Name: ______________________________ CG: __________ Date: ____________

Marking Scheme for Question 1

No	Mark Scheme	Mark	Score
1(a)	d measured to the nearest 0.01 mm with consistent unit Evidence of repeated measurements of d	1	
(b)	A calculated correctly to correct s.f	1	
(e)	I recorded to the nearest 0.1 mA with consistent unit. V_1 and V_2 recorded to the nearest 0.001 V	1 1	
(f)	Tabulate at least 6 sets of readings with correct d.p for I, V_1 and V_2. Award 0 marks if $\leq$ 5 readings are taken. Award 0 marks if assistance is provided in circuit setup. Correct d.p for $V_1 + V_2$ Correct column headings with units Note: − 2 marks for table if unable to obtain varying I, V_1 and V_2 values.	1 1 1	
(g)	Graph Correct linearization equation. Note: $(V_1 + V_2)$ against I Correct label of axes and graph should occupy at least half of graph paper. Correct plotted points Gradient coordinates read correctly and correct calculation of gradient. Correct calculation of ρ with units.	 1 1 1 1 1	
(i)	Sensible method to obtain ratio of cross-sectional areas. e.g. ratio of $\frac{V_1}{V_2}$.	1	
	Total	13	

No	Marking Instructions	Mark	Score
2(b)(i)	*L and a* recorded to nearest mm or 1 dp in cm or 3 dp in m.	1	
2(b)(ii)	*b* recorded to nearest mm or 1 dp in cm or 3 dp in m. b should be between 70 % to 90 % of a Repeat measurement	1 1	
2(c)(i)	Acceptable explanation	1	
2(c)(ii)	Uncertainty in b greater than 0.2 cm Percentage uncertainty to 2 sf	1	
2(d)	K calculated correctly to 3 sf	1	
2(e)	Correct linearization of eqn Correct expression for gradient	1 1	
	Total	8	

No	Marking Instructions	Mark	Score
3(a)(i)	D recorded to nearest 0.01 cm with unit Zero error recorded or evidence of repeat measurement (**range of D is with 10%)**	1	
(a)(ii)	d recorded to nearest 0.01 cm with unit. Evidence of repeat measurement	1	
(a)(iii)	r calculated correctly to correct d.p. with unit	1	
(a)(iv)	Correct calculation of % uncertainty using sensible value of ΔD and Δx. (0.03 cm $\leq \Delta D$ and $\Delta x \leq$ 0.05 cm)	2	
(b)(i)	T_R calculated correctly to 3 sf with clear working from <t>	1	
(b) (ii)	T_S calculated correctly to 3 sf with clear working from <t>, $T_S > T_R$	1	
(c)	L recorded to the correct d.p. with unit . Evidence of repeat measurement T_R calculated correctly to 3 sf with clear working from <t> T_S calculated correctly to 3 sf with clear working from <t> **(*value of T_S larger than T_R , otherwise minus 1 mark)**	2	
(d)(i)	Correct calculations of the two k values with correct unit	1 1	
(d)(ii)	Correct justification of s.f. of k linked to s.f. in r, L and T_R (lowest s.f.)	1	
(d)(iii)	Draw conclusion based on stated criterion. (e.g. not obeyed because % difference of k values > % uncertainty of r in (a)(iii))	1	
(e) (i)	All observations plotted and line of best fit is drawn	1	
(e)(ii)	Linearising equation and deriving gradient/y-intercept of graph Gradient – hypotenuse of the triangle is greater than half the length of the drawn line. Read-offs must be accurate to half a small square Value of n calculated correctly using gradient	1 1 1	
(f)	Correct method to locate the centre of the discs accurately Basic procedure and method of measuring period and r Control of variable : Keep L constant at the 3 positions of disc with the help of a metre rule Correct graph to plot How the graph shows that T is inversely proportional to r	1 1 1 1 1	
	Total	22	

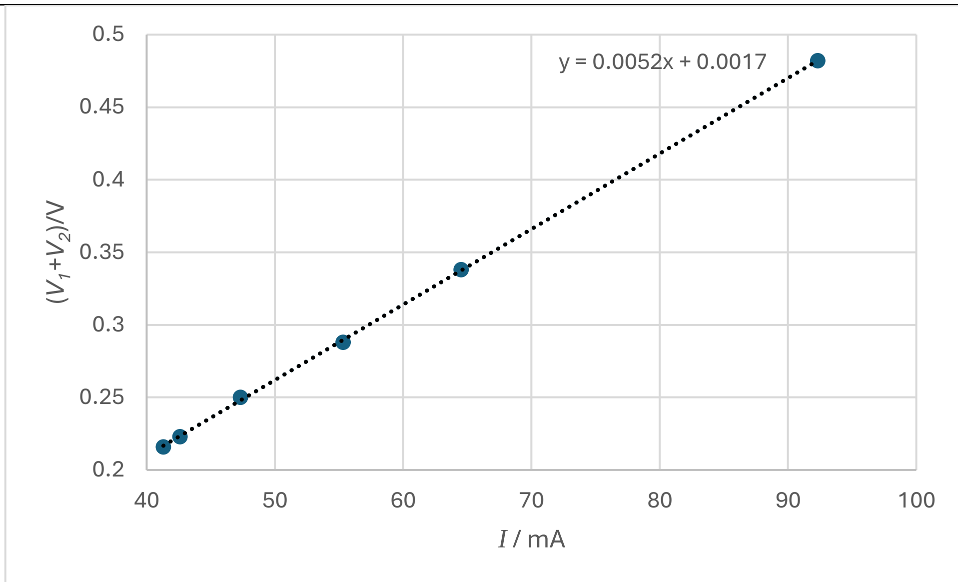
Suggested mark scheme for question 4 :

	Marks	
	A1	**Design (1 A mark)** Diagram with method to produce sound (using *loudspeaker connected to signal generator*) and CRO to measure frequency and amplitude of reflected sound (and incident sound)
	B1 B2 B3 B4 B5	**Procedure (5 B Marks)** Method of determining the density; measuring mass of foam (mass balance) and dimensions of foam (vernier calliper or micrometer, accept ruler) Method of measuring the frequency of transmitted sound (f =1/T where T from time-base on CRO; time base setting x no. of div for 1 complete wave shown on CRO.) Method of measuring the intensity of transmitted sound; Measure amplitude from vertical sensitivity on CRO; height × y-gain and determine the intensity of sound; $I \propto \text{Amplitude}^2$ Method to vary the frequency of sound (by varying frequency on signal generator) Method to vary foam ; replace with another foam of different density.
	C1 C2 C3 C4	**Safety and Analysis (4 C marks)** Expt 1 : constant ρ , Plot lg I vs lg f , gradient = m, y-intercept = lg (P ρ^n) Expt 2 : constant f, Plot lg I vs lg ρ , gradient = n, y-intercept = lg (P f^m) Obtain P from intercept of Expt 1: $10^{\text{y-intercept}} = A\,\rho^n$ Or from Expt 2: $10^{\text{y-intercept}} = A\,f^m$ (Need to show fully linearised equation to get the mark) $\lg I = m \lg f + n \lg \rho + \lg P$ Precaution linked to **loud sounds** e.g. use ear plugs/muffs.
	D1 D2 D3 D4 D5	**Details (Max 2 D marks)** The experiment conducted in a quiet room or soundproof enclosure to reduce background noise/ensure no other background noise. Do a pre-experiment to select an appropriate volume of sound that will be comfortably detected/measurable by the CRO Keep position and angle between loudspeaker and foam constant, as well as position and angle between microphone and foam constant by measuring regularly, using a metre ruler / making markings and checking angles to ensure they are always constant. 90° angle to be avoided Keep amplitude of incident sound constant by not changing the setting on the signal generator and to ensure it is constant by measuring it using a sound intensity meter/checking the amplitude using the vertical displacement on the CRO regularly. Other possible good physics suggestions
	12	

Experimental data and suggested solutions for Question 1

<table>
<tr><td>1(a)</td><td>Zero error = 0.00 mm
$d'_1 = 0.32$ mm
$d''_1 = 0.32$ mm
$d = 0.32$ mm</td></tr>
<tr><td>1(b)</td><td>$A_1 = \pi\left(\frac{0.32\times10^{-3}}{2}\right)^2 = 8.04\times10^{-8} = 8.0\times10^{-8}\ \text{m}^2$</td></tr>
<tr><td>1(c)</td><td>Zero error = 0.00 mm
$d'_2 = 0.46$ mm
$d''_2 = 0.46$ mm
$d_2 = 0.46$ mm

$A_2 = \pi\left(\frac{0.46\times10^{-3}}{2}\right)^2 = 1.66\times10^{-7} = 1.7\times10^{-7}\,\text{m}^2$</td></tr>
<tr><td>1(e)</td><td>$I =$ 41.3 mA
$V_1 =$ 0.115 V
$V_2 =$ 0.101 V</td></tr>
<tr><td>1(f)</td><td>
<table>
<tr><th>I/ mA</th><th>V_1 / V</th><th>V_2 / V</th><th>($V_1 + V_2$) / V</th></tr>
<tr><td>41.3</td><td>0.115</td><td>0.101</td><td>0.216</td></tr>
<tr><td>42.6</td><td>0.119</td><td>0.104</td><td>0.223</td></tr>
<tr><td>47.3</td><td>0.133</td><td>0.117</td><td>0.250</td></tr>
<tr><td>55.3</td><td>0.153</td><td>0.135</td><td>0.288</td></tr>
<tr><td>64.5</td><td>0.180</td><td>0.158</td><td>0.338</td></tr>
<tr><td>92.3</td><td>0.257</td><td>0.225</td><td>0.482</td></tr>
</table>
</td></tr>
<tr><td>1(g)</td><td></td></tr>
</table>

	 Gradient of graph = $\frac{y_1 - y_2}{x_1 - x_2} = 0.0052$ V/mA = 5.2 V A^{-1} Gradient of graph = $\rho L\left(\frac{1}{A_1}+\frac{1}{A_2}\right)$ $\rho(35\times10^{-2})\left(\frac{1}{8.04\times10^{-8}}+\frac{1}{1.66\times10^{-7}}\right)=5.2$ $\rho = 8.05 \times 10^{-7}\ \Omega$ m
1(h)	The ratio $\frac{V_1}{V_2}$ gives the ratio of the cross-sectional areas $\frac{A_2}{A_1}$. (Since current is constant, $V = IR = I\frac{\rho L}{A}$. The voltage across wire V is inversely proportional to cross-sectional area. Hence the ratio of cross-sectional area can be obtained from voltmeter readings.)

2(b)(i)	a = 25.0 cm
2(b)(ii)	b = 20.7 cm
2(c)(i)	Use of fiducial marker Repeated observations to refine position Or anything that is reasonable
2(c)(ii)	0.5 / 20.7 × 100% = 2.4%

2(d)	k = (50.0 – (50.0^2 – 20.7^2)$^{1/2}$) / (50.0 – (50.0^2 – 25.0^2)$^{1/2}$) = 0.670
2(e)	$k = \dfrac{L-\sqrt{L^2-b^2}}{L-\sqrt{L^2-a^2}}$ $L-\sqrt{L^2-a^2} = \dfrac{L-\sqrt{L^2-b^2}}{k}$ $\sqrt{L^2-a^2} = -\dfrac{L-\sqrt{L^2-b^2}}{k}+L$ Plot a graph $\sqrt{L^2-a^2}$ vs $L-\sqrt{L^2-b^2}$ to get a straight line With gradient = 1/k so k = 1/gradient

Question 3 Suggested solution

(a)(i) zero error $= 0.00$ cm

$D_1 = 15.00$ cm , $D_2 = 14.80$ cm

$\langle D\rangle = \frac{1}{2}(D_1 + D_2) = 14.90$ cm

(a)(ii)

$d_1 = 0.21$ cm, $d_2 = 0.27$ cm, $d_3 = 0.27$ cm

$\langle d\rangle = \frac{1}{3}(d_1 + d_2 + d_3) = 0.25$ cm

(a)(iii)

$r = \frac{1}{2}D - x = \frac{1}{2}\times 14.90 - 0.25 = 7.20$ cm

(a)(iii) Measure distance x of one hole from its nearest edge of the disc with vernier callipers. Repeat for the other holes and take average of x . Distance $r = \frac{1}{2}D - < x >$

(a)(iv) $\Delta r = \frac{1}{2}\Delta D + \Delta x = \frac{1}{2}\times 0.04 + 0.04 = 0.06$ cm

percentage uncertainty $= \dfrac{\Delta r}{r}\times 100\% \approx \dfrac{0.06}{7.20}\times 100\% = 0.83\%$

(b)

$L_1 = 29.8$ cm, $L_2 = 30.0$ cm, $L_3 = 30.2$ cm

$\langle L\rangle = \frac{1}{3}(L_1 + L_2 + L_3) = 30.0$ cm

(b)(i) Timing for 20 oscillations

$t_1 = 16.4$ s , $t_2 = 16.0$ s

$\langle t\rangle = \frac{1}{2}(t_1 + t_2) = 16.2$ s

Period

$$T_R = \frac{\langle t\rangle}{20} = 0.810 \text{ s}$$

(b)(ii)

Timing for 20 oscillations

$$t_1 = 21.8\text{s},\ t_2 = 21.7\text{ s}$$

$$\langle t \rangle = \tfrac{1}{2}(t_1 + t_2) = 21.8\text{ s}$$

Period

$$T_S = \frac{\langle t \rangle}{20} = 1.09\text{ s}$$

(c)

$$L_1 = 50.0\text{ cm},\ L_2 = 50.0\text{ cm},\ L_3 = 50.0\text{ cm}$$

$$\langle L \rangle = \tfrac{1}{3}(L_1 + L_2 + L_3) = 50.0\text{ cm}$$

Timing for 20 oscillations in **(b)(i)**

$$t_1 = 21.4\text{ s},\ t_2 = 20.9\text{ s}$$

$$\langle t \rangle = \tfrac{1}{2}(t_1 + t_2) = 21.2\text{ s}$$

Period $T_R = \dfrac{\langle t \rangle}{20} = 1.06\text{ s}$

Timing for 20 oscillations in **(b)(ii)**

$$t_1 = 27.8\text{ s},\ t_2 = 27.8\text{ s}$$

$$\langle t \rangle = \tfrac{1}{2}(t_1 + t_2) = 27.8\text{ s}$$

Period $T_S = \dfrac{\langle t \rangle}{20} = 1.39\text{ s}$

(d)(i)

Since $k = \dfrac{T_R r}{\sqrt{L}}$,

$$k_1 = \frac{T_{R1} r}{\sqrt{L_1}} = \frac{0.810 \times 0.0720}{\sqrt{0.300}} = 0.106\text{ m}^{1/2}\text{ s}$$

$$k_2 = \frac{T_{R2} r}{\sqrt{L_2}} = \frac{1.06 \times 0.0720}{\sqrt{0.500}} = 0.108\text{ m}^{1/2}\text{ s}$$

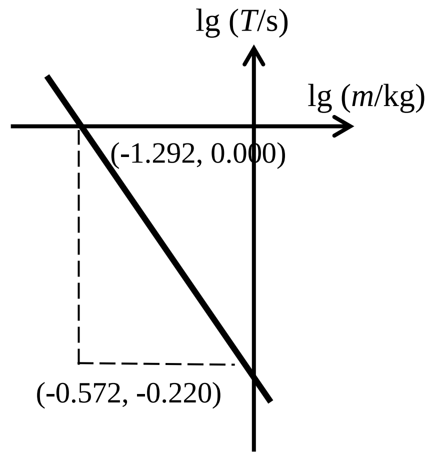
(d)(ii)

The values of k involves multiplication and division of quantities. The significant figures (s. f.) of k follows the data with the least s.f. of T_R, r or L. Since all of them have 3 s.f., the value of k is expressed to 3 s.f.

(d)(iii)

Percentage difference from lower value of k = (0.108 – 0.106)/0.106 = 1.87 %
This percentage difference is more than the percentage uncertainty calculated in (a)(iv), so the results do not support the suggested relationship.

(e) (i)



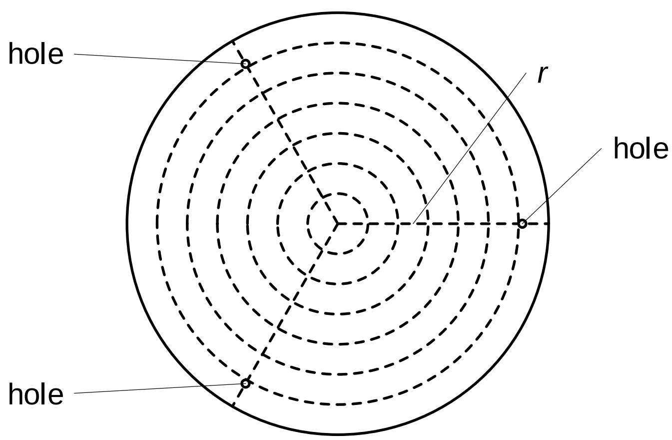
(e)(ii)

Given $T = km^n \Rightarrow \lg T = n \lg m + \lg k$

Plot a graph *of* lg T / s versus lg m / kg

$$n = \text{gradient} = \frac{0.000 - 0.220}{-1.292 - -0.572} = \frac{0.220}{-0.720} = -0.306$$

(f)



1. Attached a plumbline to the holes to locate the centre of the disc.

2. With a compass, draw 11 concentric circles of incremental radius of 0.5 cm up to 7.5 cm (radius of the disc). Also draw 3 radial lines at 120° interval from the centre of the circle with the help of a protractor.

2. Stack disc A and B and align the discs to the circle and secure with a clamp.

3. Drill small holes (diameter of 1 mm) at all intersection points between the lines and circles.

4. Measure r using the method described in (a)(ii).

5. Setup the apparatus as shown in Fig. 3.2.

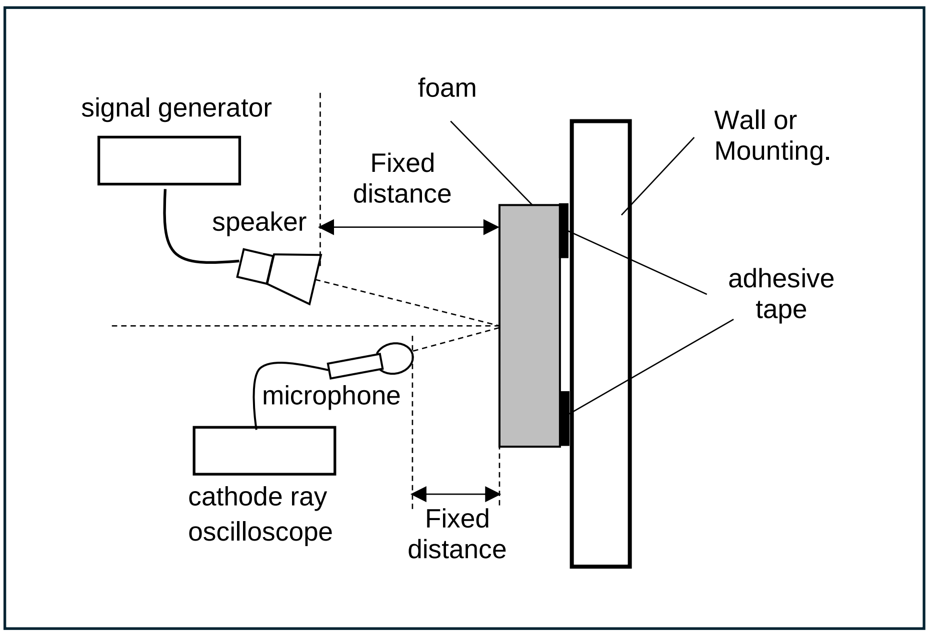
6. Measure distance L between discs at 3 positions (near the strings) with a metre rule. Calculate the average distance L.

7. Rotate disc B about a vertical axis and release. Measure the time t for N number of oscillations with a stopwatch such that $t > 20$ s. Period $T = t/N$.

8. Repeat step 7 for a total of 6 sets of readings of r and T by threading the strings through different sets of holes of same r. Ensure that L is constant at the 3 positions using a metre rule before timing.

9. If $T \propto 1/r \Rightarrow T = k/r$, where k is a constant. Plot a graph of T against $1/r$. If a straight-line graph with zero vertical intercept (or close to zero) is obtained, then T is inversely proportional to r.

Question 4



Procedure:

Expt 1: Keep ρ constant. Vary f to measure I

1. Set up the rest of the apparatus as shown. Measure the dimensions of the foam using vernier callipers and its mass using mass balance. Attach the foam on wall as shown. Use the same foam material throughout.
2. Adjust the frequency of the signal generator to produce a sound in the audible range (20 H to 20 kHz), eg 1 kHz. Do not change the amplitude on the signal generator.
3. Adjust the Y-scale to maximize the waveform on the CRO display of reflected sound. Measure the amplitude y (see Figure) and hence calculate the amplitude of the reflected sound A in volts, where A is the product of y and the vertical sensitivity.
   Calculate Intensity$\propto$A^2

4. Adjust the time-base (X-scale) of the CRO to get a stable waveform of at least one but preferably two cycles. Measure x, time for 1 complete waveform. Calculate the period, *T* in seconds, where *T* is the product of *x* and time-base.
5. Calculate the frequency of the sound using $f = \frac{1}{T}$.
6. Adjust frequency setting of signal generator and repeat steps 1 to 5 until 6 sets of readings for *I* and *f* are collected.

Analysis:

For constant ρ , Plot lg I vs lg f , gradient = m, y-intercept = lg (P ρ^n)

<u>Expt 2: Keep *f* constant. Vary ρ to measure *I*</u>

7. Adjust the frequency of the signal generator to produce a sound in the audible range (20 H to 20 kHz) and keep frequency and the amplitude of the incident sound throughout the whole experiment.
8. Measure the dimensions of foam using vernier callipers and its mass using mass balance. Calculate and record the density of the foam, ρ = mass/volume. Attach the foam on wall as shown.
9. Repeat step 3 in Expt 1 to calculate the intensity of the reflected sound in volts.
10. Remove and replace the foam for different values of foam density ρ and repeat procedure until 6 sets of readings for *I* and ρ are obtained.

Analysis:
lg I =m lg f +n lg ρ + lgP

For constant ρ,
Plot lg *I* vs lg ρ , gradient = n, y-intercept = lg (P f^m)

to obtain P; from equation
Obtain P from intercept of Expt 1: $10^{\text{y-intercept}} = P \rho^n$ Or
from Expt 2: $10^{\text{y-intercept}} = PA f^m$

or sub known constants to find P from
lg I =m lg f +n lg ρ + lgP

Safety precaution

1. Wear ear plugs/ noise cancelling headphones in case sound is too loud such that it may damage the ear.

Other reliability measures/Additional details

1. The experiment should be conducted in a quiet room or sound proof box to reduce background noise.
2. Do a pre-experiment to select an appropriate volume of sound that will be comfortably detected by the CRO for the range of air gaps used.
3. Both the loudspeaker directed at a fixed position from foam, using a ruler to measure. Mark out the positions and trace a line from the wall to the speaker and align the speaker to the line so the sound signal directed to the wall at the same fixed angle throughout the experiment.
4. Use a protractor to measure out the expected path of the reflected wave (angle of reflection = angle of incidence) and position the microphone along this path.
5. Angle of 90^0 should not be used as the incident and reflected waves would overlap and interfere affecting the measurement of I *of the reflected wave; stationary wave would form too.*
6. Loudspeaker and microphone should be isolated e.g, rested on a damping sheet to reduce sound transmission via benchtop.
7. Keep amplitude of incident sound constant by not changing the setting on the signal generator or volume control from the loudspeaker.