PHYS101 EXPERIMENT 2. VELOCITY AND ACCELERATION

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Data & Results: [20]

Data Point	Time (ms)	Displacement (mm)
1	50	21
2	100	43
3	150	67
4	200	92
5	250	117
6	300	142
7	350	167
8	400	192
9	450	217
10	500	242
11	550	267
12	600	292
13	650	316
14	700	341
15	750	366

Table 1: Motion with constant velocity

Data Pairs	Δt (ms)	Δx (mm)	v_{av} ($\frac{mm}{ms}$)
1-15	700	345	0.493
2-14	600	298	0.497
3-13	500	249	0.498
4-12	400	200	0.500
5-11	300	150	0.500
6-10	200	100	0.500
7-9	100	50	0.50

Table 2: Average velocity

Instantaneous velocity (from the graph)	Instantaneous velocity (Lagrange`s formula)	% Error
0.5 mm/ms	0.5 mm/ms	0 %

Lagrange's formula: $\frac{dx}{dt} = \frac{(1/3)}{\Delta t}\left[\frac{1}{4}x_{-2} - 2x_{-1} + 2x_1 - \frac{1}{4}x_2\right]$

$$\frac{dx}{dt} = \frac{1/3}{50}\left[\frac{1}{4}\cdot(142) - 2\cdot(167) + 2\,(217) - \frac{1}{4}\,(242)\right]$$

$= 0.5$ mm/ms

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$x = \frac{1}{2} a t^2$

$x = \frac{1}{2} g \sin\alpha \, t^2$

$\underset{m}{0.2} = \frac{1}{2} \cdot g \cdot (0.13) \cdot \overset{s^2}{(0.25)}$

$g = (0.2) \cdot 2 \cdot \frac{100}{13} \cdot 4$

$(\sin\alpha = 0.13)$

x(mm)	t(ms)	t^2 (ms^2)
5	50	2500
13	100	10000
25	150	22500
40	200	40000
59	250	62500
80	300	90000
105	350	122 500
134	400	160 000
165	450	202 500
200	500	250000

Table 3: Motion with constant acceleration

g (theoretical)	g (experimental)	% Error
9.80 m/s^2	12.3 m/s^2	% 25,5

$\frac{(12.3 - 9.8)}{9.8} \cdot 100 =$

Questions:

1) **[2.5]** Average velocity and instantaneous velocity are generally different quantities. Can they ever be equal for a specific type of motion? Can the instantaneous velocity of an object ever be greater in magnitude than the average velocity? Can it ever be less?

When there is no acceleration (constant speed), instantaneous and average velocity will be equal. However, when there is acceleration, magnitude of instantaneous velocity can be greater or lesser depending on the acceleration.

2) **[2.5]** Measurements on a moving particle show that its average velocity is equal to its instantaneous velocity at every instant. What can you say about its acceleration?

For average velocity to be equal with instantaneous velocity, there must be no acceleration and constant speed. Thus, acceleration is equal to zero.

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3) **[2.5] What are the possible sources of experimental errors in the experimental setup? Is it more appropriate to use a heavy (or light) puck, a small (or large) tilt angle in order to make a better estimate for *g*?**

One possible source of experimental errors is friction. Higher we put the object, the higher will the friction force will be. By the equation $ma = mg\sin\alpha - mg\cos\alpha$; we can see that mass is not important. To make a better estimation for g, we need large tilt angle so that we will have less friction.

4) **[2.5] Suppose you travel a distance *d*. If you travel at speed v_1 for half the total distance and at speed v_2 for the other half of the total distance, derive an expression for your average speed for the complete trip.**

$\boxed{d = vt}$

$$\left.\begin{aligned} v_1 t_1 &= \frac{d}{2} \\ v_2 t_2 &= \frac{d}{2} \end{aligned}\right\} \quad \left.\begin{aligned} t_1 &= \frac{d}{2v_1} \\ t_2 &= \frac{d}{2v_2} \end{aligned}\right\} \quad v_{avg} = \frac{d}{t_1 + t_2} = \frac{d}{\underbrace{\frac{d}{2v_1} + \frac{d}{2v_2}}_{\frac{d(v_1+v_2)}{2v_1 v_2}}} = \frac{2v_1 v_2}{v_1 + v_2}$$

Conclusion: [10]

- In the first part, we studied motion with constant speed. By using an air table parallel to the ground and a puck, we examined the positions with constant speed. We didn't include first few positions due to the initial push acceleration. After that, we calculated Δt, Δx and v_{avg} using different values of time and displacement. At the end, we calculated instantaneous velocity both theoretical and experimental. Using these values, we calculated the error rate of instantaneous velocity which for me happened to be 0% somehow.
- In the second part, we tilted the air table using a wooden piece and now studied the motion with constant acceleration. We let the puck go from the top of the tilted air table so that it would have acceleration equal to $g.\sin\alpha$. We examined the time and displacement values. By using these values, we calculated experimental g. At last, by comparing theoretical and experimental values of g, we calculated the error rate, which for me happened to b 25.5%.

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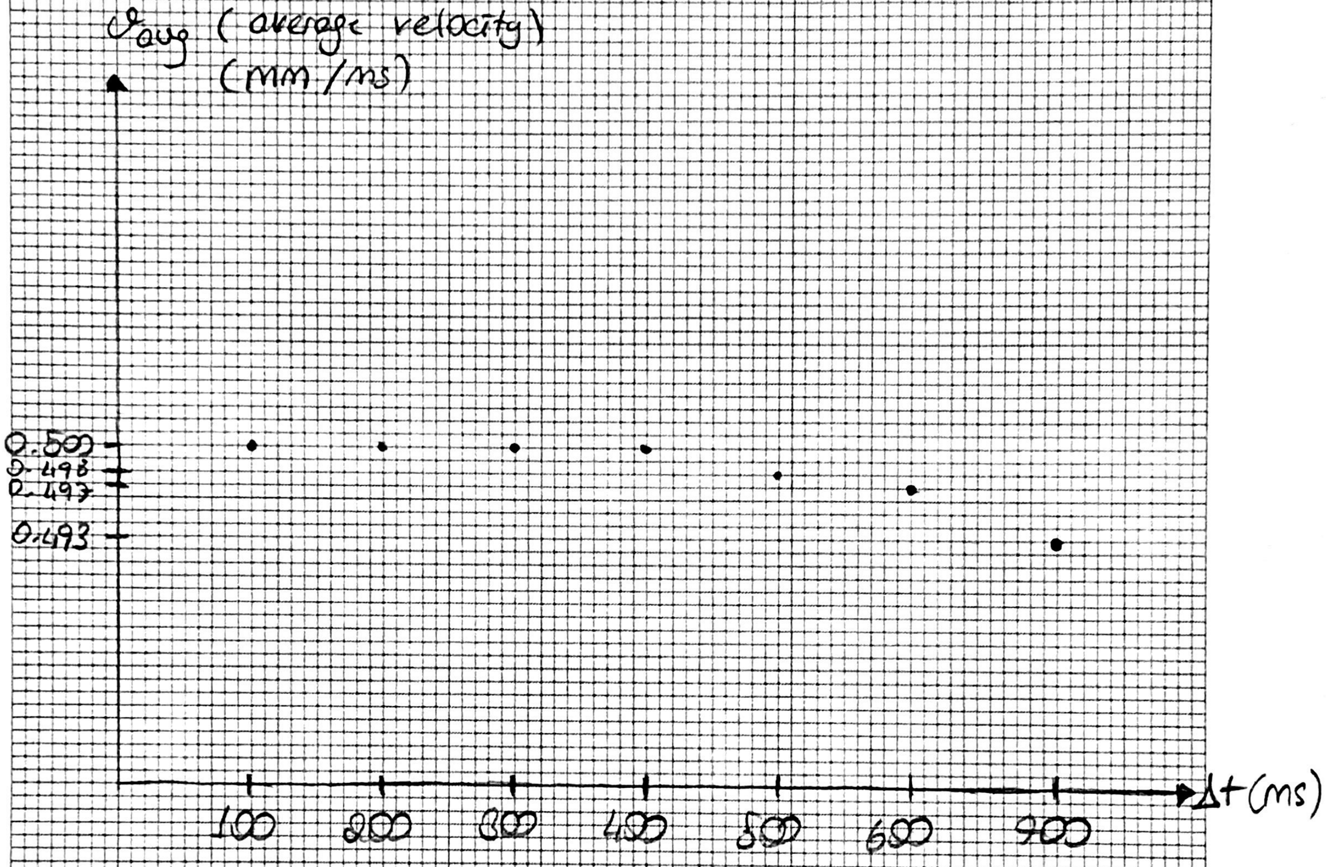
Plot 1 [10]

Average Velocity / Δt Graph



At $\Delta t = 0$, instantaneous velocity should be 0.5 mm/ms
With Lagrange's Formula;

$$\frac{dx}{dt} = \frac{1/3}{50} \left[\frac{1}{4}(142) - 2(167) + 2(217) - \frac{1}{4}(242) \right]$$

$$= 0.5 \ \text{mm/ms}$$

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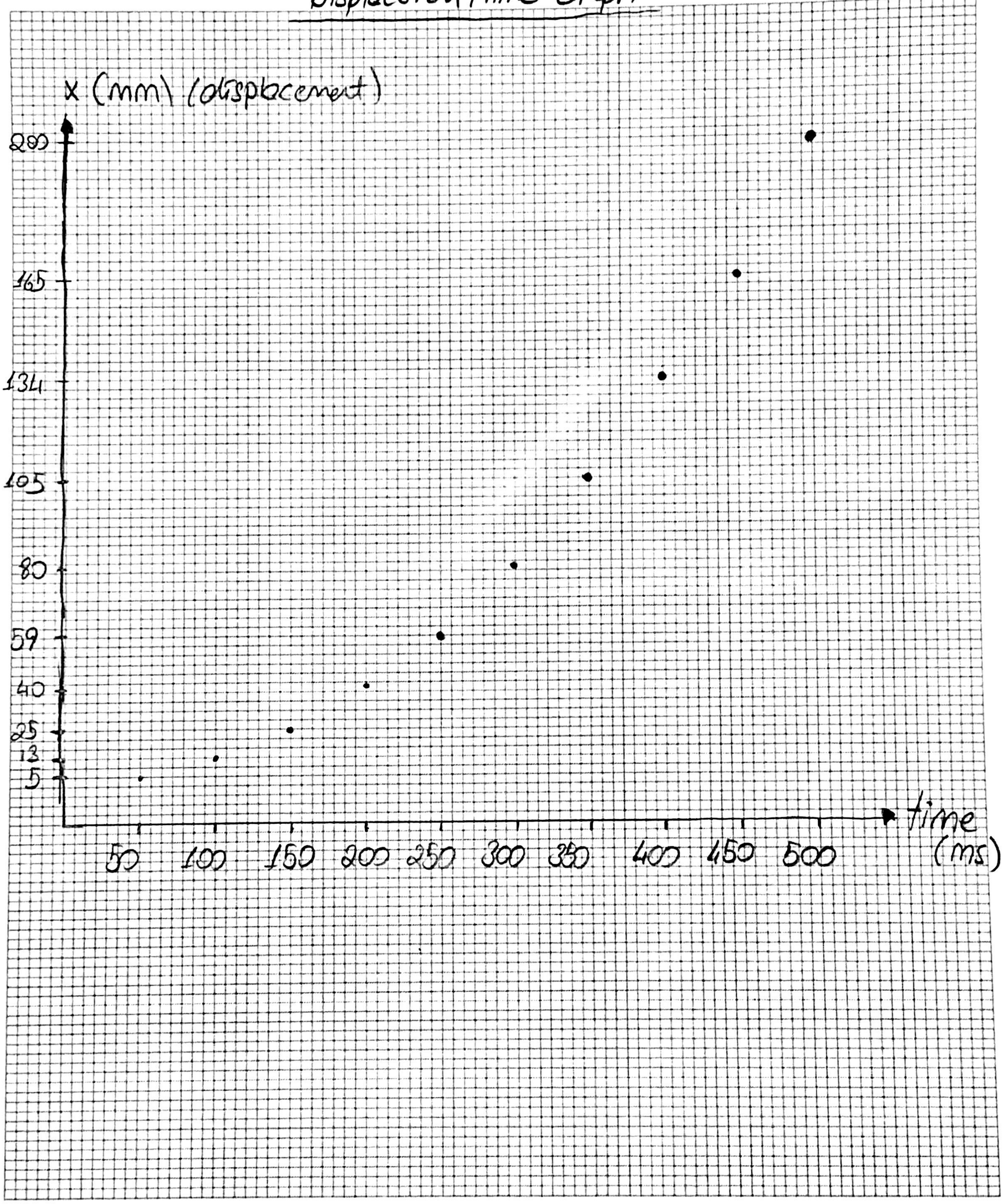
Plot 2 [10]

Displacement/Time Graph



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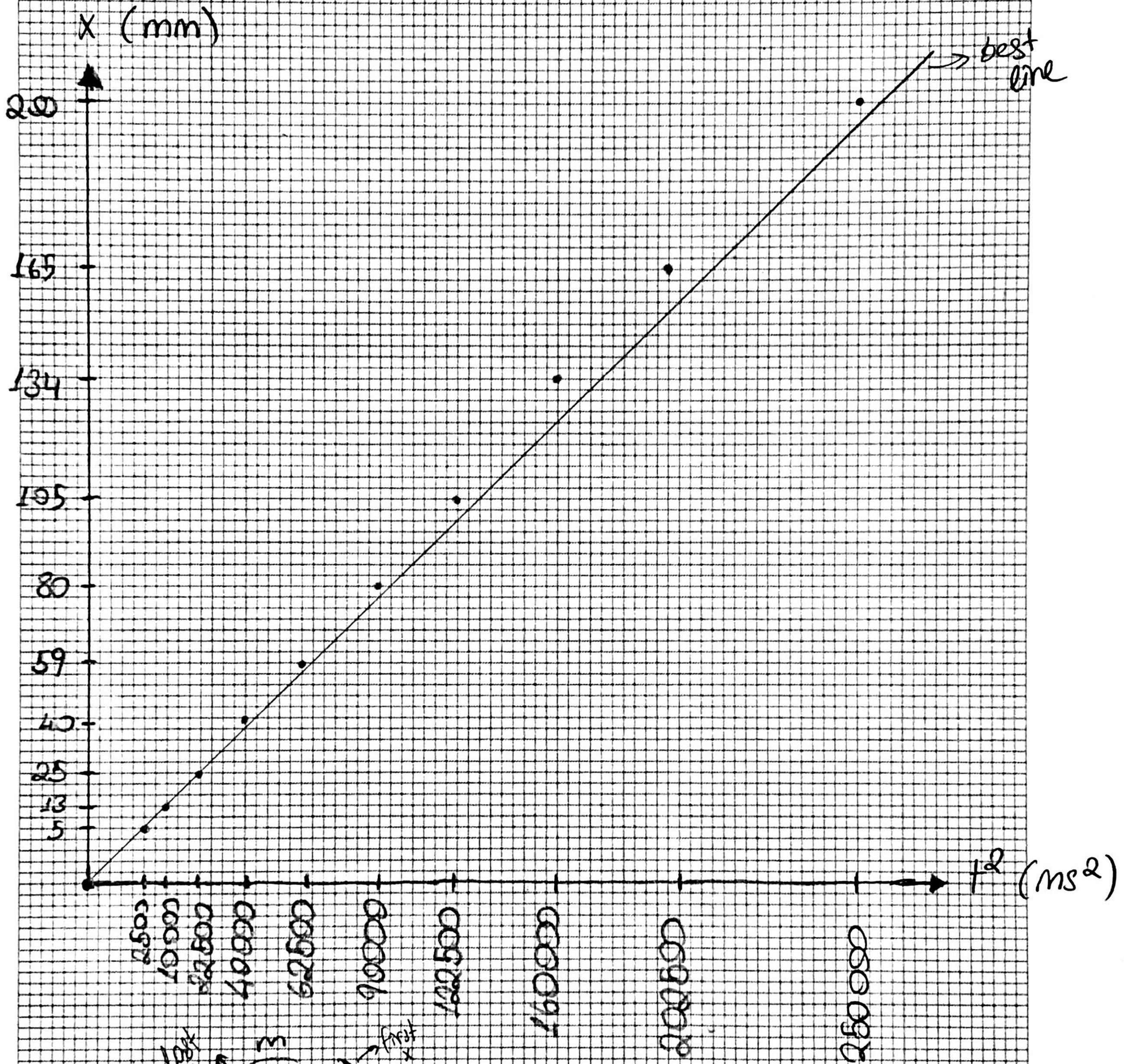
Plot 3 [10]

Displacement / Time^2 Graph



last x ; first x ; last t^2 ; first t^2

$$\text{slope} = \frac{(0.2 - 0)\ \text{m}}{(0.25 - 0)\ \text{s}^2} = 0.8 = \frac{a}{2} = \frac{g \sin\alpha}{2}$$

$$\sin\alpha = 0.13 \Rightarrow \frac{g \cdot 0.13}{2} = 0.8 \Big\} \; g = \frac{1.6}{0.13} = \underbrace{12{,}3076923}$$

rounded to 2 significant digits $= 12\ \frac{m}{s^2}$

$$\boxed{g = 12.3\ m/s^2}$$