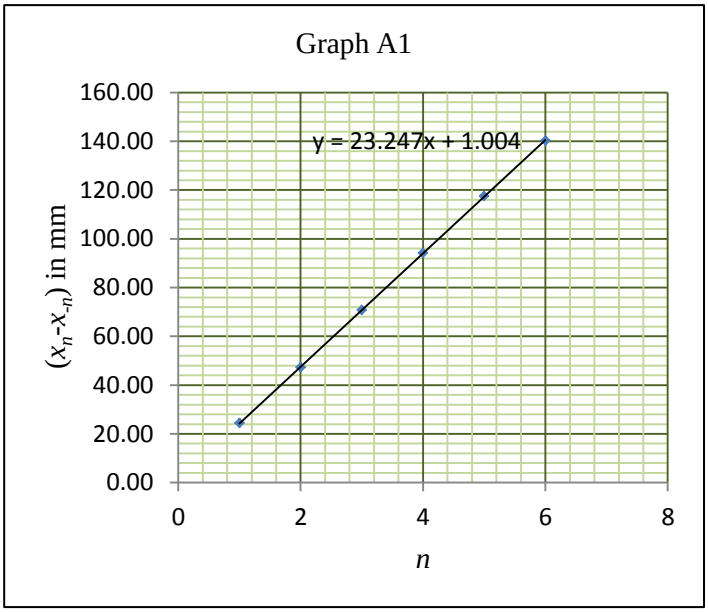
Diffraction due to Helical Structure[1]

Part A: Determination of geometrical parameters of a helical spring

Tasks	Description	Marks
A1	Number of attached pattern marking sheet(s) for Part A: 2 with label(s): P1, P2 (patterns on page 7)	**0.7**
A2	Table A1: Observations from pattern P1	**0.5**
A3	Graph A1	**0.7**

Table A1: Observations from pattern P1

Sr. No.	Order (n)	$(x_n - x_{-n})$ in mm
1	1	24.40
2	2	47.24
3	3	70.69
4	4	94.08
5	5	117.53
6	6	140.28



Graph A1 for determination of a_1: n versus $(x_n - x_{-n})$
Slope of the graph A1 = 23.25 mm
Calculation of a_1:

$$a_1 = 2 \times \lambda \times \frac{D}{\text{Slope}} = 2 \times \lambda \times \frac{2770}{23.25}$$

$$a_1 = 0.151 \text{ mm}$$

[1] *Praveen Pathak (HBCSE-TIFR, Mumbai), Charudatt Kadolkar (IIT, Guwahati), and Manish Kapoor (Christ Church College, Kanpur) were the principal authors of this problem. The contributions of the Academic Committee, Academic Development Group and the International Board are gratefully acknowledged.*

A4

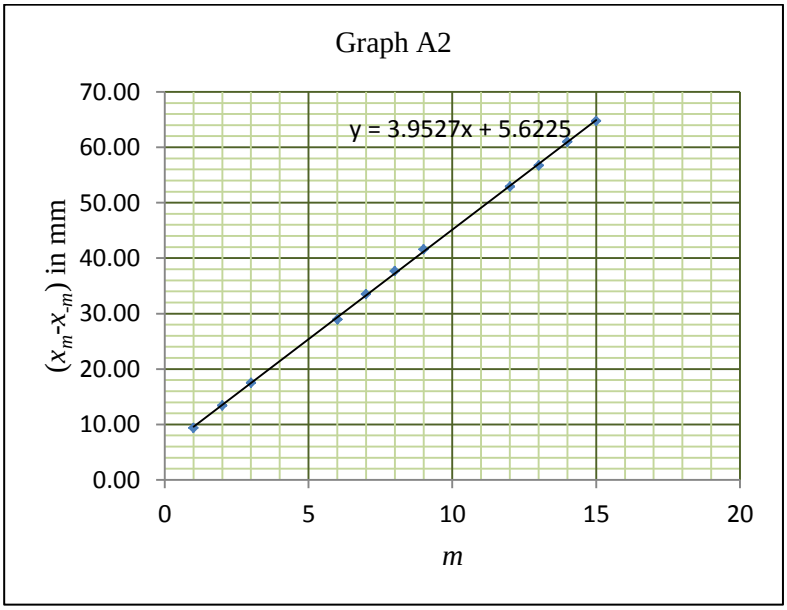
Table A2: Observations from pattern P1

Sr. No.	m	$(x_m - x_{-m})$ in mm
1	1	9.39
2	2	13.43
3	3	17.53
4	6	28.98
5	7	33.53
6	8	37.66
7	9	41.61
8	12	52.93
9	13	56.76
10	14	61.03
11	15	64.74

0.8

A5

Graph A2



Graph A2 for determination of d_1: m versus $(x_m - x_{-m})$

Slope of the graph A2 = 3.95 mm

Calculation of d_1:

$$d_1 = 2 \times \lambda \times \frac{D}{\text{Slope}} = 2 \times 0.000635 \times \frac{2770}{3.95}$$

$$d_1 = 0.89\ mm$$

0.6

A6

$\alpha_1 = 10.96°$

0.2

A7

Expression of P in terms of d_1 and α_1:

0.2

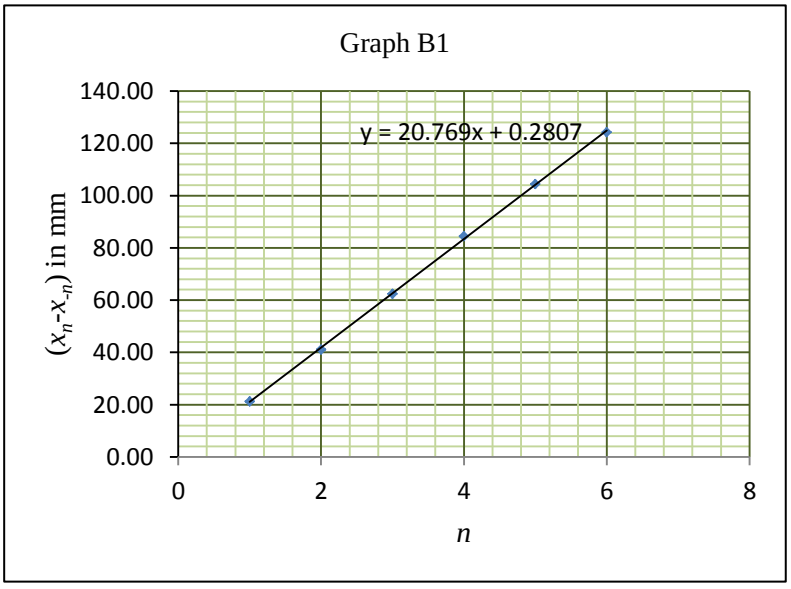
	$P = \frac{d_1}{\cos \alpha_1} = \frac{0.89}{\cos 10.96}$ $P = 0.91$ mm	

A8	Expression of R in terms of P and α_1: $\tan \alpha_1 = \frac{P}{2\pi R}$ $R = \frac{P}{2 \times \pi \times \tan \alpha_1} = \frac{0.91}{2 \times \pi \times \tan 10.96}$ $R = 0.75$ mm	**0.2**
	Total	**3.9**

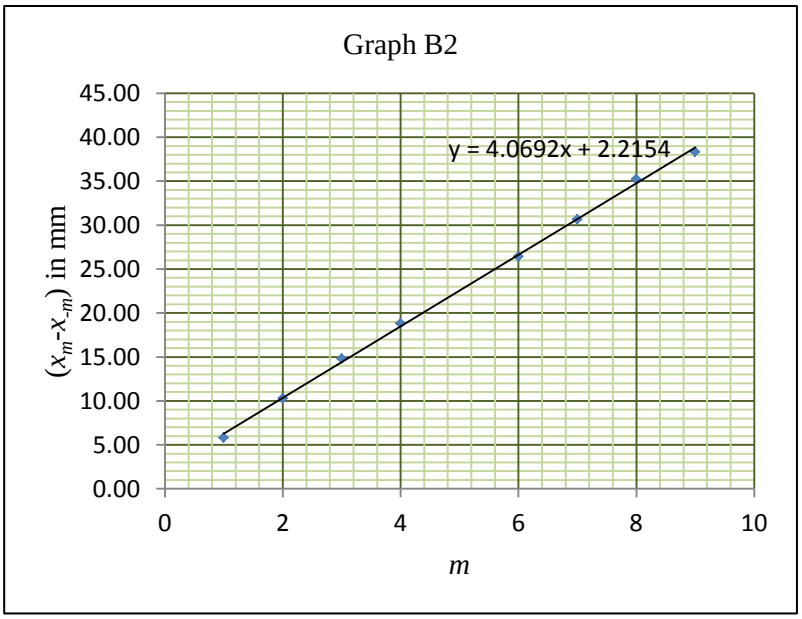
Part B: Determination of geometrical parameters of double-helix-like pattern

Tasks	Description	Marks
B1	Attached pattern marking sheet number(s): 2 with label(s): P3, P4 (patterns on page 7)	**1.1**
B2	Table B1: Observations from pattern P3	**0.5**

Sr. No.	Order (n)	$(x_n - x_{-n})$ in mm
1	1	21.24
2	2	41.12
3	3	62.41
4	4	84.40
5	5	104.41
6	6	124.25

B3	 Graph B1 for determination of a_2: n versus $(x_n - x_{-n})$	**0.5**

	Slope of the graph B1 = 20.8 mm Calculation of a_2: $a_2 = 2 \times \lambda \times \frac{D}{\text{Slope}} = 2 \times 0.000635 \times \frac{795}{20.8}$ $a_2 = 0.049$ mm	

B4	Table B2: Observations from pattern P3 Sr. No. | m | $(x_m - x_{-m})$ in mm 1 | 1 | 5.84 2 | 2 | 10.29 3 | 3 | 14.83 4 | 4 | 18.84 5 | 6 | 26.44 6 | 7 | 30.65 7 | 8 | 35.26 8 | 9 | 38.34	**1.2**
B5	Graph B2  Graph B2 for determination of s: m versus $(x_m - x_{-m})$ Slope of the graph B2 = 4.07 mm Calculation of s: $s = 2 \times \lambda \times \frac{D}{\text{Slope}} = 2 \times 0.000635 \times \frac{795}{4.07}$ $s = 0.248$ mm	**0.5**

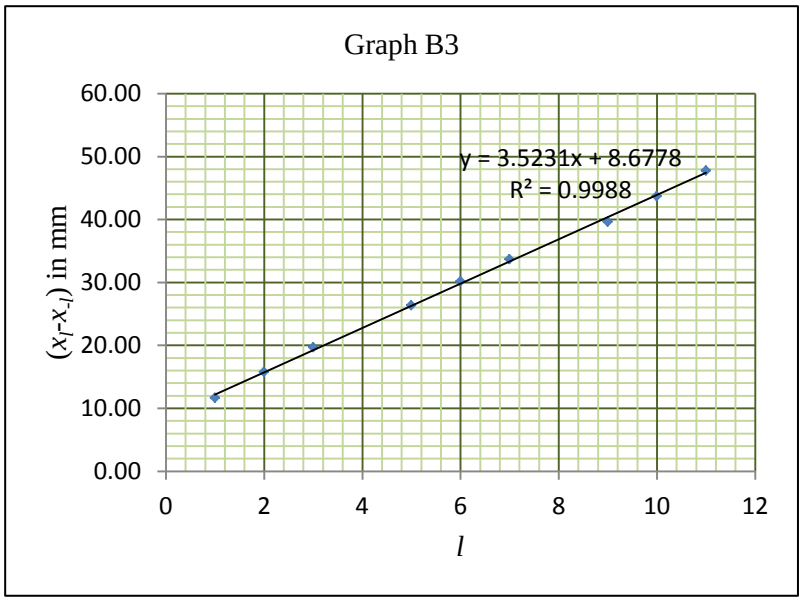
B6

Table B3 Observations from pattern P4

Sr. No.	Order (l)	$(x_l - x_{-l})$ in mm
1	1	11.64
2	2	15.77
3	3	19.71
4	5	26.33
5	6	30.14
6	7	33.69
7	9	39.62
8	10	43.70
9	11	47.75

1.6

B7



Graph B3 for determination of d_2: l versus $(x_l - x_{-l})$

Slope of the graph B3 = 3.52 mm

Calculation of d_2: $d_2 = 2 \times \frac{\lambda \times D}{\text{Slope}} = 2 \times 0.000635 \times \frac{2770}{3.52}$

$d_2 = 1.00$ mm

0.5

B8 $\alpha_2 = 9.88°$ **0.2**

Total **6.1**

Reference for Part A : G. Braun, D. Tierney and H. Schmitzer, Phys. Teach. **49**, 140 (2011).

Pattern P1 ($D = 2770$ mm)

$$\tan 2\alpha_1 = \frac{42.43}{105.40}$$
$$\alpha_1 = 10.96\,^\circ$$

Pattern P2

$$\tan 2\alpha_2 = \frac{36.67}{102.04}$$
$$\alpha_2 = 9.88^\circ$$

Pattern P3 ($D = 795$ mm)

Pattern P4 ($D = 2770$ mm)

Diffraction due to surface tension waves on water[1]

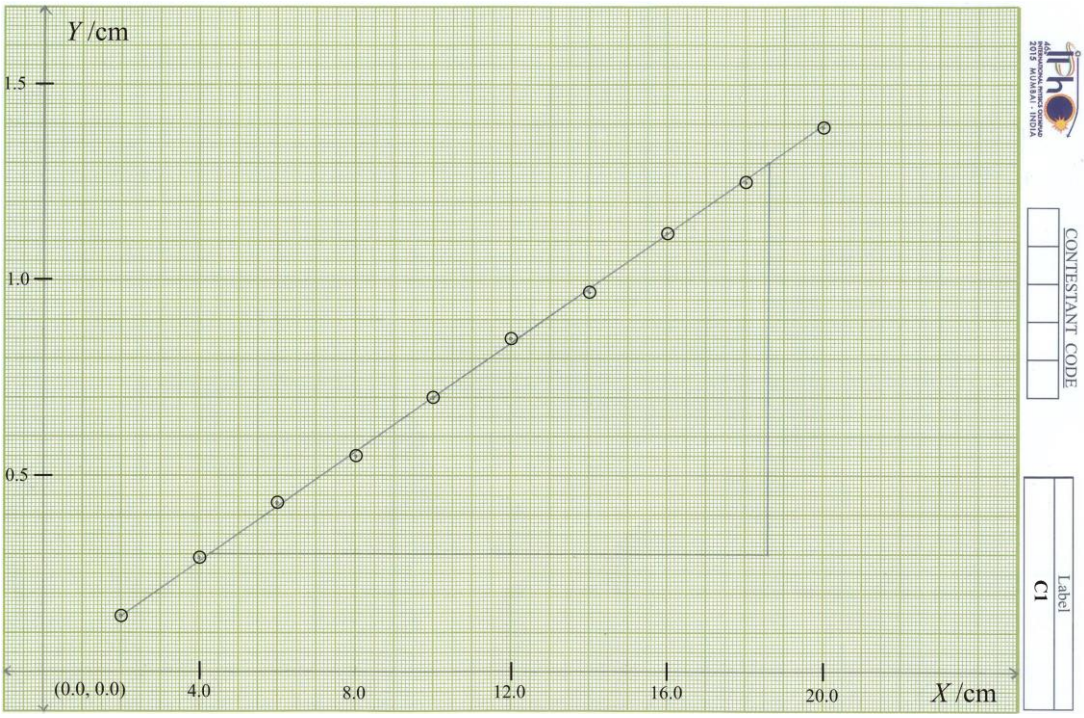
Part C: Measurement of angle, θ

[C1] **Table C1**

Obs. no.	X /cm	Y /cm
1	2.0	0.136
2	4.0	0.285
3	6.0	0.425
4	8.0	0.549
5	10.0	0.703
6	12.0	0.846
7	14.0	0.965
8	16.0	1.124
9	18.0	1.251
10	20.0	1.390

[C2]

Graph C1 for determination of θ: X versus Y



[1] *Shirish Pathare (HBCSE, Mumbai)and K G M Nair (CMI, Chennai) were the principal authors of this problem. The contributions of the Academic Committee, Academic Development Group and the International Board are gratefully acknowledged.*

Slope = 0.0699

$\theta = 4.0°$

Part D: Determination of the surface tension of the liquid

[D1]:

l_1 = 98.5 cm	l_2 = 5.5 cm	L = 1.04 m

[D2]:

Table D1

Obs. no.	f **/Hz**	$2x_2$ **/cm**	x_1 **/cm**	x_1 **/m**
1	60	0.782	0.196	0.00196
2	70	0.880	0.220	0.00220
3	80	0.966	0.242	0.00242
4	90	1.030	0.258	0.00258
5	100	1.096	0.274	0.00274
6	110	1.184	0.296	0.00296
7	120	1.253	0.313	0.00313
8	130	1.336	0.334	0.00334
9	140	1.415	0.354	0.00354
10	150	1.489	0.372	0.00372
11	160	1.545	0.386	0.00386

[D3]:

$$\omega^2 = \frac{\sigma}{\rho} k^q$$

$$f^2 = \frac{1}{4p^2}\frac{s}{r}\left(\frac{2p}{l}\frac{\sin q}{L}\right)^q (x_1)^q$$

$$\ln f = \frac{1}{2}\ln\left[\frac{1}{4\pi^2}\frac{\sigma}{\rho}\left(\frac{2\pi}{\lambda}\frac{\sin\theta}{L}\right)^q\right] + \frac{q}{2}\ln x_1$$

Graph for determination of q: ln(f) versus ln(x_1)

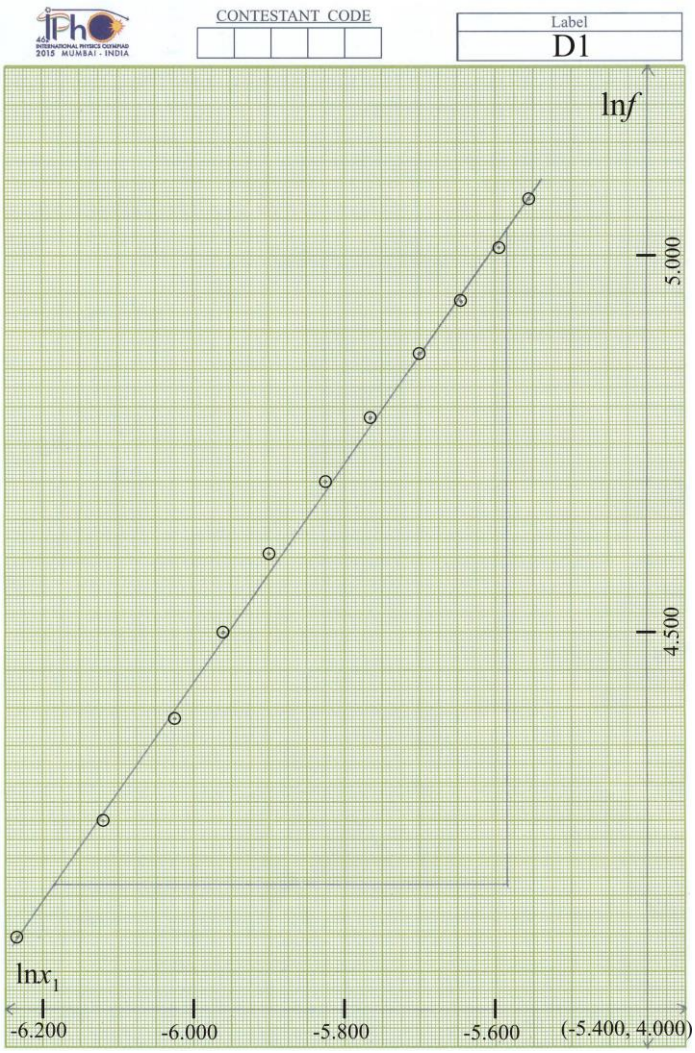


Table D2		
Obs. No.	ln x_1	ln f
1	-6.235	4.094
2	-6.119	4.248
3	-6.024	4.382
4	-5.960	4.500
5	-5.900	4.605
6	-5.823	4.700
7	-5.767	4.787
8	-5.702	4.868
9	-5.644	4.942
10	-5.594	5.011
11	-5.557	5.075

Slope = 1.45

q = 2.90

Determination of surface tension:

Equation 2:

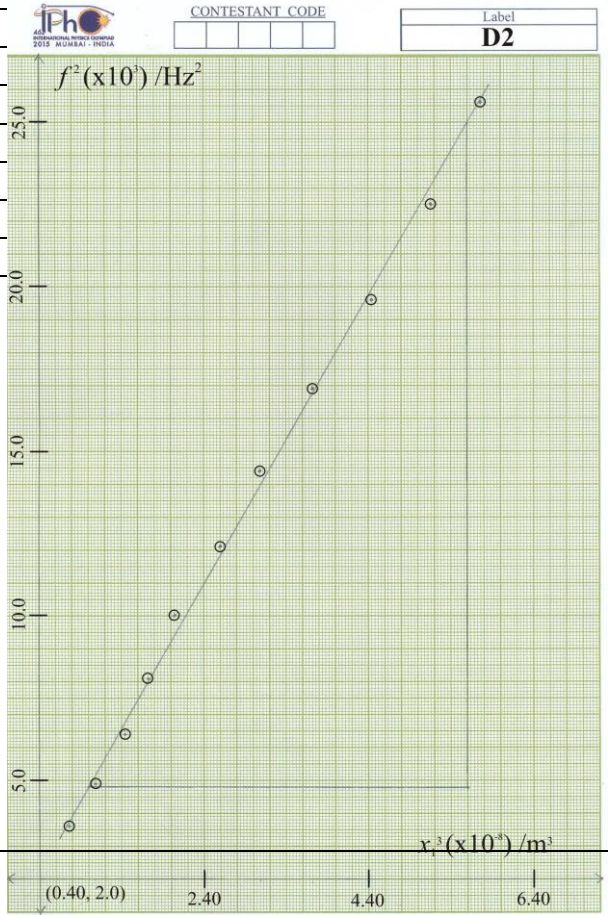
$$\omega^2 = \frac{\sigma}{\rho} k^3$$

[D4]:

Graph for determination of σ: f^2 versus x_1^3

Table D3

Obs. No.	f^2 ($\times 10^3$) /Hz^2	x_1^3 ($\times 10^{-8}$) /m^3
1	3.6	0.75
2	4.9	1.07
3	6.4	1.42
4	8.1	1.72



Surface Tension:

$$\omega^2 = \frac{\sigma}{\rho} k^3$$

$$f^2 = \frac{\sigma}{\rho} \frac{2\pi}{\lambda^3} \frac{\sin^3\theta}{L^3} (x_1)^3$$

Calculations:

Slope = 4.39×10^{11} Hz^2/m^3

$$\therefore \text{ Slope } = \frac{\sigma}{\rho}\frac{2\pi}{\lambda^3}\frac{\sin^3\theta}{L^3} = \frac{\sigma}{1000}\times\frac{2\times 3.14}{(635\times 10^{-9})^3}\frac{(0.0698)^3}{(1.04)^3}$$

$$\therefore \frac{s}{1000}\times 7.415\times 10^{15} = 4.39\times 10^{11}$$

$$\boxed{\therefore s = 59.2\text{mN/m}}$$

Part E: Determination of the viscosity of the water sample

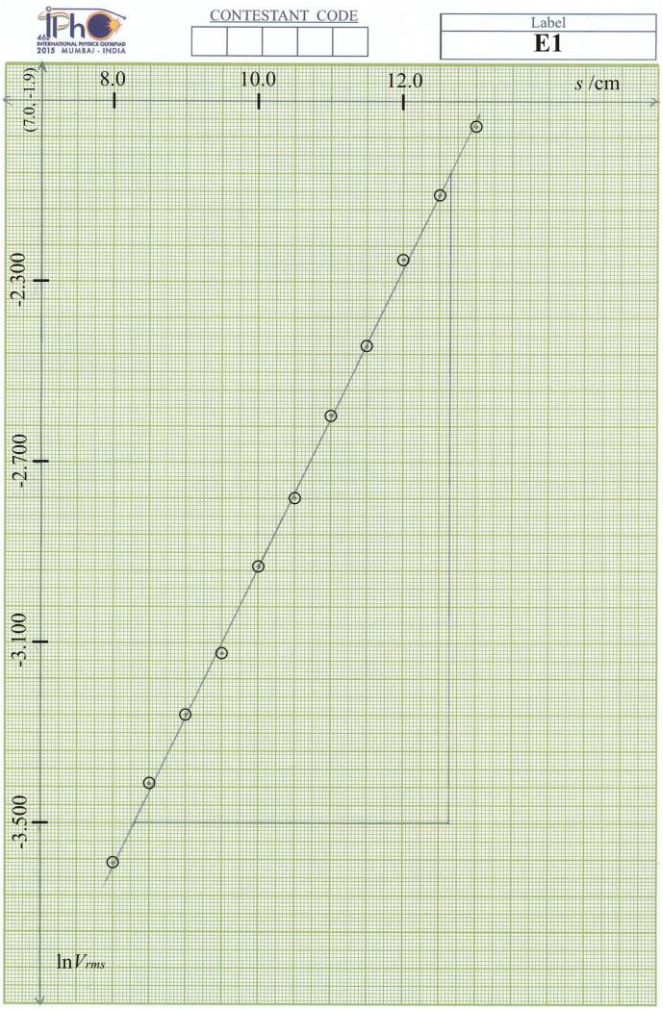
[E1]: Frequency of the signal generator = **100 Hz**

Table E1

Obs. No.	s /cm	V_{rms} /V	ln(V_{rms})
1	8.0	0.0276	-3.590
2	8.5	0.0330	-3.411
3	9.0	0.0385	-3.257
4	9.5	0.0441	-3.121
5	10.0	0.0534	-2.930
6	10.5	0.0622	-2.777
7	11.0	0.0745	-2.597
8	11.5	0.0870	-2.442
9	12.0	0.1050	-2.254
10	12.5	0.1215	-2.108
11	13.0	0.1412	-1.958

[E2]:

Graph for determination of δ: ln (V_{rms}) versus s



Slope = 0.331 cm^{-1}

$\therefore d = 0.4 \times 0.3310 = 0.1324 cm^{-1}$

δ = **13.2 m^{-1}**

[E3]:

Determination of viscosity, η:

$$\delta = \frac{8}{3}\frac{\pi\eta f}{\sigma}$$

$$\eta = \frac{3}{8}\frac{\delta\sigma}{\pi f} = \frac{3}{8} \times \frac{13.2 \times 59.2 \times 10^{-3}}{3.14 \times 100} = 0.933 \text{ mPa.s}$$

η = **0.93 mPa.s**