TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CIVICS GROUP	

H2 Physics 9749/04

Paper 4 Practical

24 August 2023

2 hours 30 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page, page **9** and **17**.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **ALL** questions.

You are allowed 1 hour to answer Questions 1 and 2; and you are allowed another 1 hour to answer Question 3.

Question 4 is a question on the planning of an investigation and does not require apparatus.

Write your answers in the space provided in 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 of the practical shift and laboratory where appropriate in the boxes provided.

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	**/7**
3	**/21**
4	**/12**
Total	**/55**

1 In this experiment you will be required to investigate the use of a combination of resistors in circuit analysis.

Set up the apparatus as shown in Fig. 1.1. Resistor *R* represents the combined resistance of one to three 10.0 Ω resistors connected in parallel, series or a combination.

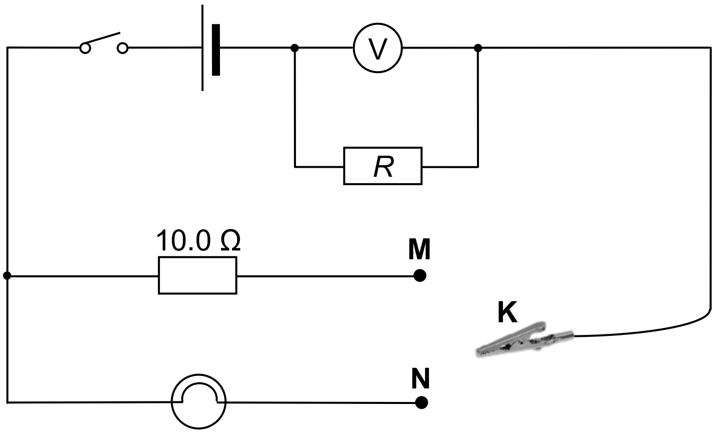


Fig. 1.1

(a) **(i)** Set *R* to be 10.0 Ω.

(ii) Attach the crocodile clip **K** to **M**.
Close the switch and record the voltmeter reading V_M.

V_M = ...0.727 V ....

(iii) Open the switch. Attach the crocodile clip **K** to **N**.
Close the switch and record the voltmeter reading V_N.

V_N = ...1.238 V ....[1]

- Correct dp and units for V_M and V_N.
  $V_N > V_M$

(iv) Calculate the value of $\frac{1}{V_M} - \frac{1}{V_N}$.

$$\frac{1}{V_M} - \frac{1}{V_N} = \frac{1}{0.727} - \frac{1}{1.238}$$

$$= 0.568\ V^{-1}$$

$\frac{1}{V_M} - \frac{1}{V_N}$ = ...0.568 V^{-1}.................

(v) Repeat steps **(a)(ii)** to **(a)(iii)** to obtain further sets of readings for V_M and V_N by varying R.

R / Ω	V_M / V	V_N / V	$\frac{1}{V_M}-\frac{1}{V_N}$ / V^{-1}	$\frac{1}{R}$ / Ω^{-1}
3.33	0.362	0.668	1.27	0.300
5.00	0.481	0.949	1.03	0.200
10.0	0.727	1.238	0.568	0.100
15.0	0.872	1.314	0.386	0.0667
20.0	0.979	1.364	0.288	0.0500
30.0	1.109	1.408	0.1915	0.0333

- Able to setup experiment to obtain 6 sets of readings [2].
  - Deduct 1 mark if only 5 sets of readings.
  - Zero marks if 4 sets or less
  - Deduct 2 mark if trend is wrong.
  - Deduct 1 mark if 1st set is not recorded in table
  - Deduct 1 mark if V > 2 V
  - Deduct 1 mark if $V_N < V_M$ (if mark not deducted earlier)
  - R = 0 Ω or other impossible R values are not considered as sets of readings
- Correct quantity and units in the headers. [1]
- Correct d.p. for raw data & s.f. of derived data [1]
- Correct calculation for all derived data [1]

[5]

(b) Theory suggests that V_M, V_N and R are related by the expression

$$\frac{1}{V_M}-\frac{1}{V_N}=\frac{B}{R}+C$$

where B and C are constants.

Plot a suitable graph to determine B and C.

Plot a graph of $\frac{1}{V_M}-\frac{1}{V_N}$ against $\frac{1}{R}$. If the equation is valid, a straight line graph with gradient B and vertical intercept C will be obtained.

Gradient = 4.96

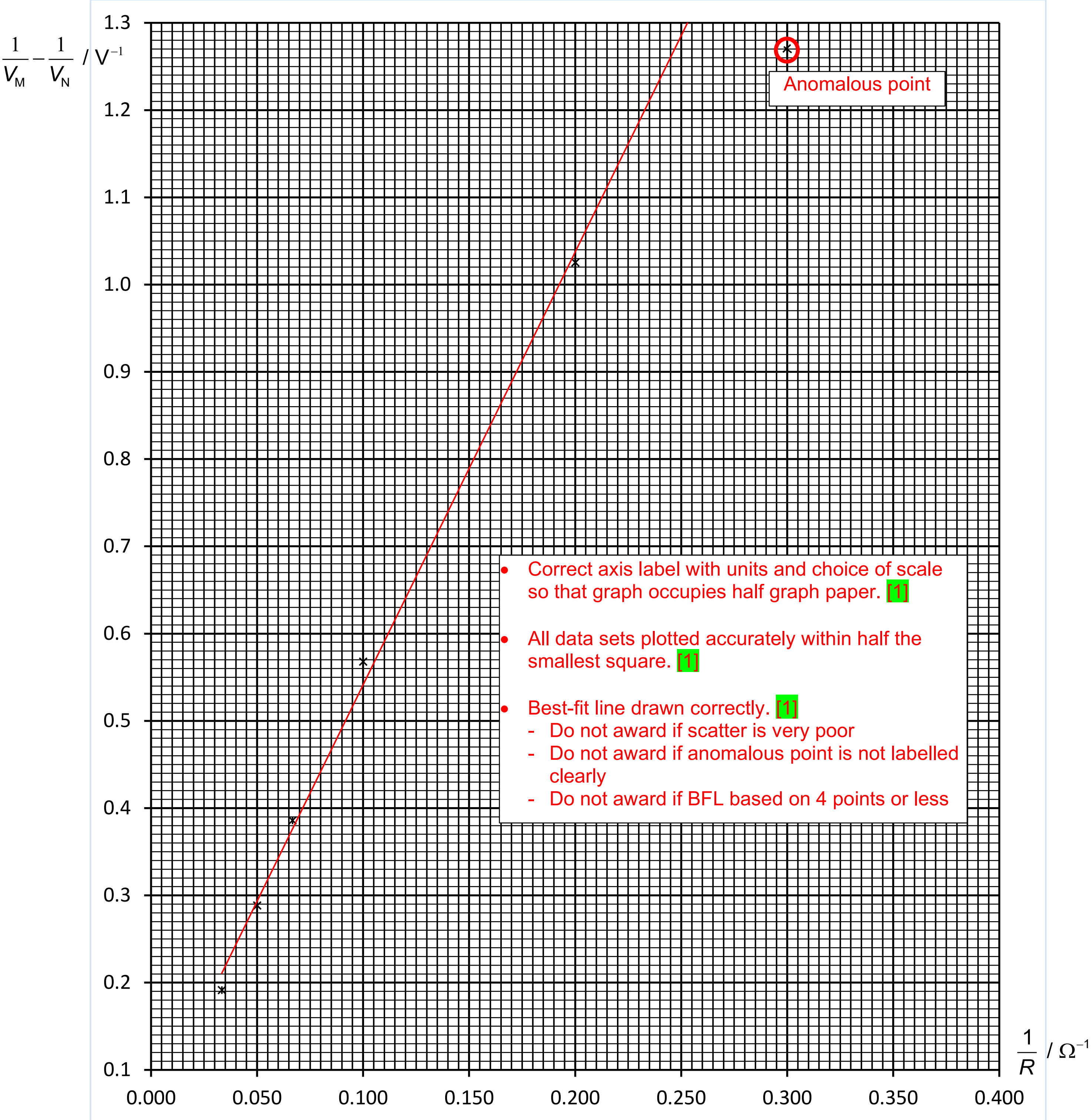
B = 4.96 Ω V^{-1}

Vertical intercept:
Using the equation $c = y - mx$,
C = 0.0453
C = 0.0453 V^{-1}

- Correct linearisation. [1]
- Gradient triangle is large enough, covering >1/2 of BFL. Correct read-off of gradient triangle coordinates. B calculated correctly. [1]
- C calculated correctly. [1]
- Correct s.f. and units for both B & C [1]
  - If C is not calculated, award this mark based on B alone

B = ……4.96 Ω V^{-1}…………………

C = ……0.0453 V^{-1}………………… [4]



$\frac{1}{V_M} - \frac{1}{V_N}$ / V^{-1}
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
$\frac{1}{R}$ / Ω^{-1}
Anomalous point
• Correct axis label with units and choice of scale so that graph occupies half graph paper. [1]
• All data sets plotted accurately within half the smallest square. [1]
• Best-fit line drawn correctly. [1]
- Do not award if scatter is very poor
- Do not award if anomalous point is not labelled clearly
- Do not award if BFL based on 4 points or less

[3]

(c) By making suitable calculations, determine whether $V_M = V_N$ can be achieved for this setup.

$$\frac{1}{V_M} - \frac{1}{V_N} = \frac{B}{R} + C$$

$$0 = \frac{4.96}{R} + 0.0453$$

$$R = -109\ \Omega$$

- Correct calculation of *R* [M1]
  - Do not award if wrong linearization
- Correct conclusion based on *R* obtained. Explanation must be clear [A1]

$V_M = V_N$ cannot be achieved from this setup since resistance cannot be negative.

If positive *R* calculated, students may state

- that $V_M = V_N$ cannot be achieved using combinations of the resistors provided, or
- that $V_M = V_N$ can be achieved by using R of the calculated value / or R is positive

....

.... [2]

[Total: 15]

2 This experiment considers the forces on a wooden cylinder.

(a) You have been provided with a wooden cylinder with a spring attached.

The distance *L* between the centre of the hole at one end of the cylinder and the other end of the cylinder is shown in Fig. 2.1.

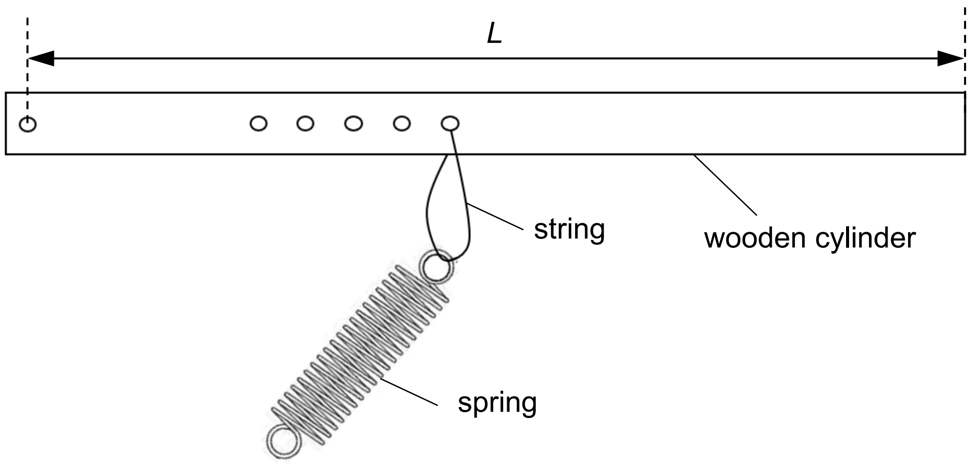


Fig. 2.1

The length of the unstretched spring is *S*, as shown in Fig. 2.2.

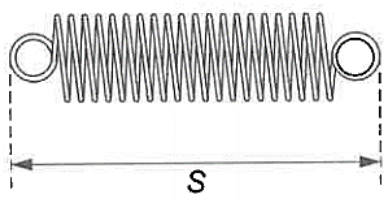


Fig. 2.2

Measure and record *L* and *S*.

L_1 = 59.0 cm

L_2 = 59.0 cm

<*L*> = 59.0 cm

1st *S* = 5.3 cm

2nd *S* = 5.3 cm

<*S*> = 5.3 cm

- Correct dp and unit for both *L* and *S*.
- 58.5 cm ≤ *L* ≤ 59.5 cm
- Repeated readings
- 4.8 cm ≤ *s* ≤ 5.8 cm

L = ...

S = ... [1]

(b) Set up the apparatus as shown in Fig. 2.3.

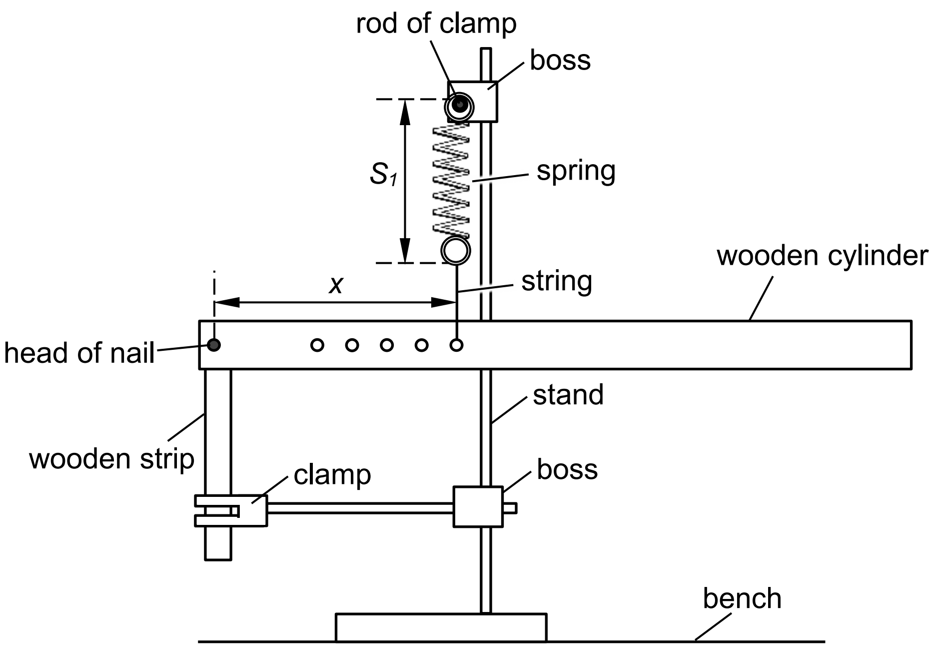


Fig. 2.3

Place the nail through the hole at the end of the wooden cylinder.

Adjust the apparatus until the spring and the wooden strip are vertical and the wooden cylinder is horizontal.

The distance x between the hole with the string and the hole with the nail is shown in Fig. 2.3.

The length of the stretched spring is S_1.

(i) Measure and record x and S_1.

x_1 = 21.0 cm

x_2 = 21.0 cm

$\langle x \rangle$ = 21.0 cm

1st S_1 = 14.6 cm

2nd S_1 = 14.6 cm

$\langle S_1 \rangle$ = 14.6 cm

- Correct dp and unit for both x and S_1
- Repeated readings for both x and S_1.
- 20.4 cm ≤ x ≤ 21.6 cm

x = ...

S_1 = ... [1]

(ii) Calculate e, where

$$e = S_1 - S.$$

e = 14.6 – 5.3 = 9.3 cm

- Correct calculation.
- Follow least dp from 1a and 1bi (subtraction) with correct unit.
- Ecf error from previous part (d.p. or unit)

[1]

(c) Theory suggests that

$$e = \frac{MgL}{2kx}$$

where g is 9.81 N kg^{-1}, M is the mass of the wooden cylinder and k is the spring constant of the spring.

Mass M is given on the card pasted on the wooden cylinder.

(i) Calculate k

$$0.093 = \frac{0.163(9.81)(0.590)}{2k(0.210)}$$

$$k = 24 \text{ N m}^{-1}$$

- Correct conversion of quantities to kilogram and metre [M1]
- Correct calculation (to N m^{-1}) [A1]
  - Zero for negative k-values (no ecf)

k = ... N m^{-1} [2]

(ii) If you were to repeat the experiment using the other holes in the cylinder, describe the graph you would plot to determine k.

Plot a graph of e vs 1/x. [M1]

The gradient of the straight line graph is equal to MgL/2k

Calculate $k = \frac{MgL}{2(gradient)}$ [A1]

Other accepted answers:
- ln e vs ln x (gradient = -1, vert int = ln (MgL/2k)
- S_1 vs 1/x (gradient = MgL/2k, vert int = S) – no need to include vert int in statement
- Or other combinations from original equation

Not accepted:
- Substitution of data points to find k

[2]

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3 In this experiment, you will investigate the oscillations of a triangular card.

(a) Cut out an isosceles triangle from the A4 size cardboard given to you as shown in Fig. 3.1.

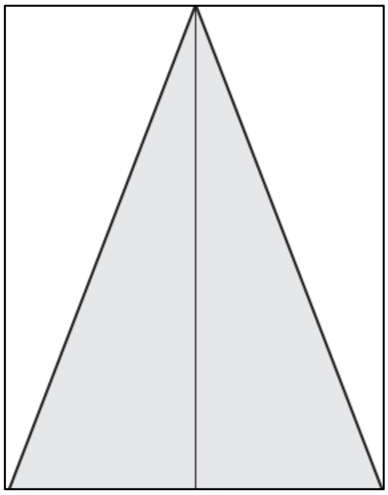


Fig. 3.1

Determine the midpoint M of the shortest side of the triangle and draw a line from M to the opposite corner of the triangle as shown in Fig. 3.2.

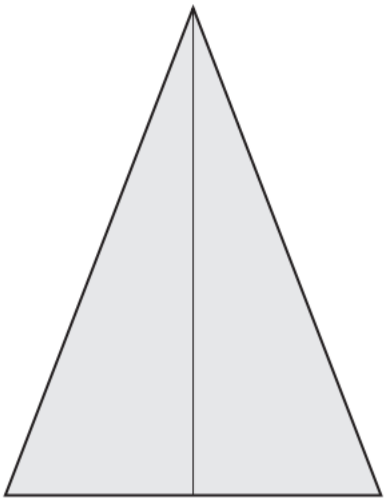


Fig. 3.2

Determine the midpoint N of one of the longer sides. Draw a line from N to the opposite corner of the triangle as shown in Fig. 3.3.

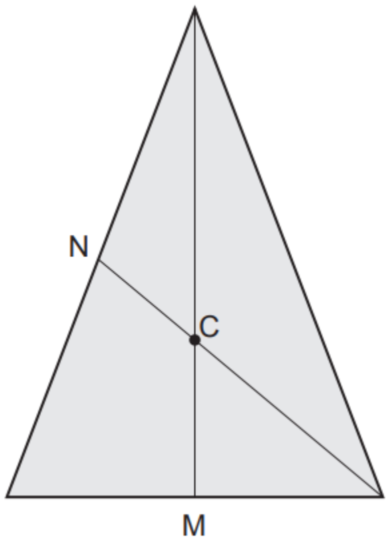


Fig. 3.3

Mark the point C where the two lines cross. The distance between C and M is *d*.

Measure and record *d*.

d_1=0.098 m , d_2 =0.098 m
d= 0.098m

- Repeated readings, with correct dp and to meter.
- 0.095m ≤ d ≤ 0.105m [1]

d = ……………………..……. m [1]

(b) **(i)** On the line from M to the opposite corner, mark a point P a distance of approximately 0.06 m from C, as shown in Fig. 3.4.

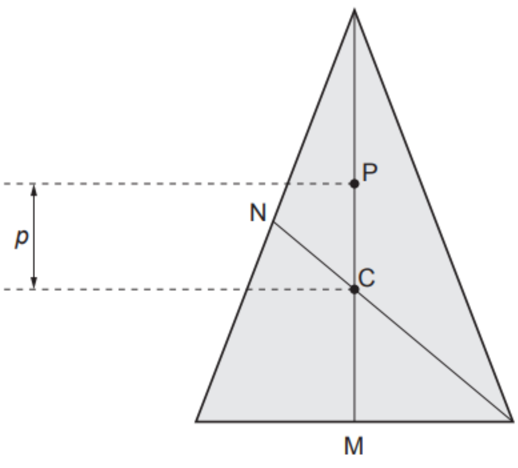


Fig. 3.4

Use the pin to carefully pierce a hole in the card at P. The distance between C and P is *p*, as shown in Fig. 3.4.

Measure and record *p* in metres.

p_1 = 0.060m , p_2 = 0.060m
p= 0.060m

p = ……………………..……. m

- Repeated readings, with correct dp and to meter.
- 0.055m ≤ p ≤ 0.065m [1]

(ii) Estimate the percentage uncertainty in your value of *p*.

$$\frac{\Delta p}{p}\times 100\% = \frac{0.002}{0.060}\times 100\% = 3.3\%$$

- 0.002 m ≤ Δp ≤ 0.003 m
- Δp and p having the same precision and percentage uncertainty calculated to 2 sf [1]

.... % [1]

(iii) Place the card on the cork. Put the pin through P into the cork.

Place the paper clip at M.

Set up the apparatus as shown in Fig. 3.5.

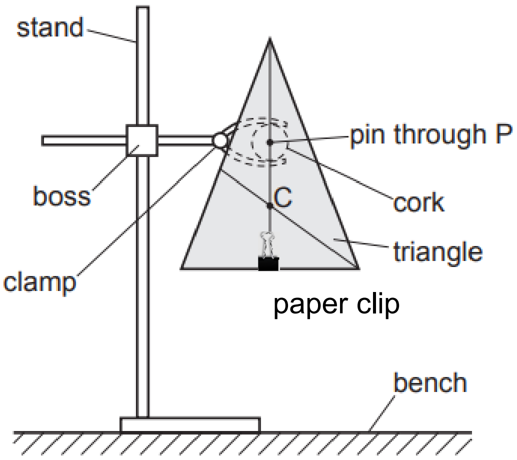


Fig. 3.5

Displace the base of the triangle through a small distance. Release it so that it oscillates about the horizontal axis through the pin as shown in Fig. 3.6.

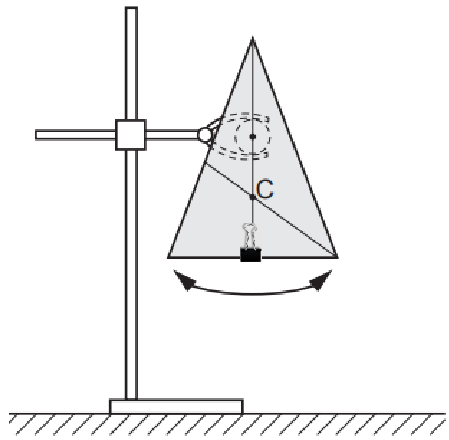


Fig. 3.6

Take measurements to determine the period *T* of the oscillations.

N=15, t_1 = 11.8 s, t_2 = 11.9s

T= 0.790 s

- t ≥ 10.0s ; Repeated readings and no. of oscillation stated [1]
- Correct dp of total time and T calculated correctly and to the correct sf and unit [1]

T = ... [2]

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

$$\frac{\Delta T}{T} = \frac{\Delta t}{t} \times 100\% = \frac{0.2}{11.9} \times 100\% = 1.7\%$$

- 0.2s ≤ *t* ≤ 0.5s
- Δ*t* and *t* (or *T*) having the same precision and percentage uncertainty calculated to 2 sf [1]

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

(v) Calculate p^2 and T^2p.

p^2 = 0.060 (0.060) =0.0036 m^2
$T^2 p = (0.790)^2 (0.060)$ = 0.037 s^2 m

- p^2 and T^2p calculated correctly [1]
- correct units given for both [1]

p^2 = ……………………..……..

T^2p = ……………………..…….. [2]

(vi) Justify the number of significant figures given in your value of T^2p.

T^2 p is left to 2 sf as it follows the least sf of T and p which is 2 sf.

- *correct justification with reference to least sf or plus 1 of both T (or t) and p* [1]
- students who left earlier sf to 1 will get zero here.

[1]

(vii) Repeat **(b)(i)**, **(b)(iii)** and **(b)(v)** with a distance p of approximately 0.12m.

p = 0.120m

p = ……………………..…….. m

N=15, t_1 = 13.2 s, t_2 = 13.2 s
T= 0.880 s

T = ……………………..……..

p^2 = 0.120 (0.120) =0.0144 m^2
T^2 p = $(0.880)^2$ (0.120) = 0.0929 s^2 m

- Correct calculation for p^2 and T^2p [1]
- correct calculation of T and T to be greater than earlier part of b)iii) [1]

p^2 = ……………………..……..

T^2p = ……………………..…….. [2]

(c) It is suggested that the relationship between T and p is

$$T^2p = qp^2 + S$$

where S has the value 0.020 m s^2 and q is a constant.

Using your values from **b(v)** and **b(vii)** to determine two values of q.

$$q_1 = \frac{T^2p - S}{p^2} = \frac{0.037 - 0.020}{0.0036} = 4.7 \text{ m}^{-1}\text{s}^2$$

$$q_2 = \frac{0.0929 - 0.020}{0.0144} = 5.06 \text{ m}^{-1}\text{s}^2$$

- q correctly calculated with correct unit (m^{-1} s^2) [1]

first value of q = ………………………..……..

second value of q = ………………………..…….. [1]

(d) State whether the results of your experiment support the suggested relationship. Justify your conclusion by referring to your values in **(b)(ii)** and **(b)(iv)**.

$$\% \text{ difference} = \frac{q_1 - q_2}{q_2} \times 100\% = \frac{5.06 - 4.7}{4.7} \times 100\% = 7.7\%$$

Since percentage difference of q is greater than **the sum of** percentage uncertainty in b)ii) and b)iv) (1.7+3.3=5.0%), the results of the experiment does no support the suggested relationship.

- show percentage different of q and make correct conclusion through comparison to **both** b)ii) and b)iv) added up.

………………………………………………………………………………………………..

……………………………………………………………………………………………… [1]

(e) Theory suggests that

$$q = \frac{4\pi^2}{g}$$

where g is the acceleration of free fall.

Use your value of q to determine g.

$$g = \frac{4\pi^2}{q_{ave}} = \frac{4\pi^2}{4.9} = 8.1\ \text{m s}^{-2}$$

- correct calculation **using** q_{ave} and correct units of g [1]

g = ……………………..……. [1]

(f) **(i)** Suggest two significant sources of error in this experiment.

[2]

- Two readings are not enough to draw a (valid) conclusion (not "not enough for accurate results", "few readings") and thus **affecting the accuracy of g or q.**
- Difficult to judge/decide/determine when to start and/or stop the stop-watch or when oscillation begins and/or ends thus **affecting accuracy of T.**
- Oscillations of cardboard is not only in the horizontal axis which will **affect the accuracy of T**.

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

[1]

- Take more readings and plot a straight line graph to determine the value of q.
- Place a grid behind the apparatus or fiducial mark at the centre of the oscillation or Video/film/record with slow motion function/ timer/frame-by-frame analysis.
- Use thicker/stiffer/heavier card

(g) It was suggested that the period of oscillation *T* for an isosceles triangle cardboard is directly proportional to the length of base *L* of the triangle.

You are given a few pieces of identical cardboard. Describe an experiment to investigate this relationship.

....

Let *L* be the length of base of triangle. Measure *L* using a meter rule and carry out the experiment as described in 3a)-b)iii) to determine the period of oscillation.

Using the identical pieces of cardboard, cut out 5 more isosceles triangle with different length of base but same area where area = length of base x height.

Repeat the experiment 5 more times using the triangles with varying length of base *L*.

Using the 6 sets of data of *T* and *L*, plot a graph of *T* vs *L*. If the relationship is valid, a straight line graph passing through the origin will be obtained.

Mention of apparatus to measure length of base and correct description of experiment (including mode of oscillation ie oscillate in horizontal axis) to determine *T* [M1]

Repeat of experiment to collect 6 sets of data (of T and L) by varying value of *L* [B1]

Keeping area of different isosceles triangle constant [C1]

Plotting of the correct graph with correct conclusion of suggested relationship [A1]

[4]

[Total: 21 marks]

Candidate Name: ____________________________ **Civics Group:** ____________

4 A solid cylinder floating in oil undergoes vertical oscillations when displaced vertically and released.

Fig. 4.1 shows an example of such a solid cylinder, with radius *r*.

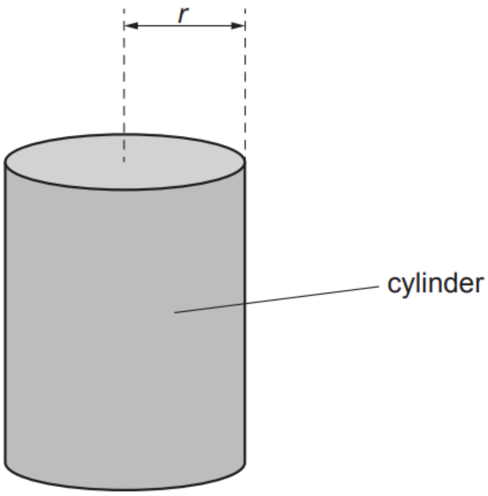


Fig. 4.1

The period of oscillation of the cylinder T in oil of density ρ is given by

$$T = K\, r^{a} \rho^{b}$$

where K, a and b are constants.

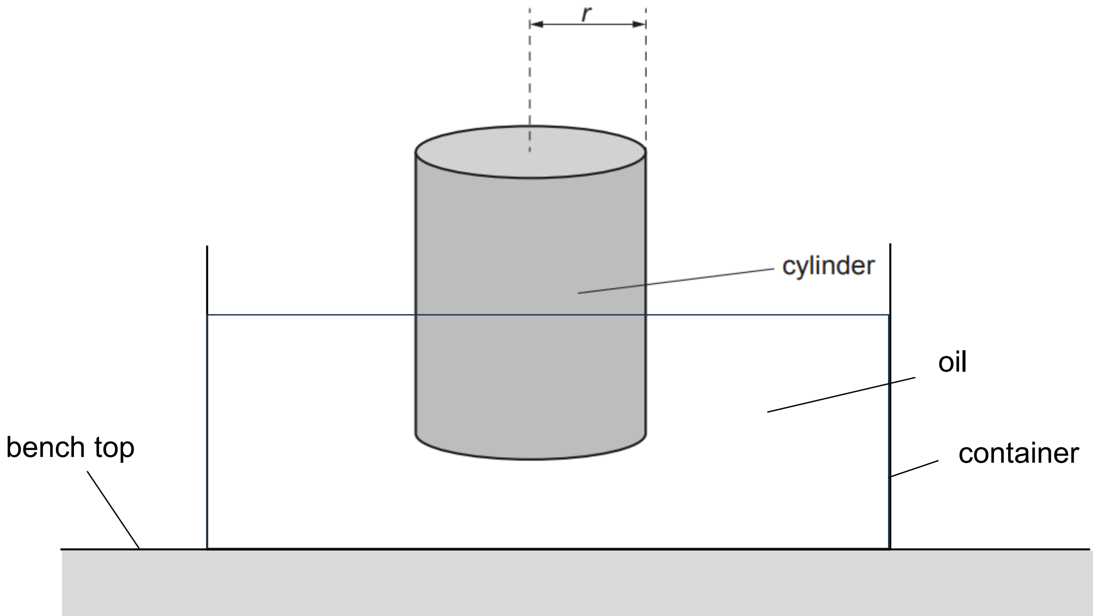
Design an experiment to determine the values of a and b.

You are provided with some cylinders of different diameters and some oils of different densities.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

- the equipment you would use
- the procedure to be followed
- how you would determine the density of the oil
- any precautions that should be taken to improve the accuracy and safety of the experiment.

Diagram



(Note:
- cylinder must be partially submerged in the oil
- container of oil should be placed on a surface)

Procedure:

1. Set up the experiment as shown above.
2. In this experiment, the variables are:
   a. Dependent variable: period of oscillation of cylinder , *T*
   b. Independent variables: radius of cylinder, *r* and the density of oil, *ρ*
3. Displace the cylinder vertically down and release it for it to undergo oscillations. After the oscillations become steady, measure time *t* for *n* number of oscillations, ensuring that *t* is more than 10 seconds. Determine *T* by calculating $T = \frac{t}{n}$.
4. To reduce random error, repeat measurement for each value of *t* to obtain average values for *T*.

Experiment 1: Keep *r* constant and vary *ρ*

5. Use the same cylinder throughout this experiment to keep *r* constant.
6. Choose an oil and pour it into an empty measuring cylinder (that is placed on a weighing balance and "tare" pressed to cater for its weight). Read off the volume of the oil from the measuring cylinder. Read off the mass of the oil from the weighing balance.
7. Determine *ρ* by calculating $\rho = \frac{\text{mass of oil}}{\text{volume of oil}}$.
8. Pour the oil into a container and place the cylinder into it. Measure *T* using the method in step 3.

9. Repeat steps 6 to 8 to carry out the experiment for a further 6 sets of readings by using oils of different densities.

10. $T = K\, r^a \rho^b$

    $\lg T = b \lg \rho + a \lg r + \lg K$

    Plot a graph of lg *T* against lg *ρ*. The value of b can be found from the gradient (the value of the vertical intercept is $a \lg r + \lg K$)

Experiment 2: Keep *ρ* constant and vary *r*

11. Use the same oil throughout this experiment to keep *ρ* constant.
12. Choose a cylinder and measure the diameter of the cylinder with a vernier caliper. *r* can be determined by calculating $r = \frac{\text{diameter of cylinder}}{2}$. To reduce random error, measure the diameter at different positions on cylinder and obtain average value.
13. Follow step 8 to obtain *T*.
14. Repeat steps 12 to 13 to carry out the experiment for a further 6 sets of readings by using cylinders of different diameters.
15. Plot a graph of lg *T* against lg *r*. The value of *a* can be found from the gradient (the value of the vertical intercept is $b \lg \rho + \lg K$)

Safety

16. Perform experiment by placing the entire set-up in a tray to prevent oil spillages.
17. Use gloves to avoid slippage when handling the cylinders.

Annotation	Rubrics	Max	Actual
Basic Procedure	In the process of measuring period T, **BP1:** mention of keeping density of oil ρ constant, vary radius of cylinder r (or diameter). Repeat for 6 sets of data. **BP2:** mention of keeping radius r (or diameter) constant, vary density of oil ρ. Repeat for 6 sets of data. For wrong proposed experiment (based on set-up in diagram), both BP1 and BP2 are deducted. (Some common examples of wrong proposed experiments: cylinder attached to string/ spring, oil put inside cylinder, cylinder coated with oil, no oil)	2	
Diagram	**D1:** Labelled diagram of workable experiment including • container of oil on a surface (e.g. bench) • cylinder partially submerged in the oil Accept (benefit of doubt) if there is no surface indicated, provided cylinder is partially submerged in a container of oil. Deduct mark if (cylinder is fully submerged, spring/ string attached to cylinder, drop cylinder from air towards oil).	1	
Measurements	**M1:** measure diameter of cylinder with vernier caliper/ruler and dividing by two to determine radius r **M2:** measure period of oscillation T with a stopwatch **M3:** measuring mass of oil with a weighing balance and volume of oil with a measuring cylinder. Determine density of oil ρ by dividing mass of oil with volume of oil. Accept if volume is determined by measuring cross-sectional area of container and height of oil with metre rule, then determined by product of cross-sectional area and height of oil	3	
Analysis of data	**A1:** Plot a suitable graph of ln T vs ln r (keeping ρ constant) gradient = a (vertical intercept = b ln ρ + ln K) **A2:** Plot a suitable graph of ln T vs ln ρ (keeping r constant) gradient = b (vertical intercept = a ln r + ln K)	2	
Other Reliability	**R1:** Measure time t for n oscillations with $t > 10$ s to determine T (to reduce fractional uncertainty of time taken) **R2:** Wait for oscillations to become steady before start timing	Max 3	

	R3: Repeat experiment (for each value of *r and ρ)* to obtain average values of *T* (to reduce random error) (Note: Must be clear that it's to repeat time measurement for the same r / ρ value) **R4:** Description of method to judge start and end of an oscillation (e.g. use of fiducial marker) (Note: not the same as having a marker to ensure same starting displacement for all oscillations (which is not a marking point)) **R5:** Repeat measurements of diameter of cylinder for different positions on the cylinder and take average (Note: need to clearly mention measure for different positions) **R6:** Using "tare" function on weighing balance to account for weight of measuring cylinder when measuring mass of oil / Or weigh container, weight container with oil separately, then minus both to find weight of oil **R7:** Any other relevant points. Some other accepted reliabilities (Note: must have proper rationale mentioned) 1) Do preliminary experiments to check range of radius used allows for clear and visible oscillations/ observable variation of period measured 2) Wipe off cylinder before using another oil (different density) 3) Ensure oil is still (using fiducial marker/spirit level) to prevent other forces acting on cylinder. 4) Ensure no bubbles/ impurities in the oil that may affect the oscillations. 5) Wash beaker (that measures oil) before adding more oil [or use a new beaker] to measure mass. 6) Check and account for zero error of the vernier caliper.		
Safety	**S1:** Perform experiment in tray to prevent oil spillages **S2:** Use gloves to avoid slippage when handling the cylinder Some other accepted safety points (Note: must have proper rationale mentioned) 1) Non-slip shoes/ footwear in case of oil spillage and floor gets slippery 2) Covered footwear in case cylinder slips from hands and hit foot. Not accepted: Avoid putting oil near flame, wear safety googles	Max 1	