SPH3UB - Data Analysis Practice Lab

Kinematics, SUVAT - November 11, 2026

1. **Research Question and Analysis**

Research Question: How does the initial launch speed of a rocket (u^2, in m^2/s^2) affect the maximum vertical displacement of a projectile launched vertically (s in m)?

With the SUVAT Kinematic equation $v^2 = u^2 + 2as$, starting with v = 0 (as v is zero at maximum height), where a is -g and s (displacement) = h (height), height is expressed as $h = u^2/2g$ [$0 = u^2 - 2gs$; $2gs = u^2$; $s = u^2/2g$].

As a result, the graph of h against u^2 would be a straight line beginning from (0,0) with the slope of $1/(2g) = 0.0510\ s^2/m$ [s = y, $x = u^2$; $s = (u^2/2g)$; $s = 1/(2g) * u^2$; $m = 1/(2g)$; $g = 9.803\ ms^{-2}$ (in Oakville); m = 0.0510].

Therefore, a linear representation passing through the origin for this relation would have the slope of:

$m_{theoretical} = 1/(2g) = 1(2 \times 9.803 ms^{-2}) = 0.0510\ s^2m^{-}$ (using b = 0 as theoretical y-intercept).

2. **Assumptions**

There are a few assumptions that were made in the conduction of this experiment.

- Lack of Air Resistance: Assumed that there is no air resistance and hence no external force affecting the vertical displacement of the projectile; ignoring drag.
- Perfect Vertical Launch: Textbooks used to align launcher allowed for a perfect 90.0° launch angle, leading to full vertical velocity and no horizontal component.
- Phone Camera Precision: The zoom used on the phone camera was sufficient to record the exact point of maximum displacement.

3. Raw and Processed Data

Set	u (km/h)	**u (m/s)**	s (set, cm)	s (average, cm)	**s (average, m)**	s (halfrange, cm) UNCERTAINTY, +_	**s (halfrange, m)** UNCERTAINTY, +-	u UNCERTAINTY ($\Delta(u^2)$) +-2.0 kmh^{-} / 3.6 = +-0.5556 ms^{-}
A	5.0	**1.39**	12, 10.5, 12	11.5	**.115**	.75	**.0075**	1.54
B	7.0	**1.94**	20, 19, 19.5	19.5	**.195**	.5	**.005**	2.16
C	12	**3.33**	55, 56, 54	55	**.550**	1.0	**.010**	3.70
D	18	**5.00**	120, 122, 123	121.7	**1.217**	1.5	**.015**	5.56
E	23	**6.39**	190, 193, 193	192.0	**1.920**	1.5	**.015**	7.10
Sample Calculations	u = (kmh^{-}) / 3.6 = ms^{-} u = (5.0 kmh^{-}) / 3.6 = 1.39 ms^{-}		$x_{avg} = (x_1 + x_2 + x_3) / 3$ x_{avg} = (55 + 56 + 54) / 3 = 55		cm / 100 = m 115 / 100 = .115	$x_{half\text{-}range} = 0.5(x_{max} - x_{min})$ $x_{half\text{-}range}$ = 0.5(56 - 54) = 1		$\Delta(u^2) = 2u\Delta u$ $\Delta(u^2)$ = 2(1.3889)(0.5556) = +-1.54m^2s^{-2}

4. **Linearisation and Graph**

R^2: 0.9987 | **Experimental Slope, m_{exp}:** 0.0467 +- 0.0032 s^2m^- | **Y-Intercept, b:** 0.0277 m (2.77 cm) | **Line of Best Fit:** $s = 0.0467u^2 + 0.0277$

5. **Uncertainty Analysis**

The theoretical value for the slope of the relation ($m_{theoretical}$) was calculated as 0.0510 s^2m^-, however the experimental slope was calculated as 0.0467 s^2m^-. As a result:

$\%_{Error} = |\ 100\% * (m_{exp} - m_{theo})/m_{theo}\ | = |\ 100\% * (0.0467 - 0.0510)/0.0510\ | = 8.43\%$.

We can then re-derive acceleration, or experimental gravity:

$g_{exp} = 1/(2m) = 1/(2 * 0.0467) = 10.71\ ms^{-2}$ (~15% off from the theoretical $9.083ms^{-2}$ as measured in Oakville).

6. **Error Evaluation**

Error	**Type**	**Effect (Impact on Data)**	**Improvement**
Launcher Speed Uncertainty (+- 2.0kmh^-)	Random / Systemic (Equipment)	Creates a wide amount of uncertainty (anywhere from +-1.54 to +-7.10 m^2s^{-2}), allowing for substantial experimental error.	Use more accurate devices to measure velocity.
Positive Y-intercept (0.0277 m)	Systematic (Zero Offset)	Line doesn't pass through origin, but rather through (0,0.0277); therefore, there is a discrepancy between s at 0 and u^2 at 0 (the line should pass through the origin).	Ensure that measurements are accurate: align measuring tape with the help of a level.
Inaccuracy in Video Measurement	Random	Distortion occurs when using a phone camera as mounted on a stepstool and attempting to read heights accurately.	Mount camera on a vertical tripod perfectly parallel to each experiment.

7. Conclusion

The experimental data strongly aligns with the kinematic equation of $v^2 = u^2 + 2as$; the linearisation of the vertical displacement *s* against the launch speed (initial) squared u^2 produced a very strong linear relationship with the determinance coefficient, showing that the change in s accounts for ~99.87% of variation in u^2.

In addition, the experimental slope of 0.0467 +- 0.0032 s^2m^{-} agrees with $m_{theoretical}$ = 0.0510 s^2m^{-} (theoretical slope) with a minor error of 8.43%, confirming that vertical displacement directly scales with initial velocity and hence launch kinetic energy per unit mass (as E_k = $\frac{1}{2}mv^2$, so $v^2 = 2E_k/m$).