PHYSICS

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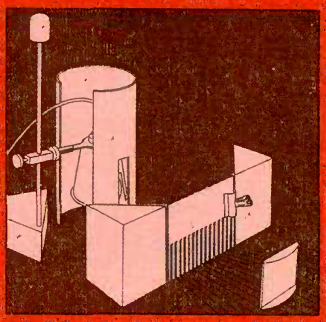

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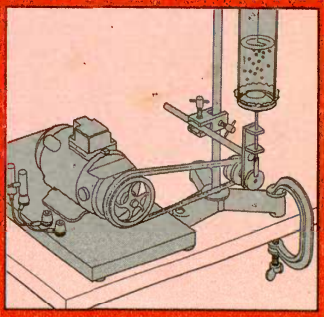
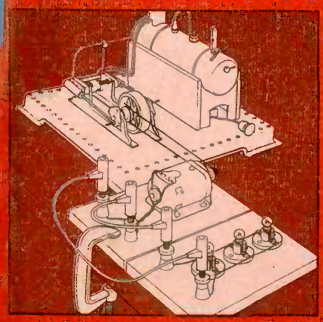
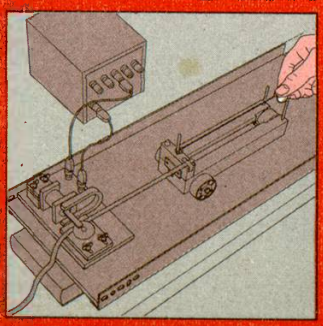
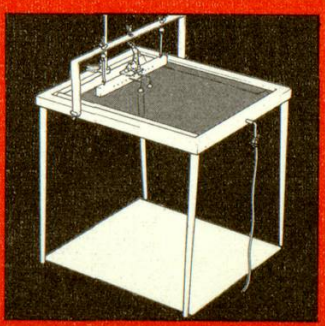








Nuffield Physics Guide to Apparatus

PGA 04217

Nuffield Physics
Guide to Apparatus

First published 1968

Longmans, Green and Co. Ltd,
London and Harlow.
Penguin Books Ltd,
Harmondsworth, Middlesex

Made and printed in Great Britain by
Western Printing Services Ltd,
Bristol

Set in Monotype Univers

Designed by Ivan and Robin Dodd

Foreword

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

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

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

To the extent that this initiative in curriculum development is already the common property of the science teaching profession, it is important that the current volumes should be thought of as contributions to a continuing process. The revision and renewal which 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

This guide includes details of the apparatus required for the Nuffield O-level Physics course. Following a statement of some general principles concerning apparatus, Section A is a list of the items necessary for the course, together with an indication of the quantity of each which is likely to be necessary for a class of thirty-two pupils. This section concludes with a list of some of the optional items to which reference is made during the course.

Included in the list are a number of kits of apparatus designed specially to meet the requirements of the course. The contents of these kits have been listed separately in Section B of the guide.

There is a series of comments on various important topics related to apparatus and equipment collected together in Section C of the guide.

The final section, D, includes lists of the apparatus needed for each year of the course.

Some general principles on apparatus

As a general statement of policy, it is desirable whenever possible to get apparatus into the hands of the pupils, to let them get the feel of science, to experience finding out for themselves. Experiment is important in physics and wherever possible an experiment should be done as a class experiment with the pupils working individually, in pairs, or at the most in groups of four.

There are two good reasons why this is not always practicable and on those occasions a demonstration should be shown instead. Sometimes the apparatus needed is too expensive (occasionally too delicate) for a school to have it in quantity and the experiment must necessarily be done by the teacher. The second reason is the time factor: if the pupils did every experiment themselves, we would never get through the course. Provided these considerations are borne in mind, we should in general aim at a class experiment; where it is not possible, a demonstration experiment should be done.

Only where a demonstration experiment is not possible should we resort to film. Films must not be allowed to become a substitute for live demonstrations or a cheap way to avoid buying apparatus. This policy – if possible class experiment, if not demonstration experiment, if not film – is of course very different from the German tradition, where the class experiment plays only a small part; it is equally different from the American PSSC scheme where for various reasons the middle stage of demonstration plays only a very small part.

This policy does condition the kind of apparatus that is needed. For the class experiment, the apparatus must be simple and inexpensive, in some cases so inexpensive that it is almost expendable. It must be commercially available and available at such a price that schools can afford to have it in large quantity. Clear indication will be given as to the quantity of each item necessary for a class of thirty-two pupils.

In addition to ensuring that the apparatus for class experiment is commercially available, the physics project will also make available drawings to enable teachers to make the apparatus themselves if they wish.* In some instances this is perfectly possible and money can be saved by this means. However, it should not be forgotten that making the apparatus is sometimes a very uneconomic use of a teacher's time.

The apparatus must of course be adequate for the purpose for which it is intended and the cost must be low enough, so that it can be used in quantity. Interchangeability is far less significant with class apparatus than it is for the demonstration apparatus discussed below.

* These apparatus drawings are available from the General Secretary, Association for Science Education, 52 Bateman Street, Cambridge.

For example, there is little point in ensuring that the rotor shaft in the electromagnetic kit can also be used as a support for the levers in the lever kit: in the long run this is not likely to be an economy and will not be followed as a general policy.

For demonstration apparatus, versatility, interchangeability, and a certain robustness are all essential. The lists that follow include basic general-purpose demonstration apparatus which is considered essential and it is assumed that every school that is efficient will be equipped with all the items.

Common sense must of course be applied to the interchangeability referred to above. If, for example, an amplifier and loudspeaker unit were included, they should not be such that they can only be used when detecting centimetre waves; the same amplifier unit should be usable when studying sound waves, in electromagnetic experiments, or any other demonstration experiment requiring such an amplifier. On the other hand, common sense would oppose using just one power pack to operate everything including the scaler, when it would be much more convenient for the scaler to have its own power supply built in.

A certain measure of standardization is considered desirable. There is already a widespread adoption of 4mm plugs and sockets on demonstration apparatus and it is advocated that standardization be also extended to coaxial connections and to such things as size of retort stand rods, retort stand bases, etc. Reference to these is made in the pages that follow.

Included in the lists are a number of General Kits for each year of the course. These contain a large variety of miscellaneous items which it is necessary for the teacher to have if the Nuffield course is to be taught in the manner intended. The teacher could certainly assemble these items himself, but his problem is time and it has been found particularly convenient to have all these items collected together for him. It is to be hoped these kits will continue to be available.

There are also lists of apparatus considered desirable but not essential. These items are optional: they are certainly desirable for more effective teaching, but where the authority concerned has to be content with a lower standard, they can be omitted.

It should be emphasized that these lists only include items necessary for an O-level course. On the other hand, the ultimate needs of A-level have been borne in mind in the development work and a large number of the items will be needed for A-level use.

Section A

Details of apparatus required

Details of apparatus

1 Materials kit

Quantity required:
1 kit per class. It contains sufficient for a class of 32 with 8 sets of each item (one per 4 pupils).

For details of contents see Section B, page 73.

This kit contains blocks of a variety of substances, the dimensions of which have been carefully chosen so that they are integral numbers of centimetres, which makes for ease of multiplication. It is important that no dimension should differ by more than 1mm from that specified.

See illustration on page 114.

2 Elastic materials kit

Quantity required:
1 kit per class. It contains sufficient for a class of 32.

For details of contents see Section B, page 74.

Some experiments with the kit are done individually, some with pupils working in pairs. Certain items in the kit, such as the expendable springs (item 2A) and the reels of copper wire (items 2B and 2C) must also be available as replacement items.

In the Nuffield trials, the expendable springs were used with the ends soldered. This type is desirable as there is otherwise a danger of the ends of the springs unwinding, but this does add to the expense.

3 Crystals kit

Quantity required:
1 kit per class of 32.

For details of contents see Section B, page 75.

The kit provides for some experiments which are demonstrations, some for pupils working in pairs, others for pupils in groups of four. There must be a large calcite crystal per class, so extra crystals must be available (item 3A) as replacement items. Extra supplies of polystyrene spheres (item 3B) should also be available.

4 Microbalance kit

Quantity required:
1 kit per class of 32. It contains sufficient for each pupil to have his own microbalance with some spares.

For details of contents see Section B, page 76.

Replacement packets of the expendable drinking straws (item 4A) should be available: care must be taken to see that they marry with the metal screws (item 4F) provided in the kit.

See illustration on page 115.

5 Lever kit

Quantity required:
1 kit per class of 32. It contains 16 sets enabling pupils to work in pairs, with some spares.

For details of contents see Section B, page 77.

See illustration on page 115.

6 Bristol pressure kit

Quantity required:
1 kit per class of 32. Some experiments in the kit are demonstrations; some provide for pupils working in groups of various sizes.

For details of contents see Section B, page 78.

7 Oil film kit

Quantity required:
1 kit per class of 32. It enables pupils to work individually, with some pieces of equipment shared among four pupils.

For details of contents see Section B, page 79. It should be noted that the special holders used in this kit require the hand lenses (item 24). It is important that the hand lenses obtained should match the holders. It is wise to purchase item 7 and item 24 from the same manufacturer. Thirty-two hand lenses are required for use with the kit when there is a class of 32.

Replacement reels of wire (2oz reel of steel wire, 0·003 inch diameter) and replacement packets of vegetable black should be available.

8 Bromine diffusion kit

Quantity required:
1 kit per school.

For details of contents see Section B, page 80.

The kit is used for demonstration purposes only, and consists of one set of apparatus with a supply of 1cm³ bromine capsules. Replacement bromine capsules (item 8A) should be available.

See illustration on page 118.

9 Malvern energy conversion kit

Quantity required:
1 per school.

The kit contains a variety of different units which can be assembled together to show energy conversion in many different forms. The recommendation is one kit per school for Year I. In Year II, it is helpful to have a duplication of some parts of the kit: for details see Section B, page 81, where the contents are listed. The items in the kit can all be purchased separately.

See illustration on page 122.

10 Year I general kit

Quantity required:
1 per class of 32. It contains a large variety of miscellaneous items which it is important for a school to have if the course is to be taught in the manner intended.

For details of contents see Section B, page 82. Certain items in the kit, such as the ball of cord (item 10A) and the packets of special graph paper (item 10B) should be available as replacement items.

11 Kinetic theory model kit

Quantity required:
1 per school. It is for demonstration purposes and contains one of each item.

For details, see Section B, page 83. The version used in the Nuffield trials was operated from the fractional horsepower motor (item 150). Some commercial versions incorporate their own motor or use the motor from the Malvern Energy Conversion Kit. All are satisfactory, provided the motor is strong enough and robust enough to withstand the vibration.

See illustration on page 116.

12 Two-dimensional kinetic model kit

Quantity required:
1 per class of 32. It contains 16 sets of apparatus, enabling pupils to work in pairs.

For details see Section B, page 84.

See illustration on page 116.

13 Vacuum pump

Quantity required:
1 per school.

This pump must be a mechanical rotary pump driven by an electric motor. (A filter pump is not a satisfactory substitute.) Either a single-stage or two-stage rotary pump would be satisfactory. If it is also to be used for A-level work, a single-stage rotary pump to which an oil diffusion pump can be attached is advantageous, but the oil diffusion pump is not required for the O-level course.

The pump should have either a needle valve or air inlet valve of some kind so that air can be let back into the apparatus without disconnecting it from the pump. The final outlet from the pump should be a metal tube of external diameter $\frac{1}{4}$in to which pressure tubing can conveniently be attached.

The motor should be supplied with electrical leads attached and clear instructions should always be provided with it giving precise instructions on oil filling.

14 E.H.T. power supply

Quantity required:
1 per school.

This should give a variable d.c. supply up to about 5,000 volts. The following general points should be incorporated in the unit:

i The supply must have an on-off switch and an indicator lamp.

ii The case should be earthed, but the output should be independent. This will enable either end to be earthed (i.e. the output could be −5,000 to 0, or 0 to +5,000 volts).

iii Power packs should have an independent 4mm earth socket on the front panel connected to the chassis and the third pin of the mains supply.

iv The output sockets should be the 4mm type advocated for all apparatus.

v For safety purposes there should be a built-in resistor limiting the short circuit output to 3mA.

vi The output should be smoothed. The ripple should not be more than 1 per cent.

vii All instruments should be such that they can be operated from 50 cycle, 200/240 volt a.c. mains.

viii A meter should be incorporated in the unit to give an indication of the voltage output.

ix An independent 6·3 volt a.c. output is a useful additional facility, but it must be independently wound.

See illustrations on pages 130 and 132.

15 H.T. power supply

Quantity required:
1 per school.

An H.T. power supply giving 0 to 250 or 300 volts d.c. output with an additional supply from 0 to about −25 volts d.c., both continuously variable. It should also give two 6·3 volt a.c. outputs for heating filaments.

General points:

i The d.c. outputs should both give about 60mA maximum current. Fuses should be incorporated for safety or preferably an automatic cut-out.

ii An on-off switch and indicator lamp should be fitted.

iii All instruments should be such that they can be operated from 50 cycles, 200/240 volt a.c. mains.

iv The output sockets should be the 4mm type.

v The output voltages need to be well smoothed to 1 per cent at 50mA, less at lower currents.

vi The case should be earthed. There should also be an independent earth socket on the front panel connected to the chassis and the third pin of the input voltage.

16 Radium source

Quantity required:
1 per school.

The source should be a single 5–10μC radium source. Official safety regulations must be complied with and only recommended sources should be used. The source is only used for demonstration purposes.

See illustration on page 130.

17 Spark counter

Quantity required:
1 per school.

This must be such that it can be operated with the E.H.T. power supply (item 14), and the radium source (item 16). It will be necessary to incorporate in the spark counter a capacitor capable of withstanding 5000 volts in order that the sparks can be clearly visible.

See illustration on page 130.

18 Expansion cloud chamber

Quantity required:
1 per school.

This should be simple in operation and if possible should operate with any type of alcohol (or even water).

See illustration on page 131.

19/1 CO_2 cylinder

Each school will require a 5lb CO_2 cylinder and a spare cylinder as well. Some schools may prefer to have a cylinder larger than 5lb; convenience is the deciding factor. This item provides solid carbon dioxide in small quantities when used with the dry ice attachment (item 19/2). The syphon type of cylinder is preferable, so that it does not have to be inverted.

Some of the cylinders available commercially are difficult to turn on or off by hand. Special spanner attachments are available from suppliers if this is found to be the case.

19/2 Dry ice attachment

An attachment to the CO_2 cylinder (item 19/1) to provide solid carbon dioxide in small quantities as and when it is required at various stages of the course.

See also Section C, page 154, for general comments on the supply of dry ice.

20 Domestic balance (5kg)

Quantity required:
1 per school.

This should be the domestic kitchen scales type (or parcel scale) with pan top. Any make can be used, provided it has a large, clear scale marked in kilograms.

21 Compact light source

Quantity required:
1 per school.

The requirement is for a very bright, very small source. It must therefore be a compact one. A suitable lamp is a tungsten iodine lamp operating at 12 volts and such a lamp is made by Atlas (their reference A1/215). It is a 100 watt lamp and therefore takes a current of just over 8 amps. It needs a special housing with two outlet windows on the front and side of the casing, and the lamp should be so placed that the filament is seen in one position sideways on, and in the other end on. It should be possible to close the apertures when not in use.

As the lamp housing is likely to get very hot in operation, it should be mounted on a suitable rod for attachment to a retort stand. The connecting leads to the lamp should not be soldered, as the solder is liable to melt, but should be secured by connecting terminals.

It is essential for a school to have a spare lamp available (item 21A).

See illustration on page 127.

22 Atom model

Quantity required:
1 per school.

This is a simple lattice model of spheres joined by loose springs so that the spheres can vibrate. The model used must be very flexible.

See illustration on page 118.

23 Microscopes

Quantity required:
8 per class, enabling pupils to work in groups of four.

Microscopes with fairly low power but large apertures are required. They will be used for looking at familiar objects, but above all for use with the smoke cells (Nuffield Apparatus Item 29). It is imperative that there be sufficient clearance between the stage and the objective to take these cells for use in the Brownian Motion experiment. The focal length of the objective should be between 10 and 30mm, preferably about 18mm, which is one of the standard values.

24 Hand lenses

Quantity required:
36 per class, which permits individual use by pupils and allows for some spares.

Any magnifying glasses of 5–7cm focal length would be adequate, but they must be of the type that can be used in the holders supplied with the oil film kit (item 7G).

Those used in the Nuffield trials were the type in black plastic cases containing two lenses which could be pivoted so that one or both were used together. These were found satisfactory.

25 Plastic measuring rules

Quantity required:
36 per class, which permits individual use by pupils and allows for some spares.

These special plastic measuring rules should be graduated in centimetres *only*. The graduations must start from one end of the scale and the total length should be just over 15cm.

See illustrations on pages 114 and 120.

26 Perspex containers

Quantity required:
16 per class, enabling pupils to work in pairs.

These Perspex containers should have internal dimensions 5cm × 5cm × 9cm.

See illustration on page 120.

27 Transformers

Quantity required:
8 per class.

These are general purpose transformers used for many experiments in different years. Outputs of 6 and 12 volts are essential up to a current of 6 amps, other tappings at 2, 4 and 8 volts are desirable. If a school has a low voltage supply, this will be suitable in place of these transformers. The recommended version used in trials and found satisfactory had 2, 4, 6, 8, and 12 volt tappings, all at 6 amps.

See illustration on page 123.

28 Diffusion cloud chambers (Taylor pattern)

Quantity required:
8 per class, enabling pupils to work in groups of four.

These are inexpensive continuous cloud chambers requiring small quantities of solid carbon dioxide (see item 19). Illuminants are also necessary (see item 47).

See illustration on page 130.

29 Whitley Bay smoke cells

Quantity required:
8 per class, enabling pupils to work in groups of four.

These smoke cells incorporate their own illuminant for ease of setting up. A small horizontal 'festoon' lamp illuminates smoke in a short vertical glass tube, closed with a cover slip. A horizontal glass rod serves as a cylindrical lens to form a 'line image' of the filament in the smoke. A low power microscope with medium aperture enables pupils to see smoke particles easily in that intensely illuminated region (see item 23). The actual cells should be clearly visible so that it is apparent to the pupil that they are looking at smoke particles.

See illustration on page 119.

30 Slotted bases

Quantity required:
16 per class, enabling pupils to work in pairs.

These bases have been specially designed to accept miscellaneous items such as boards, manometers, rulers, etc., and are for general use in the laboratory.

See illustrations on pages 121 and 127.

31/1 Weight hangers with slotted weights (10gm)

Quantity required:
16 per class, enabling pupils to work in pairs.

The simple weight hangers each weigh 10gm and included with them are nine 10gm weights. These weights are only accurate to within 5 per cent, but this is adequate for the experiments. They should be constructed in such a way that their weights do not fall off when in use.

31/2 Weight hangers with slotted weights (100gm)

Quantity required:
16 per class, enabling pupils to work in pairs.

The simple weight hangers each weigh 100gm and included with them are nine 100 gm weights. These need only be accurate to within 5 per cent. They should be constructed in such a way that the weights do not fall off when in use.

32 1kg weights

Quantity required:
16 per class, enabling pupils to work in pairs.

These should be the hexagonal type with rings so that they can be stacked on each other.

33 Paper scales

Quantity required:
1 per pupil.

These consist of sheets of strong paper with centimetre scales running the length of the sheet. These are cut up by the pupil so that he can stick them together to make a measuring tape 120cm long. Suggestions for measurement are also printed on the sheet.

As these are expendable, they should be supplied in packets of one hundred, or a gross, as convenient.

34 Variable inertia bar

Quantity required:
1 per school.

This consists of an arm, free to rotate when held in a boss attached to a retort stand, with equal masses on each end of the arm, whose position can be adjusted to change the moment of inertia. A falling

mass attached to the axle causes the arm to rotate with varying speeds depending on the moment of inertia.

See illustration on page 120.

35 S-hooks

Quantity required:
16 per class.

These simple lightweight hooks are needed to support the ring weights (items 32, 36 and 83) or the weight hangers (items 31/1 and 31/2). They are also convenient for joining expendable springs (item 2a) together.

36 1lb weights

Quantity required:
8 per class.

These 1lb masses can be of any type provided they have a ring.

37 1oz weights

Quantity required:
8 per class.

These 1oz masses should be the type with a small hole at the top so that the weights can be suspended by a thread. Alternatively they could have a ring, or hook, incorporated, to which the thread can be secured.

38 Single pulleys

Quantity required:
16 per class, enabling the pupils to work in pairs.

These pulleys must be lightweight and will have to carry up to 3kg.

39 Double pulleys

Quantity required:
16 per class, enabling the pupils to work in pairs.

They should be capable of carrying up to 3kg.

40 Single pulley on clamp

Quantity required:
16 per class, enabling the pupils to work in pairs.

The requirement is for a single pulley which can be rigidly attached either to the end of a bench or to a retort stand.

See illustration on page 121.

41 Evesham pressure apparatus

Quantity required:
1 per school.

An apparatus designed for connection to a water-filled 4ft manometer (item 6G) to demonstrate the dependence of pressure on force and area.

See illustration on page 117.

42 Lever arm balances

Quantity required:
8 per class of 32 pupils.

These must be of the single pan Butchart type. Two scales are desirable, one reading up to a maximum of 1kg and the other up to 250 or 300gm. The scales should be clear and the method of transferring from one to the other as simple as possible to avoid confusion for the relatively young children who will be using these balances.

See illustration on page 114.

43 Spring balances (1kg wt)

Quantity required:
16 per class of 32 pupils.

These should read up to 1kg weight and should be the cylindrical type.

44/1 G-clamps (4in)

Quantity required:
16 per class of 32 pupils.

44/2 G-clamps (2in)

Quantity required:
16 per class of 32 pupils.

45 Foot pump and adaptor

Quantity required:
1 per school.

A bicycle pump is not adequate for the experiment on weighing air or for the Boyle's Law experiment; an inexpensive foot pump should be used. It must necessarily have a valve attached and a suitable connector for pressure tubing.

See illustration on page 117.

46/1 Translucent screen

Quantity required:
1 per school.

A translucent screen is important for demonstration purposes. The size of screen which is desirable is 3ft high by 2ft wide. It should be supplied in a wooden frame with feet attached so that it can stand freely on a bench. Wide angle scattering of light is essential and architects' tracing linen has been found to be the most suitable material for this purpose.

46/2 Lamp for translucent screen

Schools will require a lamp for use with the translucent screen (item 46/1). Teachers will usually improvise their own, but some manufacturers supply a suitable lamp.

47 Illuminants

Quantity required:
8 per class of 32 pupils.

These illuminants will be used primarily in the ripple tank work (see item 90), but they should also be suitable for other experiments in the course. The lamps themselves are straight filament projection bulbs (12V, 24 or 36 watt) in a holder (which acts as a shield) and this holder should be attached to a rod long enough to project light from a point above the centre of the ripple tanks. The filament in the lamp will need to be parallel to the vibrating beam in the ripple tank.

See illustration on page 126.

48 Statistics frame

Quantity required:
1 per school.

This consists of a free-standing, square, vertical board with nine vertical slots into which circular brass blanks ($1\frac{1}{4}$in dia.) can be placed. It should be supplied complete with 36 blanks. The slots will take ordinary pennies.

49 Graph plotting board optional

See page 56, where details are given of some of the optional items.

50/1 Pairs of cylindrical magnets

Quantity required:
32 pairs for a class of 32.

It is essential that these magnets be cylindrical and made of alnico or similar material. Cobalt steel is not satisfactory, nor are magnets with square section. Those recommended are 25mm long by 8mm diameter.

50/2 Horseshoe magnets

Quantity required:
2 per class of 32.

These magnets should be alcomax. Those recommended are Eclipse Type C, $1\frac{1}{8}$ inches in height.

50/3 Magnet 'Eclipse Major'

Quantity required:
1 per school.

This magnet is one of the magnetron type and is a useful item of demonstration apparatus.

51 Malvern electrostatics kit

Quantity required:
1 per class.

For details of contents see Section B, page 85.

This kit contains sufficient for a class of 32 with 16 sets of each item, enabling pupils to work in pairs. In the earlier years of the course,

the complete kit is not required. Manufacturers can supply the kit broken down into smaller units. By the end of the course the whole kit will have been used.

A particular feature of the electroscopes is that the plate is detachable, making them electroscopes of very low capacity.

See illustration on page 124.

52 Worcester circuit board kit

Quantity required:
1 per class.

For details of contents see Section B, page 86.

This kit contains sufficient for a class of 32 with 16 sets of each item, enabling pupils to work in pairs. Replacement packets of lamps (item 52A) and replacement batteries (item 52B) should be available.

See illustration on page 124.

53 Worcester current balance kit

Quantity required:
1 per class.

For details of contents see Section B, page 87.

This kit is sufficient for a class of 32, and contains 16 sets of apparatus enabling pupils to work in pairs. Replacement packets of drinking straws (item 53A) should be available. It is also advisable to have a supply of spare magnets (item 53B): these are Alcomax III magnets, $\frac{5}{32}$in square and $\frac{1}{2}$in long.

See illustration on page 124.

54 Worcester gas voltameter kit

Quantity required:
1 per school.

For details of contents see Section B, page 88. It is for demonstration purposes and contains one set of apparatus.

55 Friction kit

Quantity required:
1 per school.

For details of contents see Section B, page 89. It is used for demonstration purposes.

56 Conductivity kit

Quantity required:
1 per class.

For details of contents see Section B, page 90. One kit is sufficient for a class of 32 and contains eight sets of each item.

57 Year II general kit

Quantity required:
1 per class.

For details of contents see Section B, page 91. One kit is sufficient for a class of 32. It contains a large variety of miscellaneous items which it is important for a school to have if the course is to be taught in the manner intended.

58 Radiation kit

Quantity required:
1 per class.

For details of contents see Section B, page 92. One kit is sufficient for a class of 32. Expendable aluminium leaf (item 58A) and packets of vegetable black (item 58B) should also be available for replacement.

59 L.T. variable voltage supply

Quantity required:
1 per school.

This is a general purpose item of demonstration equipment providing up to 25 volts both d.c. and a.c. at 8 amperes. Where a school has a built-in low voltage supply (for example, a Legg unit) capable of giving this current, this item is not essential, though it is strongly recommended as useful.

See illustrations on pages 125 and 127.

60/1 Van de Graaff generator

Quantity required:
1 per school.

A good Wimshurst is barely satisfactory as a substitute. Various types of Van de Graaff are available and any can be used. A range of accessories for use with the generator is a useful asset (see item 60/2).

60/2 Accessories for Van de Graaff generator

Optional accessories should be commercially available for use with the Van de Graaff generator (item 60/1), though many schools will be prepared to improvise their own. They should include a 'head of hair', and an insulating column with a suspension attached at the top with a light conducting sphere on the end. In addition a metal can, a neon lamp, a vibrating column of conducting spheres, a discharge point, and a discharge sphere can all be useful. A Hamilton Mill is a pleasant toy, but a doubtful asset.

61 Fine beam tube

Quantity required:
1 per school.

The fine beam tube is a large demonstration tube inside which a gas-focused electron beam is clearly visible. It must be capable of showing both electrostatic and magnetic deflection of the beam. An internal scale is not required and in fact adds confusion for many pupils. Item 15 (H.T. power supply) is available as the source of energy. Item 62 is also required for use with the tube.

See illustration on page 133.

62 Fine beam tube base

Quantity required:
1 per school.

A base, complete with coils, is needed for use with the fine beam tube, item 61.

See illustration on page 133.

63 Forces demonstration box

Quantity required:
1 per laboratory, as it needs to be fixed.

This piece of essential demonstration equipment provides experience of forces of 1lbwt, 1kgwt and 1 newton, and also of energy transfers of 1ftlbwt, 1kgwt metre and 1 joule. The front panel must carry engraved inscriptions with a clear statement about the forces and the energy changes, for the suggested wording see the Experiment Guides.

See illustration on page 121.

64 Oscilloscope

Quantity required:
1 per school.

This is a general purpose demonstration oscilloscope.

i It should incorporate at least a 4in flat-faced tube; a 5in tube is desirable.

ii It should provide a clear, bright trace.

iii The Y-amplifier should respond to d.c. and also to a.c. up to 1Mc/sec.

iv The Y-amplifier should be variable in steps and calibrated from, say, 100mV/cm to 50V/cm.

v The X-amplifier should be continuously variable.

vi The instrument should incorporate a calibrated time base with pre-set sweep speeds ranging from 10ms to 1μs per cm. There should also be a continuously variable control for intermediate speeds.

vii Good synchronization is essential.

viii All input sockets should be the 4mm type.

See illustration on page 134.

65 Metal plates with insulating handles

Quantity required:
1 pair per school.

A pair of brass discs, about 5 inches in diameter, fitted with insulating supports is required. The discs should have small brass pegs at the back to which crocodile clips can be attached to save attaching the clips to the edge of the plates themselves.

See illustration on page 132.

66 Neon lamp

Quantity required:
1 per school.

A mains operated neon lamp is suitable.

67 Bourdon gauge

Quantity required:
8 per school.

This gauge must be calibrated from 0 to 20lb/in^2 giving atmospheric pressure as approximately 15lb/in^2. The type which reads 0 at atmospheric pressure is not suitable. It should preferably be mounted on a stand, and one side should be transparent to show the working. The outlet tube should have an external diameter of $\frac{1}{4}$in to which the recommended size of pressure tubing can be attached. Manufacturers will need to remember that the gauges may be used in regions of high altitude where the pressure is very different from 15 lb/in^2. A convenient method of adjustment is therefore necessary.

See illustration on page 119.

68 Phototransistor

Quantity required:
1 per school.

The phototransistor should be mounted for convenience of handling. It requires a shielding cap with a small aperture.

69 High dispersion prism

Quantity required:
1 per school.

It should have a 2in face, at least.

70 Demonstration meters

Quantity required:
2 per school.

It is important that demonstration meters are available in schools and clearly visible to the whole class. Some schools will already have such meters and a range of shunts and bobbins, but the type with changeable scales is particularly recommended as it is then clear to the pupils precisely what is being read.

See also the note on electrical measuring instruments in Section C, page 142.

See illustration on page 135.

71 Dials for demonstration meters

These dials are for use with those demonstration meters (item 70) which require interchangeable scales. One dial for each of the following ranges is needed: two dials of 71/4 and 71/2 are needed in years IV and V respectively.

71/1 d.c. dial: 1amp
71/2 d.c. dial: 5amp
71/3 d.c. dial: 5 volts
71/4 d.c. dial: 2·5–0–2·5mA
71/5 a.c. dial: 5 volts
71/6 a.c. dial: 15 volts
71/7 a.c. dial: 5amp
71/8 a.c. dial: 1amp
71/9 a.c. dial: 300 volts
71/10 d.c. dial: 15 volts
71/11 d.c. dial: 300 volts
71/12 d.c. dial: 100mA

72 Lamps (12V, 24W)

Quantity required:
16 per school.

These are S.B.C. car headlamp bulbs.

73 Lamps (12V, 36W)

Quantity required:
8 per class.

These are S.B.C. car headlamp bulbs.

74 Lampholders (S.B.C.) on bases

Quantity required:
16 per school.

These lampholders take the S.B.C. lamps, items 72 and 73 above. They should be mounted on wood blocks and have 4mm terminal sockets.

75 Immersion heaters

Quantity required:
8 per class, enabling pupils to work in groups of four.

These special heaters are 12V, 50 watt and fit into the aluminium blocks, item 77. They must be such that they can be used for heating water as well as for heating the aluminium blocks and be capable of operation in air.

76 Aluminium containers

Quantity required:
8 per class, enabling pupils to work in groups of four.

These containers should be domestic cooking vessels without lids, and should have small side handles, not one long handle. They must be wide so that a thermometer in a litre of water will slant at a shallow angle, enabling it to be read in the water. A suitable size is 6in wide and 4in deep, which will take a litre of water.

77 Aluminium blocks

Quantity required:
8 per class, enabling pupils to work in groups of four.

These blocks must weigh 1kg and be drilled to accept an immersion heater (item 75) and a thermometer (item 542).

78 Variable a.c. supply ('Variac' type)

Quantity required:
1 per school.

The L.T. variable voltage supply (item 59) provides a continuously variable voltage supply 0–25 volts a.c. and d.c., at up to 8 amperes. This is satisfactory for all the recommended experiments, but in addition a variable voltage a.c. supply from 0 to 270 volts is an asset in any school laboratory. It should provide at least 2 amperes; the 8amp type is more versatile but costs over twice as much.

79 D.C. ammeters (0–1amp)

Quantity required:
16 per class, enabling pupils to work in pairs.

Any moving coil d.c. ammeter with a clear scale and a range of 0–1amp is satisfactory. Meters with a range 0–1·5amp will do, but are not as good as 0–1amp. Some schools, however, which are considering the needs of later work may prefer multi-range meters.

See also the general note on electrical measuring instruments in Section C, page 142.

80 D.C. voltmeters (0–5 volts)

Quantity required:
16 per class, enabling pupils to work in pairs.

Any moving coil d.c. voltmeter with a clear scale and a range of 0–5 volts is satisfactory. Moving iron instruments will *not* do. Meters with a range of 0–6 volts can be used, but meters of 0–10 volts are barely satisfactory.

See also the general note on electrical measuring instruments in Section C, page 142.

81 Newton spring balances (10N)

Quantity required:
8 per class.

These should be the cylindrical type similar to item 43, but calibrated in newtons up to 10 newton.

82 Iron flasks for freezing

Quantity required:
4 per class.

These should be cheap expendable flasks for filling with water, and such that they will break on freezing.

83 ½lb weights

Quantity required:
32 per class.

Any type is satisfactory provided it has a ring.

84 Wire strippers

Quantity required:
16 per class.

These should be similar to the type manufactured by Multicore Solder, Ltd., and suitable for cutting and stripping wire.

85 Demonstration spring balance (5kg)

Quantity required:
2 per school.

This should have a large dial scale (preferably 8 inches diameter) with a clear pointer visible at a distance.

86 Mounted glass plate

Quantity required:
1 per class.

This is a glass plate, at least 12 × 15in, preferably 15 × 18in, mounted in a wooden frame, and preferably with a black painted base.

87 Clapper bell in round flask

Quantity required:
1 per school.

This item consists of a 2-litre wide-mouthed round-bottomed flask (bolthead flask) with a rubber bung to fit. The bung has a glass tube through it for connection to the vacuum pump so that the air inside the flask can be removed. A brass rod ($\frac{3}{16}$in or $\frac{1}{4}$in dia.) also passes through the bung and supports a bell. The glass tube should have external diameter not less than 6mm and not more than 8mm so that the recommended pressure tubing can be attached. See Section C, page 144.

88 Large compression springs

Quantity required:
3 per class.

A suitable spring is made by Messrs Terry, reference 762/$\frac{3}{8}$in × 19 SWG, and is 12in long.

89 Water circuit board

Quantity required:
1 per school.

This is an item of demonstration apparatus for showing water circulating around a circuit of glass or transparent plastic tubing. It should incorporate a motor, operating from voltages up to 12 volts, and which pumps the water round the circuit. There must be some form of indicating device to show the change in 'current' as the pressure increases. At one point the circuit should divide so that a change in 'effective resistance' is possible. There should also be a manometer arrangement to demonstrate the change in pressure. As this manometer is not required in the early stages, only in later parts of the course, it must be possible to disconnect it from use.

See illustration on page 125.

90 Ripple tank kit

Quantity required:
1 kit per laboratory.

For details of contents see Section B, page 93.

This kit is sufficient for a class of 32 and contains 8 ripple tank frames and accessories so that pupils can work in groups of four. The accessories should all be boxed together in a separate package and not with the individual ripple tanks.

See illustration on page 126.

91 Pinhole camera kit

Quantity required:
1 per class.

For details of contents see Section B, page 94.

This kit is sufficient for a class of 32 and contains 32 sets of apparatus, sufficient for pupils to work individually. It does not include the lenses (item 112) which are necessary for use with the kit.

92 Westminster electromagnetic kit

Quantity required:
1 per class.

For details of contents see Section B, page 95.

This kit is sufficient for a class of 32. It contains 16 sets of apparatus, enabling pupils to work in pairs.

See illustration on page 125.

93 Smoke box kit

Quantity required:
1 per school.

For details of contents see Section B, page 96.

This kit consists of demonstration apparatus and therefore includes one set of items.

94 Kit for ray optics

Quantity required:
1 per class.

For details of contents see Section B, page 97.

This kit contains 16 sets of apparatus, enabling pupils to work in pairs.

See illustration on page 126.

95 Edinburgh CO_2 pucks kit

Quantity required:
1 per school.

For details of contents, see Section B, page 98.

This kit consists of demonstration apparatus.

See illustration on page 123.

96 Kit for particle model of refraction

Quantity required:
1 per class.

For details of contents see Section B, page 99.

This kit includes 8 sets of apparatus so that the pupils can work in groups of four.

97 Double slits kit

Quantity required:
1 per class.

For details of contents see Section B, page 100.

This kit provides the wherewithal to enable pupils to make their own double slits.

98 Reels of bare eureka wire SWG 28

Quantity required:
8 2oz reels per class.

This eureka wire must be SWG 28 and is needed in the power line experiments.

99 Power line terminal rods

Quantity required:
16 per class of 32, enabling pupils to work in groups of four.

These rods for use in the power line experiments are made from $\frac{3}{8}$in dowel, cut to 4in lengths, with two terminals mounted on each.

100/1 Rectangular plastic tanks

Quantity required:
8 per class, enabling pupils to work in groups of four.

These are used for experiments in ray optics. Plastic 'lunch' boxes, size $7\frac{1}{2}$in × $4\frac{1}{2}$in × 3in deep are suitable. The bottom should be painted white *internally* using a flat undercoat.

100/2 Large rectangular transparent tank

Quantity required:
1 per school.

This tank must be transparent and can be made either of Perspex or glass. It must be jointed to hold water. It need not be wide from front to back, 3 inches would suffice. The height should be about 8 inches and the length about 2 feet: a foot is too short; three feet would be good, but expensive. A wooden block for generating water waves should be provided with the tank.

See illustration on page 128.

101 Large Slinky

Quantity required:
1 per school.

This should be 3 inches in diameter and at least $4\frac{1}{2}$ inches in length when fully closed.

102 White screen

Quantity required:
1 per school.

The requirement is a simple hardboard screen, painted white. It should be at least 18 inches square. It should be possible to fit it to a retort stand and also into a pair of slotted bases (item 30).

103 Bicycle dynamo assembly

Quantity required:
1 per school.

This assembly enables a bicycle dynamo to be driven by hand at a low speed to show slow a.c. on an oscilloscope or meter. It should also be geared so that it can run faster to light a lamp. A perfect sine wave could be obtained with a specially designed dynamo, but there is an advantage here in using a simple bicycle dynamo with which pupils are familiar.

See illustration on page 134.

104 Low voltage power units

Quantity required:
16 per class, enabling pupils to work in pairs.

These special low voltage units have an output of 1 volt d.c., and 1 and 2 volts a.c. at up to 6 or 8amp. They are for use with the experiments with the Westminster electromagnetic kit (item 92). The recommended version is mains operated. Some authorities prefer to have units which operate from 12 volts a.c. and these are also available from some suppliers.

See illustration on page 125.

105/1 Hand stroboscopes

Quantity required:
32 per class as it is essential for each pupil to have one.

They consist of hardwood discs with twelve slots cut in them mounted on a suitable handle. Those used in trials had wooden handles and the discs were secured with screws and washers. An alternative version with metal handles has an advantage in providing a better bearing, but is a little more costly.

105/2 Masking tape

Quantity required:
4 reels per class.

The black adhesive masking tape is used for masking the slits of the hand stroboscopes (item 105/1) in order to vary the number of slits.

106/1 Dynamics trolleys

Quantity required:
32 per class.

It is essential they are robust trolleys using wheels with good bearings.

See illustration on page 123.

106/2 Elastic cords for accelerating trolleys

Quantity required:
96 per class.

The elastic cords are 7in long and have eyelets attached to the ends. They are used for the acceleration of the dynamics trolleys (item 106/1).

See illustration on page 123.

107 Runways

Quantity required:
16 per class.

These are essential for trolley experiments. They are made from blockboard (either 8ft × 1ft or 6ft × 1ft, depending on laboratory space available) with sides of metal angle (for example, Dexion or Handy Angle).

See illustration on page 123.

108/1 Tickertape vibrators

Quantity required:
16 per class.

Although two types have been used in the trials – a.c. vibrators requiring about 6 volts, and d.c. vibrators requiring about 4 volts – the a.c. vibrators at 6 volts are recommended for school use. Vibrators operating at 12 volts are also satisfactory.

See illustration on page 123.

108/2 Carbon paper discs

For use with the tickertape vibrators (item 108/1).

108/3 Rolls of tickertape (plain)

For use with tickertape vibrators. Two types should be made available, plain and gummed (see item 108/4).

108/4 Rolls of tickertape (gummed)

The same as item 108/3, but gummed on one side to assist pupils in making charts

109 Boyle's Law apparatus

Quantity required:
1 per school.

This item is for demonstration use and consists of an air space trapped in a wide glass tube by oil from a reservoir. It is essential that the volume is clearly visible to a class 25ft away, for which reason capillary tubes with mercury, as used in some traditional apparatus, are unsuitable. The pressure is read directly by a Bourdon gauge calibrated so that atmospheric pressure reads approximately 15lb/in^2. The type of gauge with atmospheric pressure reading 0 is not satisfactory. The gauge should read up to at least 45lb/in^2. The pressure is raised using the foot pump (item 45).

See illustration on page 117.

110 Tubes for 'guinea and feather' experiment

Quantity required:
8 per class, enabling pupils to work in groups of four.

These glass tubes, 24 inches by 2 inches in diameter, are supplied complete with bungs with tubes, plain bungs, and lengths of pressure tubing for connection to the vacuum pump (item 13). See Section C, page 144, for the recommendations of size of tubing.

111 60° prisms

Quantity required:
16 per class, enabling pupils to work in pairs.

The faces should be at least $1\frac{1}{2} \times 1\frac{1}{2}$in. They need not be optically worked.

112 Lenses (+7D)

Quantity required:
32 per class, enabling pupils to work individually.

These can be plano-convex spherical lenses or meniscus lenses. They must be +7D. The diameter recommended is 50mm, but other diameters will of course be suitable. For example, 48mm lenses will perform as well. Whatever lenses are supplied should fit the holders mentioned in item 115.

These lenses are required for use with the pinhole camera kit (item 91) and in other experiments.

113/1 Plano-convex lenses (+14D)

Quantity required:
16 per class, enabling pupils to work in pairs.

They should be +14D, 25mm diameter plano-convex lenses. Double convex lenses are not so satisfactory.

These lenses are used as eyepieces for the telescope and microscope. They must fit the holders in item 115.

113/2 Plano-convex lenses (+20D)

Quantity required:
16 per class, enabling pupils to work in pairs.

These *must* be plano-convex spherical lenses of +20D and 25mm in diameter.

These lenses are used as microscope objectives and they must fit the holders in item 115.

113/3 Plano-convex lenses (+2·5D)

Quantity required:
16 per class, enabling pupils to work in pairs.

These should be plano-convex spherical or meniscus lenses of +2·5D. Diameter recommended is 50mm, but see also the note in item 112.

These lenses are used as telescope objectives and they must fit the holders in item 115.

114 Model eye kit

Quantity required:
1 per school.

For details of contents see Section B, page 101.

One kit is sufficient for demonstration and contains a 5-litre round-bottomed flask and the necessary lenses for a demonstration of a model eye.

See illustration on page 127.

115 Telescope mount

Quantity required:
16 per class, enabling pupils to work in pairs.

The lens holders and mount can be of any simple design that enables pupils to set up the telescope easily and use it comfortably at eye level. (It must not have scales on it for measurement as this is a distraction.) Squatting or bending over to look through a telescope at bench level puts the observer at a considerable disadvantage. Therefore the rod, or other mount used to carry the telescope lenses, should have a side rod projecting from its centre to enable it to be clamped by a boss to a tall retort stand. The mount should be at least 30in long.

The lens holders should accept the sizes of lenses given in items 113/1, 113/2 and 113/3. There should be three lens holders per mount, two should take lenses 25mm in diameter and one a lens 50mm in diameter. The holders should also be capable of taking vertical cards. They should slide easily along the rod or mount so that the pupil can easily adjust the lens positions in a half-darkened room. The lens holders themselves should accept lenses easily and hold them firmly with their axes parallel to the slide.

116 Plane mirrors

Quantity required:
16 per class, enabling pupils to work in pairs.

These should be approximately 5cm × 15cm.

117 Holders for mirrors

Quantity required:
16 per class, enabling pupils to work in pairs.

These holders are simple blocks of wood with a slit cut in the side to take the side of the mirror.

118 Cylindrical concave mirrors

Quantity required:
4 per class.

Stainless steel mirrors are advised. They are almost as good as glass ones, and are not so easily broken. They should be 6 to 8 inches in diameter, and 1 inch or more wide.

119 Flexible curtain rail

Quantity required:
1 per school.

This should be at least a 6ft length of flexible plastic curtain rail. It is used as a track for rolling steel ball bearings: it must have a symmetrical cross section to prevent the ball falling off one side. An 8ft length is preferable.

120 Hack-saw blades

Quantity required:
16 per class enabling pupils to work in pairs.

These are required for introductory experiments with stroboscopes. All that is needed is a thin strip of metal similar to a hack-saw blade and of similar dimensions.

121 2in metal strips as jaws

Quantity required:
32 per class, enabling pupils to work in pairs, each pair requiring two strips.

These are necessary as jaws for clamping the metal blades in item 120. They should be made of $\frac{1}{8}$in metal strip.

122 Magnetization kit

Quantity required:
1 per class.

For details of contents see Section B, page 102.

123 Launching ramp

Quantity required:
1 per school.

A simple wooden launching ramp for use in the 'Monkey and Hunter' experiment. A marble is placed on the ramp and projected along it using the spring mechanism of one of the dynamics trolleys (item 106/1).

124/1 Lens holder for 5cm diameter lens

Quantity required:
1 per school.

A lens holder capable of taking a 50mm or 48mm lens. It should be attached to a 6in rod, so that it can be held by a retort stand and boss.

124/2 Lens holder for 10cm diameter lens

Quantity required:
1 per school.

This is similar to item 124/1, except that the holder should be large enough and strong enough to hold a lens 10cm or 4 inches in diameter (for example, the plano-convex condenser lens, item 93B).

125 Skelton variable focus eye

Quantity required:
1 per school.

A simple apparatus using a cylindrical gelatine lens, the curvature of which can be varied, to demonstrate the principles of accommodation in the eye.

See illustration on page 127.

126 Plastic waves

Quantity required:
2 per school.

These should be made of clear Perspex sheet (preferably 5ft long) with engraved sine curves along their lengths. The ends should have a hole for supporting the Perspex, say, $\frac{3}{8}$ inch diameter.

See illustration on page 128.

127 Coil (120 turns)

Quantity required:
2 per class.

These should be fitted with sockets which will take 4mm plugs and the coils must be on formers which will go over the C-cores used in the Westminster electromagnetic kit, item 92. A centre tap giving 0–60–120 turns is an advantage.

128 Coil (2400 turns)

Quantity required:
2 per class.

These should be the same as item 127, but with 2400 turns.

129 Plate glass plates for interference

Quantity required:
16 pairs per school, enabling pupils to work in groups of two.

A convenient size for these plates is 8 × 1in. They are used for showing interference fringes in a wedge, formed by the plates when a sheet of tissue paper is inserted between the pair of plates at one end. They do not need to have high optical quality, but they must be good enough for almost straight fringes to be seen.

130/1 Scaler

Quantity required:
1 per school.

This should include two dekatron tubes and a mechanical register and should be such that it can be operated from a halogen quenched GM tube. It should incorporate the necessary voltage supply for the GM tube, but as only halogen quenched tubes will be used, this need not exceed about 450 volts. It should also be possible to use the scaler with a solid state detector for the detection of alpha particles and it should incorporate the necessary connections for this. A P.E.T. connection is required for the input connection from the GM tube as this has now become standard in schools.

The scaler will also be used as a timing device and it must therefore incorporate a 1000c/s oscillator for direct internal feed to the dekatron tubes. The necessary switches must be included so that the timing can be started and stopped either by making or breaking a circuit.

The photodiodes necessary for the switching in timing experiments are included as item 130/2. The GM tube holder for use with the scaler is included as item 130/3, and the solid state detector and pre-amplifier as item 130/4.

See illustration on page 131.

130/2 Photodiode assembly with light source

Quantity required:
4 per school, two for use and two as essential spares.

The photodiodes are illuminated by the pre-focus bulbs and used as switches for the scaler (item 130/1). Both the photodiodes and the bulb should be mounted so that they can conveniently be supported from retort stands or other holders.

130/3 GM tube holder

Quantity required:
1 per school.

A suitable holder for the GM tubes, items 130/5 and 130/6, complete with lead for connection to the P.E.T. socket on the scaler.

130/4 Solid state detector and pre-amplifier

Quantity required:
1 per school.

The solid state detector and pre-amplifier enable the scaler to be used for counting alpha radiation.

130/5 Thin window GM tube

Quantity required:
1 per school, though a spare might be an advantage.

The tube should be a thin end window halogen quenched tube capable of detecting beta as well as gamma radiation. It should have an operating voltage around 400 volts.

130/6 Gamma GM tube

Quantity required:
1 per school.

Similar to item 130/5, but without the thin end window so that it can be used for gamma detection, but not beta.

131 Year IV general kit

Quantity required:
1 per class.

For details of contents see Section B, page 103.

It contains a variety of miscellaneous items which it is important for a school to have if the course is to be taught in the manner intended.

132 Year IV electrical general kit

Quantity required:
1 per class.

For details of contents see Section B, page 104.

This contains a variety of miscellaneous electrical items, not included in the Year IV General Kit, item 131, which it is important for a school to have if the course is to be taught in the manner intended. They are brought together in a single kit as a matter of convenience for the teacher and some manufacturers have made this kit available. On the other hand, many of the items will be more cheaply obtained from a supplier such as Radiospares and teachers may prefer to purchase them direct.

133 Camera

Quantity required
1 per school.

An ordinary camera, suitable for use with 35mm or 120 film, can be used for the experiments specified. Developing equipment will be necessary and this is discussed in Section C of this volume, page 150. The best technique for developing films is that produced by Kodak Limited, in association with the Nuffield Physics Project (see page 151); for this, any ordinary camera which will take a 35mm 20 exposure film is suitable. A Polaroid Land Camera is a luxury that may replace the ordinary camera where funds permit, but it has the disadvantage of producing only one print from one exposure.

See illustration on page 123.

134/1 Motor driven stroboscope (synchronous)

Quantity required:
1 per school.

This motor should be a 240V, 50c/s mains synchronous motor giving 300 r.p.m. It should be mounted on a convenient rod which can be attached to a retort stand and should be supplied with two light rotating discs, one with five slits and the other with six.

134/2 Xenon flasher optional

See page 56, where details are given of some of the optional items.

See illustration on page 123.

135 Demonstration diode

Quantity required:
1 per school.

The diode should have a directly heated tungsten filament which can be operated from 6·3 volts. The tube should be large enough so that the inside is clearly visible and the filament can be seen glowing.

136 Maltese cross tube

Quantity required:
1 per school.

This should be a large demonstration unit similar to the demonstration diode (item 135). It should incorporate a directly heated tungsten filament, capable of operation from 6·3 volts. There should be a perforated anode and a Maltese cross inside the tube so that a sharp shadow is cast on the end of the tube by the electron beam. It should also be possible to get a direct shadow from the light from the bright filament in order to show that the light shadow is undeflected, whereas the electron beam is deflected, by a magnetic field.

See illustration on page 133.

137 Perrin tube optional

See page 56, where details are given of the optional items.

138 Deflection tube

Quantity required:
1 per school.

This should have a directly heated tungsten filament capable of operation from 6·3 volts. It should have an inclined mica plate inside so that the electron beam is clearly visible. Also included within the tube are plates for electrostatic deflection of the beam. Magnetic deflection of the beam can be produced by using the coils, item 139.

See illustration on page 133.

139 Set of coils and supports

Quantity required:
1 per school.

The coils are used for producing a magnetic field to deflect the electron beam when a current is passed through them. They should have suitable means of support for use with the tubes, items 135, 136, 137, and 138 above.

140 Stand for tubes

Quantity required:
1 per school.

It is imperative to have a satisfactory stand for use with the tubes, items 135, 136, 137, and 138, so that they can be easily set up in the class room for demonstration purposes without danger of the tubes getting broken.

See illustration on page 133.

141 Demonstration triode optional

See page 56, where details are given of the optional items.

142 Macro-Millikan apparatus

Quantity required:
1 per school.

The purpose of the experiment, for which this apparatus is used, is to show that there is a force on a small charged conducting sphere placed between two parallel plates when a high potential difference is maintained between them.

143 Pair of Bernoulli tubes

Quantity required:
1 pair per school.

One consists of a 50cm length of glass tubing with T-junctions 10cm, 25cm, and 40cm from one end. The outlet at each T-junction should be connected by rubber tubing to a 30cm glass tube. The second tube should have identical overall dimensions, but the main tube should be reduced over a length of 10cm at the middle to a much smaller bore.

144 Demountable discharge tube for positive rays optional

See page 56, where details are given of the optional items.

145 Demonstration thermometer

Quantity required:
1 per school.

In certain demonstration experiments on heat exchanges, it is essential for pupils to be able to see the temperature change and not merely to be told about it by the teacher reading a mercury-in-glass thermometer. A thermometer with a dial is therefore necessary. Mercury-in-steel dial thermometers are ideal, but expensive. Bimetallic thermometers are satisfactory. The range —20°C to 120°C would be ideal; 0°C to 80°C can be used.

146 Inertia balance kit

Quantity required:
1 per class of 32. It contains 16 sets of apparatus enabling pupils to work in pairs.

For details of contents see Section B, page 105.

147 Demountable transformer kit

Quantity required:
1 per school.

The transformer is used for demonstration purposes. The kit includes a basic core with a series of coils for use with it.

For details of contents see Section B, page 106.

See illustration on page 135.

148 Syringe kit

Quantity required:
1 per school (unless purchased as separate items – see 148/1, 148/2, 148/3).

For details of contents see Section B, page 107.

This kit includes a 100ml glass syringe, as developed and used in the Nuffield Chemistry Project, rubber caps for fitting over the end of the syringe and an inexpensive hypodermic syringe for injecting small quantities of water (0·1ml) through the rubber cap into the large

syringe. These items are available as a single kit for the convenience of teachers. If they buy the syringe separately, they may find they have not got the right size of cap to fit over the end. However, the items can be purchased separately if this is preferred (see items 148/1, 148/2, 148/3).

For the physics experiments with the syringe, there is no need for it to have a tap.

148/1 Glass syringe

Quantity required:
1 per school (unless the complete kit, item 148, has been purchased).

This glass syringe is as used in the Nuffield Chemistry Project. There is no need for a tap in the version used in the Physics programme.

148/2 Rubber caps

Quantity required:
12 per school, which allows for plenty of spares.

These caps are included in the complete kit, item 148, but as a matter of convenience are available separately.

148/3 Hypodermic syringe

Quantity required:
2 per school, one for use and one spare.

This should be inexpensive and is merely required for injecting small quantities of water (0·1ml) through the rubber caps (item 148/2) into the main syringe (item 148/1).

149 Electric field apparatus

Quantity required:
1 per school.

This device, connected to an E.H.T. supply, is used to show electric fields in a similar way to iron filings showing magnetic fields.

See illustration on page 132.

150 Fractional horse power motor

Quantity required:
1 per school.

The type of motor recommended is a 12 volt d.c. shunt wound motor, about $\frac{1}{16}$ h.p., maximum speed 3000 r.p.m., with separate leads for field and armature.

The motor should be available mounted on a suitable baseboard. The design of mount should be such that a gear box can be added if required.

The motor should also be available unmounted, so that teachers can mount it themselves.

See illustration on page 116.

151 Rotating disc for fhp motor

Quantity required:
1 per school.

An 8in black disc with a single white radial arrow painted on it (approximately $\frac{1}{4}$in thick), which can be connected to the fractional horse power motor (item 150). It is used for introducing the ideas of a stroboscope.

152 Rotating sphere attachment

Quantity required:
1 per school.

The requirement is for some arrangement to rotate a polystyrene sphere in a circle of diameter 4 to 6in at slow speed. Some teachers will happily improvise this themselves. The rotating sphere can conveniently be driven with the fractional horse power motor (item 150) with a gear box attached to it, which reduces the speed down to approximately 1 revolution per sec. Such attachments to item 150 are commercially available.

153 Copper voltameters

Quantity required:
3 per school.

These can be of the conventional type long used in schools.

154/1 Turntable

Quantity required:
1 per school.

A gramophone turntable with variable speed can be used for the circular motion experiments in year V. But the turntable specially designed for the Nuffield course is a versatile item which can be used for a large variety of experiments, both at O-level and A-level. It can conveniently be driven through a gear box from the fractional horse power motor (item 150).

See illustration on page 136.

154/2 Truck attachment

Quantity required:
1 per school.

A simple attachment to the turntable with a truck, radial railway track and spring for investigating circular motion in Year V.

See illustration on page 136.

154/3 Small motor on base plate

Quantity required:
1 per school.

An inexpensive motor mounted on a base plate with a worm gearing to enable a sphere to rotate very slowly. This is useful for a model in Year V to show planetary motion, it should be battery operated and should be such that it can be attached to the turntable.

155 Small electric motors

Quantity required:
16 per class.

These are low cost d.c. motors operating at 2 to 6 volts. Motors as in the Malvern energy conversions kit (item 9A – see Section B, page 81) are very satisfactory.

156 Diodes and holders

Quantity required:
8 per class.

These should be the EA 50 type which can be operated at very low voltages.

157 Microphones

Quantity required:
8 per class.

The requirement is for a simple inexpensive microphone which can be used in connection with the class oscilloscope (item 158). It needs to have a high enough output to be able to show the voice waveform on the oscilloscope.

158 Class oscilloscopes

Quantity required:
8 per class.

The requirement is for a simple inexpensive oscilloscope for class use. The oscilloscope is such a widely used instrument that it is considered very desirable to have a simple version enabling pupils to handle it themselves during the course. To keep the cost down, it should be confined to basic requirements as follows:

i A $2\frac{3}{4}$in minimum diameter tube with a medium persistence screen.

ii A Y-amplifier with maximum sensitivity 1cm per volt and minimum sensitivity to display 6 volt r.m.s. sine wave. The frequency response should be d.c. to 10kc/s.

iii It must be possible to couple d.c. to the Y-plates and to get a deflection so that the oscilloscope can be used as a voltmeter.

iv The sweep generator on the X-plates should be variable from 1 sweep per second to 1000 sweeps per second. It is desirable, but not essential, to be able to switch off the sweep generator. Suppression of the spot during fly-back is desirable.

v Synchronization must be very good and preferably automatic.

vi 4mm socket terminals should be used for the Y-input. It would be advantageous if neither terminal were connected to the mains earth wire provided that there is adequate safety.

vii The controls should be as few and as simple as possible and all should be clearly labelled. The minimum list is probably: Brilliance, Focus, Sweep Speed (coarse and fine if necessary), Y-shift, Y-gain.

viii Improvements to this specification which increase the complexity of operation or raise the cost appreciably are undesirable.

The one exception is an X-input socket on the back of the instrument. In that position; it will not confuse young pupils, it adds very little to the cost, and it is an extra facility which some teachers welcome.

See illustration on page 135.

159 Air rifle

Quantity required:
1 per school.

A B.S.A. 'Merlin' air rifle is suitable for this. This will require mounting on a board. This can be done by the teacher. Some manufacturers supply it already mounted on an 8ft board, complete with two 'circuit breaker' mounts, positioned 1 metre apart on the board, and suitable railway track for use with an O gauge railway truck for momentum experiments to find the speed of the air pellet.

160/1 Demonstration trolleys optional

See page 57, where details are given of the optional items.

160/2 Meter attachment for demonstration trolley optional

See page 57, where details are given of the optional items.

161 Gantry for CO_2 pucks kit

Quantity required:
1 per school.

It is used for supporting a stroboscope and camera over the glass plate in the CO_2 pucks kit. For convenience it should be easily demountable.

See illustration on page 123.

162 Lampholder (BC) on base

Quantity required:
2 per school.

The BC batten type lampholder is fixed to the base which has facilities for 4mm plugs. It is a potentially dangerous item as it will be used with the a.c. mains, but it is only used for demonstration purposes by the teacher.

163 Cardboard tubes

Quantity required:
16 per class.

Cardboard tubes similar to those used for the storage of wallcharts can be used. They should be 2 inches in diameter and 30 inches long.

164 Cardboard cups

Quantity required:
16 per class.

Any paper cups, or the disposable plastic cups such as those used in automatic drink vending machines, are suitable. They are used to collect lead shot in the experiment on J and are recommended because of their low thermal capacity.

165 Air blower

Quantity required:
1 per school.

An air blower is required for experiments on the Bernoulli effect. A vacuum cleaner with flexible hose, or a hair dryer, can be used.

166 Constant pressure apparatus

Quantity required:
1 per school.

The traditional device for providing a constant head of water.

167 Water rocket

Quantity required:
1 per school.

A toy water rocket which is partially filled with water, pumped up with air and released.

168 CO_2 capsule rocket optional

See page 57, where details are given of optional items.

169 Large magnetic pucks

Quantity required:
4 per school, in addition to the two already included in the Edinburgh CO_2 pucks kit.

These should be the same as in the Edinburgh CO_2 pucks kit (item 95).

170 Low frequency a.c. generator

Quantity required:
8 per school.

A form of converter, using a smooth d.c. input from an accumulator or battery, to give a very low frequency a.c. output. One satisfactory version is driven by a handle and provides one cycle of a.c. across the output terminals each time the handle is turned. It can also be driven by the motor from the Malvern Energy Conversion Kit (item 9A).

The peak voltage of the a.c. must not depend on the speed of turning. The waveform should preferably be sinusoidal, but a triangular waveform will do. A square waveform is not satisfactory.

See illustrations on page 135.

171 Photographic accessories kit

Quantity required:
1 per school.

For details of contents, see Section B, page 108. See also page 150 in Section C, where photographic techniques are discussed.

See illustration on page 129.

172 Centripetal force kit

Quantity required:
1 per school.

The kit contains sufficient to enable the pupils to work in pairs.

For details of contents see Section B, page 109.

173 Malvern current balance kit

Quantity required:
1 per school.

This is a demonstration item for measuring the field inside two Helmholtz coils. It can be used with the fine beam tube (item 61) and the coils (item 139). It is essential equipment for the measurement of e/m for electrons.

For details of contents see Section B, page 110.

See illustration on page 173.

174 Collision in two dimensions kit optional

See page 57, where details are given of optional items.

175 60° isometric grid graph paper

Quantity required:
1 packet per school. Each pupil will require a sheet of this triangular graph paper.

176 12 volt battery

Quantity required:
4 per school.

Either a car battery or a battery of Nife cells is suitable. It must be possible to tap off intermediate voltages. Although 4 are specified, some schools may prefer to have 8 such batteries to avoid taking two experiments off one battery.

177 Lamps (12V, 6W)

Quantity required:
16 per school.

These should be S.B.C. lamps, similar to items 72 and 73, but of lower wattage.

178 D.C. ammeters (0–1A, 0–5A)

Quantity required:
16 per class.

In Years IV and V of the course, moving coil d.c. ammeters covering the two ranges 0–1amp and 0–5amp are necessary. In earlier years, the d.c. ammeter (0–1amp), item 79, was all that was required. Some schools will prefer separate instruments, some dual range instruments, some a basic instrument with interchangeable shunts: it is a matter of personal preference. See the note on Electrical Measuring Instruments in Section C, page 142, for a full discussion.

179 D.C. voltmeters (0–5V, 0–15V)

Quantity required:
16 per class.

In the Years IV and V of the course, moving coil d.c. voltmeters covering the two ranges 0–5 volts and 0–15 volts are necessary. In earlier years, the d.c. voltmeters (0–5 volts), item 80, was all that

was required. Some schools will prefer separate instruments, some dual range instruments, some a basic instrument with interchangeable bobbins: it is a matter of personal preference. See the note on Electrical Measuring Instruments in Section C, page 142, for a full discussion.

180 Galvanometers

Quantity required:
16 per class.

These should be hairspring controlled. A possible range is 3·5–0–3·5mA with a resistance of 10 ohms, which works well with the Nuffield experiments. Other ranges can be used; this is merely an indication of sensitivity.

See note on Electrical Measuring Instruments in Section C, page 142.

181 General purpose amplifier optional

See page 58 for details.

182 L.F. signal generator optional

See page 58 for details.

183 Loudspeaker optional

See page 58 for details.

184/1 3cm wave transmitter optional

See page 58 for details.

See illustration on page 129.

184/2 3cm wave receiver optional

See page 58 for details.

See illustration on page 129.

185 Transistor oscillator optional

See page 59 for details.

186/1 Large gyroscope

Quantity required:
1 per school.

This must be large so that it is clearly visible to the class, and not the small model type available from toyshops. A bicycle wheel, 18 inch in diameter, is ideal, fitted with handles on either side of the axle. One of the handles should be drilled with a hole near the outer end so that it can be held up by a length of cord or string to show precession.

See illustration on page 136.

186/2 Mount for large gyroscope

Quantity required:
1 per school.

A special frame to hold item 186/1, designed to show precession when small forces are applied.

See illustration on page 136.

187 Rotating stool

Quantity required:
1 per school.

Many teachers will improvise this from a rotating music stool. It does, however, require to be as frictionless as possible and commercial versions are available. The requirement is for a rotating stool on which a pupil can sit to show the changes which occur when raising or lowering his arms when holding massive weights.

188 Metal sphere on insulating handles

Quantity required:
2 per school.

The metal spheres should be approximately 3 inches in diameter, fixed to 6 inch insulating rods.

189 Ultra-violet lamp
Quantity required:
1 per school.

Used for simple photo-electric experiments to show the discharging of a zinc plate attached to an electroscope.

190/1 Zinc plate attachment
Quantity required:
1 per school.

A simple zinc plate for attachment to the top of a gold leaf electroscope, item 51A.

190/2 Grid plate
Quantity required:
1 per school.

Grid plate on insulated support rod for use with zinc plate attachment (190/1).

191/1 Coarse gratings
Quantity required:
16 per school.

Simple inexpensive gratings with approximately 2,000 lines/inch mounted in a holder. The grating should not be so blazed that the central image cannot be seen when the spectra are projected. The spectra should be as nearly equal in brightness as possible.

191/2 Fine gratings
Quantity required:
16 per school.

Similar to item 191/1, but with approximately 7,500 lines/inch.

191/3 Set of diffraction grids optional

This is an optional item in the Physics course, and one set only would be required. It consists of the special set of diffraction grids produced by the Nuffield Chemistry Project.

192/1 Red filters

Quantity required:
16 per school.

Red filters for use with the diffraction gratings, 191/1 and 191/2. They should be mounted similarly to the gratings.

192/2 Green filters

Quantity required:
16 per school.

Green filters similar to the red ones, item 192/1.

193/1 Neon spectrum tube

Quantity required:
1 per school.

A sealed tube to provide a single line source of neon light.

193/2 Hydrogen spectrum tube

Quantity required:
1 per school.

A sealed tube to provide a single line source of hydrogen light.

194 Holder for spectrum tubes

Quantity required:
1 per school.

A simple holder for the tubes, fitted with 4mm terminals for connection to the E.H.T. power supply (item 14). Alternatively, some manufacturers produce a holder with mount which incorporates its own voltage supply; this is convenient but much more expensive.

195/1 Pure gamma source

Quantity required:
1 per school.

A Co60 5μC source is suitable for this. Official safety regulations must be complied with and only recommended sources should be used.

195/2 Pure beta source

A Sr90 5μC source is suitable for this. Official safety regulations must be complied with and only recommended sources should be used.

195/3 Pure alpha source

Quantity required:
1 per school.

A Pu239 5μC source is suitable for this. Plutonium is expensive and a cheaper substitute is a 5μC Am241 source. The Americium source does, however, give off some weak gamma radiation so it is not in fact a pure alpha source. Official safety regulations must be complied with and only recommended sources should be used.

196 Source holder

Quantity required:
1 per school.

A suitable tool for holding the recommended radioactive sources.

197 Electron diffraction tube optional

See page 59 for details.

198 Rotating devices

Quantity required:
8 per school.

The rotating device contains a finely woven cloth or fine mesh gauze. Pupils view a point source of light through it and then spin the device to see what happens.

Optional Items

49 **Graph plotting board** optional

Many schools will have a blackboard with a grid of 2in squares. Those that have not will find the graph plotting board an asset. It consists of a framed transparent sheet which can be written on with a chinagraph pencil. It should be possible to back the transparent sheet with a white sheet with a grid of 2in squares which would be clearly visible to a class 25ft away. A school would only need one.

134/2 **Xenon flasher** optional

Some of the experiments using a motor driven stroboscope can conveniently be done using a Xenon flasher. This is available as an optional item for school use where funds permit. A school which gets this would only need one.

See illustration on page 123.

137 **Perrin tube** optional

This should be a large demonstration tube with a Faraday cylinder incorporated into which the electron beam can be deflected by a magnetic field so that the charge on the electrons can be shown to be negative. It should have a directly heated filament capable of operation from 6·3 volts. A school which gets this would only need one.

141 **Demonstration triode** optional

The triode is similar to the demonstration diode (item 135) with a grid between the filament and the anode. A school which gets this would only need one.

144 **Demountable discharge tube for positive rays** optional

The discharge tube should be demountable and should incorporate two plates with a fine slit in each of them for use as cathode and anode. The plates should be connected to 4mm plugs so that connections to an E.H.T. supply (item 14) can be made through a 4mm female connector. The tube requires a suitable holder: the stand (item 140) can be constructed in such a way that it also takes this tube. The tube must have a lead attached for connection to the vacuum pump (item 13) and a leak arrangement would be an advantage. Only one would be required in a school which gets this item.

160/1 **Demonstration trolleys** optional

Quantity required:
2 per school.

These demonstration trolleys are described in the Ministry of Education pamphlet No.38 *Science in Secondary Schools*. They are not being recommended strongly as part of the Nuffield programme. Schools that have them may care to use them in the course.

160/2 **Meter attachment for demonstration trolley** optional

This is an attachment to the optional demonstration trolley, item 160/1, and is referred to in the Ministry of Education pamphlet No.38 *Science in Secondary Schools*. It consists of a generator which is driven by a wheel of the demonstration trolley; a meter is put across the generator so that the deflection is proportional to the speed. It should also be possible to incorporate a transformer between the generator and the meter so that the meter reading is now proportional to the acceleration of the trolley. The meter should be uncalibrated, as the pupils can do that for themselves.

The demonstration trolleys (item 160/1) are optional, but at the most one meter attachment only would be necessary per school, even if they have two trolleys.

168 **CO_2 capsule rocket** optional

Various forms of toy are available in which a CO_2 capsule is pierced so that the escaping gas propels the vehicle. One might be available in a school as an optional item.

174 **Collision in two dimensions kit** optional

Quantity required:
1 per school.

This kit contains sufficient to enable a class of 32 to work in pairs.

For details of contents see Section B, page 111.

181 General purpose amplifier optional
Quantity required:
1 per school.

A general purpose low frequency variable gain amplifier of about 3 watts output. The input terminals should be such that they can be used with two 4mm plugs or with a coaxial cable. See the recommendation on sockets in Section C, page 141. There should preferably be a low and a high impedance output.

182 L.F. signal generator optional
Quantity required:
1 per school.

There should be a square wave and a sine wave output. It should give, as a minimum, an output of frequencies ranging from 10c/s to 20kc/s.

183 Loudspeakers optional
Quantity required:
2 identical speakers per school.

Capable of operation from the amplifier, item 181. These would be used for various sound experiments and to provide two coherent sources for interference experiments.

184/1 3cm wave transmitter optional
Quantity required:
1 per school.

This should incorporate its own power supply and be capable of modulation with audio frequencies.

See illustration on page 129.

184/2 3cm wave receiver optional
Quantity required:
1 per school.

This should be such that it can be used in conjunction with the amplifier, item 181.

See illustration on page 129.

185 Transistor oscillator optional

Quantity required:
1 per school.

A transistorized oscillator producing very low frequency oscillations of the order of 1 oscillation every one or two seconds.

197 Electron diffraction tube optional

Quantity required:
1 per school.

A demonstration tube for showing the phenomenon of electron diffraction. It is essential that it is such that the diffraction pattern can be shown to change with changing voltage applied.

The 500 Series

The following are basic items, which many schools will already possess. They are essential equipment for the course and are listed here for completeness, together with the maximum numbers of each item that are required during the whole five-year Nuffield Physics Course. In any one year, the maximum number required for that year may be less.

501 Metre rules

Quantity required:
16 per class.

These should include inches as well as centimetres. The scales should begin at the *end* of the rules.

502 Foot rules

Quantity required:
16 per class.

These should be ordinary school rulers.

503 Retort stand bases

Quantity required:
32 per class.

Conventional retort stands can be used for the course, but the preferred type uses a base with a screw attached so that rods of various lengths can be inserted into it. These bases should be available in large, medium, and small size.

504 Retort stand rods

Quantity required:
32 per class.

Though conventional retort stands can be used, it is convenient to use the type of base recommended above (item 503) into which rods of 50cm, 75cm, or 100cm length can be inserted.

505 Bosses

Quantity required:
32 per class.

506 Clamps

Quantity required:
24 per class.

These should be of the type that close completely, i.e. will hold a pin.

507 Stop watches or stop clocks

Quantity required:
16 per class.

508 Bunsen burners

Quantity required:
16 per class.

509 Asbestos mats

Quantity required:
16 per class.

These should be simple asbestos sheets about 9in square.

510 Gauzes

Quantity required:
16 per class.

Any type to go on a tripod.

511 Tripod

Quantity required:
16 per class.

Any type to suit the Bunsen burners (item 508).

512/1 250ml beakers

Quantity required:
16 per class.

512/2 400ml beakers

Quantity required:
32 per class.

512/3 600ml beakers
Quantity required:
16 per class.

513 1000ml deep beakers
Quantity required:
8 per class.

514 Gas jars
Quantity required:
16 per class.

Any type will be satisfactory.

515 Cover glasses
Quantity required:
3 per class.

To match gas jars (item 514).

516 Separating funnel
Quantity required:
1 per class.

50ml size, but larger would be satisfactory.

517 1 litre volumetric flask
Quantity required:
1 per school.

518/1 Measuring cylinder: 250ml
Quantity required:
2 per class.

518/2 Measuring cylinder: 1000ml
Quantity required:
1 per class.

519

520 Tuning forks
Quantity required:
8 per class.

Any tuning forks are suitable as no particular frequency is required.

521 5 inch bell jar
Quantity required:
1 per class.

522 Hoffmann clips
Quantity required:
8 per class.

523 Aspirator (10 litres)
Quantity required:
1 per class.

524 Mercury tray
Quantity required:
1 per class.

525

526 Test-tube holders
Quantity required:
16 per class.

527 Simple pendulum
Quantity required:
2 per class.

Brass weight or iron bob on a string.

528 Crystallizing dishes
Quantity required:
16 per class.

Pyrex glass dishes 10cm or more in diameter.

529 Scissors
Quantity required:
8 per class.

These should be inexpensive.

530 Pliers
Quantity required:
1 per school.

These should be large-nosed and will be used for breaking the bromine capsules in the bromine diffusion experiments.

531 Electrical screw drivers
Quantity required:
16 per class.

532 Large transparent trough
Quantity required:
1 per class.

533 Buckets
Quantity required:
8 per class.

These should be plastic.

534 Bottles (medicine type)
Quantity required:
3 per class.

535 Bottle of mercury (7lb)
Quantity required:
1 per school.

536 Bottle of aniline (250gm)
Quantity required:
1 per school.

Old aniline preferred.

537

538

539

540 Flat-bottomed flask (500ml)
Quantity required:
1 per school.

541/1 Rheostats (10–15 ohms)
Quantity required:
8 per class.

Any rheostat with an overall resistance of 10 to 15 ohms and a current rating of at least 3amp is satisfactory. Particularly recommended are the rheostats made with 4mm socket terminals which are 11·5 ohms, 5amp.

541/2 Rheostats (330 ohms)
Quantity required:
1 per school.

A rheostat with overall resistance of 330 ohms taking 1·2amp. Particularly recommended are those with 4mm socket terminals and this rheostat should be protected so that it can be used on the mains.

542 Thermometers (−10° to 110°C in degrees)
Quantity required:
24 per class.

543 Chinagraph pencils
Quantity required:
16 per class.

544

545 Soft glass test-tubes (75mm × 10mm)
Quantity required:
144 per class.

546 Pyrex glass test-tubes (75mm × 10mm)
Quantity required:
144 per class.

547 Capillary tubing with bung to fit test-tubes
Quantity required:
32 per class.

Short lengths of fine capillary tubing (1·0 or 1·2mm bore) through a bung such that will fit the test-tubes, item 546.

548 250ml round-bottomed flasks
Quantity required:
8 per class.

549/1 Bungs with 10in narrow bore glass tubes
Quantity required:
8 per class.

To fit item 548.

549/2 Bungs with glass tube and rubber tubing
Quantity required:
8 per class.

To fit item 548 to connect to Bourdon gauge (item 67).

550 Protractors
Quantity required:
16 per class.

Preferably 360° paper type.

551 Drawing boards
Quantity required:
16 per class.

552

553

554

555 Iron filings
Quantity required:
1lb.

556 Compasses
Quantity required:
36, one per pupil with some spares.

These should be of the cheap type.

Section B

Nuffield Apparatus Kits

Nuffield Apparatus Kits

Contents

1 Materials kit

Nuffield apparatus item no.1

Contents of a class package

8	blocks 5cm × 4cm × 3cm	Soft wood	1A
8	blocks 5cm × 4cm × 3cm	Hard wood	1B
8	blocks 5cm × 4cm × 3cm	Paraffin wax	1C
8	blocks 5cm × 4cm × 3cm	Aluminium	1D
8	blocks 5cm × 4cm × 3cm	Iron	1E
8	blocks 5cm × 4cm × 3cm	Foamed polystyrene	1F
8	blocks 2cm × 2cm × 10cm	Perspex	1G
8	blocks 2cm × 2cm × 10cm	Glass	1H
8	blocks 2cm × 2cm × 10cm	Slate	1I
8	blocks 2cm × 2cm × 10cm	Aluminium	1J
8	blocks 2cm × 2cm × 10cm	Soft wood	1K
8	blocks 2cm × 2cm × 10cm	Marble	1L
8	blocks 5cm × 5cm × 2cm	Lead	1M
8	blocks 5cm × 5cm × 8cm	Aluminium	1N
8	blocks 5cm × 5cm × 20cm	Hard wood	1P
8	blocks 2cm × 2cm × 5cm	Brass	1Q
8	blocks 4cm × 4cm × 2cm	Iron	1R

The aluminium, iron, and brass blocks must be to a $\frac{1}{2}$mm tolerance. The remainder should be as near this as possible, no dimension should differ by more than 1mm from those specified.

Requirement

One kit is sufficient for a class of 32 and contains 8 sets of each of the 17 items (one for 4 pupils).

See illustration on page 114.

2 Elastic materials kit

Nuffield apparatus item no.2

Contents of a class package

100	expendable steel springs	2A
4	2oz reels of 32 SWG bare copper wire	2B
8	2oz reels of 26 SWG bare copper wire	2C
8	wide steel springs (4½in × 3in diameter)	2D
8	soft latex foam blocks	2E
2	3ft lengths valve rubber tubing	2F
16	lengths of elastic cord with eyelets	2G
16	soft erasers for twisting	2H

Replacements

Replacement packets of 100 expendable steel springs must also be available. These are listed as Nuffield apparatus item no.2A.

Replacement 2oz reels of 32 SWG bare copper wire and 26 SWG bare copper wire are available as Nuffield apparatus items 2B and 2C respectively.

Details of expendable springs

These should be made of steel wire. Normal length 1in. They should double their length with about 100gm, they should take loads up to 600–700gm without distortion, and they should run out with loads about 1kg. The end turns should be bent at right angles to the spring for convenient support, preferably soldered.

3 Crystals kit

Nuffield apparatus item no.3

Contents of a class package

12	calcite crystals*	3A
200	polystyrene spheres (1½in diameter)	3B
1	alum crystal (not less than 30gm in weight)	3C
1	wooden base with ridges to take polystyrene spheres	3E
2	cast bismuth samples	3F
1	packet of 72 microscope slides	3G
1	packet of 5 single sided Ever Ready razor blades	3H
2kg	alum	3J
500gm	hypo	3K
500gm	common salt (commercial NaCl)	3L
500gm	washing soda	3M
500gm	copper sulphate	3N
250ml	amyl acetate	3P

* Ideally the crystals should be as large as possible and it is recommended that manufacturers offer a variety of sizes ranging upwards of 5gm in weight.

Replacements

Further supplies of calcite crystals must be available as replacements. These are listed as Nuffield apparatus item 3A.

Additional supplies of polystyrene spheres

Further polystyrene spheres may be required. These are listed as Nuffield apparatus item 3B.

4 Microbalance kit

Nuffield apparatus item no.4

Contents of a class package

240	drinking straws	4A
36	wooden blocks ($1\frac{1}{2}$in × $1\frac{1}{2}$in × $\frac{3}{4}$ in)	4B
36	wooden strips (6in × $\frac{3}{4}$in) (e.g. medical tongue depressors)	4C
36	elastic bands (2in)	4D
36	needles (fine)	4E
36	metal screws ($\frac{1}{2}$in, $\frac{5}{32}$in Whitworth thread)	4F
36	aluminium supports	4G

Supply

One class package contains 32 pupil kits, with 4 spares, sufficient for a class of 32.

See illustration on page 115.

5 Lever kit

Nuffield apparatus item no.5

Contents of a class package

20	wooden beams	5A
16	fulcrums	5B
160	special square pennies (1in × 1in)	5C

The wooden beams should be 24in long by 1¾in wide and made from 3mm plywood. At the centre of the beam a small groove should be cut across the beam so that it will balance on the fulcrum. The beam should have graduations ruled across the beam at 1½in intervals from the centre outwards along both ends of the beam. The groove cut across the beam does weaken it and for this reason some spares are included in the kit.

The fulcrums should be made from triangular section wood (1¼in × 1¼in) cut into lengths 2½in long.

The special square pennies should be 1in × 1in; they should be about 9–10gm in mass, and it is important that they do not differ in mass amongst themselves by more than 1 per cent.

Supply

One class package, sufficient for a class of 32, contains sufficient for 16 pupil kits enabling the class to work in pairs. It includes some spare beams.

Note

The wooden beams suggested for this are very thin plywood made still weaker by the groove at the centre where they are placed on the fulcrum. This is intentional because this arrangement of a beam with loads on top is unstable; and a thicker beam makes it more unstable, though probably less sensitive. The unstable arrangement is intentional so that pupils can do their balancing 'like weighing sweets'; this means pupils are intended to tip the scale each way.

See illustration on page 115.

6 Bristol pressure kit

Nuffield apparatus item no.6

Contents of a class package

8	U-tube manometers	6A
2	paper Bourdon gauges	6B
1	bottle (125ml) of methyl orange	6C
16	nylon syringes (large)	6D
16	large nylon syringes connected to small nylon syringes	6E
2	8ft mounted U-tubes	6F
1	4ft mounted U-tube	6G
1	2ft manometer with unequal limbs	6H
2	barometer tubes, internal diameters 3mm and 8mm	6I
1	glass tube (4ft long, 4mm bore, 8mm ext. diameter)	6J
1	trough for mercury	6K
1	plastic funnel	6L
32	mouthpiece tubes	6M

Supply

One kit is sufficient for a class of 32. Some experiments in the kit are demonstration, some provide for pupils working in groups of various sizes.

7 Oil film kit

Nuffield apparatus item no.7

Contents of a class package

1	½lb packet of vegetable black	7B
8	special trays with drain hole	7C
12	rubber bungs for above (including spare)	7D
32	½mm graticules	7E
64	3in lengths of steel wire (dia. ·003in) looped and mounted on card	7F
32	special holders with clips, etc.	7G
1	250ml bottle of pure olive oil	7H
1	100gm bottle lycopodium powder	7I
16	metal booms (½in × ¼in in cross section, longer than width of tray)	7J
32	10ml glass beakers	7K
32	rubber wedges	7L
8	lycopodium powder dispensers	7M
8	cheese cloth covers	7N
8	rubber bands for above	7P
8	large sponges	7Q
1	2in soft paint brush	7R
7lb	white paraffin wax	7S
1	painter's can (iron or galvanized iron)	7T
1	25gm bottle of camphor	7U

Supply

The kit provides sufficient material for a class of 32 enabling pupils to work individually and use trays in groups of four.

Replacements

Replacement 2oz reels of steel wire (diameter ·003in) are available separately (Nuffield apparatus item 7A).

Replacement packet of vegetable black is available as Nuffield apparatus item 7B.

8 Bromine diffusion kit

Nuffield apparatus item no.8

Contents of a class package

12	1ml bromine capsules	8A
2	special glass tubes (approx. 18in × 2in with 1in diameter entry tube)	8B
2	'Interkey' taps with rubber bungs attached (8mm bore)	8C
6	hard glass tubes (Pyrex), closed at one end, to take bromine capsules	8D
12	short lengths of rubber tubing to connect glass tubes to tap	8E
1	small brush for cleaning tap	8F
1	small tin of vaseline for greasing tap (not tap grease)	8G
6	spare bungs for 'Interkey' taps	8H

Supply

The kit is used for demonstration purposes and one kit is sufficient per school.

Replacements

Replacement 1ml capsules of bromine can be obtained separately (Nuffield apparatus item 8A).

See illustration on page 118.

9 Malvern energy conversion kit

Nuffield apparatus item no.9

Contents of a kit

1	motor/generator unit	9A
1	small motor/generator unit	9B
1	switch unit	9C
1	lamp unit	9D
1	flywheel unit	9E
1	lineshaft unit	9F
1	spring unit	9G
1	friction calorimeter unit	9H
1	steam engine unit	9I
1	turbine/pump unit	9J
1	head of water unit	9K
1	storage battery unit	9L
6	driving belts	9M

Supply

The above provides sufficient for the teacher to demonstrate the series of experiments on energy transfer. This is adequate for Year I of the course. In Year II, it is suggested that the experiments be set up as a circus with groups of four pupils moving from one experiment to the next. Such a circus requires extra numbers of the following:

9A – 7 more; 9C – 2 more; 9D – 6 more; 9J – 1 more.

Furthermore in Year IV 16 small motors are needed for a class experiment (item 155) and the motor/generator 9A is very suitable for that.

Optional extra

As some schools may not have sufficient water pressure to drive the turbine, some kind of force pump should be available as an optional extra item (item 9N) to give the necessary pressure.

See illustration on page 122.

10 General kit for year I

Nuffield apparatus item no.10

Contents of kit

1	ball of cord for pulleys	10A
1	packet of 250 sheets of special graph paper (10in × 10in marked in $\frac{1}{10}$in)	10B
1	crude balance	10C
1	Perspex box (10 × 10 × 11cm)	10D
2	plastic containers with tap (at least 1ft × 1ft × 1ft)	10E
1	set of parts for heavy pendulum	10F
12	books of aluminium leaf	10G
32	6in nails	10H
1	foamed polystyrene sheet (2in × 12in × 16in)	10J
1	1 litre round-bottomed flask	10K
1	bung and tube to fit flask	10L
1	compression spring (Terry 762, $\frac{3}{8}$in × 19 SWG)	10M
1	bottle polystyrene beads	10N
16	2in lengths of lead (1in wide, thickness $\frac{1}{16}$in)	10P
16	iron wires to hold lengths of piping	10Q
5	lengths straight gauge O railway track	10R
2	flat trucks (gauge O)	10S
2	wooden blocks with buffer springs	10T
1	packet rubber bands for fixing blocks to trucks	10U
2	Hoffmann clips	10V
1	glass sheet (6in × 6in, $\frac{1}{4}$in thick)	10W
1	tube vacuum grease	10X
1	bottle Aquadag	10Y
16	eye droppers	10Z
1	reel $\frac{1}{2}$in Sellotape	10AA
1	4oz reel 16 SWG iron wire	10BB
1	smoke filter	10CC
1	4ft length of pressure tubing	10DD

The above essential items should be available as a matter of convenience as a complete kit. It contains miscellaneous items which it is important for a school to have if the course is to be taught in the manner intended. The contents are sufficient for one class.

Note

The graph paper (10in × 10in marked in $\frac{1}{10}$in) should be specially selected to give a round number weight per square inch.

11 Kinetic theory model kit

Nuffield apparatus item no.11

Contents of a class package

1	Perspex tube, 2in diameter, 15in length	11A
3	rubber bases	11B
1	brass cap for top	11C
1	lightweight paper piston with cardboard weights	11D
144	phosphor bronze spheres	11E
1	attachment for fractional horse power motor	11F

Note

In the original version of this model, an Advance vibrator with a boss attached was used. Unfortunately there was not quite sufficient power for the important experiments involved and there was a sad story of several schools in the trials burning out vibrators through overloading them in an attempt to get more power. Schools which have such vibrators may care to use them, but a more satisfactory arrangement is to use the fractional horsepower motor, item 150. The kit is provided with an attachment to this motor. It incorporates an eccentric arrangement to produce the vibration. As schools will necessarily have to have item 150, this does mean there will be an overall reduction in cost as well as a more effective driver. More recently some manufacturers have made models with a self-contained inexpensive motor. These are also satisfactory.

Supply

The kinetic theory model is an important demonstration experiment. As it is used only for demonstration, one per school is sufficient.

See illustration on page 116.

12 Two dimensional kinetic model kit

Nuffield apparatus item no.12

Contents of a class package

16	trays with cork lined bottom	12A
400	marbles (about $\frac{5}{8}$in diameter)	12B
32	large marbles (about 1in diameter)	12C

The marbles should be ordinary coloured toyshop type.

The trays should not be lightweight: they should be much more massive than the marbles so that the marbles lose little energy on collision with the walls. It is essential for the sides to be vertical, not sloping outward. A commercial baking tin with vertical sides $\frac{3}{4}$in deep, and a rolled edge at the top, has been found satisfactory.

Requirement

One kit is sufficient for a class of 32, enabling pupils to work in pairs.

Extra marbles

There are some experiments in the course where extra marbles are required over and above those listed above. Extra marbles (item 12B) should therefore be available as a separate item.

See illustration on page 116.

51 Malvern electrostatics kit

Nuffield apparatus item no.51

Contents of a class package

16	electroscope boxes	51A
16	plates	51B
16	packets gold leaf with fixing instructions	51C
64	metallized polystyrene balls	51D
16	reels nylon suspension	51E
16	cellulose acetate strips	51F
16	polythene strips	51G
16	wire stirrups for suspending strips	51H
16	'rubbers'	51I
16	hooks	51J
16	electrophorus plates	51K
16	proof planes	51L
32	square polythene tiles	51M
32	small calorimeters	51N

Supply

One class package is sufficient for a class of 32, enabling pupils to work in pairs. However, only a limited number of the items in the kit is used in Year II; the electroscopes themselves are not required until Year IV and some parts not until Year V.

See illustration on page 124.

52 Worcester circuit board kit

Nuffield apparatus item no.52

Contents of a class package

288	flashlamp bulbs (1·25 volt, 0·25A, M.E.S. of good quality)	52A
48	U.2 batteries (preferably leak proof type)	52B
16	baseboards with clips, terminals, and pegs	52C
150	spring connectors with lampholder	52D
200	spring connectors only	52E
16	spring connectors with rheostat (25 ohm, 1 watt, wirewound)	52F
16	rectifiers (silicon, maximum current 500mA)	52G
16	resistors (3·9 ohm, 3 watt, wirewound)	52H
32	flexible leads with 4mm plug and crocodile clip and wire 12in long (16 red, 16 black)	52I
32	flexible leads with crocodile clips at each end and wire 12in long (16 red, 16 black)	52J
32	crocodile clips	52K
32	mounted bell-pushes	52L
32	soft iron nails (2in square-headed)	52M
1	4oz reel bare copper wire (not tinned) SWG20	52N
1	4oz reel bare eureka wire, SWG34	52P
1	100 yard reel plastic covered copper wire, SWG26	52Q
16	hardboard discs (3in diameter) with holes for carbon leads	52R
8	packets of 4B 2·0mm pencil leads, 4in long	52S
1	sheet (2ft × 6in) copper foil (approx 0·1mm thick)	52T
1	packet steel wool (grade 2)	52U

Supply

One class package is sufficient for a class of 32, enabling pupils to work in pairs.

Packaging

The accessories should be boxed separately from the baseboards. This enables the teacher to produce items as required instead of the pupils getting them all together.

Replacements

Replacement packets of lamps are available (Nuffield apparatus item 52A) and also U.2 batteries (Nuffield apparatus item 52B).

See illustration on page 124.

53 Worcester current balance kit

Nuffield apparatus item no.53

Contents of a class package

100	drinking straws	53A
32	'Alcomax III' magnets ($\frac{5}{32}$in sq × $\frac{1}{2}$in long)	53B
16	bases (with coil, channel piece and terminals)	53C
32	needles (fine)	53D
16	wooden blocks (1$\frac{1}{2}$in × 1$\frac{1}{2}$in × $\frac{3}{4}$in)	53E
16	wooden strips (6in × $\frac{3}{4}$in) (e.g. medical tongue depressors)	53F
16	elastic bands (2in)	53G
1	2oz reel tinned copper wire, SWG26	53H
1	reel of $\frac{1}{2}$in Sellotape	53I

Supply

One class package is sufficient for a class of 32, enabling pupils to work in pairs.

Replacements

Replacement packets of drinking straws are available (Nuffield apparatus item 53A).

Replacement packets of magnets are available (Nuffield apparatus item 53B).

See illustration on page 124.

54 Worcester gas voltameter kit

Nuffield apparatus item no.54

Contents of a class package

1	tall jar	54A
2	dispensing burettes	54B
1	double electrode unit	54C
1	supporting clip	54D
1	plastic bottle and tube	54E

Supply

The apparatus is required for demonstration purposes and one kit is sufficient per school.

55 Friction kit

Nuffield apparatus item no.55

Contents of a class package

1	smooth plank with screw eye (30in × 6in × $\frac{3}{4}$in)	55A
1	smooth block with screw eye (9in × 4$\frac{1}{2}$in × $\frac{3}{4}$in)	55B
3	extra blocks without screw eye (9in × 4$\frac{1}{2}$in × $\frac{3}{4}$in)	55C
10	rollers of $\frac{1}{2}$in stainless steel (smooth-ground) rod, 8in long	55D
1	crank assembly with hole on the shaft for fixing cord	55E

Supply

Only one set is required for demonstration purposes, but if it is used as a class experiment, several sets will be required. These, however, could be easily constructed by the teacher himself. The requirement therefore is one kit per school.

56 Conductivity kit

Nuffield apparatus item no.56

Contents of a class package

8	rods, 10in long, $\frac{1}{8}$in diameter, copper	56A
8	rods, 10in long, $\frac{1}{8}$in diameter, brass	56B
8	rods, 10in long, $\frac{1}{8}$in diameter, aluminium	56C
8	rods, 10in long, $\frac{1}{8}$in diameter, iron	56D
8	rods, 10in long, $\frac{1}{8}$in diameter, glass	56E
8	rods, 10in long, $\frac{1}{16}$in diameter, copper	56F
8	rods, 10in long, $\frac{1}{16}$in diameter, brass	56G
8	rods, 10in long, $\frac{1}{16}$in diameter, iron	56H

Supply

One class package is sufficient for a class of 32, enabling pupils to do the experiments in groups of four.

57 General kit for year II

Nuffield apparatus item no.57

Contents of kit

1	large clock spring	57A
1	cell for lead tree experiment	57B
6	balloons (large round rubber)	57C
2	PVC clear tubes (6in long, bore 1cm)	57D
1lb	styrocell beads	57E
1lb	polystyrene beads	57F
4oz	nichrome wire (SWG26)	57G
1	roll of $\frac{1}{2}$in Sellotape	57H
1	roll of $\frac{1}{2}$in write-on Sellotape	57I
2	sheets Cinemoid filter (20in × 20in, heavy frost, Strand Electric)	57J
1	reel nylon sewing thread	57K
2	table tennis balls, coated with Aquadag	57L
2	table tennis balls, plain	57M
24	ball bearings ($\frac{1}{8}$in)	57N
24	ball bearings ($\frac{1}{16}$in)	57P
8	iron rods (2ft × $\frac{1}{4}$in diameter)	57Q
4	special styluses	57R
32	5in soft glass tubes (6mm external diameter)	57S
32	5in Pyrex glass tubes (6mm external diameter)	57T
2	5in clear silica tubes	57U

The above essential items should be available as a matter of convenience as a complete kit. It contains miscellaneous items which it is important for a school to have if the course is to be taught in the manner intended. The contents are sufficient for one class.

58 Radiation kit

Nuffield apparatus item no.58

Contents of a class package

4	books of aluminium leaf	58A
1	packet of vegetable black	58B
4	radiant heaters (500 watt) mounted on base and complete with lead	58C
1	mounted copper sheet	58D
4	asbestos sheets with 1in circular hole at correct height for radiant heater	58E
4	glass sheets ($\frac{1}{8}$in × 9in × 9in)	58F

The mounted copper sheet is made from a sheet of $\frac{1}{8}$in copper, blackened on one side, with $\frac{1}{2}$in iron rod handle secured with two nuts and bolts.

Supply

One class package is sufficient for a class of 32 enabling pupils to work in pairs, taking turns to do the experiments in varied order.

Replacements

Replacement books of aluminium leaf are available as item 58A.
Replacement packs of vegetable black are available as item 58B.

Note

Some manufacturers supply shielded versions of the heaters for greater protection.

90 Ripple tank kit

Nuffield apparatus item no.90

Contents of a class package

8	ripple tank frames, legs and gauzes	90A/B/C
1	box of accessories, including:	
16	straight barriers	90D
8	short straight barriers	90E
8	circular barriers	90F
16	dippers	90G
8	water droppers	90H
8	sets of leads to motor	90I
8	wooden rods (9in long, 1in diameter)	90J
16	rubber bands	90K
8	motors mounted on wooden beam	90L
*1	elliptical reflector	90M
8	lengths of rubber tubing for emptying tank	90N
8	plates of glass	90P
8	Hoffmann clips	90Q
8	sponges	90R
8	supports for illuminants	90S

Supply

The class package is sufficient for a class of 32 enabling pupils to work in groups of four.

Illuminants

In addition to the items listed above and included in the kit, each ripple tank will require an illuminant, item 47.

Note

Each motor should have an arrangement to change its eccentric loading.

* Item 90M elliptical reflector. This should not be included in main kit, but available as an optional extra.

See illustration on page 126.

91 Pinhole camera kit

Nuffield apparatus item no.91

Contents of a class package

32	cardboard boxes, 6in × 4in × 4in, with ½in lid	91A
200	sheets black paper (8in × 10in)	91B
4	200W carbon filament lamps	91C
4	mounted lampholders with 6ft flex	91D
1	packet of pins (gross)	91E

Each box has a 1½ inch diameter hole at one end and a 2½in square hole at the other end. The latter is closed with a square of frosted plastic or greaseproof paper, which is stapled, glued or taped in place.

Lenses

32 lenses (+7D, 50mm diameter) are required for use with the pinhole cameras. These, however, are supplied separately – see Nuffield apparatus item 112.

Supply

One class package is sufficient for a class of 32, enabling pupils to work individually.

92 Westminster electromagnetic kit

Nuffield apparatus item no.92

Contents of a class package

32	ticonal magnets	92A
32	magnadur magnets	92B
16	reels of cotton	92C
24	plotting compasses	92D
16	pepper pots	92E
16	wooden rods for winding coils	92F
16	double C-cores and clips	92G
16	armatures (wood block with aluminium tube)	92H
16	mild steel yokes	92I
16	support bases	92J
32	split pins	92K
64	rivets	92L
16	knitting needle shafts	92M
16	reels of Sellotape	92N
16	aluminium rings	92P
16	aluminium rings (split)	92Q
36	M.E.S. bulbs (2·5V, 0·3A)	92R
18	neon lamps	92S
32	M.E.S. holders	92T
16	squares of Bristol board	92U
16	plain postcards	92V
1	stock bottle of iron filings	92W
16	reels of 26SWG PVC covered copper wire	92X
3ft	valve rubber	92Y
16	special hardboard pieces to take compass	92Z
16	100 ohm carbon resistors ($\frac{1}{2}$ watt)	92AA
16	10 ohm carbon resistors ($\frac{1}{2}$ watt)	92BB

Supply

A class package is sufficient for a class of 32 enabling pupils to work in pairs.

See illustration on page 125.

93 Smoke box kit

Nuffield apparatus item no.93

Contents of a class package

1	smoke box	93A
1	large plano-convex lens (condenser quality, 10cm diameter, 15cm focal length)	93B
1	lens holder	93C
1	set of three aluminium sheets	93D
1	plane mirror (5in × 5in on wooden mount)	93E
1	concave mirror (10cm diameter, focal length 30cm)	93F
1	smoke generator	93G

The three aluminium sheets should be painted black and are used in conjunction with the compact light source to give a three-dimensional beam through the smoke box. One sheet has a single central hole, the other two similar arrays of circles of small holes, but with different radii of circles.

Supply

The kit is required for demonstration purposes and one only is needed per school.

94 Kit for ray optics

Nuffield apparatus item no.94

Contents of a class package

16	lamps, holders and stands	94A
8 pr	housing shields	94B
16	metal plates with single slits	94C
16	metal plates with three parallel slits	94D
16	metal combs	94E
16	holders for combs and plates	94F
32	barriers	94G
32	plano-cylindrical lenses +7D	94H
16	plano-cylindrical lenses +10D	94I
16	plano-cylindrical lenses +17D	94J
16	plano-cylindrical lenses −17D	94K

The cylindrical lenses must be at least 2in wide and 2in high and made of good glass. The powers can have an optical tolerance of 10 per cent, but the faces must be optically polished. They must have flat bases so that they will stand upright.

The housing shields are both 'left-handed' and 'right-handed'. This enables two lamps to be positioned close together when showing the principles of microscopes and telescopes.

Supply

One class package is sufficient for a class of 32 enabling pupils to work in pairs.

See illustration on page 126.

95 Edinburgh CO_2 pucks kit

Nuffield apparatus item no.95

Contents of a class package

1	special mounted plate glass base (at least 3ft × 3ft)	95A
4	wedges	95B
2	magnetic ring pucks	95C
2	brass ring pucks	95D
2	pointer attachments	95E
2	small magnetic pucks	95F
1	reel of magnetic strip	95G

Supply

The kit is required for demonstration purposes, and one is sufficient per class.

See illustration on page 123.

96 Kit for particle model of refraction

Nuffield apparatus item no.96

Contents of a class package

8	hinged hardboard platforms	96A
8	launching ramps	96B
8	steel ball bearings ($\frac{7}{8}$in)	96C

Supply

The kit is suitable for a class of 32 enabling pupils to work in groups of four.

97 Double slits kit

Nuffield apparatus item no.97

Contents of a class package

144	microscope slides	97A
1	bottle Aquadag	97B
4	holders for ruling slits (see note below)	97C

Supply

One kit is sufficient for a class of 32 enabling pupils to prepare their own slides.

The holders

Some commercially available versions of this kit incorporate a holder for the slides which makes it easier to move the slide by a small amount and ensure that the slits are parallel. This is not essential and many teachers will be content to use a metal rule and a pin or ball-point pen to make the lines, dispensing with the holder.

114 Model eye kit

Nuffield apparatus item no.114

Contents of a class package

1	5 litre round-bottomed flask	114A
1	cork ring as stand for flask	114B
1	bottle fluorescein	114C
1	packet Plasticine	114D
1	each of the following lenses:	
	+11D meniscus lens, 48mm to 50 mm diameter	114E
	+8D meniscus lens, 48 mm to 50mm diameter	114F
	+5·5D meniscus lens, 48mm to 50mm diameter	114G
	+2·5D meniscus lens, 48mm to 50mm diameter	114H
	−3·0D meniscus lens, 48mm to 50mm diameter	114I

The first three of the lenses are fixed to the flask with Plasticine to show normal sight, long sight, and short sight respectively, when a beam of light from a strong point source passes through them.

The other two lenses are used for correcting the short and the long sight. The sizes of all the lenses have been carefully chosen so as to suit a 5 litre round-bottomed flask of diameter approximately 22cm (for details, see *Nuffield Physics Teacher's Guide III*).

Supply

One kit is sufficient for a class of 32 as it is required only for demonstration purposes.

See illustration on page 127.

122 Magnetization kit

Nuffield apparatus item no.122

Contents of a class package

144	oil-hardened steel rods	122A
144	oil-hardened steel shim rings	122B

The rods are 4in long and $\frac{1}{16}$in diameter.

Note

The oil-hardened shim rings should be $\frac{3}{4}$in outside diameter and $\frac{3}{8}$in internal diameter. They should be ·010in thick. It is important that this hole is centred accurately.

Both the rods and the shim rings must be glass hard so that they can conveniently be snapped in two by a child using his fingers without undue effort. (They must not necessitate using pliers.) They must be made of steel which magnetizes when hardened. The rods will be magnetized by passing them through a coil carrying a current, the rings will be magnetized by threading on a length of copper wire and shorting across a Nife cell or car battery.

Each pupil will need to do this experiment for himself and the class package therefore includes a good supply of both rods and rings.

131 General kit for year IV

Nuffield apparatus item no.131

Contents

6	steel ball bearings ($\frac{3}{4}$in diameter)	131A
2	steel balls with hooks (2in diameter)	131B
1	steel ball with hook (1in diameter)	131C
1	steel ball with hook ($\frac{1}{2}$in diameter)	131D
2	ping-pong balls coated with Aquadag	131E
1	glass tube (30in long, 2in diameter)	131F
36	steel ball bearings ($\frac{1}{8}$in diameter)	131G
1	release mechanism (3 pin type)	131H
1	trip switch	131I
1	tape plate	131K

Supply

The above essential items should be available as a matter of convenience as a complete kit. It contains miscellaneous items which it is important for a school to have if the course is to be taught in the manner intended. The contents are sufficient for one class.

132 Electrical general kit for year IV

Nuffield apparatus item no.132

Contents

8	electrolytic capacitors, 100μF, 50V	132A
8	electrolytic capacitors, 250μF, 15V	132B
1	electrolytic capacitor, 500μF, 50V	132C
1	electrolytic capacitor, 50μF, 350V	132D
1	paper capacitor, 0·001μF, 20 kV	132E
16	resistors, 15 ohm, 10W	132F
1	resistor, 680 ohm, 1W	132G
8	resistors, 1kohm, $\frac{1}{2}$W	132H
8	resistors, 1·5kohm, $\frac{1}{2}$W	132I
1	resistor, 4·7kohm, 2W	132J
8	resistors, 20kohm, $\frac{1}{2}$W	132K
1	resistor, 100kohm, 2W	132L
1	transistor OC 81	132M
1	thermistor (Radiospares TH3) – cold 400 ohms, hot 28 ohms	132N
1	germanium slice (Mullard n type 5mm sq, 1–2mm thick)	132P

The germanium slice should be supplied with leads attached.

Supply

This kit contains items which could be brought together in a single kit as a matter of convenience for the teacher. Many teachers may prefer to buy the items more cheaply from a supplier such as Radiospares Ltd.

146 Inertia balances kit

Nuffield apparatus item no.146

Contents of a class package

16	inertia balances ('wig-wag')	146A
48	masses for use with balance	146B

Note

The balances should be such that they can conveniently be clamped with a G-clamp to the side of a bench in a horizontal position. It should also be possible to clamp them vertically.

To avoid energy losses by damping the supporting arms must be rigidly clamped to the cross pieces on both sides.

Supply

One kit is sufficient for a class of 32 enabling pupils to work in pairs.

147 Demountable transformer kit

Nuffield apparatus item no.147

Contents of kit

1	laminated U-core	147A
1	laminated top for core	147B
1	clamping device for core	147C
1	coil with 300 turns	147D
2	coils with 600 turns	147E
1	coil with 1,200 turns	147F
1	centre tapped coil with 3,600 turns	147G
1	coil with 12,000 turns	147H
2	pole pieces to fit U-core	147I

Note

The 12,000 turn coil should be suitable for working at 240 volts a.c.

Supply

The transformer is required for demonstration purposes and one is sufficient per school.

See illustration on page 135.

148 Syringe kit

Nuffield apparatus item no.148

Contents of kit

1	large syringe	148/1
12	rubber caps	148/2
2	hypodermic syringes	148/3

The large syringe should be the type with ground glass plunger as used in the Nuffield Chemistry Project. It need not have a tap attached.

The rubber caps should be of a convenient size to fit tightly over the outlet of the syringe.

The two hypodermic syringes – one for use, one spare – should be the inexpensive type and capable of injecting 0·1ml of water through the rubber cap into the large syringe.

Supply

For convenience, the above items have been put together in a single kit. Some will prefer to purchase the items separately: they are listed as follows:

Large syringe	148/1
Rubber caps	148/2
Hypodermic syringe	148/3

The kit is required for demonstration purposes and one is sufficient per school.

171 Photographic accessories kit

Nuffield apparatus item no.171

Contents of a kit

1	beaker for cassette film	171A
1	twiddle stick	171B
1	holder for paper	171C
2	developing dishes	171D

Photographic techniques

The Nuffield Physics Project has been in close liaison with Kodak Limited on a technique for taking photographs in the school laboratory followed by rapid developing and printing in normal lighting in front of the whole class. This is discussed in detail in Section C of this volume, page 150. The necessary film, paper, and chemicals are obtainable from Kodak, but the above listed accessories are also essential for the technique. For convenience, they have been put together in a single kit and made commercially available.

Supply

One kit is sufficient per school.

See illustration on page 129.

172 Centripetal force kit

Nuffield apparatus item no.172

Contents of a class package

20	glass tubes with rubber tubing	172A
20	rubber bung attachments	172B
20	end clips	172C
200	metal washers	172D
20	indices	172E
1	ball of cord	172F

Supply

The class package is sufficient for a class of 32 enabling pupils to work in pairs. It includes some spares.

173 Malvern current balance kit

Nuffield apparatus item no.173

Contents of a kit

1	hardboard support	173A
1	hardboard index	173B
1	wire balance frame with pointer	173C

Supply

Quantity required is 1 per school. It is a demonstration item for measuring the field inside two Helmholtz coils. It must be used with the fine beam tube, item 61, and the coils, item 139. It is essential equipment for the measurement of e/m for electrons.

See illustration on page 134.

174 Collision in two dimensions kit

Nuffield apparatus item no.174

Contents of a class package

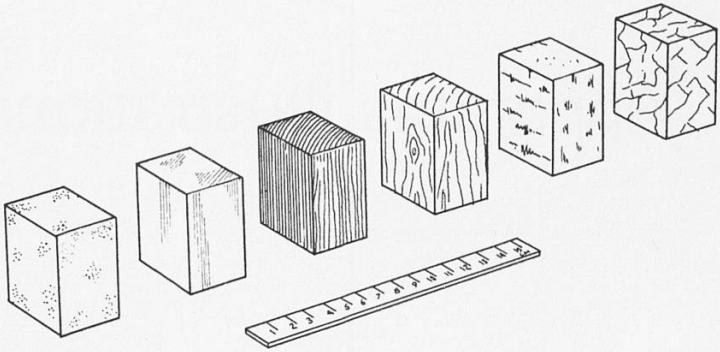
16	curved ramps with groove and plate	174A
16	plumb bobs	174B
32	steel balls (diameter $\frac{5}{8}$in)	174C

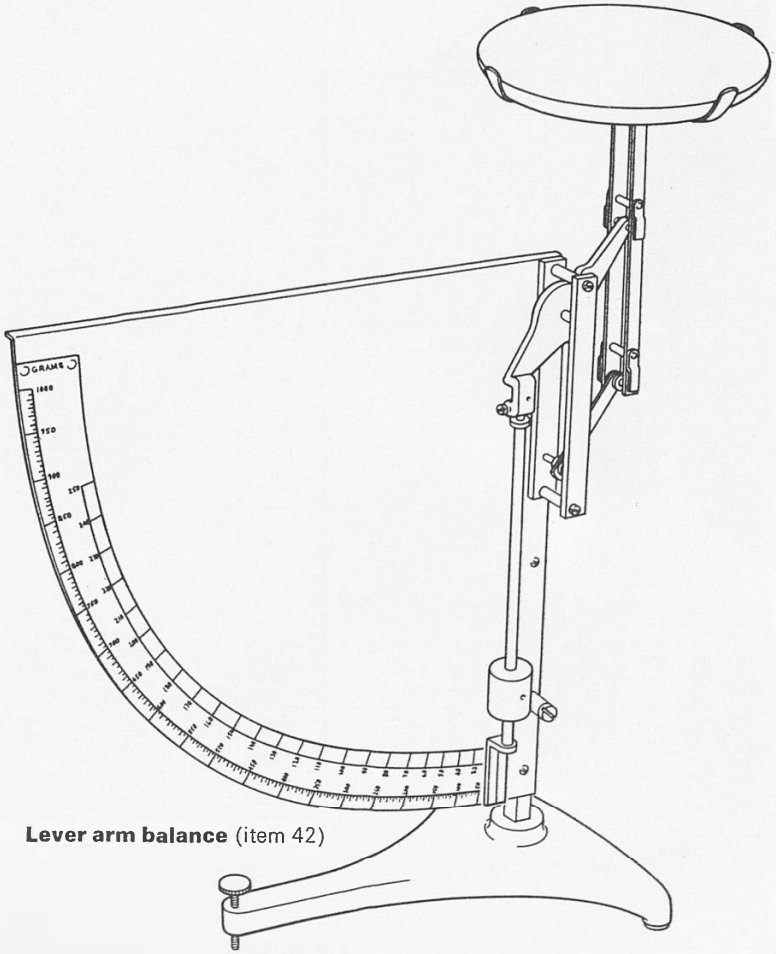
Supply

This is an optional item. The class package is sufficient for a class of 32 enabling pupils to work in pairs.

Apparatus illustrations

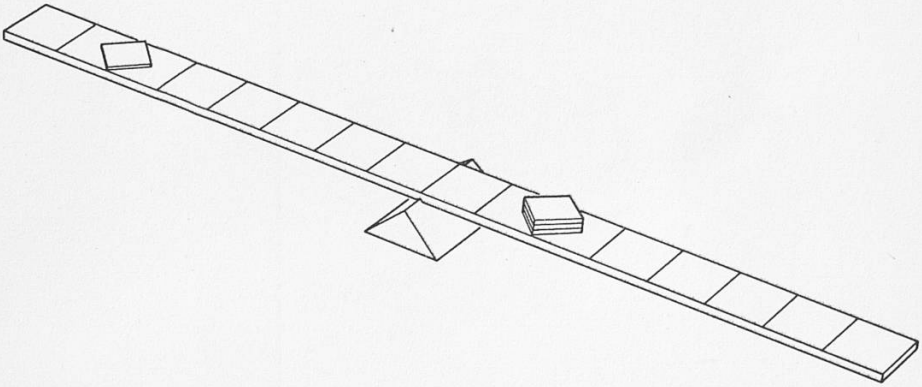
Materials kit (item 1), **and large measuring rule** (item 25)

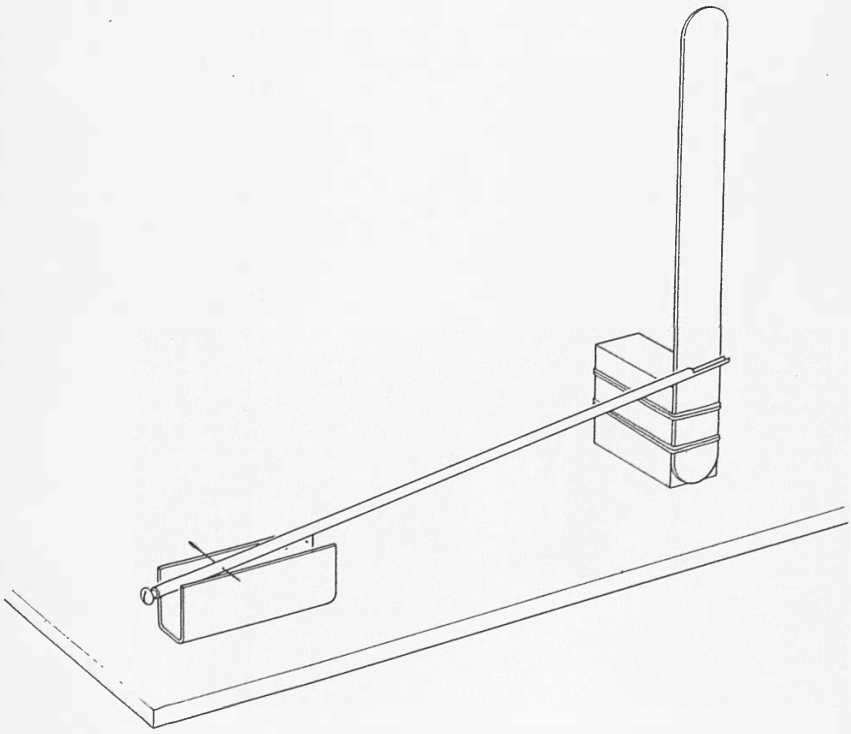




Lever arm balance (item 42)

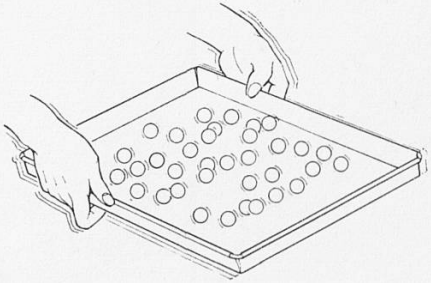
Lever kit (item 5)

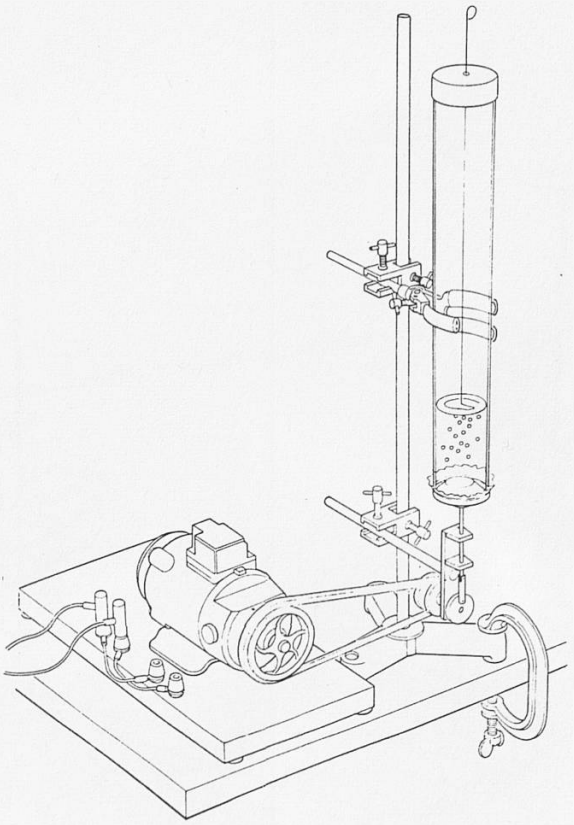




Microbalance kit (item 4)

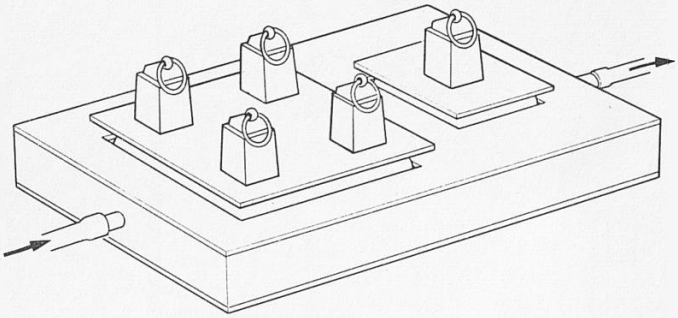
Two dimensional kinetic model kit (item 12)

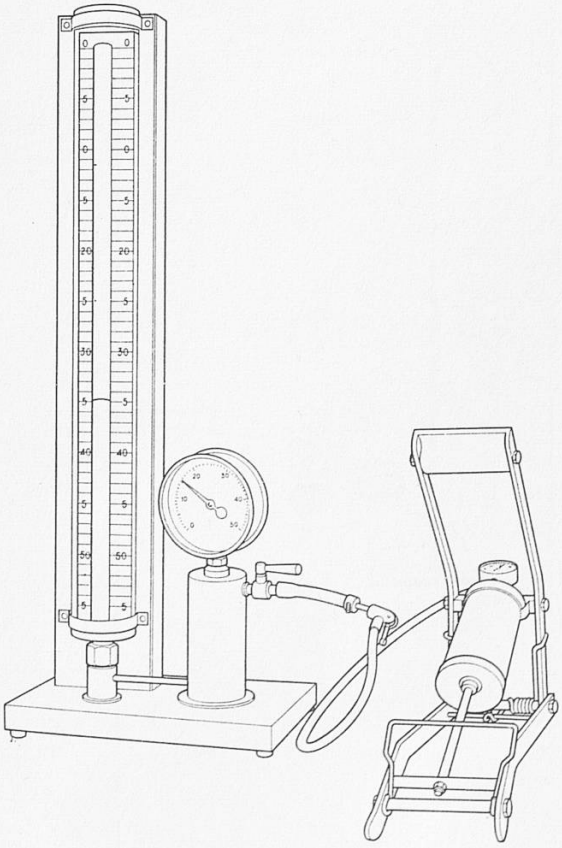




Kinetic theory model kit (item 11), **with fractional horse power motor** (item 150)

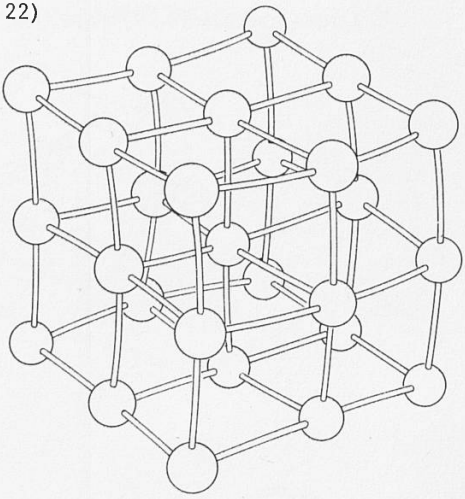
Evesham pressure apparatus (item 41), **with weights** (item 36)

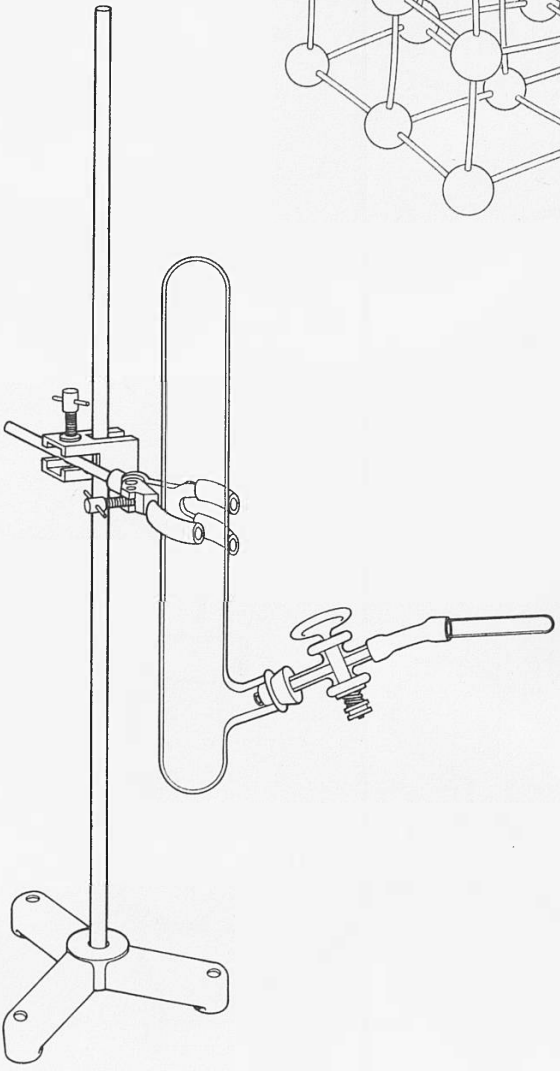




Boyle's Law apparatus (item 109), **with foot pump and adaptor** (item 45)

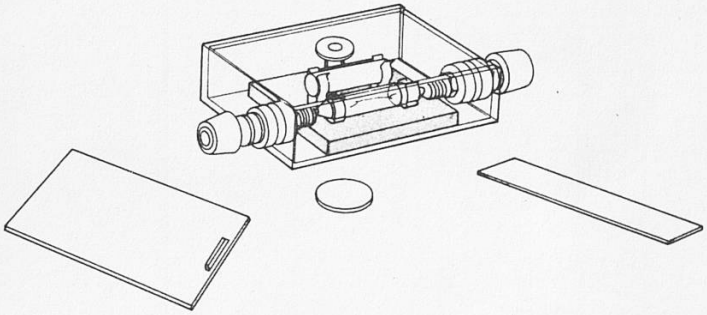
Atom model (item 22)

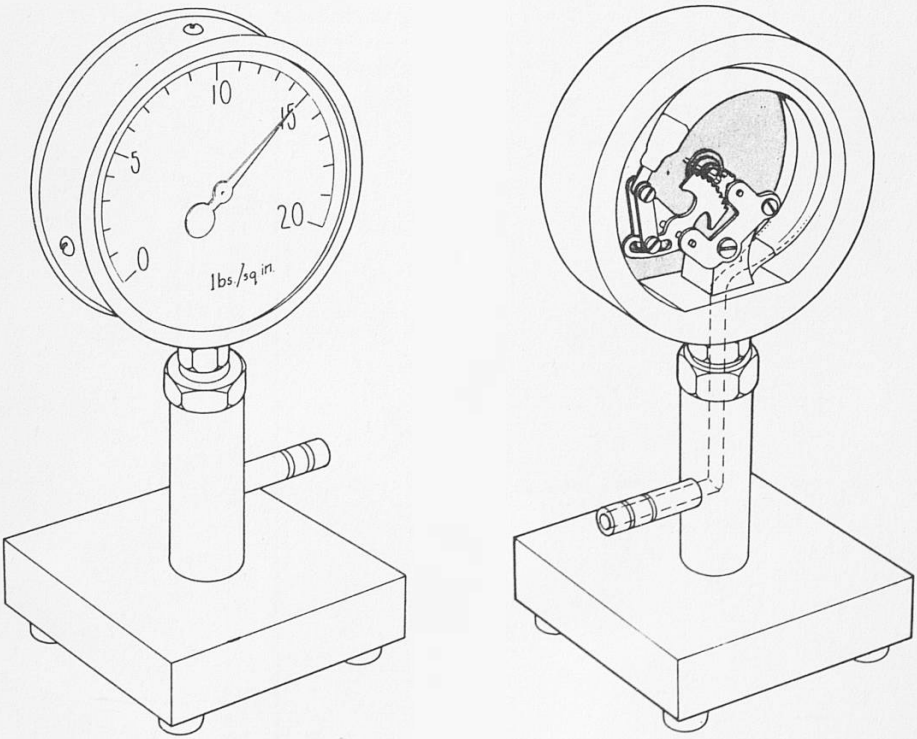




Bromine diffusion kit (item 8)

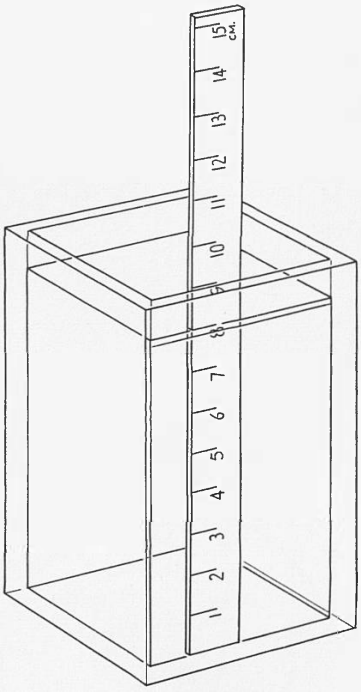
Whitley Bay smoke cells (item 29)

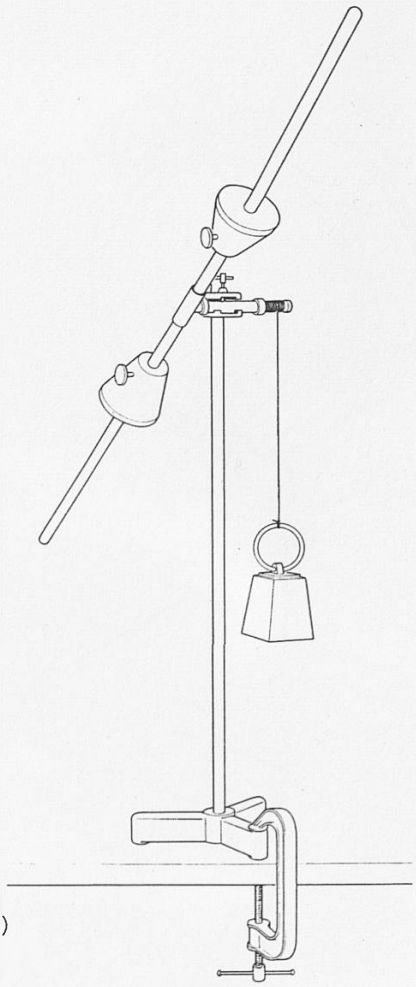




Bourdon gauge (item 67), **front and back view**

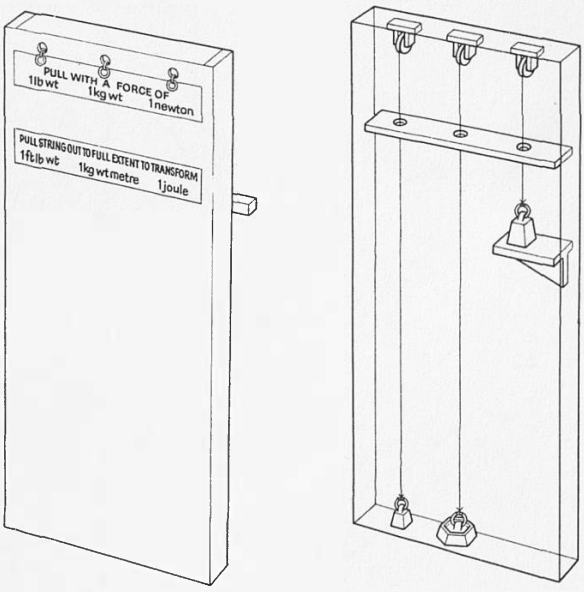
Perspex container (item 26) **with plastic measuring rule** (item 25)

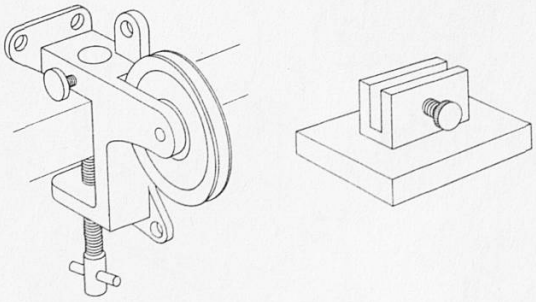




Variable inertia bar (item 34)

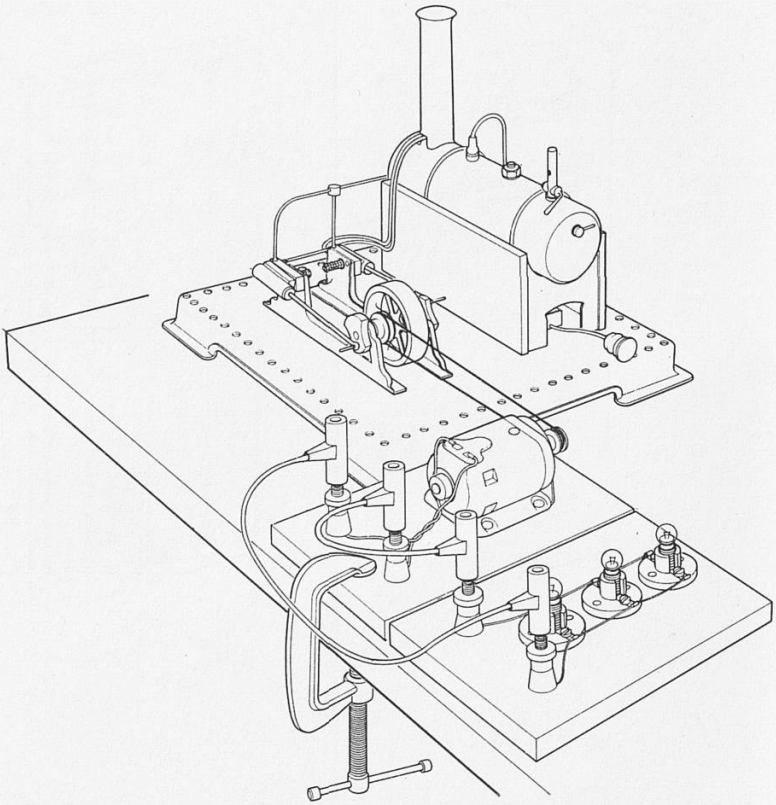
Forces demonstration box (item 63), **front and back view**

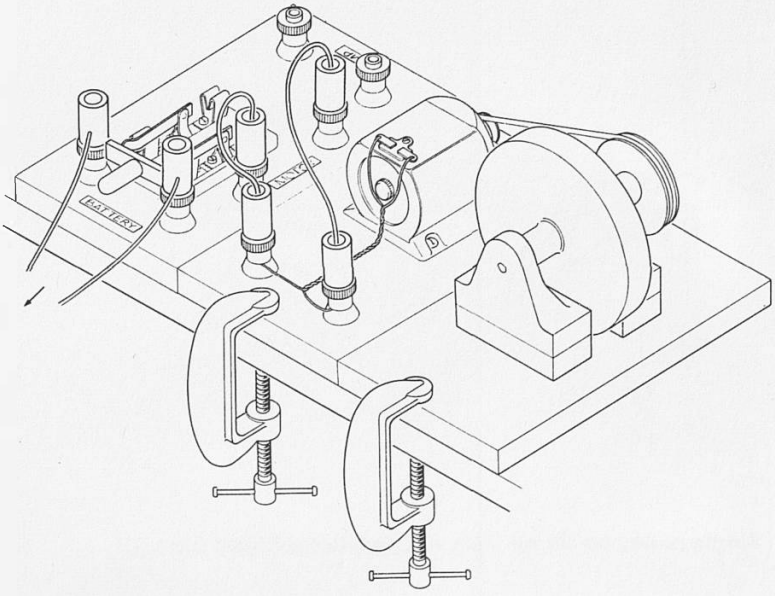




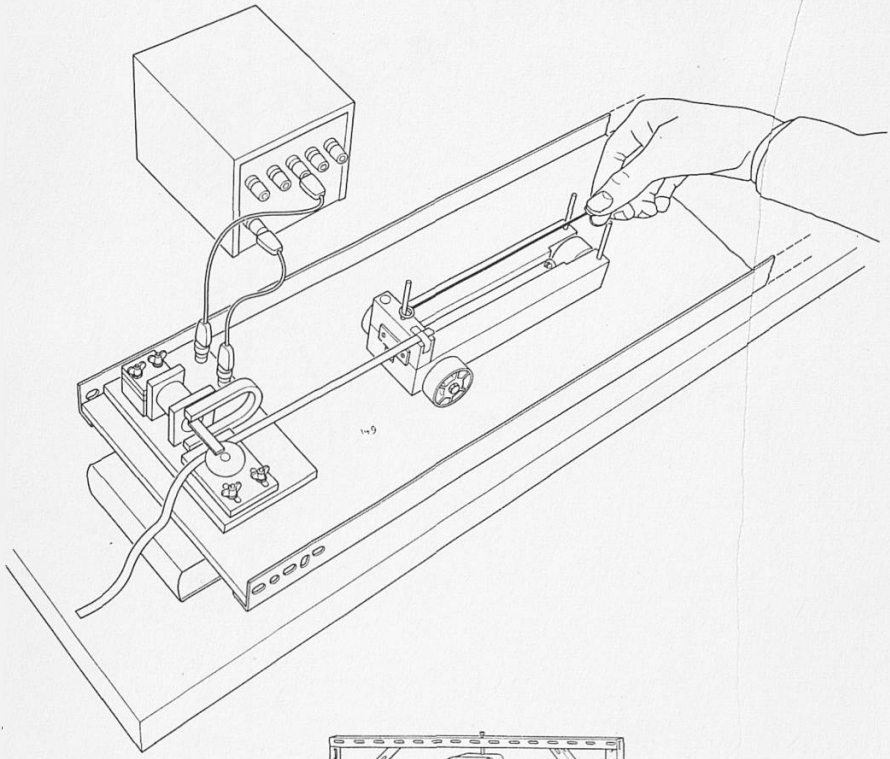
Single pulley on clamp (item 40), **and slotted base** (item 30)

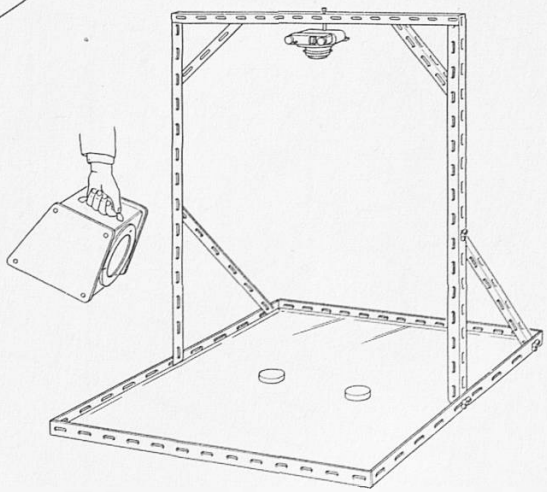
Some parts from Malvern energy conversion kit (item 9)





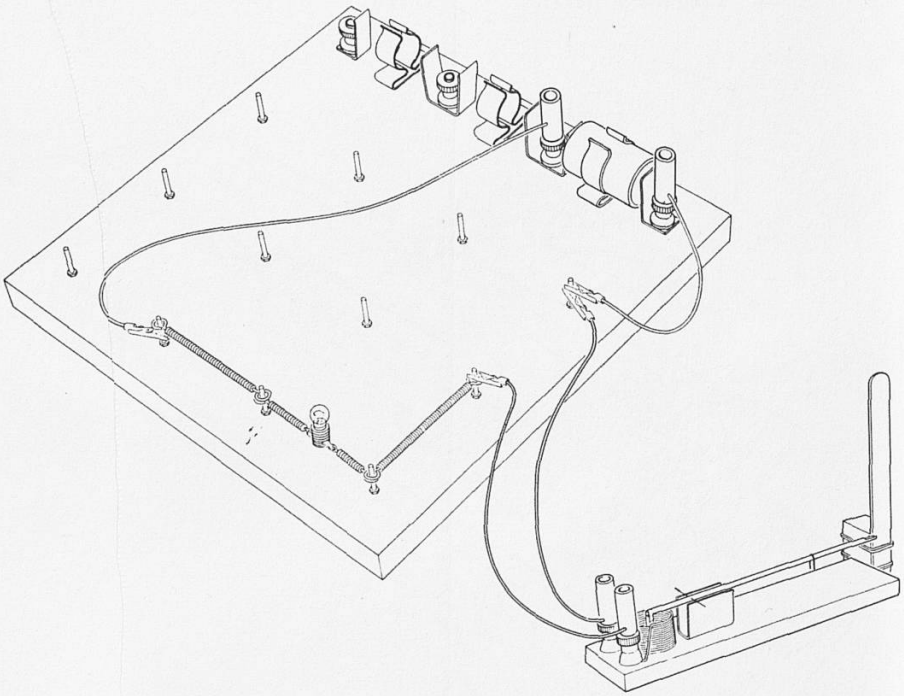
Dynamics trolley (item 106/1), **with runway** (item 107), **ticker tape vibrator** (item 108/1), **transformer** (item 27), **and elastic cord** (item 106/2)

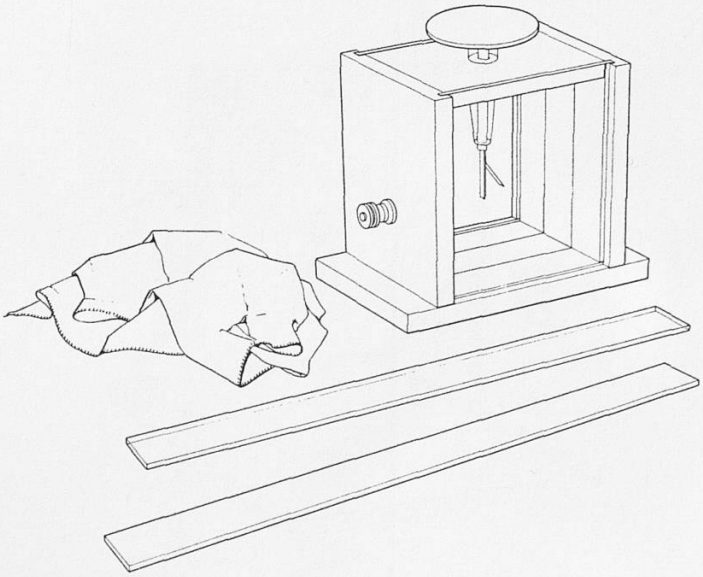




Edinburgh CO_2 Pucks kit (item 95), **with gantry** (item 161)
Xenon flasher (item 134/2), **and camera** (item 133)

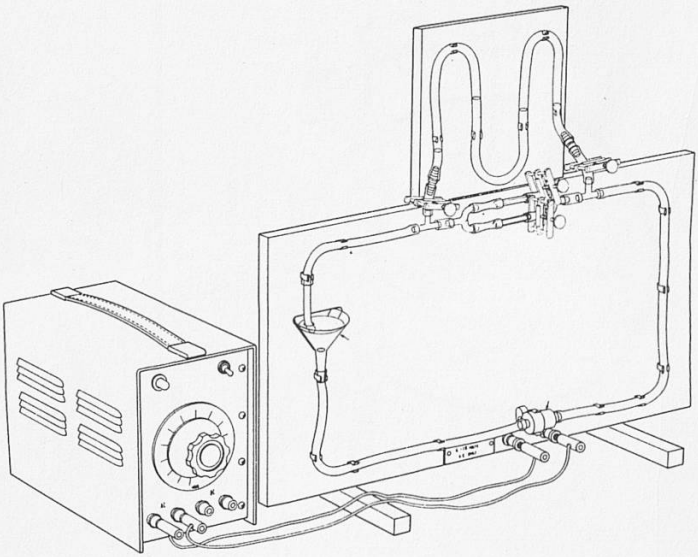
Worcester circuit board (item 52) **with Worcester current balance** (item 53)

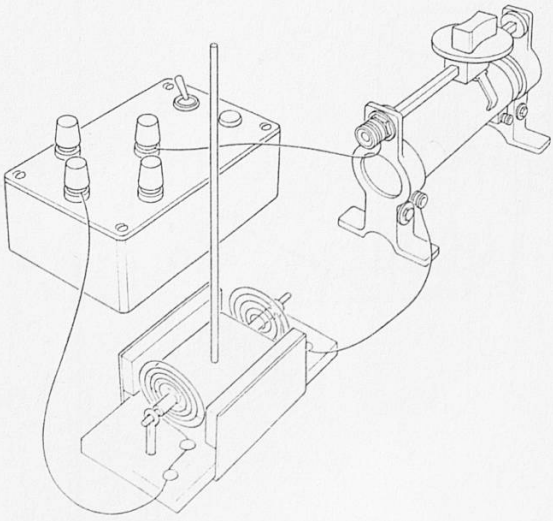




Parts of Malvern electrostatics kit (item 51)

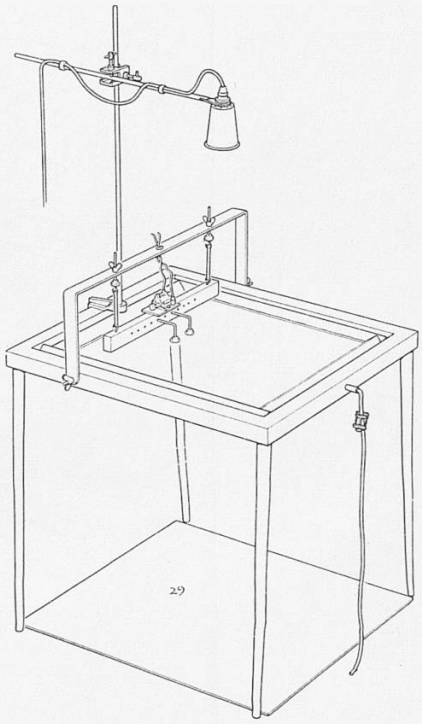
Water circuit board (item 89) **with L.T. variable voltage supply** (item 59)

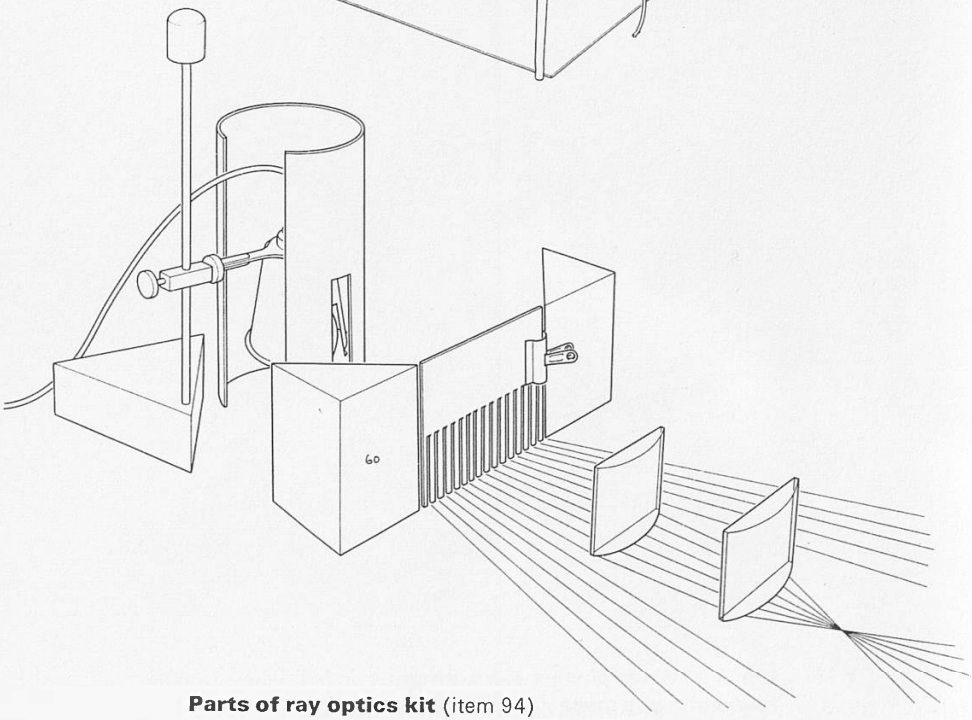




Parts of Westminster electromagnetic kit (item 92) **with low-voltage power unit** (item 104) **and rheostat** (item 541/1)

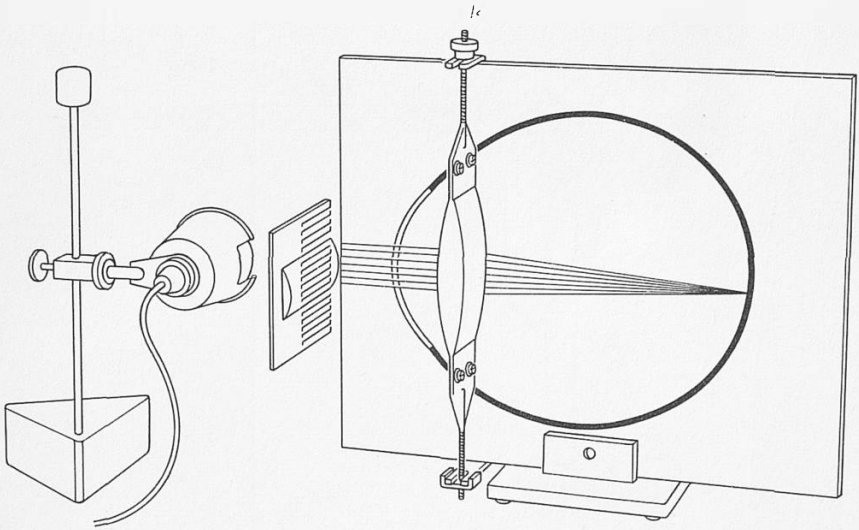
Parts of ripple tank kit (item 90) **with illuminant**

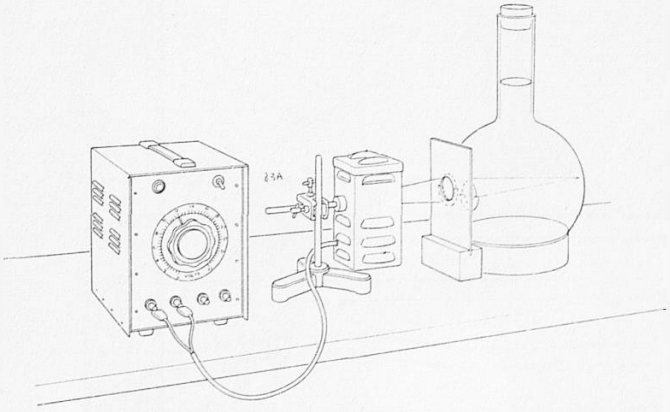




Parts of ray optics kit (item 94)

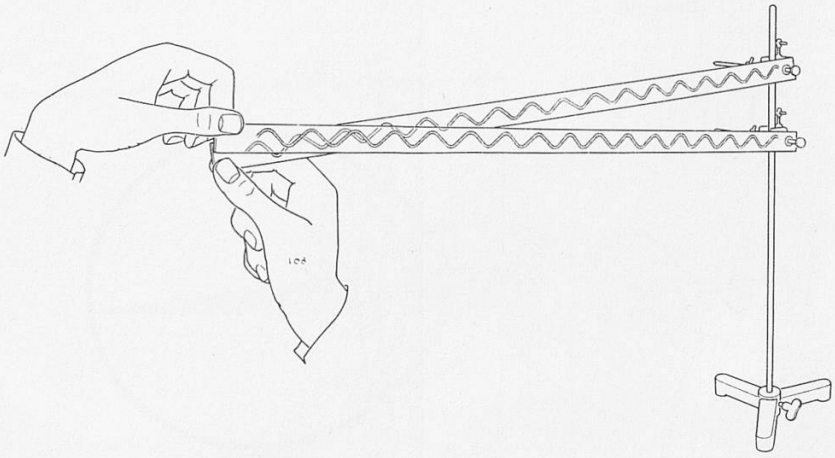
Skelton variable focus eye (item 125) **with slotted base** (item 30)

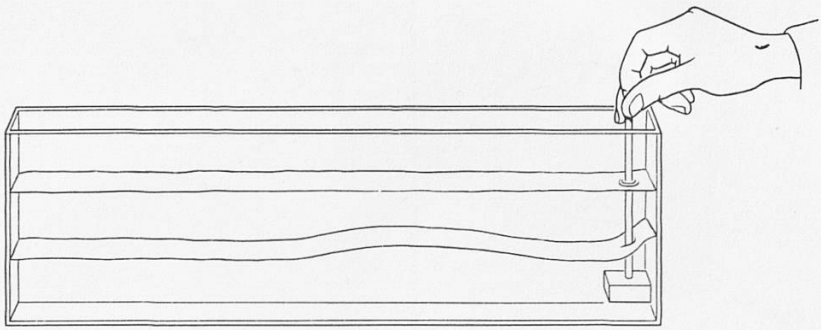




Model eye kit (item 114) **with L.T. variable voltage supply** (item 59), **and compact light source** (item 21)

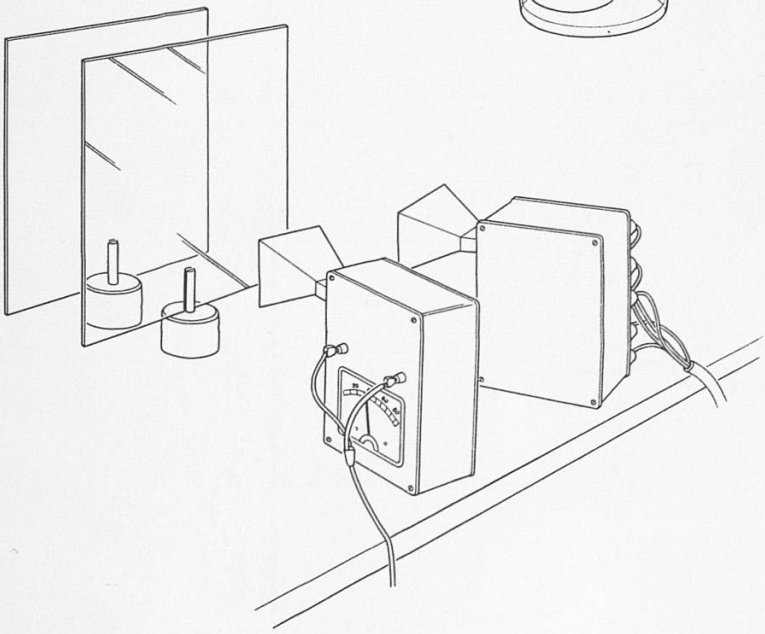
Plastic waves (item 126)





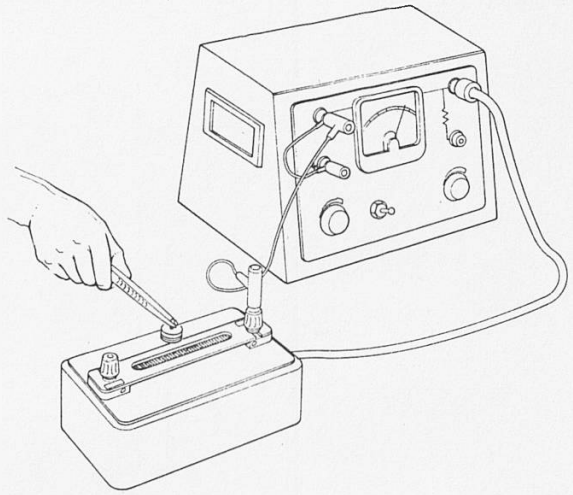
Large rectangular transparent tank (item 100/2)

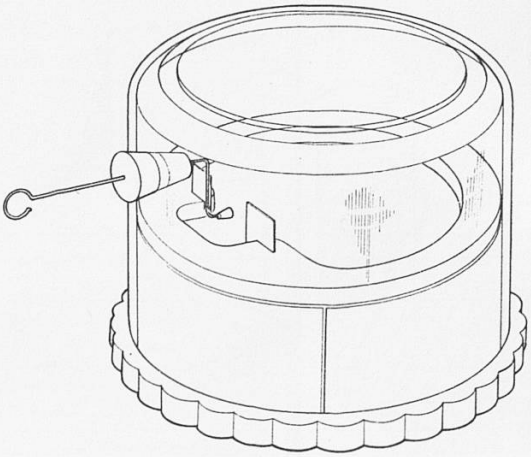
Cassette being developed: part of photographic accessories kit (item 171)



Centimetre wave transmitter (item 184/1), **and receiver** (item 184/2)

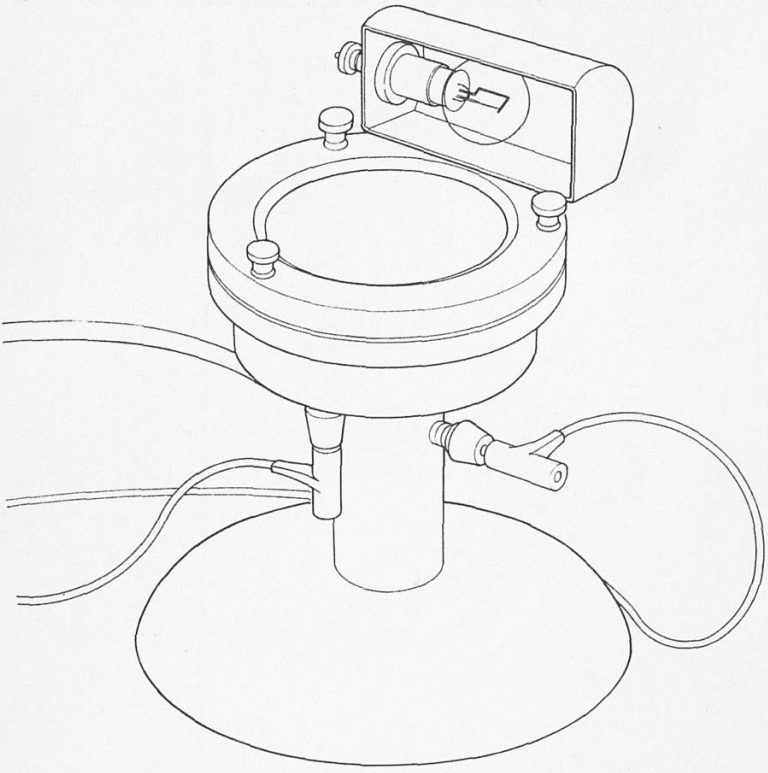
Spark counter (item 17), **E.H.T. power supply** (item 14), and **radium source** (item 16)

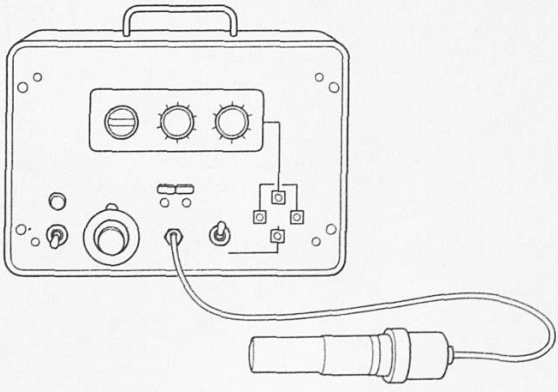




Taylor cloud chamber (item 28)

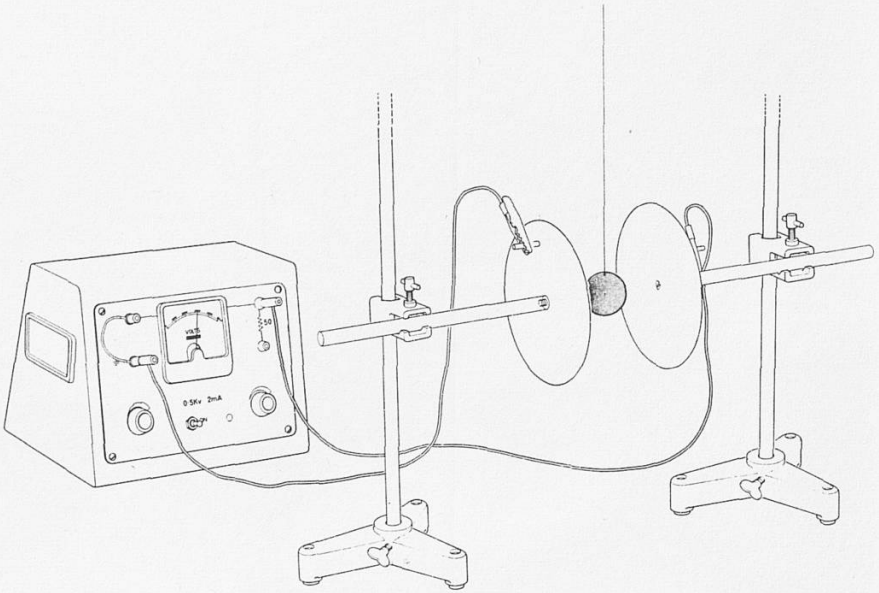
Expansion cloud chamber (item 18)

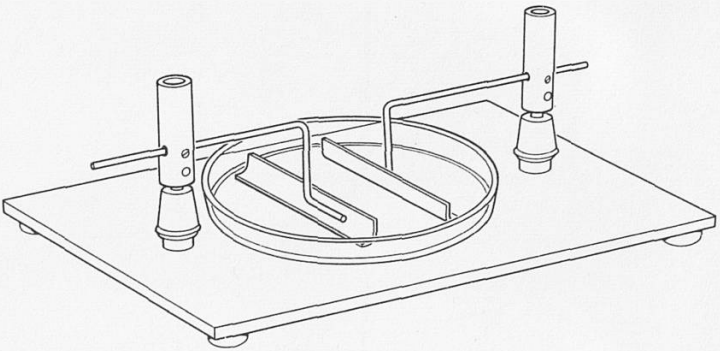




Scaler (item 130/1), **with GM tube and holder** (items 130/5 and 130/3)

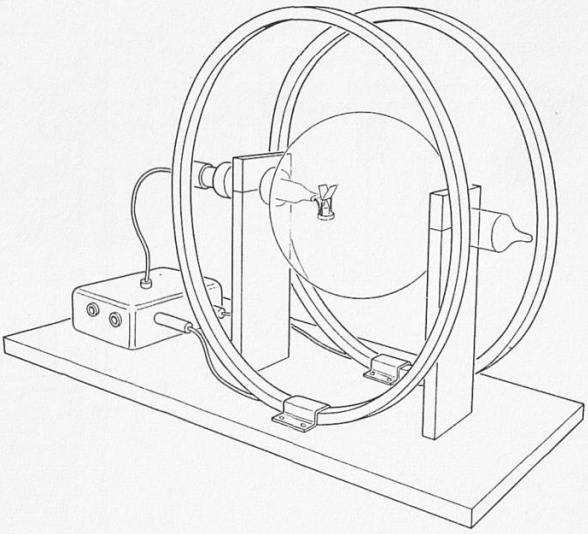
Metal plates with insulating handles (item 65), **with ball, coated with Aquadag, and E.H.T. power supply** (item 14)

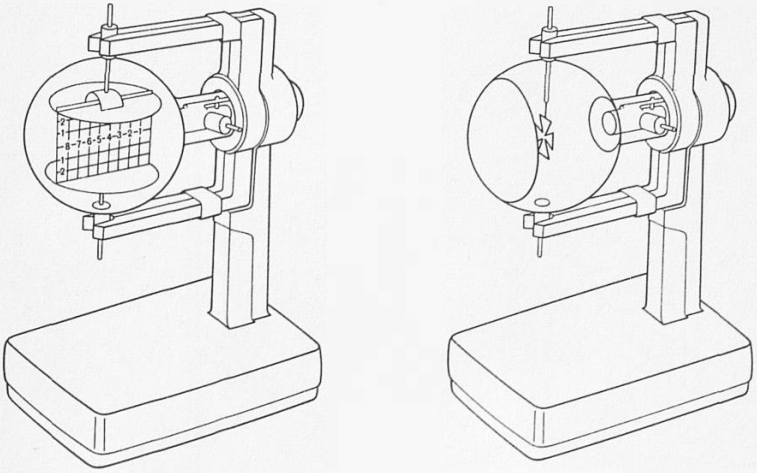




Electric field apparatus (item 149)

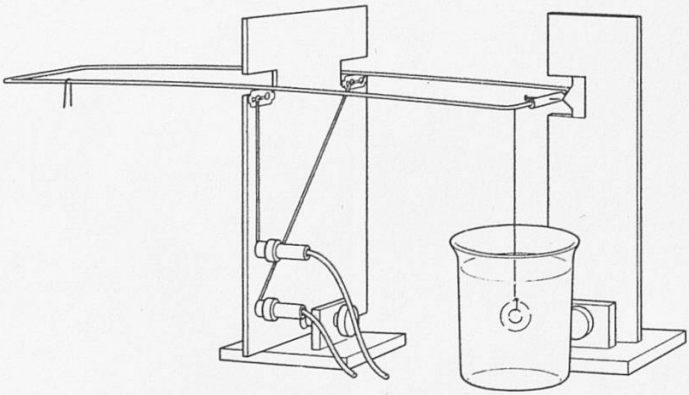
Fine beam tube (item 61), **and base** (item 62)

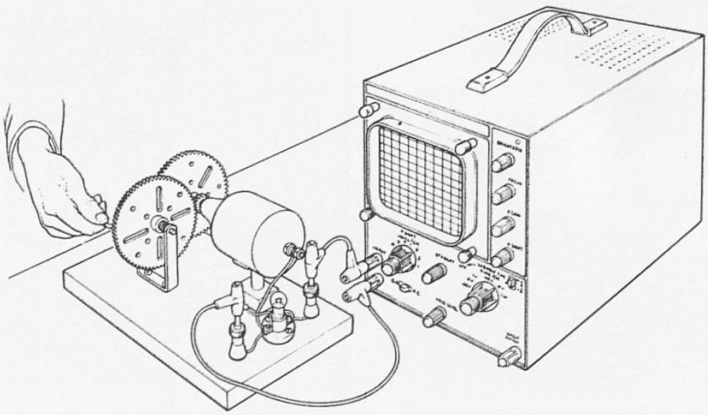




Deflection tube (item 138), **and Maltese cross tube** (item 136), **both in stands** (item 140)

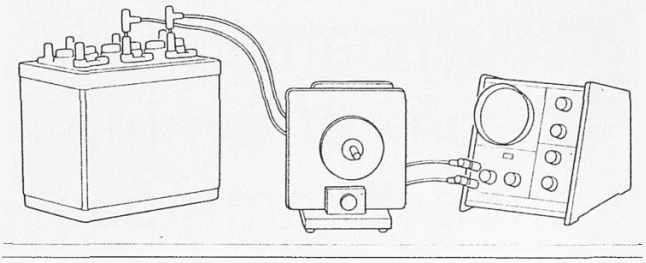
Malvern current balance (item 173)

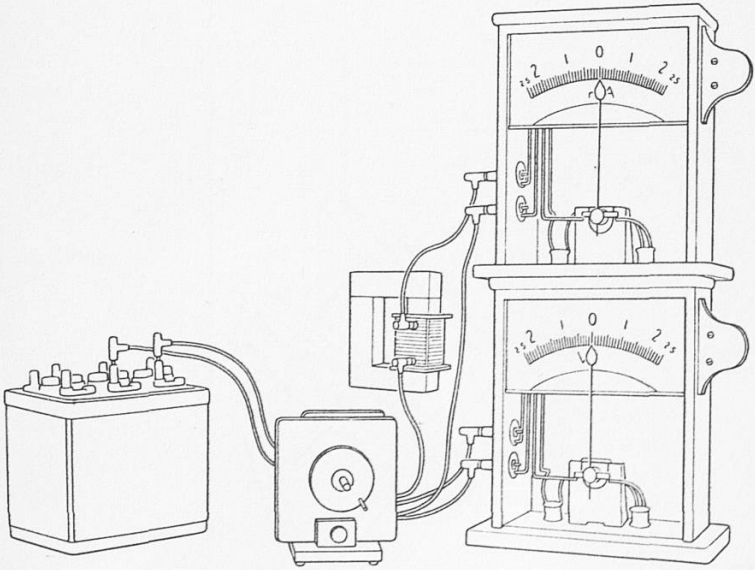




Bicycle dynamo assembly (item 103), **and oscilloscope** (item 64)

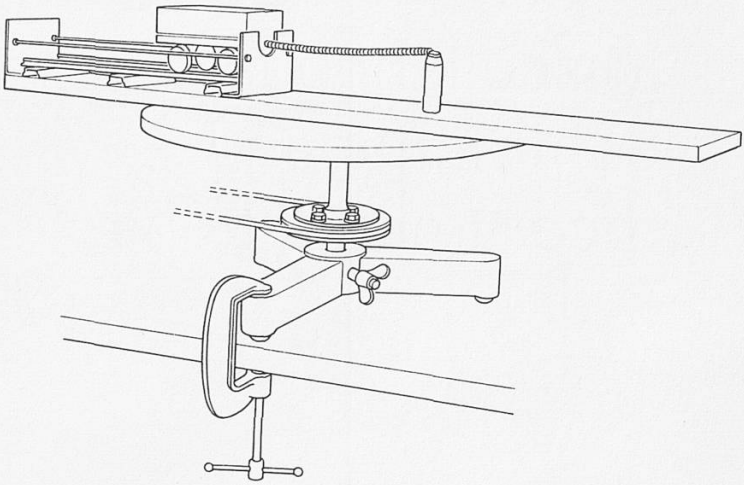
12-volt battery (item 176), **A.C. generator** (item 170), **and class oscilloscope** (item 158)

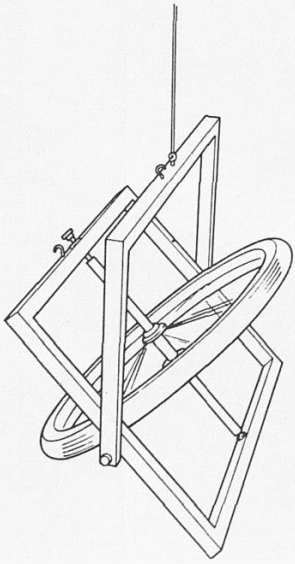




12-volt battery (item 176), **A.C. generator** (item 170), **with demonstration meters** (item 70), **and demountable transformer** (item 147)

Truck attachment (item 154/2) **on turntable** (item 154/1)





Large gyroscope (item 186/1), **and mount** (item 186/2)

Section C

Miscellaneous comments and recommendations

Miscellaneous Comments and Recommendations

Contents

Plugs and sockets

4mm plugs and sockets

The use of 4mm plugs and sockets for the connection of school physics teaching apparatus has long been traditional on the Continent. It has now become standard on English school demonstration equipment as well. Terminals with 4mm sockets are now available.

Unfortunately there are two standards for 4mm sockets! There is the English 4mm with a hole size ·152in to ·157in in diameter and the Continental 4mm with a hole size ·161in to ·165in in diameter.

A decision has now been taken that in future all Nuffield apparatus (and all apparatus advocated by the Apparatus Committee of the Association for Science Education) shall use the Continental 4mm size socket, which is specified as ·161in (+·004in —·000in).

Belling and Lee Ltd, Great Cambridge Road, Enfield, Middlesex, produce sockets to the Continental 4mm specification: their L.1499 series and their L.1568 series. These terminals take a plug $\frac{1}{2}$in in length. In addition to these two series, Belling and Lee Ltd are now producing an E.6017 series which is also to the Continental 4mm specification but takes a plug $\frac{3}{4}$in in length. All these terminals are satisfactory.

Colour of terminal sockets

A standard colour code is essential for school physics apparatus. For d.c. work, red and black should be used for positive and negative terminals respectively. Green should be used for an earth terminal. Another colour – yellow, blue, grey, or white, as convenient – should be used for a.c. work.

Twin connectors

Any apparatus requiring a twin connector should use 4mm sockets which are separated by 19mm or $\frac{3}{4}$in. This is standard on the Continent and will be used on future Nuffield apparatus.

Belling and Lee Ltd make a double stacking plug to this specification: their series E.6016.

Coaxial connectors for Geiger-Muller tubes

It has already been decided by the Modern Physical Sciences Committee of the A.S.E. that all ratemeters and scalers for school use shall have a P.E.T. coaxial connector. This connector reduces the danger of electrical noise and the production of spurious counts. It continues as standard for GM tube work.

Coaxial connectors

It has now been decided to accept as an A.S.E./Nuffield standard a particular type of socket for all coaxial connections, other than GM tube work. This is the UHF panel socket with PTFE insulation. It is manufactured in this country by Greenpar (Greenpar Engineering Limited, Station Works, Harlow, Essex) with their reference GE 40003.

The advantage of this coaxial socket is that it will also accept a 4mm plug.

This means that if a general purpose amplifier, for example, were fitted with such a socket, it would be used for most purposes with a single 4mm plug but it could also be used for cm wave work where a coaxial lead is necessary. In addition to the coaxial socket, there should also be an additional 4mm earth socket nearby on the amplifier.

This type of socket is substantially more satisfactory for school use than the domestic type of coaxial connector, as used for connecting aerials to television sets. On a television set the aerial is left permanently connected, whereas in school the plug will be repeatedly connected and disconnected and bad connections soon result.

Radiospares supplies the same UHF socket as the Greenpar one (Radiospares reference: UHF socket SO 239). The Radiospares plug to marry with it is 'UHF plug PL 259'.

Fuses

A very wide range of cartridge fuse-links has been used in school science apparatus in the past. It would be much easier for teachers if a standard were adopted, and it is recommended that, in future, apparatus requiring cartridge fuses should use 20mm fuses in the preferred ranges 50mA, 100mA, 250mA, 500mA, 1A, 2A, 5A. These fuses are covered by British Standard BS 4265 : 1968.

Electrical measuring instruments

1 Meters for pupil use stage 1

This covers the meter requirements for class use in the first three years of the Nuffield O-level physics course.

d.c. moving coil ammeter: 0–1amp – item 79
d.c. moving coil voltmeter: 0–5 volts – item 80
galvanometer: 3·5–0–3·5mA/10 ohms – item 180

The suggested galvanometer range works well with the Nuffield experiments, other possibilities could be used. This is merely an indication of the sensitivity required.

16 of each will be required for a class of 32, enabling pupils to work in pairs.

2 Meters for pupil use stage 2

This covers the meter requirements for class use in the final two years of the Nuffield O-level physics course.

d.c. moving coil ammeter: 0–1amp, 0–5amp – item 178
d.c. moving coil voltmeter: 0–5 volts, 0–15 volts – item 179

3 Demonstration meters

Two identical demonstration meters with bold markings are required.

Interchangeable scales are ideal and the following ranges should be available:

d.c. 300 volts	d.c. 5amp	a.c. 300 volts	a.c. 5 amp
15 volts	1amp	15 volts	1 amp
5 volts	100mA	5 volts	
	2·5–0–2·5mA		

Multi-range demonstration meters can be used instead of the interscale type.

Meeting the need

The meter requirements for class use can be met in a number of different ways. Some schools will prefer separate instruments, some dual range meters, some a basic meter with interchangeable shunts. It is partly a matter of personal preference, and it partly depends on what the school already possesses. No attempt is therefore made to say which is the best way of meeting the requirements: it is very much hoped that manufacturers will suggest various different ways in which it can be done.

Method 1 To supply 16 of each of the following single range meters:

ammeter (0–1A)
ammeter (0–5A)
voltmeter (0–5 V)
voltmeter (0–15 V)
galvanometer

Method 2 To supply 16 of each of the following:

dual range ammeter (0–1A, 0–5A)
dual range voltmeter (0–5V, 0–15V)
galvanometer

Method 3 To supply 32 basic instruments, which can be used as the galvanometer, together with:

16 shunts for 0–1amp range
16 shunts for 0–5amp range
16 bobbins for 0–5 volt range
16 bobbins for 0–15 volt range

Combinations of these three are, of course, possible.

Some teachers may prefer Method 1 as there is less danger of confusion to a young pupil when using a single range meter with only two terminals.

Some may prefer Method 2 as it involves purchasing fewer meters.

Some may feel that in Method 3 the disadvantage of having a conversion factor by which to multiply the scale reading is offset by the greater versatility of the instruments, remembering the requirements of A-level, when it may only be necessary to purchase extra shunts and bobbins.

Combinations of the three methods are, of course, possible and will be adopted by some teachers.

Note
No a.c. meters are required for class experiments in the O-level course. The a.c. requirements can be met by the demonstration meters.

Pressure tubing and glass tubing

A rotary vacuum pump is an essential item of apparatus for any school following the Nuffield O-level course. It is necessary to connect this to various other items of apparatus and standardization of connections will make the experiments substantially easier for the teacher.

In the specification for the vacuum pump (item 13) it is stated that the outlet should have external diameter $\frac{1}{4}$in. This will be satisfactory for use with pressure tubing of internal diameter 5mm (British Standard size M5) and this will be adopted as the standard size of pressure tubing in all Nuffield Physics experiments.

Having decided on the size of the pressure tubing, it is essential that all items which have to be connected to the pump by this pressure tubing should have glass tubes of external diameter suitable for use with this pressure tubing; in practice this will usually mean glass tubes not less than 6mm external diameter and not more than 8mm external diameter. The same comments apply where the connection is to a metal tube, for example, in the Bourdon gauge (item 67).

Typical items involved are:

Item 67 Bourdon gauge
Item 87 Clapper bell in round flask
Item 110 Tubes for 'guinea and feather' experiment
Item 6J 4ft glass tube in Bristol Pressure Kit

The one exception to this is the glass tube connected to the 'Interkey' tap in the Bromine Diffusion Kit, for which an adaptor is necessary.

Hardware

The Nuffield Physics Project has paid some attention to the basic hardware for use in school physics laboratories.

Retort stands

The traditional type of retort stand in which a threaded rod is screwed into a base is not the most economic type either in cost or in storage space. Furthermore it is not the most versatile in use.

It is advocated that retort stands be used in which a plain rod is inserted into a base and secured by a screw in the base. This arrangement enables rods of various lengths to be put into the base and saves the necessity for having a large variety of sizes as was the case with traditional stands. The base can also be used to hold other objects, from pins to mercury vapour lamps on a rod mount.

The bases should be stackable on each other. This will mean a substantial saving in storage space.

Rods should be available in the following lengths, 25cm, 50cm, 75cm, 100cm, though the 50cm length will be the most frequently used.

Clamps
These should be the type with overlapping jaws which will hold both large objects and small ones such as pins.

Bosses
These should be as versatile as possible to hold rods in many different ways at right angles to the supporting rod. They should be so designed that they will also hold flat objects such as rules, boards, etc.

Slotted bases
The Physics Project has found the slotted bases (Nuffield apparatus item no.30) exceptionally useful and versatile on the repeated occasions throughout the course when a card, a board, a manometer etc., need to be held vertically. Though used extensively on the Continent, they are not usually seen in English schools. They can however be warmly recommended. They are a useful economy in the long run, as they obviate the need for feet on certain apparatus, reducing the cost and also helping with storage.

Storage and packaging

The Nuffield Physics Project will result in a substantial increase in the amount of apparatus in those schools which are following the programme. This will present problems of storage. Certain individual items, such as power supplies or the scaler, will no doubt be stored on shelves, on the laboratory bench or in cupboards. On the other hand it will be found convenient to keep a great deal of the equipment stored in the boxes in which it is supplied. Manufacturers need to bear this in mind. The apparatus should be supplied, where appropriate, in strong cardboard boxes, preferably with a loose fitting lid. Though such packaging may add a little to the cost, it is essential for the user.

Secondly it should be remembered that one of the objects of the Nuffield Physics Project is to get the pupils doing experiments themselves. This means that with a class of 32, sixteen sets of apparatus from the electromagnetic kit will be required. It will therefore help the object of the project – as well as make easier the assembly of kits – if manufacturers refrain from attempting to pack them as single items but together as a class package (or half-class package, as may be appropriate). We shall be very sorry indeed if experiments which were intended for the pupil turn into a demonstration by the teacher because he purchased only one set rather than the class package.

Teachers themselves will want to consider carefully the problem of storage. There is much to recommend the use of a standard size of tray for a great deal of the equipment, particularly for the kits which include large numbers of small items.

Teachers are also advised to read the report by O. M. Stepan, *The Storage of Apparatus,* obtainable for 5s from the A.S.E., 52 Bateman Street, Cambridge. The Nuffield Foundation recognized the difficulties of storage and commissioned Mr Stepan, an architect in the Department of Education and Science, to consider the problem. His report deals with physics and chemistry apparatus for O-level courses.

Elementary physics laboratories

Many teachers using the Nuffield programme will have to use whatever laboratories are already available in their school. The comments that follow outline possible ideal conditions for Nuffield work; they may be helpful where new laboratories are being built.

Current developments in the teaching of physics make new demands upon the laboratories in which the subject is taught. Perhaps the two major requirements are:

i flexibility in furnishing and layout;
ii storage, which must be both ample and accessible.

Considerable emphasis is placed on individual practical work by the pupils, who, in general, work together in pairs. Assuming classes of 32, this requires 16 sets of equipment, these covering the wide fields of Light, Electricity, Heat, Mechanics, and General Physics. During a normal teaching day when classes with totally different requirements may be using a laboratory, considerable quantities of equipment will need to be moved in and out of store and the very layout of the room itself may need to be changed. Thus a double period in which eight free-standing ripple tanks are used in partial darkness may be followed by another requiring 8ft long runways for dynamics experiments.

It follows that storage space must be ample (25 per cent of the laboratory area, for example 240 sq ft where the laboratory is 960 sq ft, would not be unreasonable) and that it should be so designed that apparatus can be got out and put away with ease. Ease of access adds very considerably to the success of the practical work. The provision of simple trolleys, with their top surface at the level of the laboratory tables, helps greatly. Such trolleys should, of course, be capable of going through the doors and split levels should be avoided.

It also follows that the laboratory furnishings should provide a flexible layout. It is far better to have robust movable tables than fixed ones with complex supplies. Such tables should not have drawers or cupboards; should be light enough for two children to carry them; should be overhung so that G-clamps can be used to clamp equipment to them; should be the same height as any fixed benches; and should fit flush against one another (no bevelled edges or rounded corners). A useful size ratio is 2:1 in length and breadth.

In the Nuffield course the demand for water (and therefore for sinks) is small, the demand for gas is smaller than hitherto, whilst the requirement for electrical services is greatly increased. But, at the same time, the development of portable L.T. supplies operated from electrical mains has obviated the necessity for expensive centralized L.T. supplies.

The few sinks which are required – four to six in number – are best sited within the wall benches and must have good, easily accessible traps. Each sink should have four taps, two to take small rubber tubing and two to take $\frac{1}{2}$ inch hose fittings, all supplied from the main (not from a tank). A hot water supply to one sink is desirable. Detachable covers to the sinks provide additional bench space over the periods when the sinks are not required.

The demonstration bench, if provided, should be at the same height as the other benches and tables: no podium is necessary. It should be well supplied with gas and mains electricity, though its top surface should be quite free of these services.

Other mains outlets should be provided round the walls, preferably just above bench height so that the working surface is free of encumbrances. A sloping panel at the back of the bench carrying these and gas outlets is useful.

The total number of mains outlets required is large: a minimum of twenty-four pairs of outlets will be called for, twenty-four triple outlets would be better. Some of these should be sited in the floor of the room using very robust dips. All outlets should be of the 13amp flat-pin type, though it should be appreciated that the total current load would never exceed 40amps and would usually be substantially less.

In the type of teaching now envisaged in the Nuffield course, class practical work, teacher demonstrations and class discussion are inextricably mixed. Consequently, all teaching must take place within a laboratory and that laboratory must provide good facilities for all these activities. This suggests that the space in front of the teacher's bench should be free of fixtures so that the whole class can be seated comfortably for discussion and demonstration. The teacher must have ample blackboard space (preferably large roller or sash), with an adjacent screen and display area. Nearby there should be a wall clock with a sweep seconds hand.

In the ceiling, in front of the teacher's bench, there should be a beam giving provision for hanging fairly heavy loads (say 50lb). This should *not* be above the bench – but above a clear floor space so that the full height of the laboratory can be used.

The side walls, one of which will usually carry the windows, can be equipped with wall benches. These will not normally be used for class experiments – and can therefore be fitted out with drawer units. Even so, knee spaces should be left at convenient intervals. These benches, with their services, serve the movable tables, and also can act as areas where experiments can be left out for a longer period of time than a lesson. The fourth wall should be free of benches. Covered with soft board for display, it can also make a useful vertical working surface, especially if a light load-bearing beam is fastened above it.

Two doors should be provided, one near the teacher's bench and one remote from it.

Blackout is invaluable and half blackout essential. This should be designed carefully so that ventilation is still effective. Ideally it should draw up from the bottom rather than from the top down.

Preparation room, workshop and stores

Each laboratory demands its own preparation room and its own store, whilst the block of laboratories requires a well equipped workshop. The functions of the three rooms are quite different. The preparation room is a room equipped as a laboratory with a bench and full services. There the teacher can prepare his demonstrations, etc. Here, too, is the best place for battery charging equipment. The workshop is equipped for the repair and maintenance of apparatus, and for the construction of new apparatus. It is the province of the laboratory technicians.

The design of suitable storage rooms demands more attention than has usually been given hitherto. As has already been indicated, large quantities of equipment have to be stored – and yet be readily accessible. Bulk apparatus for class use can well be stored on deep shelving, but demonstration apparatus requires shallow shelving so that one piece does not hide behind another. Perhaps racking mounted on rails might be explored so that ample storage is provided.

A cupboard suitable for radioactive sources should be provided within the store.

Direct access from the laboratory to the store and preparation room is necessary. It should be possible to enter the preparation room without passing through the laboratory.

Lighting

Really good lighting is essential. Warm white strip lighting is very suitable, and the switch panel should enable these to be switched individually so that selected areas can be brighter than others.

Wall space is so valuable that the practice of installing windows along the whole length of two facing walls should be discouraged.

Strobe photography

At various stages of the Nuffield Physics course, strobe photographs need to be taken. In the past, some teachers have been apprehensive about this because of the difficulties attendant on developing and printing in a school.

Recent developments with Kodak Limited have perfected a system whereby a 35mm cassette of 20 exposure Plus-X film can be exposed and then developed in normal lighting in front of the class using a monobath developer and fixer. The film can be cut up, put in a plastic holder and projected in an Aldis projector. Using daylight photographic paper, prints can be readily obtained for use by the pupils. In the technique advocated, the first print is obtained 10 minutes after starting to develop the exposed film.

This technique is liable to transform the photographic work that can be done in the school laboratory. Details of the technique and of the materials required are given below.

Recommended photographic materials

1 Kodak 'Plus-X' Pan film in 20 exposure cassettes. Reference: PX.135-20

2 Kodak Projection Paper. Reference: P.153

3 Kodak 'Plus-X' Monobath (supplied in 120cc bottles)

4 Kodak Universal Developer (supplied in 250cc bottles) (dilutes 1 + 7 for use)

5 Kodak 'Kodafix' Fixer (supplied in 250cc bottles) (dilutes 1 + 7 for use)

6 Kodak Ready-Mounts 24mm × 36mm (Latex Adhesive) (supplied in boxes of 50)

Photographic accessories kit

In addition to the photographic materials listed above, the following items are also required:

1 beaker for cassette film
1 twiddle stick
1 holder for paper
2 developing dishes

For convenience the above items have been put together in a single kit (item 171) and are now commercially available. Details of these items are given below.

The technique for processing films in the laboratory

The description that follows applies to one particular developer used with one particular film. Whichever film or developer is used, it is essential to follow the maker's instructions. If this type of monobath is used with the wrong film, or under the wrong conditions, it may well fix the film before the developing process is complete.

The film used must not be longer than a 20 exposure length, otherwise the pumping action which takes place in the cassette will be ineffective.

1 Load the cassette of film into the camera as instructed in the camera manual, but make two additional blank exposures at the beginning of the film. After making 16 exposures, wind the 20 exposure length of film back into its cassette leaving the final inch of the tongue protruding. Cut the tongue off and bend the last inch of film back and secure with an elastic band.

2 Take the twiddle stick (item 171B) which is about 3in long, and fit the slot over the key in the cassette. Then wind the film up (but without forcing) on its spool. (A 3 to 4in length of PVC tubing can be used in place of the twiddle stick.)

3 Lower the cassette gently into 40cc of the monobath in a small container (item 171A) until all but the top of the cassette is immersed. The container is a glass vessel of about 70cc capacity – for example, a vodka glass. See illustration on page 129.

Whilst lowering the cassette into the glass, gently unwind the film with the rod. Air will bubble out. Gently, but not slowly, rewind the film so that the monobath is pumped through the cassette and repeat the process until the liquid is forced out of the top of the cassette. All air bubbles have now been removed and the cassette may be lowered completely into the small container. With the cassette thoroughly immersed, wind and unwind the film through $1\frac{1}{2}$ turns so continuing the pumping action. This should be gentle but at about once every 2 seconds.

4 After the correct time has elapsed ($3\frac{1}{2}$ to 4 minutes at 20° to 23°C), take the cassette from the container and plunge the whole into water. Open the cassette or unspool the film under water. (Should the film appear cloudy transfer it to a bath of an acid fixer containing a hardener.) Wash the film in water briefly (10 seconds, say) and inspect it. Should dark bands occur across the width of the film at its ends, then the rotating backwards and forwards was performed using too many revolutions in each direction. Should scratches along the film length occur, then the processing has been performed too vigorously.

5 Select a suitable negative, cut it out with scissors and immediately mount it in a cardboard mount and project it.

6 Throw the monobath away after use.

7 If an archivally permanent negative is required, re-fix the negative to harden it and wash with three 2-minute rinses each in a fresh supply of water at 18° to 24°C (65° to 75°F).

Making positive prints

The mounted negative may be used to produce prints within a matter of minutes if special paper is used. The paper must be such that it will not fog if exposed to normal tungsten room lighting for, say, half a minute.

The technique requires a simple printing frame (item 171C, see details below) and a slide projector. The whole operation can be carried out in a room lit with tungsten lighting (or subdued daylight but not fluorescent). Project an image of the negative chosen on to the frame using the 500 watt projector. Switch the projector off and slip a piece of cut paper into the frame. A suitable size is 8in by 5in. Expose for about 5 seconds to the light from the projector, which should be about 1 metre away.

Develop the paper immediately (face down) in a dish of developer for half a minute and then transfer the paper print to a bath of fixing solution for 1 minute. Rinse the print briefly in clean tap water, preferably at about 20°C to remove excess fixer salts. If it is intended to preserve the print, it should be more thoroughly washed for about 20 minutes in running water.

The printing frame is available commercially in the photographic accessories kit (item 171) or can be made from a sheet of hardboard about 11in square, to which a piece of thin black card 8in by 9½in is stuck. Double strips of black card 8in long and 2½in wide are stuck to this leaving a strip 8in long and 4½in wide across the centre. The double strips are stuck down with the inner edges left free so that a strip of the printing paper 8in by 5in can be held between them in the centre of the frame.

The whole frame is supported vertically in a slotted base (item 30).

Esso films

A series of films for science teachers has been sponsored by Esso Petroleum Company in consultation with the Nuffield Foundation Science Teaching Project. These films are intended for teachers and are not suitable for showing to pupils.

The films are available on free loan from Esso Petroleum Company, Public Affairs Department, Victoria Street, London, S.W.1, or direct from Esso's distributors, Travelling Films Limited, 78 Victoria Road, Surbiton, Surrey (Elmbridge 1022).

The films relevant to the Nuffield O-level physics course are:

The Electromagnetic Kit	J. M. Osborne
An Approach to the Electron	W. Llowarch
Elementary Experiments in Heat Radiation	Miss J. B. Tresise
The Worcester Circuit Board	E. J. Wenham
Experiments in Force and Motion	W. Ritchie
Momentum and Collision Processes	J. T. Jardine
An Approach to Kinetic Theory	Sister St. Joan of Arc
Experiments in Ray Optics	G. W. Dorling
Waves and the Ripple Tank	M. J. Elwell
Oscilloscopes and Slow A.C.	G. E. Foxcroft
Kinetic Energy: Introductory Experiments	K. M. Grayson

Further films in the series include material not only relevant to O-level, but also to A-level. They are:

The Use of Centimetre Waves	J. L. Lewis
Electrostatics: A Modern Approach	E. J. Wenham and M. J. Harrap
Introduction to Radioactivity	J. L. Lewis
Further Experiments in Radioactivity	A. F. Vyvyan-Robinson
Electrical Oscillations and the Electromagnetic Spectrum	D. C. F. Chaundy

The films can also be purchased at cost price from Esso Petroleum Company, Public Affairs Department, Victoria Street, London, S.W.1.

Apparatus construction sheets

The Nuffield Physics Project set up an apparatus drawings group so that those teachers who wish to construct some of the apparatus themselves might be able to do so. This clearly saves considerable expense, though it involves a great deal of time on the part of the teacher concerned.

Over forty of the construction sheets have now been published and further sheets are in the course of preparation. They can be obtained from the General Secretary, Association for Science Education, 52 Bateman Street, Cambridge.

Supply of solid carbon dioxide

Schools following the Nuffield programme will require supplies of dry ice from time to time. The CO_2 cylinders and dry ice attachments (items 19/1 and 19/2) do meet the problem when limited quantities are needed.

It is not always realized, however, how easy it is to obtain blocks of 'Drikold' both cheaply and rapidly from I.C.I.

A large block can be ordered from an I.C.I. Sales Office which will often deliver over-night to the nearest railway station to the school concerned. Details are given below of the Drikold depots and the I.C.I. Sales Offices. Orders for Drikold should be placed with the nearest I.C.I. Sales Office, whose telephone numbers are given below.

Drikold depots	address	I.C.I. sales office	telephone
Aberdeen	British Railways, Guild Street Goods Station, Aberdeen.	Glasgow	City 5020
Belfast	Imperial Chemical Industries Ltd, Duncrue Street, Belfast.	Belfast	Belfast 27741–7
Billingham-on-Tees	Imperial Chemical Industries Ltd, Billingham Division, Billingham, Co. Durham.	Newcastle	Newcastle 2–5077
Birmingham	British Railways, Central Goods Station, Suffolk Street, Birmingham, 1.	Birmingham	Central 7070
Blackpool	Shaw's Depository Ltd, 87, Whitegate Drive, Blackpool North.	Manchester	Central 8555
Braintree	A. T. Lobb & Sons Ltd, Braintree, Essex.	London	Chancery 9711
Bristol	British Railways, Canons Marsh Goods Depot, Bristol, 1.	Bristol	Bristol 26021
Cardiff	British Railways, Newtown Yard Goods Station, Davis Street, Cardiff.	Cardiff	Cardiff 22731

Drikold depots	address	I.C.I. sales office	telephone
Cole Green	F. & F. Robinson (Transport) Ltd, Cole Green Works, Cole Green, Hertfordshire.	London	Chancery 9711
Devonport	British Railways, King's Road Station Devonport, Devon	Bristol	Bristol 26021
Doncaster	British Railways, Goods Department, Cherry Tree Depot, Hexthorpe Bridge, Doncaster, Yorkshire.	Bradford	Bradford 29530
Douglas Isle of Man	The Isle of Man Steam Packet Co Ltd, P.O. Box No. 5, Imperial Buildings, Douglas.	Liverpool	Central 8000
Dublin	British Railways, North Wall, Dublin.	Dublin	Dublin 76576
Edinburgh	British Railways, Lothian Road Goods Station, Edinburgh.	Glasgow	City 5020
Glasgow	British Railways, High Street Goods Station, Glasgow, C. 2.	Glasgow	City 5020
Grimsby	British Railways, Dock Agents, Fish Docks, Grimsby.	Bradford	Bradford 29530
	Northern Cold Store, Ladysmith Road, Grimsby.	Bradford	Bradford 29530
Hull	Eskimo Foods Ltd, Cold Store, Walcott Street, Hull.	Bradford	Bradford 29530
Leeds	British Railways, Hunslet Goods Station, South Accommodation Road, Hunslet, Leeds, 10.	Bradford	Bradford 29530

Drikold depots	address	I.C.I. sales office	telephone
Leicester	British Railways, Braunstone Gate Goods Yard, Western Boulevard, Leicester.	Birmingham	Central 7070
Liverpool	British Railways, Goods Department, Sandon Dock Goods Station, Liverpool, 5.	Liverpool	Central 8000
London Kings Cross	Barnes Transport Ltd, 7, River Street, London, E.C.1.	London	Chancery 9711
Marylebone	British Railways, Rossmore Road, Marylebone, London, N.W.7.	London	Chancery 9711
Manchester	Imperial Chemical Industries Ltd, Castle Field Depot, Potato Wharf, Off Liverpool Road, Manchester, 2.	Manchester	Central 8555
Norwich	Norfolk Haulage Co. Ltd, Trowse, Norwich.	London	Chancery 9711
Southampton	British Railways, Millbrook Goods Station, Southampton.	London	Chancery 9711
Stoke-on-Trent	British Railways, Goods Traffic Department, Stoke Station, Stoke-on-Trent.	Manchester	Central 8555
West Malling	J. C. Wells (Transport) Ltd, West Malling, Kent.	London	Chancery 9711
Wimblington	Knowles (Transport) Ltd, New Road, Wimblington, March, Cambridgeshire.	London	Chancery 9711

Section D

Lists of Apparatus

List of Apparatus

Contents

Apparatus for year I

The following list is based on a single class of 32 pupils.

If more than one class is following the course, the list provides sufficient material as long as two or more classes are not doing Physics at the same time. If however there are parallel classes doing the work simultaneously, extra quantities will be essential.

item no.	quantity	description	experiment numbers
1	1	Materials kit (solids)	1 2a 13
2	1	Elastic materials kit	1 2a 2c 33a 33b 35 36 37 70
3	1	Crystals kit	1–12 19 59 64
4	1	Microbalance kit	22 23 27 36 67
5	1	Lever kit	32a 77
6	1	Bristol pressure kit	38–46
7	1	Oil film kit	64 66 68
8	1	Bromine diffusion kit	60 61
9	1	Malvern energy conversion kit	72 73 74
10	1	Year I general kit	2b 13 15 16a 16b 16c 17 18 21 23 27 30b 33a 33b 36 44 45 46d 48 61 64 66 70 73 74 75a 75b 78
11	1	Kinetic theory model kit	51 53
12	1	Two-dimensional kinetic model kit	7 49 50 53
13	1	Vacuum pump	2b 16a 16b 16c 17 44 45 46d 46f 48 61
14	1	E.H.T. power supply	85
16	1	Radium source	85
17	1	*Spark counter*	85
18	1	Expansion cloud chamber	81
19/1	2	CO_2 cylinder	1 20a 82
19/2	1	Dry ice attachment	1 20a 82
20	1	Domestic balances (5kg)	46e
21	1	Compact light source	79a 79b
22	1	Atom model	55
23	8	Microscopes	12a 12b 12c 52
24	36	Hand lenses	1 2a 12a 12c 68
25	36	Plastic measuring rules	1 13 14 15 27
26	16	Perspex containers	14 15 62
27	8	*Transformers*	12a 12b 12c 52 82
28	8	Taylor cloud chambers	82
29	8	Whitley Bay smoke cells	52
30	8	Slotted bases	39a 39c
31/1	16	Weight hangers with slotted weights (10g)	21 33a 36
31/2	16	Weight hangers with slotted weights (100g)	21 29 33b 36
32	16	1kg weights	29 32b 78

Apparatus for year I (continued)

item no.	quantity	description	experiment numbers
33	32	Paper scales	24
35	16	S-hooks	various experiments
36	8	1lb weights	29 39a 72 73 74
37	8	1oz weights	29
38	16	Single pulley	78
39	16	Double pulley	78
40	2	Single pulley on clamp	36 70 72 73
41	1	Evesham pressure apparatus	39a
42	8	Lever arm balances	1 2a 13 14 17 18 23 29 42
43	16	Spring balances (1kgwt)	78
44/1	16	G-clamps (4in)	36 37 72 73 75b
44/2	16	G-clamps (2in)	37 73 74
45	1	Foot pump and adaptor	18 43
46/1	1	Translucent screen	45 46a–d 57 60 61 65
46/2	1	Lamp for translucent screen	45 46a–d 57 60 61 65 80
47	8	Illuminants	12a 12b 12c 82
48	1	Statistics frame	31
49	10 pt	Graph plotting board	34
50/1	32 pr	Cylindrical magnets	2d
50/2	2	Horseshoe magnets	74
59	1	L.T. variable voltage supply	51 53 72 73 74 79a 79b
60/1	1	Van de Graaff generator	79b
67	1	Bourdon gauge	43
88	1	Large compression spring	72 73
148	1	Syringe kit	20b
150	1	Fractional horse power motor	51 53
196	1	Source holder	85

In addition to the above, schools will require a quantity of basic equipment (such as retort stands, bosses, clamps, etc.) which it is assumed is available in any well-equipped school. This basic equipment, assumed available, is listed separately for all the years of the course (see page 191).

Apparatus for year II

The logical starting point for a school wishing to teach the Nuffield Physics programme is obviously Year I. It is suggested elsewhere that a school could start with Year III, but it is not recommended that a school start at Year II. For that reason the first list of apparatus given below for Year II of the course assumes that the school has already taught Year I and that the apparatus for that year is therefore available. The items listed are therefore *additional* items. A second list is added giving those items in Year I which are used again in Year II: these need not be ordered by a Year II school which already has Year I apparatus.

The list is based on a single class of 32 pupils.

If more than one class is following the course, the list provides sufficient material as long as two or more classes are not doing Physics at the same time. If, however, there are parallel classes doing the work simultaneously, extra quantities will be essential.

item no.	quantity	description	experiment numbers
15	1	H.T. power supply	32 33 34
34	1	Variable inertia bar	61
50/3	1	Magnet 'Eclipse major'	7
51	1	Malvern electrostatics kit	35 36 38
52	1	Worcester circuit board kit	12–26
53	1	Worcester current balance kit	14 17a 71
54	1	Worcester gas voltameter kit	28
55	1	Friction kit	44
56	1	Conductivity kit	84
57	1	Year II general kit	6 10 23 27 29 35 38 45 46 48 50 53 62 71 73 74
58	1	Radiation kit	89–95
60/2	1	Van de Graaff accessories	37
61	1	Fine beam tube	33 34
62	1	Fine beam tube base	33 34
63	1	Forces demonstration box	52
64	1	Oscilloscope	34
65	1 pr	Metal plates with insulating handles	31 32 38
66	1	Neon lamp	32
67	7	Bourdon gauges (8 needed in all, 1 available from previous year)	62 80
68	1	Phototransistor	97
69	1	High dispersion prism	97
70	1	Demonstration meter	28 64 67 97
71/1	1	D.C. dial (1amp)	28

Apparatus for year II (continued)

item no.	quantity	description	experiment numbers
71/2	1	D.C. dial (5amp)	64 67
71/4	1	D.C. dial (2·5–0–2·5mA)	97
71/7	1	A.C. dial (5amp)	64
72	1	Lamp (12 volt, 24 watt)	64
73	1	Lamp (12 volt, 36 watt)	64
74	1	Lampholder (SBC) on base	64
75	8	Immersion heaters	65 66
76	8	Aluminium containers	65 72 80
77	8	Aluminium blocks	66
78	1	Variable a.c. supply ('Variac' type)	32
79	16	D.C. ammeters (0–1amp)	17a 18 20 21 22a–c 24 25 26
80	16	D.C. voltmeters (0–5 volt)	23
81	4	Newton spring balances (10N)	51
82	4	Iron flask for freezing	78
83	32	½lb weights	50
84	16	Wire strippers	Many experiments
85	1	Demonstration spring balance (5kg)	44 49
86	1	Mounted glass plate	53
87	1	Clapper bell in flask	62
89	1	Water circuit board	19
91D	1	Lampholder (BC) on base	64
93B	1	Large convex lens (from smoke box kit)	97
102	1	White screen	31 97
103	1	Bicycle dynamo assembly	61
106/1	1	Dynamics trolley	58 59 60
176	4	12 volt batteries	29 33 34 61 64

For the apparatus needed for Year II, but already used in Year I, see next page.

In addition to the above, schools will require a quantity of basic equipment (such as retort stands, bosses, clamps, etc.) which it is assumed is available in any well-equipped school. This basic equipment, assumed available, is listed separately for all the years of the course (see page 191).

List of apparatus needed for Year II, but used in Year I

item no.	quantity	description	experiment numbers
2	1	Elastic materials kit	1 3b 14 39 41 42
5	1	Lever kit	3a 3b
9	1	Malvern energy conversion kit	61 67
10	1	Year I general kit	2 3b 8 9 39 41 46 56 59 62 67 68 69
11	1	Kinetic theory model kit	83
12	1	Two-dimensional kinetic model kit	70 82
13	1	Vacuum pump	62
14	1	E.H.T. power supply	31 32 35 38
19/1	2	CO_2 cylinder	75
19/2	1	Dry ice attachment	75
21	1	Compact light source	31 88 97
22	1	Atom model	81
27	8	Transformers	29 64 65 66
31/1	16	Weight hangers with slotted weights (10g)	41
31/2	16	Weight hangers with slotted weights (100g)	50
32	16	1kg weights	3b 40 49 53 67 71
36	8	1lb weights	53–60 68 71
37	2	1oz weights	59
38	1	Single pulley	56 68
39	1	Double pulley	56 68
40	1	Single pulley on clamp	2 55 59 60
42	8	Lever arm balances	65 66
43	16	Spring balances	2 50
44/2	16	G-clamps (2in)	60 61
46/1	1	Translucent screen	31 88
50/1	32 pr	Cylindrical magnets	7
50/2	2	Horseshoe magnets	7 8
59	1	L.T. variable voltage supply	19 27 28 31 34 61 62 67 83 88 97
60/1	1	Van de Graaff generator	30 32 37 38
67	1	Bourdon gauge	62 80
88	1	Large compression spring	60
148	1	Syringe kit	77
150	1	Fractional horse power motor	83

Apparatus for year III

The majority of schools doing Year III of the Nuffield Physics programme will already have done Years I and II. The first list of apparatus given below assumes that the school has already taught the earlier years and that the apparatus for those years is therefore available. The items listed are therefore *additional* items.

The second list gives those items in Years I and II which are used again in Year III. A school starting at Year III will need the items in both these lists.

The list is based on a single class of 32 pupils.

If more than one class is following the course, the list provides sufficient material as long as two or more classes are not doing Physics at the same time. If, however, there are parallel classes doing the work simultaneously, extra quantities will be essential.

item no.	quantity	description	experiment numbers
70	1	Demonstration meter (2 needed in all, 1 available from earlier years)	83 88f 88g 92b 93 101
71/1	1	D.C. dial (1amp)	101
71/3	1	D.C. dial (5 volts)	92b
71/6	1	A.C. dial (15 volts)	93
72	15	Lamps (12V, 24 watt) (16 needed in all, 1 available from earlier years)	93, 94a
74	15	Lampholders (SBC) on bases (16 needed in all, 1 available from earlier years)	93 94a 94b
81	4	Newton spring balances (10N) (8 needed in all, 4 available from earlier years)	70
88	2	Large compression springs (3 needed in all, 1 available from earlier years)	60a–b
90	1	Ripple tank kit	4a–u, 34
91	1	Pinhole camera kit	7 12 13 18
92	1	Westminster electromagnetic kit	Very many experiments
93	1	Smoke box kit	5 8 9 67
94	1	Kit for ray optics	Very many experiments
95	1	Edinburgh CO_2 pucks kit	54
96	1	Kit for particle model of refraction	31
97	1	Double slits kit	33a 36
98	8	Reels of bare eureka wire SWG 28	94a–b
99	16	Power line terminal rods	94a–b
100/1	8	Rectangular plastic tanks	27a

Apparatus for year III (continued)

item no.	quantity	description	experiment numbers
100/2	1	Large rectangular transparent tank	3 6c,d
101	1	Large Slinky	1b
104	16	Low voltage power units	Very many experiments
105/1	32	Hand stroboscopes	4g,h,o–u 5 34 43
105/2	4	Masking tape	5 43
106/1	32	Dynamics trolleys	42 49 50 51 52 58 59 69a
106/2	48	Elastic cords for accelerating trolleys	58 59
107	16	Runways	42 49 50 51 52 58 59
108/1	16	Tickertape vibrators	Very many experiments from 44–67
108/4	16	Rolls of tickertape (gummed)	Very many experiments from 44–59
109	1	Boyle's law apparatus	79
110	8	Tubes for 'guinea and feather' experiment	65
111	16	60° prisms	29
112	32	Lenses (+7D)	6c–d 7 10 21b
113/1	16	Plano-convex lenses (+14D)	12 13 18 19 20 36
113/2	16	Plano-convex lenses (+20D)	20
113/3	16	Plano-convex lenses (+2·5D)	12 13 18
114	1	Model eye kit	22b
115	16	Telescope mount	12 13 18 19 20 25
116	16	Plane mirrors	6e 14 15 26
117	16	Holders for mirrors	14 15 26
118	16	Cylindrical concave mirrors	14p
119	1	Flexible curtain rail	53a
120	16	Hack-saw blades	43 80o
121	32	2in metal strips as jaws	43 53b
122	1	Magnetization kit	101 104
123	1	Launching ramp	69a
124/1	1	Lens holder (for 5cm diameter lens)	6c–d 21b 22b
124/2	1	Lens holder (for 10cm diameter lens)	5 67
125	1	Skelton variable focus eye	23
126	2	Plastic waves	35a
127	1	Coil (120 turns)	69a
128	1	Coil (2400 turns)	101
129	16 pr	Glass plates for interference	39a
131A	1	Steel ball bearing ($\frac{3}{4}$in diameter)	53a 63 66b
133	1	Camera	63 66b
134/1	1	Motor driven stroboscope (synchronous)	63 66b 67
142	1	Macro-Millikan apparatus	97
147	1	Demountable transformer kit	89b 90c 101 103

Apparatus for year III (continued)

item no.	quantity	description	experiment numbers
149	1	Electric field apparatus	95a
151	1	Rotating disc for FHP motor	5
158	8	Class oscilloscopes	89c
160/1	2 Opt	Demonstration trolleys	60a–b 62
166	1	Constant pressure apparatus	67 69b
180	16	Galvanometers	87a–b 88a–e 90a
181	1 Opt	General purpose amplifier	39b
182	1 Opt	L. F. signal generator	39c
183	2 Opt	Loudspeakers	39b 39c
184/1	1 Opt	3cm wave transmitter	39b
184/2	1 Opt	3cm wave receiver	39b

List of apparatus needed for Year III, but used in previous years

item no.	quantity	description	experiment numbers
7E	8	$\frac{1}{2}$mm graticules	36
8	1	Bromine diffusion kit	74
11	1	Kinetic theory model kit	71a
12	1	Two-dimensional kinetic model kit	71b
13	1	Vacuum pump	65
14	1	E.H.T. power supply	95a–b 96 97 99b
15	1	H.T. power supply	94b 100
19/1	2	CO_2 cylinder	54
19/2	1	Dry ice attachment	54
21	1	Compact light source	Very many experiments
23	8	Microscopes	72
27	8	Transformers	Very many experiments
29	8	Whitley Bay smoke cells	72
30	1	Slotted bases	22b
32	8	1kg weights	57 70
43	3	Spring balances	60a–b
44/1	8	G-clamps (4in)	43
44/2	16	G-clamps (2in)	43
45	1	Foot pump and adaptor	79
46/1	1	Translucent screen	67 74
46/2	1	Lamp for translucent screen	74
47	8	Illuminants	4a–u 34
48	1	Statistics frame	41
51	1	Malvern electrostatics kit	97 99a–d
52	1	Worcester circuit board kit	91 92b
57	1	Year II general kit	91 96
59	1	L.T. variable voltage supply	Very many experiments
60/1	1	Van de Graaff generator	98
60/2	1	Accessories for Van de Graaff generator	98
61	1	Fine beam tube	100
62	1	Fine beam tube base	100
64	1	Oscilloscope	89a–89b

List of apparatus needed for Year III, but used in previous years continued

item no	quantity	description	experment numbers
65	1 pr	Metal plates with insulating handles	95b 96
67	8	Bourdon gauge	75 77
70	1	Demonstration meters	83 88f 88g 92b 93 101
71/2	1	D.C. dial (5amp)	83 93 101
71/4	1	D.C. dial (2·5–0–2·5mA)	88f 88g
72	1	Lamps (12V, 24 watt)	93 94a
73	1	Lamps (12V, 36 watt)	93
74	1	Lampholders (SBC) on bases	93 94a–b
76	1	Aluminium containers	75
79	1	D.C. ammeters (0–1amp)	69a
80	16	D.C. voltmeters (0–5 volt)	91
81	4	Newton spring balances (10N)	70
84	16	Wire strippers	Very many experiments
85	1	Demonstration spring balance (5kg)	60a–b
88	1	Large compression springs	60a–b
89	1	Water circuit board	92a
102	1	White screen	6a–e 21b
103	1	Bicycle dynamo assembly	88g 89a
150	1	Fractional horse power motor	5 71a 86 88f
176	4 or more	12 volt battery	94a 100 104

Apparatus for year IV

All schools doing Year IV of the Nuffield Physics programme will have followed earlier years of the course. The first list below includes only *additional* items which will be required. The second list gives those items from previous years which are used in Year IV.

The list is based on a single class of 32 pupils.

item no.	quantity	description	experiment numbers
40	16	Single pulley on clamp (16 needed in all, 2 from previous years)	17b 58 59 60 62
71/5	1	A.C. dial (5 volts)	131b 132
71/8	1	A.C. dial (1amp)	120 122 123 125b 131b
71/9	1	A.C. dial (300 volts)	123 125b 151 153 154d
71/10	1	D.C. dial (15 volts)	128 138 141 150 151 156
71/11	1	D.C. dial (300 volts)	142 154c
71/12	1	D.C. dial (100mA)	142 148 164
81	16	Newton spring balances (10N) (16 needed in all, 8 from previous years)	32a 33a 61a,b 114
85	2	Demonstration spring balance (5kg) (2 needed in all, 1 from previous years)	6 17a,b 34 57 80
98	16	Reel of bare eureka wire (SWG 28) (16 needed in all, 8 from previous years)	143 154a 157
128	2	Coil (2400 turns) (1 from previous year)	154d
130/1	1	Scaler	9 20 35 55 129b
130/2	2	Photodiode assembly with light source	9
131	1	Year IV general kit	1 2 14 18 20 22 34 44 45 51 65 66
132	1	Year IV electrical general kit	144 147 148 151 158 159
134	1 Opt	Xenon flasher	119
136	1	Maltese cross tube	160
137	1 Opt	Perrin tube	165
138	1	Deflection tube	161
139	1	Set of coils and supports	163 165
140	1	Stand for tubes	160 161 165
143	1	Pair of Bernoulli tubes	39
144	1 Opt	Demountable discharge tube for positive rays	166
145	1	Demonstration thermometer	106
146	1	Inertia balance kit	27 30 31
153	3	Copper voltameters	117 141
155	16	Small electric motors	149b
156	8	Diodes and holders	158 159 172
157	8	Microphones	93b 94 129c,e 171

Apparatus for year IV (continued)

item no.	quantity	description	experiment numbers
159	1	Air rifle	54 55
160/2	1 Opt	Meter attachment for demonstration trolley – optional	10
161	1	Gantry for CO_2 pucks kit	43
162	4	Lampholder (BC) on base	111 120 122 123 125b 142 154b
163	16	Cardboard tubes	107
164	16	Cardboard cups	107 127
165	1	Air blower	37
167	1	Water rocket	23
168	1 Opt	CO_2 capsule rocket	23
169	4	Large magnetic pucks	92b
171	1	Photographic accessories kit	Various experiments
174	1 Opt	Collision in two dimensions kit	48
175	32	60° isometric grid graph paper	98
176	4+	12 volt battery	Many experiments
177	16	Lamps (12V, 6 watt)	115 120 125a 128 149a 151
178	8	D.C. ammeters (0–1A, 0–5A)	127 140 154a 155
179	16	D.C. voltmeters (0–5V, 0–15V)	125a 126 127 140 149a 151 152 153 154c 155

List of apparatus needed for Year IV, but used in previous years

item no.	quantity	description	experiment numbers
2	1	Elastic materials kit	58 59 143
6	1	Bristol pressure kit	78 84
8	1	Bromine diffusion kit	89 90 99
9	1	Malvern energy conversion kit	110 121 149b
10	1	Year I general kit	54 64 79a,b 86 87a,b 95
11	1	Kinetic theory model kit	71 73b 75a 81
12	1	Two-dimensional model kit	70 72 73a 77 100 101
13	1	Vacuum pump	56 79a 87a 90 94 166
14	1	E.H.T. power supply	49b 119 160 161 165 166 167 168 169
15	1	H.T. power supply	119 142 154b 162a,b 163 164 165
16	1	Radium source	168
18	1	Expansion cloud chamber	49b
19/1	2	CO_2 cylinder	8 13 15 43 92b 94
19/2	1	Dry ice attachment	8 13 15 43 92b
20	1	Domestic balance (5kg)	33a 34 60 85 86 106a
21	1	Compact light source	21b 95 167
22	1	Atom model	68
23	8	Microscopes	74
27	8	Transformers	Many experiments

Apparatus for year IV used in previous years (continued)

item no.	quantity	description	experiment numbers
29	8	Whitley Bay smoke cells	74
31/1	1	Weight hangers with slotted weights (10gm)	17b 62
31/2	16	Weight hangers with slotted weights (100gm)	58 59 60
32	16	1kg weights	Many experiments
35	16	S-hooks	Various experiments
36	8	1lb weights	25 32c 114
40	2	Single pulley on clamp	17b 58 59 60 62
42	8	Lever arm balances	35 79b 87b 106b,c,d,e 107
44/1	16	G-clamps (4in)	18 64
44/2	16	G-clamps (2in)	48 62 65 121
45	1	Foot pump and adaptor	76 79b 83 87b
46/1	1	Translucent screen	39 78 84 89 90 99 167
46/2	1	Lamp for translucent screen	39 78 84 89 90 99
50/2	2	Horseshoe magnets	52 58
51	1	Malvern electrostatics kit	51 165 168 169
52	1	Worcester circuit board kit	129d,f 138 139 147 148 158
54	1	Worcester gas voltameter kit	118 141
55	1	Friction kit	17a,b
58	1	Radiation kit	123 146 151 153
59	1	L.T. variable voltage supply	Many experiments
60/1	1	Van de Graaff generator	51 119
61	1	Fine beam tube	162a,b 163
62	1	Fine beam tube base	162a,b 163
63	1	Forces demonstration box	32b 113
64	1	Oscilloscope	93b 94 129a,b 132 172
65	1 pr	Metal plates with insulating handles	167 168
66	1	Neon lamp	142
70	2	Demonstration meters	Many experiments
71/1	1	D.C. dial (1amp)	Many experiments
71/2	1	D.C. dial (5amp)	121 150 156
71/3	1	D.C. dial (5 volts)	132, 157
71/4	2	D.C. dial (2·5–0–2·5mA)	119 148
71/7	1	A.C. dial (5amp)	131b 146 151 153
72	16	Lamps (12V, 24W)	154a, 156
74	16	Lampholders (SBC) on bases	Many experiments
75	8	Immersion heaters	106b,d 127 155
76	8	Aluminium containers	106b,c,d 140
77	8	Aluminium blocks	106d,e 155
79	16	D.C. ammeters (0–1amp)	Many experiments
80	16	D.C. voltmeters (0–5 volts)	129f 139 149b
81	8	Newton spring balances	32a 33a 61a 61b
84	16	Wire strippers	Many experiments
85	1	Demonstration spring balance (5kg)	17a 17b
86	1	Mounted glass plate	25 32c

Apparatus for year IV used in previous years (continued)

item no.	quantity	description	experiment numbers
89	1	Water circuit board	116 124
92	1	Westminster electromagnetic kit	130 131a,b 148 154d 163
93	1	Smoke box kit	21b
95	1	Edinburgh CO_2 pucks kit	8 13 15 43 92b
98	8	Reel of bare eureka wire (SWG 28)	143 154a 157
99	16	Power line terminal rods	154a
101	1	Large Slinky	92a
102	1	White screen	21b
103	1	Bicycle dynamo assembly	132
104	16	Low voltage power units	131a,b 133
106/1	32	Dynamics trolleys	Many experiments
106/2	48	Elastic cords for accelerating trolleys	4 6 7 9 11 12 30 31 47 67
107	16	Runways	Many experiments
108/1	16	Tickertape vibrators	Many experiments
108/4	16	Rolls of tickertape (gummed)	Many experiments
109	1	Boyle's law apparatus	76 83
110	1	Tubes for 'guinea and feather' experiment	56
119	1	Flexible curtain rail	18 45 65 66
121	32	2in metal strips as jaws	64
127	2	Coils (120 turns)	154d
133	1	Camera	1 2 8 13 22 43 57 101
134/1	1	Motor driven stroboscope (synchronous)	1 2 8 13 21b 22 43 57
142	1	Macro-Millikan apparatus	169
147	1	Demountable transformer kit	130
148	1	Syringe kit	91d
150	1	Fractional horsepower motor	71 75a 81 110 150 151
158	8	Class oscilloscope	129a,c–f 133 159 171
160/1	2 Opt	Demonstration trolleys	6 10 29 33b 53
166	1	Constant pressure apparatus	21b
180	8	Galvanometer	158
181	1 Opt	General purpose amplifier	93b 94
196	1	Source holder	168

Apparatus for year V

All schools doing Year V of the Nuffield Physics programme will have followed earlier years of the course. The first list below includes only *additional* items which will be required. The second list gives those items from previous years which are used in Year V.

The list is based on a single class of 32 pupils.

item no.	quantity	description	experiment numbers
130/3	1	GM tube holder	124 127 131 133
130/4	1	Solid state detector and pre-amplifier	124 125
130/5	1	Thin window GM tube	124 127 131 133
130/6	1	Gamma GM tube	124
135	1	Demonstration diode	18
152	1	Rotating sphere attachment	78
154/1	1	Turntable	6 13 31c 44 78
154/2	1	Truck attachment	13
154/3	1	Small motor on base plate	31c 44
170	8	Low frequency a.c. generators	91a–d 92a–b
172	1	Centripetal force kit	4 7 12 57 60
173	1	Malvern current balance kit	23
181	1 Opt	General purpose amplifier	99a 107b
182	1 Opt	L.F. signal generator	98 107a
183	2 Opt	Loudspeakers	98 99a 107a 107b
184/1	1 Opt	3cm wave transmitter	99a 107b
184/2	1 Opt	3cm wave receiver	99a 107b
185	1 Opt	Transistor oscillator	90
186/1	1	Large gyroscope	69 70
186/2	1	Mount for large gyroscope	70
187	1	Rotating stool	61
188	2	Metal spheres on insulated handles	123b
189	1	Ultra-violet lamp	137
190/1	1	Zinc plate attachment	137
190/2	1	Grid plate	137
191/1	16	Coarse gratings	108a 109 142a
191/2	16	Fine gratings	108b 109 112 116
191/3	1 Opt	Set of diffraction gratings	143
192/1	16	Red filters	108b 109
192/2	16	Green filters	108b 109 112
193/1	1	Neon spectrum tube	108b
193/2	1	Hydrogen spectrum tube	108b
194	1	Holder for spectrum tube	108b
195/1	1	Pure gamma source	124 127
195/2	1	Pure beta source	124 133
195/3	1	Pure alpha source	124 125
198	8	Rotating devices	142 146

List of apparatus needed for Year V, but used in previous years.

item no.	quantity	description	experiment numbers
2	1	Elastic materials kit	71 78
7E	8	½mm graticules	105
9A	1	Motor/generator unit	91b
10F	1	Set of parts for heavy pendulum	73 75
14	1	E.H.T. power supply	Many experiments
15	1	H.T. power supply	Many experiments
16	1	Radium source	122 123c 124 125
17	1	Spark counter	123c 125
18	1	Expansion cloud chamber	125 128a
19/1	2	CO_2 cylinders	1 128b 130
19/2	1	Dry ice attachment	1 128b 130
21	1	Compact light source	Many experiments
27	8	Transformers	Many experiments
28	8	Taylor cloud chambers	128b
30	2	Slotted bases	23
31/1	1	Weight hangers with slotted weights (10gm)	86
31/2	6	Weight hangers with slotted weights (100gm)	71 97
32	6	1kg weights	71 80
35	16	S-hooks	71 78
36	16	1lb weights	78 80
40	1	Single pulley on clamp	97
43	1	Spring balances (1kgwt)	13
44/1	16	G-clamps (4in)	80 93 134
44/2	12	G-clamps (2in)	71 72
46/1	1	Translucent screen	78 101 120 122
46/2	1	Lamp for translucent screen	122
47	8	Illuminants	100 102 110 128b
50/3	1	Magnet 'Eclipse major'	133
51	1	Malvern electrostatics kit	85 121 122 126 135 137
54	1	Worcester gas voltameter kit	25
59	1	L.T. variable voltage supply	Many experiments
60/1	1	Van de Graaff generator	135
61	1	Fine beam tube	3 16 19a 20 24
62	1	Fine beam tube base	3 16 19a 20 24
64	1	Oscilloscope	74 82 84 89 90 98
65	1 pr	Metal plates with insulating handles	120 121
69	1	High dispersion prism	114 115 118
70	2	Demonstration meters	Many experiments
71/1	1	D.C. dial (1amp)	25
71/2	2	D.C. dials (5amp)	23 24
71/3	1	D.C. dial (5 volts)	91b 91c 92a
71/4	1	D.C. dial (2·5–0–2·5mA)	18 82 91c 92a
71/5	1	A.C. dial (5 volts)	91b
71/6	1	A.C. dial (15 volts)	88

Apparatus for Year V, but used in previous years (continued)

item no.	quantity	description	experiment numbers
71/8	1	A.C. dial (1amp)	88
71/11	1	D.C. dial (300 volts)	24
72	1	Lamps (12V, 24W)	53 86 108b 119
73	1	Lamps (12V, 36W)	112
74	1	Lampholders (SBC) on bases	53 86 108b 112 119
78	1	Variable a.c. supply ('Variac' type)	85
84	16	Wire strippers	21
85	1	Demonstration spring balance (5kg)	22
90	1	Ripple tank kit	100 102 110
92	1	Westminster electromagnetic kit	3 16 20 21 81
94	1	Kit for ray optics	105
95	1	Edinburgh CO_2 pucks kit	1 59 93 130
97	1	Double slits kit	104 105
98	1	Reel of bare eureka wire (SWG 28)	86
100/2	1	Large rectangular transparent tank	93 94
101	1	Large Slinky	93 94
102	1	Screen	76
103	1	Bicycle dynamo assembly	82 89
104	16	Low voltage power units	21
105/1	32	Hand stroboscopes	97 100 102
106/1	20	Dynamics trolleys	71 93
108/1	1	Tickertape vibrators	97
111	16	60° prisms	117
112	2	Converging lenses (+7D)	76 119
113/1	8	Plano-convex lenses (+14D)	105
113/3	1	Plano-convex lenses (+2·5D)	114 115 118
119	1	Flexible curtain rail	8
121	32	2in metal strips as jaws	71 78 80
124/1	2	Lens holders (for 5cm diameter lens)	109 114 115 118
126	2	Plastic waves	103a
130/1	1	Scaler	75 124 125 127 131 133
130/2	1	Photodiode assembly with light source	75
131	1	Year IV general kit	8 130
132	1	Year IV electrical general kit	Many experiments
136	1	Maltese cross tube	17
138	1	Deflection tube	15 19b
140	1	Stand for tubes	15 17 18 19b
141	1 Opt	Demonstration triode	18
144	1 Opt	Demountable discharge tube for positive rays	26

Apparatus for Year V, but used in previous years (continued)

item no.	quantity	description	experiment numbers
146	1	Inertia balance	72
147	1	Demountable transformer kit	87 92a
150	1	Fractional horsepower motor	13 22 76 78
157	8	Microphones	77 98
158	8	Class oscilloscopes	77 81 83 91a,d 92b
162	1	Lampholder (BC) on base	85 123a
169	4	Large magnetic pucks	93
176	8	12 volt batteries	Many experiments
180	16	Galvanometers	81 91d 92b
196	1	Source holder	122 123c 124 125

Additional apparatus assumed available

item no.	description	year	quantity	experiments
501	Metre rules	I	16	Many experiments
		II	1	41 68
		III	8	4h, 25 36 61
		IV	16	Many experiments
		V	32	100 105 112
502	Foot rules	I	16	28 29
		III	16	78
503	Retort stand bases	I	32	Many experiments
		II	32	Many experiments
		III	32	Many experiments
		IV	16	Many experiments
		V	16	Many experiments
504	Retort stand rods	I	32	Many experiments
		II	32	Many experiments
		III	32	Many experiments
		IV	16	Many experiments
		V	16	Many experiments
505	Bosses	I	32	Many experiments
		II	32	Many experiments
		III	32	Many experiments
		IV	16	Many experiments
		V	16	Many experiments
506	Clamps	I	24	Many experiments
		II	24	Many experiments
		III	24	Many experiments
		IV	16	Many experiments
		V	16	Many experiments
507	Stop watches or stop clocks	I	16	29 30a
		II	8	64 65 66
		III	16	Many experiments
		IV	16	Many experiments
		V	16	12 13 80 100
508	Bunsen burners	I	16	Many experiments
		II	32	Many experiments
		III	16	39a 75–78
		IV	1	91d 145
509	Asbestos mats	I	16	19 66
		II	8	75

Additional apparatus assumed available (continued)

item no.	description	year	quantity	experiments
510	Gauzes	I	16	79a
		IV	1	91d
511	Tripod	I	16	19 20b 79a-b
		II	16	Many experiments
		III	16	75 76 77 78
		IV	1	91d 145
512/1	250ml beakers	II	16	24 25 26
512/2	400ml beakers	I	32	Many experiments
		II	16	Many experiments
		III	1	38
		V	1	23
512/3	600ml beakers	I	16	47
		II	16	86
513	1,000ml deep beakers	I	1	20b 65
		II	2	77
		III	16	4a–v 38 77 78
514	Gas jars	I	2	57 58a 59
		II	16	46
515	Cover glasses	I	2	57 59
516	Separating funnel	I	1	65
517	1 litre volumetric flask	I	1	11b
518/1	Measuring cylinder: 250ml	I	2	15
518/2	Measuring cylinder: 1,000ml	I	1	15
		II	1	48 65
		IV	1	91c
520	Tuning forks	IV	8	129e
		V	8	76 77 96
521	5in bell jar	I	1	48
522	Hoffmann clips	III	8	65 67
523	Aspirator (10 litres)	I	1	1 41 80
524	Mercury tray	I	1	42 44 45 46a–e
		IV	1	78 84

Additional apparatus assumed available (continued)

item no.	description	year	quantity	experiments
526	Test-tube holders	I	16	19
		II	16	75
527	Simple pendulums	I	2	75a–c
		III	16	53b
		IV	16	64
		V	16	72 78 79 80
528	Crystallizing dishes	I	16	66
		II	1	95
		III	1	24
529	Scissors	I	8	23
		III	8	27b
530	Pliers	I	1	60 61
		III	1	74
		IV	1	89 90 99
532	Large transparent trough	I	1	2b 16a 18 67
		IV	1	74a 79b 87a 87b
533	Buckets	I	8	5 46f 68
		II	1	78
		III	8	4a–v 67 69b
		IV	2	89 90 99 106a
534	Bottles (medicine type)	I	3	42
		IV	3	80 85
535	Bottle of mercury (7lb)	I	1	42 44 46a–e
		IV	1	78 80 84 85
536	Bottle of aniline (250gm)	I	1	65
540	500ml flat-bottomed flask	I	1	79a–b
541/1	Rheostats (10–15 ohms)	II	4	28 29
		III	16	4g 81 84 103
		IV	8	Many experiments
		V	2	Many experiments
542	Thermometers (−10 to 110°C)	II	24	65–66 72 75 77 97
		III	16	77 78
		IV	8	Many experiments

Additional apparatus assumed available (continued)

item no.	description	year	quantity	experiments
543	Chinagraph pencil	I	1	14 34
		II	16	46 48
		IV	1	14 75a 99
545	Soft glass test-tube (75mm × 10mm)	II	32	72
546	Pyrex glass test-tube (75mm × 10mm)	I	32	4 19
		II	32	72 75 86 87
547	Capillary tubing with bung to fit tube	II	32	72
548	250ml flasks (round-bottomed)	II	8	79 80
		III	8	75 77
549/1	Bungs with 10in narrow bore glass tube	II	8	79
549/2	Bungs with glass tube and rubber tubing	II	8	80
		III	8	75 77
550	Protractors	III	16	26
551	Drawing boards	III	16	35b 69a
		V	16	103b
555	Iron filings (1lb)	II	1	7 13b
556	Compasses	II	36	7 13b

Chart of apparatus by years

item no.	description	quantities required in any one year				
		I	II	III	IV	V
1	Materials kit (solids)	1				
2	Elastic materials kit	1	1		1	1
3	Crystals kit	1				
4	Microbalance kit	1				
5	Lever kit	1	1			
6	Bristol pressure kit	1			1	
7	Oil film kit	1	8-7E			8-7E
8	Bromine diffusion kit	1		1	1	
9	Malvern energy conversion kit	1	1		1	1-9A
10	Year I general kit	1	1		1	1-10F
11	Kinetic theory model kit	1	1	1	1	
12	Two-dimensional kinetic model kit	1	1	1	1	
13	Vacuum pump	1	1	1	1	
14	E.H.T. power supply	1	1	1	1	1
15	H.T. power supply		1	1	1	1
16	Radium source	1			1	1
17	Spark counter	1				1
18	Expansion cloud chamber	1			1	1
19/1	CO_2 cylinder	2	2	2	2	2
19/2	Dry ice attachment	1	1	1	1	1
20	Domestic balance (5kg)	1			1	
21	Compact light source	1	1	1	1	1
22	Atom model	1	1		1	
23	Microscopes	8		8	8	
24	Hand lenses	36				
25	Plastic measuring rules	36				
26	Perspex containers	16				
27	Transformers	8	8	8	8	8
28	Taylor cloud chambers	8				8
29	Whitley Bay smoke cells	8		8	8	
30	Slotted bases	8		1	8	2
31/1	Weight hangers with slotted weights (10gm)	16	16		1	1
31/2	Weight hangers with slotted weights (100gm)	16	16		16	6
32	1kg weights	16	16	8	16	6
33	Paper scales	32				
34	Variable inertia bar		1			
35	S-hooks	16			16	16
36	1lb weights	8	8		8	16
37	1oz weights	8	2			
38	Single pulleys	16	1			
39	Double pulleys	16	1			
40	Single pulley on clamp	2	1		16	1
41	Evesham pressure apparatus	1				
42	Lever arm balances	8	8		8	
43	Spring balances (1kg weight)	16	16	3		1

item no.	description	quantities required in any one year				
		I	II	III	IV	V
44/1	G-clamps (4in)	16		8	16	16
44/2	G-clamps (2in)	16	16	16	16	12
45	Foot pump and adaptor	1		1	1	
46/1	Translucent screen	1	1	1	1	1
46/2	Lamp for translucent screen	1		1	1	1
47	Illuminants	8		8		8
48	Statistics frame	1		1		
49	Graph plotting board	1 Opt				
50/1	Pairs of cylindrical magnets	35 Pr	32 Pr			2
50/2	Horseshoe magnets	2	2		2	
50/3	Magnet 'Eclipse major'		1			1
51	Malvern electrostatics kit		1	1	1	1
52	Worcester circuit board kit		1	1	1	
53	Worcester current balance kit		1			
54	Worcester gas voltameter kit		1		1	1
55	Friction kit		1		1	
56	Conductivity kit		1			
57	Year II general kit		1	1		
58	Radiation kit		1		1	
59	L.T. variable voltage supply	1	1	1	1	1
60/1	Van de Graaff generator	1	1	1	1	1
60/2	Accessories for Van de Graaff generator		1	1	1	1
61	Fine beam tube		1	1	1	1
62	Fine beam tube base		1	1	1	1
63	Forces demonstration box		1		1	
64	Oscilloscope		1	1	1	1
65	Pr. of metal plates with insulating handles		1 Pr	1 Pr	1 Pr	1 Pr
66	Neon lamp		1		1	
67	Bourdon gauge	1	8	8		
68	Phototransistor		1			
69	High dispersion prism		1			1
70	Demonstration meters		1	2	2	2
71/1	D.C. dial (1amp)		1	1	1	1
71/2	D.C. dial (5amp)		1	1	1	2
71/3	D.C. dial (5 volts)			1	1	1
71/4	D.C. dial (2·5–0–2·5mA)		1	1	2	1
71/5	A.C. dial (5 volts)				1	1
71/6	A.C. dial (15 volts)			1		1
71/7	A.C. dial (5amp)		1		1	
71/8	A.C. dial (1amp)				1	1
71/9	A.C. dial (300 volts)				1	
71/10	D.C. dial (15 volts)				1	
71/11	D.C. dial (300 volts)				1	1
71/12	D.C. dial (100mA)				1	

item no.	description	quantities required in any one year				
		I	II	III	IV	V
72	Lamps (12V, 24W)		1	16	16	1
73	Lamps (12V, 36W)		1	1		1
74	Lampholders (SBC) on bases		1	16	16	1
75	Immersion heaters		8		8	
76	Aluminium containers		8	1	8	
77	Aluminium blocks		8		8	
78	Variable a.c. supply ('Variac' type)		1			1
79	D.C. ammeters (0–1amp)		16	1	16	
80	D.C. voltmeters (0–5 volts)		16	16	16	
81	Newton spring balances (10N)		4	8	16	
82	Iron flasks for freezing		4			
83	$\frac{1}{2}$lb weights		32			
84	Wire strippers		16	16	16	16
85	Demonstration spring balance (5kg)		1	1	2	1
86	Mounted glass plate		1		1	
87	Clapper bell in round flask		1			
88	Large compression springs	1	1	3		
89	Water circuit board		1	1	1	
90	Ripple tank kit			1		1
91	Pinhole camera kit		1-91D	1	1-91D	
92	Westminster electromagnetic kit			1	1	1
93	Smoke box kit		1-93B	1	1-93B	
94	Kit for ray optics			1		1
95	Edinburgh CO_2 pucks kit			1	1	1
96	Kit for particle model of refraction			1		
97	Double slits kit			1		1
98	Reel of bare eureka wire (SWG 28)			8	16	1
99	Power line terminal rods			16	16	
100/1	Rectangular plastic tanks			8		
100/2	Large rectangular transparent tank			1		1
101	Large Slinky			1	1	1
102	White screen		1	1	1	
103	Bicycle dynamo assembly		1	1	1	1
104	Low voltage power units			16	16	16
105/1	Hand stroboscopes			32		32
105/2	Reels of masking tape			4		
106/1	Dynamics trolleys		1	32	32	6
106/2	Elastic cords for accelerating trolleys			48	48	
107	Runways			16	16	

item no.	description	quantities required in any one year				
		I	II	III	IV	V
108/1	Tickertape vibrators			16	16	1
108/2	Carbon paper discs					
108/3	Rolls of tickertape (plain)					
108/4	Rolls of tickertape (gummed)			16	16	
109	Boyle's law apparatus			1	1	
110	Tubes for 'guinea and feather' experiment			8	1	
111	60° prisms			16		1
112	Lenses (+7D)			32		1
113/1	Plano-convex lenses (+14D)			16		8
113/2	Plano-convex lenses (+20D)			16		2
113/3	Plano-convex lenses (+2·5D)			16		1
114	Model eye kit			1		
115	Telescope mount			16		
116	Plane mirrors			16		
117	Holders for mirrors			16		
118	Cylindrical concave mirrors			16		
119	Flexible curtain rail			1	1	1
120	Hack-saw blades			16		
121	2in metal strips as jaws			32	32	12
122	Magnetization kit			1		
123	Launching ramp			1		
124/1	Lens holder (for 5cm diameter lens)			1		1
124/2	Lens holder (for 10cm diameter lens)			1		
125	Skelton variable focus eye			1		
126	Plastic waves			2		2
127	Coil (120 turns)			1	2	
128	Coil (2400 turns)			1	2	
129	Prs of plate glass plates for interference			16		
130/1	Scaler				1	1
130/2	Photodiode assembly with light source				2	1
130/3	GM tube holder					1
130/4	Solid state detector and pre-amplifier					1
130/5	Thin window GM tube					1
130/6	Gamma GM tube					1
131	Year IV general kit			1-131A	1	1
132	Year IV electrical general kit				1	1
133	Camera			1	1	
134/1	Motor driven stroboscope (synchronous)			1	1	
134/2	Xenon flasher				1 Opt	
135	Demonstration diode					1
136	Maltese cross tube				1	1
137	Perrin tube				1 Opt	1 Opt
138	Deflection tube				1	1

item no.	description	quantities required in any one year				
		I	II	III	IV	V
139	Set of coils and supports				1	1
140	*Stand for tubes*				1	1
141	Demonstration triode				1 Opt	1 Opt
142	Macro-Millikan apparatus			1	1	1
143	Pair of Bernoulli tubes				1	
144	Demountable discharge tube for positive rays				1 Opt	1 Opt
145	Demonstration thermometer				1	
146	Inertia balance kit				1	1
147	Demountable transformer kit			1	1	1
148	Syringe kit	1	1		1	
149	Electric field apparatus			1		1
150	Fractional horse power motor	1	1	1	1	1
151	Rotating disc for FHP motor			1		
152	Rotating sphere attachment					1
153	Copper voltameters				3	
154/1	Turntable					1
154/2	Truck attachment					1
154/3	Small motor on base plate					1
155	Small electric motors				16	
156	*Diodes and holders*				8	8
157	Microphones				8	8
158	Class oscilloscopes			8	8	8
159	*Air rifle*				1	
160/1	Demonstration trolleys			2 Opt	2 Opt	
160/2	Meter attachment for demonstration trolley – optional				1 Opt	
161	Gantry for CO_2 pucks kit				1	
162	Lampholder (BC) on base				4	2
163	Cardboard tubes				16	
164	Cardboard cups				16	
165	Air blower				1	
166	Constant pressure apparatus			1	1	
167	Water rocket				1	
168	CO_2 capsule rocket				1 Opt	
169	Large magnetic pucks				4	4
170	Low frequency a.c. generator					8
171	Photographic accessories kit				1	1
172	*Centripetal force kit*					1
173	Malvern current balance kit					1
174	Collision in two dimensions kit				1 Opt	
175	60° isometric grid graph paper				32	
176	12 volt battery		4	4	4+	4+
177	Lamps (12V, 6 watt)				16	
178	D.C. ammeters (0–1A, 0–5A)				8	
179	D.C. voltmeters (0–5V, 0–15V)				16	
180	Galvanometers			16	8	16

item no.	description	quantities required in any one year					
		I	II	III	IV	V	
181	General purpose amplifier			1	Opt	1	Opt
182	L.F. signal generator			1	Opt	1	Opt
183	Loudspeakers			2	Opt	2	Opt
184/1	3cm wave transmitter			1	Opt	1	Opt
184/2	3cm wave receiver			1	Opt	1	Opt
185	Transistor oscillator					1	Opt
186/1	Large gyroscope					1	
186/2	Mount for large gyroscope					1	
187	Rotating stool					1	
188	Metal sphere on insulated handle					2	
189	Ultra-violet lamp					1	
190/1	Zinc plate attachment					1	
190/2	Grid plate					1	
191/1	Coarse gratings					16	
191/2	Fine gratings					16	
191/3	Set of diffraction grids					1	Opt
192/1	Red filters					16	
192/2	Green filters					16	
193/1	Neon spectrum tube					1	
193/2	Hydrogen spectrum tube					1	
194	Holder for spectrum tube					1	
195/1	Pure gamma source					1	
195/2	Pure beta source					1	
195/3	Pure alpha source					1	
196	Source holder	1			1	1	
197	Electron diffraction tube					1	Opt
198	Rotating devices					8	

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Associate organizers J L Lewis E J Wenham
Assistant organizer D W Harding

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