

Equations of motion for constant acceleration

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab

Name: _____ Date: _____ Class: _____

Does a trolley rolling down a gentle ramp really have constant acceleration, and how big is it? You record the time to reach five marks, plot distance against time squared, and compare your acceleration with the ideal value calculated from the slope of the ramp.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.4, IB A.1

Aim

To show that a trolley rolling from rest down a gentle ramp has constant acceleration, and to find that acceleration from a graph of distance against time squared.

Equipment

- Smooth board about 1.2 m long and a toy trolley or toy car
- Books to raise one end by about 10 cm
- Metre rule and masking tape for the marks
- Phone or stopwatch reading to 0.01 s
- Graph paper

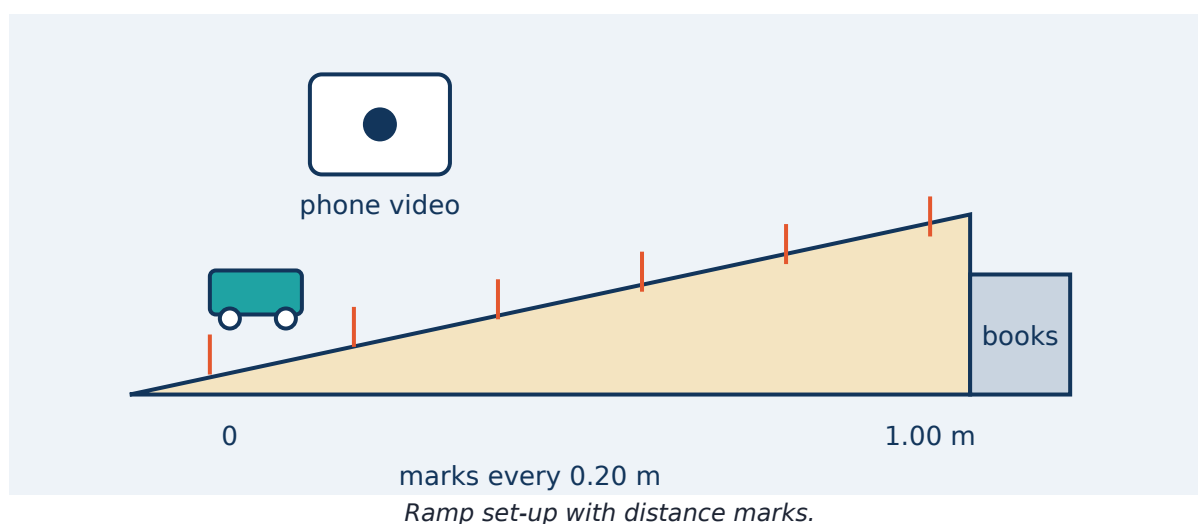
Safety

Safety

Place a soft stop such as a folded towel at the bottom of the ramp so that the trolley cannot hit a foot or fall off the table. Keep the books in a stable stack.

Method

1. Raise one end of the board with the books and mark positions at 0.20, 0.40, 0.60, 0.80 and 1.00 m from the release line.
2. Release the trolley from rest at the top mark without pushing it.
3. Time how long it takes to pass each mark. Use a phone video played frame by frame for the best precision.
4. Repeat three times for each distance and calculate the mean time.
5. Calculate t^2 for each distance and plot s (y-axis) against t^2 (x-axis).



Results

The board is 1.20 m long and is raised by 0.10 m at one end. Sample data (mean of three timings):

Distance s (m)	Mean time t (s)	t^2 (s^2)
0.20	0.71	0.50
0.40	1.02	1.04
0.60	1.22	1.49
0.80	1.42	2.02
1.00	1.59	2.53

Analysis questions

Question 1 Shape of the graph

Describe the graph of s against t^2 you would expect if the acceleration is constant and the trolley starts from rest.

Question 2 Gradient

Use the points (0, 0) and (2.53, 1.00) to calculate the gradient of the best-fit line.

Question 3 Acceleration

Calculate the acceleration of the trolley.

Question 4 Speed at the bottom

Use your acceleration to find how fast the trolley is moving as it passes the last mark.

Question 5 Theory comparison

The ideal acceleration of a frictionless trolley is $g \times (\text{height} \div \text{length})$. Calculate it for this ramp and the percentage difference from your result.

Question 6 Timing uncertainty

The timings repeat to ± 0.03 s. Estimate the percentage uncertainty in the time for 1.00 m and in t^2 .

Question 7 Improvement

Suggest two changes that would make the result more reliable.

Question 8 Hypothesis check

A student claims that doubling the distance doubles the time. Test this claim with your data.