華僑中學

HWA CHONG

INSTITUTION

C2 H2 PHYSICS

PLANNING QUESTION REVISION PACKAGE 2019

BOOK B

Planning Question

Suggested Mark Schemes

& Solutions

Produced by HCI Physics Unit

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PLANNING QUESTION COMPILATION (By Topics)

A. MECHANICS

01 UCLES 2004 Nov P5 Q1 Range of Projectile Motion

The range of a projectile depends on many factors, such as the velocity v and angle θ of projection, air resistance and the shape of the projectile.

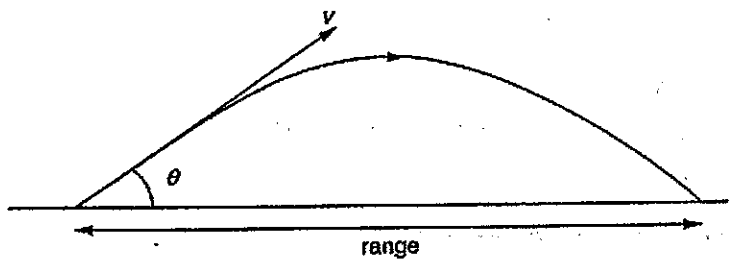


Fig. 1.1

In some situations it is important to maximise the range by using a particular angle of projection. This is important in competitions such as throwing the javelin and putting the shot.

Design a laboratory experiment to investigate how the range of a projectile depends upon the angle of projection. You should draw a diagram showing how the equipment would be arranged. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the method of projection of the projectile,

(c) how the range and angle of projection would be measured,

(d) the control of variables,

(e) any safety precautions you would take,

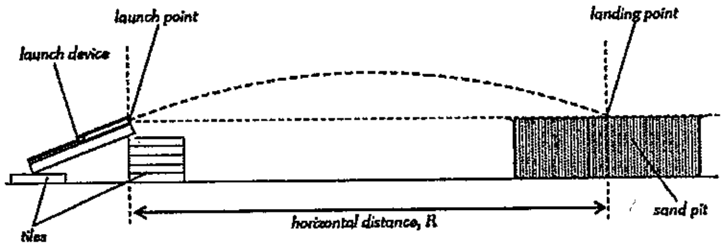
(f) any precautions that you would take to improve the accuracy of the experiment.

Suggested Mark Scheme

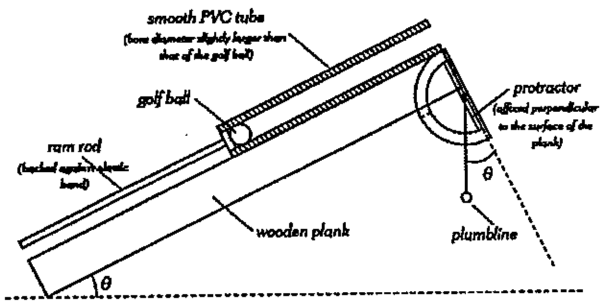
	Marks	Marking Points
Diagram	1	• Clear, workable labeled diagram showing a method of projection onto a horizontal surface.
Variables	4	• Workable method to launch projectile at measurable projection angles (reject dropping a weight onto one side of a pivoted beam that contains the projective on the other side, reject human thrower). • Method to measure projection angle; e.g. a big protractor or trigonometric calculation. • Measure horizontal range with a statement of the instrument to be used (e.g. measuring tape). • Vary angle of projection, measure horizontal range. Change angle of projection and repeat for $\geq$ 8 more iteration.
Analysis	2	• Hypothesize $R = k\theta^n$. Linearize: $\lg R = n \lg \theta + \lg k$. • Plot $\lg R$ vs $\lg \theta$. Relation is verified if a straight line graph is obtained. Where gradient: n; y-intercept: $\lg k$
Reliability	max. 4	• Workable launch method that keeps launch speed constant. • Preliminary test to determine where the projectile lands. • Repeat measurement for each angle and take average to reduce random errors. • Steps to improve accuracy of angle of projection; e.g. use of plumb line, trigonometric calculation. • Suitable surface for projectile to land on, e.g. carbon paper, plasticine, sand pit, or a painted projectile that leaves a mark on the landing surface. • Correct labeling of the range in the diagram. This mark is often lost because many answers show range starting from resting position rather than from the position where projectile becomes air borne.
safety	1	Any relevant safety precaution pertaining to the risk of projectile, e.g.: • Set up barrier around the setup area so that no one gets hit/injured by the flying objects.

Suggested Solution

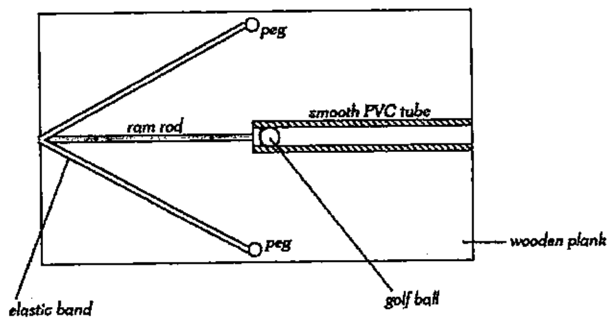
Diagram



Set up



side view of launch device



top view of launch device

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Procedure

1. *Set up the apparatus as shown.*
2. *Wedge tiles under the launch device to arrange for angle of projection of about 5°.*
3. *Use the protractor and plumbline as reference to record the angle of projection ϑ.*
4. *Insert a golf ball into the launch device, pull back the ram rod to stretch the elastic band, and release. Identical, if not the same golf ball(s), should be used for every projectile to make sure the mass of projectile, among other things, are kept constant. Care should be taken to ensure the elastic band is stretched by the same amount for every launch.*
5. *See that the golf ball lands and makes a depression in the sand pit.*
6. *Use a measuring tape to measure the horizontal range R, measured to be the distance between the launch point and the landing point.*
7. *Repeat step 5 so that a more reliable value of R can be obtained by averaging (reduce random errors).*
8. *Repeat steps 2 - 6 for 7 other values of ϑ, in increments of about 5°, until ϑ is about 85°.*
9. *Hypothesize $R = k\vartheta^n$. $\lg R = n \lg \vartheta + \lg k$. Plot $\lg R$ vs $\lg \vartheta$. Relation is valid if straight line is obtained where gradient: n; y-intercept: lg k.*

Safety Precaution

10. *Ensure everybody stands behind the projection device during each launch so as to prevent anyone getting hit and injured by the projectile.*

Additional Details

11. *Certainly some trial and error is needed to find an elastic band of suitable tension, and in positioning the sand pit to catch the golf ball's landing.*
12. *The vertical height of the launch point can be adjusted (using tiles), together with the height of the sand pit, so that launch point and landing points are at about the same vertical height to minimize error.*

Notes by Editor

- *Other designs of launch device to ensure constant launch speed, possibly involving springs or ramps, are certainly acceptable.*
- *Other possible ways to mark the landing point are to use plasticine, or painting the projectile for it to make a marking when it lands on paper or concrete floor.*

02 UCLES 2003 Nov P5 Q2 Efficiency of a Bow

Fig. 2.1 illustrates a bow used in archery competitions.

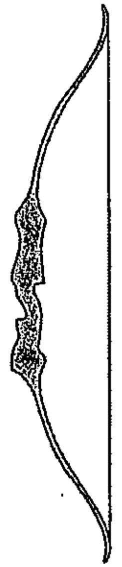


Fig. 2.1

A designer of bows is attempting to maximise the efficiency of his bow. This means that as much of the potential energy stored in the bow as possible is converted to the kinetic energy of an arrow. Some preliminary experiments are carried out with the bow when the centre of the string is moved through a distance x by a force F as shown in Fig. 2.2.

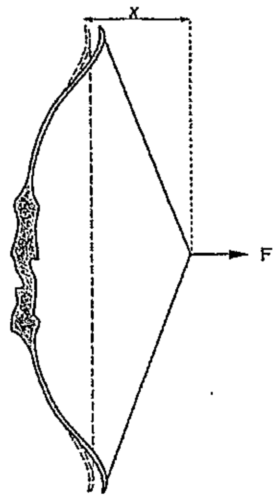


Fig. 2.2

These experiments indicate that x is not proportional to F.

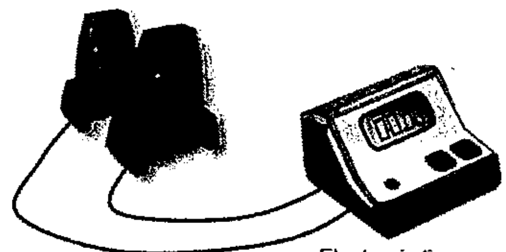
The efficiency of the bow may be defined as

$$\text{efficiency} = \frac{\text{kinetic energy of an arrow}}{\text{potential energy of the bow}}$$

Design a laboratory experiment to investigate how the efficiency varies with the distance x moved by the centre of the string.

In addition to standard equipment found in a physics laboratory, you are provided with

- Archer's bow and arrow
- A electronic timer activated by two upward facing light sensors. The timer is started and stopped by dips in light intensity in the first and second light sensor respectively.



Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	• Clear, workable labeled diagram showing metre rule measuring *x* correctly
Variables	4	• PE of Bow - Vary *x* (or *F*), measure *x* and *F* - Repeat above steps (e.g. for ≥ 8 more iteration) • KE of Arrow - Vary *x*, measure *v* - Repeat above steps (e.g. for ≥ 8 more iteration) • Method of measuring *F* e.g. using newton-meter, or using standard masses and calculating *F=mg* • Shooting the arrow above the 2 light sensors, and obtaining *v* from dividing distance between light sensors with electronic timer reading
Analysis	2	• Plotting the *F-x* graph and obtaining PE from area under graph • Obtaining KE from ½mv², *m* measured using a weighing balance
Reliability	max. 4	• Steps to make sure distances are constant between the light sensors are e.g. marking initial positions, or placing along a metre rule • Steps to make sure arrow's flight is directly above the light sensor e.g. aligning using a rope, laser pointer • Repeat experiment with arrows of same type and determine an average • Bow clamped firmly and stably with the right alignment • Methods to make sure stretching of bow is perpendicular to bow, e.g. spirit levels and set squares • Methods to guide the archer's aim, e.g. bull's eye, guiding sticks • Preliminary trial to make sure the arrow's shadow triggers the light sensors, e.g. adjusting the vertical height of the sensors, or if indoor, adjust the lighting, or simply adjusting the trigger threshold assuming it is adjustable • Details in calculating the area under F-x graph, e.g. best fit curve, smaller increments in x in regions when F is changing rapidly • Keep the distance between light sensors constant
safety	1	• Any relevant safety precaution, e.g.: • A target board to stop the arrows from hurting people during its flight • Fencing off the area to prevent people from getting hit by arrow in flight

Suggested Solution

Diagram

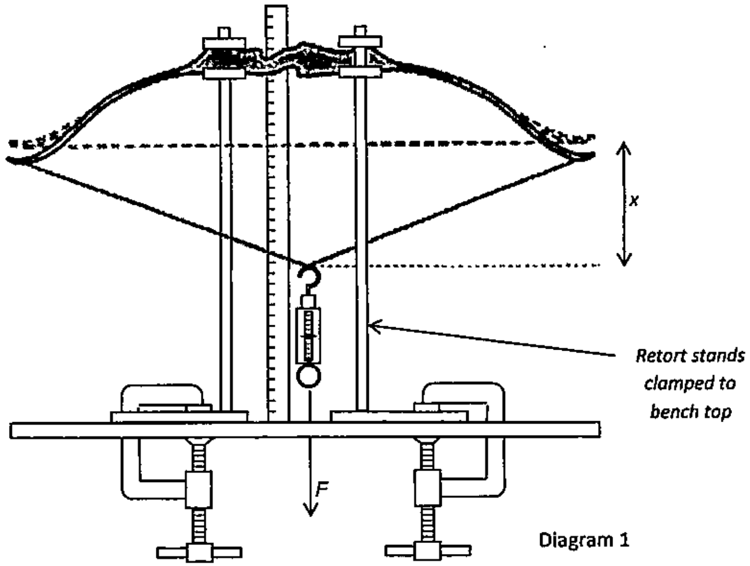


Diagram 1

Procedure

Obtaining the PE of bow (refer to Diagram 1)

1. *Clamp the bow horizontally.*
2. *Position a metre rule vertically right behind the bow.*
3. *Use a spirit level to make sure the bow is clamped horizontally and the metre rule is vertical.*
4. *Record the metre rule reading h_0.*
5. *Pull the bow string downwards with a newtonmeter.*
6. *Record the newton meter reading F and metre rule reading h. Calculate $x = h_0 - h$*
7. *Repeat steps 5 and 6 at every 1 cm interval of x until the full drawn length.*
8. *Plot the F-x graph.*

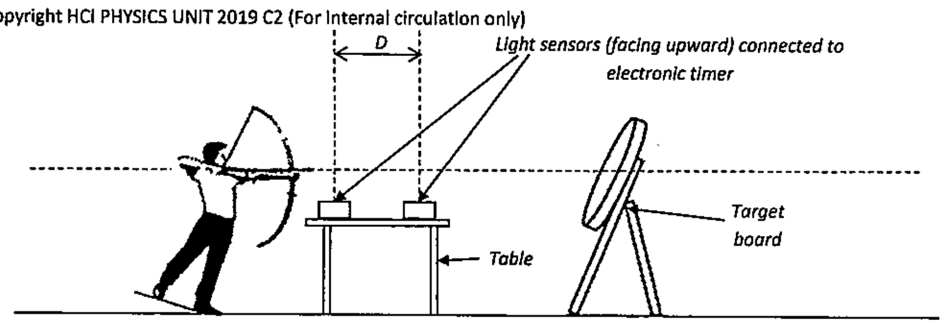


Diagram 2

Obtaining the KE of arrow (refer to Diagram 2)

1. Make markings for the position of the light sensors on the table, the table and the foot of the archer. This is to keep their relative positions constant. Measure D, the distance between the two light sensors using a metre rule.
2. Trial shoot an arrow to make sure its shadow triggers the electronic timer. Raise the height of the table, or position a strong light source above the sensors if necessary.
3. Use a weighing balance to measure the mass m of the arrow.
4. Use a marker to mark off 1 cm intervals along the shaft of the arrow.
5. With the help of markings on the arrow, draw the bow to x = 5.0 cm.
6. Use a rope to help align the archer, light sensors and centre of target board in a straight line.
7. Shoot the arrow horizontally and make sure it passes right above both the light sensors.
8. Read the time interval T as recorded by the electronic timer.
9. Repeat steps 3 to 7 2 more times, so that T can be averaged for reliability.
10. Repeat steps 3 to 8 at every 5 cm increment of x until the drawn length.
11. Calculate speed of arrow using $v = \frac{D}{T}$
12. Calculate KE of arrow using $KE = \frac{1}{2}mv^2$
13. Calculate PE of arrow using area under the F-x graph between x = 0 to the x value.
14. Calculate the efficiency using $\eta = KE \div PE$
15. Plot a graph of η against x.
16. The same type of arrows should be used throughout the experiment. Reject arrows whose mass is different from the mean value by more than 2%.
17. The distance between the light sensors is kept constant by fastening them to a half-metre rule.

Safety Precautions

18. Position a large target board to catch the arrow.
19. Fence off the firing range so that no passerby accidentally enters in the line of fire.

Further measures to improve accuracy

20. A pair of vertical sticks about 10 cm apart (made of thin flexible plastic) can be positioned on both sides of each light sensor to guide the archer's aim. Arrows that did not fly in between the sticks should be rejected since they would not have passed right above the light sensors.

03 CIE 2010 Nov P5 Q1 Hammering Nail

A hammer is often used to force a nail into wood. The faster the hammer moves, the deeper the nail moves into the wood.

This can be represented in a laboratory by a mass falling vertically onto a nail.

It is suggested that the depth d of the nail in the wood (see Fig. 1.1) is related to the velocity v of the mass at the instant it hits the nail by the equation

$$d = kv^n$$

where k and n are constants.

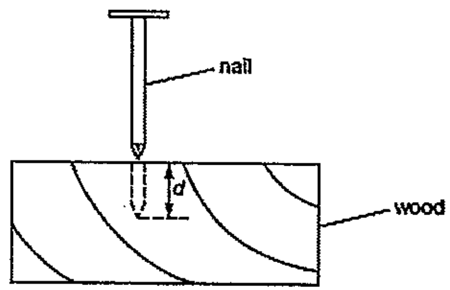


Fig. 1.1

Design a laboratory experiment to investigate the relationship between v and d so as to determine a value for n. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken.

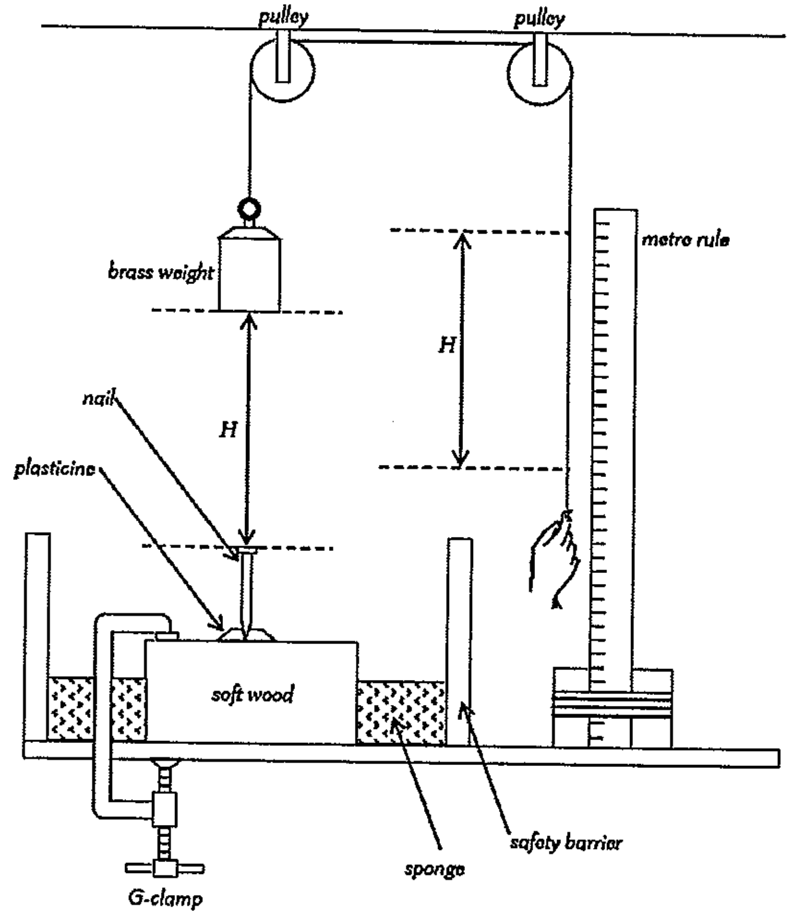
[15]

Suggested Mark Scheme

[illegible]	Marks	Marking Points
Diagram	1	• Clear, workable labeled diagram showing a mass falling on centre of nail
Variables	4	• Change height of falling mass to change v • Measurements to allow v to be determined, e.g. measure height fallen; light gates connected to electronic timer/data-logger measuring time, ticker tape/motion sensor. Do not accept stopwatch methods. • Measurement to obtain d, e.g. subtracting length of nail left protruding from original length (measure lengths using vernier calipers) <u>OR</u> extracting the nail and using tail end of vernier calipers to measure d. • Vary v, measure d and repeat steps for ≥ 8 more iteration
Analysis	2	• Appropriate equation to determine v, e.g. $v^2 = 2gh$. • Plot a graph of lg d against lg v. $\lg d = n \lg v + \lg k$ Equation is valid if graph obtained is a straight line. n is gradient (and lg k is y-intercept).
Reliability	max. 4	• Method to create a large d, e.g. large falling mass, thin nails, soft wood. • Use of a guide for falling mass or nail • Repeat experiment and determine an average d for each v to reduce random errors • Use different parts of same wooden block for each test • Discussion or preliminary experiment to find appropriate nails, e.g. too thin nails may go totally into the wood; too thick nails may not penetrate cleanly
safety	1	• Any relevant safety precaution. • E.g. Use of sand trays around experimental setup to cushion falling masses to prevent any injury to experimenter's feet

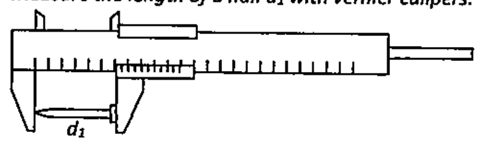
Suggested Solution

Diagram

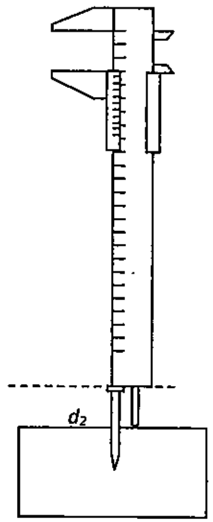


Procedure

1. *Refer to figure above.*
2. *Measure the length of a nail d_1 with vernier calipers.*



3. *Arrange a nail to stand vertically on the softwood with the help of a small lump of plasticine. Nails of the same type should be used for each test.*
4. *Use the pulley to lower the brass weight gently until it just touches the nail. The same weight should be used throughout the experiment.*
5. *Life the weight up by H = 40.0 cm by pulling the string down by 40.0 cm.*
6. *Calculate the velocity* $v = \sqrt{2gH} = \sqrt{2(9.81)H}$
7. *Release the weight.*
8. *Measure the length of the nail still protruding above the softwood* d_2 *using a vernier caliper. (Reject and redo if the nail was not driven vertically into the softwood.)*
9. *Calculate the depth d of the nail in the wood by* $d = d_1 - d_2$.
10. *Replace the nail, and repeat the experiment for the same H. Take average of d to reduce random errors.*
11. *Replace the nail, and repeat the experiment for 7 other values of H, decrementing H by 5.0 cm each time.*
12. *($\lg d = n \lg v + k$) Plot the graph of lg d against lg v. If the equation is valid, a linear trend will be observed, the gradient is n and the y-intercept is lg k.*



Safety Precautions

13. *Sponge is used to cushion the falling/rebounding pieces to prevent any possible injury to experimenter.*
14. *Wear goggles to protect eyes against flying nails.*

Additional Details

15. *Preliminary trial should be done to make sure d values of at least a few cm is obtained. This may require the use of softwood, thin nail or larger mass.*

Notes by Editor

- *Using a stopwatch to time the fall is not acceptable. The time is just too short to be measured reliably by a human operated stopwatch.*
- *Other ways to guide the falling "hammer" or nail are possible.*
- *Marks can be scored by statements such as "use a set square to ensure the nail is vertical" and "use a plumb line to ensure the metre rule is vertical".*

04 CIE 2003 Nov P5 Q2 Atwoods Machine

Modern day lifts in tall buildings are of a relatively simple design. A passenger car is connected to a counterweight by a steel cable which passes over a system of pulleys at the top of the lift shaft, as shown in Fig. 2.1.

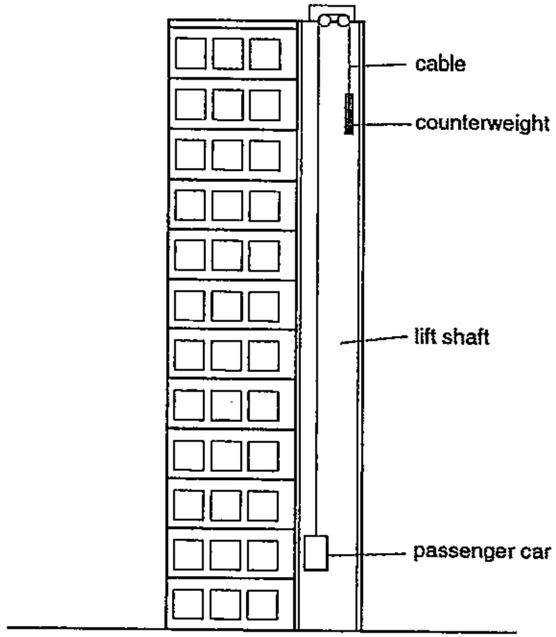


Fig. 2.1

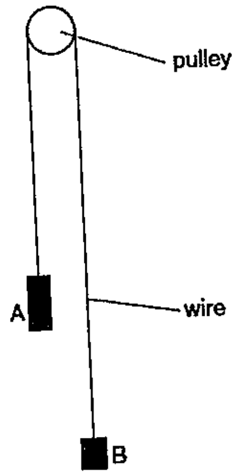


Fig. 2.2

Design a laboratory experiment to investigate how the acceleration of object A depends on the mass m_B of object B when the system is allowed to move freely under the action of gravity. You may assume that m_A is constant throughout and that $m_A > m_B$. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements that would be taken,

(c) how the acceleration of object A would be determined,

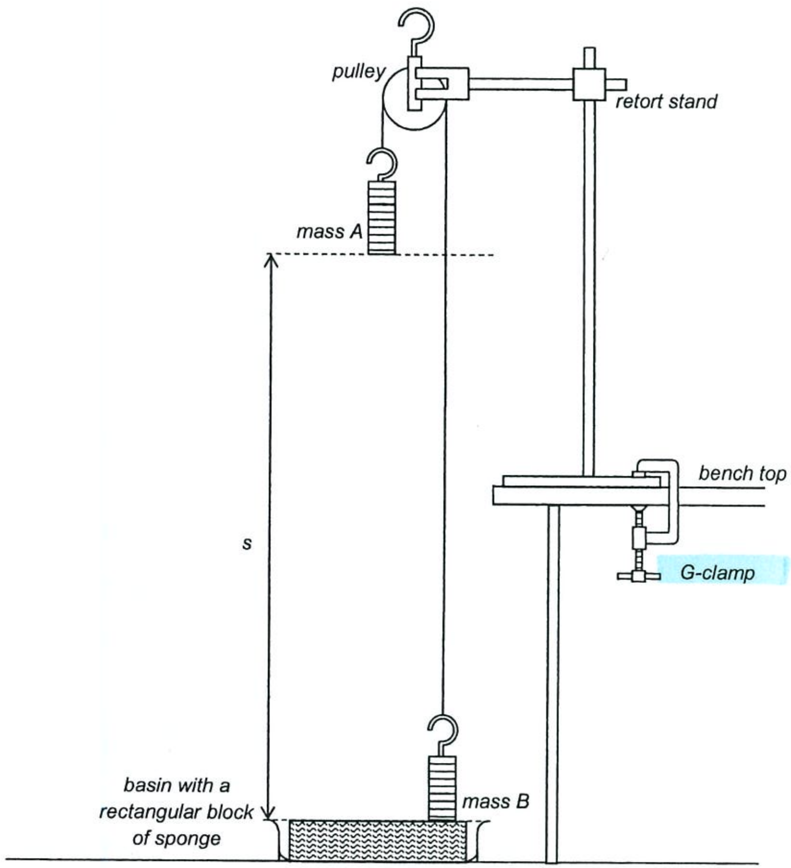
(d) any safety precautions that you would take.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	Clear, workable labelled diagram showing • Falling masses between two markers with pulley at the top properly clamped.
Variables	4	• Measuring M_B, using electronic balance/newtonmeter/calibrations engraved on standard masses • Workable method to measure t, e.g. stopwatch, light gates, ticker tape. • Workable method to obtain s, e.g. using a metre rule. • Change M_B and repeat for ≥ 8 iteration.
Analysis	1	• Use of results to calculate a e.g. using equation $s = \frac{1}{2}at^2$ • Plot graph of a against M_B. [0]
Reliability	max. 5	Any good further design details, some of these might be: • Method to reduce fractional uncertainty in measurements of t, e.g. use of large distances. Could do a preliminary trial to check that time is long enough (many times that of human reaction time; to reduce percentage error to under 1% if a stop watch is used, time should be more than 20 s. Should use light gates if time is too short.) • Method to reduce errors due to friction in pulley, e.g. applying lubricant to axles of pulleys, use of large masses • Using a graphical method (e.g. s-t graph) to find the acceleration for each M_B • For each M_B, repeating and averaging t to obtain more reliable values of a, to reduce random errors • Steps to improve accuracy of s, e.g. using markers for start/end point • Explanation on choice of masses, e.g. larger masses so that the mass of the connecting string/wire can be neglected • Making sure M_B's cross-sectional area remains the same
safety	1	Any relevant safety precaution, e.g: • A bucket of sand to cushion the impact of falling weights • Wear goggles in case the wire breaks/snaps resulting in whiplashes

Suggested Solution

Diagram



Procedure

1. Set up the apparatus as shown. Start with mass A having 9 slotted masses and mass B having 8 slotted masses.
2. With mass B just touching the top edge of the sponge, use a measuring tape to measure the vertical distance s between the top edge of the sponge and the bottom edge of mass A.
3. Record the total mass of mass B as m_B. The mass of each slotted mass and the mass hanger can be read from the calibration engraved on the slotted mass.
4. Release mass B from the top edge of the sponge, and start the stopwatch at the same time.

5. Stop the stopwatch at the instant when the bottom edge of mass A touches the top edge of the sponge.
6. Record the stopwatch reading as time duration t.
7. Repeat steps 4 to 6 for another reading of t. Take average to reduce random error.
8. Since mass A accelerates from rest over time t to travel a displacement of s, $s = \frac{1}{2}at^2$. This implies that a can be calculated by $a = \frac{2s}{t^2}$.
9. Repeat steps 3 to 8 for 7 other values of mass B. (Remove one slotted mass from mass B each time)
10. Plot a graph of a against m_B to study their relationship.

Safety Precautions

11. The retort stand is clamped so that it does not topple (a likely occurrence for such experiment, from experience) and hurt anyone as it falls.
12. Place a basin of sponges to catch the falling object A to prevent damage to the slotted mass or the floor.

Additional Details

13. Lubricate the axle of the pulley to minimize friction at the axle.
14. Use large masses for mass A and mass B. This can help to reduce the percentage error caused by the friction in the pulley.
15. Distance s should be made as large as possible. This is to maximize the duration of fall t so as to minimize the percentage error caused by timing inaccuracy caused by human reaction time.

Notes by Editor

- Item 15 above is an important consideration, since the time taken may be too short if s is not large enough.
- There are other designs which may overcome the limitation of the stopwatch method (this is not to say that the stopwatch method will not get you full credit, especially if you also take preventive measures such as item 15 above).
    a. Using a motion sensor. I personally would not recommend this method for exam purpose because there is too little to write about. If you insist on this method, do provide details like what your software displays on the monitor, and how you go about analyzing the results to obtain acceleration.
    b. Using an electronic timer circuit. You must provide detail of the timer circuit: start/stop terminals on timer connected to double pole switch and electromagnet, etc.
    c. Using light gates. First, be aware that there are many brands of light gates, each having different functions and capabilities. So if you are designing an experiment around light gates, make sure you explain the types of data your light gates provide you, how you go about collecting the data, and how you analyse the data.
- Instead of calculating, one may also propose a graphical method to find acceleration. For each mass B, vary s to measure t, collecting at least 6 data points. Plot the graph of s vs t^2 to find acceleration from the gradient.

05 CIE 2007 Jun P5 Q1 Terminal Velocity in Liquid

It is useful to know how the speed of an object is affected by its size when it moves through liquid in a confined space. In a laboratory this can be modelled by dropping small steel balls through oil.

It is suggested that the terminal velocity v is related to the radius r of a steel ball by the equation

$$v = kr^2$$

where k is a constant.

Design a laboratory experiment to investigate whether v is related to r as indicated in the above equation. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) how the radius of the steel ball would be measured,

(c) how the terminal velocity of the steel ball in oil would be measured,

(d) the control of variables,

(e) how the data would be analysed,

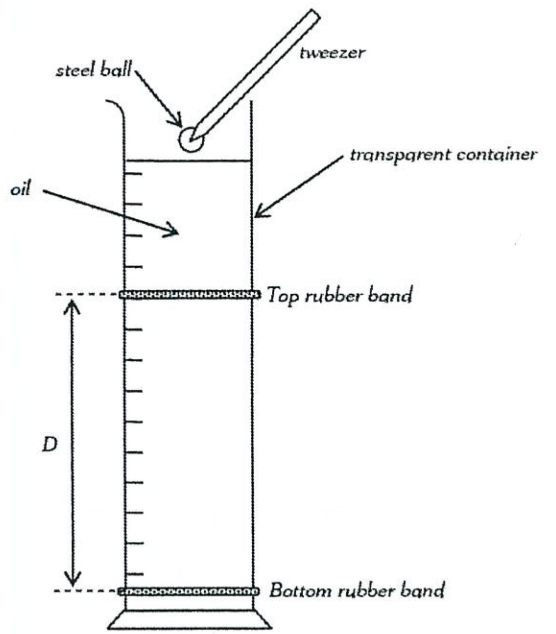
(f) any safety precautions that you would take.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	Clear, workable labelled diagram showing • Deep container of oil, ball and some measurement indicated for either time or distance
Variables	5	• Measure diameter d by using a micrometer/vernier calipers and use $r = d/2$ to obtain radius r • Measure the time for the ball to fall a set distance in oil using a suitable apparatus • Measure the (constant) distance fallen and show how v is calculated • Some indication that ball has reached terminal velocity (e.g. starting mark <u>well below</u> surface of oil) • Vary r, measure v. Repeat for ≥ 8 iterations. (Retrieve balls using magnet.)
Analysis	2	• Plot a graph of v against r^2. • Relationship is valid if graph is a straight line passing through the origin. (gradient is k)
Reliability	max. 3	Any good further design details, some of these might be: • Repeat diameter measurements and obtain average to reduce random errors • Distance markings should be made as far as possible/use long tube to reduce percentage uncertainty • Method to ensure that terminal velocity has been reached for measurements to be made • Maintain and check temperature of oil is constant as temperature affects viscosity • Drop ball gently at surface to prevent bubbles from forming around the ball and affecting the drag force and upthrust the ball experiences • Wide tube to reduce edge effects • Discussion of method to reduce parallax errors
safety	1	Any relevant safety precaution relating to the oil: • Mop up spillages of oil to prevent accidental slips • Cooking oils are highly flammable so do not place setup near ignition source

Suggested Solution

Diagram



Procedure

1. Fill a tallest and widest available transparent container with clear oil. Keep the ambient temperature constant as the viscosity of oil will change with temperature.
2. Mark a horizontal level at about two-third the height of the oil column, using a rubber band.
3. Mark another horizontal level a few mm above the bottom of the measuring cylinder, using a rubber band.
4. Measure D, vertical distance between the two rubber bands, using a metre-rule.
5. Measure the diameter d of the steel ball using a micrometer screw gauge. Repeat measurements at two other cross sections. Take average to reduce random error/check for reproducibility.
6. Calculate radius r by $r = d/2$.
7. Drop the ball bearing from just above the oil surface. Use a tweezers for better grip. Dropping gently from the surface ensures that no air bubbles are formed – air bubbles may affect the drag force and also the upthrust experienced.
8. Measure t, the time taken for the ball bearing to travel the distance between the two rubber bands, using a stop watch.
9. Calculate the terminal velocity $v = D/t$.
10. Retrieve the ball bearing using a magnet. Wipe dry the ball bearing.
11. Repeat the experiment (steps 7 to 9) for a repeat measurement of v. Take average to reduce random error.
12. Repeat steps 5 to 11, for all the other steel balls (of different diameters). Obtain at least 8 sets of readings.

13. ($v = kr^2$) Plot a graph of v against r^2. A straight line **passing through the origin** is obtained if the equation is valid.

Safety Precautions

14. The experiment should be done away from any ignition source since oil is flammable.

Additional Details

15. Some preliminary trials should be done to verify that the ball bearing attains terminal velocity before crossing the top rubber band. One way is to put another rubber band mid-way between the two rubber bands. The time taken for the ball bearing to move from the top to middle rubber band should be the same as that taken for it to move from the middle to the bottom rubber band. If not, shift the rubber bands lower.
16. To minimize parallax error, position the eye near the top rubber band at first before releasing the ball bearing, and swiftly reposition the eye near the bottom rubber band once the ball bearing crossed the top rubber band.

Notes by Editor

- It may bother some of us that the mass of the steel ball will obviously increase with diameter, so it seems like an obvious variable has not been controlled. But it is unavoidable that the radius and mass of a solid spherical steel ball must increase together. So let's not be too bothered and just keep to the spirit of the experiment.

06 CIE 1998 Nov P4 Q4 Terminal Velocity of Parachute vs Diameter

A parachute falling in air eventually moves with a constant velocity known as the terminal velocity. A toy rocket contains a small parachute which is ejected from the rocket a short time after launching. The designer of the rocket wishes to know how the terminal velocity of this parachute is affected by the diameter of the canopy and the load which it carries.

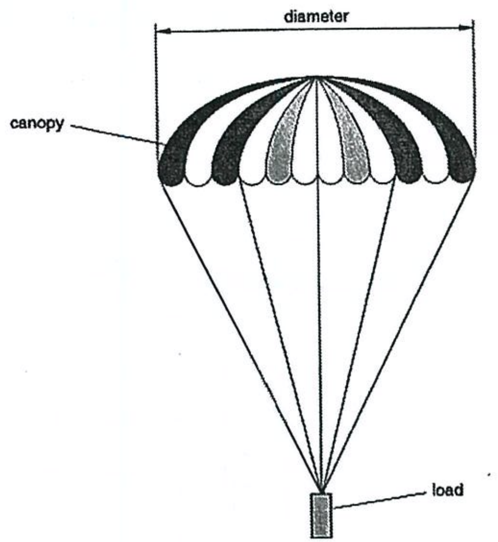


Fig. 4.1

Design a laboratory experiment to investigate how the terminal velocity of the parachute depends upon the load which it carries and the diameter of the canopy. In your account you should pay particular attention to the following:

(a) the method by which the diameter of the canopy and the terminal velocity are to be measured,

(b) the control of variables,

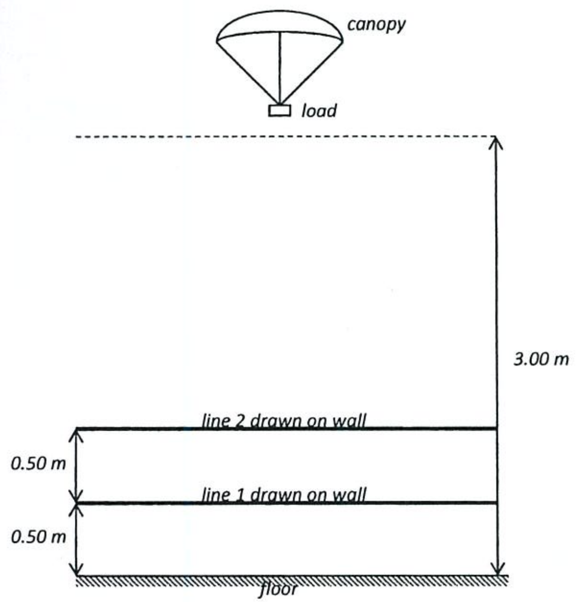
(c) any important precautions you would take which may improve the accuracy of your experiment.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	Clear, workable labelled diagram showing • Parachute dropped from substantial height, and some measurement indicated for either time or distance
Variables	6	• Method to measure diameter of parachute (e.g. lay it out flat, or use a blower to inflate) using appropriate apparatus (e.g. metre rule, measuring tape) • Measure load using an electronic balance/calibrations engraved on standard masses • Method to measure time (e.g. measure the time for the parachute to fall a set distance) using a device such as a stop-watch • Calculate *v*. Include the formula to do so. • Vary diameter, measure terminal velocity, repeat for $\geq$ 8 more iterations. • Vary load, measure terminal velocity, repeat for $\geq$ 8 more iterations. Note: Mark is awarded even if diameter and load are varied in the same run
Analysis	1	• Plot a graph of terminal velocity (y-axis) vs. diameter (x-axis) for various loads. This means we will get one line for each load; so we should have 8 lines altogether with data points on each line. (64 data points altogether)
Reliability	max. 3	Any good further design details, some of these might be: • Method to achieve terminal velocity (e.g. measure velocity at a distance well below the point of release) • Method to check that terminal velocity has been reached. (e.g. measure velocity again some time later to show that it has not changed.) • Repeat diameter measurements and averaging to reduce random errors • Distance marks should be as far as possible to reduce percentage uncertainty in the measurement of distance • Explicit statement that o In one experiment, keep load constant while varying diameter o In another experiment, keep diameter constant while varying load
safety	1	Any relevant safety precaution relating to dropping loads from great height, e.g: • Use a ladder to reach height • Keep to small loads • Thick newspaper/sponges to cushion the fall of parachutes

Suggested Solution

Diagram



Procedure

Experiment 1

1. *Prepare at least 8 parachutes with different canopy diameters.*
2. *Lay each canopy flat on the table. Use a meter rule to measure its diameter d at 3 different sections. Take average to reduce random error/ensure consistency.*
3. *Draw two horizontal lines across the wall. Line 1 is drawn 0.50 m above the floor. Line 2 is 1.00 m above the floor. Measurements are made using a measuring tape.*
4. *Toss the parachute at least 3 m high, as high as the ceiling of the lab allows. The experiment should be carried out in a draught free environment.*
5. *As the parachute descends, start the stopwatch when the bottom of the parachute touches line 2.*
6. *Activate the "Split" function when the bottom of the parachute touches line 1. Record the time as t1.*
7. *Stop the stopwatch when the bottom of the parachute touches the floor. Record the time as t2.*
8. *Calculate and compare (t2 – t1) and t1. Reject this reading and redo the experiment if they are different by more than 5%. If t1 is persistently shorter than (t2 – t1), it is probably because terminal velocity has not been attained. Drop it from/toss it to a greater height.*
9. *Calculate terminal velocity v using v = 1.00/t2.*
10. *Repeat measurement of v (steps 4 to 9). Take average to reduce random error.*

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11. *Repeat experiment (steps 4 to 10) for the 7 other parachutes, but keeping the load constant.*
12. *Plot a graph of v vs d to study their relationship.*

Experiment 2

13. *Prepare 8 different loads. Measure the mass of the load m using an electronic balance.*
14. *Carry the experiment same as experiment 1, except that this time the load is varied while keeping the diameter of canopy constant.*
15. *Plot a graph of v vs m to study their relationship.*

Safety Precautions

16. *Do not toss the parachute at locations where there are ceiling lamps, as they may hit/break the lamps accidentally.*
17. *If using a ladder to raise the parachutes, make sure the ladder is properly supported against the wall.*
18. *Keep to small loads in case they detach themselves and fall and cause injury/damage.*

Additional Details

19. *Discard results when the parachutes do not open fully.*
20. *Toss the parachute close to the wall (close to the horizontal lines) so as to reduce parallax errors in determining when the parachutes cross the lines.*

Notes by Editor

- *One could also show the results another way – plot terminal velocity against diameter for each of the eight loads on a graph sheet. This means we will get eight lines (one for each load) with eight data points (the various diameters) on each line.*

conduct expt in enclosed room in the absence of wind etc.

- conduct preliminary trial to determine the height to drop the parachute from such that they are travelling at terminal v when they pass the lines

07 CIE 1997 Nov P4 Q3 Pellet Penetration vs Speed

An air rifle can be used to fire small metal pellets which have a speed of about 150 ms^{-1} on leaving the rifle. When an absorbent material is placed some distance from the rifle, the pellets are observed to penetrate the material to a depth of three or four centimetres.

Design an experiment to investigate how the depth of penetration varies with the speed of the pellet. Your answer should include a diagram and make particular reference to

(a) how the speed of the pellets may be measured,

(b) how the depth of penetration of the pellets into the absorbent material is to be measured,

(c) how the speed of the pellets is to be changed (assuming that the pellets leave the rifle with a fixed speed),

(d) any safety precautions which should be taken during the experiment.

You may assume that all of the following equipment is available, together with any other standard laboratory apparatus that would be found in a school or college science laboratory.

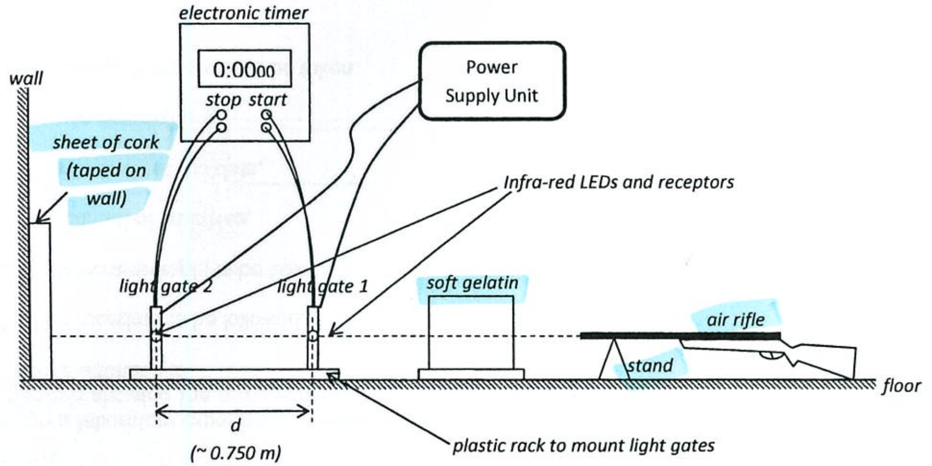
Mounted air rifle	Electronic timer
Connecting wires	Rule
Stopwatch	Sheets of absorbent material (e.g. cork)
Power supply unit	Thin aluminium foil
Light gates	

Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	Clear, workable labelled diagram showing • Rifle and lightgates positioned to enable measurement of velocity (reject stopwatch) • Show circuit of how light gates, power supply unit and electronic timer are connected.
Variables	5	• Vary speed of bullet and measure depth of penetration and repeat for ≥ 8 more iteration • Method to measure and vary speed of bullet (e.g. inserting different number of aluminium sheets between the rifle and absorber, varying the distance with explanation of air resistance) • Show how speed of bullet, v is calculated. • Explanation of how the light gates are triggered (e.g. pellet passing through the first gate starts the timer, pellet passing through the second gate stops the timer) • Method to measure depth of penetration (e.g. insert a thin rod into the hole, mark it and measure the length after removal, use the tail of the vernier calipers, reject ruler)
Analysis	2	• Hypothesize $D = kv^n$. Linearize: $\lg D = n \lg v + \lg k$. • Plot lg D vs lg v. Relation is verified if straight line graph is obtained with gradient: n; y-intercept: lg k
Reliability	max. 3	Any good further design details, some of these might be: • Taking into account diameter of pellet when measuring depth of penetration • Statement that the absorber must be uniform • Repeating readings of v and obtain average to reduce random error • Using laser to guide the alignment of rifle and light gates • Steps to make sure distances are constant between the light gates e.g. marking initial positions, or placing along a metre rule • Methods to make sure rifle is perpendicular to light gates' infrared beam, e.g. set squares • Pellets used should be of the same shape, mass and hardness
safety	1	Any relevant safety precaution relating to prevention of pellets injuring anyone, e.g: • Position a soft target board to stop the pellets to prevent pellets from rebounding off surfaces • Fence off the firing range, do not aim rifle at other people

Suggested Solution

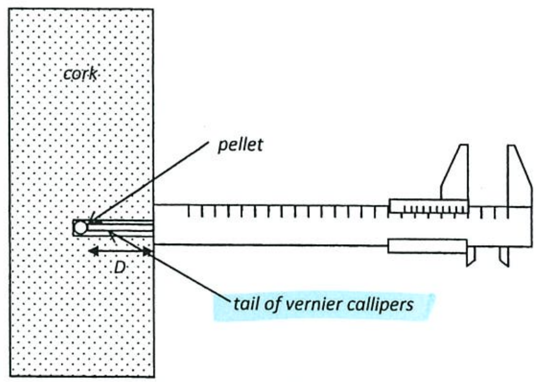
Diagram



Procedure

1. Set up the apparatus as shown.
2. Test fire a few shots to confirm that the pellet will first pass through the gelatin, then cut off the infra-red beam of light gate 1, which will trigger the start of the electronic timer, then cut off the infra-red beam of light gate 2, which will trigger the stop of the electronic timer, and finally implants itself in the sheet of cork.
3. Measure the distance between the two light gates d using a metre ruler. We are now ready to start the experiment.
4. Fire one round.
5. Record the time t as shown on the electronic timer. Calculate speed of pellet v using $v = d/t$.
6. Measure the penetration depth D (of pellet into the sheets of cork) using the tail of a vernier calipers.

preliminary trials to determine position to fire the rifle from such that ...



7. Replace the cork. All the sheets of cork used should be uniform.
8. Replace the gelatin with another of different thickness. Repeat the experiment (steps 4 to 6) until 20 sets of data for various speed of pellet are obtained.
9. Hypothesize $D = k(v)^n$. $\lg D = n \lg v + \lg k$. Plot lg D vs lg v. Relation is verified if straight line graph is obtained with gradient: n; y-intercept: lg k

Safety Precautions

10. Wear goggles to avoid injuries caused by ricochets. Use only wooden or plastic stands or racks, and make sure there is no hard surface in the path of the pellet to reduce chance of ricochets.
11. Do not aim the rifle at anybody. Do not fire any shot before making sure no one is in the path of the pellet. The experiment should be conducted in an air rifle range.

Additional Details

12. A laser pointer and a few sprays of aerosol can be used to guide the alignment of the rifle and light gates.
13. For additional accuracy, the diameter of pellets can be added to the penetration measurement to include the space occupied by the pellet lodged in the cork. The diameter of pellet can first be measured using a micrometer screw gauge before firing.
14. It is possible that the penetration is so narrow that the tail of the vernier calipers cannot fit into the penetration. In that case, insert a thin but stiff wire into the penetration, mark how far the wire extends into the penetration, and measure that length of wire using the vernier calipers.

Notes by Editor

- Some students may think that it is near impossible for the pellet to block out the infra-red beam completely each time. They have a point. In practice, photodiodes used to detect the passing bullet are calibrated to trigger the electronic timers as long as there is a reduction in light level.
- Instead of optical methods (i.e. using light gates or photodiodes), students could have proposed an electromechanical method. Typically, this means using two strips of aluminum foil spaced closely apart. When the passing pellet brushes through the gap between the two strips, it will close the circuit which will start the electronic timer. A second pair of aluminum strips is used to stop the electronic timer. Obviously, the strips should very thin and flexible so that change to pellet's speed is not significant.

B. OSCILLATIONS

08 CIE 2009 Jun P5 Q1 Cantilever

A student wishes to determine the Young modulus E of wood from the period of oscillation of a loaded wooden rule, as shown in Fig. 1.1.

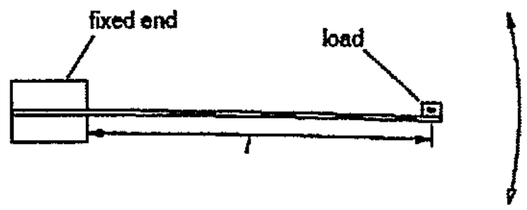


Fig. 1.1

An equation relating the period of oscillation T to the overhanging length l of the rule is

$$T^2 = \frac{kl^3}{E}.$$

The constant k is given by

$$k = \frac{16\pi^2 M}{wd^3}$$

where M is the mass of the load, w is the width of the rule and d is the thickness of the rule.

Design a laboratory experiment to determine the Young modulus of wood. You should draw a diagram showing the arrangement of your equipment. In your account, you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) how to analyse the data,

(e) how to determine E,

(f) the safety precautions to be taken.

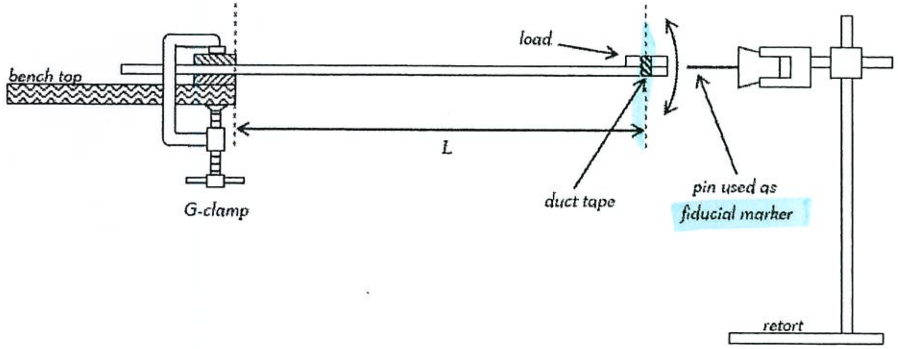
[15]

Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	• Clear, workable labeled diagram showing a fixed cantilever (e.g. G-clamp and bench, retort stand and clamp)
Variables	3	• Measuring timing t for many oscillations ($t > 10$ s) and averaging to determine T • Use of electronic balance to measure M, use of ruler to measure l and vernier calipers/micrometer screw gauge to measure d and w • Vary l, measure t and calculate T. Repeat steps for ≥ 8 more iteration
Analysis	3	• Equation to calculate T. $T = \frac{t}{N}$, where N: no. of oscillations • Plot a graph of T^2 against l^3 (accept other appropriate graphs) Relationship is valid if graph is a straight line passing through the origin • Calculate $E = \frac{16\pi^2 M}{wd^3 G}$ where G is the gradient of the straight line graph
Reliability	max. 4	• Repeat measurements of d and/or w along the ruler and take average to reduce random errors • Use of small amplitude or small angle oscillations (to ensure equation is valid). • Method of securing load to rule (e.g. with tape/glue) • Preliminary trials to determine the constant M to use. The value of M must be large enough to cause T to be large enough for all l • Use of fiducial marker to help in counting of number of oscillations • Start timing only after oscillations have stabilized • Repeat experiment at decreasing l to check if ruler has deformed permanently
safety	1	Any relevant safety precaution, e.g., • Use of sand trays below experimental setup to cushion any falling load to prevent any injury to experimenter's feet • Do not position eyes above the setup in case one gets hit by the oscillating cantilever

Suggested Solution

Diagram



Procedure

1. *Measure mass of the load M using a weighing balance.*
2. *Measure the width of the ruler w using vernier calipers. Take 3 readings along different sections of the ruler. Average them.*
3. *Measure the thickness of the ruler d using a micrometer screw gauge. Take 3 readings along different sections of the ruler. Average them to reduce random error.*
4. *Secure the load to one end of the ruler using duct tape.*
5. *Set up the apparatus as shown, with the overhanging length L of about 0.900 m.*
6. *An optical pin is positioned near the equilibrium position to help count the oscillations.*
7. *Measure the overhanging length L using a meter rule.*
8. *Displace the load downward slightly and release. The amplitude of oscillation should be small so as to ensure the equation is valid.*
9. *Start timing the oscillations only after the oscillations have stabilised.*
10. *Measure the time t taken for N oscillations. N should be large enough so that t is at least 10 seconds.*
11. *Calculate the period T as t/N.*
12. *Repeat steps 7 to 11 for 7 other values of L, ranging from 0.500 m to 0.900 m. The same ruler and load should be used throughout the experiment (to ensure w, d and M are constant).*
13. *($T^2 = \frac{k}{E}L^3$) Plot a graph of T^2 against L^3. A straight line is obtained if the equation is valid.*
14. *Determine the gradient G of the straight line.*
15. *Calculate E using* $E = \frac{16\pi^2 M}{wd^3 G}$.

Safety Precautions

16. *Do not position eyes directly above the cantilever in case the oscillating cantilever hits and injures the eyes.*
17. *Do not position feet underneath the setup in case the load falls.* Place sand trays below experimental setup to cushion any falling load.

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Additional Details

18. *L should be measured to the estimated centre of gravity of the mass.*
19. *A preliminary trial to identify a suitable load. It should be heavy enough so that the period of oscillation is large enough for the oscillations to be counted comfortably. On the other hand, it should also be light enough so that the ruler is not permanently deformed.*

Note by Editor

- *The determination of period of oscillation can be easily determined using the straight forward traditional method using a stop watch. It would be absolutely unnecssary to use light gates, motion sensors, video cameras, dataloggers or supercomputers.*

C. THERMAL

09 CIE 2005 Nov P5 Q2 Rate of Heat Loss from Hot Wire

A hot wire in air loses energy. Some of the energy is lost to the air particles that hit the wire. This energy lost depends on the number of particles hitting the wire per second, and hence on the air pressure.

If the temperature of the wire is constant then the total energy lost per second is equal to the electrical energy supplied per second.

Design a laboratory experiment to investigate how the total energy lost per second from a wire depends on the air pressure. You should draw a detailed labelled diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) how the electrical energy supplied to the wire per second would be measured,

(c) the type of thermometer used to check that the temperature of the wire remains constant during the experiment,

(d) how the pressure would be changed and measured,

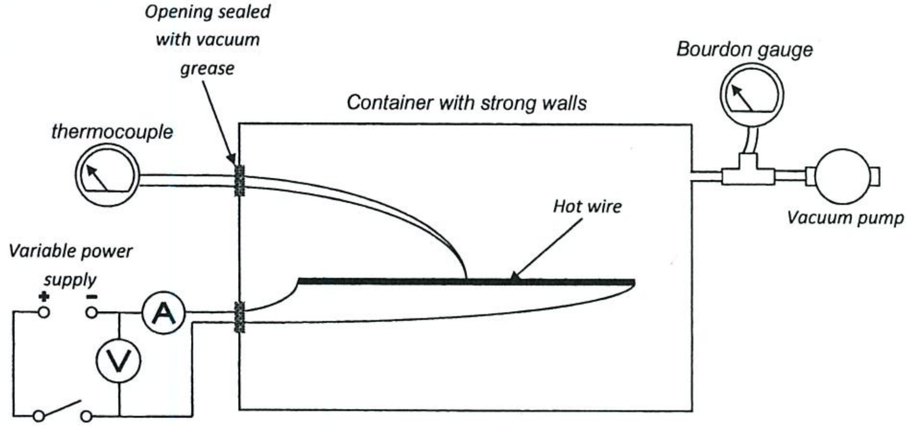
(e) any safety precautions that you would take.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labeled diagram showing • Wire must be shown inside a closed container with some means of changing the pressure (e.g. vacuum pump). • Wire connected to power supply, voltmeter and ammeter connected correctly to measure power dissipated in wire
Variables	5	• Vary pressure *p*, determine power *P* and repeat steps (e.g. for ≥ 8 more iteration) • Measure pressure using Bourdon gauge/pressure gauge/manometer • Calculate power *P* using *V* x *I* • Use of thermocouple thermometer to monitor temperature of wire • Adjust power supply when necessary to keep wire at constant temperature
Analysis	2	• Hypothesize $P = kp^n$. lg P = n lg p + lg k. • Plot lg P vs lg p. Relation is verified if straight line is obtained with gradient: n; y-intercept: lg k
Reliability	max. 2	Any good further *design* details, some of these might be: • Diagram shows thermocouple attached to the wire to monitor temperature • Further method to ensure good thermal contact • Use of a needle valve to control pressure • Vacuum grease the instrumentation wires • Allow time between readings for pressure and temperature to stabilize • Repeat experiment for a second set of data, average values taken for power for reliability • Vacuum chamber with strong walls • Detail of calibration of thermocouple
safety	1	Any relevant safety precaution relating to the low pressure chamber: • Safety screen/goggles/wire mesh surrounding vacuum chamber

Suggested Solution

Diagram



Procedure

1. Set up the apparatus as shown.
2. Close the circuit.
3. Allow time for the wire to reach equilibrium temperature.
4. Measure the temperature of the hot wire T as shown by the thermocouple.
5. Activate the pump to decrease the pressure in the container.
6. Allow time for the pressure and temperature of the container to stabilize. kept constant
7. Adjust the voltage of the power supply until the thermocouple shows temperature T. This has to be done in small steps because time must be allowed by the wire to reach its new equilibrium temperature.
8. Measure the pressure p as shown by the Bourdon gauge.
9. Measure the potential difference across the hot wire V by using the voltmeter.
10. Measure the current through the wire I using the ammeter.
11. Calculate rate of heat loss by the hot wire P by using $P = VI$. repeat. calculate avg. to reduce random error
12. Repeat steps 5 to 11 for 7 other values of pressure.
13. Hypothesize $P = kp^n$. $\lg P = n \lg p + \lg k$. Plot $\lg P$ vs $\lg p$. Relation is verified if a straight line is obtained where gradient: n; y-intercept: $\lg k$

Safety Precautions

14. The temperature of the hot wire must not be so high that the thermocouple melts. Decrease the voltage of the power supply if necessary.
15. Wear goggles to protect the eyes in case the container implodes, crushed by atmospheric pressure.

Additional Details

16. Temperature of the hot wire should be the same for all data points.
17. The opening through which the connecting wires are fed to the hot wire and thermocouple should be sealed with vacuum grease.

Notes by Editor

18. This experiment is about power lost to air particles, i.e. rate of conduction of heat from wire to air. This rate of energy lost is affected by air pressure because the frequency of collision of air particles should decrease as the air becomes thinner. If you understand this mechanism, you will be able to appreciate why the temperature of the wire should be kept constant. It is to keep the power lost through radiation (which has nothing to do with air pressure) constant.
19. Another way to monitor the temperature of the hot wire is to calculate its resistance by $R = \frac{V}{I}$. The power supply can then be adjusted until the hot wire's resistance is measured to be constant. This works because resistance is after all a thermometric property.

10 CIE 1999 Nov P4 Q3 Hardness of Lead vs Setting Time

Many complex metal parts of machinery, such as cylinder heads on car engines, are made by pouring liquid metal into a mould and allowing it to set over a given period of time. Often it is found that this 'setting time' is a crucial factor in determining the physical properties of the metal, such as hardness. If the setting time is very short (e.g. a few seconds) then the solid formed is often very hard but usually very brittle. Long setting times (such as a few hours) can decrease the brittleness.

The hardness of a sample of metal can be found by dropping an indenter made of a very hard material onto the surface of the metal and measuring the diameter d of the indentation at the surface, as shown in Fig. 3.1.

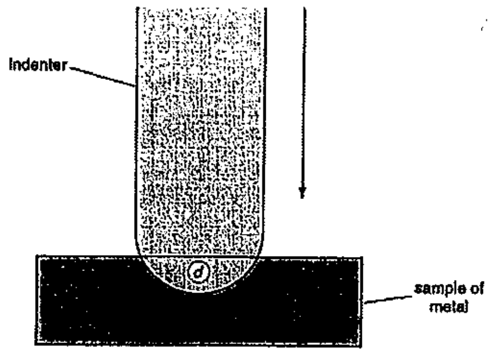


Fig. 3.1

Design a laboratory experiment to investigate how the hardness of lead (as measured by the test described above) depends on the setting time of molten lead. You may assume that all the apparatus listed below is available, together with any other standard equipment which may be found in a school or college science laboratory.

Lead shot	Travelling microscope
Rectangular clay trough	Voltmeter
Bunsen burner	Thermocouple thermometer
Stopwatch	Low voltage power supply unit
Small coil of wire	Switch
Fume cupboard	Indenter
Micrometer screw gauge	Metre rule

In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the method of measuring the diameter of the indentation,

(c) control of variables,

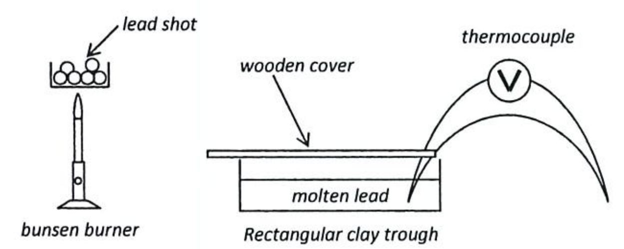
(d) any necessary safety precautions which you would take.

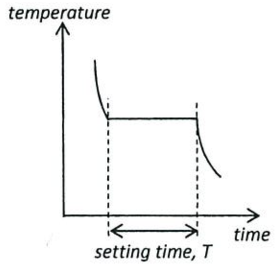
Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	Clear, workable labelled diagram showing • indenter released from height, lead sheet positioned below
Variables	5	• Drop the indenter, measure diameter of the indentation, change the setting time and repeat for ≥ 8 more iteration • Method to vary the setting time (e.g. different amount of insulation) • Use a thermocouple thermometer to measure temperature of lead (reject thermometer) • Plot the cooling curve to determine the setting time • Use a traveling microscope to measure diameter of indentation (some credit may be given to other methods which are workable)
Analysis	2	• Hypothesize diameter = k(time)^n. Linearize lg (diameter) = n lg (time) + lg k • Plot lg diameter vs lg time. Relation is verified if a straight line is obtained where gradient: n; y-intercept: lg k
Reliability	max. 2	Any good further design details, some of these might be: • Keep height from which to drop the indenter constant and/or keep thickness of lead sheet used constant • Carry out the hardness test on a rigid surface • Repeat measurement of diameter in two perpendicular directions and take average to reduce random error • Diagram of a cooling curve indicating clearly how the setting time is to be read • Detailed explanation of using the traveling microscope to measure diameter
safety	2	One relevant safety precaution each relating to • Lead fumes: Heat lead shot in a fume cupboard as lead fumes are poisonous • Hot lead: Wear gloves or use tongs to prevent scalding

Suggested Solution

Diagram

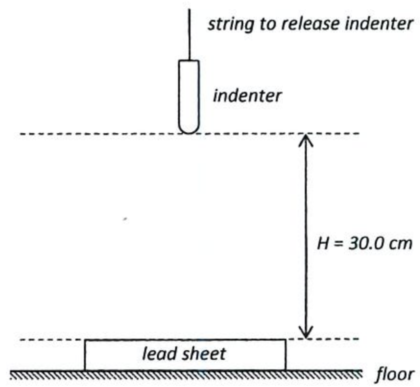


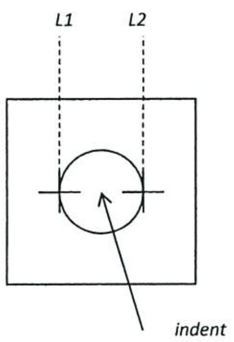


Procedure for preparation of lead sheets

1. *Prepare a pot full of lead shot.*
2. *Melt the lead shot completely with a Bunsen flame.*
3. *Continue heating the Bunsen flame for about 3 minutes to raise the temperature above melting point.*
4. *Pour the molten lead into the rectangular clay trough.*
5. *Partially cover the clay trough with a wooden board.*
6. *Record the temperature of the lead as shown by the thermocouple every one minute, until the all the lead has solidified.*
7. *Plot the cooling curve. The setting time T is derived from measuring the duration of time when the temperature is constant.*
8. *Repeat the procedure to prepare more lead sheets. The setting time can be varied by varying the amount that the wooden board covers the clay trough.*

Procedure for experiment





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9. *Set up the apparatus as shown.*
10. *Hold the indenter so that the bottom of the indenter is 30.0 cm above the indenter.*
11. *Release the indenter.*
12. *Use a traveling microscope to measure the diameter of the indent. First position the cross hair on the left edge of the indent and read the scale reading L1. Next position the cross hair on the right edge of the indent and read the scale reading L2. The diameter D is calculated by $D = L2 - L1$.*
13. *Rotate the lead sheet by 90° and repeat measurement of D across the new cross section. Take average to reduce random error.*
14. *Repeat experiment for all the other lead sheets.*
15. *Hypothesize $D = kT^n$. $\lg D = n \lg T + \lg k$. Plot $\lg D$ vs $\lg T$. Relation is verified if a straight line is obtained with gradient: n; y-intercept: lg k*

Additional Details

16. *Always pour the molten lead until to a certain level marked on the inside of the trough so that all the lead sheets have about the same thickness.*
17. *The indenter is not held by hand but through a string is tied to the indenter. This helps to release the indenter always vertically and without imparting any momentum to the indenter.*

Safety Precautions

18. *Lead fumes are poisonous. The lead sheets should be prepared in a fume cupboard.*
19. *Use tongs or heat proof gloves when handling molten lead to prevent scalding.*
20. *Do not place hands or eyes directly above the molten lead. There is going to be a lot of extremely hot gases and scalding may occur.*
21. *Wash hands thoroughly to avoid ingesting lead dust.*

D. ELECTRICAL

11 UCLES 2003 Nov P5 Q1 Electric Fuse

Many sensitive pieces of equipment such as computers and fax machines may be damaged by current overload, even when this overload occurs for a relatively short time. One method of protection is to use a fuse in which the fuse wire melts a very short time after the circuit overloads. Typically this time is of the order of a few milliseconds.

Fig 1.1 illustrates a one-ampere 'quick-blow' fuse.

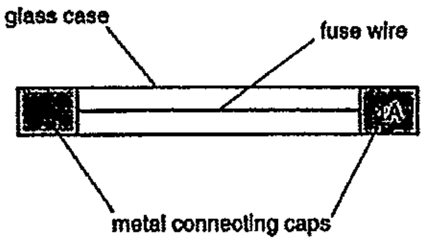


Fig. 1.1

One way of measuring the time taken for the fuse wire to melt is to use a circuit containing a delay-trace oscilloscope. In this oscilloscope the trace remains visible on the screen for several seconds after the signal has been received.

Fig. 1.2 shows the screen of such an oscilloscope used in a circuit where a quick-blow fuse has been tested.

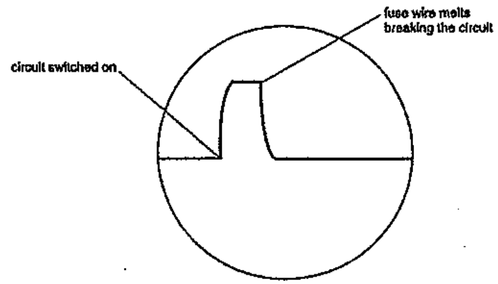


Fig. 1.2

Design an experiment using a delay-trace oscilloscope to measure the time taken for a 1A fuse to blow in a circuit in which there is a current of 2A. You should draw a circuit diagram showing how the equipment would be arranged. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the magnitudes of any potential differences and resistances used in your experiment,

(c) how the oscilloscope would be used to measure the time taken for the fuse wire to melt,

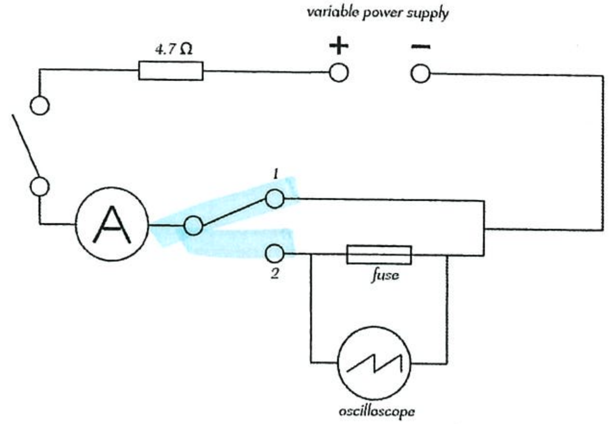
(d) any precautions that you would take to improve the accuracy of the experiment.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labelled diagram showing • Power supply, fuse and resistor connected in series • Oscilloscope connected in parallel across fuse or resistor
Variables	4	• Correct values of voltage and resistance to produce 2 A • Reading a distance from the CRO trace • Use the time-base to calculate melt time • A suitable time-base (~milliseconds per cm) was quoted
Analysis	0	-
Reliability	max. 5	Any good further design details, some of these might be: • Repeat experiment using another identical fuse to obtain another melt time, take average • Any details in the operating the CRO o Using the X-shift and Y-shift to centre waveform o Using the X-scale and Y-scale to maximize waveform o Arming the CRO • Use a rheostat (without the fuse) to adjust for a current of 2A • Use of two-way switch • Use a resistor of high power rating/Discussion of using rheostat over potentiometer
safety	1	One relevant safety precaution: • Wait for the blown fuse to cool down before touching it • Wear gloves while handling blown fuse

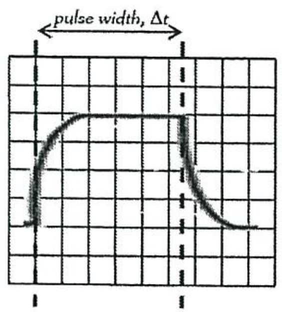
Suggested Solution

Diagram



Procedure

1. *Set up the apparatus as shown.*
2. *Set the power supply to DC 0.0 V.*
3. *Close the switch.*
4. *Gradually adjust the power supply towards about 9.4 V until the ammeter reads exactly 2.0 A.*
5. *Set the time-base to be 10.0 ms / divisions.*
6. *"Arm" the oscilloscope by setting the trigger, and select the "delay-trace" function.*
7. *Flip the 2-way switch to position 2 so that 2 A runs through the fuse.*
8. *Adjust the Y-scale and Y-shift setting of the CRO so that the waveform is as large as possible.*
9. *Adjust the time-base (X-scale) and X-shift to centre and maximise the pulse width on the screen.*



10. *Measure the length of the pulse in terms of number of divisions, multiply it with the time-base to obtain the pulse width. E.g. if the pulse looks like as shown in figure above, and the time-base is 0.5 ms / division, the pulse width is 5.5 times 0.5 = 2.75 ms.*

11. Turn off the switch, replace the broken fuse, and repeat the experiment two more times so that averaging can be done for a more accurate measurement of the pulse width.

Safety Precautions

12. Wear gloves to handle the blown fuse as it could still be hot.

13. The circuit should be switched off once measurements have been completed to prevent overheating.

Additional Details

14. The power dissipation in the resistor is expected to be $2.0^2 \times 4.7$ which is close to 20 W. A proper resistor with the correct power rating must be used.

Notes by Editor

- *It is acceptable to use a fixed power supply and adjust a variable resistor (rheostat, not potentiometer) to obtain a current of 2.0 A.*

12 CIE 2009 Nov P5 Q2 Expansion of Hot Wire

When a current passes through a wire, the wire becomes hot and expands.

This can be investigated in a laboratory by passing a current through a wire of diameter d and measuring the displacement y, as shown in Fig. 1.1.

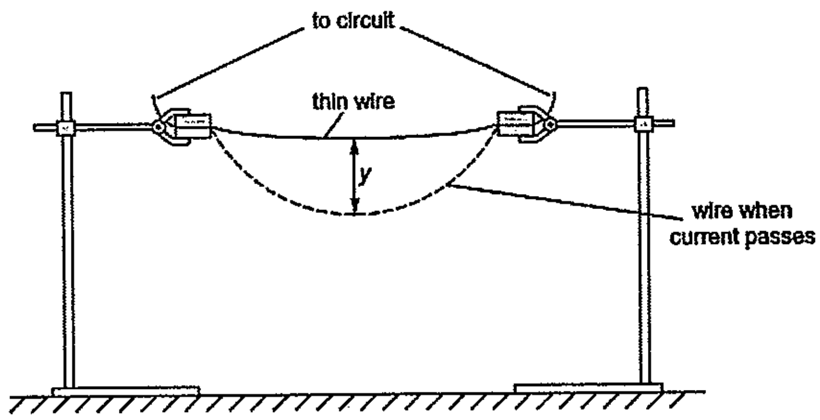


Fig. 1.1

It is suggested that the diameter d of the wire is related to y by the equation

$$y = pd^q$$

where p and q are constants.

Design a laboratory experiment to investigate the relationship between d and y, so as to determine a value for q. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

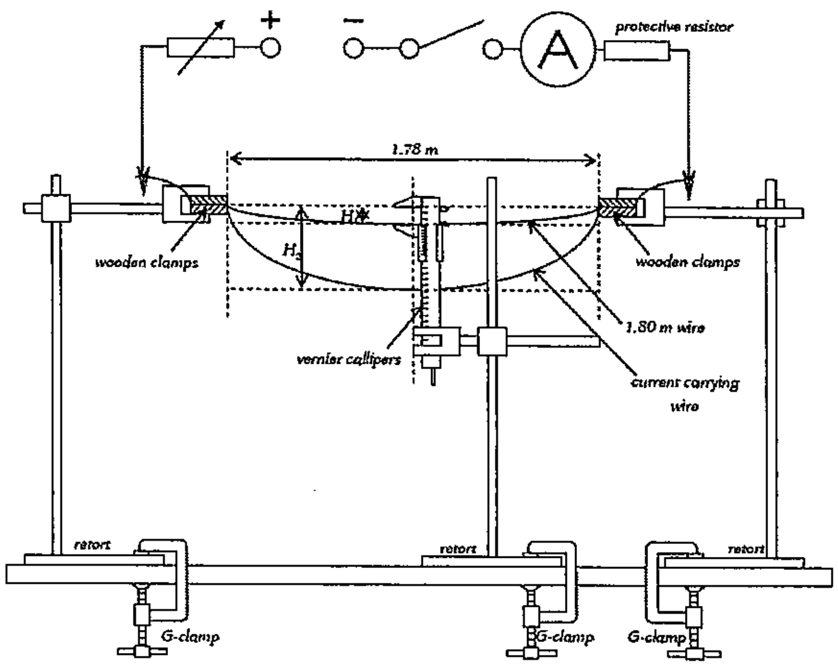
(e) the safety precautions to be taken.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	Clear, workable labelled diagram showing • power supply connected to wire
Variables	4	• Vary d, measure y and repeat steps (e.g. for ≥ 8 more iteration) • Measurement of d using micrometer screw gauge • Use of ammeter connected correctly to monitor current • Method to measure y (e.g. final reading – initial reading). Measurement of height reading using appropriate instrument (e.g. Vernier calipers)
Analysis	2	• Plot a graph of lg y against $lg\ d$ • Linearise $\lg y = q \lg d + \lg p$ Relationship valid if graph is a straight line. q is gradient (and $\lg p$ is y-intercept)
Reliability	max. 4	Any good further design details, some of these might be: • Method to keeping current constant, e.g. use of rheostat • Control of additional variables, e.g. separation between supports, room temperature • Use of vernier scale to measure y/well described optical method/use of set square • Repeat measurements of d at different points along the wire and determine average to reduce random error • Check starting position for y for every wire • Use of protective resistor (either labeled or explained) • Preliminary experiment to determine the constant current that produces large enough y for wires of all diameters • Allow time for displacement of wire to stabilize before taking readings of final reading
safety	1	Any relevant safety precaution relating to hot wire, e.g: • Wear gloves/ wait to cool down when changing wires to prevent scalding • Switch off power supply when not in use to prevent wire overheating

Suggested Solution

Diagram



Procedure

1. *With the help of a measuring tape, cut a piece of wire 2.00 m long.*
2. *Use a micrometer screw gauge to measure the diameter d. Measure d at three different cross sections and obtain average d to reduce random error.*
3. *Hang the wire between two retort stands. Make sure the two retort clamps are at the same level by measuring the height of the wire at two ends to be the same.*
4. *The length of wire between the two wooden clamps should be 1.80 m. Let it sag a little such that the two ends are 1.78 m apart horizontally.*
5. *Clamp a vernier calipers on to a third retort. Position the vernier calipers at the middle of the wire, such that the wire is in between the two jaws of the vernier calipers.*
6. *Use a G-clamp to clamp all the retort stands tightly to the workbench.*
7. *Adjust the lower jaw until it just touches the wire. Record the vernier reading as H_1.*
8. *Lower the lower jaw to allow room the wire to expand and sag later.*
9. *Connect the wire to the electrical circuit using crocodile clips.*
10. *Close the circuit.*
11. *Adjust the rheostat until the ammeter reads 1.0 A.*

12. Wait for the wire to reach final state of expansion. The room temperature may affect the final temperature of the wire, so it should be maintained constant.
13. Adjust the lower jaw until it just touches the wire. Record the vernier reading as H_2.
14. Calculate y by $y = H_2 - H_1$
15. Repeat the experiment for wires of 7 other diameters, but of the same material.
16. $\lg y = \lg p + q \lg d$
Plot a graph of lg y against lg d. A straight line is obtained if the equation is valid. Gradient corresponds to q and y-intercept corresponds to lg p.

Safety Precautions
17. Switch off circuit when not in use to prevent overheating.
18. Wear gloves when handling and changing wires to prevent electric shock or scalding.

Additional Details
19. Use a plumb line to check that the vernier calipers is placed vertically.

Notes by Editor
- *A better way to measuring y may be to tie a taut horizontal string. This string can serve as a reference line, so there is no need for the vernier scale to be clamped.*
- *Actually, a travelling microscope is arguably a better instrument than the vernier calipers.*

13 CIE 2008 Nov P5 Q1 Resistance of LDR

A student wishes to investigate how the resistance R of a light-dependent resistor varies with the distance d from an intense light source.

It is believed that the relationship between R and d is

$$R = kd^n$$

where k and n are constants.

Design a laboratory experiment to test the above relationship. The light-dependent resistor has a resistance of 100 Ω when it is in bright light and a resistance of 500 kΩ when no light falls on it.

You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements that would be taken,

(c) the control of variables,

(d) how the data would be analysed,

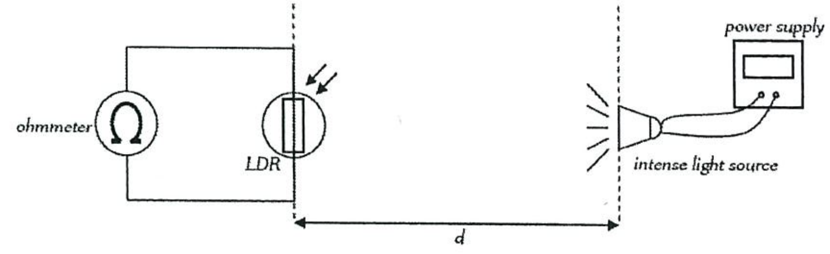
(e) any safety precautions that you would take.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labelled diagram showing • An LDR in a circuit with an independent lamp • A ruler measuring appropriate distance or *d* labeled correctly
Variables	3	• Vary *d*, measure *R* and repeat steps (e.g. for ≥ 8 more iteration) • Correct circuit diagram for LDR using conventional symbols; ohmmeter <u>without</u> power supply, or ammeter and voltmeter with power supply • Method of determining *R*; ohmmeter or $R = V/I$
Analysis	2	• Plot a graph of lg *R* against *lg d* • Linearise $\lg R = n \lg d + \lg k$ Relationship valid if graph is a straight line where *n* is gradient and lg *k* is y-intercept
Reliability	max. 4	Any good further design details, some of these might be: • Detail on measuring the distance • Method of keeping orientation of LDR with respect to the light source constant (e.g. use of set square, fix to rule, optical bench or equivalent) • Method of keeping output of light source constant (allow constant current/emf/voltage/power) • Detail in using the digital multimeter as ohmmeter/ammeter (e.g. range of ohmmeter/ammeter) • Control (or monitoring) of an additional variable with reason e.g. temperature because LDR as a semiconductor is sensitive to temperature • Method for checking the output of the light source is constant • Preliminary experiment to determine the constant current that produces large enough *y* for wires of all diameters • Perform experiment in a dark room/tube and is corresponding reason
safety	1	Any relevant safety precaution relating to bright light source, e.g: • Wear shades or do not look directly at bright light source

Suggested Solution

Diagram



Procedure

1. *Set up the apparatus as shown.*
2. *Line up the light source and LDR such that the light is shining directly into the light sensing "window" of the LDR. The power supply for the light source should be set to a constant voltage throughout the experiment. A worthwhile check is to use a light meter (planted at a fixed distance and orientation to the light source) to monitor that the output from the light source is constant.*
3. *Use a metre rule to measure the distance d between the estimated geometric centres of the light element and the LDR.*
4. *Measure the resistance of LDR R using a digital multimeter. The multimeter should be set to the ohmmeter mode. The range setting should be adjusted (Ω, kΩ, MΩ and so on) to always obtain a 3 significant figure reading.*
5. *Repeat steps 2 to 5 for at least 7 other values of d.*
6. *lg R = lg k + n lg d*
   Plot a graph of lg R against lg d. A straight line is obtained if the equation is valid. Gradient corresponds to n and y-intercept corresponds to lg k.

Safety Precautions

7. *Wear glasses to avoid looking directly into the blinding light source to prevent any potential retinal damage*
8. *Wear gloves to avoid touching the heated light source and prevent scalding your fingers or electrocution*

Additional Details

9. *Preliminary trials should be performed to identify the range of d leading to R ranging between 100 Ω to 100 kΩ.*
10. *Experiment should be performed in a dark room. Any other light source would have added intensity to the intended intensity of the original light source, contributing to a systematic error to the experiment.*

14 CIE 2008 Jun P5 Q1 Resistivity of Glass

A student wishes to measure the resistivity of glass. A teacher suggests that its resistivity is of the order of $10^6\,\Omega\,m$ which is very large.

Resistivity ρ is defined by the equation

$$\rho = \frac{RA}{l}$$

where R is resistance, A is cross-sectional area and l is the length of the material.

The student is given a number of sheets of glass of the same thickness and of different areas.

Design a laboratory experiment to determine the resistivity of glass. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) how the glass would be connected to the circuit,

(c) the measurements that would be taken,

(d) the control of variables,

(e) how the data would be analysed,

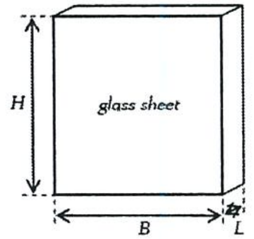
(f) any safety precautions that you would take.

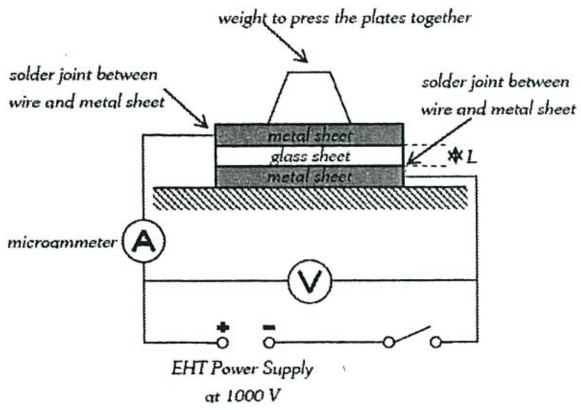
Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labelled diagram showing • Basic circuit diagram; Ammeter and voltmeter with power supply, or ohmmeter without power supply • Correct orientation of glass between electrodes – largest cross-sectional area
Variables	4	• Vary A, measure R and repeat steps (e.g. for ≥ 8 more iteration) • Thickness measured using a micrometer/vernier calipers • Method to determine A (e.g. distances measured and multiplied together) This mark may only be scored if it is clear that the dimensions are being used • Method of determining resistance; $R = V/I$ justified / ohmmeter
Analysis	1	• Plot an appropriate graph that allows ρ to be calculated
Reliability	max. 4	Any good further design details, some of these might be: • Calculation of typical resistance of glass using value of resistivity given ($10^6\,\Omega\,m$) • Range of ammeter or ohmmeter setting, with reasoning • Use of EHT or power supply > 100 V or micro-ammeter/galvanometer • Repeat measurements of thickness at different sections and take average • Good contact between circuit and glass (e.g. metal plates, foil, conducting putty) • Further method to secure good contact between circuit and glass (e.g. clamps, weights, clean/dry the glass) • Metal plates/foil/conducting putty to cover all of the cross-sectional area in use • Allow time for glass to reach equilibrium temperature before taking measurements
safety	1	Any relevant safety precaution relating to the use of EHT power supply (>100 V): • Wear thick rubber gloves and switch off power when changing circuit

Suggested Solution

Diagram





Procedure

1. Measure the thickness of the glass sheet L at 3 different positions using a micrometer screw gauge. Take average to reduce random error.
2. Measure the breadth of the glass sheet B at 3 different positions using vernier calipers. Take average to reduce random error.
3. Measure the height of the glass sheet H at 3 different positions using vernier calipers. Take average to reduce random error.
4. Calculate the area A using $A = B \times H$.
5. Prepare two metal sheets with the same (or slightly larger) cross sectional area as the glass sheet.
6. Clean and wipe dry the glass and metal sheets.
7. Set up the apparatus as shown in the diagram.
8. Close the switch.
9. Adjust the power supply until meaningful readings are obtained on both for both the voltmeter and micro-ammeter.
10. Allow time for temperature of glass and the readings to stabilise before measuring the voltage V and current I.
11. Calculate resistance R by $R = \frac{V}{I}$
12. Repeat steps 1 to 11 for all the other glass sheets. Obtain at least 8 sets of readings.
13. $R = \frac{L}{A}\rho$

    Plot a graph of R against L/A.
14. A straight line is obtained if the equation is valid. Gradient corresponds to the resistivity ρ of glass.

Safety Precautions

15. Always switch off the EHT power supply except when making measurements to prevent any electric shock.
16. Wear thick gloves when handling glass sheets to prevent any electric shock.

Additional Details

17. The resistance of a 10 cm x 10 cm glass sheet of 1 cm thickness is about $10^6 \times \frac{1\times10^{-2}}{(10\times10^{-2})^2} = 10^6\ \Omega$. A potential difference of 100 V across the glass sheet will produce a current of 100 μA.

Notes by Editor

- Credit is given for justification for the use of EHT and micro-ammeter. So show your working.
- In practice, one may measure the resistance directly using a higher end digital ohmmeter that can measure up to hundreds of MΩ. Modern digital millimeters with such capability are becoming cheaper and more common. This will allow us to avoid the power supply, voltmeter and the micro-ammeter.
- Instead of metal sheets, one may use metal foils, or even conducting putties. In practice, conducting putties is probably the better choice because they can be molded into the required dimension easily, and banana plugs can be pressed into the putty without the need of soldering for good contact.
- It is unclear how the temperature of glass can be kept constant. But don't let them stop you from writing that point down in your answers.

E. WAVES

15 CIE 2009 Nov P5 Q1 Resonant Frequency of a Bottle

The volume of air in a bottle affects its resonant frequency.

It is suggested that the resonant frequency f is related to the volume V by the equation

$$f^2 = \frac{k}{V}$$

where k is a constant.

Design a laboratory experiment to determine whether this equation is correct. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) how to analyse the data,

(e) the safety precautions to be taken.

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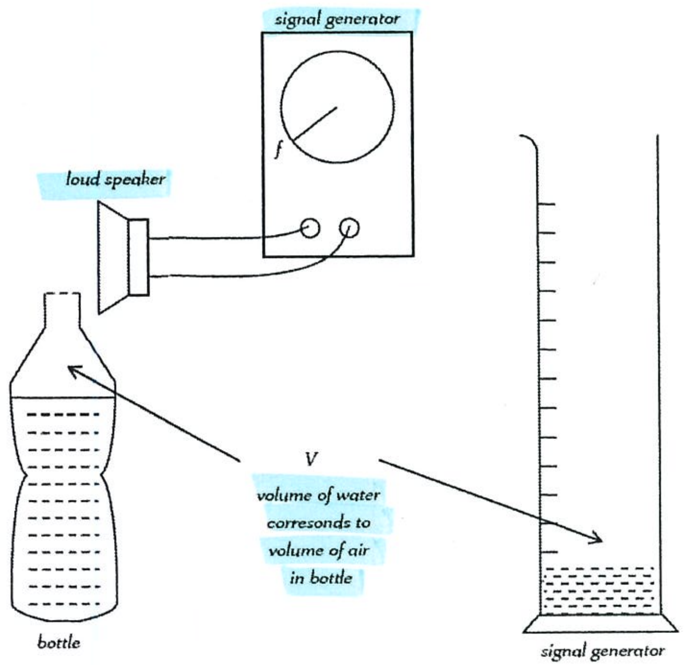
Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	Clear, workable labelled diagram showing • Source of sound (e.g. loudspeaker/tuning fork) adjacent to the opening of bottle
Variables	5	• Vary V, measure f (or vary f, measure V) and repeat steps (e.g. for ≥ 8 more iteration) • Method of producing sounds of different frequencies, e.g. several tuning forks or signal generator • Determination of frequency using oscilloscope/read off tuning fork or signal generator • Method of measuring volume of air (use of measuring cylinder/burette and possibly a subtraction method e.g. volume of container – volume of water) • Method to determine resonant frequency (e.g. largest sound heard or largest amplitude on oscilloscope)
Analysis	1	• Plot a graph of f^2 against V^{-1} Relationship is valid if graph is a straight line passing through the origin where k is the gradient
Reliability	max. 4	Any good further design details, some of these might be: • Detailed timebase calculation (if oscilloscope is used) • Discussion of container (e.g. end correction/shape of mouth of bottle) • Explanation of method to ensure fundamental frequency (e.g. starting from lowest frequency) • Repeat experiment, reversing the changes in V or f • Perform experiment in a quiet room • Keep temperature of air in bottle constant
safety	1	Any relevant safety precaution relating to loud sound: • Wear ear plug for loudspeaker method • Switch off power supply when not in use

Suggested Solution

Diagram



Procedure

1. Fill the bottle (0.5 litre coke glass bottle) full with water. Room temperature water should be used.
2. Pour about 1/10 of the water in the bottle into a 1-litre measuring cylinder. Measure the volume of water, which is equal to the volume of air in the bottle, V. Temperature of air in the bottle should be constant. Wear gloves and minimise body contact with the bottle to avoid warming up the bottle.
3. Position the loudspeaker near the opening of the bottles.
4. Switch on signal generator and loudspeaker.
5. Starting from the lowest frequency, increase the frequency of the signal generator slowly to search for the lowest frequency for resonance, i.e. when the loudest sound is heard from the bottle. Read the resonance frequency f off the signal generator scale.
6. Repeat the experiment for 7 other values of V, each time pouring about 1/10 of the water from the bottle into the measuring cylinder.
7. Plot a graph of f^2 against $1/V$. Equation is valid if graph is a straight line passing through the origin. Gradient corresponds to k.

Safety Precaution

8. Wear ear plugs to prevent loud sound from causing injury to the ear drum.

Additional Details

9. Conduct experiment in a quiet room to obtain better results.
10. The experiment can be repeated, this time collecting data as water is added back into the bottle. The values of f can be averaged for better reliability. to reduce random error
11. There is arguably some inaccuracy because the human ear's perception of loudness does vary with frequency.
12. It is possible that the resonance frequency is beyond the audible range. In that case, a microphone positioned near the bottle can be connected to an oscilloscope. The amplitude of the sound wave can be monitored on the oscilloscope to determine the resonant frequency.

Notes by Editor

- It is also acceptable to use a set of tuning forks, and keep adjusting the volume of air (by pouring and adding the amount of water in the bottle) until resonance is achieved.
- Instead of reading the frequency off the scale of signal generator, one can also use a digital oscilloscope. In fact, detail of timebase calculation will entitle you to score one reliability mark.
- By the way, the bottle actually behaves as a Helmholtz resonator, in which the volume concerned is the volume of the cavity, excluding the opening or neck of the bottle. However, students are not expected to know this and so ignorance is bliss in a way.

16 CIE 2007 Nov P5 Q1 Attenuation of Sound by Glass

Double glazing can be used for sound insulation. Double-glazed windows consist of two panes of glass with air in the space between them. Manufacturers reduce the air pressure in the space between the panes of glass to reduce the amplitude of sound transmitted through the window.

It is suggested that the amplitude A of sound transmitted through a double-glazed window is related to the air pressure p in the space between the panes by the equation

$$A = k\sqrt{p}$$

where k is a constant.

Fig. 1.1 shows a laboratory model of a double-glazed window. It consists of two panes of glass. There is a tube connected to the space between the two panes so that air may be removed.

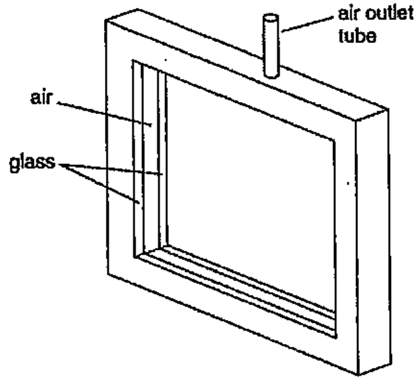


Fig. 1.1

Design a laboratory experiment to investigate whether A is related to p as indicated in the above equation when p is reduced. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) how the air pressure between the panes of glass would be measured,

(c) how the amplitude of the sound would be measured,

(d) the control of variables,

(e) how the data would be analysed,

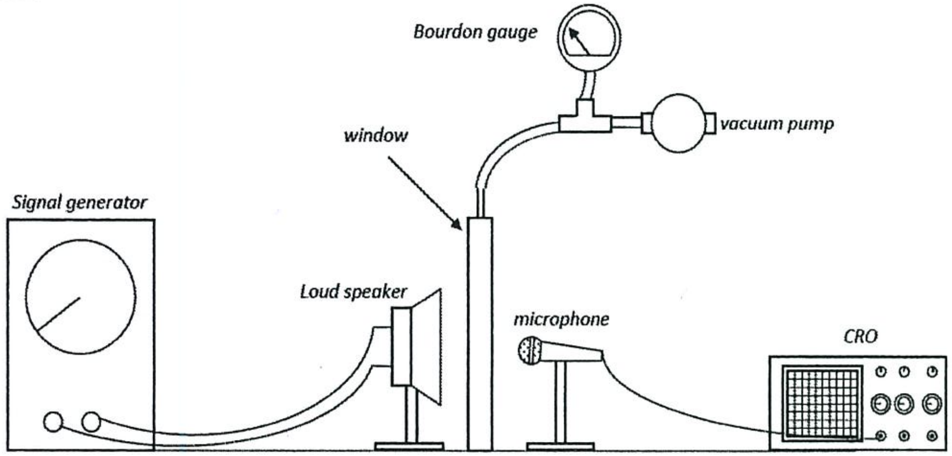
(f) any safety precautions that you would take.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labelled diagram showing • Source of sound (e.g. loudspeaker, bell, buzzer, siren but not musical instruments) • Glass window • Detector of sound (e.g. microphone)
Variables	4	• Vary p, measure A and repeat steps (e.g. for ≥ 8 more iteration) • Method of reducing pressure. (e.g. use vacuum pump to withdraw air from glass window) • Method of measuring pressure (e.g. bourdon gauge, manometer/pressure gauge, do not allow barometer or pressure meter) • Method of measuring A (e.g. use an oscilloscope)
Analysis	2	• Plot a graph of A^2 against p. (or A against $\sqrt{p}$, or lg A against lg p) • Relationship valid if graph is a straight line passing through the origin. (or gradient should be 0.5 if lg is used)
Reliability	max. 3	Any good further design details, some of these might be: • Method of ensuring that output from speaker is constant • Method of reducing sound reflections from glass (e.g. foam/speaker & microphone close to glass) • Window is perpendicular to sound source • Detail explaining use of oscilloscope to measure amplitude • Difficulty in measuring amplitude at small pressures/use a loud incident source • Control (or monitoring) of one additional variable with explanation e.g. temperature, frequency, distances • Allow time for temperature/pressure between the glass to stabilize • Discussion of attenuation in air/frame/glass • Method to keep the incident amplitude constant • Perform experiment in a quiet room
safety	1	Any relevant safety precaution relating to: • Intensity of sound: wear ear plugs • Use of glass: wear goggles in case glass breaks under low pressure

Suggested Solution

Diagram



Procedure

1. Set up the apparatus as shown. The loudspeaker, glass and microphone should be duct taped to the bench so that their positions remain constant.
2. Both the loudspeaker and microphone should be facing perpendicularly into the window. They should also be as close to the window as possible (without touching the window). This is to minimise errors caused by sound from the loud speaker reaching the microphone via reflected paths (from the window and room walls)
   20 – 20k Hz
3. Fix the frequency of the signal generator to 2 kHz (or some other audible frequency). The amplitude and frequency of the signal generator must be kept constant so that the loud speaker outputs a constant sound. If possible, position another microphone on the loudspeaker side of the window to monitor and make sure the loud speaker's output is constant.
4. Activate the vacuum pump to withdraw air from the window to lower the pressure in the window.
5. Allow time for the pressure and temperature of the glass window to stabilise.
6. Record the pressure p as shown on the Bourdon gauge.
7. Switch on the loudspeaker.
8. Adjust the Y-scale and Y-shift to maximise the waveform on the CRO display. Measure the amplitude A, taking into account the Y-scale. For example, if the amplitude is 3.1 cm on the display and the Y-scale is 2 V/ cm, then the amplitude is 6.2 V.
9. Switch off the loudspeaker.
10. Repeat steps 4 and 9 to repeat the experiment for 7 other values of p.
11. $A = k\sqrt{p}$

    Plot a graph of A against $\sqrt{p}$. A straight line **passing through the origin** is obtained if the equation is valid.

Safety Precautions

12. Wear goggles to protect the eyes. The glass window may be crushed as air is drawn out.
13. Wear ear muffs to protect the ears if the sound intensity is high.

Additional Details

14. The experiment should be performed in a quiet room to avoid background noise (literally).
15. In preliminary trial, the time-base on the CRO should have been adjusted so that a few complete sinusoids are visible on the display.

Notes by Editor

- A manometer can be used instead of a Bourdon gauge, although in practice, the Bourdon gauge is often easier to use. The less specific "pressure gauge" is likely to be accepted. A barometer, however, is likely to be rejected. A barometer refers to a pressure gauge that measures the atmospheric pressure only.

17 CIE 2004 Nov P5 Q2 Ringing Bell in Bell Jar

Two students are having a discussion about an experiment in which the air inside a bell jar is gradually removed. The sound of a ringing bell inside the jar is heard to diminish in intensity during this process. One student suggests that the frequency of the sound changes as the pressure changes; the other student thinks that the frequency remains constant as the air is removed.

Design a laboratory experiment to investigate how the frequency of a sound wave depends on the pressure of air. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements that would be taken,

(c) how the frequency of the sound would be measured using a cathode ray oscilloscope,

(d) the control of variables,

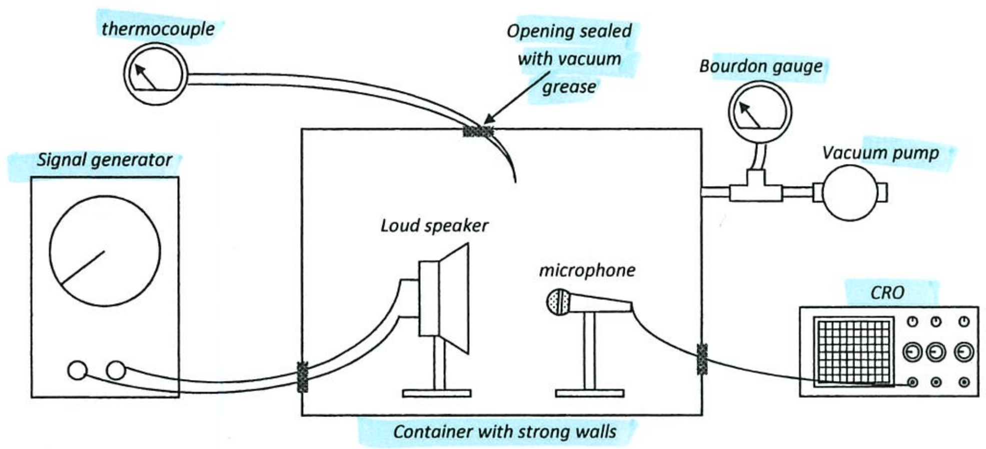
(e) any safety precautions that you would take.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	3	Clear, workable labeled diagram showing • Source of sound in 'closed box' • Correct usage of Bourdon gauge/pressure gauge/manometer/pressure sensor + datalogger to measure pressure in box • Microphone + CRO
Variables	4	• Vary pressure p, measure f and repeat steps (e.g. for ≥ 8 more iteration) • Use vacuum pump to change pressure • Correct measurements taken to find period using CRO, i.e. length of trace on screen x time base setting • Use of measurement to calculate frequency, $f = 1/T$
Analysis	2	• Hypothesize $f = k(p)^n$. Linearize: $\lg f = n \lg p + \lg k$ • Plot $\lg f$ vs $\lg p$. Relation is verified if straight line graph is obtained where gradient: n; y-intercept: lg k
Reliability	max. 2	Any good further design details, some of these might be: • Use a signal generator connected to speaker • Vacuum grease the wires • Monitor temperature with thermometer during experiment • Avoid unwanted sounds/use soundproof room • Increase p as well as decrease p for give spread of readings • Fix position of microphone relative to sound source • Allow sufficient time between readings for pressure and temperature in box to stabilise • Maintain constant temperature and frequency of sound source
safety	1	Any relevant safety precaution each relating to low/high pressure: • Low/high pressure: Safety screens/wear safely goggles in case of implosion/explosion/use container with strong walls

Suggested Solution

Diagram



Procedure

1. *Set up the apparatus as shown.*
2. *The signal generator should be set to an audible frequency (e.g. 500 Hz). The volume should be set loud enough for a clear signal to be picked up comfortably by the CRO.*
3. *Activate the vacuum pump to set the air pressure in the container to the desired pressure.*
4. *Allow time for the pressure and temperature in the container to stabilize.*
5. *Record the air pressure p as shown by the Bourdon gauge.*
6. *Adjust the Y-scale and Y-shift setting of the CRO so that the sound wave is displayed clearly on the CRO.*
7. *Adjust the time-base (X-scale) so that only one or two complete cycles are displayed on the CRO.*
8. *Measure the period of the sound wave T by multiplying the length of one cycle with the time-base. For e.g. if one cycle occupies 4.0 cm on the display, and the time-base is 0.5 ms/cm, the period will be calculated to be 4.0 x 0.5 = 2.0 ms.*
9. *Calculate frequency f by $f = 1/T$.*
10. *Repeat the experiment (steps 3 to 9) for 7 other values of p.*
11. *Hypothesize $f = k(p)^n$. Linearize: $\lg f = n \lg p + \lg k$. Plot lg f vs lg p. Relation is verified if straight line graph is obtained. Gradient: n; y-intercept: lg k*

Control Variables

12. *The frequency of signal generator should be constant.*
13. *Use the thermocouple to monitor that the temperature in the container is constant.*

Safety Precautions

14. *Wear goggles because the container may explode/implode under pressure.*

Additional Details

15. *Use a container with strong walls to withstand the pressure.*
16. *The openings through which all the wirings are fed into the container should be sealed air tight with vacuum grease.*
17. *Experiment should be conducted in a quiet room to reduce background noise literally.*

Notes by Editor

- *Do not be misled by the storytelling at the beginning of the question into thinking the experiment is to be carried out with a bell jar and a bell.*

18 *CIE 1998 Nov P4 Q3 Frequency Response of a Microphone*

A biologist wishes to investigate how bats navigate around obstacles at night. One way of doing this is to monitor the high frequency sound waves generated by the bats. The biologist decides to use a microphone and some recording equipment.

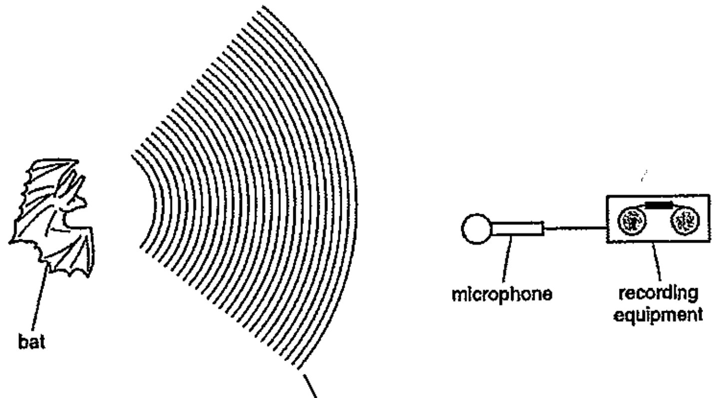


Fig. 3.1

However, the recording equipment fails to register any signals. It is suspected that the frequency response of the microphone does not match the frequency of the sound waves given out by the bats.

Design an experiment to investigate how the output of a microphone varies with the frequency of the sound waves which it receives. You may assume that the following apparatus is available:

Loudspeaker
Cathode ray oscilloscope (with accurately calibrated timebase)
Microphone
Connecting wires

In addition to the apparatus listed above, a signal generator is available. However, the scale of this generator is unreliable and cannot be used to give an indication of frequency. No other signal generator is available.

Any other standard equipment (which may be found in a school or college science laboratory) can be used.

In your account you should pay particular attention to:

(a) the procedure to be followed,

(b) how the magnitude of the output signal from the microphone may be measured,

(c) how the frequency of the signal may be determined,

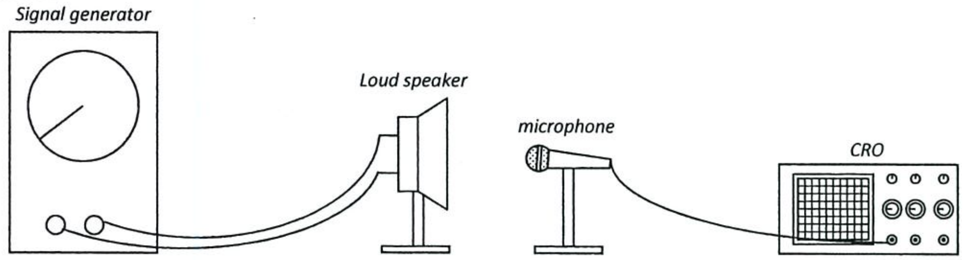
(d) precautions taken and control of variables.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labelled diagram showing • Signal generator connected to a loudspeaker • Microphone connected to a CRO • Microphone positioned close to and facing the loudspeaker
Variables	4	• Change frequency of signal generator, measure amplitude of microphone output and repeat for ≥ 8 more iteration • Use CRO to measure frequency • Calculate $f = 1/T$ • Use CRO to measure amplitude of microphone output
Analysis	2	• Hypothesize $A = k(f)^n$. $\lg A = n \lg f + \lg k$ • Plot $\lg A$ vs $\lg f$. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept: lg k
Reliability	max. 3	Any good further design details, some of these might be: • Details of using CRO (up to 2 marks may be scored): o Scaling and shifting o y-scale calculation, o timebase calculation • Discussion on frequency response of loudspeaker (output of speaker may vary with frequency for the same signal generator output) • Method to keep distance between loudspeaker and microphone constant • Monitor output from signal generator (e.g. connect signal generator output to a CRO) and keep output constant • Perform experiment away from external noise/soundproof room
safety	1	Any relevant safety precaution, e.g.: • Wear ear plug to protect ears from loud sound

Suggested Solution

Diagram



Procedures

1. *Set up the apparatus as shown.*
2. *Set the signal generator to a frequency of 4000 Hz. The amplitude should be adjusted until a clear signal is picked up comfortably by the CRO.*
3. *Adjust the X-scale, X-shift, Y-scale and Y-shift setting of the CRO so that only one or two complete cycles are displayed on the CRO.*
4. *Measure the period of the sound wave T by multiplying the length of one cycle with the time-base. For e.g. if one cycle occupies 5.0 cm on the display, and the time-base is 0.05 ms/cm, the period will be calculated to be 5.0 x 0.05 = 0.25 ms.*
5. *Calculate frequency f by f = 1/T.*
6. *Measure the amplitude of the microphone output A by multiplying the amplitude of the voltage signal as displayed on the CRO screen by the Y-scale.*
7. *Repeat the experiment (steps 3 to 6) for other values of f.*
8. *Hypothesize $A = k(f)^n$. Linearize $\lg A = n \lg f + \lg k$. Plot lg A vs lg f. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept: lg k*
9. *Amplitude of sound emitted by loudspeaker should be kept constant. To achieve this, the amplitude of the signal generator is kept constant. The loudspeaker must have uniform frequency over the frequency range used in this experiment.*
10. *Distance between the loudspeaker and the microphone must be kept constant by checking after every reading.*

Safety Precautions

11. *Wear ear plugs to protect the ears.*

Additional Details

12. *Experiment should be conducted in a quiet room to reduce background noise literally.*

Notes by Editor

- *Do not be misled by the scene setting narrative. We understand from the examiners' report that many candidates used the bat as the sound source.*

- *The output of any loudspeaker is also dependent on frequency. A loudspeaker has a so-called frequency response. Typically, for input signal of the same amplitude, the output amplitude is constant only over a certain range of frequency. Beyond both ends of this middle band, the output amplitude falls towards zero. That is the reason your hifi system comes with tweeters and hoofers, which are loudspeakers designed with middle bands at high and low pitched notes respectively.*

F. SUPERPOSITION

19 UCLES 2002 Nov P5 Q1 Umbrella Diffraction Grating

A manufacturer of umbrellas is attempting to cut costs by using cloth of coarsely-woven material instead of finely-woven material, as shown in Fig. 1.1.

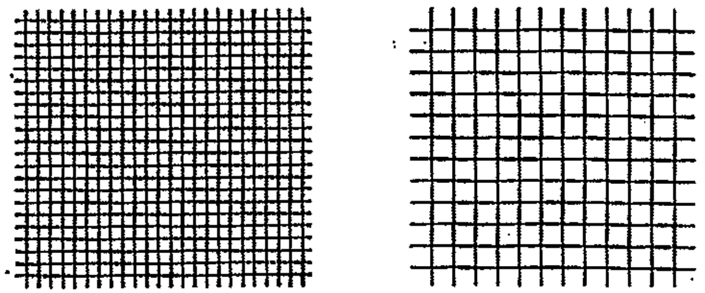


Fig. 1.1

One problem of using the coarsely-woven material is that water may pass through the material when water drops fall onto it, as shown in Fig. 1.2.

$d \sin\theta = m\lambda$

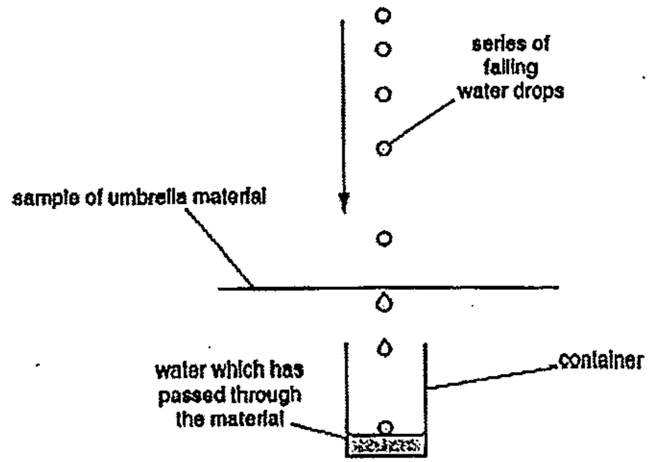


Fig. 1.2

The individual threads in a cloth are very close together. Under certain conditions, where light passes through the material, it behaves like a diffraction grating.

Design an experiment to investigate how the rate at which water passes through a sample of umbrella material depends upon the separation of the individual threads in the material.

You may assume that the following equipment is available, together with any other apparatus which may be found in a school or college science laboratory.

Ammeter
Battery
Cloths of variously spaced threads
Connecting wires
Funnel
Large tank of water
Low power helium-neon laser emitting light of wavelength 633 nm
Measuring cylinder
Metre rule
Oscilloscope
Screen
Top pan balance
Umbrella
Voltmeter

You should draw diagrams showing the arrangement of your apparatus. In your account you should pay particular attention to

(a) how the rate of flow of water through the material would be measured,

(b) how the separation of the threads in the cloth would be measured by a method involving the diffraction of light,

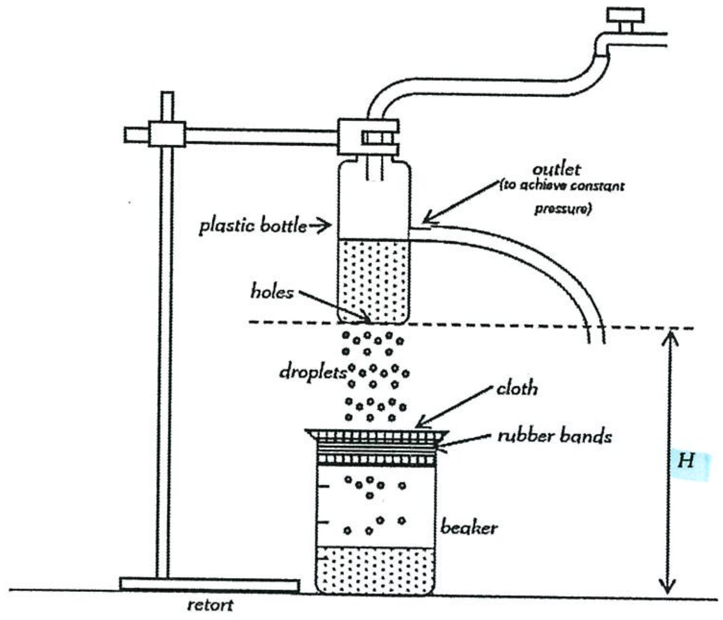
(c) control of variables.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labelled diagram showing • A setup to measure volume flow rate • A second setup to measure thread separation (Correct arrangement of laser, cloth and screen)
Variables	4	• Changing cloth and repeating experiment and collecting data for ≥ 8 more iteration (or for all cloth used) • Method of measuring the volume flow rate of water (e.g. beaker and stopwatch) • Sketch of the two-dimensional diffraction pattern • Method of measuring fringe spacing/angle of deviation
Analysis	3	• Show how the thread separation can be calculated (e.g. of $n\lambda = d\sin\theta$) • Hypothesize $rate = k(d)^n$. Linearize: $\lg rate = n \lg d + \lg k$. • Plot lg *rate* vs lg *d*. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept = lg k
Reliability	max. 2	Any good further design details, some of these might be: • Method to achieve constant rate of water dropping onto the cloth (e.g. constant drop height, constant pressure head) • Allowing the cloth to become wet before measuring flow rate (or dry before the diffraction test, or do diffraction test before the water flow test) • Using trigonometric ratio to obtain angle of deviation • Using higher order maxima to reduce percentage error in measurement • Using large distance between cloth and screen to reduce percentage error • Measuring the angle of deviation in 4 different directions, take average • Pasting a grid paper on screen to aid in measuring fringe separation • Method to ensure constant tension in the cloth
safety	1	Any relevant safety precaution relating to the use of laser, e.g.: • Do not point laser beam into other people's eyes/Do not look directly into laser beam

Suggested Solution

Diagram

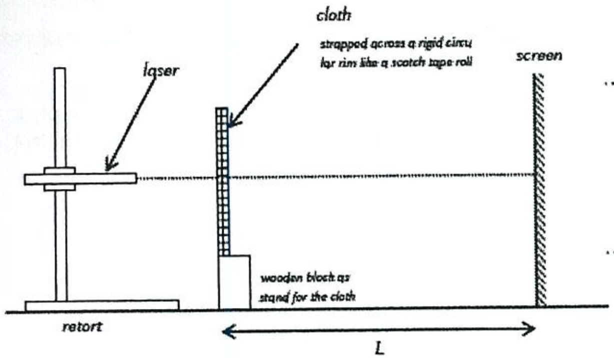


flow rate experiment

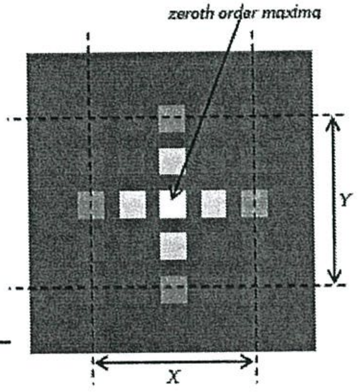
Procedure

Obtaining the flow rate

1. *Refer to the diagram above for the setup of apparatus.*
2. *The plastic bottle's bottom has 10 holes pierced by a needle, distributed evenly.*
3. *An outlet of diameter about 1 cm is pierced about 15 cm from the bottom of the bottle. This outlet serves to drain excess water to make sure the droplets are dripping under constant pressure condition. The same "droplet dispenser" should be used for all experiment to ensure the drop rate and the drop height are constant.*
4. *Measure the height of the bottle above the ground H.*
5. *Turn on the tap. Adjust the tap flow and wait for the "droplet dispenser" to achieve steady state condition.*
6. *Move the beaker (with the cloth strapped across its mouth) into position centred about the droplets. The same beaker should be used for all experiments so that the area of the cloth and the collection area are constant. All the cloths should be strapped to about the same tightness so that the thread separation is not adversely affected.*
7. *Start the stopwatch immediately.*
8. *Stop the stopwatch at $\Delta t = 5$ min*
9. *Empty all the water in the beaker into a measuring cylinder. Measure the volume V.*
10. *Calculate the flow rate (in L/min) by $\frac{V}{\Delta t}$.*



diffraction experiment setup



expected fringe pattern on the screen

Obtaining the thread separation

11. Set up the apparatus as shown above.
12. Switch on the laser. Double check that the laser is oriented perpendicular to both the grating and screen.
13. Measure with a measuring tape the distance between the grating and the screen L.
14. Measure with a ruler the distance between the two 2nd order vertical fringes Y, and the two 2nd order horizontal fringes X.
15. Calculate D by averaging X and Y, $D=\frac{1}{2}(X+Y)$
16. Calculate $\theta=\tan^{-1}(\frac{D}{2}\div L)$
17. Calculate thread separation d using $d\sin\theta=2(633\times10^{-9})$
18. Repeat the whole experiment for other pieces of cloth.

Analysis

19. Hypothesize $rate=k(d)^n$. Linearize: lg rate = n lg d + lg k. Plot lg *rate* vs lg *d*. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept: lg k

Safety Precautions

19. Do not point the laser beam into some one's eyes.
20. Do not look directly into the laser beam.

Additional Details

21. The cloth should be dry when performing the diffraction experiment.
22. Δt can be adjusted so that a good amount of water is collected.
23. It is preferable to conduct the diffraction experiment in a dim environment for better contrast. If higher order maxima were distinctly observable, they should be used (instead of the 2nd order) to reduce fractional uncertainty.

G. ELECTROMAGNETISM

20 UCLES 2002 Nov P5 Q2 Magnetic Flux Density of a Circular Coil (1)

Flat circular coils carrying a current can be used in television sets to deflect a electrons. ror

Fig. 2.1 illustrates the magnetic flux pattern due to a narrow circular coil carrying a current.

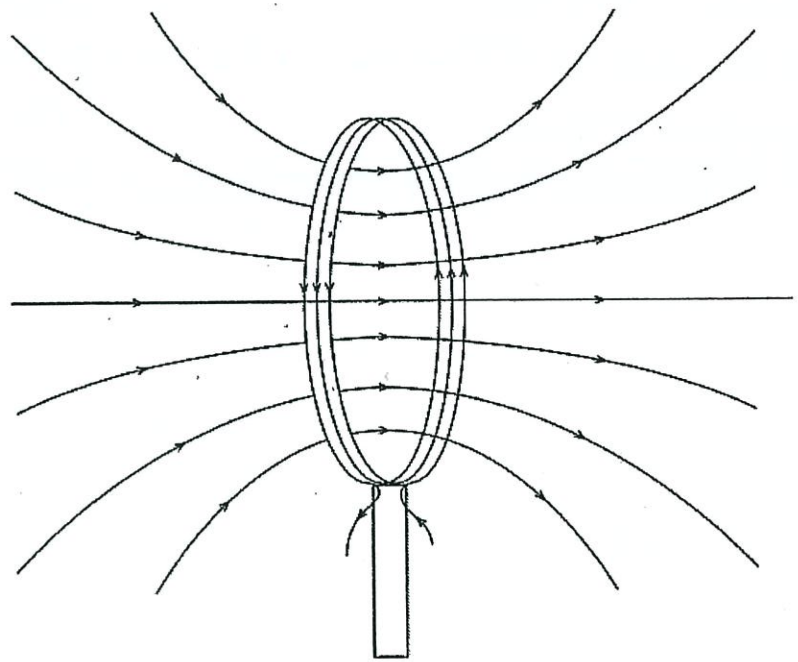


Fig. 2.1

Theory suggests that the magnetic flux density B at the centre of a flat circular coil of N turns and radius r carrying a current I is given by the expression

$$B = \frac{\mu_0 N I}{2r}$$

where μ_0 is the permeability of free space.

Design an experiment to show that the magnetic flux density at the centre of a flat coil is directly proportional to the number of turns in the coil. You should draw a diagram showing how the apparatus would be arranged. In your account you should pay particular attention to

(a) the method of measuring the magnetic flux density,

(b) the procedure to be followed,

(c) control of variables.

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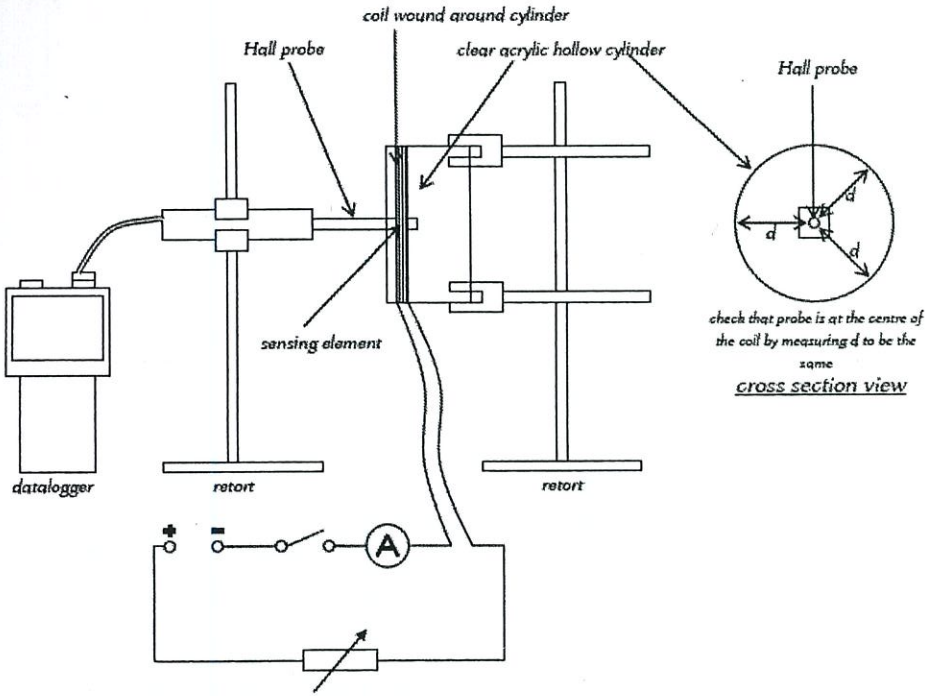
Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labelled diagram showing • Power supply, coil and ammeter connected in series • Correct orientation of the Hall probe (parallel to coil in axial mode)
Variables	3	• Vary N, measure B and repeat steps (e.g. for ≥ 8 more iteration) • Use Hall probe with datalogger to measure B • Method to determine centre of coil (e.g. look for maximum magnetic field, use ruler to measure)
Analysis	2	• Plot a graph of B against N • Statement that states "Relationship is valid if graph is a straight line passing through the origin"
Reliability	max. 4	Any good further design details, some of these might be: • Discussion or preliminary experiment to create a large enough magnetic field, e.g. large current or large number of turns • Method to monitor and maintain constant current (e.g. ammeter and rheostat) • Method to align orientation of the Hall probe (e.g. use of set square, fix to rule, optical bench or equivalent) • Conduct experiment away from other magnetic fields/A statement that the Earth's magnetic field is negligible/Take into account background magnetic field • Method to keep current in the coil constant • Method to keep radius of the coil constant
safety	1	Any relevant safety precaution, e.g.: • Switch off power supply when not in use • Do not touch coil with bare fingers because it could be hot

Suggested Solution

Diagram



check that probe is at the centre of the coil by measuring d to be the same

cross section view

Procedure

1. Set up the apparatus as shown. Beginning with N = 5.
2. Set the Hall probe to "axial" mode, i.e. measuring magnetic field in the direction into the stem.
3. Make sure that the axes of the hall probe and the coil are aligned.
4. Check that the sensing element is at the centre of the coil. This should be verified by looking from the side of the acrylic cylinder, and looking into the coil. The latter can be further checked by measuring the perpendicular distances between the probe and the coil for three different points, and checking that they are the same (refer to cross section view).
5. "Zero" the Hall probe to eliminate the effect of "background" magnetic field.
6. Close the circuit.
7. Adjust the rheostat until the ammeter reads 1.0 A.
8. Measure the magnetic flux density B, as shown on the datalogger display.
9. Open the circuit.
10. Repeat steps 3 to 8 for 7 other values of N, increasing N by 1 each time.
11. Plot a graph of B vs N. If the suggested formula is valid, linear trend should be observed, and the best fit line should pass through the origin.

Safety Precautions

12. Always leave the circuit open except when making measurements to prevent overheating.
13. Do not touch the wires with bare fingers since they could be hot and scalding may happen.

Additional Details

14. Radius of the cylinder should be large compared to the thickness of the coil wires so that it remains a flat circular coil.

Notes by Editor

- *Earth's magnetic field can be ignored since the hall probe is "zeroed". It may also be argued that the Earth's magnetic field is negligible compared to the circular coil's.*

21 CIE 2010 Jun P5 Q2 Magnetic Flux Density of a Circular Coil (2)

A current in a flat circular coil produces a magnetic field.

A student suggests that the strength B of the magnetic field is related to the distance x from the centre of the coil (see Fig. 1.1) by the equation

$$B = B_0 e^{-px}$$

where B_0 is the strength of the magnetic field for $x = 0$, and p is a constant.

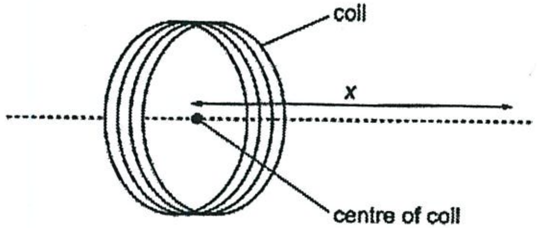


Fig. 1.1

Design a laboratory experiment that uses a Hall probe to investigate the relationship between B and x. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

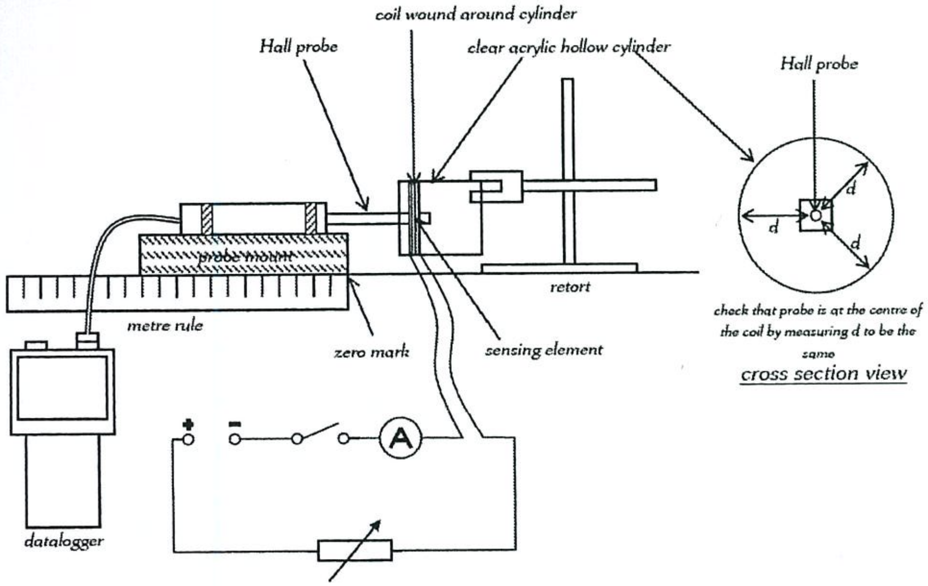
(e) the safety precautions to be taken.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labelled diagram showing • Coil and Hall probe with a means of read out appropriately positioned along axis. • Coil connected to a power supply
Variables	4	• Vary x, measure B and repeat steps (e.g. for ≥ 8 more iteration) • Measure x with a ruler • Hall probe at correct orientation to give maximum output for each reading (e.g. axial mode and stem of probe parallel to axis of coil) • Method to determine axis of coil or to find $x = 0$
Analysis	2	• $\ln B = -px + \ln B_0$ Plot a graph of $\ln B$ against x • Relationship is valid if graph obtained is a straight line where $-p$ is the gradient and $\ln B_0$ is the y-intercept.
Reliability	max. 3	Any good further design details, some of these might be: • Discussion or preliminary experiment to create a large enough magnetic field, e.g. large current or large number of turns • Method to keep current in the coil constant (e.g. rheostat and ammeter) • Method to align orientation of the Hall probe (e.g. use of set square, fix to rule, optical bench or equivalent) • Detail of calibration of Hall probe (e.g. B is proportional to voltage across Hall probe, calibrate probe in a known magnetic field) • Repeat experiment with Hall probe reversed, or retracting the changes in x • Method to keep number of turns, radius and current in the coil constant • Avoid external magnetic fields/take into account background magnetic field
safety	1	Any relevant safety precaution relating to large current in coil/heating, e.g.: • Switch off when not in use to avoid overheating the coil • Do not touch the coil because it is hot

Suggested Solution

Diagram



Procedure

1. *Set up the apparatus as shown in figure above.*
2. *The coil consists of 50 turns of wire wound compactly around hollow cylinder made of clear acrylic. The number of turns in the coil is kept constant.*
3. *The hall probe is securely duct taped to a rectangular block, hence forth referred to as the probe mount.*
4. *Set the Hall probe to "axial" mode, i.e. measuring magnetic field in the direction into the stem.*
5. *Make sure that the axes of the hall probe and the coil are aligned.*
6. *Check that the sensing element is at the centre of the coil.*
7. *Place a metre rule against the side of the probe mount, such the metre rule's zero mark is at the front of the edge of the probe mount.*
8. *"Zero" the Hall probe to eliminate the effect of "background" magnetic field.*
9. *Close the circuit.*
10. *Adjust the rheostat until the ammeter reads 2.0 A. The current in the coil is kept constant throughout the experiment.*
11. *Measure the magnetic flux density B, as shown on the datalogger display. This corresponds to the data for x = 0.*
12. *Open the circuit.*
13. *Repeat steps 8 to 12 for 7 other values of x, incrementing x by 1.0 cm each time, until the magnetic field is too weak to be measured.*
14. $\ln B = \ln B_0 - px$

    Plot a graph of ln B vs x. If the suggested formula is valid, a linear trend should be observed. The gradient of the best fit line would correspond to -p, and the y-intercept $\ln B_0$.

Safety Precautions

15. *Always leave the circuit open except when making measurements to prevent overheating.*
16. *Do not touch the wires with bare fingers since they could be hot and scalding may happen.*

Additional Details

17. *'Make sure that the axes of the hall probe and the coil are aligned.' - This should be verified by looking from the side of the acrylic cylinder, and looking into the coil.*

    'Check that the sensing element is at the centre of the coil.' - This can be further checked by measuring the perpendicular distances between the probe and the coil for three different points, and checking that they are the same (refer to cross section view).
18. *It is useful at step 7 to use duct tape to securely tape the ruler to the workbench to prevent accidental movement of the metre rule. Care should also be taken to ensure the retort and the coil remains in the same position from this point onwards.*
19. *It is beneficial to repeat the experiment in the reverse order of decreasing x. That is, after step 13, repeat steps 8 to 12 again, but this time from the largest x back to x = 0, decreasing x by 1.0 cm each time. Averaging x will reduce random error.*
20. *A preliminary trial should be performed to make sure the magnetic field of the coil is sufficiently strong. Increase the number of turns or increase the current if the field is too weak.*

Notes by Editor

- *Earth's magnetic field can be ignored since the hall probe is "zeroed". It may also be argued that the Earth's magnetic field is negligible compared to the circular coil's.*

22 CIE 2004 Jun P5 Q2 Deflection of Beta Radiation by Magnetic Field

Beta particles can be deflected by magnetic fields.

Design a laboratory experiment to investigate how magnetic flux density affects the angle through which beta particles are deflected when they pass through a uniform magnetic field. The only radioactive source that is available to you is a Radium-226 source which emits α, β and γ radiation.

You should draw a diagram showing the arrangement of your apparatus. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the method by which beta particles **only** would be detected,

(c) the method of measuring the angle of deflection,

(d) how the magnetic field would be produced, measured and changed,

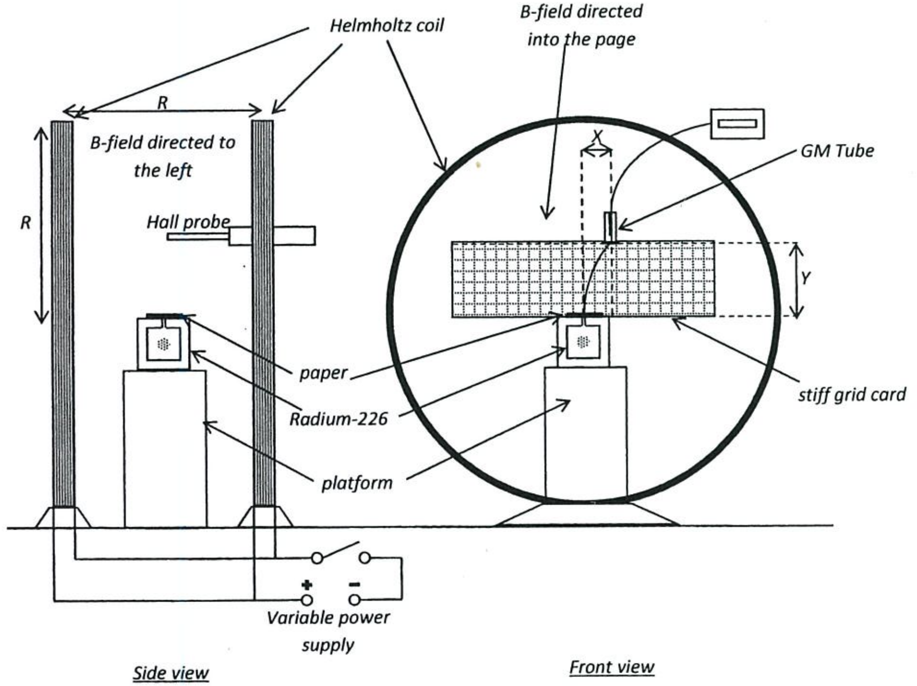
(e) any safety precautions you would take.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	2	Clear, workable labeled diagram showing • Region of uniform magnetic field to conduct experiment • Method of measuring θ (e.g. detector at edge of large protractor, measure lengths and use trigo ratio, reject vague 'use a protractor')
Variables	5	• Vary magnetic flux density B, measure angle of deflection θ and repeat steps (e.g. for ≥ 8 iteration) • Method to remove α radiation (e.g. use paper or distance to detector > few cm of air, reject lead/aluminum plate since it absorbs β as well or use of magnetic field to deflect α radiation and β radiation in different directions) • Statement that gamma radiation is undeflected. Reject lead plate since it absorbs β as well. • Method to vary B (e.g. change the current in coil) • Use Hall probe to measure B
Analysis	2	• Hypothesize $\vartheta = k(B)^n$. Linearize: $\lg \theta = n \lg B + \lg k$ • Plot $\lg \vartheta$ vs $\lg B$. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept: lg k
Reliability	max. 2	Any good further design details, some of these might be: • Type of detector (GM tube/film, reject cloud chamber and CRO) selected • Repeat readings to allow for randomness of activity • Correct direction of deflection of beta on diagram • Helmholtz coil (separation of coils = radius of coils) for uniform B field. • Correct orientation of Hall probe's sensing element. • Collimation ideas • Detector/screen far enough so that θ can be measured with smaller percentage error • Make sure there is no interference from other magnetic field nearby
safety	1	Any relevant safety precaution each relating to radioactive source: • Store source in lead lined box when not in use/do not point source at people/do not look directly at source/use tongs to handle source. (Reject non feasible suggestions such as wear lead suits/lead lined rooms/lead gloves etc)

Suggested Solution

Diagram



Procedure

1. *Set up the apparatus as shown.*
2. *Conduct the experiment under ambient conditions such as room temperature and humidity.*
3. *The two coils that make up the Helmholtz coil should be spaced about one radius apart so as to achieve a (close to) uniform magnetic field in the region between the coils.*
4. *With the circuit switched off, use the hall probe to measure the magnetic flux density in the region between the coils. The Hall probe should be set to the "axial" mode so that it measures magnetic field in the direction "into" the coil. "Zero" the hall probe to eliminate the effect of "background" magnetic field.*
5. *Position the Radium-226 source at the mid-point between the coils. (Use a platform support if necessary) The opening of the container should be pointing vertically upward. Cover the opening with a piece of paper to block out alpha radiation.*
6. *A stiff rectangular grid card is mounted on the Radium-226 source to aid in subsequent measurement.*
7. *Comb the GM tube along the edge of the grid card. Verify that the count rate is highest at position X=0.*
8. *Switch on the power supply.*
9. *Adjust the power supply to the desired voltage.*

10. *Measure the magnetic flux density B using the Hall probe.*
11. *Comb the GM tube along the top edge of the grid card. Find the position X on the right of X = 0 where the count rate is highest. If the magnetic field is arranged to point into the page (in front view), the beta particles are expected to be deflected to the right. Gamma radiation is not deflected by magnetic field and hence will not be picked up by the GM tube.*
12. *Calculate the angle of deviation θ by $\theta = \tan^{-1}\frac{X}{Y}$, where Y is the distance between the opening of the beta emitter and the top edge of the grid card.*
13. *Repeat steps 8 to 11 for 7 other values of magnetic flux density.*
14. *Hypothesize $\vartheta = k(B)^n$. Linearise: $\lg \vartheta = n \lg B + \lg k$. Plot $\lg \vartheta$ vs $\lg B$. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept: lg k*

Safety Precautions

15. *Use a pair of tongs to handle the radioactive source to avoid direct physical contact. Store the source in lead lined container when not in use to minimize radioactive exposure.*
16. *Switch off the Helmholtz coil when not in use to prevent overheating.*

Additional Details

17. *The Radium-226 source is expected to be a collimated beam. If not an aluminum tube could be attached to the opening of the container so that the beta stream is directional.*

Notes by Editor

- *Helmholtz coil is the standard method to obtain a uniform magnetic field. If you want to use two pole magnets (and vary the distance between them to vary the field strength), you should at least state clearly that you are using two gigantic pole magnets so that you have a big enough region of uniform magnetic field density to conduct your experiment.*
- *A better detector than the GM tube (which may be too bulky) could be a film/screen that is sensitive to electron beams. But do not make the mistake of conducting the experiment in a cloud chamber.*

H. NUCLEAR

23 UCLES 2004 Nov P5 Q2 Gamma Ray Half Length

The attenuation of a γ-ray beam is the reduction in its intensity due to its passage through a material. One way of investigating the attenuation of a γ-ray beam is to measure the half-value thickness. The half-value thickness is the thickness of material that reduces the intensity of the γ-ray beam to half its original value.

Design a laboratory experiment to measure the half-value thickness of a material. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) how the γ-rays would be detected and the measurements that would be taken,

(c) the control of variables,

(d) the safety precautions that you would take,

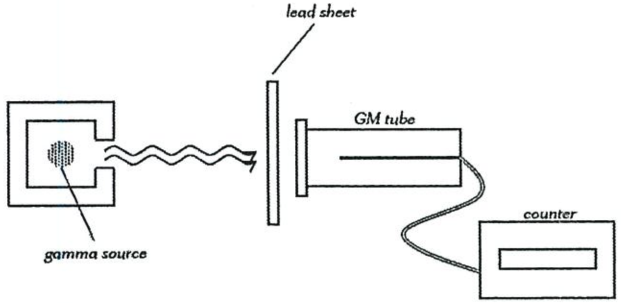
(e) any precautions that you would take to improve the accuracy of the experiment.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	Clear, workable labeled diagram showing • Gamma source, GM tube and an absorber in between
Variables	4	• Vary thickness of absorber, measure count rate for ≥ 8 iteration • Measurement of the thickness of the absorber using a micrometer screw gauge, vernier caliper or travelling microscope • Measurement of count rate using GM tube connected to counter/any appropriate detector • Use of the term 'count rate'
Analysis	2	• Plotting a graph of count rate against thickness • Locating the thickness of material that corresponds to half the initial count rate without any material placed between radioactive source and detector
Reliability	max. 4	Any good further design details, some of these might be: • Taking into account background radiation • Using lead or concrete as absorber for gamma-rays • More details on how to use the count rate vs thickness graph to obtain half-value thickness • Measure thickness at different locations and take average • Repeating count rate measurement because of random nature of radioactive decay • Using a source with a long half life mark out using tape • Keep distance between the source and the detector constant
safety	1	One relevant safety precaution each relating to handling of radioactive source: • Store source in lead lined box when not in use/do not point source at people/do not look directly at source/use a pair of tongs to handle source. (Reject non feasible suggestions such as wear lead suits/lead lined rooms/lead gloves etc)

Suggested Solution

Diagram



Procedure
1. Refer to the diagram above for the setup of the experiment.
2. Prepare 8 lead sheets of varying thickness (probably a few mm).
3. Measure the thickness D of each lead sheet using a micrometer screw gauge.
4. Repeat step 3 at two other points on the lead sheet so that averaging can be done to achieve better accuracy.
5. Without the gamma source and any lead sheets, measure the background count rate, C_b, using the Geiger-Muller counter.
6. With the gamma source in position, but without any lead sheet in between the gamma source and the GM Tube, measure the un-attenuated count rate C_u. (subtract C_b from the count rate to account for the background radiation). Once set up, the distance between the source and the GM tube and their orientations should remain fixed.
7. Insert a lead sheet in between the gamma source and the GM tube. All lead sheets must be inserted normal to the source and GM tube windows, and near the GM tube window.
8. Record the new count rate C in counts per minute. (subtract C_b from the count rate)
9. Repeat step 8 so that averaging can be done for better accuracy. – since radioactive decay is a random process
10. Repeat steps 7 to 9 for 8 or more lead sheets of different thickness.
11. Plot a graph of C against D using the data points.
12. Draw the best-fit-curve. The half-value thickness is obtained by reading the value of D corresponding to $C = 0.5C_u$ on the best-fit-curve.

Safety Precautions

13. Use a pair of tongs to handle the radioactive source to avoid direct physical contact.
14. Put the source back in its lead box immediately after use to reduce unnecessary radioactive exposure.

Additional Details

15. The source should have a long half-life so that its activity is constant throughout the experiment.
16. A trial should be performed prior to actual experiment to find out roughly the thickness that will cut off the gamma source almost completely. The experiment can then be carried out using lead sheets of thickness ranging from 20% to 80% of that thickness.

Editor's Comments
- Beside lead sheets, concrete blocks is another possible material to use. If so, vernier calipers will be more appropriate than a micrometer screw gauge for the kind of thickness expected.

24 UCLES 2001 Nov P4 Q3 Absorption of Beta Radiation

A particular radioactive source emits alpha (α), beta (β) and gamma (γ) radiation.
Information relating to the penetrating properties of each type of radiation from this source is given in Fig. 3.1.

radiation type	penetrating properties
α	Complete absorption by a sheet of paper or by a sheet of aluminium 5 mm thick
β	Negligible absorption by paper; 99% absorption by a sheet of aluminium 5 mm thick
γ	Negligible absorption by paper or by a sheet of aluminium 5 mm thick

Fig. 3.1

A scientist wishes to know how well a beam of beta radiation is absorbed by air, but the only radioactive source available is a radioisotope which emits all three types of radiation as detailed above. Design a laboratory experiment to investigate how the absorption of beta radiation only depends on the distance which the radiation has travelled through the air. The information in Fig. 3.1 may be helpful in some aspects of the design. You may assume that all the equipment listed below is available, together with any other standard laboratory apparatus which may be found in a school or college science laboratory.

Radioactive source emitting α-, β- and γ- radiation	Ammeter
Ratemeter	Voltmeter
Scalar	Stopwatch
Long glass tank filled with water	Small plate of lead (2 mm thick)
Oscilloscope	Small sheet of aluminium (5 mm thick)
Geiger-Müller tube	Sheet of paper
Signal generator	Metre rule
High voltage power supply unit	Tongs

You should draw a diagram of the arrangement of the apparatus you would use, and in your account you should pay particular attention to

(a) the method by which the count rate due to beta radiation only is measured,

(b) the procedure to be followed,

(c) any safety precautions which you would take.

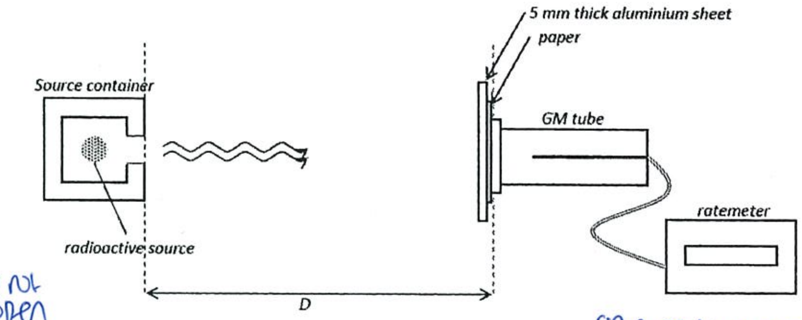
Suggested Mark Scheme

	Marks	Marking Points
Diagram	1	Clear, workable labelled diagram showing • Radioactive source and GM tube as the detector
Variables	6	• Vary distance between source and detector, measure count rate for ≥ 8 iteration • Using a ruler to measure *D* • Using GM tube connected to ratemeter to measure count rate • Use paper to absorb α-particle. Measure count rate • Use aluminum sheet to absorb α and β. Measure count rate again • Subtract to find count rate due to β only
Analysis	2	• Hypothesize *count-rate* = ke^{nD}. ln (*count-rate*) = n*D* + ln k. • Plot ln *count-rate* vs *D*. Relation is verified if a straight line is obtained. Gradient: n; y-intercept: ln k
Reliability	max. 2	Any good further design details, some of these might be: • Repeating the readings and take average, since radioactive decay is a spontaneous process • Taking into account background radiation • Observation there is error that high-energy beta will still pass through the aluminium sheet • Observation that there is error in the measurement of D because of the length of the GM tube • Making sure that the mica window always faces radioactive source directly (e.g. use set square) • Detail in measuring D (e.g. lining source and GM tube along a ruler/tape rule fixed on bench top) • A statement that the source should have a long half-life
safety	1	Any relevant safety precaution each relating to radioactive source: • Store source in lead lined box when not in use/do not point source at people/do not look directly at source/use tongs to handle source. (Reject non feasible suggestions such as wear lead suits/lead lined rooms/lead gloves etc)

- conduct a preliminary trial to find distance D where CB is just 0.
the values of D for the experiment should range from 20% to 80% of this maximum D value.

Suggested Solution

Diagram



source not open

since radioactive decay is a random process

Procedure

1. *Strap a sheet of paper across the entire mica window of the GM tube.*
2. *Measure the background radiation of beta and gamma radiation, $C_{\beta\gamma,b}$ (If the rate is fluctuating, take 3 readings at 2 seconds apart, and obtain average to reduce random error)*
3. *Strap another sheet of paper and a 5 mm thick aluminum sheet across the entire mica window of the GM tube.*
4. *Measure the background radiation of gamma radiation only, $C_{\gamma,b}$ (If the rate is fluctuating, take 3 readings at 2 seconds apart, and obtain average to reduce random error)*
5. *Using a metre rule, positioned the radioactive source to be 80.0 cm (i.e. D = 80.0 cm) from the GM tube.*
6. *Make sure the radioactive source is facing normally into the GM tube's mica window.* using a set square
7. *Record down the count rate C_1. (If the rate is fluctuating, take 3 readings at 2 seconds apart, and obtain average to reduce random error)* with the sheet and paper
8. *Calculate the gamma count rate due to radioactive source $C_\gamma = C_1 - C_{\gamma,b}$*
9. *Repeat steps 2 to 4 for D = 70.0 cm, 60.0 cm ... 10.0 cm.*
10. *Remove the aluminum sheet and repeat the experiment (steps 5 to step 7).*
11. *Record the count rates as C_2.* only beta
12. *Calculate the gamma plus beta count rate due to radioactive source $C_{\beta\gamma} = C_2 - C_{\beta\gamma,b}$*
13. *Calculate the count rate for only beta radiation at each position C_β using $C_\beta = C_{\beta\gamma} - C_\gamma$*
14. *Collect at least 8 sets of data.* Hypothesize *count-rate* = ke^{nD}. Linearise: *ln (count-rate) = nD + ln k.* Plot ln *count-rate* vs *D*. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept: ln k.

Safety Precautions

15. *Use a pair of tongs to handle the radioactive source to avoid direct physical contact.*
16. *Put the source back in its lead box immediately after use to reduce unnecessary radioactive exposure.*

Additional Details

17. *Use the high voltage power supply unit to power the GM tube, which typically requires about 300 V to function.*
18. *There is arguably some error in the measurement of x due to the thickness of the aluminum sheet.*

Notes by Editor

- *There is arguably some inaccuracy because 1% of beta radiation (the high energy ones) is able to pass through the aluminum sheet.*

25 CIE 2005 Jun P5 Q2 Smoke Detector

Many homes have smoke detectors fitted to the ceilings of certain rooms to provide an early warning of a fire. These detectors contain a weak radioactive source that ionises the air between two metal plates. See Fig.2.1.

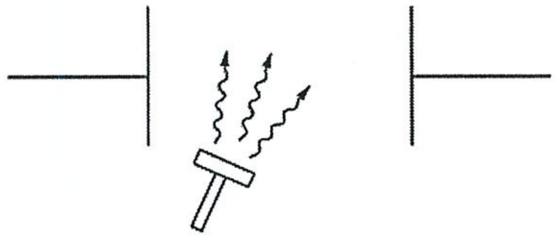


Fig.2.1

A low voltage battery in the detector causes the ions to move. This produces a very small ionisation current in a circuit containing the battery and the plates. Any reduction in this ionisation current due to smoke is detected and an alarm sounds.

An airline company wishes to install some of these smoke detectors in its aircraft and needs to know if changes in air pressure will affect the ionisation current.

Design a laboratory experiment to investigate how the ionisation current depends on air pressure. You should draw a detailed labelled diagram showing the arrangement of your apparatus. In your account you should pay particular attention to

(a) the type of source used in the investigation (i.e. whether it is an alpha, beta or gamma emitter) giving a reason for your choice,

(b) how the ionisation current would be measured (given that it is very small),

(c) the method of changing and measuring the air pressure,

(d) the procedure to be followed,

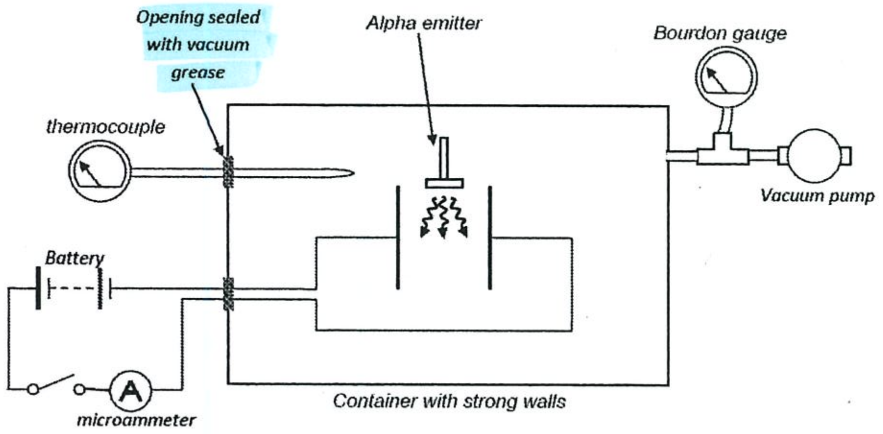
(e) any safety precautions that you would take.

Suggested Mark Scheme

	Marks	Marking Points
Diagram	3	Clear, workable labeled diagram showing • Ammeter connected correctly to power supply • 'Closed box' surrounding the equipment with gauge measuring the pressure in box • Vacuum pump to change pressure
Variables	4	• Vary pressure p, measure ionization current I and repeat steps (e.g. for ≥ 8 more iteration) • Use of alpha emitter as a source • Reason for choice of alpha emitter as a source (strongly ionizing) • Measure pressure using Bourdon gauge/pressure gauge/manometer/pressure sensor + datalogger
Analysis	1	• Hypothesize $I = kp^n$. Linearize: $\lg I = n \lg p + \lg k$. Plot $\lg I$ vs $\lg p$. Relation is verified if a straight line. Gradient: n; y-intercept: lg k
Reliability to reduce random error	max. 2	Any good further design details, some of these might be: • Use high voltage as current is small • Use of milliammeter/microammeter as current is small • Use GM tube and scalar/ratemeter to monitor activity to ensure that it does not change • Place source close to plates (as range of alpha in air is small) • Fix position of source relative to plates • Allow sufficient time for pressure and temperature in box to stabilise • Repeat experiment in increasing pressure for a second set of data, average for reliability. • Use of source of long half-life so that activity is constant
safety	2	One relevant safety precaution each relating to: • Handling of radioactive source: store source in lead lined box when not in use/do not point source at people/do not look directly at source/use a pair of tongs to handle source. (Reject non feasible suggestions such as wear lead suits/lead lined rooms/lead gloves etc) • Low/high pressure: Safety screens/wear safely goggles in case of implosion/explosion/use container with strong walls

Suggested Solution

Diagram



Procedure

1. *Set up the apparatus as shown. The position of the alpha emitter and the plates should be fixed using duct tapes so that their relative positions remain constant. The alpha source should have a long half-life so that its activity is constant throughout the entire experiment.*
2. *Activate the vacuum pump to reduce the pressure in the container.*
3. *Allow time for the pressure and temperature of air in the container to stabilize. Air temperature in the container is monitored with a thermocouple to make sure it remains at ambient temperature.*
4. *Measure the pressure p as shown by the Bourdon gauge.*
5. *Close the switch.*
6. *Measure the ionisation current I as shown by the microammter.*
7. *Open the switch*
8. *Repeat steps 2 to 7 for 7 other values of pressure.*
9. *Hypothesize $I = kp^n$. Linearize: $\lg I = n \lg p + \lg k$. Plot lg I vs lg p. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept: lg k*

Safety Precautions

10. *Store the alpha particle emitter source in a lead-lined box to reduce unnecessary radioactive exposure. Use a pair of tongs to handle the alpha particle emitter source.*
11. *Use a strong container that is able to withstand the pressure difference. Wear goggles in case the container explodes/implodes.*

Additional Details

12. *The alpha particle emitter source should be positioned near the plates because of the short range nature of alpha radiation in air.*
13. *Check for zero error of the microammeter since for this experiment the zero error could be significant.*

26 CIE 2003 Jun P5 Q2 GM Tube with Choice of Radioactive Sources

One type of radiation detector known as a Geiger-Müller tube is shown in Fig. 2.1.

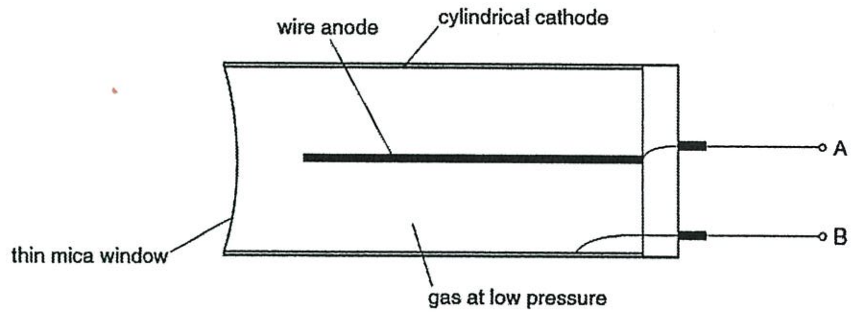


Fig. 2.1

In order for the tube to function, a potential difference V_{AB} has to be applied between A and B. The count rate registered by an instrument connected to the tube depends on several factors such as the distance from the radioactive source to the thin mica window, the activity of the source and V_{AB}. The tube can detect α, β and γ-radiation.

Design a laboratory experiment to investigate how the count rate due to γ-radiation only depends upon the potential difference V_{AB}. You have access to three different radioactive sources only. Information relating to each of these sources is given in the table below.

source	type of radiation emitted	half-life of source
Radium-226	α, β and γ	1600 years
Bismuth-214	β and γ only	20 minutes
Cobalt-60	β and γ only	5 years

You may assume that the following equipment is available, together with any other apparatus that may be found in a school or college science laboratory.

Aluminium plates of different thicknesses
Ammeter
Connecting wires
Datalogger
Geiger-Müller tube
Lead plates of different thicknesses
Metre rule
Oscilloscope
Ratemeter
Scaler
Signal generator
Source handling tool
Variable d.c. power supply
Voltmeter

You should draw a diagram showing the arrangement of your apparatus. In your account you should pay particular attention to

(a) which source you would use, giving a reason for your choice,

(b) the procedure to be followed, including how the count rate would be measured,

(c) the control of variables,

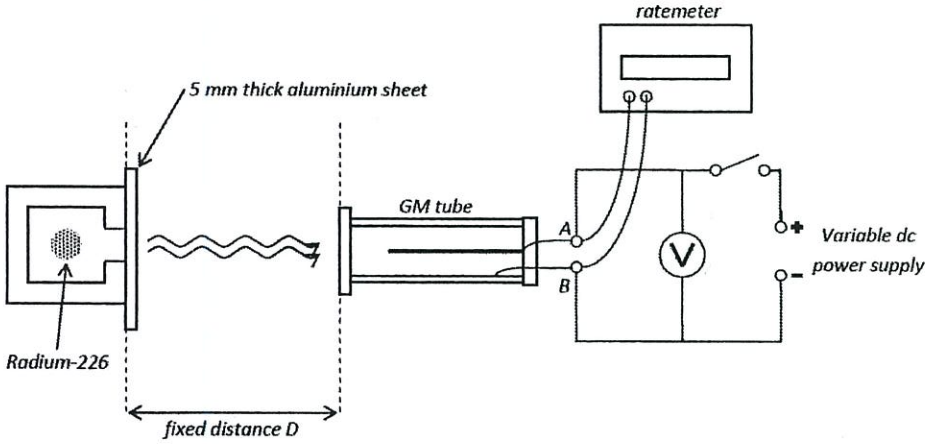
(d) any safety precautions you would take.

Suggested Mark Scheme

	Marks	Marking Points
<u>D</u>iagram	2	Clear, workable labelled diagram showing • Voltmeter connected in parallel with the GM tube or the supply • Ratemeter/scalar/datalogger connected to terminals A and B of GM tube
<u>V</u>ariables	4	• Measure p.d. and count rate; change p.d. and repeat for ≥ 8 more iteration • Radium or Cobalt source used • Reason for choice based on half-life • Method of removing α and β radiation (e.g. aluminum or <u>thin</u> lead)
<u>A</u>nalysis	2	• Hypothesize *count-rate* = $k(pd)^n$. Linearize: lg (*count-rate*) = n lg (*pd*) + lg k. • Plot lg *count-rate* vs lg *pd*. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept: lg k
<u>R</u>eliability	max. 2	Any good further design details, some of these might be: • Sensible value of p.d. applied to GM tube (i.e. 50 V to 1000 V) • Repeat readings to allow for randomness of radioactivity • Subtract background count rate • Aluminum sheets' thickness stated to be mm or cm • Keep distance from source to GM tube constant by checking after every measurement (mark out relative position using duct tape
<u>s</u>afety	2	Any two relevant safety precaution each relating to radioactive source: • Store source in lead lined box when not in use/do not point source at people/do not look directly at source/use a pair of tongs to handle radioactive source (Reject non feasible suggestions such as wear lead suits/lead lined rooms/lead gloves etc)

Suggested Solution

Diagram



Use Radium-226. Its long half-life of 1600 years ensures that its activity stays practically constant during the entire experiment. A 5-mm aluminum sheet covers the opening of the Radium-226 source so that alpha and beta radiation are fully absorbed, leaving only gamma radiation.

Procedure

1. *Set up the apparatus as shown.*
2. *Mark the positions of the Radium-226 and GM tube so that the distance between them can be kept constant throughout the experiment.*
3. *Close the circuit. Adjust the variable dc power supply so that the voltmeter shows about 200 V.*
4. *Record V_{AB} as shown on the voltmeter.*
5. *Record the count rate C_1 as shown on the ratemeter.*
6. *Repeat step 5 to take average.*
7. *Put the Radium-226 source back into its container lined with thick lead.*
8. *Record the background count rate C_0 as shown on the ratemeter.*
9. *Repeat step 8 to obtain an average background count since activity is random in nature.*
10. *Calculate count rate C using $C = C_1 - C_0$.*
11. *Put the Radium-226 source back into the setup, taking care to keep to its original distance D from the GM tube.*
12. *Repeat the experiment (steps 4 to 11), increasing the voltage in steps of 25 V, until 800 V. Obtain 8 sets of data.*
13. *Hypothesize $C = k(V_{AB})^n$. Linearize: $\lg C = n \lg V_{AB} + \lg k$. Plot $\lg C$ vs $\lg V_{AB}$. Relation is verified if a straight line graph is obtained. Gradient: n; y-intercept: lg k*

Safety Precautions

14. *Use a pair of tongs to handle the radioactive source to avoid direct physical contact.*
15. *Store the source in lead lined container when not in use to avoid unnecessary exposure to radioactive source.*

Notes by Editor

- *Notice that the background count rate must be taken at every V_{AB}, since the count rate is affected whenever V_{AB} is changed.*
- *This question came as a surprise to many because it forces upon us a situation when a separate power supply is to be used to provide the potential difference between the cathode and anode of the GM tube. In practice, ratemeters are designed to provide the potential difference to the GM tube. The only connection that needs to be made is a CNC cable between the GM tube and the ratemeter.*

at different voltages
☆ take repeated readings for background count rate too!

I. 3-VARIABLE PQ

27 2018 MJC Prelim P4 Q4

A student wishes to investigate projectile motion.

A small ball is rolled with velocity v along a horizontal surface. When the ball reaches the end of the horizontal surface, it falls and lands on a lower horizontal surface. The vertical displacement of the ball is h and the horizontal displacement of the ball is d, as shown in Fig. 4.1.

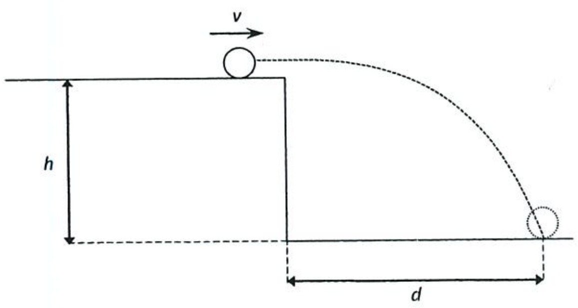


Fig. 4.1

The student suggests that d is dependent on h and v according to the equation

$$d = kh^p v^q$$ $\ln d = \ln k + p \ln h + q \ln v$

where k, p and q are constants to be determined.

Design a laboratory experiment to determine the values of k, p and q.

You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the identification and control of variables,

(b) the equipment you would use and measurements to be taken,

(c) procedure to be followed,

(d) the analysis of the data,

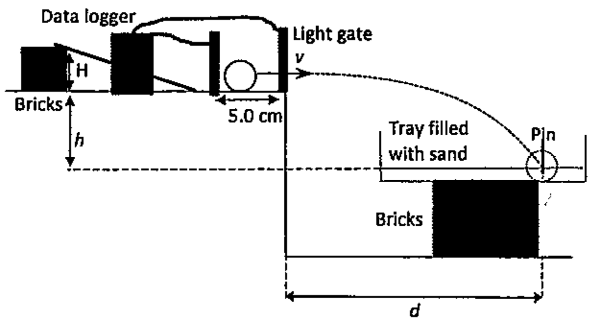
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Suggested Marking Scheme

	Marks	Marking Points
Diagram	1	Clear, labelled diagram showing clearly • a workable set up.
Variables	4	**V1.** Vary h, keep v constant for 10 sets of h and d. Then vary v, keep h constant for 10 sets of v and d. **V2.** The vertical distance of the surface of sand in the tray to the table surface is properly defined, varied and measured using appropriate equipment and method. **V3.** The horizontal linear speed of spherical object is determined using appropriate equipment (e.g. stopwatch and metre rule or measuring tape, timer, light gates and datalogger) and method (distance / time). **V4.** The distance d. is properly defined, varied and measured using appropriate equipment and method.
Analysis	3	**A1.** Linearise equation correctly and plot graphs of e.g. lg d vs lg h, lg d vs lg v. **A2.** p and q are determined from the gradient of graph. **A3.** k is determined using the y- intercept.
Reliability	max 3	Any good further design details, some of these might be: • Repeat measurements and take average for d • Use longer planks/ smaller angle of elevation so that the time of sphere rolling is relatively longer, and can be timed with smaller percentage error. • Method/ preliminary trials ○ to keep the spheres roll downslope in the same straight path of the shortest distance. ○ to ensure rolling and no sliding. ○ to determine where the ball lands • Method to ensure that the ball leaves the surface with the same horizontal speed • Suitable surface for projectile to land on, e.g. carbon paper, plasticine, sand pit, or a painted projectile that leaves a mark on the landing surface
safety	max 1	Any relevant safety precaution pertaining to the risk of flying ball, • Set up barrier around the setup area so that no one gets hit/injured by the flying ball.
Total	12	

Suggested Solution

Diagram



1. Set up a pair of light gates connected to a data logger. Use a meter rule to measure the distance between the light gates, place the gates 5.0 cm apart. Input the distance between the light gates into the data logger and set the data logger to show the time *t* for the ball to pass through the gates. Place a tray filled with sand on a brick placed on the ground at where the ball is expected to land.

Experiment I – Vary *h* to determine *p*

2. In order to ensure that the ball leaves the table surface with the same horizontal speed *v*, the ball is released from rest from the edge of a wooden board with the edge raised at a fixed height *H* above the surface. This can be done by resting the edge of the board on a brick.
3. Record the vertical distance of the surface of sand in the tray to the table surface, *h*.
4. The ball is now released and the location where it lands on the tray filled with sand can be marked by placing a pin there. Record the initial horizontal speed *v* that the ball leaves the horizontal surface where $v = 0.050/t$
5. Use a meter rule to measure the distance of the pin from the point directly below the edge of the table surface, *d*. Record this distance.
6. Repeat step 3 and 4 another two times and take the average <d>, where $\langle d \rangle = \frac{1}{3}(d_1 + d_2 + d_3)$
7. By adding more bricks under the tray filled with sand, we can vary *h*. Repeat steps 3 to 6 for another 8 different values of *h*.
8. $d = kh^p v^q$, lg <*d*> = *p* lg *h* + *q lg v* + *lg k*
9. Plot a graph of lg <*d*> against lg *h* such that the gradient $m_1 = p$ and y-intercept = *q lg v* + *lg k*.
10. Use the gradient to determine *p*.

Experiment II – Vary *v* to determine *q*

11. *h* is now kept constant by placing the tray on the ground and remove all bricks under the tray. Record *h*.
12. The initial horizontal speed *v* can be varied by varying *H*. This can be done by changing the number of bricks under the edge of the wooden board.

13. Repeat step 4 to 6 for at least 8 different values of *v*.
14. Plot a graph of lg *d* against lg *v* such that the gradient $m_2 = q$ and y-intercept = *p lg h* + *lg k*.
15. Use the gradient to determine *q*.
16. Use the y-intercept, *h* from step 10 and the earlier found values of *p* and *q* to determine average value of *k*.

Safety Precaution

17. *Barrier is set up in that area during each launch so as to prevent anyone getting hit and injured by the projectile.*