SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 99.

October, 1977.

Contents

Introduction

The article on microbiology in Bulletin 98 has produçed a number of requests for additional copies both from assistant teachers of biology and principal teachers of related subjects such as home economics. We have also arranged to give two lectures on safety in microbiology on 25th October in the Russell Street Science Centre, Ayr for science teachers and technicians in the afternoon, and in Newton Advisers' Centre, Ayr in the evening for teachers of home economics, anatomy, physiology and health, and physical education.

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The Governing Body have approved the secondment of the Director to work for UNESCO at the Pakistan Education Equipment Centre, Lahore for a period of three months. His absence, coupled with the fact that for reasons of economy we have not replaced our main grade technician, places an extra burden on the remaining staff in preparing and holding exhibitions outside Edinburgh and in Saturday morning duty. We do not intend any reduction in the commitment to exhibitions but the Saturday morning opening will be limited to the first two Saturdays of the month during November, December and January. Accordingly the Centre will be closed on 19th and 26th November; 17th, 24th and 31st December, and 21st and 28th January, 1978.

Opinion

There is a story, told so often by comedians on the media that most of my readers should have heard it, of the landlord of a pub who bought from one of his customers, for a fantastic sum, a dancing duck. This animal, placed on top of a biscuit tin, danced and flapped its wings and quacked to the great delight of the pub's clientele, so that the landlord's takings went far beyond the usual and he went to bed well pleased.

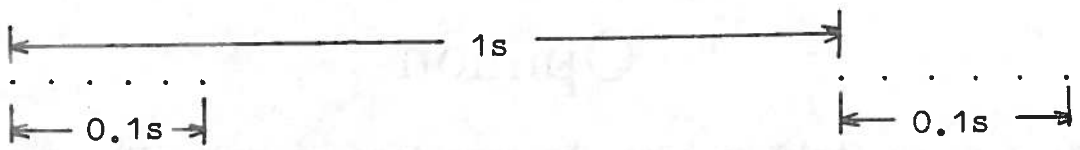
His only trouble was that he could not get to sleep for the noise made by the duck, still quacking and flapping and dancing on the biscuit tin on the bar top. So he phoned the person who had sold him the duck, asking what he should do. 'Simple', came the reply, and with it the punch line of the joke, 'open the tin and blow out the candle'. On first hearing it, this amuses because of the juxtaposition of a very unusual effect and an apparently simple, even absurd cause. We all think - don't we? - that it is the discomfort of having its feet hot that makes the duck behave in this way. Now I have to think again.

I have seen the publicity film 'Science in S1 and S2' made for the National Working Party which has just completed a four year programme on teaching integrated science to mixed ability classes. The film shows in considerable detail how Section 3, Energy Changes, is treated in two different schools. In an extension for most able pupils, two lasses gather wood-lice and place some in three test-tubes, the tubes being immersed in ice-cold, room temperature and lukewarm water respectively. They observe that in the last case the animals are most active. 'This', says the teacher, 'shows that the increased temperature makes the energy in the animals' food more readily available to them so that they move quicker'. I am giving the gist of his argument rather than his actual words - for one thing I believe he used the word 'metabolism'. This should teach me to be more careful in applying anthropomorphic reasons to phenomena observed in other species.

The reception of this by the lasses concerned was beyond reproach. Insofar as the film showed us, they did not bat an eyelid. It is comforting to see that, despite all the pedagogues have done to change it, the received doctrine attitude is still as firmly held as in the days of the dominie and the parish school.

Physics Notes

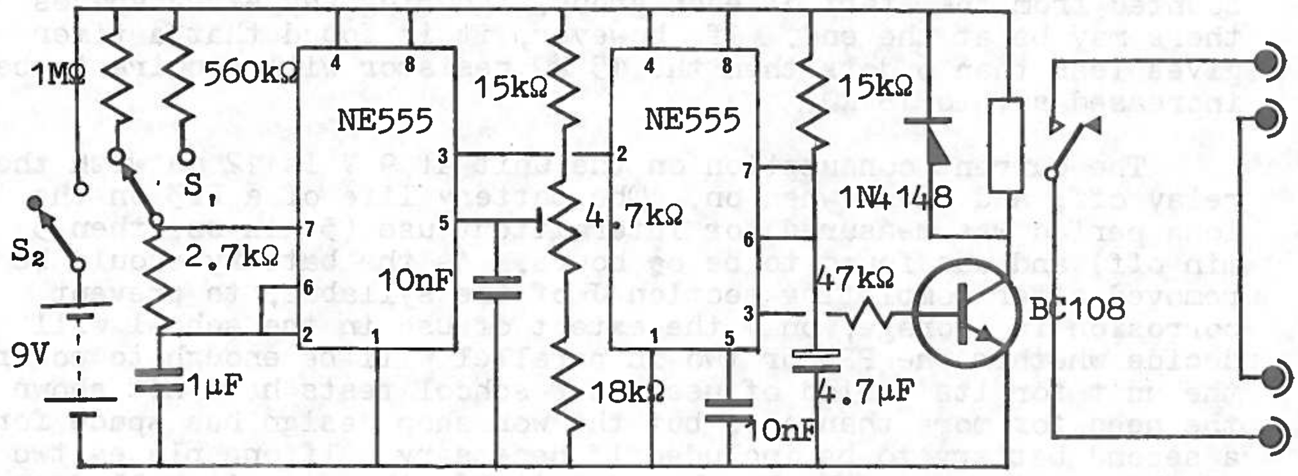
In the workshop section of this bulletin we give constructional details of a ticker timer drive suggested by a lecturer in Aberdeen College of Education. He believed there was a need for an apparatus which would simplify for the average and less able pupil the business of calculating acceleration from a ticker timer trace. His proposal (see Fig. 1 below) was to have the timer switched on for 0.1 s at intervals of a second.



The pupil would measure the distance over 5 spaces (or 10 for a 100 Hz timer) and multiply by 10 to get the velocity, and the difference between successive velocity readings will give the acceleration directly. Unfortunately for this simple scheme, there are some experiments in the mechanics course which would require an excessively long runway to give two groups of dots one second apart, and one has to compromise by introducing a ½ s interval also, which means that the difference in velocity must then be doubled to get the acceleration.

In practice a relay is used to switch the timer on and off for the required periods. The timing circuit controlling the relay is shown below. The first NE555 timer generates a short pulse every second, or every half second, depending on the position of the switch S_1. This pulse drives the second NE555, which then produces a pulse of about 0.1 s duration, which switches the relay through the transistor.

Measuring the one second interval over which the acceleration is timed has an inherent error of 2% (1% for a 100 Hz timer). This is due to the fact that as the drive is not synchronised to the mains, the point on the mains cycle at which the drive pulse switches on is purely arbitrary so that the first of the group of dots on the tape may be up to 0.02 s late. The measured time interval is therefore (1 ± 0.02)s, or 2% error. This will add to any error which may exist due to inaccurate adjustment of the timing resistors, so that one should not expect the results to be more accurate than 3 - 5%.



The timing resistors which determine the 1 and ½ s intervals are the 1 MΩ and 560 kΩ associated with switch S, in Fig. 1. These will not provide the exact time intervals required, because of tolerances on both the 1 μF capacitor and the 555 timer, and we used the following compromise which made the setting up fairly easy to carry out. Tests had shown that with the above resistors the 1 s period was short and the ½ s period long. Timing can be altered slightly by varying the voltage on pin 5 of the timer, and the pre-set 4.7 kΩ potentiometer was set to give ½ s period as accurately as possible, measured by counting 60 pulses against a stop-watch. The switch was then put to the 1 s position, and various values of standard resistor inserted in the switch lead, i.e. in series with the 1 MΩ until the interval was within 1% of 1 s. Values of the additional resistance varied from 100 - 330 kΩ. The ultimate aim was to achieve a count of 60 pulses in 60 ± 0.5 s for the longer interval, and 30 ± 0.3 s for the shorter, with the pre-set potentiometer not too close to either end of its track, so that there is a possibility of readjustment either way to allow for ageing of the components.

In all we made ten ticker timer drives - eight have been extensively tested in two schools - and we found a wide variation in the resistance values needed to get accurate timing. Probably this was due to varying amounts of leakage from the 1 μF capacitors which in our case were electrolytics, and with hindsight it might have been better had we used tantalum, e.g. R.S. Components 101-771, or polycarbonate 113-538, the latter having 5% tolerance. Variation in supply voltage to the circuit has very little effect on timing; a drop from 9 to 7 V reduced the 1 s interval by 0.3%.

The second 555 timer receives a 3 ms triggering pulse which causes it to switch on for 0.1 s, the components producing this time interval being the 15 kΩ and 4.7 μF attached to pins 6 and 7. It might be thought that 0.1 s will not be enough to ensure that one always gets 6 dots, i.e. 5 spaces, but we found that on a 100 Hz ticker timer we got 12 and sometimes 13 dots with a 0.1 s interval, which we could measure to 1 ms. The reason is the elasticity of the tongue of the timer which causes it to produce a few more dots while its oscillation is dying away after the end of the pulse. As different timers will have different amounts of inertia, short of matching individual timers and drivers, it will not be possible to arrange that one always gets 6 or 11 dots in each group. Pupils must therefore understand that the five or ten spaces needed are counted from the start of each group, ignoring any extra spaces there may be at the end. If, however, it is found that a timer gives less than 6 dots then the 15 kΩ resistor will require to be increased say to 18 kΩ.

The current consumption on the unit at 9 V is 12 mA with the relay off, and 26 mA when on. The battery life of a PP3 on the long period was measured for intermittent use (5 min on, then 5 min off) and was found to be 6½ hours. As the battery should be removed after completing section J of the syllabus, to prevent corrosion in storage, only the extent of use in the school will decide whether one PP3 or two in parallel will be enough to power the unit for its period of use. Our school tests have not shown the need for more than one, but the workshop design has space for a second battery to be included if necessary. If one places two of these drivers on the bench and switches them on, it will soon be evident to pupils that they give different times, as they will alternate between being in and out of phase. In fact this phenomenon may be noticed by two adjacent groups of pupils when the drivers are being used, and they may object that both drivers cannot be 'right', whatever that may mean. The teacher must decide for himself whether this constitutes an insuperable difficulty to their use, or whether he can use it to discuss how, by measuring the time between 'beats', one could calculate the difference of the two nominal 1 s intervals. One experiment for which the drivers will not be suitable is the measurement of g by free fall, because of the large distances involved.

<u>Components</u>.

Box, 509-579	R. S. Components	£1.94
Printed circuit board	"	0.05*
4.7 kΩ pre-set potentiometer, 186-283	"	0.36
6 V relay, 349-125	"	1.25
On/off switch, 316-563	"	0.40
Changeover switch, 316-579	"	0.45
7 resistors, 5 capacitors	"	0.75*
Battery, PP3	local	0.33
2 i.c. timers, NE555	Technomatic	0.80
16 pin d.i.l. socket	"	0.15
Transistor, BC108/B	"	0.09
Diode, 1N4148	"	0.04
4 4 mm sockets, DN4	Wood and Cairns	0.19*
	Total	£6.80

* Approximate price

Chemistry Notes

The apparatus described in the Workshop section is an air table suitable for use on the overhead projector, which supports a number of small discs some of which may carry embedded magnets. The equipment can be used to demonstrate many phenomena which depend on random motion and collisions of particles, such as the action of a semi-permeable membrane, diffusion and mixing of gases or liquids, evaporation of liquids, selective adsorption of polar 'molecules' by an adsorbent, bond formation and the effect of temperature on the position of equilibrium of a decomposition reaction. It also clearly shows the need for collision and correct orientation of colliding particles before a reaction can occur.

The idea of using perspex discs on an air table came from Miller Street Centre, Clydebank. The Centre's technician demonstrated a version of the apparatus, large enough for direct viewing, at the Scottish Branch A.S.E. meeting in 1975. These pucks can be given a colour code by sticking on cinemoid filter or by giving a coating of transparent colour by a felt pen. By inserting small magnets into radially drilled holes in the pucks they can be given the ability to form bonds.

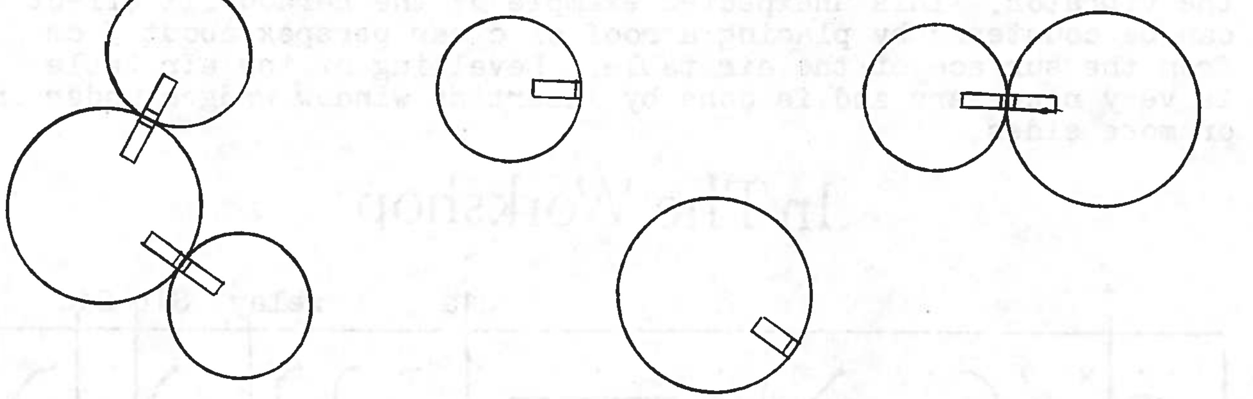


Fig. 1 Puck bonding

The air table is just large enough to cover the lens of an overhead projector and the air bearing is driven by a vacuum cleaner. To produce random motion of the pucks we used a zig-zag wire which surrounds the table and is driven by an eccentric cam on the spindle of a 3 V motor. By including a small potentiometer or other means of varying the voltage the vigour of vibration and hence the 'temperature' can be controlled.

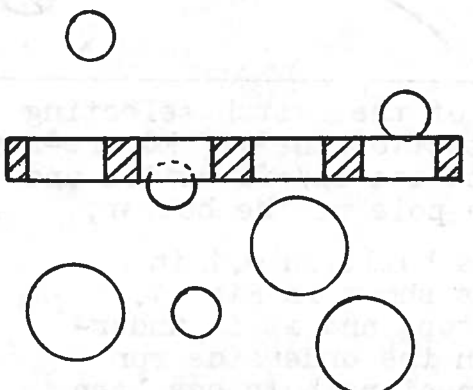


Fig. 2 Osmosis

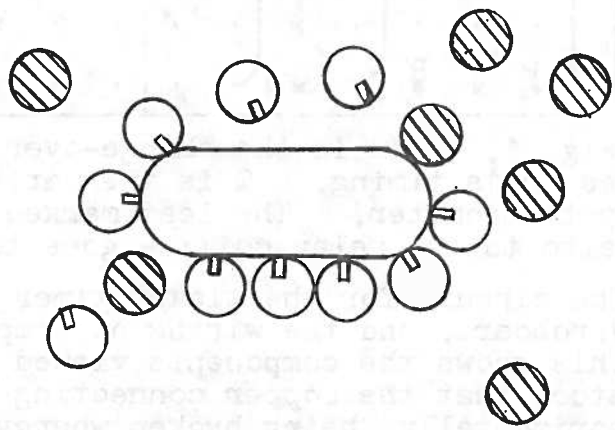


Fig. 3 Adsorption

The demonstration of osmosis is clearly that of the simplified model found in elementary texts. The adsorption model shows the preferential adsorption of 'polar molecules' and that further adsorption is impossible once the surface has become saturated. The rate of adsorption decreases greatly as a state of saturation approaches. This model could be applied to the adsorption of a substrate on an enzyme surface. Irreversible adsorption of molecules with stronger magnets could represent the action of an enzyme poison.

Evaporation from a liquid can be demonstrated by slightly tilting the table so that gravity keeps the molecules together in a bulk mass at the lower end. On raising the 'temperature' single molecules can on occasions escape from the bulk. A demonstration of an analogue of Brownian motion is not very satisfactory on this equipment, since the size of the smallest puck is governed by the fact that it must cover at least three air jets and that the 'smoke particle' needs to be many times larger.

One interesting observation is that a puck which is moving towards a side is clearly seen to be pushed back before it reaches the vibrator. This unexpected example of the Bernouilli effect can be countered by placing a roof of clear perspex about 3 cm from the surface of the air table. Levelling of the air table is very necessary and is done by inserting window wedges under one or more sides.

In The Workshop

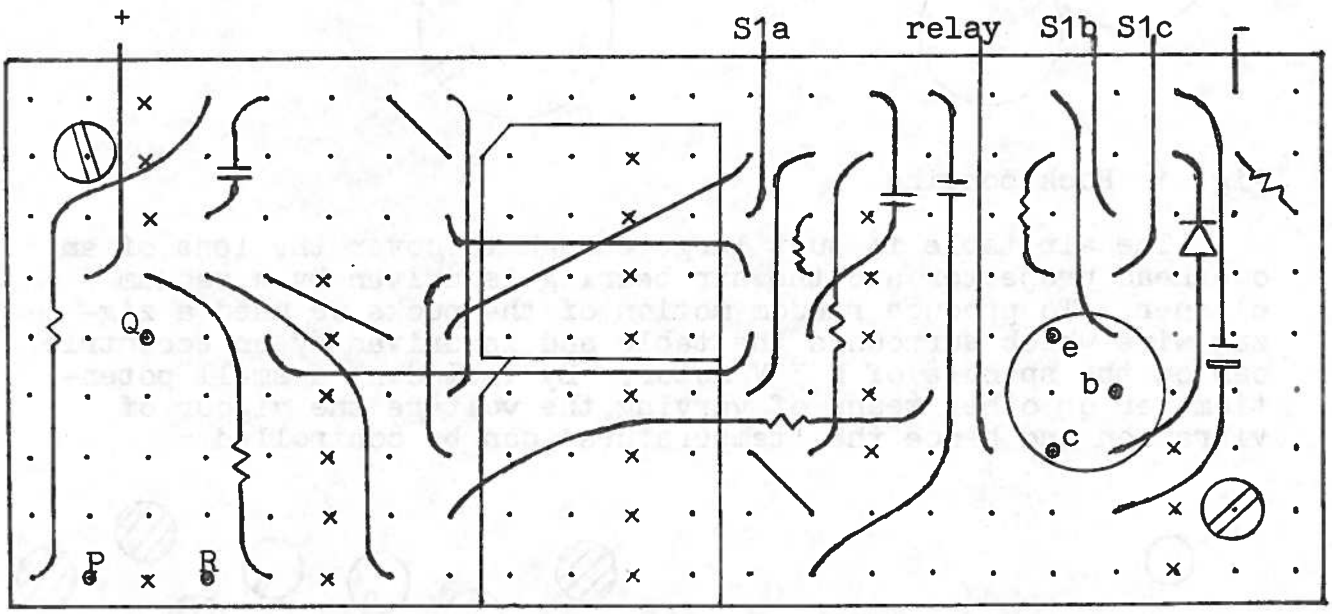


Fig. 1. S1a is the change-over contact of the switch selecting ½s or 1s timing. Q is the variable contact of the 4.7 kΩ pre-set potentiometer. The lead marked + goes to the on/off switch and also to the relay coil; - goes to the -ve pole of the battery.

The circuit for the ticker timer drive was built on 0.1 in Veroboard, and the wiring of components is shown in Fig. 1. This shows the components viewed from on top, and it is understood that the copper connecting strips on the underside run horizontally, being broken wherever a connecting hole has been marked thus (X). It is still cheaper to buy two NE555 timers than to use the double NE556 version and a 16 pin d.i.l. socket is used to mount them both. The three holes marked PQR are the mounting position for the 4.7 kΩ pre-set resistor; these hole positions will fit only the R.S. Components 186-283 type, and if another size is chosen the board layout will require to be changed.

The layout of components within the box, and of the switches on the top panel, are shown in Figs. 2 and 3. The battery is a PP3, and there is space for two of these within the box. If a second battery is used, it should be connected in parallel with the first. If not, then the space should be filled with a piece of plastic foam to wedge the battery in place. The components list specifies a DN4 type of 4 mm socket, the reason being that the type obtainable from R.S. Components is too long and fouls the switches which, like the sockets, are mounted on the lid.

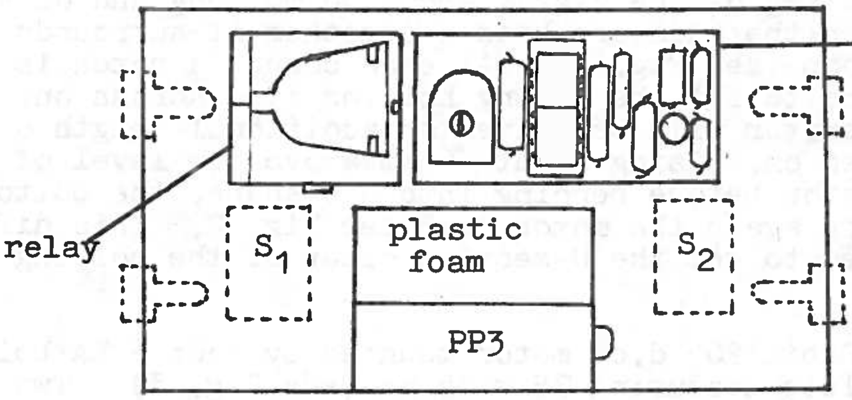


Fig. 2. Component layout.

Diagrams not to scale. Dimensions in mm.

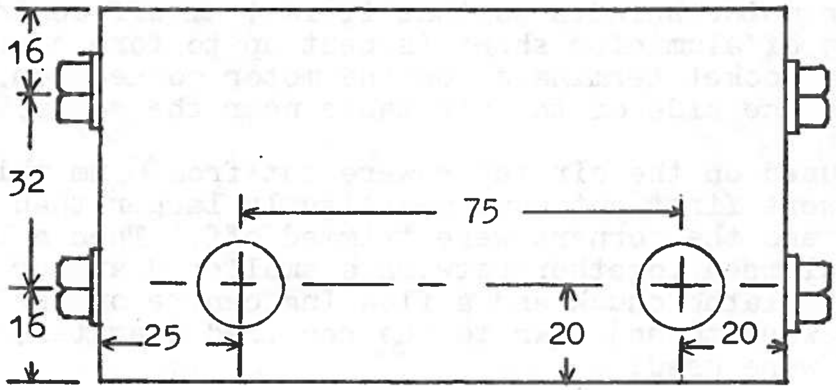


Fig. 3. Lid showing location of switches and terminals.

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The air bearing is no more than a hollow box made from perspex, with a circular hole in the middle of one side, into which is pushed the nozzle from an air blower. The outside dimensions are 28 x 28 x 5 cm; these were chosen to suit the <u>Griffin and George</u> overhead projector, and probably would suit most other makes. 6 mm perspex was used throughtout, although there is no need to have the sides of the box transparent, and these could be of wood or tufnol. The box base and sides are cemented together with perspex cement, made by dissolving small pieces of perspex in trichloromethane. The top is screwed on, using a number of 10 mm long countersunk 6 BA bolts screwed into holes which have been drilled and tapped in the sides. The need to be able to remove the top arises because in time dust, fluff and other debris will get blown into the box and will have to be cleaned out.

The top is drilled out in a square matrix of holes 10 mm apart with a No. 60 twist drill. To avoid the labour of marking out each hole we stuck a sheet of mm graph paper on the top with sellotape and drilled through the paper at the cm intersections. At each top corner a 25 mm long 6 BA roundhead bolt is inserted by drilling and tapping top and sides. The bolts protrude for 10 mm of their shank above the top and are locked by two nuts. These bolts hold four 20 mm lengths of spring made from piano wire, and these springs in turn support the vibrator. Fig. 2 shows this part of the construction.

The vibrator is made from 3 mm brass rod, bent in zigzag fashion with each leg of the zigzag about 30 mm long and of such a length that when the ends are brazed together it surrounds the table top in a loop (see Fig. 1). At each corner a notch is filed into the brass rod to fit the spring holding it. Across one corner where the vibrator will be driven an additional length of the same rod is brazed on, rising about 7 mm above the level of the rest of the vibrator before bending into a U-shape, the bottom end of which bears again the motor cam, see Fig. 2. This difference in level is needed to get the U-section clear of the holding spring at that corner.

We used an Orbit 205 d.c. motor mounted by four 6 BA bolts on a brass backplate measuring 75 x 35 mm (see Fig. 3). Two 2 BA bolts through oval slots in the plate, which have been drilled and tapped into the side of the air table allow the assembly to be moved left or right to vary the pressure of the cam on the vibrator. The cam is a 12 mm length of 19 mm dia. nylon rod fitted on to the motor spindle so that it is 1 mm off centre. A 25 mm wide strip of aluminium sheet is bent up to form a bracket holding two 4 mm socket terminals for the motor connection. The bracket bolts to the side of the air table near the motor.

The discs used on the air table were cut from 6 mm thick perspex. They were first cut square, slightly larger than their final diameter, and the corners were trimmed off. Then a batch of 8 - 10 were clamped together between a smaller diameter head board held in the lathe chuck and a floating centre on the tailstock, and they were turned down to the required diameter. The following sizes were used:

(i) 25 mm diameter with a short strip of magnetic rubber (E.J. Arnold KN 659) inserted in a 4 mm dia. hole 11 mm deep drilled radially. These are left clear and used to represent hydrogen.

(ii) as above but without magnet or hole and given a coating of black paint; used to represent a small non-polar molecule.

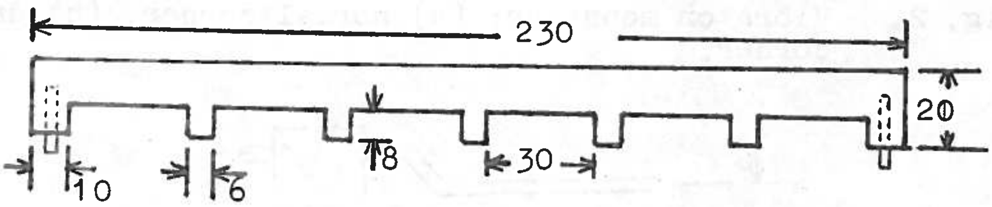
(iii) 39 mm diameter with one 6 mm dia. hole 11 mm deep. Inserted in the hole is half of a broken Alcomax magnet 13 x 4 x 4 mm (Philip Harris P46710/3). Painted green or with green filter cover this represents chlorine.

(iv) as above but with two holes at an angle of 104°. Painted red this represents oxygen.

(v) as (iii) with no holes or magnet; this represents a large solvent molecule in the osmosis model.

All the magnets are recessed by about 1.5 mm from the face of the disc. The polarities of the outer ends of the magnets are such that the 'hydrogens' are weakly attracted to the 'oxygens' or 'chlorines'.

To make the 'semi-permeable membrane' for the osmosis model, a piece of perspex 230 x 20mx 12 mm has six 30 mm wide slots cut and ground from it so that the smaller discs can pass through but the larger are blocked.



Small 3 mm pegs are fitted into the outer legs so that the 'membrane' can be located in the middle of the air table, fitting into two holes on the table top.

In showing adsorption, the adsorbent consists of a piece of hardboard with two ceramic disc magnets (E.J. Arnold KN 666) glued on top so that the pole at the bottom of the disc will attract the 'hydrogens', used here as polar molecules. A number of grooves are filed in the bottom of the hardboard to allow air to escape and so prevent the adsorbent from also floating.

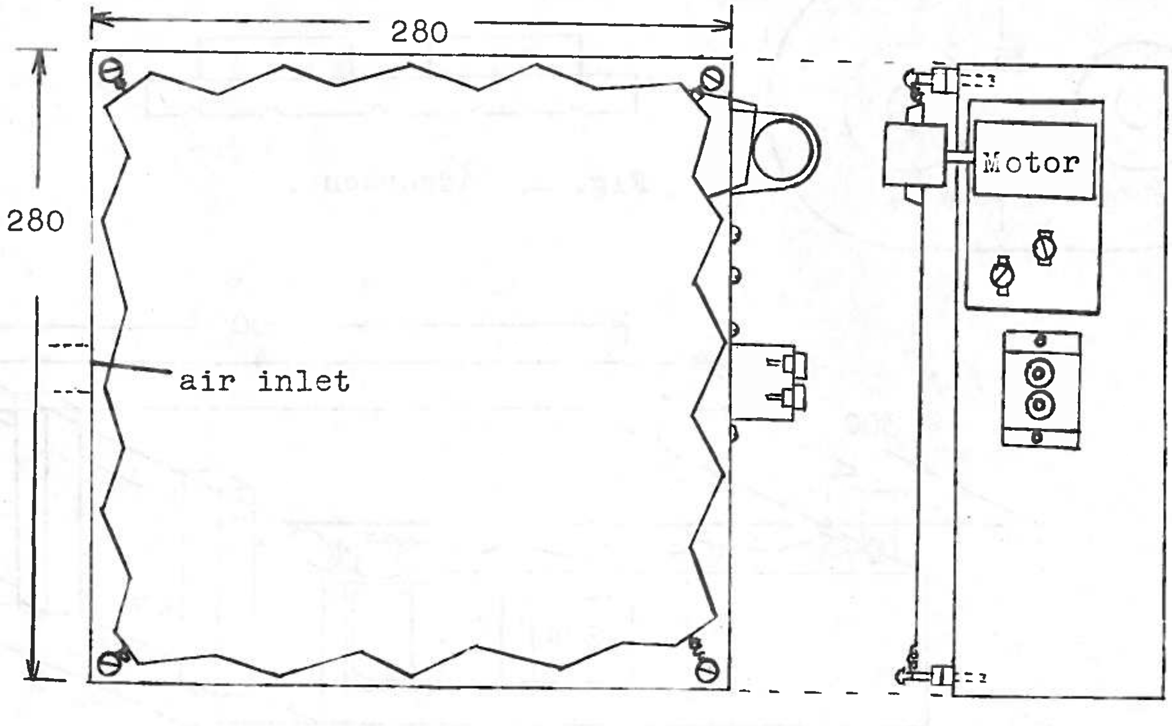


Fig. 1. Diagram not to scale: dimensions in mm.

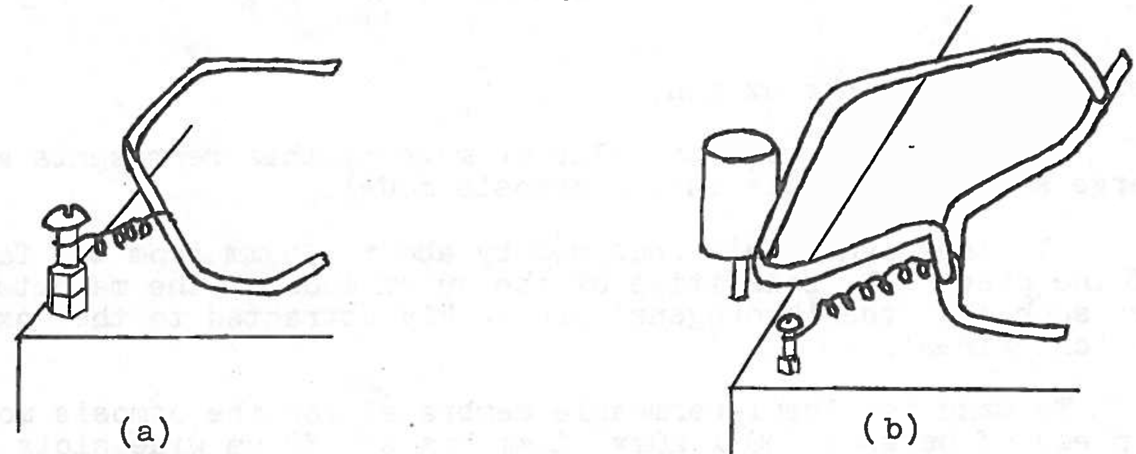


Fig. 2. Vibrator mounting; (a) normal corner, (b) drive corner.

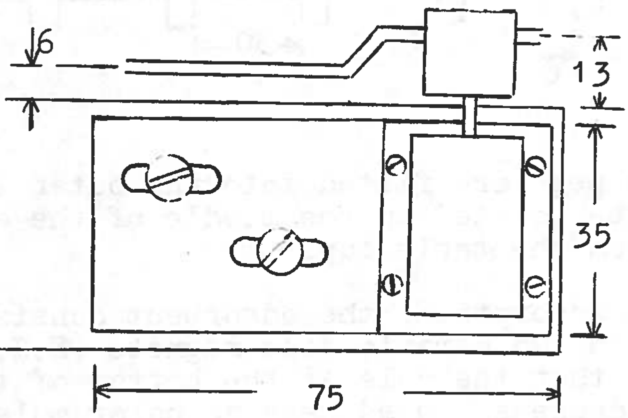
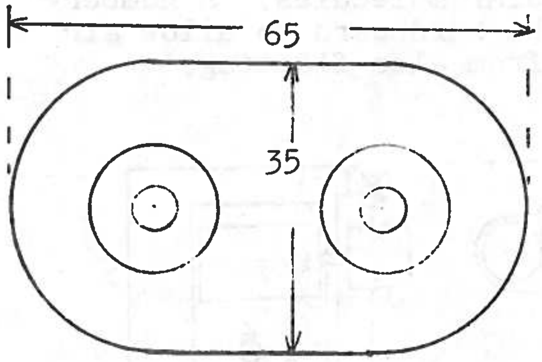


Fig. 3. Motor bracket detail.

Diagrams not to scale. All dimensions in mm.



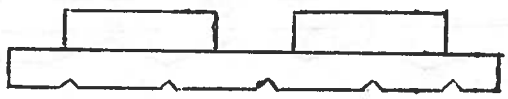


Fig. 4. Adsorbent.

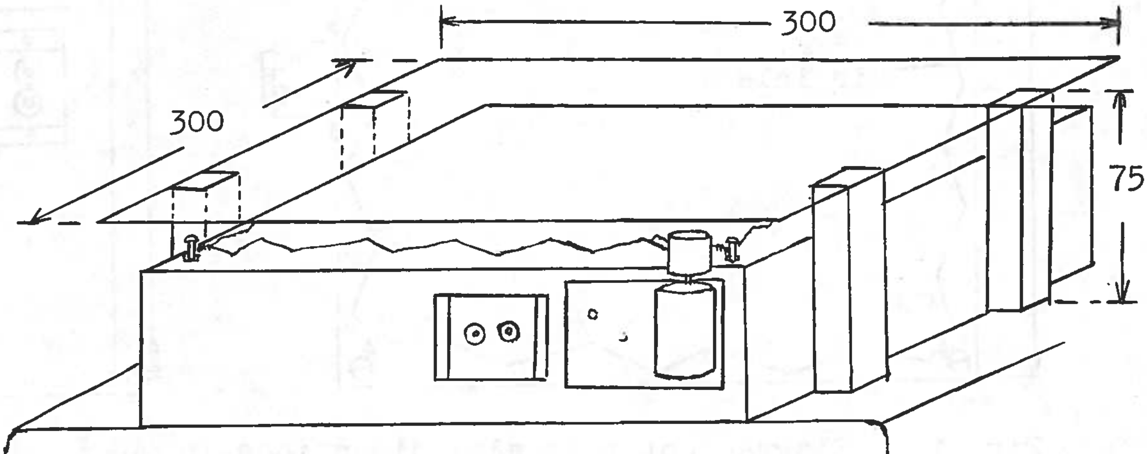


Fig. 5. Anti-Bernouilli-effect top cover.

Bulletin Supplement

Summary of Stereomicroscope tests. The instruments shown below were tested on the procedure published in Bulletin 42. Individual reports on these can be borrowed for up to one month by writing to the Director. The overall assessment classifications are: A - most suitable for school use; B - satisfactory for school use; C - unsatisfactory. All measurements in mm.

Model	Swift M20E (short arm stand)	Stereomaster 250 and 260
Supplier	Pyser Optical	W.R. Prior and Co.
Price	£55.50	Simple stand (250) £75.00 Transmitted light stand (260) £82.70 6V, 6W illuminator £12.50
Magnification	10x; 20x	10x; 20x
Change mechanism	slide out objective	slide out objective
Fields of view	14; 7.0	21; 10
Working distances	140; 115	160; 95
Eyepiece separation	50 - 72	50 - 85
Stability *		250 stand / 260 stand
(a) pull	8 N	8 N / 8 N
(b) angle	32°	33° / 30°
Distortion	B	B
Blurring	A	A
Lamp	None	6V, 6W illuminator unit
Head adjustment	None	None
Weight (kgf)	1.96	250 stand 2.14 / 260 stand 2.64
Assessment **	(1) B (2) B (3) C (4) B	(1) A (2) B/A (3) B (4) B/A

* These figures refer to the normal working position. With the head swung away from the base the instruments are completely unstable.

** (1) Ease of use; (2) Performance; (3) Versatility; (4) Overall assessment. Assessments 1 - 3 are the results of field trials in Scottish schools.

S.S.S.E.R.C., 103 Broughton Street, Edinburgh, EH1 3RZ.
Tel. 031 556 2184.

E.J. Arnold and Son Ltd., Butterley Street, Leeds, LS10 1AX.

Griffin and George Ltd., Braeview Place, Nerston, East Kilbride, Glasgow, G74 3XJ.

Philip Harris Ltd., 30 Carron Place, Kelvin Industrial Estate, East Kilbride, Glasgow, G75 OTL.

W.R. Prior and Co. Ltd., London Road, Bishops Stortford, Herts.

Pyser Ltd., Optical Division, Fircroft Way, Edenbridge, Kent.

R.S. Components Ltd., P.O. Box 427, 13-17 Epworth Street, London, EC2P 2HA.

Technomatic Ltd., 54 Sandhurst Road, London, N.W.9.

Wood and Cairns Ltd., 7 - 9 King Street, Dundee, DD1 2JE.