MAXIMUM HEIGHT OF A PROJECTILE

PRACTICAL INVESTIGATION REPORT

Comment [TB1]: Include a header and footer with your name and the date

AIM:

Comment [TB2]: Start sections with clear headings

To investigate the relationship between the launch speed and the maximum height of a projectile launched directly upwards.

Comment [TB3]: Be as specific as possible to *this* investigation

HYPOTHESIS:

Comment [TB4]: A statement of what you expect to happen, written as if it will be true. Include a specific mathematical relationship.

The maximum height *h* reached by a projectile launched directly upwards will be proportional to the square of the speed v_0 at which it was launched. This relationship can be described by the equation $h = \frac{{v_0}^2}{2g}$ where *g* is the acceleration due to gravity.

EQUIPMENT:

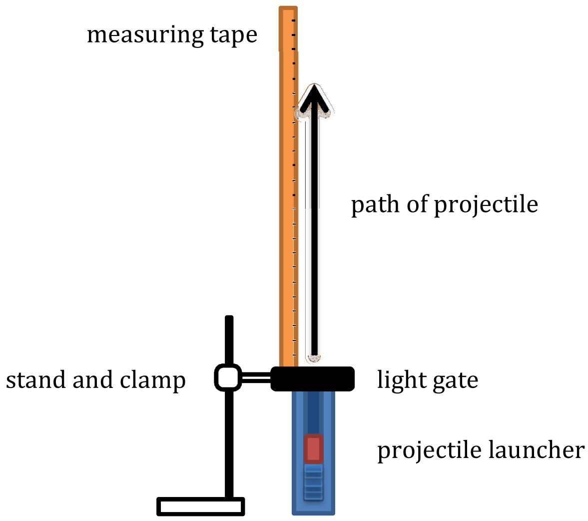
Comment [TB5]: Dot point list. Include all the things that you need to bring to where you do the prac.

- Sticky tape
- Measuring tape or metre ruler
- Projectile launcher with projectile
- Light gate with computer
- Stand with clamp

PROCEDURE:

1. Use sticky tape to hold the projectile launcher against a wall.
   - The projectile launcher should be resting on the ground.
   - The projectile launcher should be pointing directly upwards.
2. Use sticky tape to attach the measuring tape to the wall.
   - The measuring tape should be aligned straight up and down.
   - The measuring tape's zero mark should line up with the top of the projectile launcher.
3. Clamp the light gate onto the stand so the projectile will pass through the light gate.
   - The light gate should be just above the top of the projectile launcher.
   - The light gate should not obstruct the motion of the projectile.
4. Measure the length of the projectile using the measuring tape.
5. Connect the light gate to the computer and set the software up to record speed, entering the length of the projectile measured in step 4.
6. Place the projectile in the launcher and pull back to the first notch.

   Safety note: Ensure before launching that no one is going to be in the path of the projectile.
7. Launch the projectile and record the height it reaches.
8. Record the speed measured by the light gate.
9. Repeat steps 6-8 five times.
10. Repeat steps 6-9 for the second, third, fourth and fifth notches.



Comment [TB6]: Numbered steps, worded as instructions. Anyone should be able to exactly repeat your experiment by following this method.

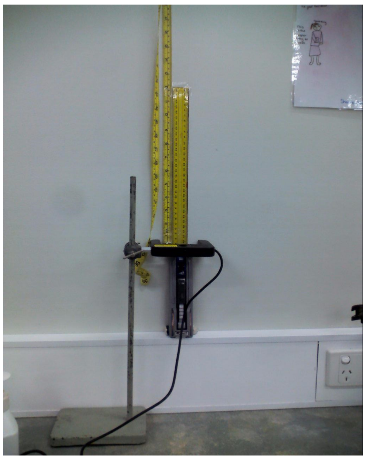
Comment [TB7]: You don't have to use dot sub-points but remember to include as many details as you can.

Comment [TB8]: Include safety precautions.

Comment [TB9]: Keep the method concise by saying this instead of rewriting instructions.

Comment [TB10]: Even if you include a photograph, you still need a clearly labelled scientific diagram.

MANIPULATION AND COLLABORATION:



As shown above, we taped a ruler to the wall in addition to the measuring tape. This helped to make sure the tape was straight up and down the wall. A large section of measuring tape was too long to tape up on the wall, so we folded it over and used the stand and clamp to keep the trailing end out of the way.

There was a board preventing us from resting the launcher against the wall and the desk at the same time. We got around this by lifting the launcher onto the top of the board (as shown) and taping everything into place.

I found it was quite hard to judge the maximum height on the first launch, so each time we moved to a new notch I asked for a 'test launch'. We didn't record the test launches, but it helped me know where to watch for the turning point of the projectile.

The projectile launched at quite low speeds, so there was no danger. We still made sure no one's eyes or head was in the path of the projectile (above the launcher).

We organised clearly defined roles so that we could work together efficiently. My job was to measure the height the projectile reached, while the other two members of the group controlled the computer and loading/firing the projectile launcher.

RESULTS:

Notches	Speed v_0 (ms^{-1})	v_0^2 (m^2s^{-2})	Max height (m)	Expected height (m)
1	1.5	2.4	0.14	0.12
2	2.1	4.4	0.23	0.23
3	2.5	6.1	0.31	0.31
4	2.8	7.8	0.39	0.40
5	3.3	11	0.52	0.56

Comment [TB11]: You don't have to include a photograph, but you must include some comments to show how you have been careful and effective.

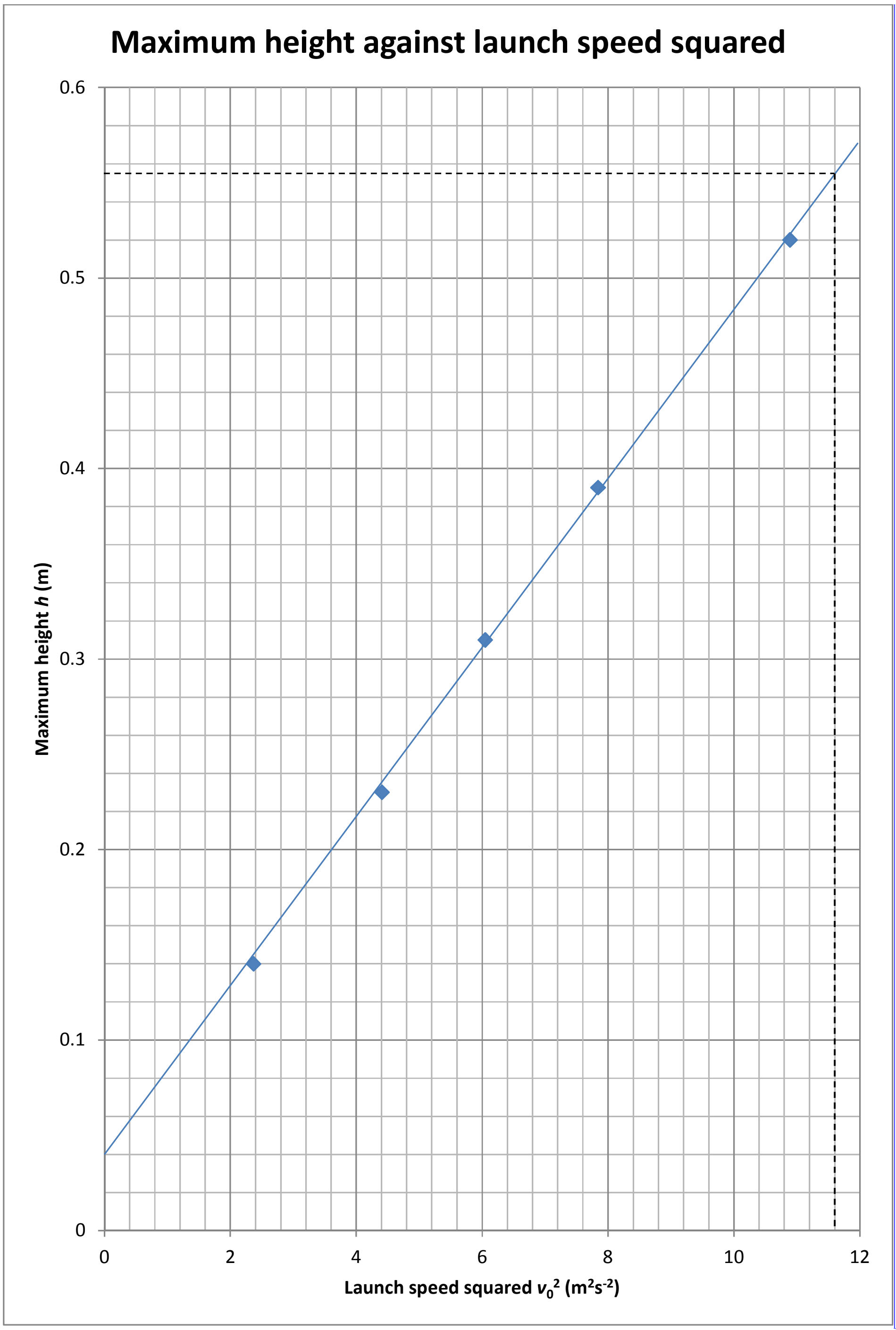
If you worked in a group, also include discussion on how you cooperated and focussed on the task, especially if you showed any initiative.

Comment [TB12]: The Manipulation and Collaboration section is the only place in the report where personal language is appropriate.
Think about:
- How you showed initiative
- Challenges overcome
- Safety precautions
- Working as a group

Comment [TB13]: You *must* include a table of results.
Variables in columns, with independent on the left and dependent on the right.
Units in brackets in the column headings.

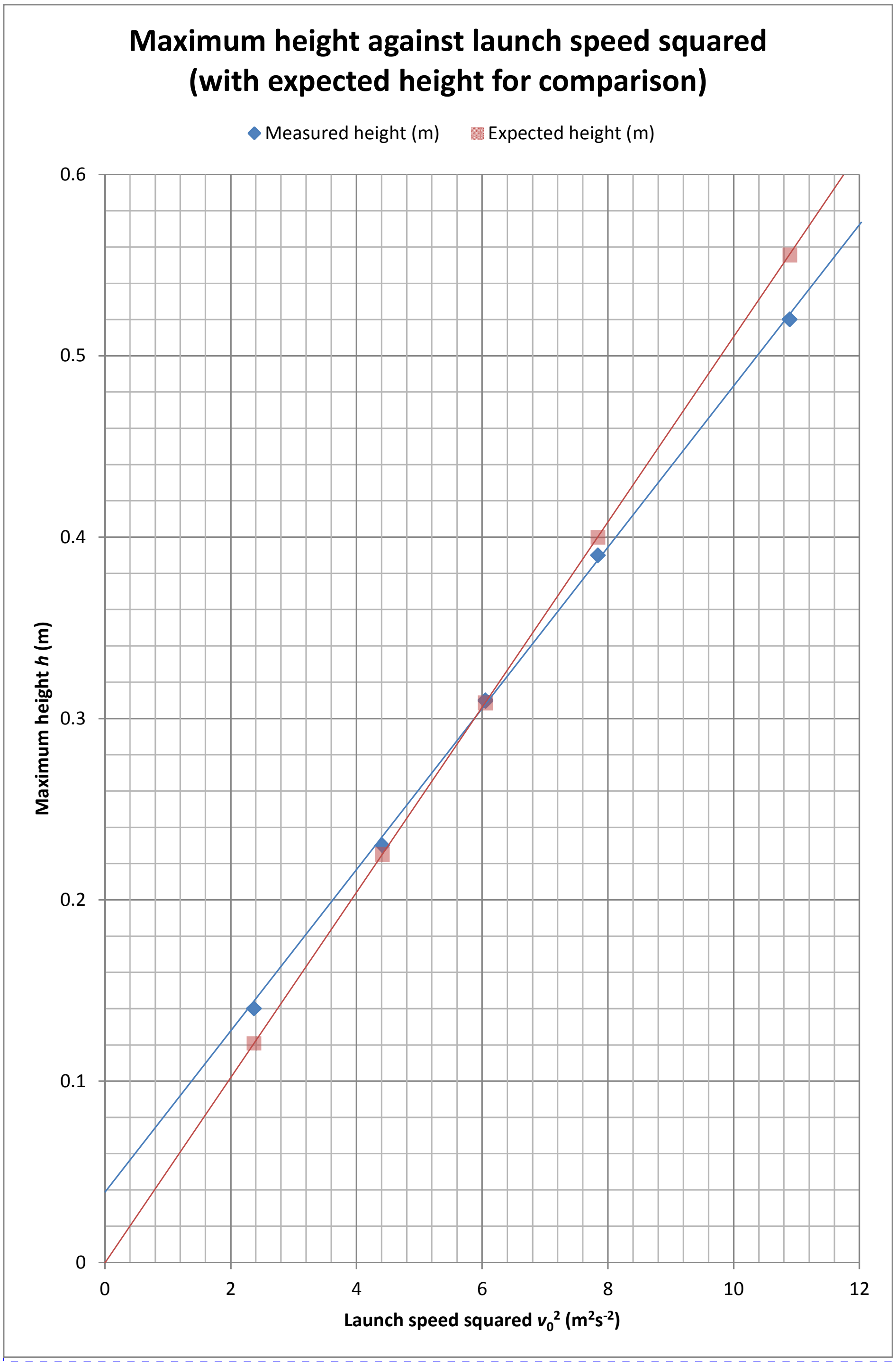
Comment [TB14]: Make sure your decimal places are appropriate for the experiment.

Comment [TB15]: Make sure your significant figures are consistent.



Comment [TB16]: Graphs can be drawn by hand or using the computer. However you do it, follow these rules:

- The graph should fill the page.
- Include a title and axis labels.
- Independent variable on horizontal axis, dependent on vertical axis.
- Choose major and minor axis scales sensibly.
- Draw linear lines of best fit manually
- Include dashed lines to show the values you used to calculate the slope (these should be far apart and on the line of best fit, not data points).
- If you include an R^2 value, explain it.



Comment [TB17]: If you include more than one graph, keep the scale the same whenever possible.

CALCULATIONS:

The hypothesis for this investigation is derived as follows:

The equation $v^2 = {v_0}^2 + 2as$ describes the vertical motion of a projectile.

At maximum height, the speed $v = 0$ and displacement $s = h$, $\therefore 0 = {v_0}^2 + 2ah$

For this investigation, acceleration due to gravity is $-g$, considering negative to be downwards and positive to be upwards.

$\therefore 0 = {v_0}^2 - 2gh$

$\therefore 2gh = {v_0}^2$

$\therefore h = \frac{{v_0}^2}{2g}$

The values for expected maximum height in the results table were calculated using this formula.

The independent variable for this investigation is the launch speed v_0, since it is directly changed by choosing the number of notches on the projectile launcher.

The dependent variable is the maximum height h the projectile reaches, since it is being measured to determine how it changes as a result of changes to the launch speed.

The only other factor in the formula above, the acceleration g of the projectile, must be kept constant throughout the investigation. Any changes to g have an effect on the maximum height that might be incorrectly assumed to be a result of changes to the launch speed. Keeping g constant in this investigation should not be challenging as it is a physical constant at any particular location on Earth.

According to the hypothesis, the line of best fit should have the form $y = mx$, where y is h, m is the slope and ${v_0}^2$ is x. From the graph of maximum height against launch speed, the slope can be calculated using $m = \frac{rise}{run}$, using the points (0.0, 0.04) and (11.6, 0.555):

$$m = \frac{0.555 - 0.04}{11.6 - 0.0}$$

$$= \frac{0.51}{11.6}$$

$$= 0.044 \text{ m}^{-1}\text{s}^{2}$$

According to the hypothesis, the slope of the graph should be equal to $\frac{1}{2g}$. The magnitude of gravitational acceleration g in Adelaide is 9.797 ms^{-2} according to Wolfram|Alpha knowledgebase, 2012. This means the expected slope is $\frac{1}{2 \times 9.797} = 0.051 \text{ m}^{-1}\text{s}^{2}$.

The percentage error can be calculated using $percentage\ error = \frac{expected - measured}{expected} \times 100$

$$percentage\ error = \frac{0.051 - 0.044}{0.051} \times 100 = 14\%$$

Comment [TB18]: You don't have to use the exact same order and section titles as this example report.

Comment [TB19]: The original hypothesis must be based on something solid, not just a guess.

Comment [TB20]: Use properly formatted equations and formulae.

Comment [TB21]: Include somewhere a discussion of the variables and things to be held constant.

Comment [TB22]: Remember to use formal, impersonal language. For example you would *not* say "we measured it" here.

Comment [TB23]: Determine the equation of the line of best fit so you can compare it to the hypothesis.

Comment [TB24]: Read values from graphs to decimal places appropriate to the graph scale.

Comment [TB25]: When you calculate the gradient, include its units.

Comment [TB26]: Feel free to get information from the Internet, library, or qualified experts; just don't forget to reference properly!

Comment [TB27]: If you have a 'true' or 'expected' value, you should always calculate the percentage error.

DISCUSSION:

Comment [TB28]: You don't have to write this discussion in the same order shown here, and you can split it into multiple smaller sections if you wish.
It should include:
- Precision and accuracy
- Possible sources of random and systematic error
- Suggestions for improvement

The measurements taken during the investigation were of reasonable precision. There is evidence of this in that even though the data supports a linear pattern, there is some scatter present around the line of best fit. This indicates the presence of random error, since there is no pattern to the variation between the measurements and the expected values.

The most likely source of random error in this investigation is the method used for measuring the maximum height reached. Although the projectile's motion was along the measuring tape as hoped, the projectile was only at its maximum height for an instant, making the judgement by eye very approximate. This meant even though the measuring tape had 1 mm increments, it would be inappropriate to record data using that detail. If a video camera was used to record and play back the motion of the projectile, measurements could use the available resolution of the measuring tape and therefore improve the precision of the results.

Another possible source of random error could be that the projectile spins as it travels. Since the projectile is rectangular and not spherical, this would mean that its length as it passes through the light gate is inconsistent. The light gate relies on the length of the projectile in order to calculate its speed, so this would cause random error in the launch speeds recorded. One possible change to the procedure that would improve this measurement is to use an appropriately sized spherical projectile, such as a marble. Another possible change could be to use two light gates, one above the other, instead of just one. This way the speed of the projectile would be determined by the time it takes for the front edge of the projectile to travel, meaning the shape of the projectile would not have as great an effect on the measurement of its speed. A limitation of this change is that it would decrease the accuracy of the measurement, since it would record an average speed over that first period of time rather than just at the beginning of the projectile's launch.

Comment [TB29]: Be realistic and specific in your improvements.

The projectile launcher had seven notches, but only five of these were used during the investigation. If the full range of available launch speeds were used, or all measurements were taken more times and averaged, the effect of random error on the fit might be reduced by the larger number of measurements.

The results of this investigation appear to be mostly accurate. The slope of the line of best fit is quite close to the expected slope according to theory, with a percentage error of only 14%. However, the line of best fit does not pass through the origin, instead intercepting the vertical axis at 0.04 m. Physically this would be impossible since a projectile with no speed should not be able to go upwards at all. This apparent shift in the data could be due to the presence of systematic error.

One possible source of systematic error is that the light gate was calibrated incorrectly. One possible reason for this is an imprecise measurement of the length of the projectile, since the light gate software uses the length to calculate the speed. If the length of the projectile entered was slightly shorter than the true value, all speed measurements would be slightly slower than the true values, since the projectile would pass through the gate in more time than the software expects. This could explain the shift of the data points to the left on the graph. This could be improved by measuring the length of the projectile with an instrument of finer resolution, such as a vernier caliper.

Comment [TB30]: Discuss specific possible effects of error in the context of the evidence in the data.

CONCLUSION:

Comment [TB31]: The conclusion is like a short version of your whole report. Someone should be able to read the aim and then skip to the conclusion and get a good idea of what happened. Only include the most important details in the conclusion.

The results mostly support the hypothesis that the maximum height of a projectile launched directly upwards is directly proportional to the launch speed, as the pattern of data supports a linear fit. The scatter is quite large, indicating low precision. The slope calculated from the line of best fit, 0.044 $m^{-1}s^2$, is 14% different from the theoretical slope $\frac{1}{2g}$, indicating reasonable accuracy. The line of best fit did not pass exactly through the origin; this is evidence against support of the hypothesis but is most likely due to systematic error.

A number of factors could potentially have caused error. The most likely of these was the measurement of the maximum height by eye, but the shape of the projectile may also have contributed, as may have the imprecise length of the projectile. The occurrence of error could be reduced by using a video camera, a marble, two light gates, and a vernier caliper. The effect of random error could be reduced by taking a greater number of measurements.

REFERENCES:

Comment [TB32]: Remember to follow the reference formatting guidelines.

Wolfram|Alpha knowledgebase 2012, Wolfram|Alpha Widget: Gravitational Fields, http://www.wolframalpha.com/widgets/view.jsp?id=d34e8683df527e3555153d979bcda9cf, accessed 5th December 2012