**Massachusetts Institute of Technology**
**Physics Department**

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**PROBLEM FOR EXPERIMENT FO: FALLING OBJECT**

Experiment FO: Solutions

1. My LVPS was set at 6.0 Volts

2. My data for the trials at 3 different distances is

| | | | |
|---|---|---|---|
| | V cap | V cap | V cap |
| distance | 260 mm | 130 mm | 65 mm |
| | 0.125 | 0.091 | 0.066 |
| | 0.132 | 0.092 | 0.065 |
| | 0.125 | 0.091 | 0.064 |
| | 0.126 | 0.091 | 0.064 |
| | 0.125 | 0.09 | 0.066 |
| | | | |
| ave | 0.1266 | 0.091 | 0.065 |
| st dev | 0.0030 | 0.0007 | 0.0010 |

3. My data for measuring the time constant $\tau = RC$ is

| | | | |
|---|---|---|---|
| | $(V\ cap)_1$ at time $t_1 = 0$ | $(V\ cap)_2$ at time $t_2 = 20s$ | time constant $\tau$ |
| | 0.24 | 0.038 | 10.85 |
| | 0.24 | 0.038 | 10.85 |
| | 0.237 | 0.039 | 11.08 |
| | | | |
| ave | 0.239 | 0.0383 | 10.93 |
| st dev | | | 0.133 |

where I used

$$\tau \cong \frac{\Delta t}{\ln(V_1/V_2)} = \frac{t_2 - t_1}{\ln(V_1/V_2)}$$

(1)

4. The average time for each distance is calculated using

$$t = \frac{\bar{\tau}\,\bar{V}_{cap}}{V_{LVPS}}$$

| average time (s) | 0.2306 | 0.1657 | 0.1184 |
|---|---|---|---|
| distance (mm) | 260 | 130 | 65 |

5. The error in the measurement of t for each distance is derived from the product rule applied to the formula

$$t = \frac{\tau\,V_{cap}}{V_{LVPS}}$$

$$\frac{\Delta t}{\bar{t}} = \left(\left(\frac{\Delta\tau}{\bar{\tau}}\right)^2 + \left(\frac{\Delta V_{cap}}{\bar{V}_{cap}}\right)^2\right)^{1/2}$$

Thus $\Delta t = \bar{t}\left(\left(\frac{\Delta\tau}{\bar{\tau}}\right)^2 + \left(\frac{\Delta V_{cap}}{\bar{V}_{cap}}\right)^2\right)^{1/2}$

where $\Delta\tau$ is the standard dev. for $\bar{\tau}$ and $\Delta V_{cap}$ is the standard dev. for each $\bar{V}_{cap}$

the results are

| distance (mm) | ave time | $\Delta t$ |
|---|---|---|
| 0 | 0 | 0 |
| 65 | 0.2306 | 0.0023 |
| 130 | 0.1657 | 0.0024 |
| 260 | 0.1184 | 0.0062 |

By the product rule the error in $t^2$ is given by

$$\Delta t^2/\bar{t}^2 = 2\Delta t/\bar{t}$$

So the error in $\Delta t^2$ is

$$\Delta t^2 = (\bar{t})^2\left(\frac{2\Delta t}{\bar{t}}\right)$$

The results are given below with

$\Delta \tau = .133$ s $\quad \bar{\tau} = 10.93$ s

| distance (mm) | time $t^2$ (s ) | $\Delta t^2$ ($s^2$) | $\bar{V}_{cap}$ (V) | $\Delta V_{cap}$ (V) | $\bar{t}$ (s) |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 65 | 0.0140 | 0.00464 | 0.1266 | 0.00305 | 0.2306 |
| 130 | 0.0275 | 0.00478 | 0.091 | 0.00071 | 0.1657 |
| 260 | 0.0532 | 0.01244 | 0.065 | 0.0010 | 0.1184 |

So the final results of distance vs $t^2$ are given in the table below

| distance (mm) | time t2 (s2) |
|---|---|
| 0 | 0 |
| 65 | 0.0140 |
| 130 | 0.0275 |
| 260 | 0.0532 |

The results are shown in the graph of $t^2$ vs distance. Since

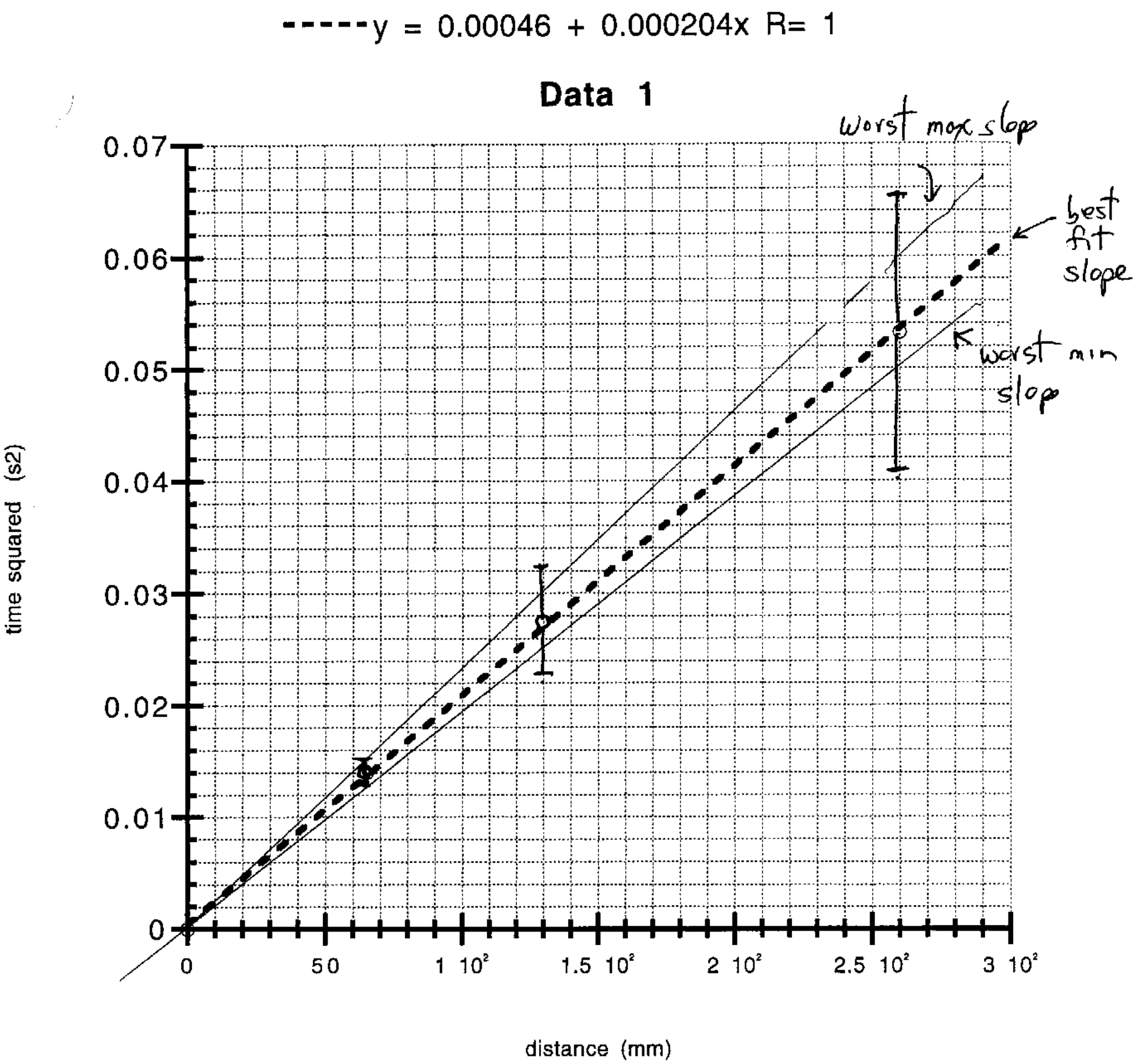
$$h = \frac{1}{2} g t^2 \Rightarrow t^2 = \frac{2}{g} h$$

and the slope $= 2/g$ so

$$g = \frac{2}{\text{slope}}$$

best fit slope : $\text{slope} = \frac{2}{\bar{g}} = 0.000204 \ \frac{s^2}{mm}$

$\bar{g} = 9.80 \ m/s^2$



Now the error in the slope due to the uncertainty in the measurements is given by computing the slope with the worst max value

$$\text{slope}_{max} = \frac{0.06\ s^2}{260\ mm} = 2.308 \times 10^{-4}\ \frac{s^2}{mm}$$

corresponding to a $m$ value of

$$g_{min} = \frac{2}{(\text{slope})_{max}} = 8.67\ m/s^2$$

The minimum value for the slope

$$(\text{slope}_{min}) = \frac{0.05\ s^2}{260\ mm} = 1.923 \times 10^{-4}\ \frac{s^2}{mm}$$

$$g_{max} = \frac{2}{(\text{slope})_{min}} = 10.4\ m/s^2$$

so

$$\bar{g} = 9.80\ \frac{m}{s^2}$$

$$\Delta g = \pm 1.6\ m/s^2$$

$$g_{expt} = 9.80\ m/s^2 \pm 1.6\ m/s^2$$

$$\frac{\Delta g}{\bar{g}} = 16\%$$