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]

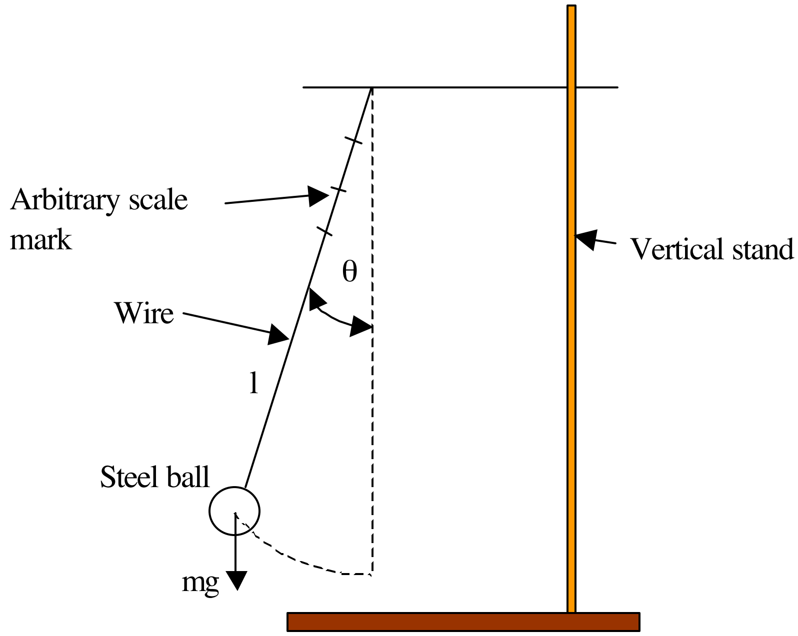


Figure 1. Sketch of the experimental set up [0.2 pts]

2. **[Total 1.5 pts]**
   The expression relating the measurable quantities: [0.5 pts]

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

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]

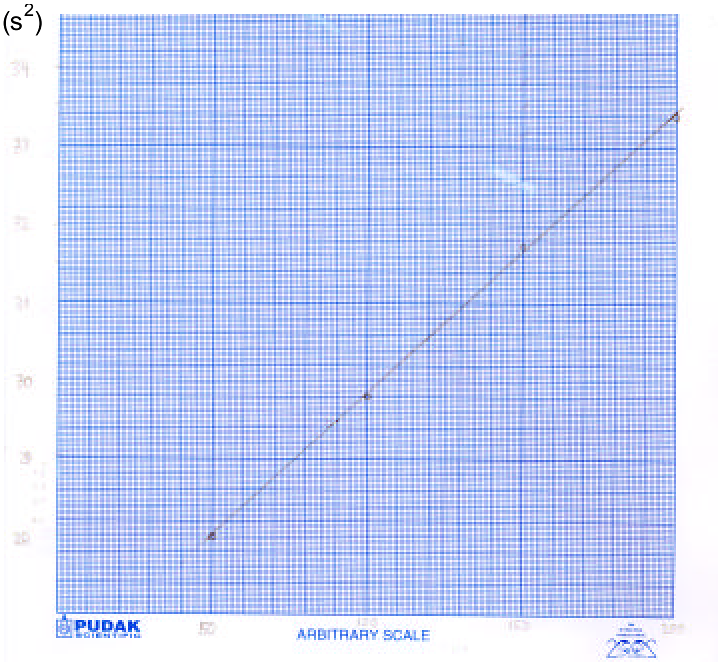
No.	t(s) for 50 cycles	Period, T (s)	Scale marked on the wire (arbitrary scale)
1	91.47	1.83	200
2	89.09	1.78	150
3	86.45	1.73	100
4	83.8	1.68	50

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:

T^2 (s^2)



Scale marked on the wire (arbitrary scale)

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

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

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

$$\Delta L = \frac{g}{4\pi^2}\left(T^2_{osc_1} - T^2_{osc_2}\right)$$ or other equivalent expression [0.5 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

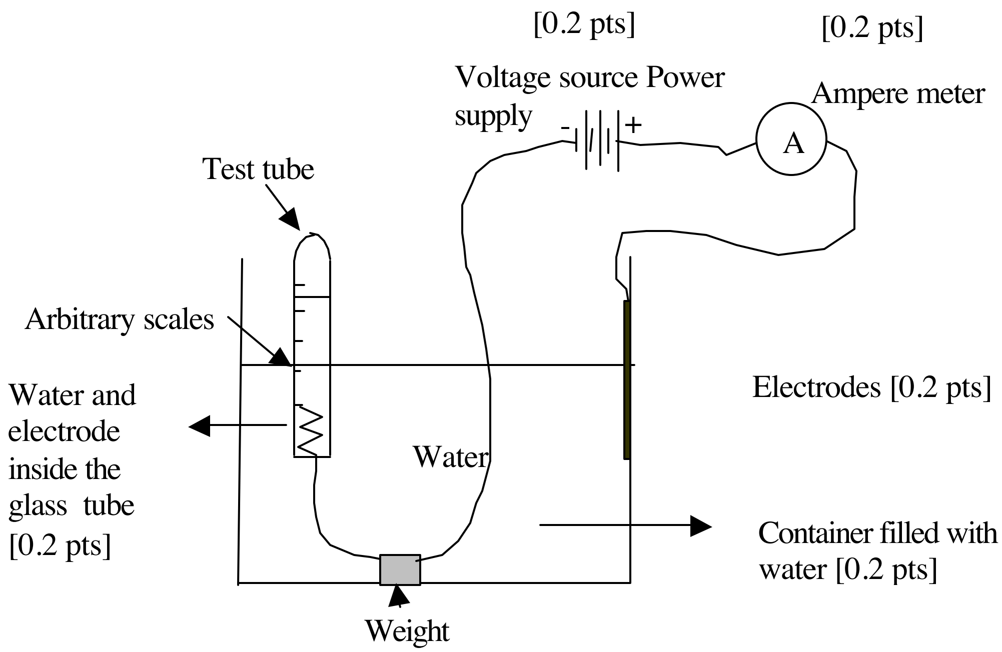
And the standard deviation is:

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

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]

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

$$P\,\Delta V = \Delta N\, k_B\, T \qquad [0.5\ pts]$$

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

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

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

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

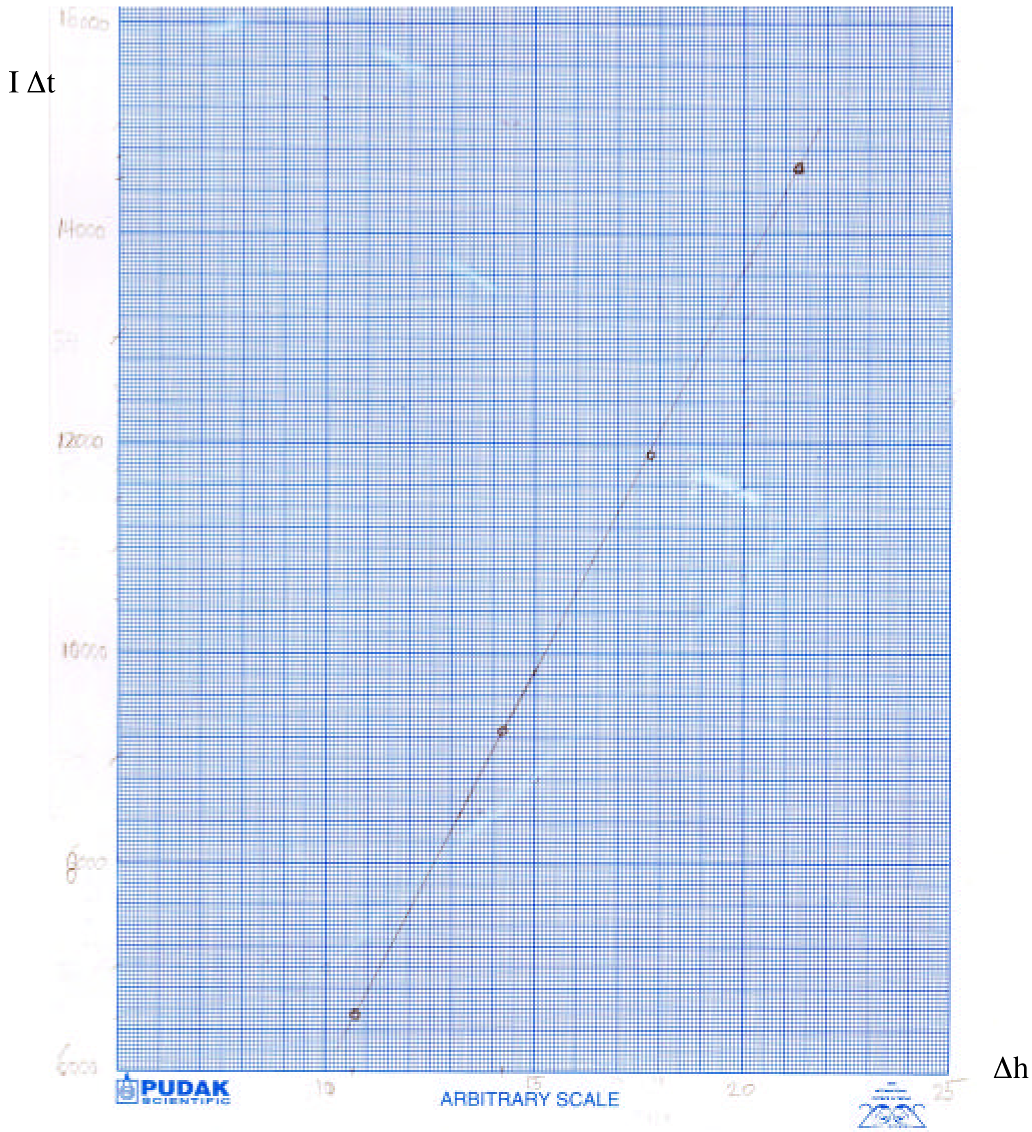
- The circumference ϕ, of the test tube = 46 arbitrary scale [0.3 pts]
- The chosen values for Δh ($\geq$ 4 scale unit) for acceptable error due to uncertainty of the water level reading and for I ($\leq$ 4 mA) for acceptable disturbance [0.3 pts]
- # of data ≥ 4 [0.4 pts]

The surrounding condition (T,P) in which the experimental data given above taken:
T = 300 K
P = 1.00 10^5 Pa

4. Determination the value of 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 $I\Delta t$ 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