15TH ASIAN PHYSICS OLYMPIAD
11 - 18 MAY 2014, SINGAPORE

Experimental Competition
May 15, 2014
0830 - 1330 hrs

Marking Rubric

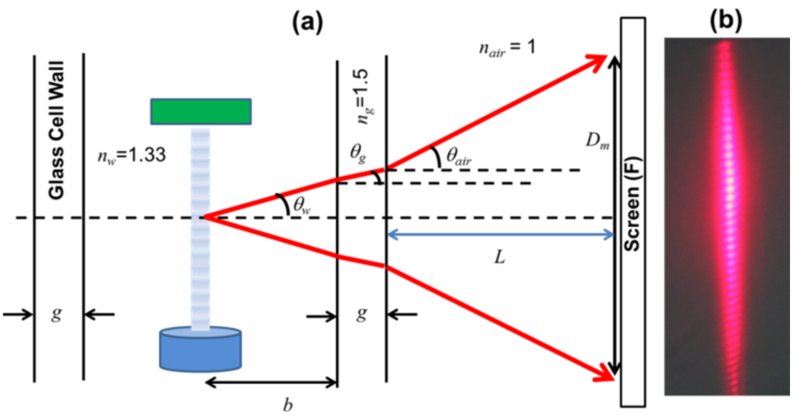
Country:	Sample Solution	Student Code:	Sample Solution

Experiment A:

A1. In the space below, derive an equation for λ_s in terms of (b, g, m, n_w, n_g, L, λ_{air}, and D_m) under small angle approximation condition.

Total = 1.5

If final answer is the same, then get full mark



Given, $d \sin\theta_w = i\,\lambda_w$ (1)

Also we know, $n_w\,\lambda_w = n_{air}\,\lambda_{air}$ (2)

Raman and Nath condition: $d = \lambda_s$ (3)

Snell's Law: water to glass $\frac{n_g}{n_w} = \frac{\sin\theta_w}{\sin\theta_g} = \frac{\lambda_w}{\lambda_g}$ (4)

Snell's Law: glass to air $\frac{n_g}{n_{air}} = \frac{\sin\theta_{air}}{\sin\theta_g} = \frac{\lambda_{air}}{\lambda_g}$ (5)

From above Figure $D_m = 2\left(b\tan\theta_w + g\tan\theta_g + L\tan\theta_{air}\right)$ (6)

Using small angle approximation:

$\tan\theta_w = \sin\theta_w$; $\tan\theta_g = \sin\theta_g$; $\tan\theta_{air} = \sin\theta_{air}$ (7)

Fron Eqns (6) and (7) $D_m = 2\left(b\sin\theta_w + g\sin\theta_g + L\sin\theta_{air}\right)$ (8)

Writing $\sin\theta_g$ and $\sin\theta_{air}$ in terms of $\sin\theta_w$ from equations (4) and (5) $D_m = 2\left(b + g\frac{n_w}{n_g} + L\frac{n_w}{n_{air}}\right)\sin\theta_w$

Substituting $\sin\theta_w$ from equations (1), (2) and (3) and counting <u>the total number of fringes</u> m in distance D_m on the screen

$$D_m = \left(b + g\frac{n_w}{n_g} + L\frac{n_w}{n_{air}}\right)(m-1)\frac{n_{air}}{n_w}\frac{\lambda_{air}}{\lambda_s} \quad (9)$$

Note that $m = 2i+1$

Rearranging the terms to get λ_s

$$\lambda_s = \left(\frac{b}{n_w} + \frac{g}{n_g} + \frac{L}{n_{air}}\right)(m-1)\frac{n_{air}\,\lambda_{air}}{D_m} \quad (10)$$

$$\boxed{A = \left(\frac{b}{n_w} + \frac{g}{n_g} + \frac{L}{n_{air}}\right)} \quad (11)$$

Marking:

0.1 for Eqn (2)

0.1 for Eqn (4)

0.1 for Eqn (5)

0.4 for Writing the correction Eqn (6)

0.1 for Small angle approximation

0.2 for expressing all angles to θ_w

0.1 for relating i to m.

0.3 for λ_s expression

0.1 for A

Some examples of

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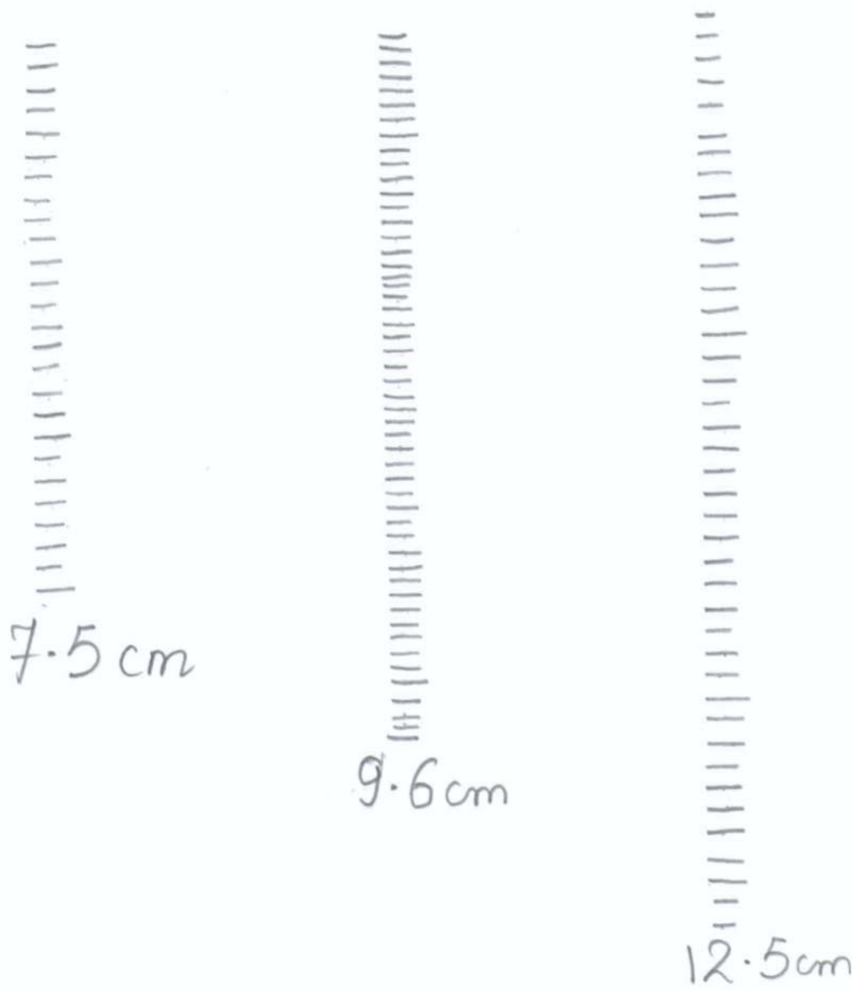
	Note - If they ignore glass, merge glass and water **(-0.3 mark, max mark =1.2)** $$A = \left(\frac{b+g}{n_w} + \frac{L}{n_{air}}\right) \qquad (11a)$$ **Note -** If they ignore glass and water and everything considered as air **(-1.0 mark, max mark =0.5)** $$\lambda_s = (b+g+L) \qquad (11b)$$	**variations to be considered**

Country:	Sample Solution	Student Code:	Sample Solution

A2. Attach this Answer Sheet to the Screen (F) and mark the fringes in the space below.



	Pattern 1	Pattern 2	Pattern 3	
m =	26	51	41	
D_m = (cm)	7.5	9.6	12.5	$\Delta D_m = \pm 0.05$
Temperature of the mineral water (°C)	22	22	22	$\Delta T = \pm 0.5$

NOTE: Temp in Exam Hall was 27 °C for water in Glass Cell under experimental conditions with precaution taken.

Total : 2.5

1.6 for Patterns
1.6 for ≥ 3 patterns
1.4 for 2 patterns
1.2 for 1 pattern

Note –
The maximum marks will be reduced to 50% of the marks mentioned above if the number of fringes marked is less than 10 on average; and 25% for less than 5 marked fringes.

0.9 for complete table

-0.1 each uncertainty missing
-0.1 each unit missing
-0.1 T missing
-0.2 m missing
-0.2 D_m missing

Note: the marks allocated for the table will be given if the values are implicitly observed in the results

Country:	Sample Solution	Student Code:	Sample Solution

A3.	Measure and record all relevant parameters in the space below and calculate the wavelength of sound, λ_s, in mineral water.	**Total : 1.0**

A3. Measure and record all relevant parameters in the space below and calculate the wavelength of sound, λ_s, in mineral water.

n_w = refractive index of water = 1.333±0.007
n_{air} = refractive index of air = 1.000±0.0003
n_g = refractive index of glass = 1.50±0.005
λ_{air}= the wavelength of laser light in air = $660 \pm 3\ nm$

Thickness of the wall of glass cell: $g = 5.05 \pm 0.05\ mm$

	$b\ (cm)$ $\pm 0.2cm$	$L\ (cm)$ $\pm 0.5cm$	$D\ (cm)$ $\pm 0.05cm$	m	$\lambda_s\ (m)$ $\times 10^{-4}$
Pattern 1	5	368.5	7.5	26	8.20
Pattern 2	5.5	235	9.6	51	8.23
Pattern 3	7.1	384.6	12.5	41	8.24

$$\lambda_s = \frac{(8.20 + 8.23 + 8.24) \times 10^{-4}}{3}\ \text{m} = 8.22 \times 10^{-4}\ \text{m}$$

λ_s=	8.22×10^{-4} m

Total : 1.0

0.1 Right value of g (between 4.9 to 5.1mm)

0.4 Tabulation of b, L

0.5 for value of λ_s

Note - λ_s is Temperature dependent

(0.5: within 5% of value of λ_s at temperature noted by Organizing Committee in Exam Hall)

(0.3: for outside 5% but within 10% of value of λ_s at noted temperature)

(0.1: for outside 10% but within 20% of value of λ_s at noted temperature)

0 otherwise

Note: If λ_s is wrong due to totally wrong A, then team leader check for value from correct formula and award from above guidelines for λ_s, but with a further deduction of 0.1 mark.

-0.1 each uncertainty missing
-0.1 each unit missing

-0.1 b missing

-0.1 L missing

-0.2 for $L < 0.5$ m

Country:	Sample Solution	Student Code:	Sample Solution

A4.	Calculate and record the frequency of ultrasonic waves, f_s, in mineral water. From the graph, Speed of ultrasound in water at 22 ^{0}C is $1484 \pm 4 m\ s^{-1}$ Frequency of ultrasound: $f_s = \frac{v_s}{\lambda_s} = \frac{1484}{8.22 \times 10^{-4}} = 1.80$ MHz f_s = 1.80 MHz If λ_s is wrong due to totally wrong A then subtract additional 0.1 from above guidelines for λ_s. **NOTE**: Temp in Exam Hall was 27 °C for water in Glass Cell under experimental conditions with precaution taken.	**Total: 0.5** **0.2** Right value of speed of sound (@ the reported *T*) **0.1** for $f_s = \frac{v_s}{\lambda_s}$ **0.1** for unit **0.1** for correct answer (full 0.1 for value within 5% of 1.786MHz; 0 otherwise) **Note**: Measured value of frequency of the piezoelectric transducers is 1.786 MHz.

Country:	Sample Solution	Student Code:	Sample Solution

A5. Carry out an error analysis to estimate the uncertainty, Δf_s, in the frequency of ultrasonic wave.

Check that small angle is appropriate $\theta \sim \frac{D_m}{L} \sim \frac{9.6}{235}$. So the percentage difference between $\tan\theta$ and $\sin\theta$ is ~0.02%.

From equation (10), relative error in λ_s can be written as

$$\frac{\Delta\lambda_s}{\lambda_s} \approx \sqrt{\frac{\left(\frac{\Delta b}{n_w}\right)^2 + \left(\frac{\Delta g}{n_g}\right)^2 + (\Delta L)^2}{\left(\frac{b}{n_w} + \frac{g}{n_g} + \frac{L}{n_{air}}\right)^2} + \left(\frac{\Delta D_m}{D_m}\right)^2}$$

$$\frac{\Delta\lambda_s}{\lambda_s} \approx \sqrt{\frac{\left(\frac{0.1}{1.333}\right)^2 + \left(\frac{0.005}{1.5}\right)^2 + (0.5)^2}{\left(\frac{b}{n_w} + \frac{g}{n_g} + \frac{L}{n_{air}}\right)^2} + \left(\frac{0.05}{D_m}\right)^2}$$

	$b\ (cm)$ $\pm 0.1cm$	$L\ (cm)$ $\pm 0.5cm$	$D_m\ (cm)$ $\pm 0.05cm$	m	$\lambda_s\ (m)$ $\times 10^{-4}$	$\frac{\Delta\lambda_s}{\lambda_s}$
Pattern 1	5.0	368.5	7.5	26	8.20	0.0068
Pattern 2	5.5	235	9.6	51	8.23	0.0056
Pattern 3	7.1	384.6	12.5	41	8.24	0.0042

$$\left(\frac{\Delta\lambda_s}{\lambda_s}\right)_{mean} = 0.0055$$

$$\frac{\Delta f_s}{f_s} = \sqrt{\left(\frac{\Delta\lambda_s}{\lambda_s}\right)^2 + \left(\frac{\Delta v_s}{v_s}\right)^2} = \sqrt{0.0055^2 + \left(\frac{2}{1484}\right)^2} = 0.006$$

$\Delta f_s =$	0.011MHz

Alternative

If students get three or more patterns and calculate the standard error using

$$standard\ error = \frac{\sigma}{\sqrt{N-1}}$$

Total: 1.0

0.8 Expression for $\frac{\Delta f_s}{f_s}$ everything combined

(**0.6** for $\frac{\Delta\lambda_s}{\lambda_s}$

0.2 for $\frac{\Delta f_s}{f_s}$ by combining $\frac{\Delta\lambda_s}{\lambda_s}$ and $\frac{\Delta v_s}{v_s}$)

0.2 for the right numerical value.

(0.2 : 0.01 MHz-0.09 MHz)

(0.1 : (0.005 to <0.01) MHz and (>0.09 to 0.18) MHz

0 otherwise

Note: if students just take one pattern but do this detail error analysis, get full 1.0 mark for error analysis if the analysis is done correctly.

Alternative (Max 1.0)

0.4 for the correct expression for the standard error.

0.4 If they do at least 6 times and then go for standard error

(**0.2** If they do at least three times and then go for standard error)

0.2 marks for numerical value. (Further penalty as per rules/range specified above)

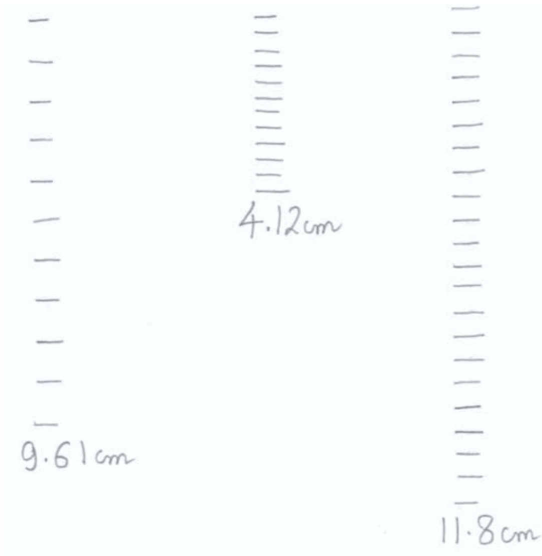
Country:	Sample Solution	Student Code:	Sample Solution

Experiment B

B1.	Write down the equation for λ_s. $$\lambda_s = \frac{2p}{m_B - 1} \quad (12)$$ m_B represents the number of fringes counted corresponding to D_B. $$M = \frac{D_B}{p} = \frac{\left[\frac{(S_1 - f_L)}{n_{air}} + \frac{2g}{n_g} + \frac{(a+b)}{n_w} + \frac{S_2}{n_{air}}\right]}{\left[\frac{(S_1 - f_L)}{n_{air}} + \frac{g}{n_g} + \frac{a}{n_w}\right]} \quad (3)$$ $$\therefore\ p = D_B \frac{\left[\frac{(S_1 - f_L)}{n_{air}} + \frac{g}{n_g} + \frac{a}{n_w}\right]}{\left[\frac{(S_1 - f_L)}{n_{air}} + \frac{2g}{n_g} + \frac{(a+b)}{n_w} + \frac{S_2}{n_{air}}\right]}$$ $$\therefore\ \lambda_s = \frac{2D_B}{(m_B - 1)} \frac{\left[\frac{(S_1 - f_L)}{n_{air}} + \frac{g}{n_g} + \frac{a}{n_w}\right]}{\left[\frac{(S_1 - f_L)}{n_{air}} + \frac{2g}{n_g} + \frac{(a+b)}{n_w} + \frac{S_2}{n_{air}}\right]}$$	**Total: 1.0** **0.2** for using M for getting p **0.8** for equation (12) **-0.8** for missing the factor 2 i.e. for not realizing that for standing wave the spacing between bright/dark spaces is $\lambda_s/2$ **-0.2** for using m_B instead of m_B -1 (no deduction if the results show that m_B = number of intervals)

Country:	Sample Solution	Student Code:	Sample Solution

B2. Attach this Answer Sheet to the Screen (F) and mark the projected standing wave pattern in the space below.



	Pattern 1	Pattern 2	Pattern 3	
$m_B =$	11	12	22	
$D_B =$ (cm)	9.61	4.12	11.80	$\Delta D_B = \pm 0.05$
Temperature of the mineral water (°C)	22	22	22	$\Delta T = \pm 0.5$

NOTE: Temp in Exam Hall was 27 °C for water in Glass Cell under experimental conditions with precautions taken.

Total : 2.0

1.4 for Patterns
≥ 3 patterns get **1.4**
2 patterns get **1.2**
1 pattern gets **1.0**

Full marks for more than 2 dark/bright region marked.

0.6 for the complete table

-0.1 each uncertainty missing
-0.1 each unit missing
-0.1 T missing
-0.1 m_B missing
-0.1 D_B missing

Note - the marks allocated for the table will be given if the values are implicitly observed in the results

B3. Measure and record all relevant parameters in the space below

Total: 1.5

Country:	Sample Solution	Student Code:	Sample Solution

	and calculate the wavelength of sound, λ_s, in mineral water.	**0.1** Right value of *g* (between 4.9 to 5.1mm) **0.9** Tabulation of *a, a+b* or *b, S_1, S_2* **0.5** for value of λ_s **Note** - λ_s is Temperature dependent (**0.5**: within 5% of value of λ_s at temperature noted by Organizing Committee in Exam Hall) (**0.3**: for outside 5% but within 10% of value of λ_s at noted temperature) (**0.1**: for outside 10% but within 20% of value of λ_s at noted temperature) **0** otherwise **Note:** If λ_s is wrong due to totally wrong *A*, then team leader check for value from correct formula and award from above guidelines for λ_s, but with a further deduction of 0.1 mark. **-0.1** each uncertainty missing **-0.1** each unit missing) up to maximum penalty of 0.5 marks **-0.1** *a* or *b* missing **-0.1** S_1 or S_2 missing **-0.1** for $S_2 < 0.3$ m

	Pattern 1	Pattern 2	Pattern 3	
a (cm)	5.2	5.5	3.5	$\Delta a = 0.1$ *cm*
a+b(cm)	11.16	11.16	12.00	$\Delta(a+b) = 0.05$ *cm*
g (cm)	0.5	0.5	0.5	$\Delta g = 0.05$ *cm*
S_1*(cm)*	12.7	12.7	20.5	$\Delta S_1 = 0.1$ *cm*
S_2*(cm)*	257.4	92.2	208.5	$\Delta S_2 = 0.1$ *to 0.5cm depending on experiment*
m_B	11	12	22	
D_B *(cm)*	9.61	4.12	11.80	$\Delta D_B = \pm 0.05$
M	22.96	8.95	12.66	
p (cm)	0.419	0.46	0.932	
$\lambda_s (\times 10^{-4} m)$	8.37	8.37	8.88	

f_L=5.0 cm

$\lambda_{s,\ mean}$=	8.54×10^{-4} m

Country:	Sample Solution	Student Code:	Sample Solution

B4.	Calculate and record the frequency of ultrasonic waves, f_s, in mineral water. Frequency of ultrasound: $f_s = \frac{v_s}{\lambda_s} = \frac{1484}{8.54\times10^{-4}} = 1.74$ MHz $f_s =$ 1.74 MHz	**Total 0.5** **0.1** for $f_s = \frac{v_s}{\lambda_s}$ **0.1** for unit **0.3** for correct answer (full 0.3 for value within 5% of 1.786MHz; 0.2 for value outside 5% but within 10% of 1.786MHz; 0 otherwise) **Note**: Measured value of frequency of the piezoelectric transducers is 1.786 MHz.

Country:	Sample Solution	Student Code:	Sample Solution

B5. Carry out an error analysis to estimate the uncertainty, Δf_s, in frequency of ultrasonic wave.

Total: 1.0

$$\frac{\Delta\lambda_s}{\lambda_s} \approx \sqrt{\left(\frac{\Delta D_B}{D_B}\right)^2 + \left(\frac{(\Delta S_1)^2 + \left(\frac{\Delta g}{n_g}\right)^2 + \left(\frac{\Delta a}{n_w}\right)^2}{\left(S_1 - f_L + \frac{g}{n_g} + \frac{a}{n_w}\right)^2}\right) + \left(\frac{(\Delta S_1)^2 + \left(\frac{2\Delta g}{n_g}\right)^2 + \left(\frac{\Delta(a+b)}{n_w}\right)^2 + (\Delta S_2)^2}{\left(S_1 - f_L + S_2 + \frac{2g}{n_g} + \frac{a+b}{n_w}\right)^2}\right)}$$

	Pattern 1	Pattern 2	Pattern 3	
a (cm)	5.2	5.5	3.5	Δa=0.1 cm
a+b(cm)	11.16	11.16	12.00	$\Delta(a+b)$=0.05 cm
g(cm)	0.5	0.5	0.5	Δg=0.05 cm
S_1*(cm)*	12.7	12.7	20.5	ΔS_1=0.1 cm
S_2*(cm)*	257.4	92.2	208.5	ΔS_2=0.5 cm
m_B	11	12	22	
D_B *(cm)*	9.61	4.12	11.80	ΔD_B= ±0.05
M	22.96	8.95	12.66	
p (cm)	0.419	0.46	0.932	
λ_s*(x* 10^{-4}*m)*	8.37	8.37	8.88	
$\Delta\lambda_s/\lambda_s$	0.012	0.016	0.008	

f_L=5.0 cm

$$\left(\frac{\Delta\lambda_s}{\lambda_s}\right)_{mean} = 0.012$$

$$\frac{\Delta f_s}{f_s} = \sqrt{\left(\frac{\Delta\lambda_s}{\lambda_s}\right)^2 + \left(\frac{\Delta v_s}{v_s}\right)^2} = \sqrt{0.012^2 + \left(\frac{4}{1484}\right)^2} = 0.012$$

Δf_s =	0.022MHz

0.8 Expression for $\frac{\Delta f_s}{f_s}$ everything combined

(0.6 for $\frac{\Delta\lambda_s}{\lambda_s}$

0.2 for $\frac{\Delta f_s}{f_s}$ by combining $\frac{\Delta\lambda_s}{\lambda_s}$ and $\frac{\Delta v_s}{v_s}$)

0.2 for the right numerical value.

(0.2 : 0.01 MHz-0.09 MHz)

(0.1 : (0.005 to <0.01) MHz and (>0.09 to 0.18) MHz

0 otherwise

Note: if students just take one pattern but do this detail error analysis, get full 1.0 mark for error analysis if the analysis is done correctly.

Alternative (Max 1.0)

0.4 for the correct expression for the standard error.

0.4 If they do at least 6 times and then go for standard error

(**0.2** If they do at least three times and then go for standard error)

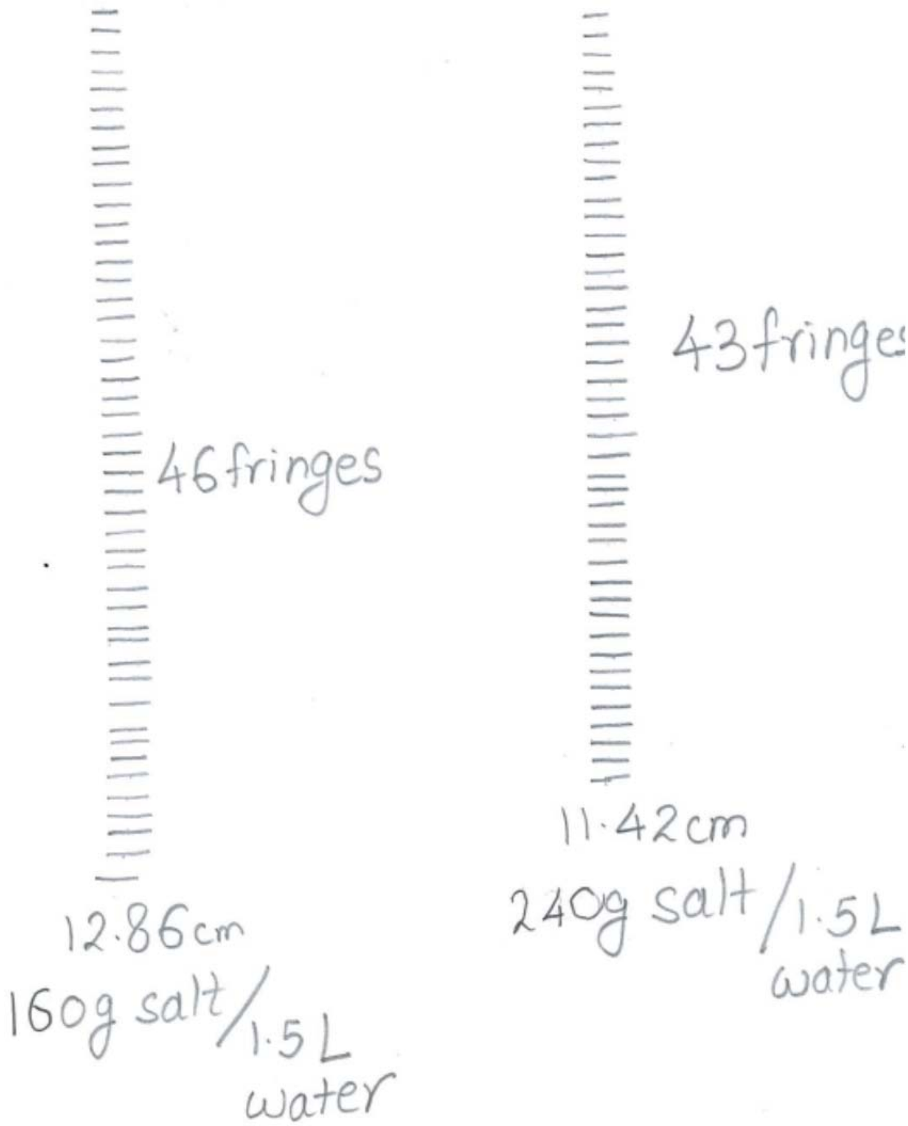
0.2 marks for numerical value. (Further penalty as per rules/range specified above)

Country:	Sample Solution	Student Code:	Sample Solution

Experiment C

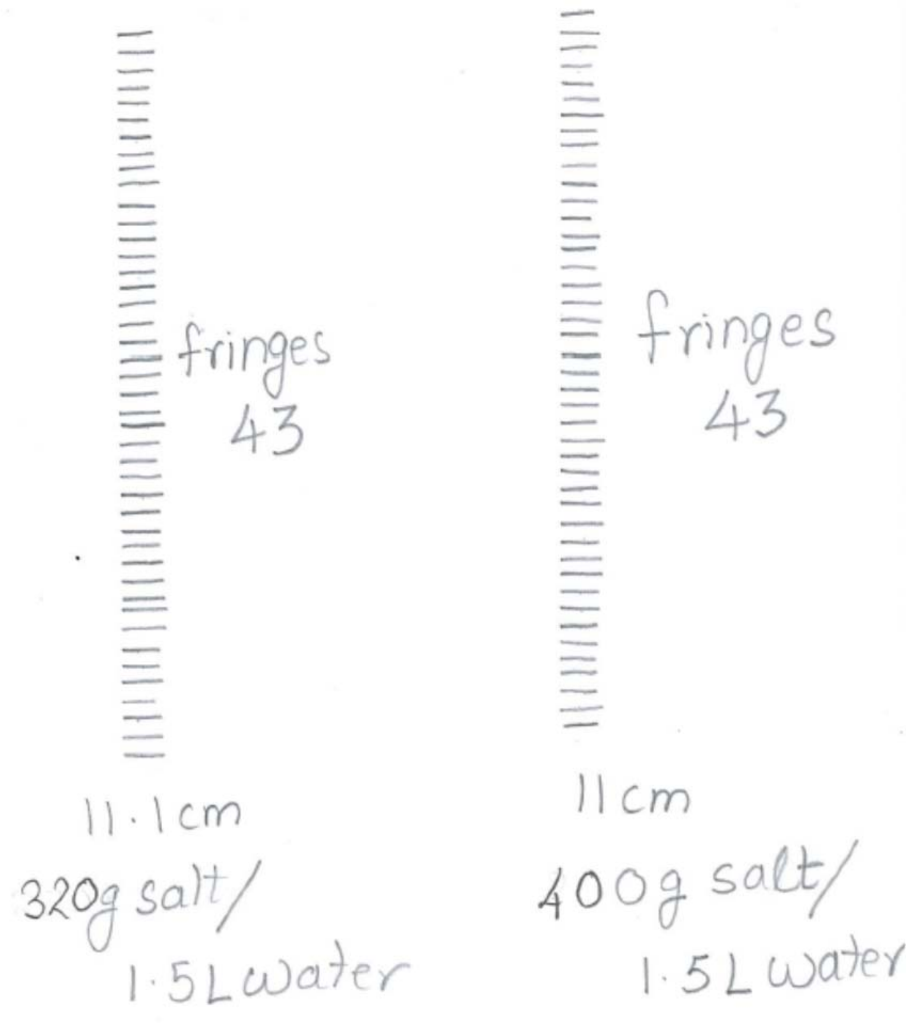
C1.	Attach this Answer Sheet to the Screen (F) and mark the observed patterns in the space below. Label each recorded pattern with the corresponding salt concentration. ***Do not forget to note down the relevant experimental parameters, in Answer Sheet C2 on page 10, needed for calculations.*** 	**Total: 1.0** ≥ 5 different Salt Conc. get 1.0 4 Conc. gets 0.8 3 Conc. gets 0.6 2 Conc. get 0.4 1 Conc. gets 0.2 Note - Above numbers exclude 0 concentration pattern which may be obtained from given graph Note – Not penalized for number of fringes

Country:	Sample Solution	Student Code:	Sample Solution

C1.	Attach this Answer Sheet to the Screen (F) and mark the observed patterns in the space below. Label each recorded pattern with the corresponding salt concentration. ***Do not forget to note down the relevant experimental parameters, in Answer Sheet C2 on page 10, needed for calculations.*** 	cont

Country:	Sample Solution	Student Code:	Sample Solution

C1.	Attach this Answer Sheet to the Screen (F) and mark the observed patterns in the space below. Label each recorded pattern with the corresponding salt concentration. ***Do not forget to note down the relevant experimental parameters, in Answer Sheet C2 on page 10, needed for calculations.***	cont



Country:	Sample Solution	Student Code:	Sample Solution

C2. Measure and record all relevant parameters in the table below and calculate the speed of sound, v_s, in each of the known salt concentration.

Salt (g) in 1.5 L of water $\pm 0.1g$	0.0	80.0	160.0	240.0	320.0	400.0
C_s Salt Conc. $\pm 1\%$	0	0.0506	0.0964	0.138	0.176	0.211
Temperature $\pm$ 0.5 °C	22	22	22	22	22	22
b (cm) $\pm 0.1cm$	7.1	6.8	8.4	7.6	7	8.9
L (cm)	375.6	381.8	380.5	371.1	373.5	375.5
D_m (cm) $\pm 0.05cm$	12.52	11.63	12.86	11.42	11.1	11
m	42	40	46	43	43	43
λ_s (m) $\times 10^{-4}$	8.24	8.57	8.94	9.15	9.47	9.64
Speed of Sound in salt solution (m/s)	1483	1543	1609	1647	1704	1735

Total : 2.0

1.0 for Salt Conc. Variation

Full 1.0 marks - if the salt conc. Ranges from 0 to 0.2 and above is covered.

Full 0.7 marks - if salt conc. from 0 to (0.1 - <0.2) is covered.

Only 0.4 marks - if salt conc. from 0 to <0.1 is covered.

Note – Data points should spread well with at least three well separated points with difference of at least 50 g per 1.5 liters. If data does not follow above mentioned rule deduct 0.3 marks.

1.0 for value of v_s

The values of speed of sound is expected to follow the equation

$v_s = 1187 * C_s + v_{sT}$

Where Cs is Salt Conc and v_{sT} is the speed of sound in mineral water (without salt) at temperature T.

At 22 °C –

$v_{sT} = 1484$ m/s

(0.2 for each value of v_s within 5% of

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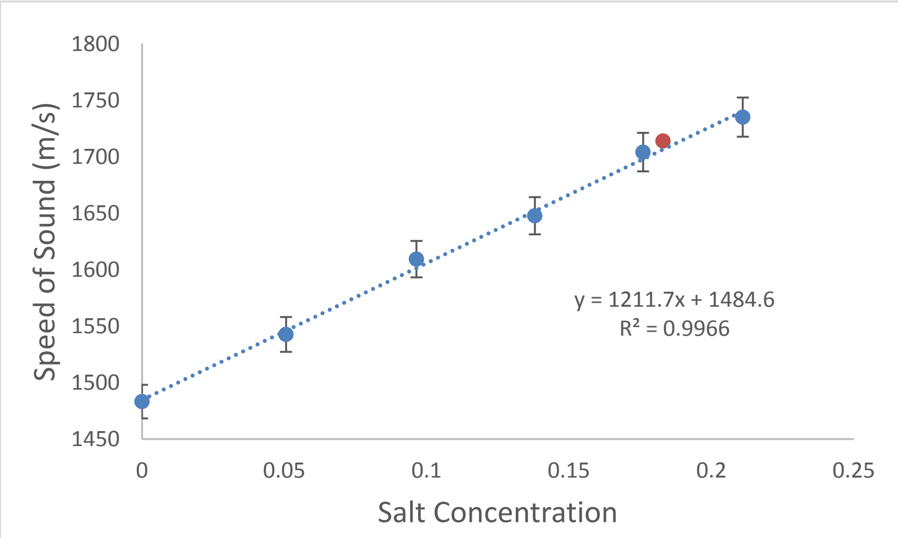
		expected value at the temperature noted by Organizing Committee) (0.1 for each value of v_s outside 5% but within 10% of expected value) 0 otherwise Maximum of 1.0 marks for v_s

Country:	Sample Solution	Student Code:	Sample Solution

C3	Plot the speed of sound in solution against the salt concentration of the solution. 	**Total: 1.0** 0.2 for Axes Labels 0.1 for Axes Units 0.5 for plotting data points correctly 0.2 for plotting error bars

Country:	Sample Solution	Student Code:	Sample Solution

C4.

Attach this Answer Sheet to the Screen (F) and mark the observed patterns in the space below for unknown salt concentration solution.

Note down the temperature of the solution and all other relevant experimental parameters needed for calculation of the speed of sound in this solution.

b (cm) $\pm 0.1cm$	L (cm) $\pm 0.1cm$	D_m (cm) $\pm 0.05cm$	m	λ_s (m) $\times 10^{-4}$	Speed of Sound in salt solution (m/s)
8.5	374.7	11.1	43	9.61	1714

T=(22 ± 0.5) °C

v_s in unknown solution =	1714 m/s

Total: 0.8

0.2 for Pattern

0.4 for the complete table

-0.1 each uncertainty missing
-0.1 each unit missing
-0.1 T missing

0.2 for correct value of v_s

(0.2 for each value of v_s within 5% of expected value)

(0.1 for each value of v_s outside 5% but within 10% of expected value)

(0 otherwise)

Note the marks allocated for the table will be given if the values are implicitly observed in the results

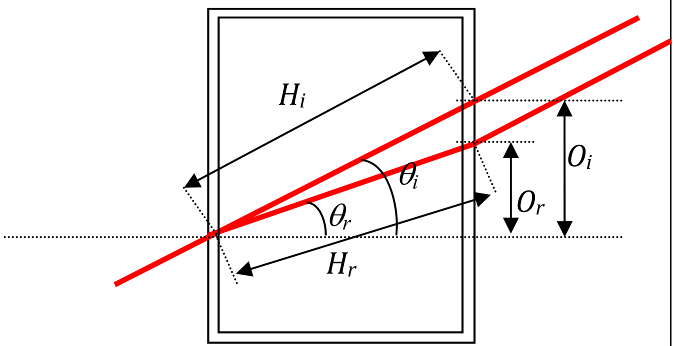
Country:	Sample Solution	Student Code:	Sample Solution

C5.	Determine the salt concentration in the unknown solution. Concentration of Salt in Unknown Solution = 0.19 ± 0.01 **NOTE**: The unknown solution has 225 g of salt dissolved per one liter of mineral water i.e. C_s=0.184	**Total :0.2** **0.2** for correct value of concentration (0.2 for value within 5% of expected value) (0.1 for value outside 5% but within 10% of expected value) (0 otherwise) -0.1 uncertainty missing

Country:	Sample Solution	Student Code:	Sample Solution

Experiment D:

<table>
<tr>
<td>D1.</td>
<td>Draw a labeled sketch of the experiment you have designed for calculation of the refractive index of the corn-syrup. Use the space below relevant parameters needed and calculate the refractive index of the corn-syrup.



$$\frac{n_{corn-syrup}}{n_{air}} = \frac{\sin\theta_i}{\sin\theta_r} = \frac{O_i}{O_r}\frac{H_r}{H_i}$$

$$\frac{n_{corn-syrup}}{n_{air}} = \frac{\sin 22.04}{\sin 15.25} = 1.42$$
Assuming glass can be ignored.

$n_{corn\text{-}syrup} =$ 1.42</td>
<td>Total: 1.5

0.5 for appropriate and properly labeled diagram

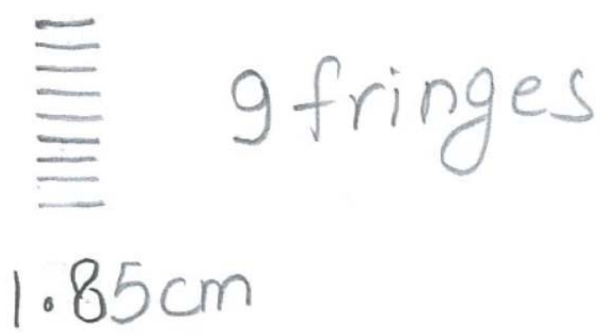
0.5 for correct expressions related to the setup used

0.5 for calculation
(full 0.5 for value between 1.38 – 1.48)
(0.3 for value between 1.34 – 1.38 or between 1.48 – 1.55)
0 for outside above mentioned range</td>
</tr>
</table>

Country:	Sample Solution	Student Code:	Sample Solution

D2. Attach this Answer Sheet to the Screen (F) and mark diffraction patterns in the space below for corn-syrup.

Note down the temperature of the corn-syrup and all other relevant experimental parameters needed to calculate the speed of sound in this solution.



Corn Syrup

$b\ (cm)$ $\pm 0.1cm$	$L\ (cm)$ $\pm 0.1cm$	$D\ (cm)$ $\pm 0.05cm$	m	$\lambda_s\ (m)$ $\times 10^{-4}$	Speed of Sound (m/s)
8.9	360	1.85	9	10.47	1885

v_s in corn-syrup =	1885 (m/s)

Total: 1.0

0.4 for pattern

0.4 for tabulation of relevant parameters.

0.2 calculation of v_s in corn syrup

(0.2 for each value of v_s within 5% of expected value)

(0.1 for each value of v_s outside 5% but within 10% of expected value)

(0 otherwise)