SOLUTION EXPERIMENT I

PART A

1. **[Total 0.5 pts]**

The experimental method chosen for the calibration of the arbitrary scale is a simple pendulum method [0.3 pts]

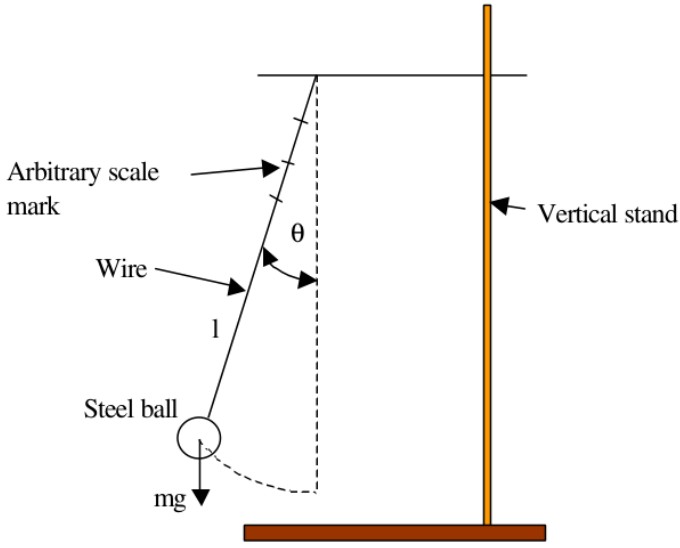


Figure 1. Sketch of the experimental set up [0.2 pts]

2. **[Total 1.5 pts]**

The expression relating the measurable quantities: [0.5 pts]

$$T_{osc} = 2\pi\sqrt{\frac{l}{g}}\,; \quad T_{osc}^2 = 4\pi^2\frac{l}{g}$$

Approximations :

$\sin\theta \approx \theta$ [0.5 pts]

mathematical pendulum (mass of the wire << mass of the steel ball, the radius of the steel ball << length of the wire [0.5 pts]

flexibility of the wire, air friction, etc [0.1 pts, only when one of the two major points above is not given]

3. **[Total 1.0 pts]** Data sample from simple pendulum experiment

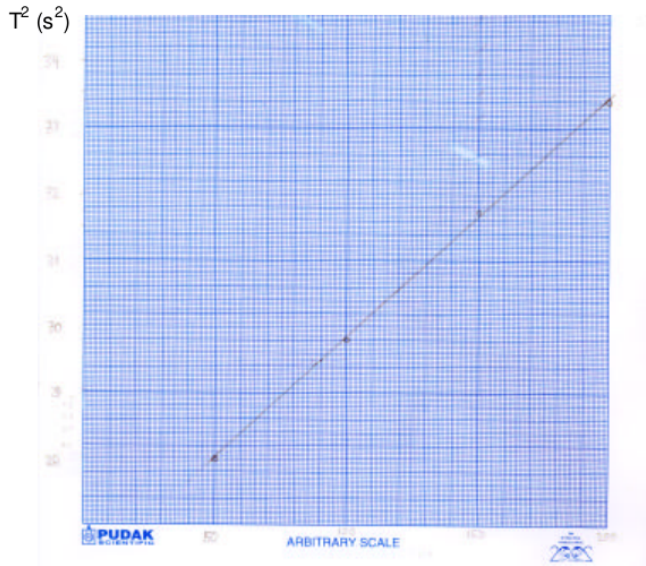
# of cycle ≥ 20 [0.2 pts.] , difference in T ≥ 0.01 s [0.4 pts], # of data ≥ 4 [0.4 pts]

No.	t(s) for 50 cycles	Period, T (s)	Scale marked on the wire (arbitrary scale)
1	91.47	1.83	200
2	89.09	1.78	150
3	86.45	1.73	100
4	83.8	1.68	50

4. [Total 0.5 pts]

No.	Period, T (s)	Scale marked on the wire (arbitrary scale)	T^2 (s^2)
1	1.83	200	3.35
2	1.78	150	3.17
3	1.73	100	2.99
4	1.68	50	2.81

The plot of T^2 vs scale marked on the wire:



5. Determination of the smallest unit of the arbitrary scale in term of mm **[Total 1.5 pts]**

$$T_{osc_1}^2 = \frac{4\pi^2}{g} L_1 \,, \qquad T_{osc_2}^2 = \frac{4\pi^2}{g} L_2$$

$$\left(T_{osc_1}^2 - T_{osc_2}^2\right) = \frac{4\pi^2}{g} L_1 - L_2 = \frac{4\pi^2}{g} \Delta L$$

$$\Delta L = \frac{g}{4\pi^2}\left(T_{osc_1}^2 - T_{osc_2}^2\right) \qquad \text{or other equivalent expression} \qquad [0.5 \text{ pts}]$$

No.		Calculated ΔL (m)	ΔL in arbitrary scale	Values of smallest unit of arbitrary scale (mm)
1.	T_1^2-T_2^2 = 0.171893 s^2	0.042626	50	0.85
2.	T_1^2-T_3^2 =0.357263 s^2	0.088595	100	0.89
3.	T_1^2-T_4^2 =0.537728 s^2	0.133347	150	0.89
4.	T_2^2-T_3^2 =0.18537 s^2	0.045968	50	0.92
5.	T_2^2-T_4^2 =0.365835 s^2	0.09072	100	0.91
6.	T_3^2-T_4^2 =0.180465 s^2	0.044752	50	0.90

The average value of smallest unit of arbitrary scale, $\bar{l} = 0.89$ mm [0.5 pts]

The estimated error induced by the measurement: [0.5 pts]

No.	Values of smallest unit of arbitrary scale (mm)	$(l-\bar{l})$	$(l-\bar{l})^2$
1.	0.85	-0.04	0.0016
2.	0.89	0	0
3.	0.89	0	0
4.	0.92	0.03	0.0009
5.	0.91	0.02	0.0004
6.	0.90	0.01	0.0001

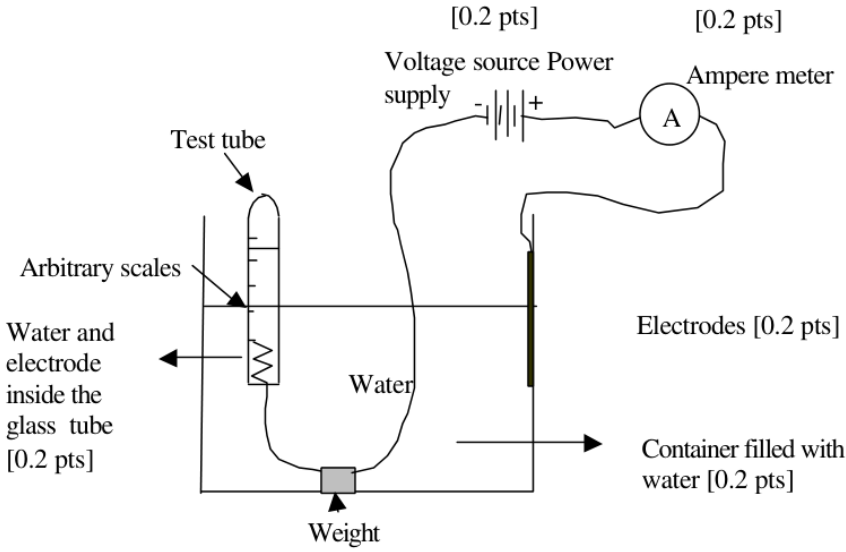
And the standard deviation is:

$$\Delta l = \sqrt{\frac{\sum_{i=1}^{6}(l-\bar{l})^2}{N-1}} = \sqrt{\frac{0.003}{5}} = 0.02\,\text{mm}$$

other legitimate methods may be used

PART B

1. The experimental set up:[**Total 1.0 pts**]



2. Derivation of equation relating the quantities time t, current I, and water level difference Δh: :[**Total 1.5 pts**]

$$I = \frac{\Delta Q}{\Delta t}$$

From the reaction: $2\ H^+ + 2\ e \longrightarrow H_2$, the number of molecules produced in the process (ΔN) requires the transfer of electric change is $\Delta Q = 2e\,\Delta N$: [0.2 pts]

$$I = \frac{\Delta \mathrm{N}\, 2\mathrm{e}}{\Delta \mathrm{t}} \qquad [0.5\ \text{pts}]$$

$$P\,\Delta V = \Delta \mathrm{N}\, k_B\, T \qquad [0.5\ \text{pts}]$$

$$= \frac{I\,\Delta t}{2e}\, k_B\, T$$

$$P\,\Delta h\,(\pi r^2) = \frac{I\,\Delta t}{2}\,\frac{k_B}{e}\,T \qquad [0.2\ \text{pts}]$$

$$I\,\Delta t = \frac{\mathrm{e}}{\mathrm{k_B}}\,\frac{2P(\pi r^2)}{T}\,\Delta \mathrm{h} \qquad [0.1 \text{ pts}]$$

3. The experimental data: **[Total 1.0 pts]**

No.	Δh (arbitrary scale)	I (mA)	Δt (s)
1	12	4.00	1560.41
2	16	4.00	2280.61
3	20	4.00	2940.00
4	24	4.00	3600.13

- The circumference ϕ, of the test tube = 46 arbitrary scale [0.3 pts]
- The chosen values for Δh (≥ 4 scale unit) for acceptable error due to uncertainty of the water level reading and for I (≤ 4 mA) for acceptable disturbance [0.3 pts]
- # of data ≥ 4 [0.4 pts]

The surrounding condition (T, P) in which the experimental data given above taken:

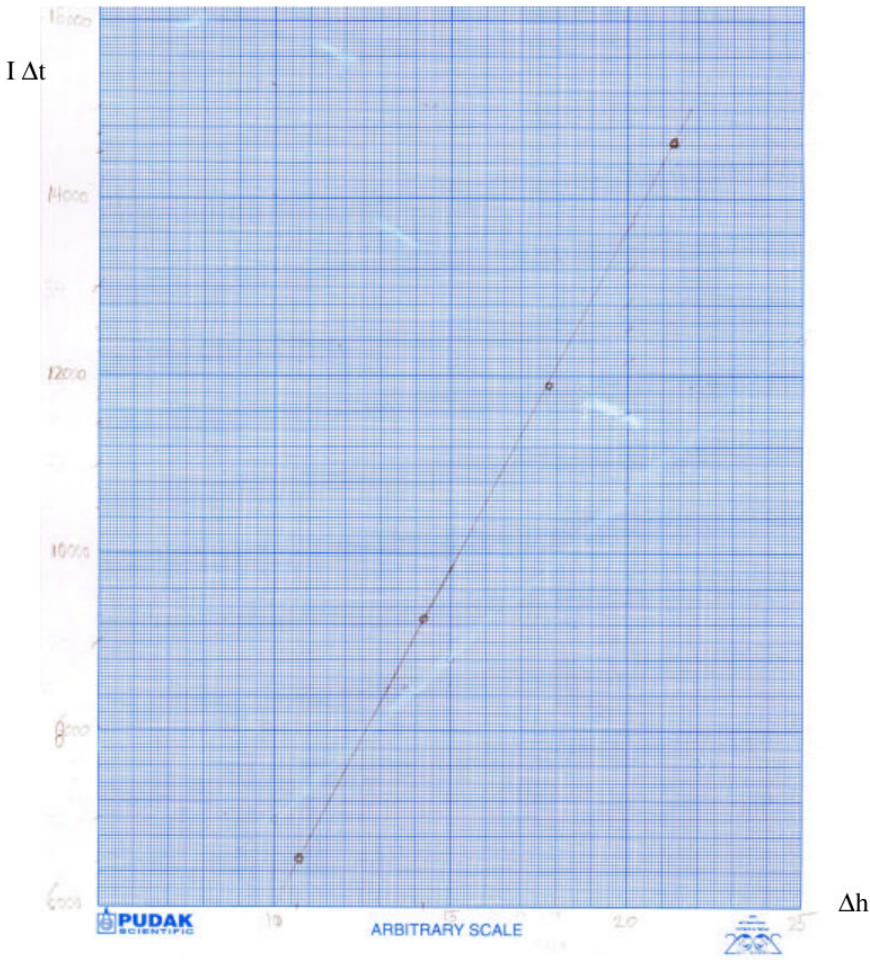
$T = 300\,\mathrm{K}$

$P = 1.00\,10^5\,\mathrm{Pa}$

4. Determination the value of $\mathrm{e/k_B}$ **[Total 1.5 pts]**

No.	Δh (arbitrary scale)	Δh (mm)	I (mA)	Δt (s)	I Δt (C)
1	12	10.68	4.00	1560.41	6241.64
2	16	14.24	4.00	2280.61	9120.48
3	20	17.80	4.00	2940.00	11760.00
4	24	21.36	4.00	3600.13	14400.52

Plot of I Δt vs Δh from the data listed above



The slope obtained from the plot is 763.94;

$$\frac{e}{k_B} = \frac{763.94 \times 300 \times \pi}{2 \times 10^5 \times (23 \times 0.89 \times 10^{-3} \times 0.82)^2} = 1.28 \times 10^4 \text{ Coulomb K/J}$$

[1.0 pts]

Alternatively [the same credit points]

No.	Δh (mm)	I Δt (C)	Slope	e/k_b
1	10.68	6241.64	584.4232	9774.74
2	14.24	9120.48	640.4831	10712.37
3	17.80	11760.00	660.6742	11050.07
4	21.36	14400.52	674.1816	11275.99

Average of $e/k_b = 1.07 \times 10^4$ Coulomb K/J

[1.0 pts]

No.	e/k_b	difference	Square difference
1	9774.74	-928.55	862205.5
2	10712.37	9.077117	82.39405
3	11050.07	346.7808	120256.9
4	11275.99	572.6996	327984.9

Estimated error [0.5 pts]

The standard deviation obtained is 0.66×10^3 Coulomb K/J, Other legitimate measures of estimated error may be also used