H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	**Solution**
CLASS	
TUTOR'S NAME	
CENTRE NUMBER	S
INDEX NUMBER	

PHYSICS 9749/04

Paper 4 Practical

21 August 2023

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name, class, tutor's name, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details on the practical shift and laboratory, where appropriate, in the boxes provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	**/ 15**
2	**/ 6**
3	**/ 22**
4	**/ 12**
Total	**/ 55**

1 In this experiment, you will investigate an electrical circuit.

(a) Set up the circuit shown in Fig. 1.1, using a 15 Ω resistor as *P* and a 22 Ω resistor as *Q*.

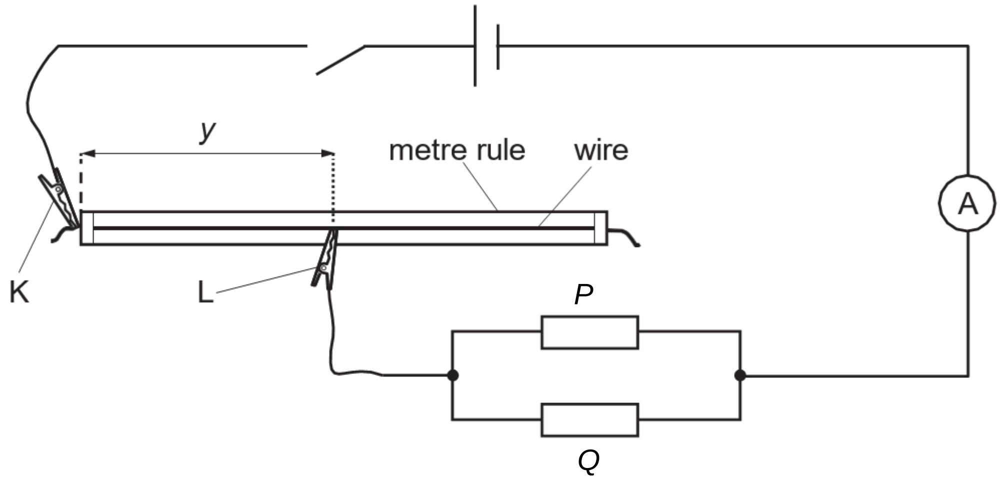


Fig. 1.1

K and L are crocodile clips.

Place L approximately half-way along the wire.

The distance between K and L is *y* as shown in Fig. 1.1.

Record *P*, *Q* and *y*.

P = 15 Ω

Q = 22 Ω

y = 50.0 cm

Close the switch.

Record the ammeter reading *I*.

I = 85.2 mA [1]

Open the switch.

Value of *I* with unit and in the range 0.010 A ⩽ *I* ⩽ 0.200 A.

(b) Change one or both of the resistors in *P* and *Q*.

Record the new values of *P* and *Q*.

P = 12 Ω

Q = 22 Ω

Close the switch.

Change the position of L on the wire so that the ammeter reading is as close as possible to the value for I in **(a)**.

Record *y*.

y = 60.2 cm [1]

Value of *y* with unit and in the range 20.0–75.0 cm.

Open the switch.

(c) Repeat **(b)** until you have six sets of readings of *P*, *Q* and *y*, using different combinations of the resistors provided as *P* and *Q*.

Present your results clearly.

P / Ω	Q / Ω	y / cm	$PQ/(P+Q)$
12	15	71.9	6.7
12	22	60.2	7.8
15	18	53.9	8.2
15	22	50.0	8.9
18	22	40.2	9.9
22	27	28.7	12.1

Six sets of readings of P, Q (different pairs) and y without help from the Supervisor
Each column heading must contain a quantity & a unit
Resistor values include the pair (15 Ω and 12 Ω) and the pair (27 Ω and 22 Ω).
All values of y must be given to the nearest mm only.
Values of PQ / (P + Q) must be given to 2 or 3 significant figures. Values of PQ / (P + Q) calculated correctly.

[5]

(d) It is suggested that the quantities *y*, *P* and *Q* are related by the expression

$$y = -\frac{MPQ}{P+Q} + N$$

where *M* and *N* are constants.

Plot a suitable graph to determine *M* and *N*.

gradient = $\frac{20.5 - 70.5}{12.80 - 6.40} = -7.81$

M = - gradient = 7.81 cm Ω^{-1}

y-intercept = 20.5 – (- 7.81 (12.8)) = 120

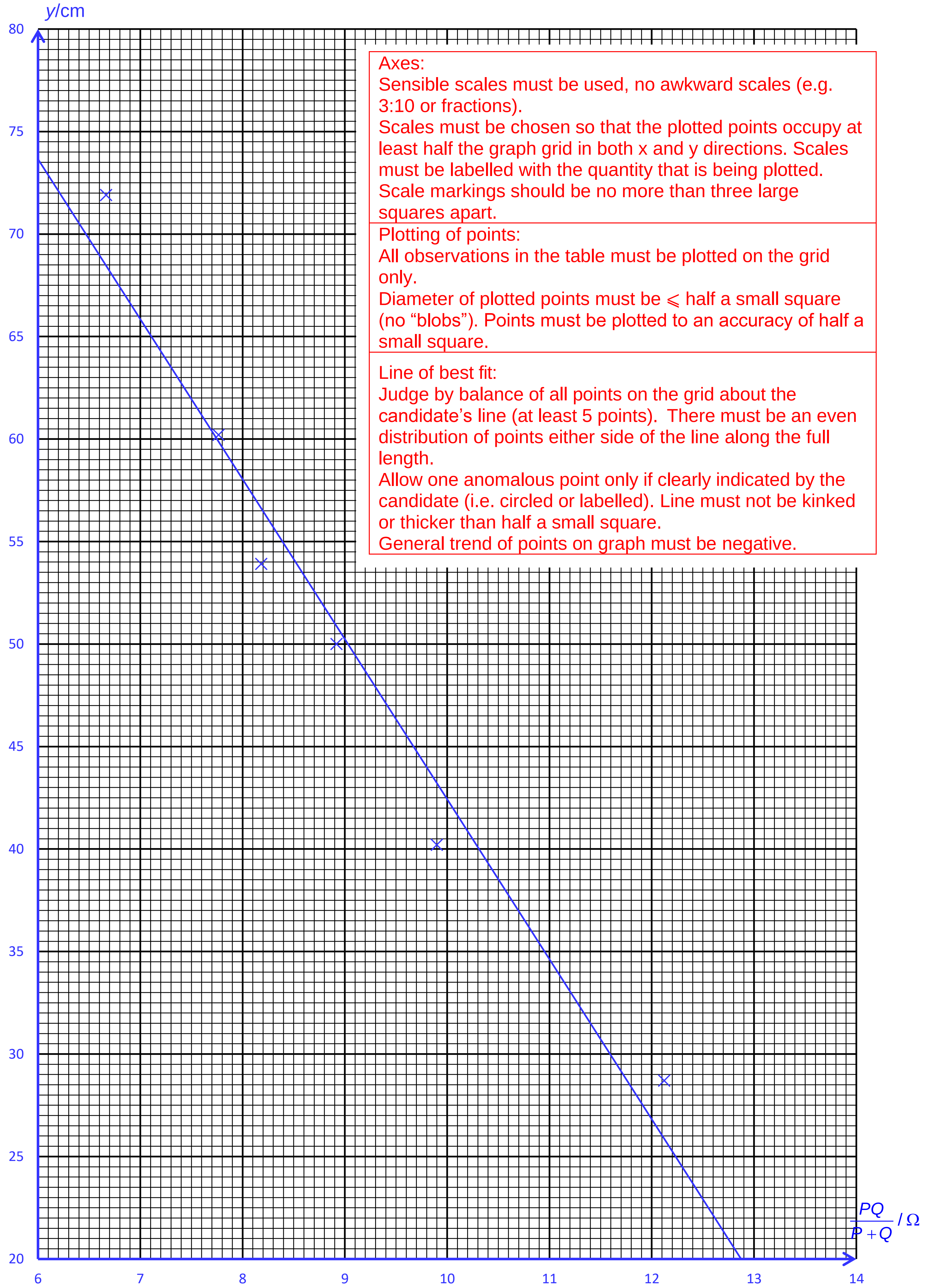
N = y-intercept = 120 cm

Gradient: The hypotenuse of the triangle used must be greater than half the length of the drawn line. The method of calculation must be correct. Δx /Δy strictly not allowed. Both read-offs must be accurate to half a small square in both the x and y directions. Sign of gradient on answer line must match graph.
y-intercept: Correct read-off from a point on the line substituted into y = mx + c. Read-off must be accurate to half a small square in both x and y directions. or Intercept read directly from the graph with read-off at x = 0, accurate to half a small square.
Value of M =–candidate's gradient and value of N = candidate's intercept. The values must not be fractions. Units for M (e.g. m^{-1} or cm^{-1} or mm^{-1}) and N (e.g. m or cm or mm) correctly given.

M = ...

N = ...

[6]



Axes:
Sensible scales must be used, no awkward scales (e.g. 3:10 or fractions).
Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Scales must be labelled with the quantity that is being plotted.
Scale markings should be no more than three large squares apart.

Plotting of points:
All observations in the table must be plotted on the grid only.
Diameter of plotted points must be ⩽ half a small square (no "blobs"). Points must be plotted to an accuracy of half a small square.

Line of best fit:
Judge by balance of all points on the grid about the candidate's line (at least 5 points). There must be an even distribution of points either side of the line along the full length.
Allow one anomalous point only if clearly indicated by the candidate (i.e. circled or labelled). Line must not be kinked or thicker than half a small square.
General trend of points on graph must be negative.

(e) Theory suggests that

$$\frac{N}{M}=\frac{E}{I}$$

where E is the electromotive force (e.m.f.) of the cell.

Calculate E. Give an appropriate unit.

$$\frac{E}{I}=\frac{N}{M}$$

$$\frac{E}{85.2\times10^{-3}}=\frac{120}{7.81}$$

$$E=1.31\text{ V}$$

Correct calculation of E with correct unit.

E = ... [1]

(f) M is inversely proportional to r, the resistance per unit length of the wire taped to the meter rule, while N is the ratio of the total resistance in the circuit to r.

On the graph on page 5, draw the line that would show the result obtained if the wire taped to the meter rule is changed to one made of the same material, but having a larger diameter. [1]

Graph with higher gradient (and higher y-intercept if graph shows X = 0).

[Total: 15]

2 In this experiment, you will investigate an oscillating system.

(a) Place the wooden strip on the pivot, as shown in Fig. 2.1.

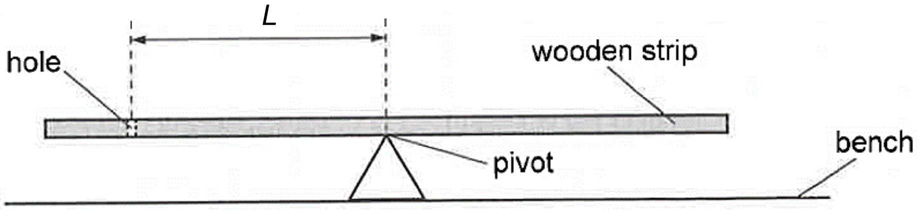


Fig. 2.1

Adjust the position of the wooden strip on the pivot until it balances. The distance between the centre of the hole in the wooden strip and the pivot is *L*.

Without marking the wooden strip, measure and record *L*.

L = ...17.8 cm............ [1]

***Value of L* between 17.4 cm to 18.4 cm**

Mesure this carefully.

(b) Set up the apparatus as shown in Fig. 2.2.

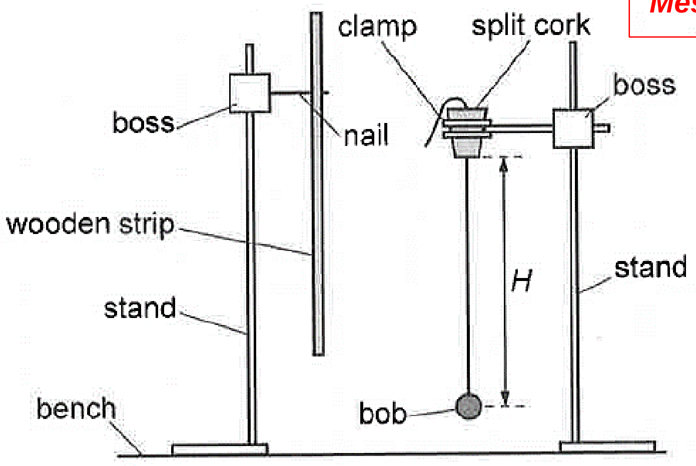


Fig. 2.2

The distance between the bottom of the split cork and the centre of the bob is *H*.
Adjust the string in the split cork until *H* is approximately 40 cm.

Displace the bob and the bottom of the wooden strip towards you through a short distance. Release the bob and the strip at the same time. The oscillations of the bob and the strip will be out of phase.

Adjust *H* so that the oscillations of the bob and the strip remain in phase for several cycles after release.

Measure and record *H*.

***Value of H* between 27.0 cm to 32.0 cm**

H = ...28.8 cm............ [1]

You may need to adjust your view or place the pendulum so that you can observe more clearly. The starting point is at 40cm but the value of H is unlikely to be 40 cm.

(c) The quantities L and H are related by the equation

$$b = \sqrt{L(H-L)}$$

where b is a constant.

(i) Calculate b.

$$b = \sqrt{L(H-L)}$$
$$= \sqrt{17.8(28.8-17.8)}$$
$$= 14.0 \text{ cm}$$

b calculated correctly. Please use the reading you have obtained earlier in (a) and (b) for H and L.
Minus 1 mark if expressed in cm.

b = 0.140 m [2]

(ii) If you were to repeat this experiment using a similar wooden strip with several holes at different positions along its length, describe the graph that you would plot to determine *b*.

$$b = \sqrt{L(H-L)}$$
$$b^2 = LH - L^2$$
$$LH = L^2 + b^2$$

Plot a graph of LH against L^2 [1] such that the gradient is equal to 1 and vertical intercept is equal to b^2 [1]. Then b = square root of y-intercept.

[2]

[Total: 6]

Describe the graph means indicate the graph you need to plot, what is the x and y axis.
Linearise the equation correctly to a form Y = MX + C where Y and X are variable, M and C are constants. Since the relationship is such that variables are L and H,
Most direct method is

$$b = \sqrt{L(H-L)}$$
$$\sqrt{L(H-L)} = b$$
$$\sqrt{L} = \frac{b}{\sqrt{(H-L)}}$$

Plot √L against √(H-L) where b is the gradient of the straight line graph.

3 A simplified mechanism of a fuel gauge in a car is shown in Fig. 3.1. A rod attached to a float rotates about a pivot as the float moves up or down. This causes the reading on the fuel gauge to change.

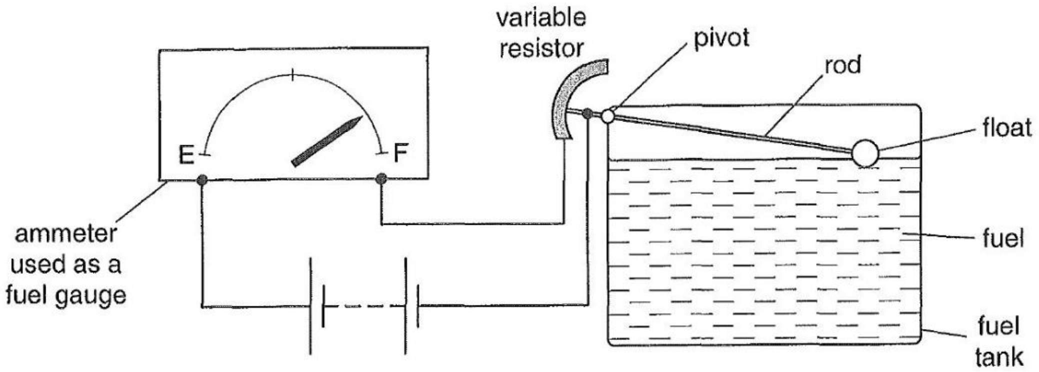


Fig. 3.1

In this experiment, you will investigate a model of this mechanism.

You have been provided with a metre rule which models as the rod, and a tube which models as the float.

(a) (i) The distance between the centre of the hole in the metre rule and the 50 cm mark on the metre rule is L, as shown in Fig. 3.2.

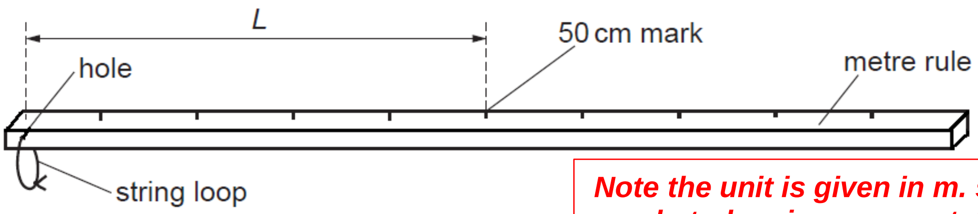


Fig. 3.2

Note the unit is given in m. so L is 0.495 m. It needs to be given accurately as it is used for calculation later. IT CANNOT BE 0.500 m since the hole cannot be on the edge of the ruler. IT ALSO CANNOT BE 0.450 m as it is near the edge, not 5 cm from the edge.
0.493 m ≤ *d* ≤ 0.497 m

Determine L in metres.

$L = 50.0 - 0.5$
$= 49.5 \text{ cm}$
$= 0.495 \text{ m}$

L = ...0.495........ m

The outer diameter of the tube is d, as shown in Fig. 3.3.

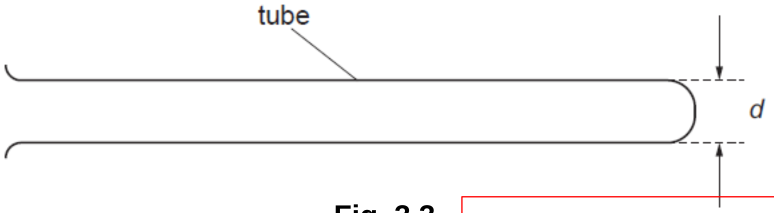


Fig. 3.3

0.0245 m ≤ *d* ≤ 0.0255 m.
Repeat reading is required.
Used the apparatus given, which is the vernier calipers. PLEASE DO NOT USE A RULER. Note that you are measuring the external diameter.

Measure and record d in metres.

$d_1 = 2.50 \text{ cm}$
$d_2 = 2.51 \text{ cm}$
$\langle d \rangle = \frac{2.50 + 2.51}{2} = 2.51 \text{ cm} = 0.0251 \text{ m}$

d = ...0.0251........ m [1]

(ii) Calculate the cross-sectional area A of the tube where

$$A = \frac{\pi d^2}{4}.$$

$$A = \frac{\pi (0.0251)^2}{4}$$
$$= 4.95 \times 10^{-4}\ \text{m}^2$$

A calculated correctly based on d value earlier.

A = 4.95 × 10^{-4} m^2 [1]

(b) (i) Add sand to the tube as shown in Fig. 3.4.

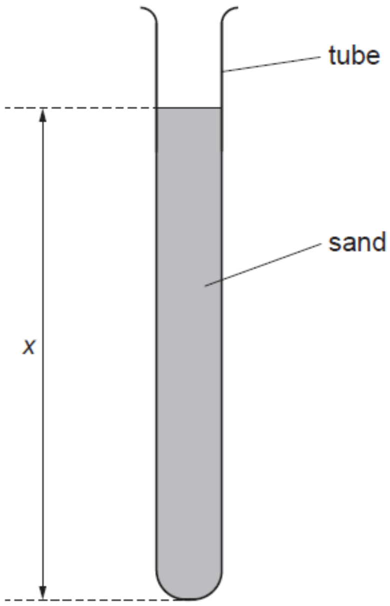


Fig. 3.4

The height of sand in the tube is x. Adjust the amount of sand in the tube until x is approximately 12 cm.

Measure and record x in metres.

x = 0.120 m

$0.115\ \text{m} \leq x \leq 0.124\ \text{m}$.
Measure using ruler. Note that this is approximately 12 cm, so the range as given.

(ii) Push the stopper securely into the tube.

(iii) Set up the apparatus as shown in Fig. 3.5. Fill the beaker with water and place it inside the tray.

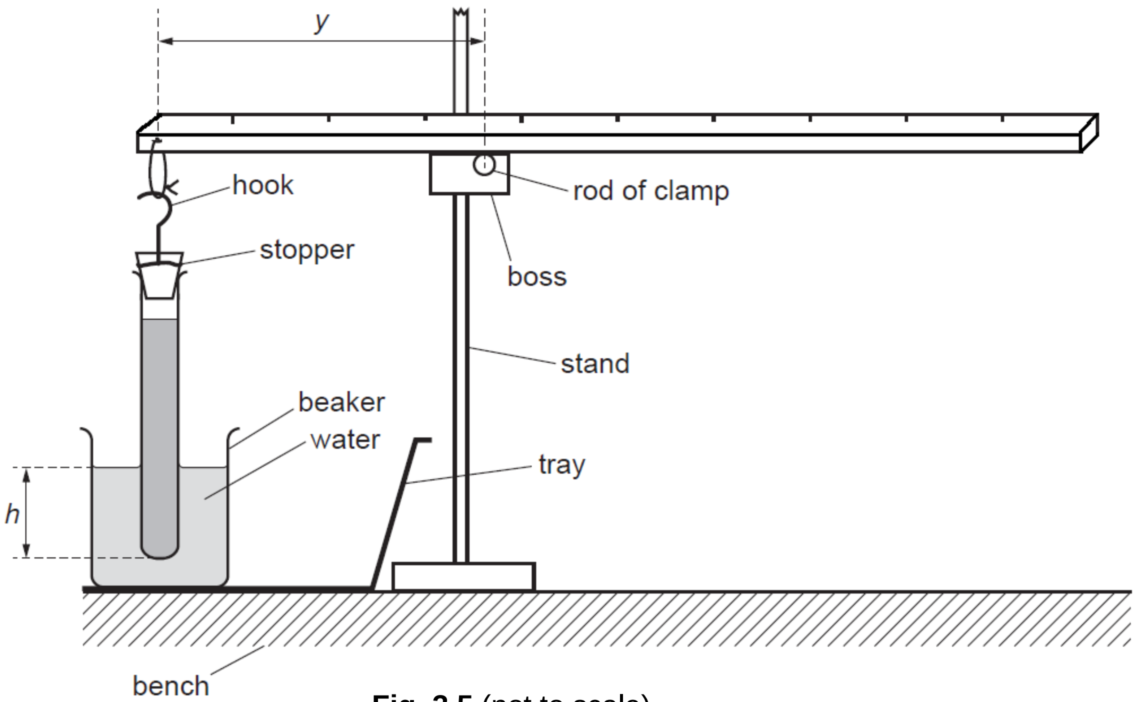


Fig. 3.5 (not to scale)

Using the hook, suspend the tube from the string loop and place the tube in the water.

The distance between the bottom of the tube and the surface of the water in the beaker is *h*.

Adjust the apparatus so that the rule is pivoted on the rod of clamp, with the rule approximately parallel to the bench and the value of *h* approximately 5 cm.

The distance between the rod of clamp and the hole in the rule is *y*.

Measure and record *h* and *y*. Give your values in metres.

$y = 27.5 - 0.5$
$= 27.0$ cm
$= 0.270$ m

0.045 m ≤ *h* ≤ 0.054 m
value of x, *y* and *h* to nearest 0.001 m
y measued correctly. Value of y is checked against a table for range of reading and your friend using the sane ruler.

h = ...0.050.......... m

y = ...0.270.......... m
[2]

(iv) Estimate the percentage uncertainty in your value of *h*.

$$\frac{\Delta h}{h} \times 100\% = \frac{0.5}{5.0} \times 100\%$$
$$= 10\%$$

0.2 cm ≤ Δ*h* ≤ 1 cm
Δ*h* expressed in 1 s.f.
% uncertainty correct to 1-2 s.f.

percentage uncertainty = ...10.......... % [1]

(v) The mass M of the metre rule and string is indicated on the metre rule.

Write down the value of M.

M = 0.0940 kg

Calculate C using

$$C = \frac{1}{L} - \frac{Ah\rho}{ML}$$

where $\rho = 1.0 \times 10^3$ kg m^{-3}.

$$C = \frac{1}{0.495} - \frac{4.95 \times 10^{-4} \times 0.050 \times 1.0 \times 10^3}{0.0940 \times 0.495}$$

$$= 1.5$$

correct calculation of C
Please check that you copy the equation correctly and the values you used for substitution correctly.

C = 1.5 m^{-1} [1]

(vi) Justify the number of significant figures that you have given for your value of C.

Number of significant figures (s.f.) for C is based on the least s.f. of L, d, h, ρ and M, which is 2 s.f. from density ρ and distance h.

[1]

Please do not use short form unless you have introduced it. (significant figures , s.f.)
Make it clear why 2 s.f. either from ρ or h.
This question ask about s.f, focus on it, the equation is a complex one, so will only depend on s.f.
d.p will only come in if it is purely addition or subtraction between 2 measurements.

(c) (i) Remove some of the sand from the tube so that x is approximately 8 cm.

Measure and record x.

x = 0.080 m

(ii) Adjust the apparatus shown in Fig. 3.4 so that the rule is approximately parallel to the bench and h has the same value as in **(b)(iii)**.

Measure and record y.

$$y = 31.5 - 0.5$$
$$= 31.0 \text{ cm}$$
$$= 0.310 \text{ m}$$

y = 0.310 m
[2]

0.075 m ≤ x ≤ 0.084 m
value of x and y to nearest 0.001 m
y measued correctly and second value of y > first value of y

(d) (i) It is suggested that the relationship between *y*, *x* and *C* is

$$\frac{1}{y} = (kx + C)$$

where *k* is a constant.

Use your values from **(b)** and **(c)** to determine two values of *k*.

$$k_1 = \frac{\frac{1}{0.270} - 1.5}{0.120} = 18\ \text{m}^{-2}$$

$$k_2 = \frac{\frac{1}{0.305} - 1.5}{0.080} = 22\ \text{m}^{-2}$$

first value of *k* = 18 m^{-2}

second value of *k* = 22 m^{-2}

two values of *k* calculated correctly AND correct unit [1]

(ii) State whether or not the results of your experiment support the suggested relationship. Justify your conclusion by referring to your value in **(b)(iv)**.

$$\frac{\Delta k}{k} \times 100\% = \frac{22 - 18}{18} \times 100\%$$
$$= 22\%$$

Since the percentage difference in *k* of 22% is more than the criterion which is the percentage uncertainty in *h* which is 10%, the results do not support the suggested relationship. [1]

(e) (i) Suggest **one** significant source of error in this experiment.

1. Difficult to measure *h* <u>with a reason</u>: effects of refraction NOT diffraction / measuring was done outside beaker / tray blocks view during measurement.

2. Difficult to measure *x* <u>with a reason</u>: sand not level / holding rule and tube at the same time.

3. Difficult to measure *y* <u>with a reason</u>: unable to judge exact centre of rod. NOT rule not parallel [1]

Examiners' comments:
A significant number of candidates mentioned that the rule was not parallel to the bench, not realising that they need to mention a *significant* source of error related to the raw data that they are measuring. Furthermore, slight bending of the rule is unavoidable but acceptable within the nature of the experiment. Some candidates still talk about the wind affecting the experiment (despite after almost 2 years of Physics practical education, there is nothing else to highlight other than 'the wind'). A small number of candidates confused refraction with diffraction (which is a 'serious' misconception).

(ii) Suggest an improvement that could be made to the experiment to reduce the error identified in **(e)(i)**. You may suggest the use of other apparatus or a different procedure.

1. Place marking on tube (NOT mark the beaker) using a marker pen before putting in the water / Remove the tray so would not block view when measuring *h*.

2. Use finer sand or compact the sand with appropriate tool (NOT change sand to liquid) / Clamp the tube during measurement of *x*, free hand to use rule. [1]

3. Use triangular pivot. NOT use thinner rod

Examiners' comments:
If the source of error is not appropriate, then the corresponding suggestion of improvement will also be irrelevant and thus not awarded the mark. A significant number of candidates suggest to mark the water level on the tube, then take out the tube and measure *h* from the marking. They did not realise that marking the tube whilst in water would disturb the equilibrium of the system even more. Candidates should understand the intent of the experiment and suggest more appropriate improvements, such as pre-marking the tube for before placing it in water. Some students suggested using a thinner rod, but the curvature of the rod is still present, hence a replacement to a triangular pivot would be better.

(f) **(i)** Using the tube of sand where *x* is approximately 8 cm, vary *h* to determine the effect on *y*.

Present your results and conclusion clearly.

For x = 0.080 m,	
h / m	y / m
0.070	0.330
0.060	0.320
0.050	0.310
0.040	0.295
0.030	0.290
0.020	0.280

At least 3 sets of *h* and *y* tabulated in a table
range of *h* at least 0.030 m
direct relationship concluded from data present

As *h* decreases, *y* decreases OR as *h* increases, *y* increases

NOT (directly) proportional [3]

Examiners' comments:
Mostly well done. Some candidates stated a direct relationship, but went on to talk about a proportional relationship. This would discredit their answers because it would seem like they interpret it as a (directly) proportional relationship. A minority of candidates did not have sufficient range for their *h*.

(ii) During actual testing, the beaker is to be filled with fuel (petrol).

Suggest, with a reason, whether your values of *y* in **(f)(i)** increase, remain the same or decrease for the same values of *x* and *h* used.

Fuel is less dense than water, lesser upthrust so perpendicular distance

y decreases to ensure equilibrium of rule for the same values of *x* and *h*.

....[1]

Examiners' comments:
There seems to be a common misconception that petrol is more dense than water. Some students misinterpreted the question and thought the sand was replaced with petrol. There were quite a few instances when the wrong reasoning led to the correct result; no credit is awarded for such cases. Students could have used the expression in (d)(i) to deduce how *y* will change.

(g) To model the emptying of the fuel tank, water is gradually removed from the beaker.

The apparatus in Fig. 3.5 requires the metre rule to be supported on the pivot and the position of the pivot must **not change**. The metre rule should rotate accordingly to achieve equilibrium.

(i) Predict, without taking further readings, whether the metre rule in Fig. 3.5 will rotate clockwise or anticlockwise about the pivot.

Anticlockwise. ....[1]

Examiners' comments:
This part was well answered.

(ii) The angle of rotation θ of the metre rule from its horizontal position about the pivot depends on the water level H in the beaker.

Describe how you would investigate the effect of H on θ.

You may suggest the use of any additional apparatus commonly found in a school physics laboratory.

You account should include:

- your experimental procedure and how can θ be measured directly
- control of variables
- how you would use your results to investigate the relationship of H on θ
- why it would be difficult to obtain enough results to reach a valid conclusion.

Mark Code	Description
M1	✓ Quantifying *IV* and *DV* measures height of water in beaker H (not h) using a (half) metre rule / graduations on beaker / <u>tail</u> of vernier calipers AND angle of rotation θ using a protractor penalize if use h instead of H
M2	✓ Varying *IV* and keeping *CV*s constant vary H by changing water level in beaker using appropriate method e.g. dropper/syringe AND constant depth of sand in test tube x; use metre rule to check, position of pivot to be kept constant; use markings on rule to check, mass of rule M kept constant; by using back same rule.
A1	✓ Analysis appropriate graph plotted with <u>DV against IV</u>, e.g. θ against H OR lgθ against lg$H$ and best-fit line or curve drawn to investigate the relationship
R1	✓ Difficult to obtain enough results [Limitation of set up] rule begins to slide off pivot / lose equilibrium as more readings are taken OR [Narrow range of IV <u>and</u> DV] unable to vary H to get a significant change in θ due to small beaker / θ varies too little with H so protractor not precise enough to get sufficient range NOT cannot get 6 values / water overflows from beaker / tube touches beaker

Control of variables: depth of sand x in tube using metre rule to check, position of pivot using markings on the rule to check

1. Use a metre rule to measure the height of water H in the beaker.
2. Use a dropper to gradually add or remove water. Use metre rule to measure the remaining height of water H in the beaker.
3. Measure the angle of rotation θ using the protractor (clamped to a retort stand).
4. Repeat steps 2 to 3 to obtain several sets of readings for H and θ.
5. Plot a graph of θ against H and draw the best-fit line/curve to investigate the relationship.
6. Difficult to obtain enough sets of readings as the rule will start to slide off the pivot (as H decreases due to the increasing moment) OR θ varies too little with H and protractor is not precise enough to get sufficient range of results OR beaker is too small to vary H sufficiently to get a significant change in θ.

....

....

Examiners' comments:
Most candidates fully or partially attempted the mini-planning; only a few left it entirely blank. General structure of mini-planning was seen which indicated some level of preparation.

1. Candidates frequently left out the instrument used to measure the IV (water level H) and CV. When keeping the CVs constant, candidates should also state how they can check that the CV remained constant, by stating the instrument used to measure and ensure that it is kept constant. A number of candidates used blu tack or nails to fix the pivot.
2. Students need to mention how to vary water level H using an appropriate method that would not disturb the system, such as by using a dropper instead of pouring out the water, which would require movement of the beaker, tube and rule.
3. Analysis of variables should always be DV (θ) plotted against IV (H), and not the other way round. Candidates should mention about drawing the line or curve of best-fit to further conclude the relationship between θ and H.
4. It is common to see vague or superficial answers for why it would be difficult to obtain enough results. It is common for candidates to say that the tube would touch the beaker or that the water would overflow hence not enough results to conclude, without showing how this led to insufficient results. Candidates should make it a point to relate back to the DV (θ) and IV (H). Candidates must realise that the aim of the experiment is not to let the beaker be empty or overflow; so this implies there is only a limited range of H to work with, which would lead to a narrow range or insignificant change in θ that cannot be measured accurately by the protractor.

....[4]

[Total: 22]

4 When a stream of water falls from a tap onto a plate, the water spreads out in a relatively thin layer until it reaches a particular distance from the stream where the water suddenly increases in depth. The phenomenon where this depth change occurs is called a hydraulic jump and separates two distinct regions A and B, as shown in Fig. 4.1.

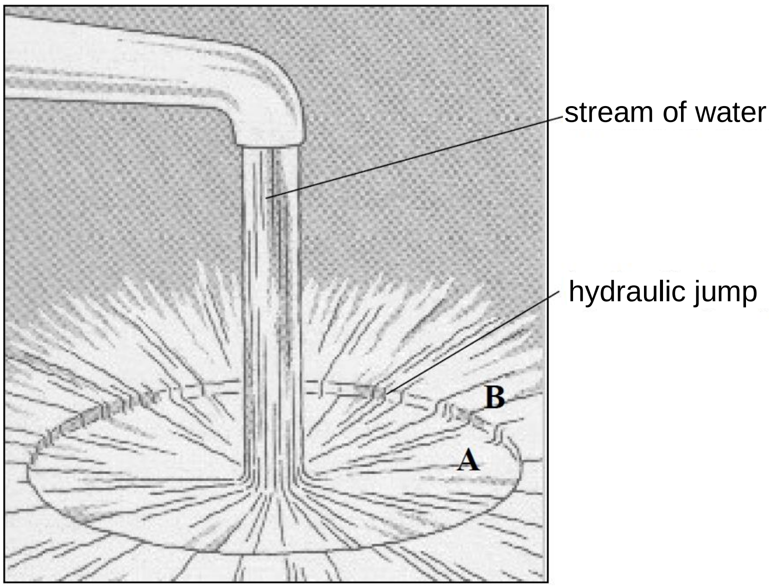


Fig. 4.1

The diameter D of region A will depend on the volume flow rate (volume per unit time) V and the height h of the stream of water.

The diameter of region A is given by

$$D = kV^p h^q$$

where k, p and q are constants.

Design an experiment to determine the values of p and q.

Draw a diagram to show the arrangement of your apparatus. You should pay particular attention to:

- the equipment you would use
- the procedure to be followed
- how the diameter of region A may be measured non-invasively
- the control of variables
- any precautions that should be taken to improve the accuracy of the experiment

Mark Code	Description	Marks
M1	*Basic Procedure* ✓ any suitable arrangement/instrument to measure D non-invasively (e.g. measuring tape, vernier callipers, metre rule placed below a transparent plate)	1
M2	✓ any suitable arrangement/instrument to measure V (e.g. flow meter connect to tap, measures time t using a stopwatch and volume of water collected W using a measuring cylinder or measures mass m of water and calculates $W=m/\rho$ and calculates $V = W/t$,)	1
M3	✓ measures h from outlet to top of plate using a metre rule	1
M4	✓ labelled diagram of workable experiment including: ▪ relative placement of water source and plate ▪ suitable setup to collect water	1
M5	✓ repeats experiment keeping h constant and vary V by changing the flow of the tap/ constant flow head	1
M6	✓ repeats experiment keeping V constant and vary h by raising the height of the plate/ water supply	1
A1	*Analysis* ✓ plot a graph of lg D against lg V calculate p which is equal to the gradient of the graph.	1
A2	✓ plot a graph of lg D against lg h calculate q which is equal to the gradient of the graph.	1
D1/2/3/4	*Additional Details* ✓ wipe off any water spills to prevent slipping ✓ measures D in different directions and takes average ✓ waits till <u>hydraulic jump is stable</u> before making measurements ✓ suitable method to improve visibility of hydraulic jump (e.g. overhead lamp) *coloured/ dyed water not acceptable ✓ use of a constant flow head setup ✓ uses a large plate for a wide range of values ✓ suitable method to ensure water does not accumulate on plate ✓ suitable method to ensure stream of water is vertical ✓ suitable method to ensure plate is horizontal ✓ suitable method to ensure metre rule is vertical when measuring h ✓ collects large volume of water / over a longer time (only for stopwatch-cylinder method to determine V) Any 4	4