A compilation of A level Physics Investigations inspired by Nuffield Practical Problems

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Contents

The Purpose of this Compilation

There is little doubt that one of the most stimulating, rewarding and enjoyable aspects of the *Advancing Physics* course is the Practical Investigation. It is a rare opportunity for students to spend a large amount of time immersed in projects and to become so familiar with certain topics or investigative techniques that they can rightly feel proud of their achievements and regard themselves as local experts. Every silver lining, however, has a cloud.

Leaving aside the usual problems associated with all types of course work in all subjects (maintaining motivation, receiving the written report on time, etc), students have sometimes found that one of the hardest things about the Practical Investigation is one of the very things intended as a strength: the open-endedness. It really is not unusual for there to be at least one student in a set to have little idea about what they wish to investigate, even on the day the project is supposed to start. Once the hurdles of deciding on an experiment and identifying a suitable direction have been cleared, there is a very high chance that the Investigation will progress smoothly.

One very rich source of possible investigations is the couple of decades'-worth of **Nuffield A level Physics Practical Problems**. It is delightful, indeed, to see that many of the ideas to which teachers and students were first introduced via this paper have made it into the *Advancing Physics* course in some form or other. There remains, however, a large number of experiments which we feel could be plundered as potential investigation topics. Those who are familiar with the Practical Problems paper will realise that many experiments, though delightful, did require very specific materials and sometimes a lot of adjustment to produce something reliable as should befit an examination question. We have therefore selected those experiments that we believe satisfy the following criteria:

1. **The apparatus is straightforward and not too critical**
2. **There is an initial, fairly convergent task available**
3. **There is scope for further investigation**
4. **The topic is interesting.**

By the time we had weeded out all the overt examination questions (e.g. capacitor discharge, "identify-the-component-in-the-box" and "press-abutton-and-measure" questions) and those that brought back painful memories, we were left with those that you will find in **Section 1**. We have adjusted the rubric from the original to a more adaptable worksheet style. We have also added some keywords to assist with searching for an experiment based on a particular topic, and we have included, where appropriate, suggestions for further investigation.

In **Section 2** we have effectively listed some more ideas based firmly on the Practical problems source, whilst in **Section 3** we have merely listed what we still hope is a lot of ideas that are more loosely inspired by the source.

In our experience, whilst it is very important that students are allowed to genuinely investigate a topic that is largely unknown to them, it is very useful to provide them with a simple question to tackle at the outset. This focuses their attention and enables them to make progress quickly.

We hope you find these useful and that, indeed, it helps ensure that all your students are able to look back over their Practical Investigation without grimacing. In the spirit of the continuity of the evolution of the course, we look forward to implementing changes and adding ideas so that the collection might remain of use.

KAPW
MAB

Section 1

The Practical Problems featured in this section are reproduced almost in their original form, with diagrams and questions being taken directly from the original sources.

We have included some keywords, that might prove useful when searching for a specific topic area, and a reference which gives the year of the original paper and the question number on that paper.

It is hoped that there is enough information in the questions to enable an investigation to proceed.

Convergent tasks alone are not always to be encouraged and we have made some suggestions here and there for further investigation.

The investigation titles are in alphabetical order.

They are presented in spreads of one or two pages, to facilitate printing and copying.

1.14 Hardness testing

1.15 High diving and water depth

1.16 Hot wire anemometer

1.17 How spaghetti snaps

1.18 LDR depth meter

1.19 Magnetic force on a current

1.20 Pile driving

1.21 Polarizing effects of adhesive tape

1.22 Polarisation by reflection

1.23 Resistance of a pencil line

1.24 Sagging wire ammeter

1.25 Sliding chain

1.26 Sound waves through carbon dioxide gas

1.27 Speed of a rolling ball

1.28 Thickness measurements using magnets

1.29 Using Solar Cells

1.30 Vertical oscillating mass

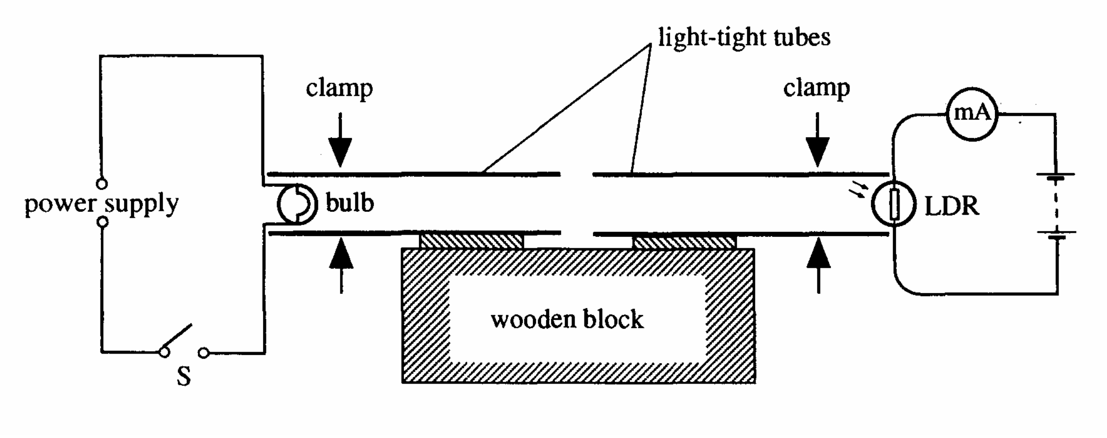
1.1 Absorption of light by Acetate

KEYWORDS

Absorption; exponential; transmission; opacity; half-thickness; LDR

AIM

In this experiment you are going to investigate how much light is transmitted by sheets of plastic.



PROCEDURE

1. Close the switch S in the bulb circuit so that light from the bulb falls on the LDR. Record the current in a table like that shown below.

Number of sheets	0	4	8	12	16	20
Current / mA						

2. Now carefully insert four transparent sheets in the gap between the black tubes. Record the new current.

3. Take readings using further sheets to complete the table.

4. Open switch S.

5. Assume that the LDR current is proportional to the intensity of the light falling on it. It is suggested that the intensity of light falls off exponentially with the number of sheets of acetate placed in the light beam. Use your results to test this suggestion.

6. There is an analogy between this experiment and an experiment investigating the transmission of gamma radiation through increasing thickness of lead. What in the gamma experiment could be analogous to:

   (i) the reading in the milliammeter,
   (ii) the reduction in light transmitted at each acetate sheet?

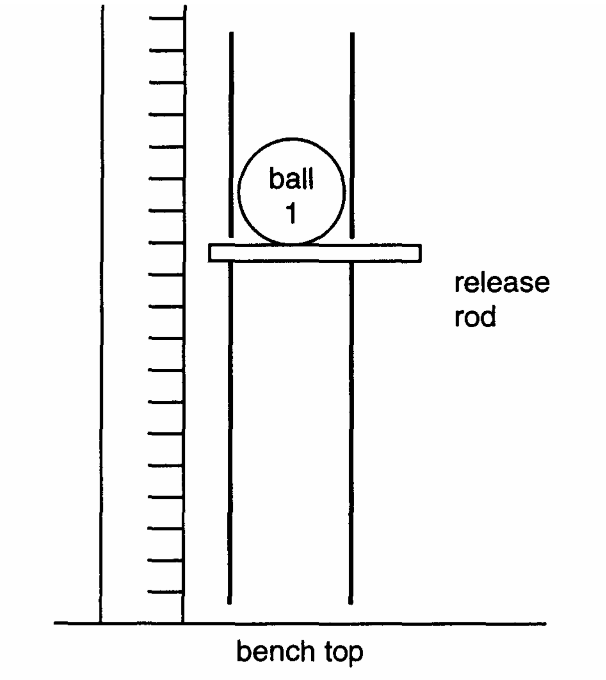
REF: 7/1996

1.2 Collision of Falling Balls

KEYWORDS
Gravitational potential energy; kinetic energy; momentum; impulse; coefficient of restitution.

AIM

In this experiment you can investigate a collision between two balls of different mass (a ping-pong ball and a golf ball).



PROCEDURE

1. Place ball 1 (a ping-pong ball) into the top of the tube and release it by withdrawing the "release rod" rapidly. (The tube could be a rolled-up acetate sheet. The fitting should not be too snug and vent holes should be made along the length to minimise drag effects. A 30 cm ruler alongside the tube will suffice.)
2. Measure and record the maximum height that the bottom of the ball reaches after the bounce.

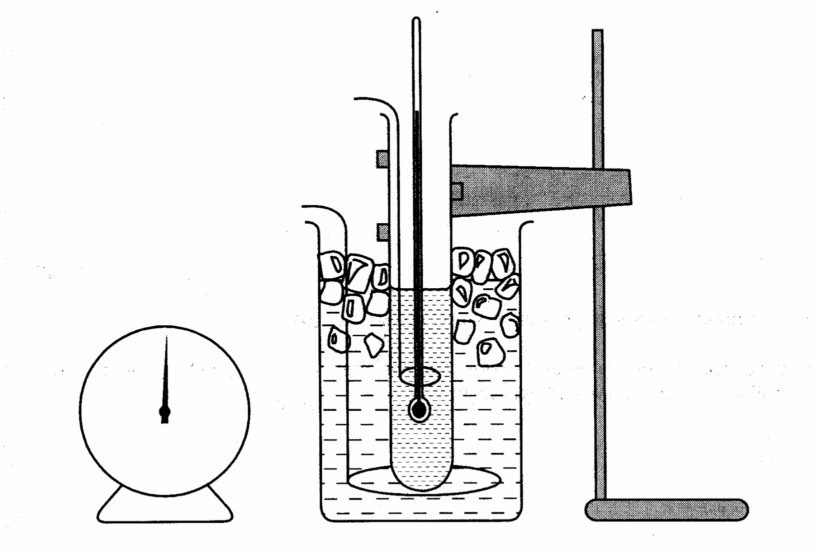
3. Explain why ball 1 does not return to the height from which it is dropped.
4. Repeat the procedure described above with ball 2 (a golf ball). Note the maximum height to which this ball bounces after release.
5. Now place ball 1 and then ball 2 into the tube. Release both balls together and observe their subsequent motion. Describe the behaviour of each ball after the impact with the bench.
6. Account for the behaviour of the balls you have observed in part (5) by considering the energy transfer between the balls.
7. Mass ratios, heights of release, landing surface and the number of balls are all accessible variables in this experiment.

REF: 1/1999

1.3 Cooling in cold surroundings

KEYWORDS
Cooling; temperature; thermodynamics; internal energy.

AIM
This is an investigation about how the temperature of a hot liquid changes in cold surroundings.



PROCEDURE

1. You will need a boiling tube of hot water, a beaker of melting ice, a thermometer and a stop-watch.

2. Arrange the boiling tube so that the hot water is surrounded by the ice mixture. You will need to take the temperature immediately and start timing.

3. Record, in a table, the temperature every 20 seconds for two minutes.

4. Draw a graph of your results.

5. What does the gradient of the graph at any instant represent?

6. Describe how the gradient of the graph changes as the liquid cools.

7. You could go on to look at how impurities affect the rate of cooling and whether the initial temperature affects the cooling too.

REF: 5/1997

1.4 Corrugated Cardboard

KEYWORDS
Young modulus; stiffness; strength; yield point; elastic limit.

AIM
This experiment concerns the use of corrugated cardboard to package fragile objects.

PROCEDURE

1. Look carefully at a sample of cardboard. Describe its construction.
2. Explain how the construction makes it suitable for protecting fragile objects.
3. Fold and unfold the sample repeatedly along a line parallel to the ridges. Open it out.
4. Repeat the folding and unfolding procedure along a line perpendicular to the ridges. Compare the force you have to apply and the effect on the cardboard in each case.
5. Use your observations to explain why the corrugated cardboard would be very good for protecting lengths of glass tubing but less effective for a sheet of glass.
6. You could go on to design and carry out an experiment in which the strength of the cardboard in different directions could be established. You will need to think carefully here about the meaning of 'strength' in this case.

REF: 8/1992

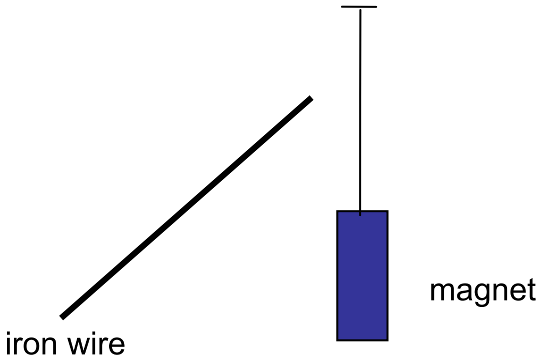
1.5 The Curie Point

KEYWORDS

Resistance; power; specific heat capacity; domains; Curie point

AIM

In this investigation you can estimate the temperature at which the magnetic properties of an iron wire change.



PROCEDURE

1. Move the suspended magnet until it touches the horizontally strung iron wire (for an initial set-up, you could use 30 cm of SWG 30 wire; the wire should be kept tense using masses suspended from the ends, since it will sag when hot! The critical current is likely to be several amperes). ***<u>The wire gets hot!</u>***

2. Pass a current through the wire until the magnet swings away. Record the values of voltage V across and current I in the wire at this point.

3. Switch the current off when the readings of V and I have been recorded. The magnetic properties of iron are destroyed when the temperature is sufficiently high; this temperature is called the Curie point.

4. Calculate the energy being supplied to the wire each second at the Curie temperature.

5. In an experiment like this, the wire typically takes about 10 seconds to reach its Curie point after the current is switched on. Use this information to estimate the final temperature of the wire.

6. You could go on to assess the method as a valid means of establishing the Curie point for a material and perhaps find out the Curie point for other materials. Does tension affect the result? Is the answer different using alternating current?

REF: 7/2000

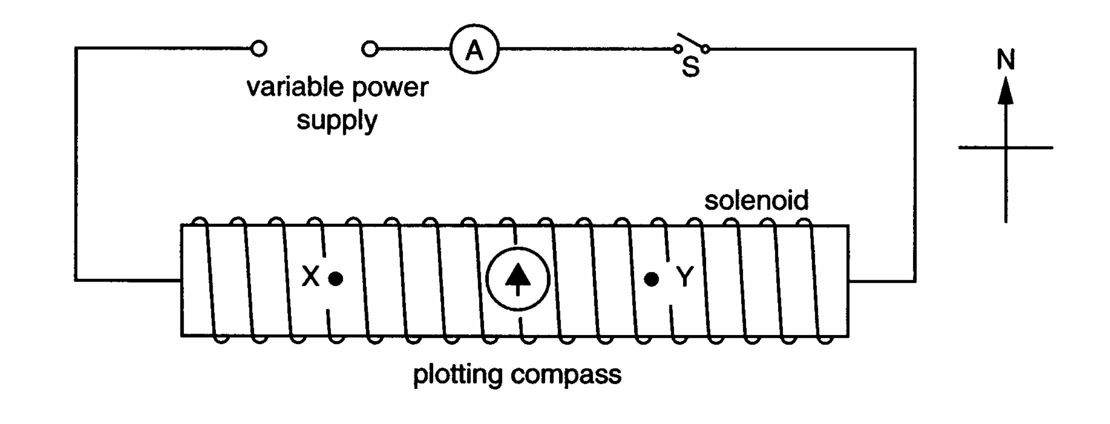
1.6 Measuring the Earth's Magnetic Field

KEYWORDS

Magnetic field strength; Earth's magnetic field; component; vectors; solenoid.

AIM

With this experiment you can investigate the horizontal component of the Earth's magnetic field.



PROCEDURE

1. A solenoid (2cm diameter, total length and turns) lies with its axis East—West. A plotting compass is mounted in the middle of the solenoid.

   Close switch S
2. Gradually increase the current (to around 0.5 A) observing the needle of the compass as you do so.
3. Describe the behaviour of the needle as the current is increased.
4. Explain why the compass behaves as you have described.
5. Increase the current until the compass needle is rotated through approximately 45° . Record this current.
6. Open switch S. You can use two points (eg X and Y) of known separation to establish the number of turns per unit length.

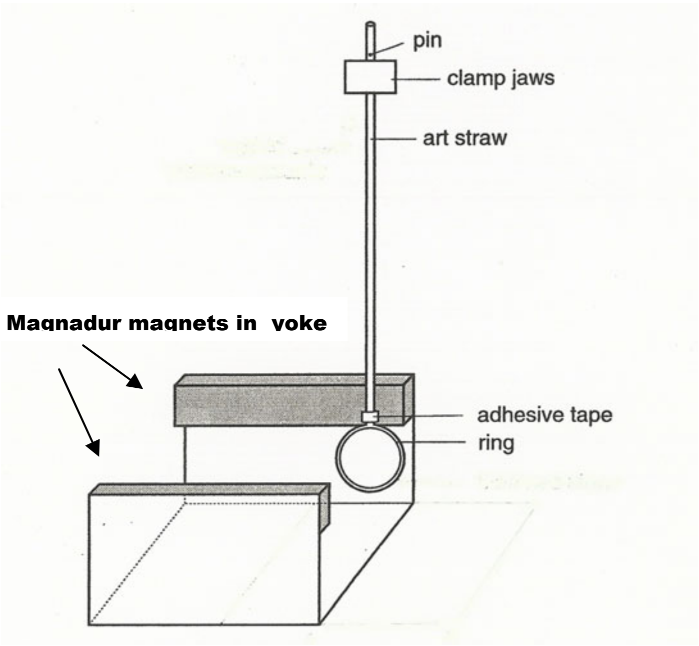
7. Hence you can calculate the B field at the centre of the solenoid in part (5).
8. Why is the answer to part (7) equal to the value of the horizontal component of the Earth’s magnetic field.

REF: 6/1999

1.7 Eddy current braking

KEYWORDS
Lenz’s law; induced emf; eddy currents; magnetic flux

AIM
In this experiment you will explore the use of a magnetic field in braking.



PROCEDURE

The pendulum shown consists of an aluminium ring mounted on a straw with adhesive tape, suspended on a pin. (The pin passes through the straw and rests horizontally on the jaws of the clamp.)

1. Displace the pendulum and allow it to swing freely a few times, noting its motion.

2. Repeat, but this time with the magnets in position (so that the direction of motion of the ring is at right angles to the field). How does the motion change? Why?

3. What happens when the pendulum is released from a greater height?

4. Replace the pendulum with one in which the ring is a broken one. How does this affect things?

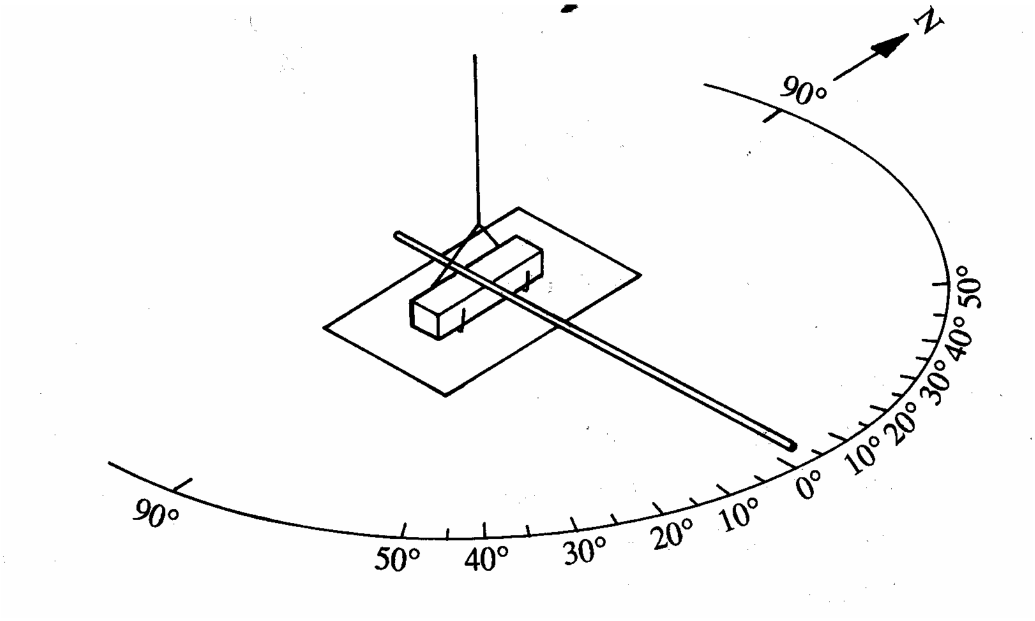
5. You might go on to investigate the effect of release height carefully and perhaps try the experiment with different metals, different diameters and different thicknesses.

REF: 4/1997

1.8 Eddy current damping

KEYWORDS
Simple harmonic motion; damping; eddy currents; Lenz's law; magnetic flux.

AIM
In this experiment you can investigate the decay of torsional oscillations of a bar magnet in the Earth's magnetic field.



PROCEDURE

The magnet is suspended horizontally by a vertical thread. A pointer (could be a drinking straw) moves across a scale marked in degrees as the magnet is set in horizontal twisting oscillations. In the diagram, the rectangle drawn underneath the suspended magnet is the position of an aluminium plate, above which (about 1 cm) the magnet will spin later on (see part 4).

1. Displace the magnet to an initial amplitude of 45°. Release it and note the amplitude every two complete oscillations. Record your results.

2. Explain carefully why the magnet oscillates when released from its displaced position.

3. What causes these oscillations to be damped?

4. Now place a thin aluminium plate underneath the magnet (preferably with a gap of less than 1cm). Repeat the procedure of step 1, again recording your results.

5. Describe and explain the effect of the presence of the aluminium on the oscillations.

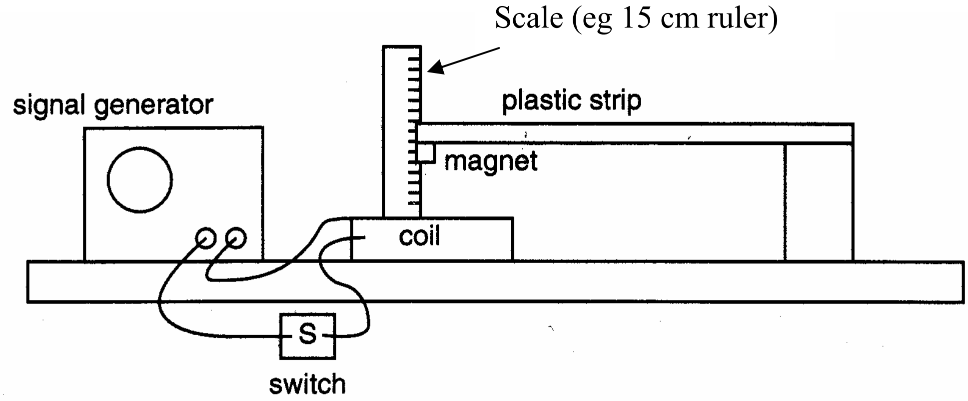
6. What do you think would happen if a thicker plate of aluminium were used? Give reasons. Try it.

REF: 1/1993

1.9 Electromagnet Resonance

KEYWORDS
Electromagnet; frequency; resonance, oscillation.

AIM
A magnet attached to a clamped plastic strip with a magnet stuck at one end, is made to vibrate using an electromagnet, enabling resonance and related phenomena to be investigated.



PROCEDURE

1. Explain why the magnet oscillates.

2. Investigate how the maximum amplitude of oscillation of the magnet varies with frequency. (Use the scale (ruler) to measure the sizes of the oscillations; don't forget the definition of amplitude!) Include, if possible, the frequency at which the largest amplitude occurs.

3. Plot a graph of your results.

4. Explain why the amplitude of oscillation is larger at some frequencies than others.

5. How does the position of the magnet on the strip affect your results?

6. How does loading the strip with extra masses affect the results?

REF: 6/2000

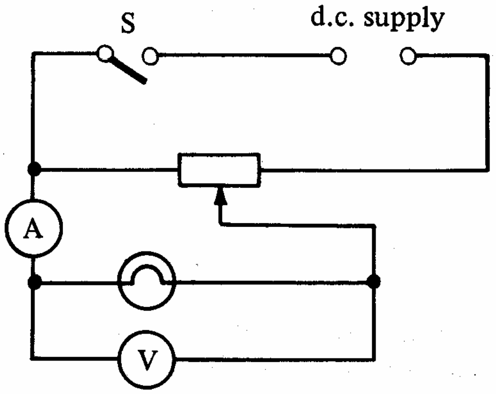
1.10 Energy transfer in a light bulb

KEYWORDS

Resistance; potential difference; current; Joule heating; energy; frequency.

AIM

With this experiment you can investigate the energy transfer in the filament of a light bulb.



PROCEDURE

1. Adjust the potentiometer to establish a range of potential differences across the tungsten filament lamp.

2. Record the current and note the appearance of the filament in each case paying particular attention to colour and brightness.

3. One model often used to explain electrical resistance considers collisions between drifting electrons and the ions in the lattice. Use this model to

i) suggest why the current in the filament increases as the p.d. across the filament increases
ii) suggest why the filament becomes hot
iii) suggest why doubling the p.d. does not double the current.

4. Suggest why the colour of the light emitted by the filament changes as the p.d. increases.

REF: 6/1990

1.11 Falling cones

KEYWORDS
Acceleration; air resistance; friction; weight; buoyancy; terminal velocity.

AIM
Early Apollo space capsules that returned to Earth were cone-shaped. In this investigation you are asked to think about how cone-shaped objects fall.

PROCEDURE

1. Drop a card cone, point downwards, from 2 m above the floor. Observe and describe the motion. ***(Be careful: moving, sharp points can be dangerous!).***

2. Find an accurate value for the time the cone takes to fall. Make clear how you arrive at your answer.

3. Calculate how long you would expect a heavy object to take to fall thorough 2 m near the Earth's surface. Make clear how you arrive at your answer.

4. Draw a sketch showing the forces on the cone as it falls, to help explain the difference between the times measured in 2 and 3.

5. How does a second cone, of identical dimensions but made of paper, fall through 2 m when released in exactly the same way as the card one in step 1? State two differences which can be observed and give reasons for these differences.

6. Blu-tak or plasticene can be added to the insides of the cones to vary the mass for a given size. How does this affect your results?

7. Does the angle of the cone-vertex have an effect? Or the diameter of the cone?

REF: 8/1997

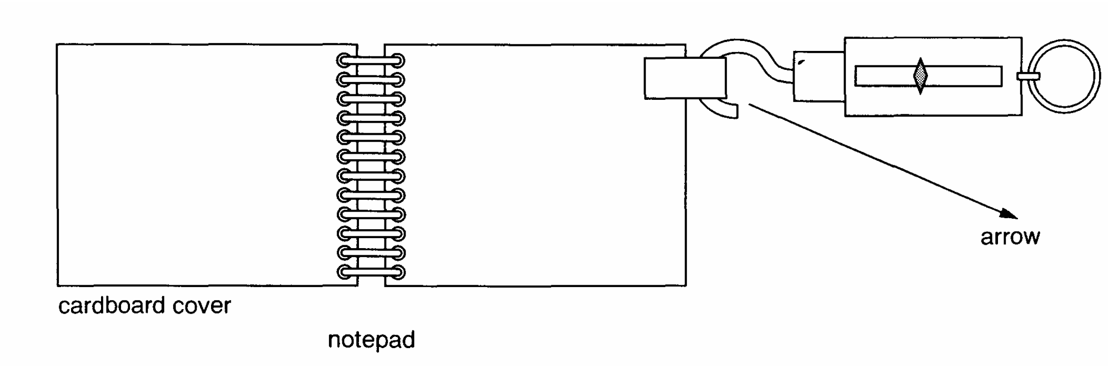
1.12 Forces and Tearing Paper

KEYWORDS

Force; components; vectors; moments; stress.

AIM

In this experiment the force required to remove a page from a notebook is measured.



PROCEDURE

1. Hook the spring balance through the tape loop on the notebook (a reporter's, spiral-bound type) and pull gently in the direction of the arrow (which makes an angle of about 30 degrees with the horizontal).

2. As soon as the page starts to tear STOP and note the maximum force indicated by the spring balance.

3. Describe how the force changes as you continue to remove the page completely from the pad.

4. Explain why the force changes as you have described.

5. Now use another notebook of exactly the same type, but which this time has a tape loop positioned at the middle of one edge of the notebook page. Repeat the procedure used above to remove a page from this notebook. Note the force required to start this page tearing as before.

6. Comment on the results that you have recorded accounting for any differences between your answers in parts (2) and (5) above.

REF: 7/1998

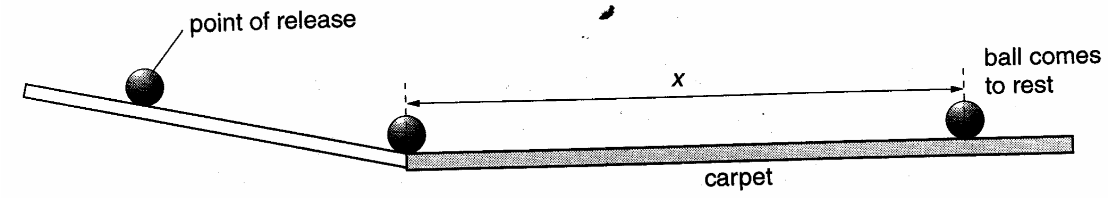
1.13 Friction and stopping distance

KEYWORDS

Friction; stopping distance; kinetic energy; internal energy; mechanical work.

AIM

In this experiment you can investigate the stopping distances of balls of different mass.



PROCEDURE

Place a smaller ball (A) part way up the ramp. Release the ball and observe the motion of the ball until it comes to rest.

1. Describe the energy transfers which take place from the moment of release to when the ball comes to rest.

2. Measure the stopping distance on the carpet as shown in the diagram.

3. Suggest and explain how the stopping distance might be related to the mass of the ball.

4. Repeat the experiment with a larger ball (B). Record the stopping distance.

5. If ball B has double the mass of ball A, make suggestions that might account for the difference between your prediction and what is actually observed.

6. Of course the balls might have different sizes as well as different masses. How does this affect things?

REF: 1/1997

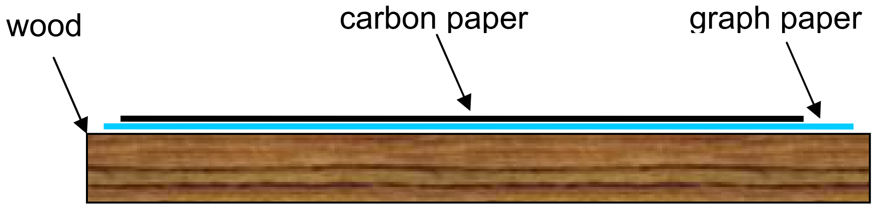
1.14 Hardness testing

KEYWORDS

Hardness; impact; potential energy; plastic deformation.

AIM

This investigation is concerned with a material's ability to resist impact.



PROCEDURE

1. The basic arrangement is as depicted. Put a sheet of graph paper on the wood and then put a sheet of carbon paper sensitive side downwards, on the graph paper.

2. Release a glass marble from a height of 0.5m so that it lands on the carbon paper and makes a mark on the graph paper. What is the area of the mark?

3. Replace the wood by a metal base and repeat so that a separate mark is made.

4. Assume that the area is proportional to the depth of the dent produced and compare as quantitatively as you can the force exerted by the marble on the wood with the force exerted by the marble on the metal.

5. State any assumptions you have made.

6. You could go on to investigate the effect of using different base materials, different marbles (mass, diameter, material) and different drop heights.

REF: 1/1981

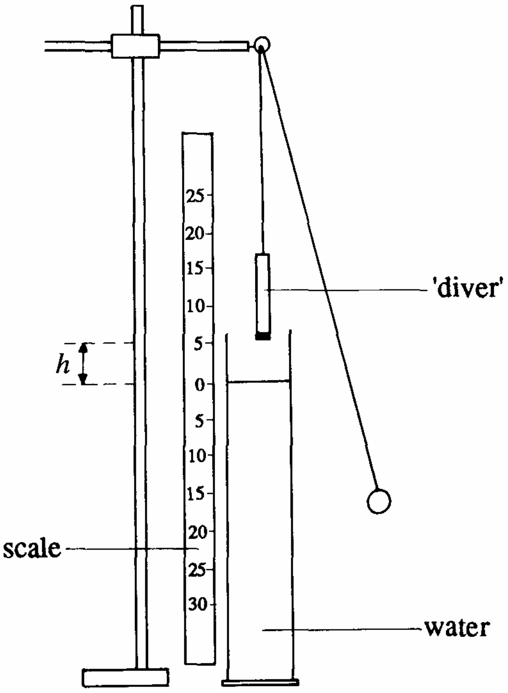
1.15 High diving and water depth

KEYWORDS

Potential energy; kinetic energy; drag; upthrust

AIM

This investigation considers the depth of water needed in a swimming pool if diving from high boards is to be allowed.



The diagram shows the arrangement of the apparatus. A weighted piece of wood represents the diver, which can be dropped from different heights (*h*) into the water. The greatest depth of immersion (*d*) can also be measured.

PROCEDURE

1 Pull on the ring to raise the diver until it is just clear of the water surface (*h* = 0). Release the ring, allowing the diver to fall. Record in a table, the depth d to which the bottom of the diver sinks.

2 Repeat the experiment for different values of h (eg *h* = 5, 10, 15, 20 cm).

3 Make a general statement summarising the pattern that you see in your results.

4 Estimate the potential energy gained by the diver when it is raised so that its lower end moves from the surface of the water to 5 cm above it.

5 What is the kinetic energy of the diver just as it enters the water?

6 This kinetic energy is dissipated as the diver is brought to rest by the water. Using the approximate value of *d* from your table calculate a value for the average force exerted by the water in bringing the diver to rest at that depth *d*.

7 The management committee of a swimming pool has met to discuss whether the diving boards could be raised to twice their height.

8 One person opposes this on the grounds that the pool would need to be twice as deep. In the light of your table of results, state with reasons, whether you agree with this objection.

9 Another person is worried that the force on the divers when they enter the water would be dangerously high. Use your results to comment on this fear.

10 What is the effect of changing the density of the water (eg by adding salt)? Or the mass of the diver?

REF: 5/1994

1.16 Hot wire anemometer

KEYWORDS

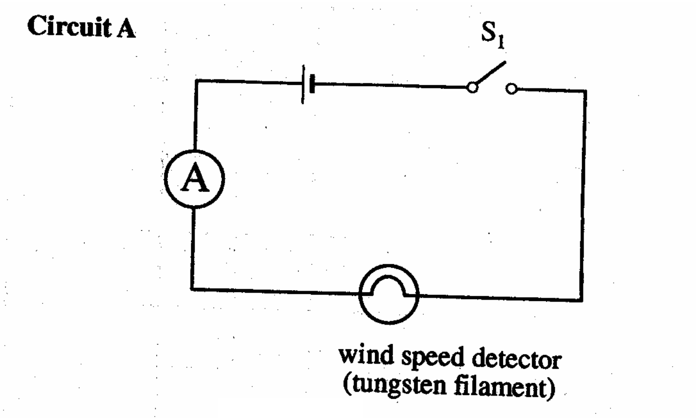
Resistance; current; potential divider; Wheatstone bridge; temperature; wind-speed; wind chill; sensitivity

AIM

In this investigation the electrical properties of two simple circuits are considered to measure moderate wind speeds.

PROCEDURE

In each of the circuits in this experiment, the wind speed detector is the tungsten filament of an ordinary torch bulb, from which the glass cover has been removed.



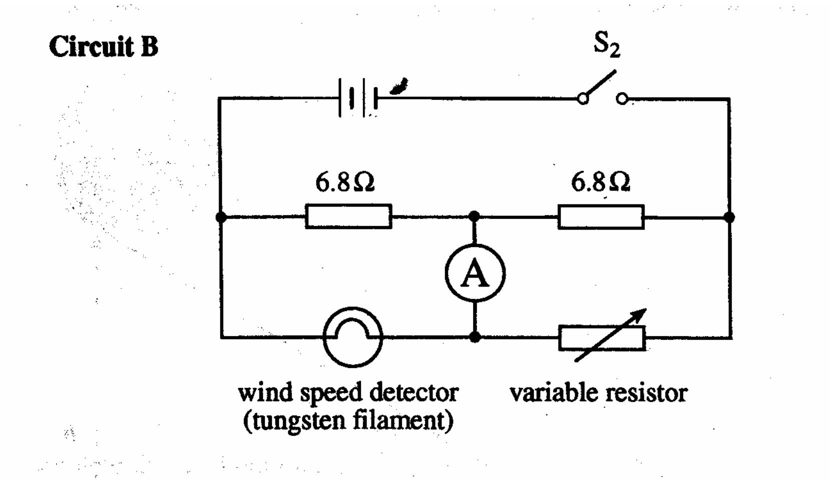
1. On closing the switch in Circuit A, the ammeter reading should increase to a steady value. Record this steady reading.

2. Estimate the resistance of the tungsten filament when no wind is blowing, using your answer to part 1.

3. Blow on the tungsten filament, changing the speed of blowing from gentle to quite hard, observing the meter reading as you do so. Record this reading and open the switch.

4. Describe your observations and explain the effects you have observed.

5. A second, identical wind speed detector (i.e. the filament) may be used as part of another circuit (Circuit B):



6. Adjust the variable resistor until the reading on the ammeter is zero.

7. Blow on the tungsten filament, changing the speed of blowing from gentle to quite hard, observing the meter reading as you do so.

8. Record your answer and open the switch (S_2 in this diagram).

9. Describe your observations and explain the effects you have described.

10. Which circuit is better for detecting small variations in wind speeds? You might try calibrating the device and using it to take some other measurements.

REF: 3/1996

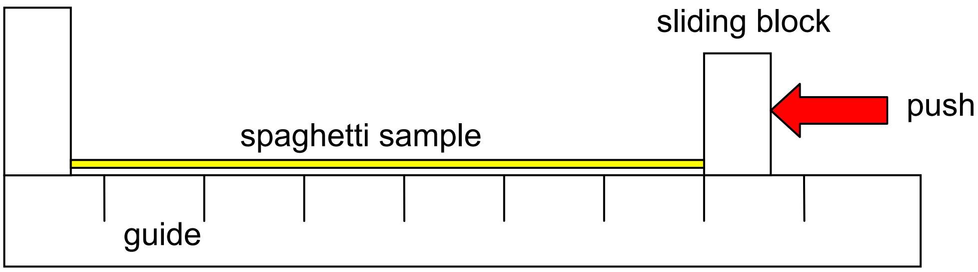
1.17 How spaghetti snaps

KEYWORDS

Brittle fracture; proportional; strength; compression; tension

AIM

This investigation is about breaking dried spaghetti.



PROCEDURE

1. Take a length of spaghetti and place it along the guide as shown above. Adjust the sliding block until it rests gently against the free end of the spaghetti.

2. Push the block about 10mm along the guide in order to bend the spaghetti in the horizontal plane.

3. Draw carefully the shape of the bent spaghetti and label a position T on your diagram where the spaghetti is in tension, and a position C where it is in compression.

4. Continue the bending process described above until the spaghetti breaks. For each sample length [a range might include 120mm, 160mm, 200mm, 240mm, 280mm] record the distance between the ends when the spaghetti breaks.

5. Plot a graph of breaking distance against sample length. Is there a pattern in your results?

6. You might go on to investigate cooking effects – lengths of spaghetti that have been subjected to different temperatures of water for different amounts of time.

REF 1/2001

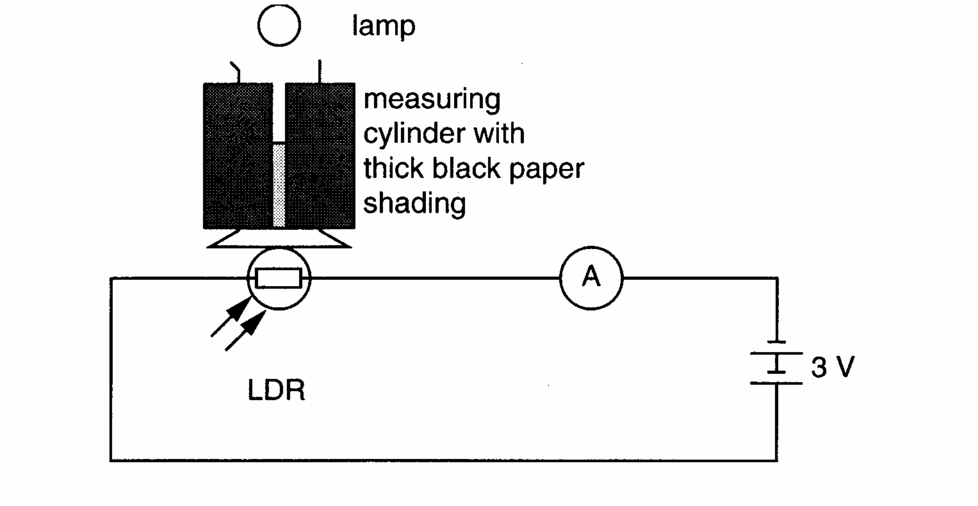
1.18 LDR Depth Meter

KEYWORDS

Depth gauge; sensor; absorption; Rayleigh scattering; exponential; LDR; sensitivity.

AIM

This investigation concerns the measurement of the depth of a translucent liquid using a light dependent resistor.



PROCEDURE

1. Produce and complete a table recording your observations by

   (i) noting the value of the current indicated with no liquid present;

   (ii) pouring the chosen liquid (should not be too opaque) into the measuring cylinder to the depths of say 0mm, 20mm, 40mm, 60mm and 80mm and noting each ammeter reading.

   (iii) calculating the resistance of the LDR for each depth.

2. Use your results to plot a graph to show how the resistance of the LDR varies with depth of liquid.

3. Why does the resistance of the LDR change with liquid depth?

4. It is suggested that equipment like this could be used as the fuel gauge in a car. Comment on the suitability of this method giving one advantage and one disadvantage that it might offer.

5. Having calibrated the system, you could look at factors affecting the opacity of the liquid e.g. concentration of milk in water, the settling of a head of beer or density of sugar solution (could be linked to polarising effects).

REF 2/2000

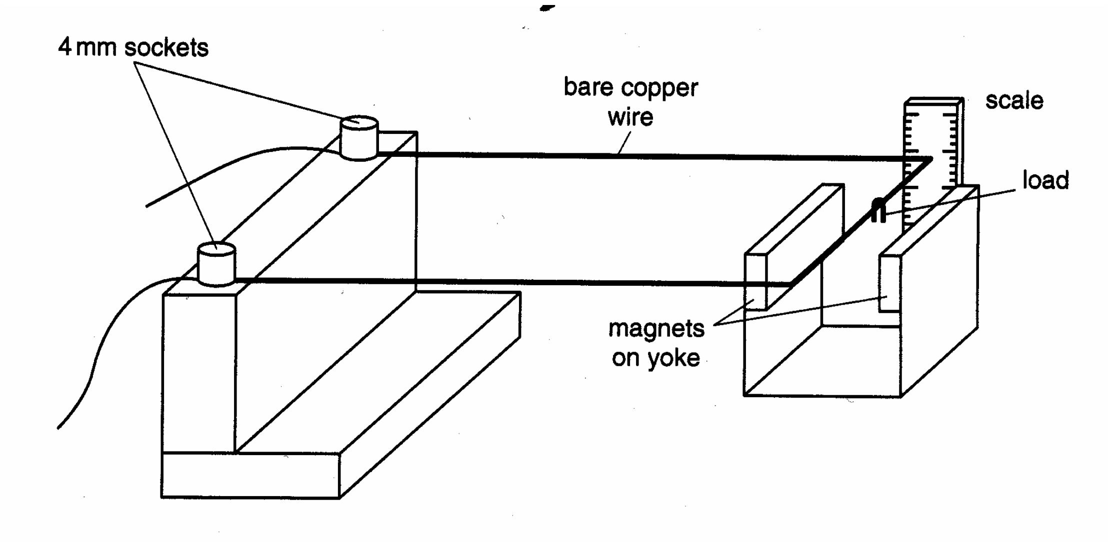
1.19 Magnetic force on a current

KEYWORDS

Magnetic force; weight; field strength; Fleming's left hand rule.

AIM

In this experiment you can investigate the strength of a magnetic field by observing the deflection of a wire.



PROCEDURE

1. Place one load across the length of wire in the magnetic field as shown in the diagram. Record how deflection varies with load (expressed in newtons).

2. Plot a graph of load against deflection.

3. Remove all the loads from the wire, and pass a current through the wire, increasing it until you can deduce from your graph a value for the force acting on the wire.

4. Write down an expression for the force on the wire due to the magnetic field at this value of current.

5. Hence calculate a value for the magnetic field at the wire.

6. You might go on to investigate whether the relationship between current and force depends upon the size of the current, the ambient temperature or the type of metal from which the wire is made.

REF: 8/2000

1.20 Pile driving

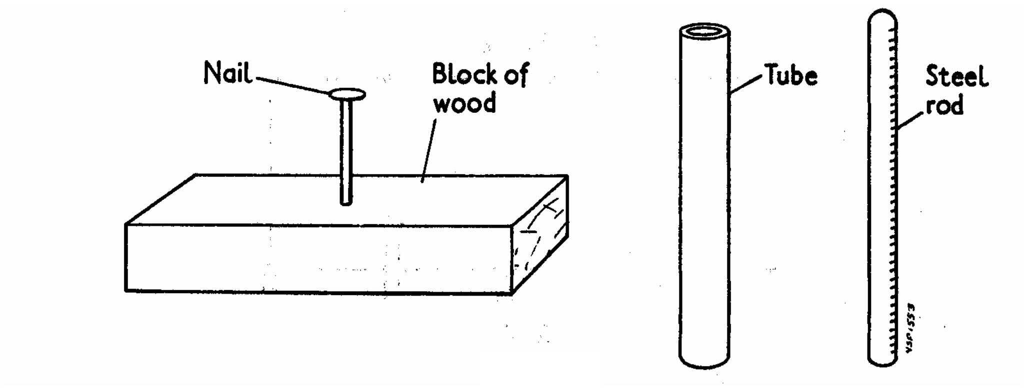
KEYWORDS

Gravitational potential energy; yield stress; toughness; impulse; kinetic energy.

AIM

In this investigation you can study the action of a pile driver.

PROCEDURE



1. It is advisable to begin with the nail already partially hammered into the wood.

2. The steel rod (with ruler scale marked on the side) is allowed to fall freely onto the head of the nail, with the tube used as a guide.

3. The amount by which the nail is driven into the wood with each drop of the rod is measured and a plot of penetration against number of drop can be made.

4. By using energy considerations, calculate the average resistive force of the wood to the penetration of the nail (assume a 100% efficient process!).

5. Can you explain the shape of the graph plotted in part 3?

6. What if different drop heights are used? Does the same pattern exist?

7. Is the pattern different for different woods and other materials?

REF: 3/1983

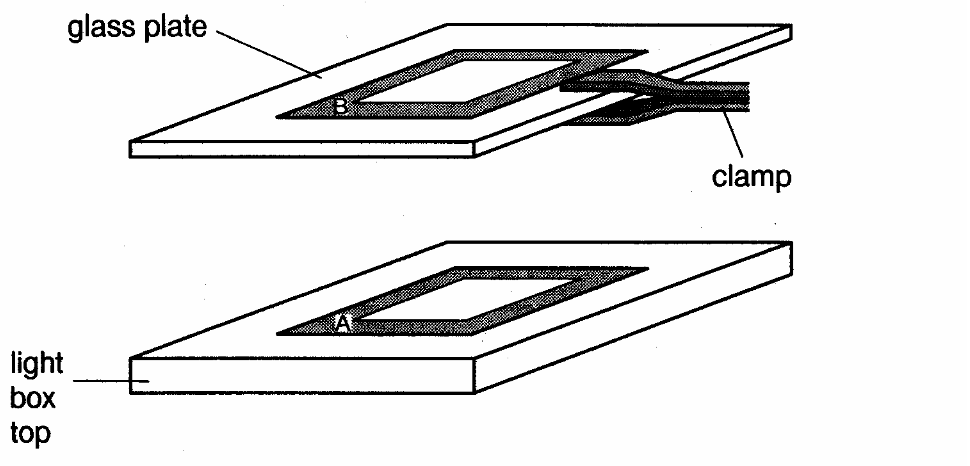
1.21 Polarising effects of adhesive tape

KEYWORDS

Polarisation; Polaroid; rotation

AIM

In this experiment you can observe the polarising effects of adhesive tape on transmitted light.



PROCEDURE

1. To investigate the polarising effects, it is recommended that a simple light box be used. This could simply be a small cardboard box containing a ray-box lamp and with a translucent screen (greaseproof paper) lid. With one Polaroid filter (A) stuck to the lid and another (B) held above it, the samples of tape, stuck to glass plates (eg microscope slides), can be inserted into the gap and the effects observed.

2. Looking directly down through the Polaroid filters without a sample inserted, observe and describe what is seen as filter B is rotated through different angles with respect to filter A.

3. Repeat 2 with a slide in position.

4. Repeat again, but this time systematically rotating the slide too.

5. How does stressed adhesive tape appear?

6. Make a St George's or St Andrew's cross shape with two strips of adhesive tape and examine the behaviour of these through the polaroids.

REF 7/1997

1.22 Polarization by Reflection

KEYWORDS

Polarization; Polaroids; glass; reflection; partial reflection; transmission.

AIM

This investigation is about the polarisation of light by reflection.

PROCEDURE

Place a piece of glass in a holder so that it stands vertically on the table (preferably on a sheet of A3 paper). Direct a ray of light at the sheet of glass (from a standard ray box, with a fitted single slit) at an angle of incidence (measured from the normal) of 80°. Look at the image of the ray box slit, formed by reflection in the glass. Place a piece of polaroid in front of your eye and rotate it until you notice that the reflected image gets dimmer.

1. Why does the image become dimmer?

2. Repeat this procedure for decreasing angles of incidence (say 10° steps).

3. Sketch a graph of how the observed minimum brightness of the image, viewed as described above through the polaroid, varies with the angle it makes with the plane of the glass.

4. Now repeat your observations to find the precise position where the difference in brightness between the image as viewed with and without the polaroid can be made to be greatest. Measure the angle between the glass and the incident light beam at this setting.

5. Give and explain a practical application of this effect, which you could then go on to investigate in more detail.

REF: 7/1988

1.23 Resistance of a pencil line

KEYWORDS
Resistance; resistivity.

AIM
In this question you are to use the electrical properties of graphite to determine the thickness of a pencil line.

PROCEDURE

1. Begin by measuring the resistance of a pencil lead.

2. Measure the diameter and length of the pencil lead.

3. Hence calculate the resistivity of the graphite of the pencil lead.

4. Measure the resistance and linear dimensions of a pencil line drawn onto a sheet of paper (the line will probably need to be a rectangle, 0.5 cm wide by 15 cm long approximately, in order to give a measurable result).

5. Hence calculate the thickness of the graphite layer. Show your reasoning carefully.

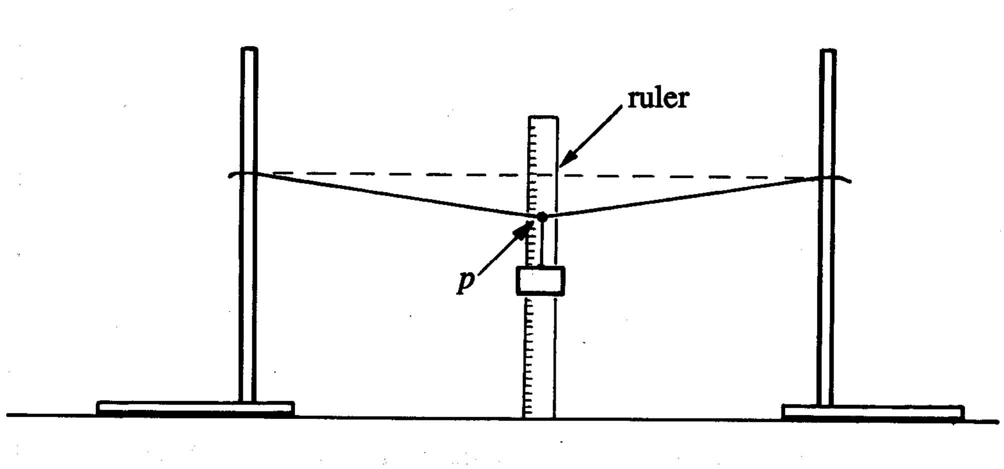
6. You could go on to measure the resistances of different pencil line shapes and assess the viability of the method.

REF 8/1999

1.24 Sagging wire ammeter

KEYWORDS
Resistance; Joule heating; linear expansivity; current

AIM
This experiment is about the possible use of a suspended wire under tension to measure current.



PROCEDURE

1. Close switch S and use the rheostat R to vary the current in the wire. Describe and explain what happens to the hanging mass.

2. Take a series of readings of the deflection (from original position) of the wire on the scale as you vary the current, recording them in a table (you could take readings every 0.3 A up to 1.5 A). ***The wire will be HOT!***

3. Plot a graph of the results and use it to discuss the following:

- What is the relationship between the deflection of the wire and the current?
- What effect do the conditions in the laboratory (eg temperature, proximity to windows) have?
- What would be the system's response to ac?

REF: 5/1995

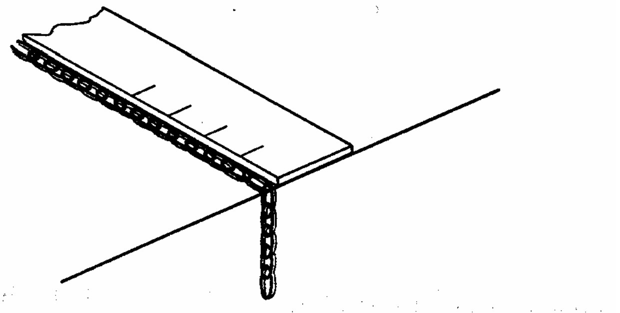
1.25 Sliding Chain

KEYWORDS

Net force; acceleration; weight; static friction; dynamic friction.

AIM

This question is about a body under the influence of changing forces.



PROCEDURE

1. Place the metre rule flat on the bench. Ensure that it is perpendicular to the edge of the bench with the 0cm mark in line with the edge.

2. Stretch out the chain parallel to the edge of the bench as in the diagram. The chain should be stationary.

3. Move the chain to find the minimum length l_1 that can stay on the bench before the whole chain begins to slip.

4. The coefficient of static friction is given by,

$$\mu = (l_o - l_1) / l_1$$

6. Show that this equation is correct and use it to calculate a value for μ in this case.

7. Now disturb the chain slightly so that it begins to slide off the bench. Sketch a graph showing how you think the speed varies with time. Label the point which represents the moment when the chain completely leaves the bench.

8. Justify the main features of your graph in terms of the forces that are acting.

9. You could go on to try chains with a different mass per unit length or the effect of suspending mass from the end of the chain.

REF 2/1989

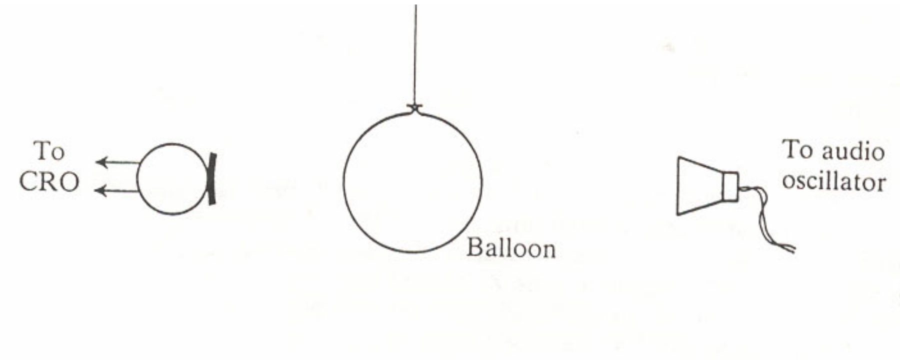
1.26 Sound waves through CO_2 Gas

KEYWORDS

Speed of sound; refraction; wavefronts.

AIM

This investigation concerns the effect of a sphere of carbon dioxide gas on the transmission of sound waves.



PROCEDURE

1. It is advisable to position the apparatus well away from walls to avoid problems with reflections. The balloon should be filled with carbon dioxide gas from a cylinder or sparklet bulb.

2. Slowly move the balloon horizontally across a plane between the loudspeaker and the microphone, recoding the CRO values at different positions.

3. Plot a graph of CRO trace amplitude against position of balloon.

4. How can the observed pattern be explained?

5. By considering the speed of sound in air, in carbon dioxide and in other gases, what results might be expected for other gases?

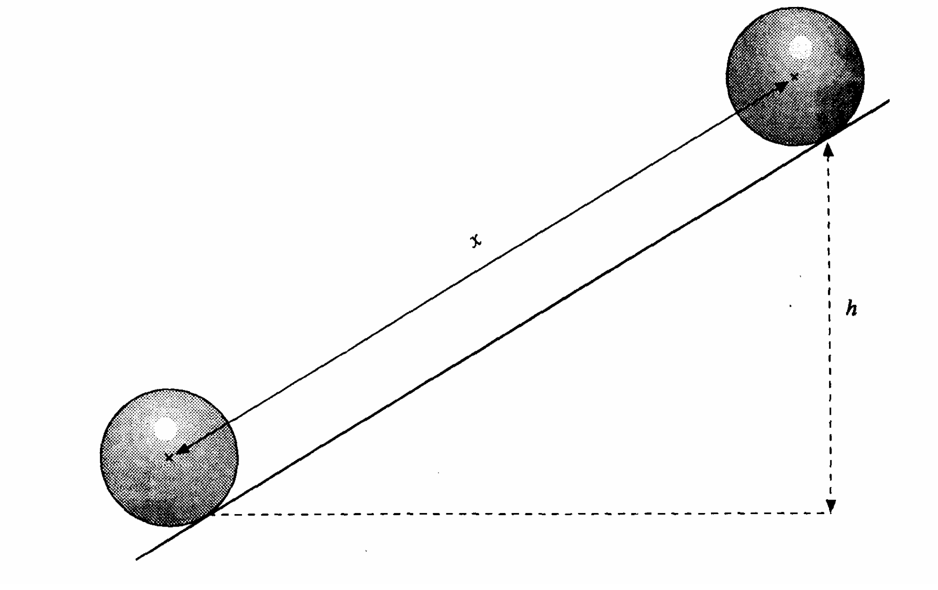
6. Does the pitch of the sound make a difference to the pattern?

REF: 7/1987

1.27 Speed of a Rolling Ball

KEYWORDS
Potential energy; kinetic energy; speed; average speed; moment of inertia.

AIM
To investigate how the gain in speed of a rolling ball-bearing depends on the height of a ramp.



PROCEDURE

1. Place the steel ball at the top of the slope, against the nail, and let it run freely down the slope. Measure the time taken, t, using an electronic timer if possible.

2. Continue by taking readings for slope heights of 10,15 and 20 cm.

slope height *h***/cm**	**time taken,** *t***/s**	**average speed/m s^{-1}**	**final speed** *v***/m s^{-1}**
5			
10			
15			
20			

3. For each height, h, explain why you might expect the final speed to be twice the average speed.

4. Complete the final column of the table.

5. It is suggested that the final speed, v, and the height of the slope, h, are related by the formula:

$$v^2 = k\,h$$

where k is a constant.

Propose and carry out a test to check this.

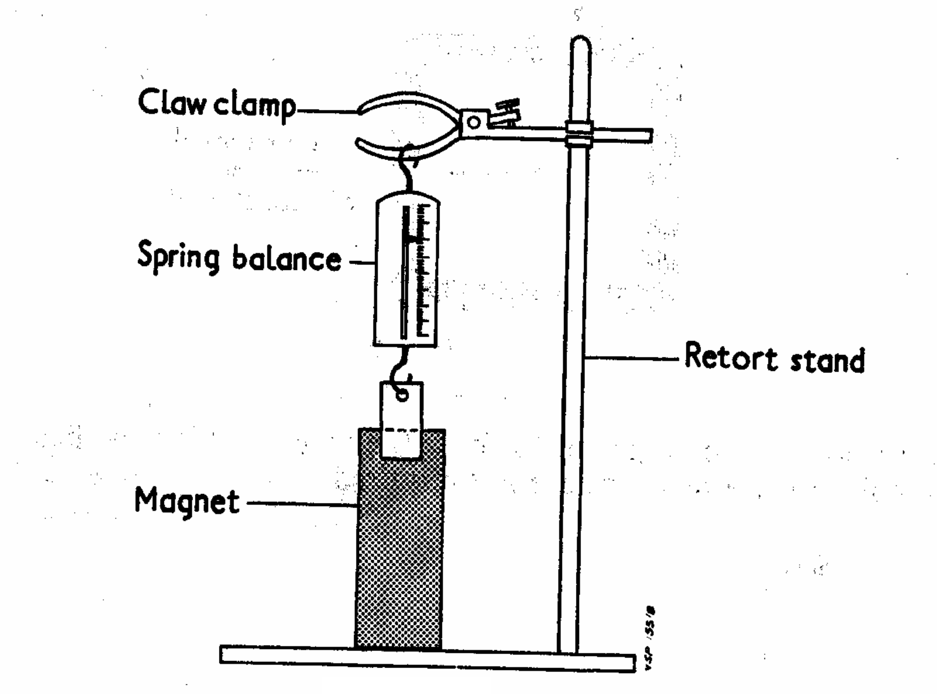
6. The effect of mass can be investigated by using different lengths of cylinder instead of ball-bearings

REF: 4/1996

1.28 Thickness measurements using magnets

KEYWORDS
Magnetism; force; magnetic field strength; interpolation; extrapolation

AIM
In this investigation you can explore a possible non-destructive method of measuring the thickness of a film covering a flat steel surface.



PROCEDURE

1. Measure the force required to pull the magnet vertically upwards away from the base of the retort stand. Use the screw of the clamp to raise the spring balance whilst watching the scale.

2. Repeat step 1, but with an increasing number of sheets of paper between the magnet and retort stand base.

3. Plot a graph of your results. What conclusions can you draw?

4. Outline the problems of using this method for measuring the thickness of films which are much thinner than the pieces of paper provided e.g. paint films.

5. Suggest how one of these problems might be solved.

6. You could go on to look at the possibilities of using an electromagnet in the same way.

REF: 5/1983

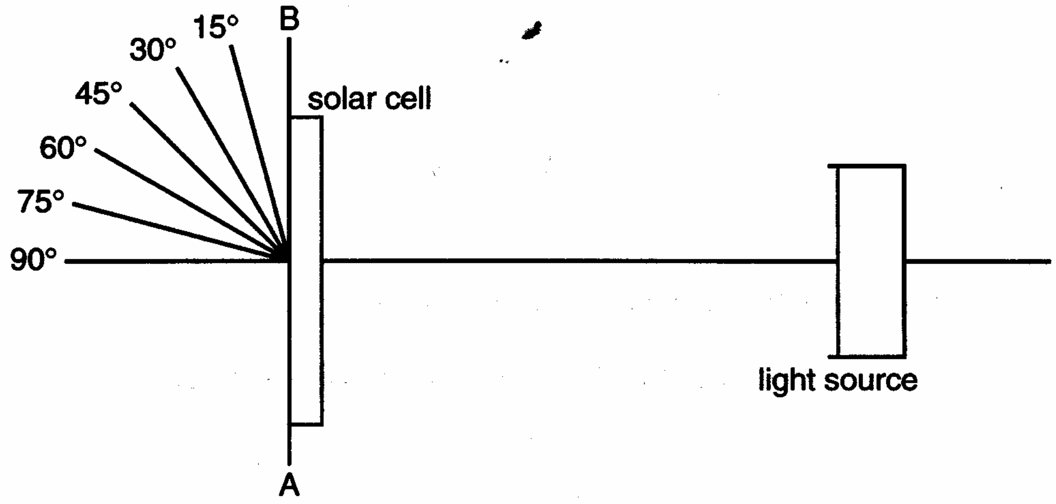
1.29 Using Solar Cells

KEYWORDS

Solar cell; intensity; vector components; photons; maximum power theorem.

AIM

In this experiment you can investigate an electrical property of a solar cell.



PROCEDURE

1. Place the solar cell square on to the light source (ie along line AB in the diagram) and measure the voltage indicated by the meter. Record the value.

2. Rotate the solar cell to 15° and record the new value of the voltage. Repeat for all angles in 15° steps up to 90° and record in a table.

3. Plot a graph of voltage against angle.

4. Why does the voltage generated by the solar cell vary with angle?

5. How should solar cells like these be positioned in normal use in order to give maximum energy output throughout the day?

6. You could go on to investigate selected wavelengths of light using filters.

7. Also, what are the implications regarding loading as the angle of incidence varies? The maximum power theorem will be useful here.

REF: 5/1999

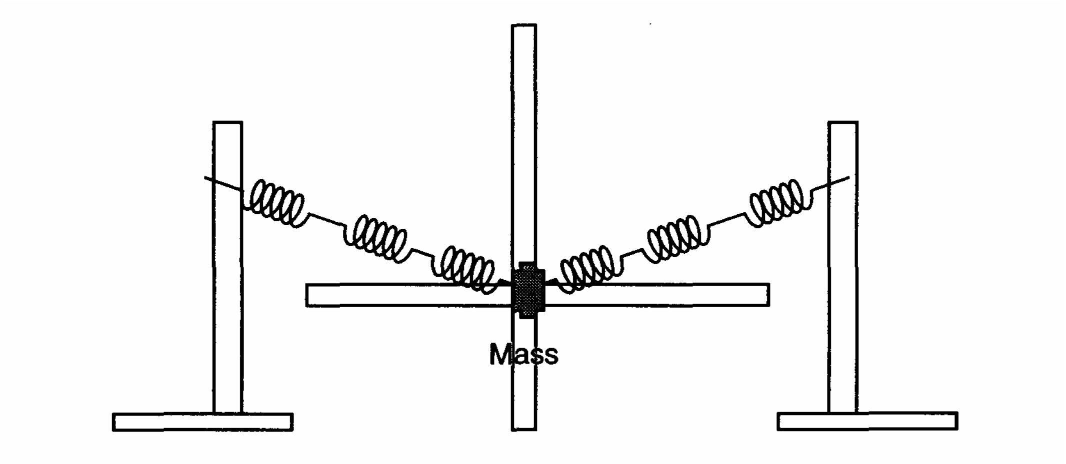
1.30 Vertical oscillating mass

KEYWORDS

Simple harmonic motion; vectors; restoring force; Hooke's law;

AIM

In this investigation you can study the oscillations of a small mass suspended by springs.

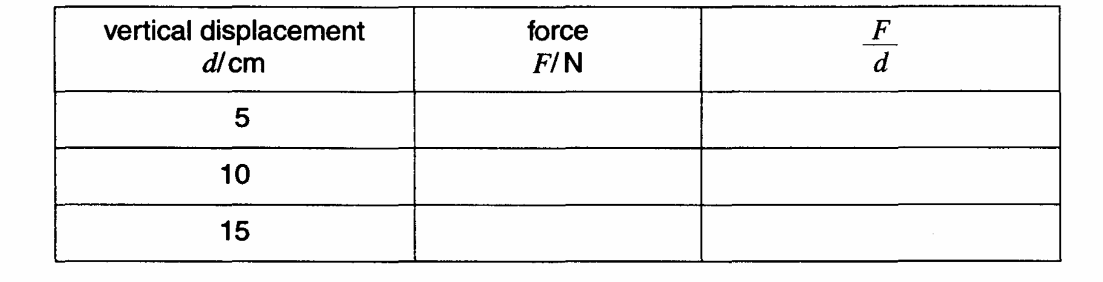


PROCEDURE

1. Displace the mass vertically through a small distance and release it. Observe its subsequent motion carefully. (The mass could be a large steel nut, the motion of which is guided vertically along a retort stand rod.)

2. Draw arrows on a copy of the diagram representing the forces acting on the mass when displaced as shown.

3. Use the newton meter to obtain values for the restoring force, F, for the different vertical displacements, d shown in the table.



vertical displacement d/cm	force F/N	$\frac{F}{d}$
5		
10		
15		

4. Complete the third column of the table by calculating the ratio F:d.

5. It is suggested that the oscillations you have observed are simple harmonic. Use your results to test this suggestion.

6. It is suggested that when the mass is given a small horizontal displacement in the line of the springs, it will oscillate with the same period as for the vertical oscillations.

7. Use the newton meter to make suitable measurements to test this suggestion.

8. How does tension affect the results?

REF: 7/1999

Section 2

Brief descriptions of problems are given in this section, again with keywords and source references. These are intended to act as seeds of ideas for students.

2.1 Using an RC circuit as an accelerometer

2.2 Loading a model forearm

2.3 Extension of polythene

2.4 Efficiency of a motor as a generator

2.5 Conduction by an Electrolyte

2.6 Jumping springs

2.7 Contact time of a hard bounce

2.8 Toppling bottles

2.9 Thixotropic materials

2.10 “Active” resistance

2.11 Using permeance to control current

2.1 Using an RC circuit as an accelerometer

Keywords: exponential decay; time constant; impulse; acceleration; momentum

A low-friction rotary potentiometer (100 kΩ) is used with a 10V, 10mF electrolytic capacitor to produce a standard RC circuit. A small rigid pendulum hangs from the rotary potentiometer. The circuit is then mounted onto a trolley; as the trolley rolls down a constant slope, the subsequent deflection of the pendulum alters R which in turn affects the rate at which the capacitor charges. It can be sued to investigate the rate at which the trolley decelerates on impact with a buffer at the end of the slope.

Ref: 2001/2

2.2 Loading a model forearm

Keywords: moments; Hooke's Law

The model is made using two hinged (using a nut and bolt) tongue depressors and a standard expendable spring (the "biceps"). The upper section ("humerus") is clamped at an angle to the vertical such that the lower section ("radius/ulna") is horizontal. Students can then load the lower section and investigate how this affects the extension. The effect of the positions of the points of attachment of the spring can also be investigated.

Ref: 2001/4

2.3 Extension of polythene

Keywords: stress; strain; plastic; yield; creep

Strips of polythene are clamped at one end and stretched using a newton-meter attached to the other end (the set-up is vertical and the closing of a retort stand clamp is used to increase the tension). The stress/strain or force/extension curves are interesting and moreover there is significant increase in extension with no increase in stress which can be investigated.

Ref: 5/2001

2.4 Efficiency of a motor as a generator

Keywords: conservation of energy; electromagnetic induction; moments; moment of inertia

An electric motor driven by a falling load acts as a generator. The efficiency can be investigated as can the effects of changing the spindle size.

Ref: 7/2001

2.5 Conduction by an Electrolyte

Keywords: current; ions; electrodes; transport equation

Two electrodes are placed on either side of a glass beaker into which a steady stream of a suitable electrolyte (e.g. copper sulphate) flows (from a burette, for instance). The electrodes form part of a simple "conductivity circuit" (i.e. milliammeter, battery and switch) and the current will vary as the depth of the electrolyte increases. But how does it vary? Further areas of investigation include the effects of the electrode separation, the electrode surface areas, electrode shapes, electrolyte concentration, temperature and the use of ac.

Ref: 3/1988

2.6 Jumping springs

Keywords: strain energy; potential energy; Hooke's law; coefficient of restitution; impulse.

A standard compression spring fits snugly onto a standard retort stand, onto which a simple scale can be drawn. By compressing the spring by different amounts onto the base and then releasing, different jump heights can be obtained. How does the height depend upon the amount of compression? What difference does the base material make? What is the bounce height when the spring is released from different heights?

Ref: 6/1998

2.7 Contact time of a hard bounce

Keywords: capacitor charge; exponential rise; coefficient of restitution; impulse

An RC circuit can be used to establish the amount of time for which a rod is in contact with a metal block off which it bounces: the contact acts as a make to start/ break to finish switch. How good is this method? Does the contact time vary with the release height of the rod? Does the base block make a difference (tin foil on wood, sponge, etc could be used as the base)?

Ref: 1/1996

2.8 Toppling bottles

Keywords: centre of gravity; moments; stability

The angle at which a plastic bottle (the square-sectioned squash bottles are recommended) topples is established for different depths of water in the bottle. Are the same results obtained when sand is used rather than water? What if a mixture is used?

Ref: 2/1995

2.9 Thixotropic materials

Keywords: viscosity; shear stress

The drag force experienced for different stirring speeds is investigated using a water/custard powder mixture and non-drip paint. Means of quantifying the shear rate can be established and used to produce a quantitative result for the shear rate versus drag force investigation. Does temperature have an effect? How does the effect change with the water/custard powder mix?

Ref: 7/1995

2.10 “Active “ resistance

Keywords: alternating current; self induction; back emf; impedance

The “ac resistance” (impedance) of a coil changes according to the frequency of the current passing through it. Part of this investigation involves choosing the correct apparatus to study this effect.

Ref: 7/1993

2.11 Using permeance to control current

Keywords: permeance; reluctance; back emf; Lenz’s Law; domains

When an iron bar is passed into a coil of wire (e.g. 1100 turns) which forms part of a simple ac “torch” circuit, the brightness of the lamp changes. Why is this? How does the current change with the position of the bar? How viable is this method as a means of controlling current?

Ref: 4/1982

2.12 Slip of a sloping board

Keywords: centre of gravity; coefficient of friction; vectors

When board placed flat on a surface is lifted up at one end, at a certain angle it will slip. What determines this angle? What if the table surface is itself on a slope? Does the speed at which the board is lifted matter? What are the mechanics involved?

Ref: 6/1987

Section 3

This is simply a list of suggested titles or topic areas. Some are specific questions whilst others are much more vague, deliberately. Rather than keywords this time, we have attempted to identify the relevant chapters on which a typical investigation might be based.

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Investigation	Chapters
1. Mechanical properties of jelly	4,5
2. Propeller efficiency	8,9
3. Motion of particles in fluids	13,14
4. Bubbles in gels	13
5. Standing waves in vertical streams of water	6
6. The string telephone	6
7. Energy transfer (coupled) pendula	10
8. Oscillations in liquids	10
9. Sails	8,9
10. Diffusion and perfusion	13,14
11. Fluid flow in pipes and heat transfer	10
12. Speed of sound at reduced pressures	6,13
13. Catapults	4,5,8,9
14. Ascent of burning paper (SAFETY!)	13
15. Descent of burning plastic (SAFETY!)	4,5,14
16. Electromagnetic propulsion	15
17. Jet propulsion	8,9
18. Mechanics of particulate solids	4,5
19. Fuses	2
20. Elastic pendulum	5,10
21. Jointed pendulum	10
22. Drops into water	4,5
23. Friction between paper	8,9
24. Restitution	4,5,8,9
25. Fluid viscosity	8,9,14
26. Rijke's tube	6,10
27. Corona discharges	13 - 17

28. 2-D waves	6,10
29. Attraction of charged liquids	16
30. Air resistance on water jets	8,9
31. Electromagnetic propulsion	15
32. Flames in electric fields	16
33. Water wheels	8,9
34. Car safety belts	8,9
35. Jumping disc (Lenz's law)	15
36. Stepper motors	15
37. Flash duration	2
38. Pop-cups and spring-loaded leaping toys	4,5,8,9
39. Refraction in alcohols	6
40. Gyroscopes	8,9
41. Strain gauges	2,5
42. Surface tension	5
43. Current-bearing sonometer	2,6,15
44. Resonance in pipes	6
45. Hydrogen gas fuel cells	2
46. Mutual inductive coupling	15
47. Cooling of liquids	10,13
48. Whirlpools	8,9
49. Coefficient of restitution	4,5,8,9
50. Optical fibre properties	3,4,5
51. Electrical conduction of flames	2,14
52. Creep in copper wire	4,5
53. Pressure/volume of a balloon	13
54. Extension of a whirling spring	4,5,10
55. Stroboscopic photography	1,3
56. Wire resistance and strain	2,4,5
57. Wire resistance and temperature	2,4,5,14
58. Electrical conductivity of heated glass (SAFETY!)	2,13,14
59. AC and electrolytes	2,16
60. Flow of water from a punctured tank	4,5,10
61. Noise	2,3,6
62. Factors affecting the speed of sound in solids	6,13
63. Deflection of alpha and beta particles	16,18
64. Physics of resistive motion	8,9
65. Standing waves in pipes	6
66. Streamlines	8,9
67. Solar panel characteristics	2
68. Resonance in model buildings	4,5,10
69. Acoustic properties of a violin	6,10

70. Sound propogation through glass	4,5,6
71. Newton’s law of cooling	10,13
72. Hydraulic pumps	8,9,13
73. EMFs in rotating discs	15
74. Freezing ice	13,14
75. Shapes of arches	4,5,8,9
76. Optical absorption spectra	6,7,17
77. Resonance in a trombone	6,10
78. Microwave absorption by solids and/or fluids	4,5,6,10
79. Aerodynamic drag	8,9
80. Test tube deterioration	4,5,14
81. Mechanics of clay	4,5
82. Rotational dynamics of a hen’s egg	8,9
83. Loudspeaker properties	2,6
84. Viscous flow of golden syrup	4,5,14
85. Cornflour in water	13,14
86. Light intensity and power of lamps	2,6,7,10
87. Electrophoresis	16
88. Helmholtz coils	15
89. Suspension bridges	4,5,8,9
90. Spinning tops	8,9
91. Evaporation of water	14
92. Regelation of ice	14
93. Sound reflection and absorption	6
94. Frequencies and bells	3,6
95. Balloon buoyancy	8,9,13
96. The centre of percussion	8,9
97. Spectra and light-bulb efficiency	2,17
98. Fluorescence	17
99. Perception of colour	6
100. Soundproofing	4,5,6
101. Surface tension	13
102. Projectiles	8,9
103. Torsional oscillations	10
104. Air rifle pellet impacts	4,5,8,9
105. Piezo electricity	2
106. Refractive index of ice	3,6
107. Playground surfaces and impulses	4,5
108. Hysteresis and rubber	4,5
109. Cricket ball swing: the Magnus effect	8,9
110. Double refraction	3,6
111. Albedo	6

112. Speed by microwaves and Doppler Shift	6
113. Boats and drag	8,9
114. Accelerometers	2,8,9
115. Parachutes	8,9
116. Reaction times of thermistors	2,14
117. The dynamics of rising bubbles in fluid columns	8,9
118. Stokes's Law	8,9
119. Forces in air jets	8,9
120. Whirlpools	8,9
121. Beats	7,10
122. Soap films	6
123. Impact deformation	4,5
124. A car alternator	15
125. Collapsing soap films	4,5,6
126. Skin electric potentials	2
127. Acoustic feedback	2
128. Properties of antennae	15
129. Lift coefficient of aerofoils	8,9
130. Absorption of liquids by filter papers	13
131. Characteristics of a dc motor	15
132. Impact of squash balls	4,5,8,9
133. Creep in plastics	4,5
134. The acoustics of drones and didgeridoos	6
135. Bounce in relay contacts	2,10
136. Crooke's radiometer	6,7,13,14
137. Strength of hair	4,5
138. Siphoning of water	8,9
139. Strength of paper strips	4,5
140. Tensile properties of cling film	4,5
141. Dielectrics	15
142. The dynamics of a yo-yo	8,9
143. Opacity of a frothy drink	2,4,5,10
144. Shadows cast by objects	6
145. Microwave cooking	10
146. Water rockets	8,9,13
147 The wind chill factor	10, 13, 14
148. Heat pumps	12,13
149. Effectiveness of sun-block cream	5,6,718
150. Photoelectric effect	7,16
151. DC in transformers	14
152. Coupled resonant LCR circuits	14
153. Electrical conduction of air	2,13,14,16

154. Power consumption of lights	2
155. Efficiency of a transformer	14
156. Blood flow in a model kidney glomerulus	2
157. Reluctance	14
158. Reflections of light from ripples	6
159. The flow of "Silly Putty"	4,5,9,10,14
160. Hitting golf balls	8,9
161. Resonance in solid plates	6,10
162. Lissajou's figures	10
163. Range of alpha particles in air of reduced pressure	10, 18
164. Glockenspiel bars	6,10
165. Temperature variation of the Speed of Sound	6, 13
166. Resonance in spring/pendulum system	10
167. Spinning discs	8,9
168. Kynor film	4,5
169. Deflection of cantilevers	4,5,8,9
170. Speed of sound in gases	6,13
171.Time periods of bouncing balls	4,5,8,9, 10
172. Air pressure round spinning golf balls	8,9
173. Dimensions of endothermic animals	13
174. Optical activity	4,5,6
175. Movement of aqueous ions in perpendicular E and B fields	2,15
176. Quantitative work hardening	4,5
177. Hysteresis in ferromagnetic material	14
178. Polar liquids in E fields	15
179. Work done to light a match	8,9,13
180. Breaking up of liquid column from tap	8,9
181. Efficiency of heating water	13
182. The attracted disc electrometer	16
183. Bounce of a tennis racquet	4,5,8,9
184. Yagi aerials	14
185. LDR characteristics	2
186. Detailed study of Leslie's cube	6,7,13,14
187. Dart flight	8,9
188. Flow of water over a dam	8,9
189. Transmission/scattering of light through water	4,5,6
190. Mechanical or acoustic resonance of chimneys	6,10
191. Heat exchangers	13
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