the dimmest picture? ....

Question 7
Figure 48(a) shows five rays of light from a small bright object, O, placed about 25 cm from a lens. You know from an experiment with the actual lens that an image is formed about twice as far away, somewhere in the region A. Add pencil lines to the sketch showing how the rays go after passing through the lens. Draw an eye placed so that a good view of the image of O can be obtained (the eye cannot see clearly anything closer than 25 cm).

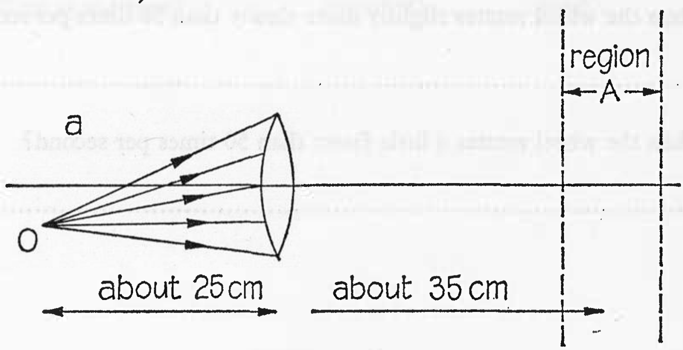
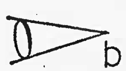


Figure 48

Note: Use a ruler; *not* freehand.
Represent the eye as in figure 48(b).



Year III July Paper Section A
time allowed, 1 hour

Questions 1–3
A boy on a harbour pier watches long waves entering the harbour. He times them against a post sticking out of the water and finds that 30 crests pass in 60 seconds. He also watches the same wave-crest passing two posts that he knows to be 50 feet apart along the line of travel of the waves; the time from one post to the other is 2 seconds.

1. What is the frequency of this wave motion?
(number) .... (unit) ....

2. What is its speed? (number) .... (unit) ....

3. What is the wavelength? (number) .... (unit) ....

Questions 4–6
A rotating stroboscope is arranged to give the observer's eye 10 'glimpses' every second. It is used to look at a white wheel which has a black arrow painted along a radius. What will the observer see:

4. when the wheel rotates 50 times per second? ....

5. when the wheel rotates slightly more slowly than 50 times per second?

....

6. when the wheel rotates a little faster than 50 times per second?

....

Questions 7–11

A car has a leaking oil-sump, so that oil drips fall from it at the rate of one drop every two seconds. The appearance of the oil spots on the road is shown (not actual size!) in figure 49. The big blobs are oil pools. The broken line, BC, means that there is a large distance between B and C for which the oil drops were not recorded. Similarly for DE and FG.

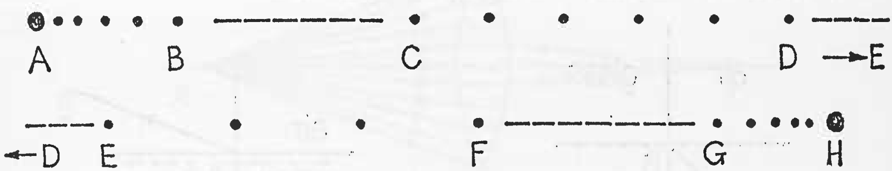


Figure 49

What was the car doing:

7. over the portion AB? ....

8. over CD? ....

9. over EF (compared with CD)? ....

10. over GH? ....

Also,

11. If the spots in the portion CD are 20 feet apart, how fast was the car travelling at the time? (number) .... (unit)..............

Questions 12–16

Complete the sketches in figure 50. You cannot do this accurately because you are not given the necessary figures; what you have to do is to make the sketches look right! In each sketch, AB is a ray of light. In (1), (3), and (4), you have to continue the ray onward from B. In (2) you have to draw the ray before it reached A. In (5) you have to draw the ray both before it reached A, and onward from B.

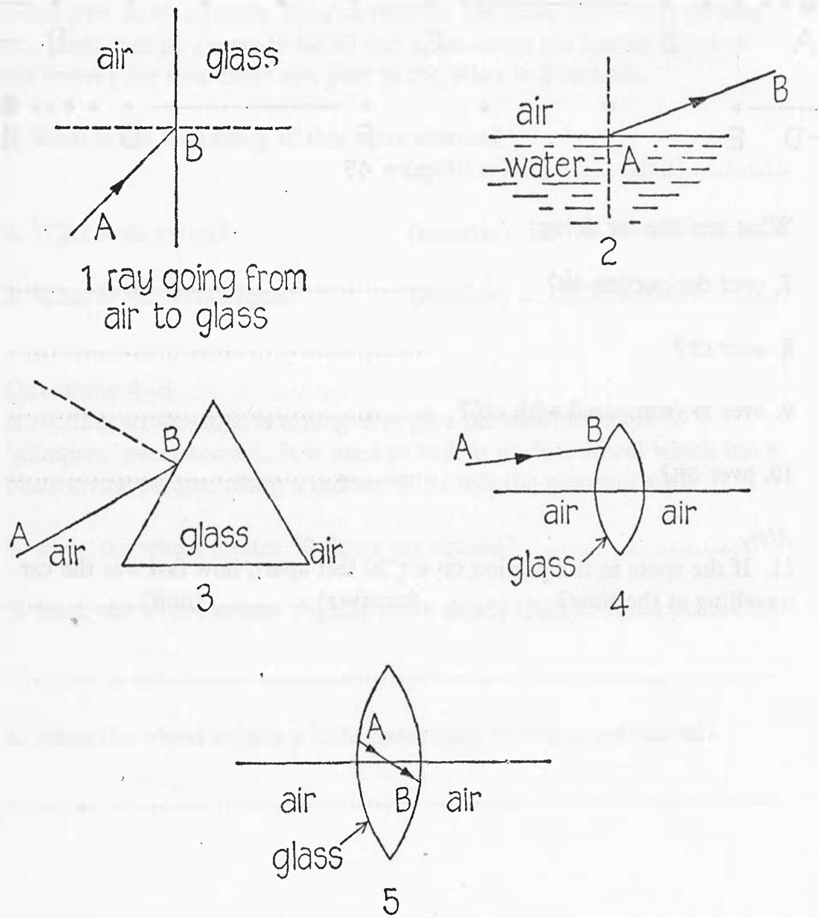


Figure 50

Question 17

Figure 51 shows eleven rays from a point source of light, X, falling on a lens. The centre ray goes through without bending, and the rays next on either side meet the centre ray at Y. Complete the picture with pencil and ruler, showing possible paths for the other eight rays.

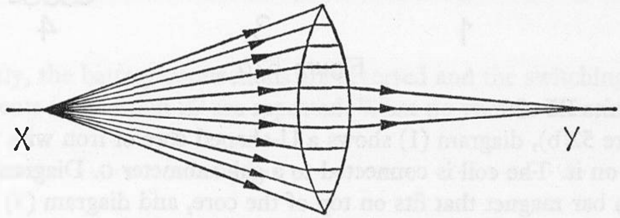


Figure 51

Questions 18–22

These were the same as question *4a.* to *f.* of the Year III July paper, Section A, on pages 72–3.

Question 24

In figure 52(a), B is a battery, L_1 and L_2 are two lamps, and V is a voltmeter. Complete the circuit to show L_1 and L_2 in series, joined to the battery, and with the voltmeter (terminals at the bottom) connected to read the potential difference across L_1.

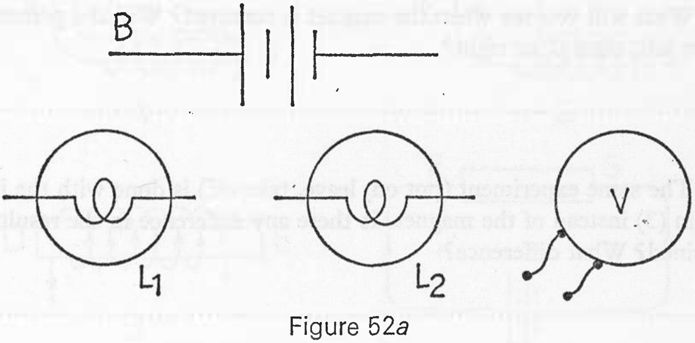


Figure 52*a*

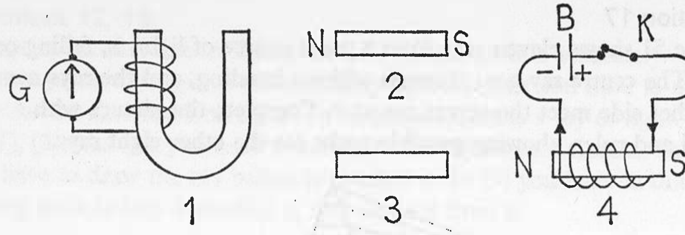


Figure 52*b*

Questions 25–29

In figure 52(b), diagram (1) shows a U-shaped core of iron with a coil wound on it. The coil is connected to a galvanometer G. Diagram (2) shows a bar magnet that fits on top of the core, and diagram (3) shows a similar unmagnetized iron bar. Diagram (4) shows the same iron bar with a coil wound on it, joined to a switch K and battery B. When K is closed, the iron becomes magnetized in the same direction as the magnet in (2). When the magnet in (2) is being placed on the U-core, with its N-pole still on the left, the galvanometer pointer moves *to the right.*

25. What will you see in the galvanometer when the magnet remains in position on the U-core? Will the galvanometer pointer be left, central, or on the right?

....

26. What will you see when the magnet is removed? Will the pointer move left, central, or right?

....

27. The same experiment (put on, leave, take off) is done with the iron bar in (3) instead of the magnet. Is there any difference in the results obtained? What difference?

....

....

28. Now the iron bar with the coil, diagram (4), is placed on the U-core, with the switch K open, and with the bar kept in the direction shown in

diagram (4). K is closed, remains closed for a few seconds, and is then opened. What do you see in the galvanometer?

....

....

29. Lastly, the battery connections are reversed and the switching experiments in question 29 are repeated. What do you see this time?

....

....

....

Questions 30–33

Write in the correct answers to the following questions about figure 53. The answers will be 'north', or 'south', or 'none'. In the diagrams, N = north, S = south.

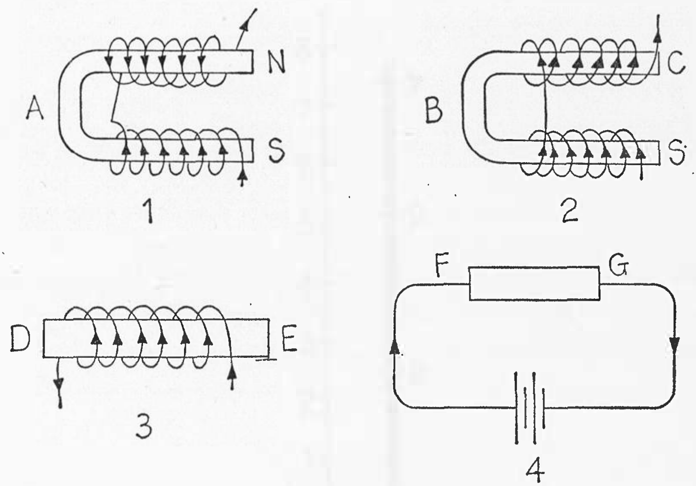


Figure 53

30. What sort of magnetic pole is there at A, diagram (1) if any?

....

31. What sort of magnetic pole is there at B, diagram (2), if any?

....

At C, diagram (2), if any? ....

32. What sort of magnetic pole is there at D, diagram (3), if any?

....

At E, diagram (3), if any? ....

33. In diagram (4), the current has actually been passed through the iron.

What sort of pole is there at F, if any? ....

At G, diagram (4), if any? ....

Year III July Paper Section B
time allowed, 50 minutes

Teachers were asked to choose THREE of these five questions. Pupils were then required to answer TWO of the three questions given.

...

Question 1

You want to make a simple telescope and you have convex lenses of about 25 cm and 10 cm focal length, together with a means of mounting them and sliding them up and down on a metal rod. You also have a piece of tissue paper.

a. Explain, with a sketch (*not* a ray-diagram), exactly what you would do.

b. Where would you expect to put your eye when you look through the telescope – up against the lens? – 25 cm from the lens? – or where? Indicate a suitable approximate position for the eye on your sketch.

c. A scale has been drawn on a distant blackboard; how do you use this scale to find the magnification of the telescope?

d. On using the telescope as in *c.* above, you see something like figure 54. What is the magnification of the telescope?

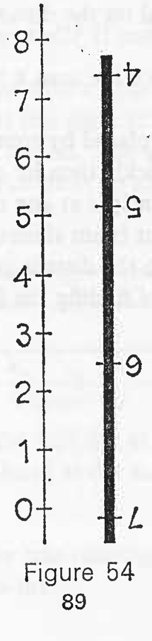


Figure 54

Question 2

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 hill. Each man had a lantern fitted with a dark shutter that could be open or closed. One man, A, had a watch that would measure in quarter seconds.

After preliminary signals to show that all was ready, A opened his lantern, sending a flash of light to B. At the same time he noted the reading on his watch. As soon as B saw the flash, he opened his lantern and sent a flash back. A 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; therefore (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 B by – what?

c. The man A 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 disc with slits. Suppose a light beam shines through a slit of a disc which is rotating; it travels to the distant point and returns – what then? Can you now suggest a way of finding the speed of light?

Question 3

In the experiment shown in figure 55 a trolley is to be pulled by elastic in order to provide a constant force as in diagram (1). One lazy pupil attaches the elastic to a stand, clamped to the bench as in diagram (2). Another pupil, equally lazy, decides that the trolley shall pull itself, as in diagram (3).

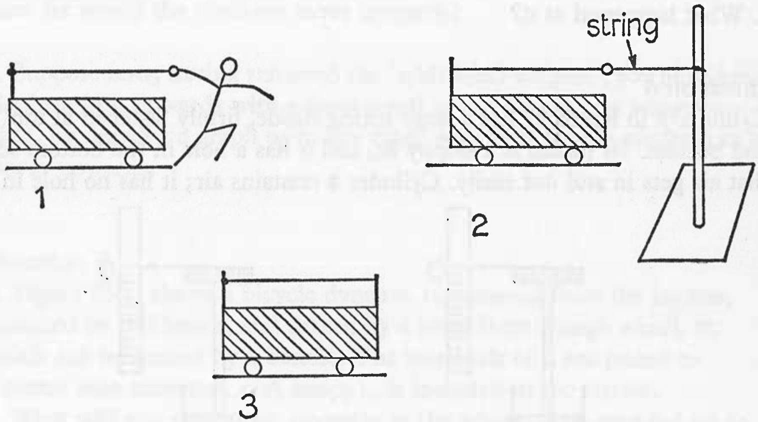


Figure 55

a. Does (2) give a constant force? if not, why not?

b. Does the trolley in (3) move at all? If not, why not?

In figure 56, a javelin is thrown with a length of ticker-tape attached to it. AE and FG show the first and last parts of the series of dots obtained. The vibrator makes 50 dots a second. The spacing of the dots in the diagram above is *one-tenth of full scale*, so all measurements should be *multiplied by* 10.

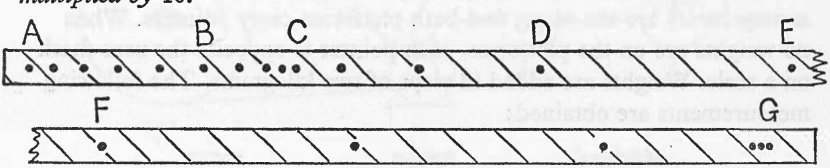


Figure 56

c. The whole tape, from A to the first dot at G, had 183 dots on it. The javelin left the thrower's hand at dot D. How long was the javelin in the air?

d. Between A and C the thrower was running up to his mark. What was the maximum speed of his run-in?

e. The thrower did not overstep his mark. What is the explanation of the closer spacing of the dots between B and C, and the wider spacing between C and D?

f. The horizontal speed of the javelin can be taken as constant during the flight. What was this speed?

g. What happened at G?

Question 4

Cylinder A in figure 57 has a large spring inside, firmly fastened at top and bottom. Its piston is a sloppy fit, and it has a hole in the bottom so that air gets in and out easily. Cylinder B contains air; it has no hole in

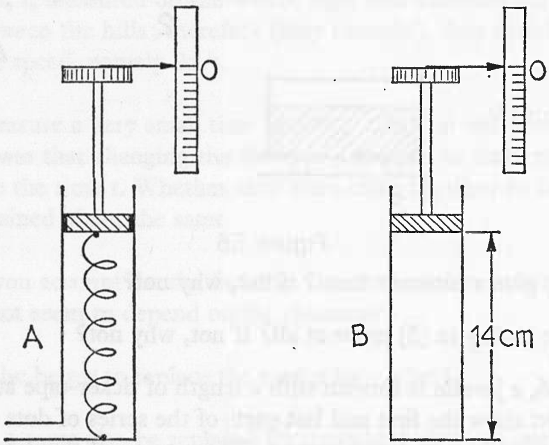


Figure 57

it and the piston, though sliding easily, is air-tight. Otherwise the arrangements are the same, and both platforms carry pointers. When no weights are on the platforms, each pointer is opposite the zero mark on a scale. Weights are added in steps of two kilograms. The following measurements are obtained:

additional weight	*pointer reading,* A	*pointer reading,* B
0 kg	0 cm	0 cm
2 kg	3·5 cm	3·5 cm
4 kg	7·0 cm	5·6 cm
6 kg	10·5 cm	7·0 cm

a. The lengths by which the spring was compressed are shown in the second column. Are these lengths proportional to the weights added?

b. The air enclosed in B is not, when compressed, following the same law as the spring – do you agree? How do you know from the readings given that it is not following the same law?

c. Suppose you removed all 'additional weights' and then pulled the platform in A upwards with a force equal to the weight of 1 kilogram. How far would the platform move upwards?

d. Suppose now, having removed the 'additional weights', you pulled the platform in B upwards with a force equal to the weight of 1 kilogram. Find, by drawing a graph or in any other way, how far the platform in B moves upwards.

Question 5

a. Figure 58(a) shows a bicycle dynamo, D, removed from the bicycle, mounted on the bench, and driven by a band from a large wheel, W, which can be turned by a handle. The terminals of D are joined to a centre zero ammeter, A. A lamp, L, is included in the circuit.

1. What will you see on the ammeter as the wheel, W, is speeded up so that at first it turns very slowly and then more rapidly until at last the dynamo is turning as fast as it would if attached to a bicycle?

2. At the higher speed the ammeter shows practically nothing, yet the lamp glows brightly. How do you explain this?

3. Why choose a wheel, W, which is much larger than the pulley on the dynamo? Why not one of the same size?

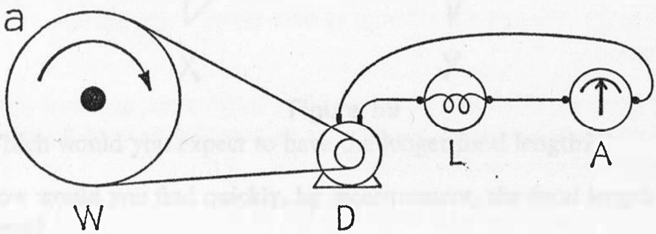


Figure 58*a*

b. In figure 58(b), the sensitive galvanometer moves to the right when the wire is moved upwards. What happens if, instead of the wire being moved upwards:

1. the magnet is moved upwards?

2. the magnet is moved horizontally, parallel to the straight wire?

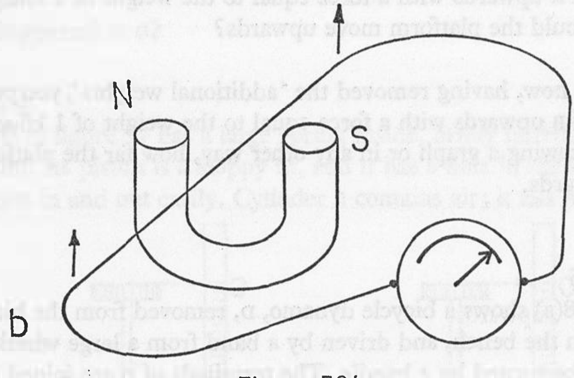


Figure 58*b*

Year III December Paper Section B

Question 1

This question, about Uncle George and the anemometer, was the same as question 4 of Year V (see page 138).

Question 2

a. A ripple, made by dipping a finger into water, hits a straight barrier. Draw a diagram, or diagrams, to show what happens.

b. How would you show that the ripple is a part of a circle *after* it hits the barrier?

c. '. . . part of a circle after it hits the barrier'. What further idea does this suggest to you? (Hint: an idea concerning images.)

Question 3

You are given two lenses, X and Y (figure 59). They have the shape shown, and X is noticeably thicker at the centre than Y.

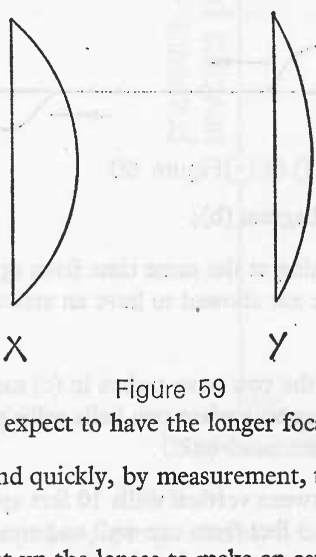


Figure 59

a. Which would you expect to have the longer focal length?

b. How would you find quickly, by measurement, the focal length of each of them?

c. How would you set up the lenses to make an astronomical telescope? Explain exactly what you would do. Draw a diagram showing clearly which lens is nearer the object, which lens nearer the eye. Show a possible position for the eye, and show a possible position for the image formed by the first lens. See that the lenses in your diagram are put the right way round (if you think that one way is better than the other).

Year III July Paper Section B

time allowed, 50 minutes

Teachers were asked to choose THREE of these four questions. Pupils were then required to answer TWO of the three questions.

Question 1

Explain how you would use a length of cord or thin rope, *or* rubber tube, *or* a 'slinky' spring, to show the following:

a. a continuous wave, as in figure 60, diagram (a);

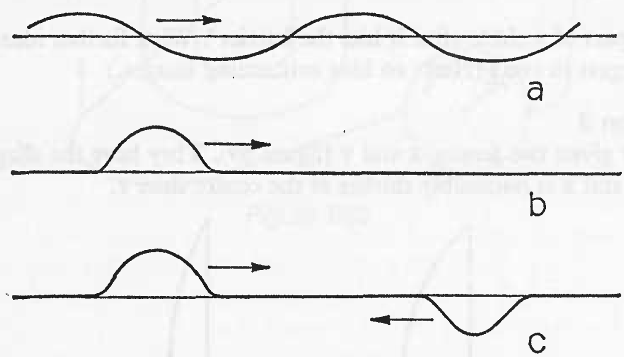


Figure 60

b. a wave pulse, as in diagram (b);

c. two wave pulses coming at the same time from opposite ends, as in diagram (c). You are *not* allowed to have an assistant for this demonstration.

d. What happens after the two wave pulses in (c) meet, and how does this differ from what happens when two balls rolling in opposite directions along a groove meet head-on?

e. Still water stands between vertical walls 10 feet apart. A duck descends on the water at a point 3 feet from one wall and sets up a train of three or four waves. Make *two* sketches showing the waves:
1. when the first wave has travelled 3 feet from where the duck came down;
2. when the first wave has travelled a further 3 feet (show clearly on this second diagram the two places where you put the point of a compass in order to draw the waves).

Question 2

This was the same as question 1 of the Year III July paper, Section B, on page 89.

Question 3

A sealed copper ball, shown in figure 61 (a), contains air. It is joined by a narrow tube to a pressure gauge which reads in newtons per square centimetre. The gauge has been arranged to read the *actual* pressure of the air (*not* the pressure above atmospheric). First the ball is immersed in melting ice, and the gauge reads 10·0 newtons per cm². Then it is placed in boiling water and the gauge reads 13·5 newtons per cm². These values are plotted on a graph, figure 61 (b).

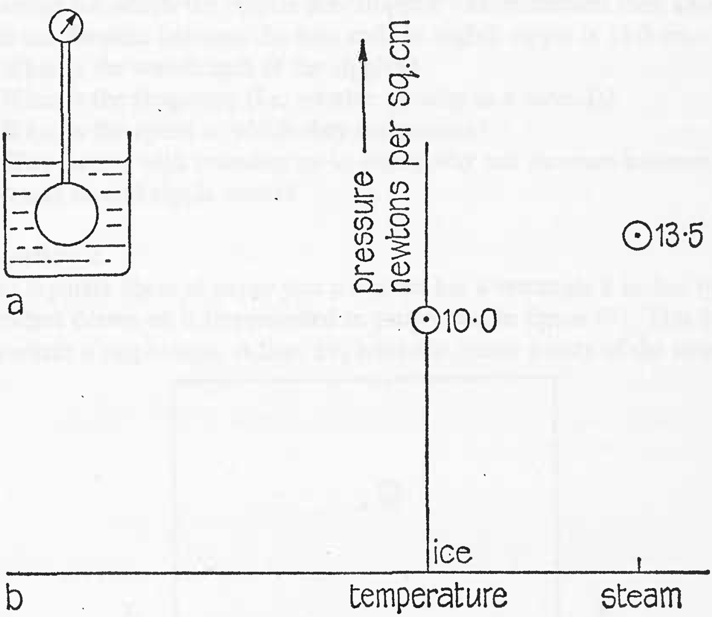


Figure 61

a. Copy the graph on graph paper (preferably at least twice the scale) and find from it the temperature of absolute zero.

b. Suppose the gauge had been marked in newtons per square metre instead of per cm². Would this have made any difference to your result for absolute zero? Give the reason for your answer.

c. If you had used a copper ball containing the same mass of air in *half* the volume, that is at twice the pressure, would this have made any difference to your answer? Give the reason.

Question 4

This was the same as question 5 of the Year III July paper, Section B, on page 93.

Year III December Paper Section B

Question 1

a. Stroboscopes are used with ripple tanks and can be used for other purposes as well. Describe briefly some interesting use you have made of a stroboscope (or would like to make), *not* with a ripple tank.

b. A straight-edged vibrator driven by a constant speed motor produces straight ripples in a ripple tank. These are viewed through a stroboscope having ten slits in its wheel. When the wheel is making five revolutions in 6 seconds the ripples appear stationary, and this is the fastest rate of spinning for which the ripples are 'stopped'. Measurement then shows that the distance between the first and the eighth ripple is 11·2 cm.

1. What is the wavelength of the ripples?

2. What is the frequency (i.e. number passing in a second)?

3. What is the speed at which they are moving?

4. Why bother with counting up to eight; why not measure between the first and second ripple crests?

Question 2

The separate sheet of paper you are given has a rectangle 8 inches by 6 inches drawn on it [represented in proportion in figure 62]. This is to represent a ripple tank. A line, XY, joins the centre points of the longer

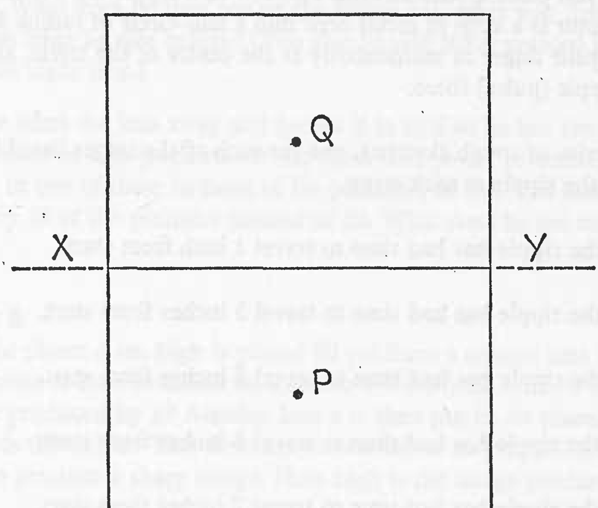


Figure 62

sides; this represents an obstacle placed across the tank. P is a point at the middle of one half of the tank, and Q is a point at the middle of the other half.

a. Imagine you have just started a wave by dipping your finger in at P. Sketch *in this* wave (1) when *it* has travelled halfway to XY (2 *inches*); (2) when it has just reached XY (2 inches).

b. Now sketch in the wave when it has travelled a further 2 inches.

c. On the same diagram repeat *a.* and *b.*, but this time starting from Q.

d. Does your diagram justify the statement that the wave after reflexion appears to come from a point which is as far behind the reflector as the source-point is in front?

e. If your answer to *d.* is 'Yes', say why you think a sketch made with pencil on paper proves anything at all about waves. If your answer is 'No', say what further evidence you would require to enable you to say 'Yes'.

Question 3

Suppose you place a semi-circular reflector in a ripple tank of water. The reflector is a strip of metal bent into a half-circle of radius 3 inches. You dip your finger in momentarily at the centre of the circle, and start a ripple (pulse) there.

Give a series of rough sketches, one for each of the stages listed below, showing the ripple at each stage.

a. After the ripple has had time to travel 1 inch from start.

b. After the ripple has had time to travel 3 inches from start.

c. After the ripple has had time to travel 5 inches from start.

d. After the ripple has had time to travel 6 inches from start.

e. After the ripple has had time to travel 7 inches from start.

Question 4

a. What do you think was the most interesting thing you did with a pinhole camera? Describe what you did, and what result you observed.

b. Suppose light bent round corners just as much as the ripples you saw in ripple tanks: what would you have expected to see on the screen of a pinhole camera when a clear electric bulb was placed in front of the hole?

c. If we have a very large gap between obstacles in a ripple tank, much larger than the wavelength of the ripples, we should not have noticed much bending of the ripples. If the light is a wave motion, what can we conclude about the diameter of the pinhole compared with the wavelength of light?

Question 5

A boy makes a pinhole camera of a cardboard box, much like the one you used in class. He makes a large number (twenty) of small pinholes in the paper front of the box, and points his camera at a lamp with a bright filament, in a fairly dark room.

a. What does he see on the screen at the back of his camera?

b. He then finds just the right lens to slide in, in front of the pin-holes, to make what seems to him a perfect lens-camera to make a picture of the lamp. What does he then see on the screen? In what way does it differ from what he saw before? (You should take it for granted he has got just the right lens.)

c. He now takes the lens away and breaks it in half so he has two semi-circular pieces of lens (each still of the same lens power as before). He slides in one of these in front of his pinholes, so that this time it covers only 10 of the pinholes instead of 20. What does he see on the screen?

Question 6

a. A bright object 4 cm high is placed 50 cm from a convex lens A, and a sharp image is then obtained on a screen 7·5 cm from A. How high is the image produced by A? Another lens B is then put in A's place, still at 50 cm from the object. This time the screen has to be put 75 cm from the lens to produce a sharp image. How high is the image produced by B?

b. Describe what you would do in order to arrange these two lenses, A and B, to make a telescope. (*Note:* you are *not* expected to calculate the focal lengths from the figures given. Describe how you would put the lenses in place by a sensible trial-and-error method.)

Question 7

You are given a black box with a horn on it (figure 63). Somebody says waves are coming out of the horn, but you cannot see or hear or feel anything. You are then given an instrument which looks like a pencil, and which is attached to a loudspeaker. When the 'pencil' point is held in front of the horn the loudspeaker makes a noise. Describe two experiments you would try in order to discover whether the emission from the horn does behave like waves. You can use whatever other apparatus you like.

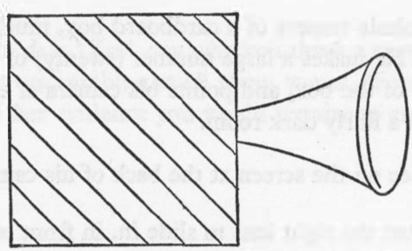


Figure 63

Year IV July Paper Section A
time allowed, 1 hour

Question 1
a. In figure 64, diagram A_1 represents the motion of a car which has already travelled 100 metres when a stopwatch was started (time 0 second). The motion is plotted over a time interval of 5 seconds. Draw, on figure A_2, as accurately as you can, a velocity–time graph for this motion.

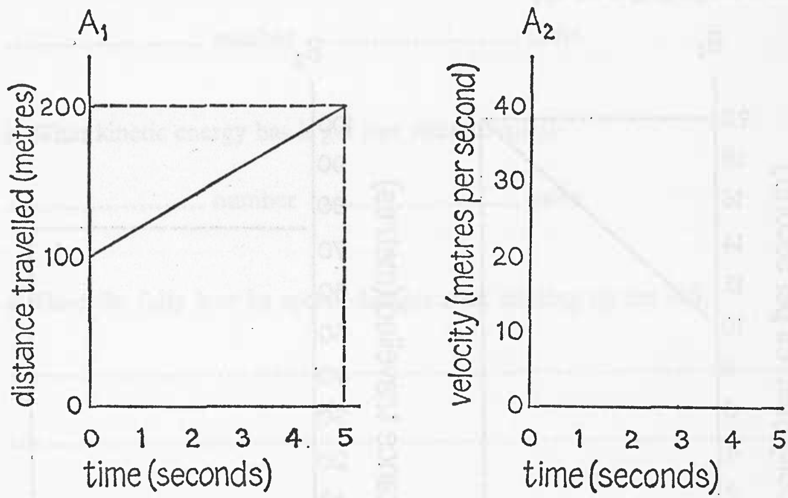


Figure 64 A_1 and A_2

b. Diagram B_1 represents the motion of a car which was already travelling with a velocity of 10 metres per second when a stopwatch was started.

1. Complete the table below, which shows the distances travelled from the time the watch was started.

Time (seconds)	0	1	2	3	4	5
Distance (metres)	0					75

2. Draw on figure B_2, as accurately as you can, a distance–time graph for this motion. (*Note:* Even if you cannot do *1.* above, you can still sketch in a rough graph on B_2.)

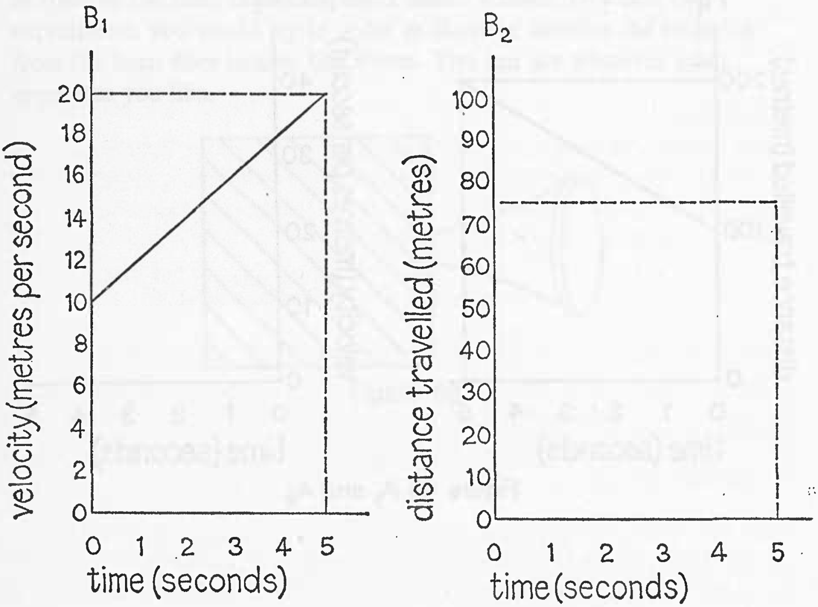


Figure 64 B_1 and B_2

Question 2

A stationary railway truck, of mass 2,000 kg, is given an impulse which sends it at 5 metres per second up a long frictionless slope.

a. What momentum has it got just after starting?

.... number .... units

b. What was the size of the impulse?

.... number .... units

c. What kinetic energy has it got just after starting?

.... number .... units

d. Describe fully how its speed changes after starting up the hill.

....

....

....

e. Describe its acceleration after starting up the hill.

....

....

....

f. If the effective force slowing it down is 100 newtons, calculate its acceleration. .... number ....units *g*. In what direction is the acceleration, up or down the hill?

.... the hill.

h. What happens to the original kinetic energy of the truck?

....

....

....

....

Question 3

You have seen an equation for the pressure, *P*, of a gas:

$$P = \frac{Nm \cdot v^2}{3V}$$

a. What do the other symbols stand for?

V represents ....

N represents ....

m represents ....

v represents ....

b. Explain why the factor $\frac{1}{3}$ appears in the equation.

....

....

....

c. Putting in values of *P*, N*m*, and *V* gives the value of about 500 metres per second for air molecules in an ordinary room. Do all the air molecules in this room move with this speed?

....

....

....

Question 4

How does the molecular theory account for the following?

a. When water in a dish is heated, the evaporation of the water is faster.

....

....

....

b. However cold the water is, evaporation does not entirely stop.

....

....

....

c. When some water has evaporated, the liquid left behind tends to be a little cooler.

....

....

Question 5

You are given a small electric motor meant to run from a 4 volt supply. You are also given three $1\frac{1}{2}$ volt dry batteries, and any other ordinary laboratory apparatus you may need.

a. Draw the circuit diagram you would use to make sure that exactly 4 volts were applied to the motor.

b. How could you find the electrical power input to the motor, in watts?

....

....

c. The motor is used to lift a load of 5 newtons through a vertical height of 2 metres. How much work will it do?

.... number .... units

d. What other measurement do you need to know in order to work out the mechanical power output of the motor in watts?

....

e. In an actual experiment it was found that the electrical power input was 6 watts while the mechanical measurements gave 5 watts. Explain briefly why the two results differ.

....

Question 6

Figure 65 represents a 'Maltese cross' vacuum tube, of a type you have seen. First, the cathode is made to glow by connecting it to a suitable supply.

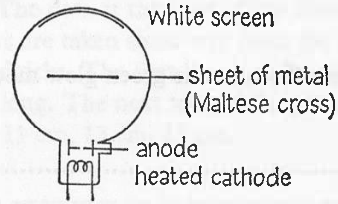


Figure 65

a. Describe what is seen on the screen.

....

....

....

....

b. When the anode is connected to a suitable high-voltage supply, parts of the screen are seen to glow green. Which end (positive or negative) of the supply is joined to the anode?

....

c. Where is the other end of the supply connected?

....

d. Describe the appearance of the screen now.

....

....

e. The glow is brighter when the voltage is bigger. Why?

....

....

f. When a magnet nears the tube the green glow moves. What does this show?

....

....

....

....

Year IV December Paper Section A

Question 1

A trolley accelerates down an inclined plane, drawing ticker-tape through a vibrator. The dots at the start of the trace are too close to count. Measurements are taken some way from the start, after an unknown number, x, of ticks. The first 'ten-tick length' (x to x + 10) is found to be 5 cm long. The next ten-tick length of tape is 7 cm, the next 9 cm, then 11 cm, 13 cm, 15 cm.

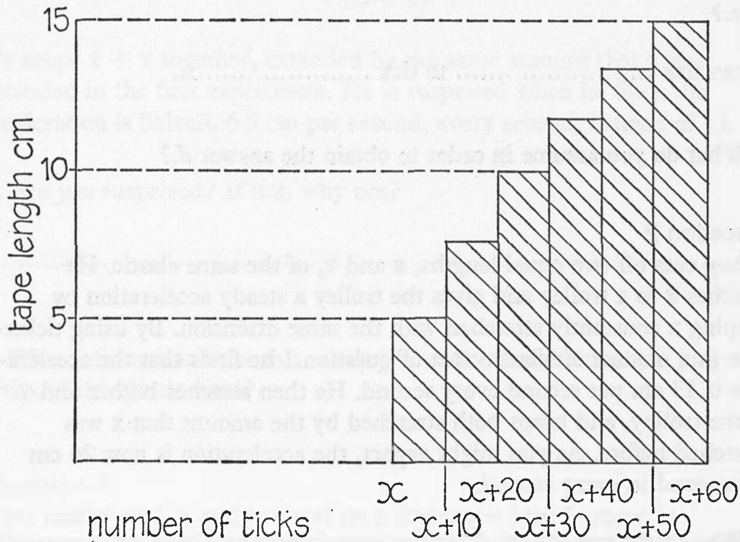


Figure 66

Figure 66 shows the lengths stuck next to each other. *50 ticks take 1 second.* Find:

a. the velocity of the trolley at the time corresponding to ticks x + 5;

........................cm per second.

b. the velocity at time x + 55;

.... cm per second.

c. the acceleration of the trolley;

........................cm per second, every second.

d. the number of ticks since the trolley started to move (that is, find x).

x = ... ticks.

e. Also, you found answer *c.* from *a.* and *b.* Over what period of time do you *know* that the trolley was accelerating with the acceleration given in *c.*?

From tick .... to tick ....

f. What do you assume in order to obtain the answer *d.*?

Question 2

A boy cuts off two equal lengths, X and Y, of the same elastic. He attaches X to a trolley and gives the trolley a steady acceleration by keeping X constantly stretched with the same extension. By using ticker-tape in a manner similar to that of question 1 he finds that the acceleration is 13 cm per second every second. He then attaches both X and Y to the trolley, and keeps both stretched by the amount that X was stretched before. As you might expect, the acceleration is now 26 cm per second in every second.

a. Why might you expect, from the experiments you have done yourself, that the acceleration would be 26 cm per second, every second?

b. He now, rather carelessly, cuts off a third length, Z, of the elastic, and uses the three lengths, X, Y, and Z together, all attached to the trolley and stretched to the same length that X and Y were previously stretched to. He finds that the acceleration is 43 cm per second, every second. He checks his results carefully and there is no mistake, it *is* 43, not 39. Also, nothing is changed except that he is now using three lengths. What do you think has happened?

....

....

c. What can you say about the result he would get if he used Z alone to accelerate the trolley, still stretched to the same length he used previously?

....

Lastly, he throws Z away and joins X and Y to form one length (figure 67). Then he uses X + Y to pull the trolley thus:

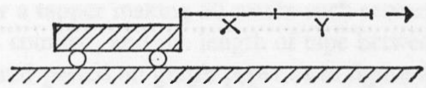


Figure 67

He keeps X + Y together, extended by the same amount that X was extended in the first experiment. He is surprised when he finds the acceleration is halved, 6·5 cm per second, every second, instead of 13.

d. Are *you* surprised? If not, why not?

....

e. What information does this result give concerning the stretch properties of the elastic used?

Question 3

Two similar cars, A and B, stand on a horizontal road bumper to bumper. John, whose mass is much less than that of either car, stands on the bumper of A with his hands resting on B and pushes hard until he falls off because the two cars have got too far apart. Ignoring the effects of friction what can you say about the velocities of the two cars:

a. at the moment John falls off?

....

b. at an earlier time, before he fell off but after he started pushing?

....

c. at a time soon after he fell off?

....

d. How is the answer to *a.* affected if equal frictional forces act on both cars?

....

e. How is the answer to *a.* affected if, instead of both cars being empty, A is empty, but B has four fat people inside, so that its total mass is $1\frac{1}{2}$ times the mass of A?

....

Question 4

A wooden block is given a push to start it moving over a table (figure 68). A horizontal pull of 3 newtons is then just sufficient to keep it moving with a steady speed. You may assume that the frictional drag is the same whatever the speed.

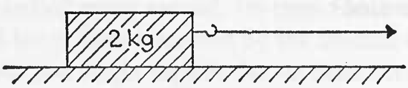


Figure 68

a. What is the force causing acceleration when the pull on the string is 7 newtons?

....

b. If the mass of the block is 2 kg, what is its acceleration under a pull of 7 newtons?

....

c. What must be the pull in order to double the acceleration in *b.*?

....

Year IV July Paper Section A

time allowed, 1 hour

Questions 1–4

On a friction-compensated track a heavy trolley is pulled along by *two* strings extended to a constant length. The trolley drags ticker-tape which goes under a tapper making 50 marks each second. The marks on the tape are then counted, and the length of tape between mark 195 and mark 205 is cut and pasted on graph paper as in figure 69. This length is 9 cm. The centre line, AX is drawn, and OA is joined and labelled '2 strings'.

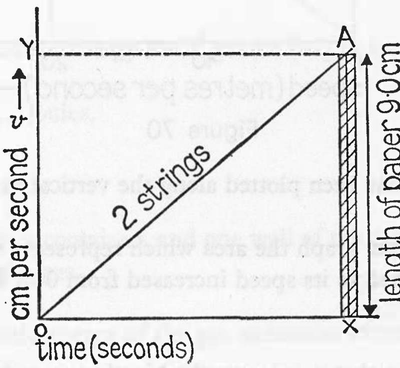


Figure 69

1. What time interval is represented by OX on the graph?

.... seconds.

2. What speed is represented by OY? .... cm per second.

3. OA represents the acceleration obtained with two strings. Draw on the graph a line, OB, representing the acceleration which would be obtained with *one* string extended to the same constant length.

4. Draw a line, OC, similarly representing the acceleration obtained with *three* strings.

Questions 5–8

A car weighing 1,000 kg was accelerated, through its gears, from rest to a speed of 20 metres per second. Someone then plotted a graph for its motion, as shown in figure 70, intending to find the car's kinetic energy.

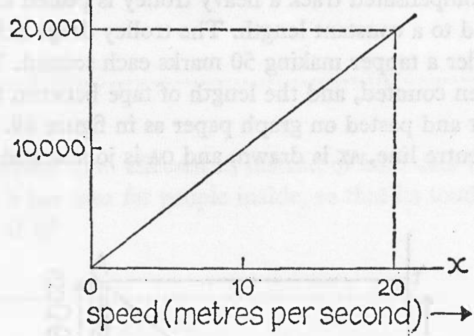


Figure 70

5. What quantity has been plotted along the vertical axis? ....

6. Cross-hatch on the graph the area which represents the kinetic energy the car gained as its speed increased from 0 to 10 metres per second.

7. Shade in the area that represents the kinetic energy the car gained from 10 to 20 metres per second.

8. How much energy was required to accelerate the car from 10 to 20 metres per second, compared with that required to accelerate from 0 to 10?

Was it *a.* the same amount? *b.* twice as much? *c.* three times? *d.* four times? (Underline the *correct* answer.)

Questions 9–15

A cricket ball of mass 0·2 kg has a speed of 20 metres per second.

9. How much kinetic energy ($\frac{1}{2}mv^2$) does it possess?

.... joules

10. It rebounds from a stationary cricket bat with the same speed, 20 metres per second. Does its kinetic energy increase, decrease, or remain the same?

....

11. Suppose, however, that the bat is moving towards the ball and that, in consequence, the ball's speed after rebound is 30 metres per second. How much kinetic energy does the ball have now?

.... joules.

12. How much kinetic energy has it gained (+) or lost (−)?

.... joules.

Questions 13–15

Gas is enclosed in a container, and one wall of the container is pushed in, compressing the gas.

13. Does the kinetic energy of the gas molecules increase, decrease, or remain the same?

....

14. Does the temperature of the gas increase, decrease, or remain the same?

....

15. What is it that you are assuming to be true, when you go from answer 13 to answer 14?

....

....

Questions 16–21

You have seen an experiment in which bromine was set free into a vacuum.

16. What does this experiment show?

....

....

17. Would you expect the same thing to happen if air were liberated into a vacuum instead of bromine?

(*Yes* or *No*).......................

18. Give the reason for your answer to 17.

....

....

19. Why use bromine?

....

20. What visible difference is there if bromine is liberated in air, instead of in a vacuum?

....

....

21. Give a reason for this difference.

....

....

....

Questions 22–24

In figure 71, in both diagrams (a) and (b), B is a battery of many cells and mA is a milliammeter. The number of cells in B can be changed, and the connections to B may be reversed.

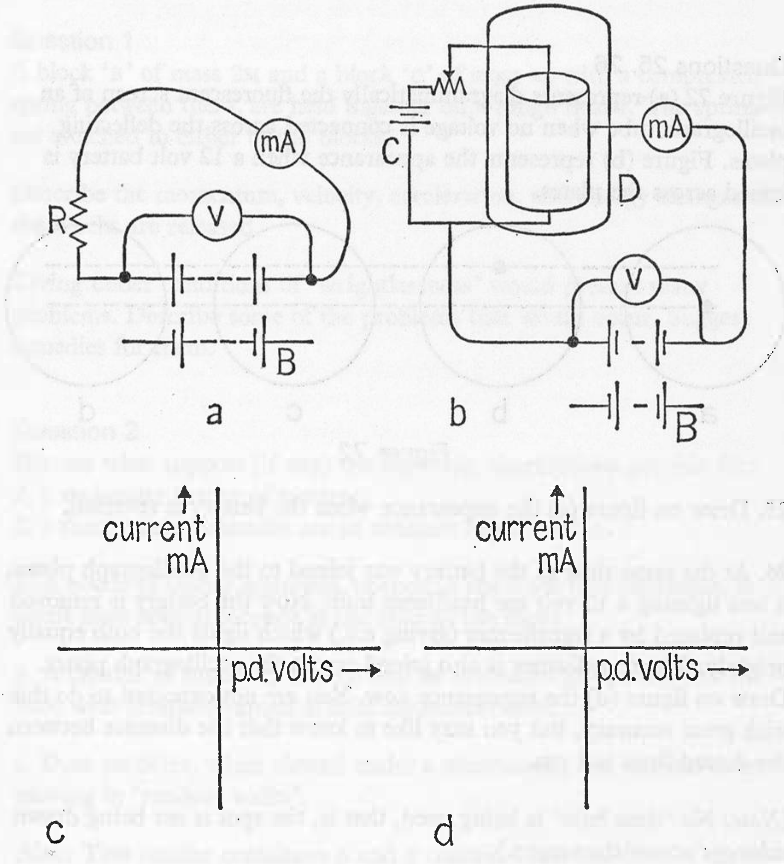


Figure 71

22. In (a), R is a wire resistor. On the axes of diagram (c) below it, draw a sketch-graph to show how the current through R changes with the p.d. of the battery.

23. In diagram (b), top right, the circuit includes a vacuum diode D. On the axes of diagram (d) below it, draw a sketch-graph to show how the current through D changes, with the p.d. of the battery.

24. In diagram (b) what is battery C for?

....

....

Questions 25, 26

Figure 72 (a) represents diagrammatically the fluorescent screen of an oscillograph tube when no voltage is connected across the deflecting plates. Figure (b) represents the appearance when a 12 volt battery is joined across the plates.

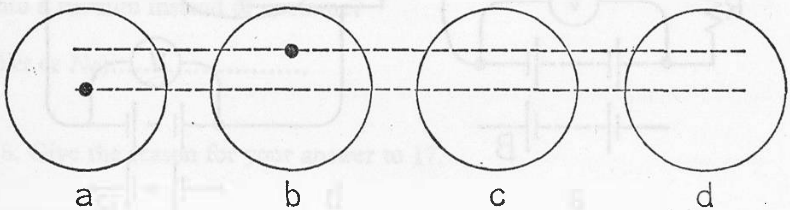


Figure 72

25. Draw on figure (c) the appearance when the battery is reversed.

26. At the same time as the battery was joined to the oscillograph plates, it was lighting a 12 volt car headlamp bulb. Now the battery is removed and replaced by a transformer (giving a.c.) which lights the bulb equally brightly. The transformer is also joined across the oscillograph plates. Draw on figure (d) the appearance now. You are not expected to do this with great accuracy, but you may like to know that the distance between the dotted lines is 1 cm.

(*Note:* No 'time base' is being used, that is, the spot is *not* being drawn *sideways* across the screen.)

Year IV July Paper Section B

time allowed, 1 hour

Answer THREE of the five questions.

Question 1

A block 'B' of mass 2M and a block 'C' of mass M, with a compressed spring between them, are held together on a rough board. The spring is *not* attached to either of the blocks.

Describe the momentum, velocity, acceleration, and energy changes after the blocks are released.

Living under conditions of 'weightlessness' would present many problems. Describe some of the problems that would occur. Suggest remedies for them.

Question 2

Discuss what support (if any) the following observations provide for:

1. a molecular theory of matter;

2. a theory that molecules are in constant rapid motion.

a. A bottle of strong ammonia, opened at the front of a classroom, is smelt after several seconds at the back of the room.

b. A capsule of bromine, broken into an evacuated glass tube, fills the tube with bromine vapour almost instantaneously.

c. Dust particles, when viewed under a microscope, can be seen to be moving in 'random walks'.

Also: Two similar containers A and B contain equal numbers of molecules of different gases X and Y. The molecules of these gases have the *same* average velocities, but the molecules of Y have greater mass than those of X.

d. How do the pressures in A and B compare? Give the reason for your answer.

e. How do the temperatures in A and B compare? Give the reason for your answer.

Question 4

a. A swinging pendulum provides a simple illustration of energy being continually changed from potential to kinetic and back again. Describe another, different, example of the same thing happening.

b. What important principle (or law) do the pendulum, and the example you describe, illustrate? Give its meaning in your own words.

'Nevertheless,' says someone who has read your answers to *a.* and *b.*, 'the pendulum slows down and after many swings it stops, and all the energy has gone.' 'Yes,' you say, 'but the energy has not gone, it has been converted to heat, which is another form of energy.' 'That may be true,' says your friend, 'but I am not convinced. I understand that the heat produced from the energy the pendulum loses may be too small to measure. But is there any evidence at all that heat is a form of energy?'

c. Give the evidence necessary to convince him that heat is a form of energy.

Question 5

Answer questions *a.*, *b.*, and *c.* below.

You are given an ammeter, a battery, and five boxes, each fitted with two terminals. The ammeter contains a resistance in series so that, when connected directly to the battery, it gives a full-scale deflection. The boxes are not labelled, but we will call them A, B, C, D, E. The following items are inside the boxes, joined to the terminals.

A contains a lamp designed to work from the battery.
B contains a diode.
C contains a length of copper strip.
D contains a piece of dry string.
E contains a thin fuse wire.

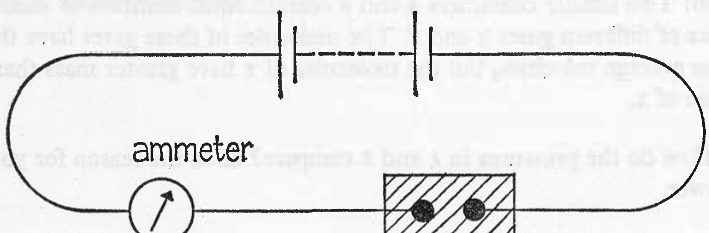


Figure 73

The ammeter and battery are connected in series with one of the boxes, as shown in figure 73. Three things might possibly happen:

1. The current rises quickly when the connection is made, then falls to zero.
2. No current flows at all.
3. The current rises to a steady value.

(Now for the questions!)

a. If *1.* happened, which box was connected? Give your reason.

b. If *2.* happened, *two* of the boxes might have given this result. Which two? Explain. Explain also a simple test (without opening the boxes) which would help you to choose between them.

c. If *3.* happened, *four* of the boxes might have given this result. Which four? Explain. Explain also simple tests (without opening the boxes) that would enable you to distinguish between them.

Year IV December Paper Section B

Question 1

This question, about Uncle George and the anemometer, was the same as question 4 of Year V (see page 138).

Question 2

a. A heavy truck runs on horizontal rails with practically no friction (figure 74). It is being pushed on one side by a force P_1 and on the other by a force P_2. It is seen to be travelling to the left, *but is slowing down.*

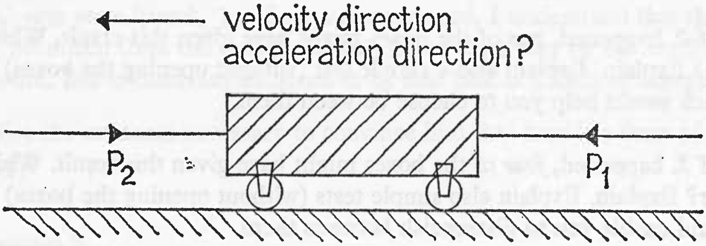


Figure 74

1. In which direction is it accelerating, left to right, or right to left (i.e. which way would you put the 'acceleration direction' arrow)?
2. Which is the bigger, P_1 or P_2? Give the reason for your answer.

b. M is an empty matchbox, or other light flat object (figure 75), D is a disc of cardboard, and G is a piece of glass tubing fitted into the centre of the disc.

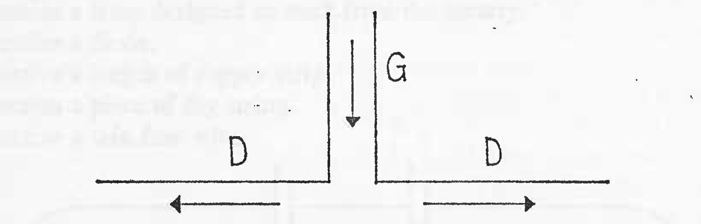


Figure 75

Someone blows down the tube G and at the same time gently raises the tube and disc. The matchbox is raised too – it can be lifted from the bench. How do you explain this?

c. Describe some example, other than *b.*, of the 'Bernouilli effect'. (Say what happens; you need not explain why.)

Question 3

Uncle George has heard you talk about friction on several occasions – you have said things like 'force needed to overcome friction', 'friction-compensated track', 'assume that friction can be neglected'. One day he remarks:

'Friction always seems to be a nuisance; it is always wasteful.'

Write a short essay (about 30 lines of writing) in answer to Uncle George's remark. Give several varied examples in which frictional forces operate, and consider what would happen if there were no friction.

Question 4

In figure 76, a trolley weighing $\frac{1}{2}$ kg runs at a steady speed down a friction-compensated track drawing tape through a vibrator behind it. The vibrator makes 50 taps a second. A ten-dot length of the tape is found to measure 12 cm. The front end of the trolley carries two pins which pierce a piece of cork on the back end of a stationary trolley halfway down the track. The two trolleys move as one after the collision. This second trolley weighs 1 kg. A 20-dot length of tape now measures 8 cm.

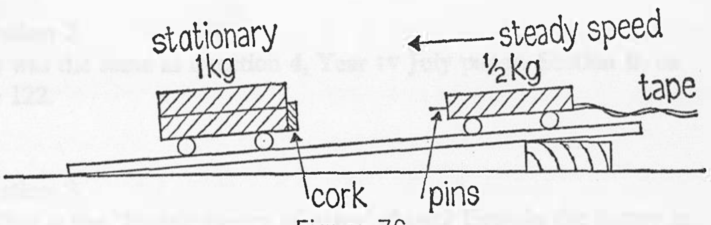


Figure 76

a. These measurements can be used to show that something – an important quantity in mechanics – has stayed the same throughout the experiment. What quantity?

b. Use the measurements to show that the quantity mentioned in your answer to *a.* has stayed the same during this experiment.

c. The time during which the pins are piercing the cork is one-thirtieth of a second. (This is the time from the instant the pins first touch until the instant the trucks are moving 'as one'.) Find the average force exerted by the $\frac{1}{2}$ kg truck on the 1 kg truck during this time. (Hint: the 1 kg truck was initially at rest, and later it was moving with a velocity which can be found from the readings above.)

d. Show that this is the same as the average force exerted by the 1 kg truck on the $\frac{1}{2}$ kg truck. (Hint: you can find the initial and final velocities of the $\frac{1}{2}$ kg truck from the readings above.)

Year IV July Paper Section B
time allowed, 50 minutes

Answer TWO of the four questions.

Question 1
You have performed an experiment which shows that, for the same moving mass, acceleration is directly proportional to force applied.

a. Briefly describe the apparatus used, giving a diagram.

b. How did you obtain forces of 1, 2, 3 units?

c. How did you measure the accelerations?

Explain, giving your reasons, what difference, if any, it would make to this experiment if it were performed:

d. on the Moon;

e. in a spaceship travelling freely with rocket motors off;

f. in a spaceship far from any stars or planets, but with the rockets switched on so that the ship accelerates in the *opposite* direction to the forces you apply in the experiment.

Question 2
This was the same as question 4, Year IV July paper, Section B, on page 122.

Question 3
a. What is the 'kinetic theory of gases' about? Explain the theory in your own words.

Explain, giving any useful diagrams, how the theory accounts for the following:

b. a gas exerts pressure on the vessel containing it;

c. doubling the volume occupied by a given quantity (mass) of gas halves its pressure (the temperature remaining the same);

d. a heavier-than-air gas, such as carbon dioxide, diffuses upwards into air above it.

Two gases, X and Y, have molecules of the *same* mass moving with the *same* average velocities, but the molecules of Y are larger than those of X. Say what difference this would make to *e.*, *f.*, and *g.* below, and give a short reason for each answer.

e. The pressure exerted by Y (compared with that exerted by X).

f. The temperature of Y (compared with that of X).

g. The rate at which Y diffuses into air (compared with the rate at which X diffuses).

Question 4

You are given a small electric motor meant to run from a 4 volt supply. It has an axle sticking out, about $\frac{1}{2}$ cm in diameter, round which thin string can be wound. Given three 2 volt accumulators, a voltmeter, a variable resistor, and any other ordinary laboratory apparatus, how would you:

a. make sure that exactly 4 volts were applied to the motor terminals;

b. find the electrical power input to the motor, in watts;

c. find the rate at which the motor can do mechanical work, also in watts;

d. calculate the efficiency of the motor in converting electrical to mechanical energy.

Note: Your answers to *a.* and *b.* should include a circuit diagram (only one is needed) and your answer to *c.* should include a sketch of the arrangement used.

Year IV December Paper Section B

Question 1

Two boys, A and B, operate a 'ticker-tape vibrator'. A starts moving, dragging the tape with him, and B switches on the vibrator just after he starts. A runs across to the opposite wall of the room, then stops. Then B switches off. They then proceed to cut up the tape. The first ten spaces occupy 7 cm. They then count another 40 dots, and cut off the strip between the 50th and the 60th marks; this strip is 12 cm long. Similarly for successive strips as shown in figure 77: 26 cm, 27 cm, 14 cm, 5 cm, 0 cm. Figure 77 shows the strips after they have been pasted in their proper places.

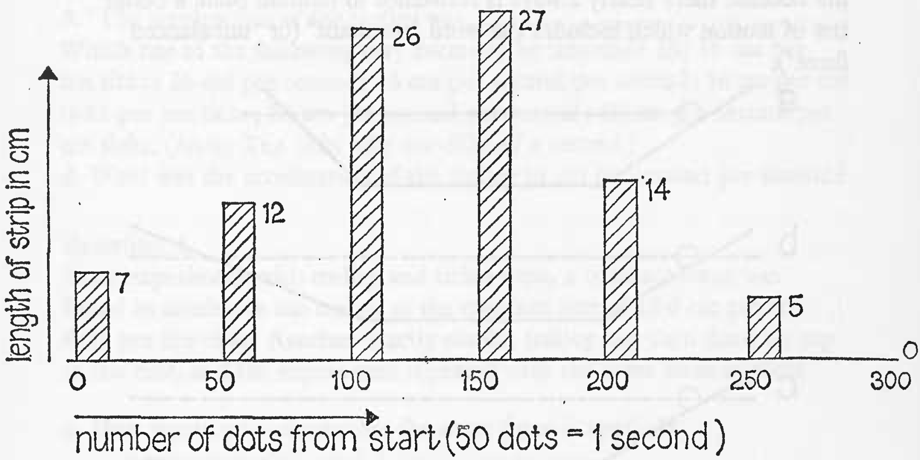


Figure 77

a. What can you say about the changing speed of the boy A during the experiment?

b. If 50 ticks take exactly one second, how far did he go in the first *fifth* of a second? How far did he go in the *first whole* second? How far did he go in the *third* second?

c. During which second did he have the greatest acceleration? During which second was he slowing down most quickly?

(*Note:* You need not copy the diagram; any drawing or measurement may be made on the diagram you are given. You need a ruler having tenth-inch marks.)

Question 2
In figure 78, (a), (b), and (c) are three diagrams of a heavy ball held at the top of a smooth, fairly steep inclined plane. In (a), the plane on the right is equally steep. In (b) it is less steep. In (c) the whole plane, after the lefthand slope, is horizontal.

1. Describe what you think actually happens in each of the three cases (a), (b), and (c) after the ball is released.

2. Describe what you think would happen, in (a), (b), and (c), if the motion of the ball were entirely unimpeded by friction and air resistance.

3. State the rule or 'law', about motion without resistance, that is suggested by *2.* above, case (c).

4. The 'law of motion' stated in *3.* has not much application to everyday life because there nearly always is resistance to motion. State a better law of motion which includes the word 'resultant' (or 'unbalanced force').

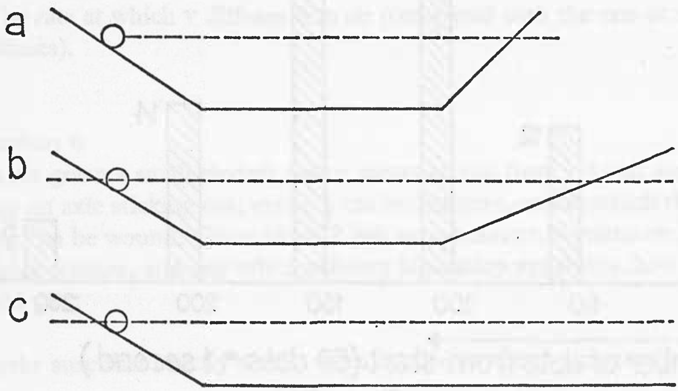


Figure 78

Question 3
Two boys carry out an experiment in which a trolley, pulled along a flat plane, is accelerated by a constant force. The 'constant force' is exerted by a length of elastic. The acceleration is measured by a vibrator making marks on ticker-tape.

a. How is the elastic kept at a constant length? (Give a sketch.)

b. How should the boys 'compensate for friction' before starting the experiment? How should this be done?

c. In an actual experiment they obtained a series of about 70 dots, but they decided to ignore the first ten, and also any dots after the 50th. Why did they ignore the beginning and end of the 'run'?

d. Measurements on the tape gave the following results (taken to the nearest centimetre):

Length from dot 10 to dot 20 = 24 cm
Length from dot 20 to dot 30 = 40 cm
Length from dot 30 to dot 40 = 56 cm
Length from dot 40 to dot 50 = 72 cm

1. What do you notice about these figures? What general conclusion do they illustrate?
2. 'The speed of the trolley increased by.. in every ten ticks.' Which *one* of the following may correctly be inserted in the 'blank': 16; 16 cm; 16 cm per second; 16 cm per ten ticks?
3. 'The acceleration of the trolley was...' Which *two* of the following may correctly be inserted? 16; 16 cm per ten ticks; 16 cm per second; 16 cm per second per second; 16 cm per ten ticks per ten ticks; 80 cm per second per second; 80 cm per second per ten ticks. (*Note:* Ten ticks take one-fifth of a second.)
4. What was the acceleration of the trolley in cm per second per second?

Question 4

In an experiment with trolley and ticker-tape, a constant force was found to accelerate the trolley at the constant rate of 12·6 cm per ten ticks per ten ticks. Another exactly similar trolley was then fixed on top of the first, and the experiment repeated with the same force applied.

a. How would you ensure that the same force is applied?

b. What value for the acceleration would you now expect to obtain?

c. What name do we give to this quantity which is changed when we use two trolleys instead of one, and which decides how much acceleration a given force produces?

d. Suppose we tied the two trolleys together, one behind the other like a toy train, instead of placing one on top of the other – would that make any difference?

e. We take away the second trolley and tie a brick onto the top of the first trolley. For the same force the acceleration of (trolley + brick) is 4·2 cm per ten ticks per ten ticks. What is the 'trolley equivalent' of one brick?

Question 5

A and B in figure 79 are bars of wood cut from the same piece. B is twice as long as A. They can move easily on small pieces of glass tube placed as rollers (or on polystyrene balls). They are joined by a strong piece of stretched elastic but they are prevented from coming together by a length of thread passing round four nails and holding them apart. The end of A towards B is at the 0 cm mark of a metre scale, and the end of B towards A is at the 36 cm mark.

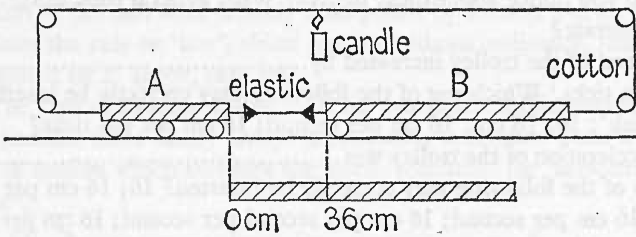


Figure 79

a. What can you say about the mass of B compared with that of A?

b. What can you say about the pull of the elastic on B compared with the pull on A?

c. The thread is burnt. What happens?

d. What can you say about the acceleration of B compared with the acceleration of A?

e. Since they both started from rest, what can you say about the average speeds of B and A from when they start moving until the moment they collide?

f. Opposite what point on the scale do they collide?

Question 6

You are in a closed van and you cannot see out. When the van is stationary you drop a penny onto the floor and leave it there. Suppose that, after the van starts moving, you were to drop further pennies from the same point. Where would you expect the pennies to land (in relation to the first penny): *a.* when the van is moving with constant speed, *b.* when it is accelerating, *c.* when it is braking, *d.* when it is turning on a lefthand curve?

Question 7

A trolley, A, on a friction-compensated track, is pulled along by a piece of string attached to another trolley, B, hanging over the side of a table; (see figure 80, diagram (a)). The acceleration is 6·0 metres per second.

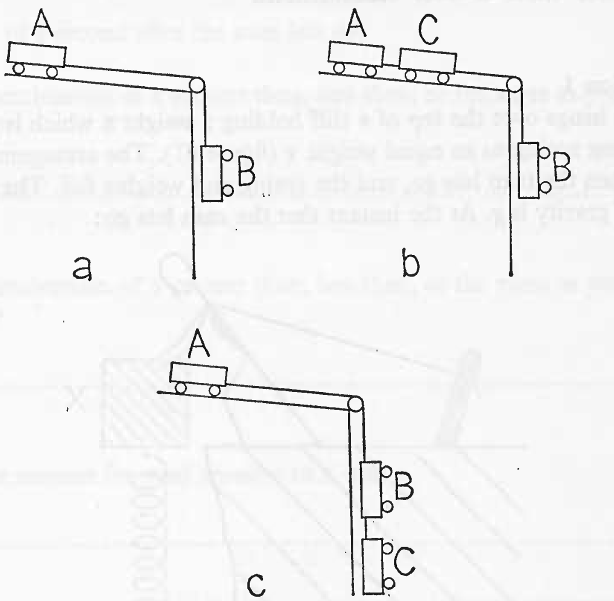


Figure 80

A third trolley, C, is then attached as shown in diagram (b). What is the acceleration of the three trolleys?

Lastly the trolley C is attached as shown in the diagram (c). What is the acceleration now?

Year V Six Questions

Here are six questions, three A-type and three B-type, which were set in December 'mock O-level' examinations.

Question 1

A man hangs over the top of a cliff holding a weight X which is attached by a long spring to an equal weight Y (figure 81). The arrangement is at rest when the man lets go, and the spring and weights fall. The acceleration of gravity is g. At the instant that the man lets go:

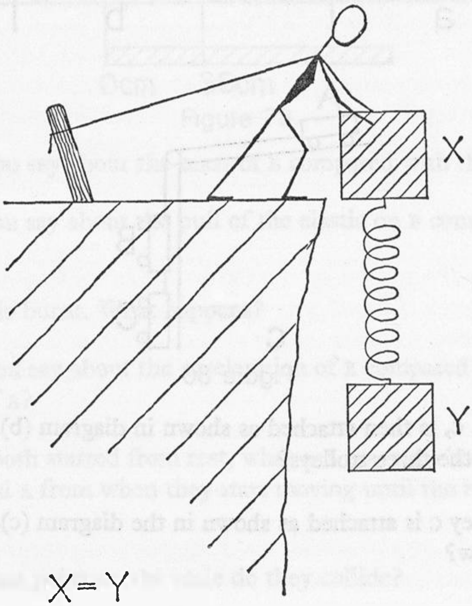


Figure 81

a. What is the acceleration of X?

....

b. What is the acceleration of Y?

....

c. Give the reasons for your answers to *a.* and *b.*

....

A fraction of a second after the man lets go:

d. Is the acceleration of X greater than, less than, or the same as your answer *a.*?

....

e. Is the acceleration of Y greater than, less than, or the same as your answer *b.*?

....

f. Give the reasons for your answers to *d.* and *e.*

....

....

g. What is the acceleration of both weights and the spring together, considered as one object?

....

h. Suppose that, as the weights fell, you could watch them from a distance through a telescope, what would you notice?

....

....

Question 2

A proton, ${}^{1}_{1}H$, is a hydrogen atom carrying a single positive charge.

A deuteron, ${}^{2}_{1}H$, is a charged hydrogen atom carrying a single positive charge, and having twice the mass of a proton.

An alpha particle, ${}^{4}_{2}He$, is a charged helium atom carrying twice the charge on a proton, and having four times the mass.

A deuteron, D, is situated between two plates, P and Q, which are suddenly charged by being joined to a battery. P becomes positive, Q negative (figure 82). The deuteron starts to accelerate with an acceleration 'x'.

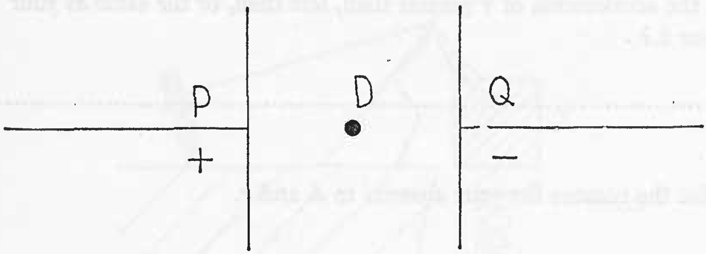


Figure 82

a. Which way does the deuteron go? Towards ....

b. Suppose we have a proton at D instead of the deuteron. What is its acceleration (in terms of 'x')?

....

c. Give the reasons for your answer to *b.*

....

....

d. Suppose we have an alpha particle at D, what is its acceleration?

....

e. Give the reasons for your answer to *d.*

....

....

....

Question 3

A length of grooved curtain rail is bent into a loop, as shown in figure 83, and supported clear of the floor.

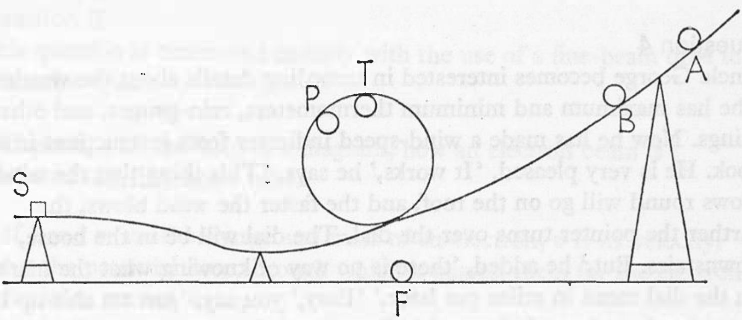


Figure 83

A heavy ball (e.g. a large ballbearing) is released at A, rolls down, 'loops the loop', and finally comes to rest against the soft rubber stop S. Friction forces can be ignored.

a. What two forces are acting *on the ball* when it is moving past T, and in what direction are they acting?

....

b. Is the ball falling when it is at T?........................(*Yes* or *No.*)

c. If 'no', why is the ball not falling?
or, if 'yes', why does it not leave the groove?

....

....

If the ball is started from B instead of A it is seen to leave the rail at the point P and hit the ground at F.

d. Draw a pencil line on figure 83 to show a likely path of the ball from P to F.

e. Why is F not directly below P? ....

f. What is the name of the path followed from P to F (circle, straight line, parabola, hyperbola, ellipse, cycloid, or something else)?

....

Question 4

Uncle George becomes interested in recording details about the weather – he has maximum and minimum thermometers, rain-gauges, and other things. Now he has made a wind-speed indicator from instructions in a book. He is very pleased. 'It works,' he says. 'This thing that the wind blows round will go on the roof, and the faster the wind blows, the further the pointer turns over the dial. The dial will be in the house, downstairs. But,' he added, 'there is no way of knowing what the marks on the dial mean in miles per hour.' 'Easy,' you say, 'just set this up by the side of another wind-speed indicator and then you can mark it from the readings of the other one.'

'Don't be silly,' he replies. 'I haven't got another indicator. If I had, I shouldn't have needed to make this one. The only dial marked in miles per hour that I have is in the speedometer in the car, and I don't see what use that is.'

'Wait a minute,' you say, 'I've an idea; listen.'

You tell him your idea, and next Saturday you and Uncle George go out in his car. It is a bright clear afternoon, with no wind, just what you wanted.

a. What was your idea? Explain fully. Say what you do while Uncle George drives and watches the speedometer, and what instructions you give him.

(*Note:* The proper name for 'wind-speed indicator' is 'anemometer', and you might use that word because it is shorter to write.)

b. Uncle George gets out of the car and holds up one finger. He says, 'I'm not sure there isn't a slight breeze blowing along the road. It's blowing steadily, that's why you don't notice it.'

How can you use the car and anemometer to find out whether he is right?

c. If he is right, what changes will you and Uncle George make in what you are doing? (Answer in one, or two, sentences, but 'subtract the wind speed' is not enough – you don't know the wind speed.)

Question 5

This question is concerned entirely with the use of a fine-beam tube to determine e/m.

a. Explain, with the help of a diagram, how an electron beam is produced in a fine-beam tube.

b. If e and m are the charge and mass of an electron, v is its velocity, and V the potential drop through which it passes, then, for the electron beam in *a.*, we can write,

$eV = \frac{1}{2}mv^2$.

1. Explain where this equation comes from.
2. When we write the above equation, what assumption are we making about energy transferred to an electron in the beam?

c. Explain, with a diagram, how the beam in a fine-beam tube is deflected into a circular path.

d. If R = radius of the circle that the beam follows, then

$$Bev = \frac{mv^2}{R}.$$

1. What is Bev?
2. What is $\frac{mv^2}{R}$.

e. What does 'B' mean? You have to know its value in order to find e/m for the electrons in a fine-beam tube. How do you find B by experiment?

Question 6

(x) Electrons may be produced in a vacuum in several ways, e.g. thermionic effect, as in the fine-beam tube, or the photoelectric effect, or from radioactive materials. For all these, the ratio of charge to mass, e/m, is the same.

(Y) In contrast, for positive ions, the ratio of charge to mass e/M, varies according to the gas in the tube, and is different from the value of e/m for electrons.

(Z) Moreover, even though there is only one gas with one kind of atom in a positive-ray tube, two or more different values of e/M are frequently found for the positively charged particles emerging from the tube.

a. Explain the importance of the observations stated under (X).

b. How do you explain the observations (Y)?

c. What is the explanation of (Z)?

d. In not more than, say, six sentences, try to give Uncle George some idea of how a modern mass-spectrograph works. (He understands that positive ions can be produced from gas atoms by means of an electron beam; you must carry on from there.)

Chapter III

Some comments on the Ordinary-Level Examination for the Physics Project

Up to the time of writing, four sets of Nuffield O-level Physics papers are available: for 1965, 1966, 1967 and 1968. Nuffield materials became available to all schools from September 1966, with the strong recommendation that the starting point should be either Year I or Year III. If that recommendation was followed, then, even in 1968, the only candidates taking the examination will have been those from the Nuffield pilot schools. In 1965 the number of pilot schools' candidates was 80, in 1966 about 200, in 1967 about 800 and in 1968 just over 1,000; the last two years included some who took 'Nuffield Physics' as part of the combined subject Physics-with-Chemistry. The papers are set and marked under the auspices of the Oxford and Cambridge Schools' Examination Board, acting on behalf of all the G.C.E. examining boards, and are taken simultaneously by candidates from all the schools concerned. This system, of the same papers for all candidates, will continue for some years yet, although, of course, the number of examiners required to mark the papers must increase as the candidates increase. There is at present no intention of adopting a mechanical system of marking together with multiple-choice questions, but this may be a future development for the first of the two papers. Experimental papers of this kind are (1968) being devised. The papers already set* (though not perhaps Paper II of 1965) give a reasonable guide: nevertheless it is to be hoped that both the course and the methods of examining it will be subject to active processes of adaptation and evolution.

Nuffield O-level papers are different in nature, as well as in content, from traditional papers, and an attempt will be made in this chapter to indicate the difference. The chapter concludes with a few specimen questions from the papers already set.

* Copies of papers are obtainable, at a small charge, from the Secretary, Oxford and Cambridge Schools' Examination Board, 10 Trumpington Street, Cambridge. Books of papers may become available at a later date.

The place of an external examination in the framework of the Nuffield Physics Project

The purpose of the traditional type of O-level examination may be stated as follows:

1. to measure knowledge and understanding and thus to certify the attainment of a certain standard in the subject examined.

As a result, several other ends may be attained, such as:

a. provision of a landmark in a pupil's study, and an indication of his progress;

b. provision of a similar check on schools and teachers;

c. acting as a prognostic test, assisting pupils in choosing their subsequent careers, or subjects of study;

d. acting as an incentive or spur to encourage diligent study.

Inevitably, however, a public examination exerts a controlling effect, not only on the syllabus which is taught, but also on the aims and methods of teaching. Pupils and teachers will study the examination papers and, from this study, decide what is the best method of achieving high marks. In consequence, a second purpose of the examination becomes of paramount importance.

2. to exhibit to teachers and pupils the aims of the course that is to be followed, and to encourage them to achieve those aims.

Suppose we design a course in which the pupil gains experience of building knowledge on experiment, a course which demonstrates the nature of scientific laws, which illustrates the importance of theory, and establishes scientific thinking as reasoning with carefully chosen data. Suppose we then set O-level questions such as the following:

'Define coefficient of linear expansion of a solid and describe an experiment to determine its value for a metal rod. What increase in length will occur in a steel girder 100 feet long when its temperature rises from 0°C to 50°C (coefficient of linear expansion = 0·000012 per °C)?'

The result will be that, in following years, pupils will pay little regard to our illustrations of law and theory, to scientific reasoning, and to discovering things for themselves. They will know what they must do: just memorize everything the month before, the week before, the night before, then reproduce what is wanted, forget it, and in due course collect the certificates. If our aim is 'teaching for understanding', if we wish to give each of our pupils the experience of 'being a scientist', then these, and not 'cheap recall', are what our examination must test. In other words, the examination must lie within the framework of the teaching programme, and it must be relevant to the real aims we have in mind.

Types of question

Reference may first be made to the types of question listed in Chapter I. Many, but not all, of these categories apply to examination questions, viz., cheap recall, simple recall, expensive recall, questions requiring imagination or intelligent guesswork, and 'Uncle George' or 'Freddie Jones' types of question – though of course these rather frivolous characters have to put on top hat and frock coat in order not to conflict with the august atmosphere of an examination paper; and then they become 'Professor P' or 'Mr X'. A few remarks on types of examination question appear below.

a. A question like the one on linear expansion in the last section tests nothing but a candidate's ability to memorize a definition, a standard experimental determination, and a formula, plus the ability to substitute some numbers in the formula. It may be called 'cheap recall' and its use in a Nuffield paper is very limited indeed. Candidates will not need to memorize formulae; they will be given a list of formulas in the questions or at the beginning of the paper.

b. Some questions, or parts of questions, may be of the 'expensive recall' type, where several pieces of knowledge may have to be put together and a conclusion drawn, or knowledge applied in circumstances new to the candidate.

c. Questions sometimes ask for intelligent guesswork, and the candidate is then asked to justify his own guesses, or to criticize 'Mr X's' suggestions.

d. A type of question useful for testing understanding is that which puts the candidate into the role of the teacher, or of an 'advisory scientist'. Candidates are used to these in 'homework' questions; they are 'Uncle George' type questions.

e. Questions designed to test ability to think scientifically may be set on topics not specifically covered in the course at all. Such a question is No. 4 on p. 138, about Uncle George and the anemometers (though *he* might not appear in a *real* paper!). The candidate is not expected to know anything about anemometers, but the question is useful in testing ability to think about simple things.

Of course the aims of all these 'types' of question may be incorporated in various parts of a single question. The examiners have tried to set 'good' questions without worrying too much about the different abilities tested. In the future, more care might be taken about segregating and testing specific kinds of attainments. Up to the present, the need has been to encourage the achievement of the aims of the course, and to test pupils, not on memorized work, but on the degree to which they have attained those aims.

Two kinds of examination paper

Physics I is, in the terminology of Chapter II, an A-type paper of short-answer questions, to be answered on the paper itself. They may be single words or several sentences; they may be short numerical problems, and may require the drawing of diagrams, or drawing on existing diagrams.

Physics II is a B-type paper and more descriptive. While this is intended to test candidates' understanding and ability to think, it also tests the candidate's ability to express himself in English upon physical topics.

Marking

Physics I: short answer questions Marking is mainly objective but not entirely. The examiner knows the expected 'satisfactory' answer to each part of each question, and if he gets it he gives full marks – perhaps 3/3 in a particular case. But there may be a rather better answer, possibly something the examiner never thought of. He then gives 4 marks (out of 3) on that part. This has been a general principle in marking these papers – to think, not of the best possible answer, but of the 'satisfactory' answer for candidates at this level, and give it 100 per cent. Then answers that are more worthy are marked up, and those that are less worthy are marked down.

Physics II: longer answers The method of marking for the 'satisfactory' answer, explained above, is also used here. Marking is more subjective; the examiner wishes to get a good general impression of the candidate, rather than award marks here and there for this, that, and the other detail. He wishes to know whether young people understand, and so he needs a flexible frame of mind; he must be ready to accept different ways of conveying that understanding. One candidate may use one vocabulary or give one set of examples, while another candidate shows his understanding equally clearly but in a different way.

In Paper I of 1968, question 4 asked about 'weightlessness' in three cases: *a.* in a room at a planet's centre, *b.* in a satellite in circular orbit, *c.* in a stationary state at a point between Earth and Moon. Three candidates provided the following answers to part *b.* about the satellite.

1. 'As the satellite falls to the Earth, the Earth gives way beneath it, so the satellite is constantly falling.' This is, at the candidate's level, a good description of 'free-fall', and the examiner gave 3/3.

2. 'The satellite is falling at the same rate as gravity is pushing, so they cancel out.' This received 1/3. The examiner was unable to accept the equating of a rate of fall and a force.

3. 'The satellite is travelling at a speed sufficient to counteract the pull of gravity.' This is typical of the still prevalent pre-Galilean ideas about motion, and it received no marks.

1 Five A-type Questions*

Question 1 (1965)

A ball, held at rest on a hard inclined surface, is released from the position A shown in figure 84.

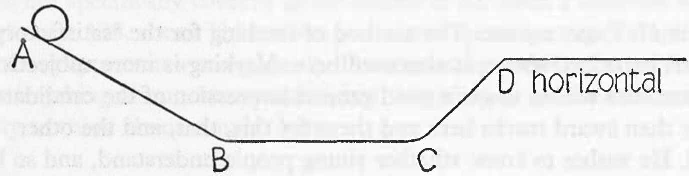


Figure 84

a. Describe the motion of the ball if friction and other opposition to motion can be entirely neglected. Pay special attention to what happens at D.

* The specimen questions in this chapter have been included with the permission of the Oxford and Cambridge Schools' Examination Board.

b. Describe the motion of the ball if there is enough friction to stop the ball reaching the top of the righthand incline although it goes some way up.

....

....

....

....

....

....

(*Note:* The ball may roll or it may slide; assume that this makes no difference to the answers expected.)

Question 3 (1965)

Diagram (a) in figure 85 shows a sealed tube 1 metre long; at the bottom is a little bromine separated from a vacuum by a partition. Some of the bromine vapour molecules are represented by dots. The temperature is room temperature and the average speed of the bromine molecules is 200 metres/second.

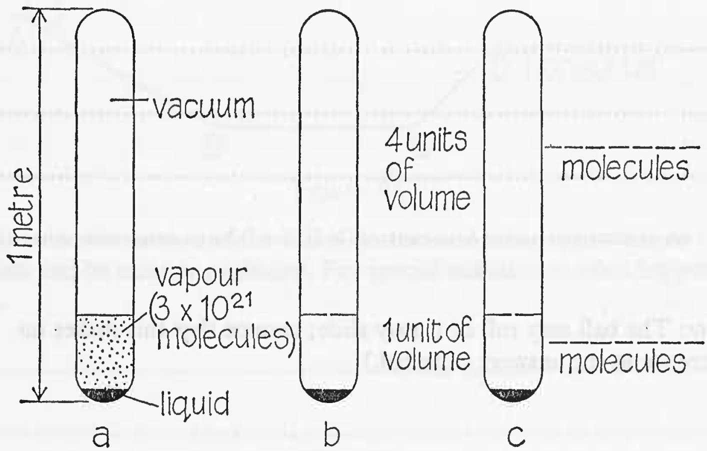


Figure 85

A hole is suddenly made in the partition.

a. Show, by putting dots on diagram (b), where bromine molecules can be expected (above the partition) $\frac{1}{1000}$ of a second later. Will any of these molecules have hit the wall of the container ? Give reasons for your answer.

....

....

....

....

b. Diagram (c) shows the tube several seconds later. The temperature is still the same and the volume of liquid bromine is slightly less. What is the cause of this decrease in volume?

....

....

c. Show, in the blank spaces of the labelling of diagram (c), your estimate of the number of vapour molecules above and below the partition. (There were 3×10^{21} vapour molecules below the partition in diagram A and the volume above the partition is four times the volume below it.)

d. If the whole tube is warmed it is found that a pressure gauge attached to the top of the tube shows an increase of pressure. Suggest how the increase is produced. (Give two separate causes if possible.)

....

....

....

....

Question 7 (1966)

Figure 86 shows some of the rays of light leaving a small electric lamp L. Some of the rays go through two lenses A and B, as shown.

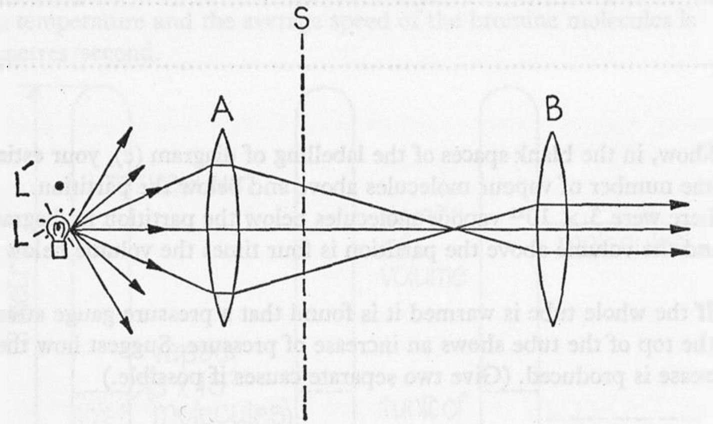


Figure 86

a. When a screen is put in the position SS′, parts of the screen appear very bright, other parts appear fairly bright, and some parts appear dark. Label the sections, on the line SS′, with the letters VB, FB and D to indicate the very bright, fairly bright, and dark parts respectively.

b. With the screen removed and the lamp moved up to the position L′ the light takes a different course through the lenses. Show this course by drawing two rays leaving L′ and going through the lenses.

c. Explain, with the help of your diagram, how it is that, to a person looking through the lens B, the movement of the lamp from L to L′ appears magnified.

....

....

....

....

Question 11 (1966)

a. Many cloud-chamber photographs have been taken of the tracks of α-particles from radioactive sources. It is rare for these photographs to show anything but straight line tracks, yet each α-particle encounters more than 100,000 atoms along its path. On this evidence alone, what can you say about the nature of the atoms of the gas in the cloud chamber?

....

....

....

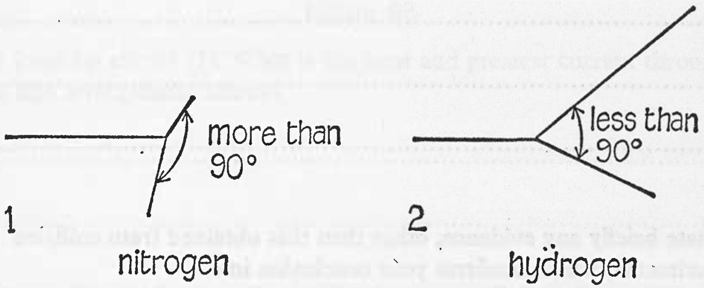


Figure 87

b. Very occasionally a forked track is found, looking like figure 87(1) (in nitrogen) or figure 87(2) (in hydrogen). In each diagram the α-particle is coming from the left, and you may assume that no nuclear transformation takes place.

What does this tell you about the mass of an α-particle compared with the masses of a nitrogen and a hydrogen atom?

....

....

....

c. If the gas in the cloud chamber is helium, and a forked track is obtained, then the angle between the forks is found to be 90°. What conclusion can be drawn from this?

....

....

....

d. How would you demonstrate the same thing happening (i.e. 90° angle after collision) with 'carbon dioxide pucks' on a glass surface?

....

....

....

....

e. State briefly any evidence, other than that obtained from collision experiments, which confirms your conclusion in *c.*

....

....

....

Question 5 (1967)

Two pupils, X and Y, are each given a piece of electrical apparatus E having a resistance of 100 ohms, and a 100 ohm rheostat. They have an electrical supply of 220 V d.c. They are told to use the rheostat so as to give the biggest possible range of current through the apparatus E (figure 88).

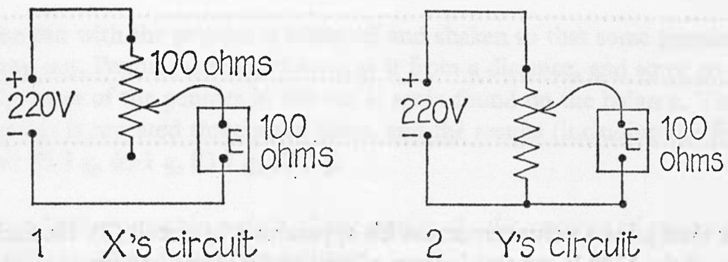


Figure 88

a. X joins up circuit (1). What is the least and greatest current through E that this arrangement allows?

....

....

....

....

b. Y joins up circuit (2). What is his least and greatest current through E?

....

....

....

....

c. X then says that, if he reverses the source connections, + to −, he will get 'the other half' of the range of currents, from 0 upwards, and will therefore do as much with his circuit as Y does with his.
Is this so? Give the reason for your answer.

....

....

....

....

d. Y then joins a voltmeter across his apparatus E in circuit (2). He finds that, if the '220 V supply' is from a large accumulator battery, then the maximum voltage across his apparatus is in fact 220. But if the supply source is a 'high-tension battery' of dry cells, then the maximum voltage across E is much less than 220, in spite of the fact that the battery shows 220 V when nothing but the voltmeter is joined to it. How do you explain this?

....

....

....

....

2 Four B-type Questions

Question 5 (1965)

a. Two exactly similar cans are placed on opposite sides of a beam balance. One contains an unknown number of pennies, the other is empty. The mass of the pennies is found by weighing to be 83·7 g.

The can with the pennies is taken off and shaken so that some pennies jump out. Pennies are also thrown at it from a distance, and some go in. The mass of the pennies in the can is again found on the balance. This process is repeated three more times, and the results (including the first) are: 83·7 g, 65·1 g, 83·7 g, 37·2 g.

Find *1.*, the probable weight of one penny, *2.*, the number of pennies in the can when it was first weighed.

b. Explain to Mr x how the 'pennies in can' experiment in *a.* resembles the Millikan oil-drop experiment, and how the Millikan experiment supports the view that electricity has a particle property. (He has not heard of the oil-drop experiment before, and he is not interested in the details of the experiment.)

Question 3 (1966)

Figure 89 shows a system invented by Ptolemy to imitate the motion of a planet (as he saw it) in its path round the Earth – the planet Jupiter, for example. The features of his system were 'fixed Earth, constant radii, rotations with constant speed'.

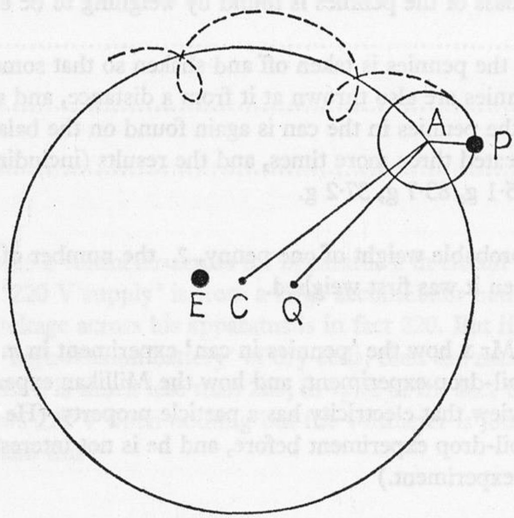


Figure 89

a. Explain Ptolemy's system in so far as it is illustrated by figure 89, and use the diagram to explain the three 'features' mentioned above.

b. What is meant by 'retrograde motion' of a planet? Say how it is shown in figure 89.

c. Draw a diagram to show how Newton would have explained the motion of a planet such as Jupiter (include the Sun as well as the Earth in your diagram). How would Newton have explained retrograde motion?

d. Why is Newton's planetary scheme regarded as a 'theory', while Ptolemy's is only a 'model'?

Question 4 (1966)

Read the following account, look at the diagrams, and answer the questions *a.* to *g.* below.

An underground railway has been designed to work between two cities, X and Y, 85 miles apart (see figure 90). It is expected to cover this distance, from the start to stop, in about a quarter of an hour.

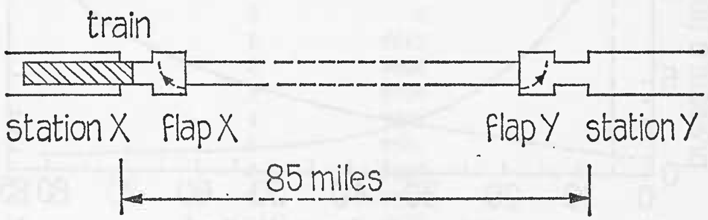


Figure 90

The train, shown at rest in station X, is a good fit (like a piston) in the tunnel, the clearance between it and the walls being less than an inch all round. Two flaps, at X and Y, seal off the main tunnel from the stations. Atmospheric pressure, in the station, is about 15 lb/in². A pump is used to reduce the pressure in the tunnel to about $\frac{1}{2}$ lb/in². The train at station X has one end just inside the tunnel, as shown. The flap X is then opened.

a. What happens to the train, and why? Why may this be called an 'atmospheric railway'?

b. When the train is 5 miles inside the tunnel, flap X is closed again, and the train continues to move rapidly towards flap Y, which is still closed. Figure 91 shows how the pressure behind the train, and in front of the train, varies as the train travels from X to Y.

Why is the portion AB straight? Give an explanation of the rest of the graph, from B to the vertical line YD.

c. When the train is near Y, flap Y opens and the train runs into station Y. Flap Y closes again. Figure 91 also shows how the pressure ahead of the train varies as its distance from X increases.

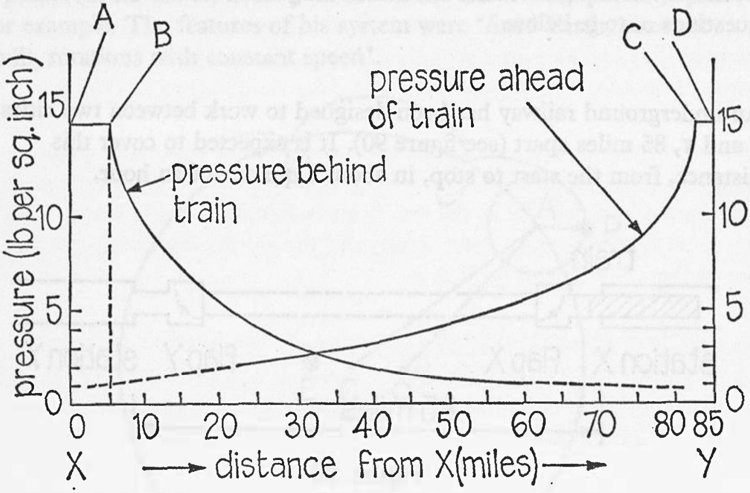


Figure 91

Explain the graph from the start, at X up to C, and also the horizontal portion CD.

d. At what distance from A was the train moving with zero acceleration? Where was it moving most rapidly? Where was its forward acceleration greatest? Where was its deceleration greatest?

e. On the assumption that Boyle's Law is followed, estimate the pressure in the tunnel after the train has gone through. (Assume that losses due to leakage can be neglected, that the temperature is the same as at the start, and that the pressure when flap X is closed is 15 lb/in^2.

f. In a railway such as this, where does the energy needed to propel the trains come from?

g. Such a train would attain a speed of, say, 420 m.p.h., while a conventional train of the same mass reaches 60 m.p.h. How many times greater is the kinetic energy of this train, compared with the kinetic energy of the conventional train? What happens to the kinetic energy of an ordinary train? What happens to the kinetic energy of the train described here?

Question 3 (1967)

A radioactive substance, labelled R, is set up in front of a G–M tube connected to a scaler. The scaler is set counting at the same moment that a stopwatch is started. Every time the seconds hand reaches a minute, a boy records the reading of the scaler without stopping it counting. He tabulates the readings as shown below:

time	*scaler reading*
0	0
1	6015
2	8026
3	9016
4	9401
5	9541
6	9802
7	9636
8	9673

a. One of the readings is suspicious. Which one? What did the boy probably mean to record?

b. Having made this correction, work out from the readings what was the count rate in each successive minute, giving your answers in number of counts per minute.

c. What do these readings suggest is happening?

d. Plot the count rates on a suitable graph and deduce a value for the half-life of the radioactive substance R. (The mean of at least two values is required.)

e. Jill says that a better result would be obtained if the readings were extended over a further eight minutes and that the boy stopped too soon. Is this a good or a bad idea? Give reasons.

f. Jack knows that there are random fluctuations in radioactive experiments. He says a better result would be obtained if more counts were taken and that it would be better to count for five-minute intervals, not one-minute intervals. Give your reasons why this is a good or a bad idea.

g. There is a slight increase in count rate during the eighth minute. Is this significant? Give the reason for your answer.

h. Suggest any way in which you think the experiment might be improved.

Pages for Notes

NUFFIELD FOUNDATION SCIENCE TEACHING PROJECT PHYSICS SECTION

The physics programme was inaugurated in May 1962 under the leadership of Donald McGill. It suffered a severe setback with his tragic death on 22 March 1963, but those who were appointed to continue the work have done so in the spirit in which he initiated it, and in the direction he foreshadowed.

Consultative committee

Chairman Professor Sir Nevill Mott, F.R.S.
Professor C. C. Butler, F.R.S.
N. Clarke
Professor J. C. Gunn
Sister Saint Joan of Arc
Professor R. V. Jones, F.R.S.
W. K. Mace
J. M. Osborne
Dr C. W. W. Read
The Rev. R. G. Wickham

Organizer

Professor E. M. Rogers

Associate organizers

J. L. Lewis
E. J. Wenham

Assistant organizer

D. W. Harding

Area co-ordinators

Sister Saint Joan of Arc
Miss D. J. Alexander
Miss A. Lipson
B. R. Chapman
D. C. F. Chaundy
M. J. Elwell
L. Ennever
R. C. Hardwick
R. D. Harrison
V. J. Long
E. W. Tapper
C. L. Williams

Examinations

Dr H. F. Boulind

Schools collaborating in the trials

The Abbey School, Ramsey
Ashfield County Secondary School

Banbury Grammar School
Baptist Mills School, Bristol
Barnard Castle School
Bartley Green Girls' Grammar School
Batley Grammar School for Boys
Batley High School for Boys
St Brendan's College, Bristol
Bridgnorth Secondary Modern School for Boys
Bromsgrove County High School

Calder High School, Mytholmroyd
Chatham House Grammar School, Ramsgate

Dame Allan's School, Newcastle
The Downs School, Colwall

Elliott School, Putney
Erith County Grammar School

Forest Hill School

Godolphin and Latymer School
The Grammar School for Boys, Cambridge

Harborne Hill School, Birmingham
Hinckley Grammar School
Huntingdon Grammar School

King's College School
Kynaston School, London, N.W.8

Maidstone Grammar School
Malvern College
Manchester Grammar School
March Grammar School
Marsh Hill Boys' Technical School, Birmingham
Mill Mount Grammar School, York
Moseley Grammar School for Boys, Birmingham

Orton Longueville Grammar School

Rainsford County Secondary School, Chelmsford
Redland High School for Girls, Bristol
La Retraite High School, Bristol
Rhodesway Secondary Modern School, Bradford
Rickmansworth Grammar School

Sheldon Heath Comprehensive, Birmingham
Soham Grammar School
Sutton County Grammar School for Boys
Swavesey Village College
Sydenham School

Tottenham County School

Valley Gardens Modern School, Whitley Bay

Welwyn Garden City High School
Westminster School
Whitley Bay County Grammar School
City of Worcester Grammar School for Girls

The Nuffield Foundation Science Teaching Project and the organizers are grateful to the following for help and advice:

Dr G. J. Alder
R. Barr
N. D. N. Belham
D. Bryant
J. C. Cain
D. G. Carter
D. Chillingworth
A. Dalziel
G. W. Dorling
J. N. Emery
G. E. Foxcroft
A. Germani
K. M. Grayson
J. T. Jardine
C. W. Kearsey
D. Layton
R. Leigh
W. Llowarch
J. G. Mattock
E. L. Pye
W. Ritchie
D. W. Scott
M. S. Smith
Dr J. R. Spooner
R. Stone
M. Stewart
A. W. Grotter
G. W. Verow
A. F. Vyvyan-Robinson

The Association for Science Education
The Institute of Physics and Physical Society
The Physics Department at Imperial College, London
The Head Master and Council of Malvern College
The Principal and Governors of Worcester College of Education
The Esso Petroleum Company Ltd
Associated Electrical Industries
Loughborough College of Advanced Technology

The many members of the area teams who contributed so much to the early discussions

The project team acknowledges the initial help and inspiration derived from the work of the Physical Science Study Committee in the U.S.A. and the Scottish Education Department's Physics Project.

Organizer Professor E M Rogers
Associate organizers J L Lewis E J Wenham
Assistant organizer D W Harding
Author of this book Dr H F Boulind

Other Nuffield Physics publications

Teachers' guide I
Teachers' guide II
Teachers' guide III
Teachers' guide IV
Teachers' guide V

Guide to experiments I
Guide to experiments II
Guide to experiments III
Guide to experiments IV
Guide to experiments V

Guide to apparatus

Questions book I
Questions book II
Questions book III
Questions book IV
Questions book V

Optical instruments and ray diagrams