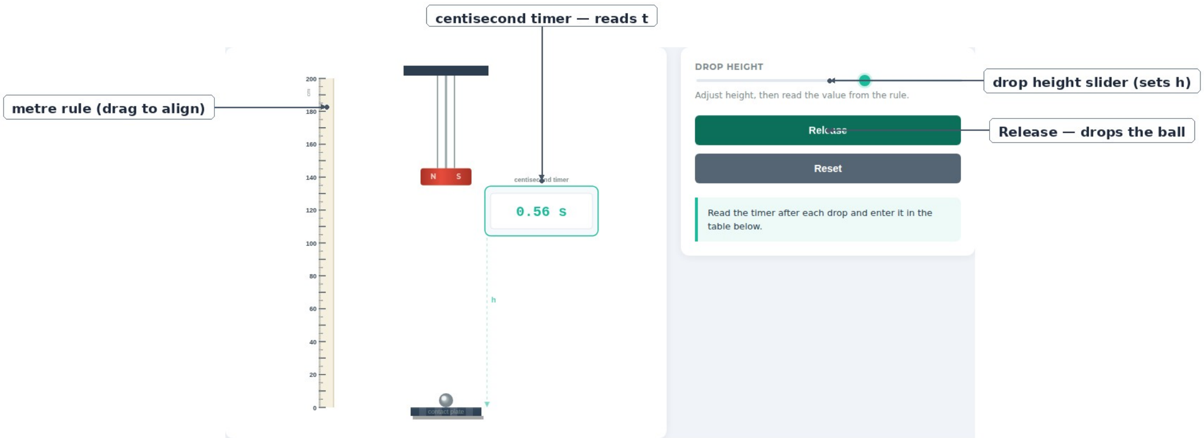
Acceleration of Free Fall

Timing a Ball and a Card Through a Light Gate

Aim:

You are investigating how the height or distance fallen affects the time taken to fall, using two independent methods, in order to find a value for the acceleration of free fall, g.



Method 1 — electromagnet and centisecond timer:

1. Set the **Drop height** slider to a value between 0.20 m and 2.00 m. Drag the metre rule sideways so it lines up with the ball, and read the height h.
2. Press **Release** to drop the ball, and read the time on the centisecond timer once it stops.
3. Record h and this time as t1 in your Method 1 results table.
4. Press **Reset**, keep the height the same, and repeat two more times to get t2 and t3.
5. Repeat steps 1–4 for at least six different heights, spread across the full range of the slider.
6. For each height, calculate the mean t and t^2.

Prediction:

A ball is released from rest and falls freely for a certain height h. If you double h, do you predict the time t will also double? Give a one-sentence reason.

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Test this using Method 1 in the sim before you take your full set of readings.

Results — Method 1:

h / m	t1 / s	t2 / s	t3 / s	mean t / s	t^2 / s^2

Method 2 — light gate and datalogger:

1. Switch to the Method 2 tab (light gate and card).
2. Set the **Drop distance** slider and choose a **Card length** (50 mm or 100 mm). Drag the metre rule so it lines up with the card, and read the distance s.
3. Press **Drop** and read the time on the datalogger once it stops.
4. Record s, L and this time as Δt1 in your Method 2 results table.
5. Press **Reset**, keep s and L the same, and repeat two more times to get Δt2 and Δt3.
6. Repeat steps 2–5 for at least six different distances, spread across the full range of the slider.
7. For each distance, calculate the mean Δt, then the speed **v = L / mean Δt**, and v^2.

Results — Method 2:

s / m	L / m	Δt1 / s	Δt2 / s	Δt3 / s	mean Δt / s	v / (m s^{-1})	v^2 / (m^2 s^{-2})

Analysis:

For Method 1, which equation of motion links the distance fallen from rest, h, to the time taken, t? Write it down, then rearrange it into the form (one quantity) = gradient × (another quantity), so that a graph of h against t^2 gives a straight line.

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Plot h (m) on the vertical axis and t^2 (s^2) on the horizontal axis for Method 1. Draw a best-fit straight line by eye, find its gradient (with units), and use your rearranged equation to calculate a value for g from Method 1.

For Method 2, which equation of motion links the speed gained, v, to the distance fallen from rest, s? Rearrange it so that a graph of v^2 against s gives a straight line.

Plot v^2 ($m^2\ s^{-2}$) on the vertical axis and s (m) on the horizontal axis for Method 2. Draw a best-fit straight line, find its gradient, and calculate a value for g from Method 2.

Compare your two values of g with each other and with the accepted value of 9.81 m s^{-2}. Are the differences small enough to be put down to random scatter in your readings, or is something more going on?

Explaining why:

Look at where your Method 1 line crosses the axes. If the timer measured only the time the ball spends falling, where would you expect the line to cross? Now release the ball once more on Method 1, watching the ball and the timer together at the instant you press Release. What do you notice, and how could this explain the intercept you found? Would it make your measured times too large or too small?

The datalogger in Method 2 gives the time the card takes to cross the gate. Using that time and the card length L, how do you work out a speed? Think about what that speed really describes: is it the card's speed at the exact instant it reaches the gate, or something else? Does this help explain why your Method 2 line does not pass through the origin?

For each method, decide whether its main source of error shifts mainly the intercept of the graph, or also changes the gradient. The gradient is what gives you g, so an error that changes the gradient matters more for your value of g. On that basis, which of your two values of g do you trust more, and why?

Suggest one change to the apparatus or procedure that would reduce the main source of error in each method.