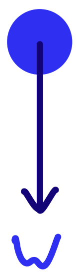
'g' by Freefall

Theory: An object in a gravitational field experiences a force due to gravity.

According to Newton's 2nd law, if the weight is the resultant force on an object it will accelerate in the direction of the force.



$$\text{Resultant force} = W = mg$$

$$\text{and} \quad F = ma$$

$$\therefore \cancel{m}g = \cancel{m}a$$

$$g = a$$

Provided air resistance is negligible, which we assume if the object is small and moving at a relatively low velocity, the size of the Earth's gravitational field strength is the same as the acceleration of the object.

By measuring a combination of displacement, initial and final velocities, and time we can calculate its acceleration using suvat equations.

$$s = ut + \frac{1}{2}at^2$$

g

The acceleration due to freefall (in m s^{-2}) is the same magnitude as the gravitational field strength 'g' (in N kg^{-1}).

Method: Several possible methods can be used to determine 'g', from a falling ball bearing to light gates and interrupt cards. Four possible methods are described here.

Risks and Hazards

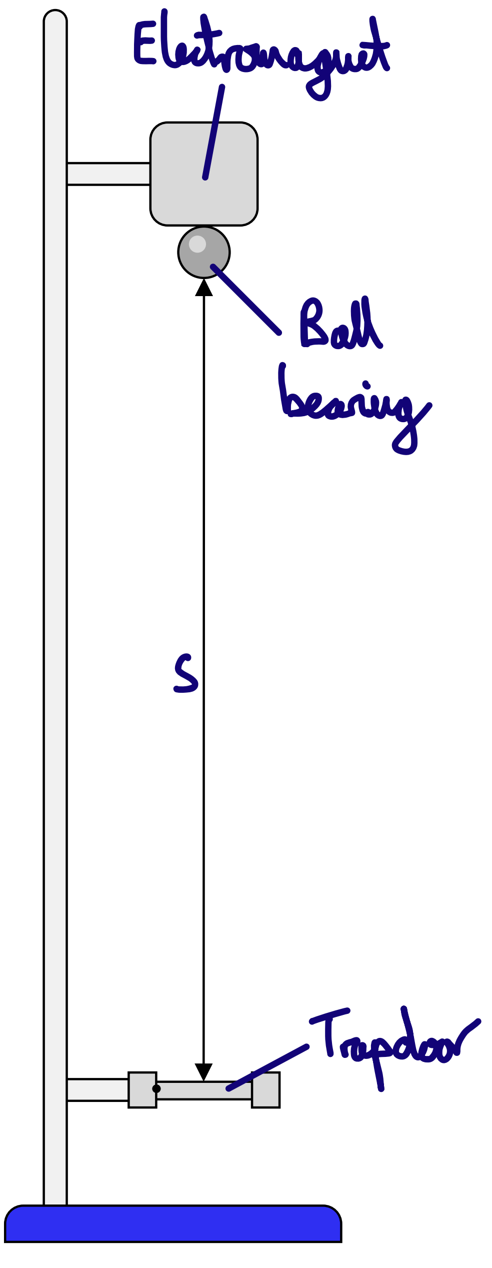
Falling objects: Beware of falling objects, and ensure tall retort stands are clamped so they don't fall over.

Method 1. Falling Ball Bearing

A metal ball bearing is held by an electromagnet. When the circuit to the electromagnet is broken, this releases the ball and starts a timer. The timer stops when the ball falls through a 'trapdoor', disconnecting that part of the circuit.

Variations include a mechanical release clip for the ball, and a trip plate that stops the timer when the ball lands on it.

Record values of **time** for a range of **heights** (including repeats).

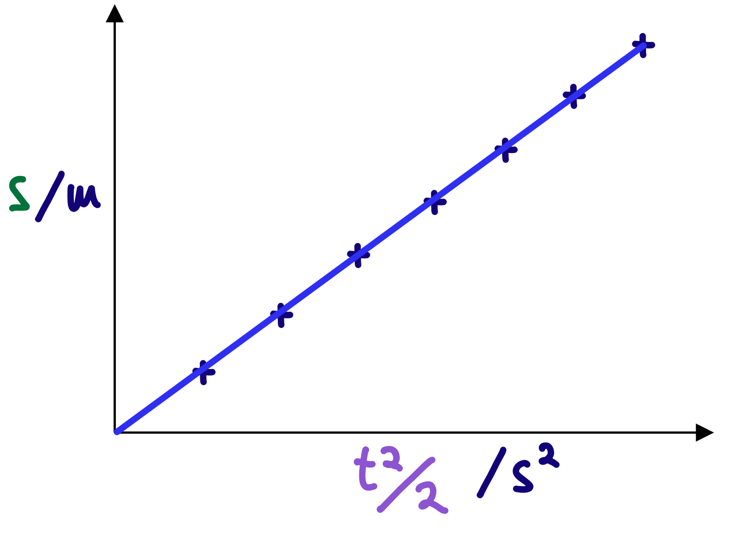


$$s = ut + \frac{1}{2}at^2$$

If $u = 0$ then $s = \frac{1}{2}at^2$

$$s = a\frac{t^2}{2}$$

$$y = m x + c$$



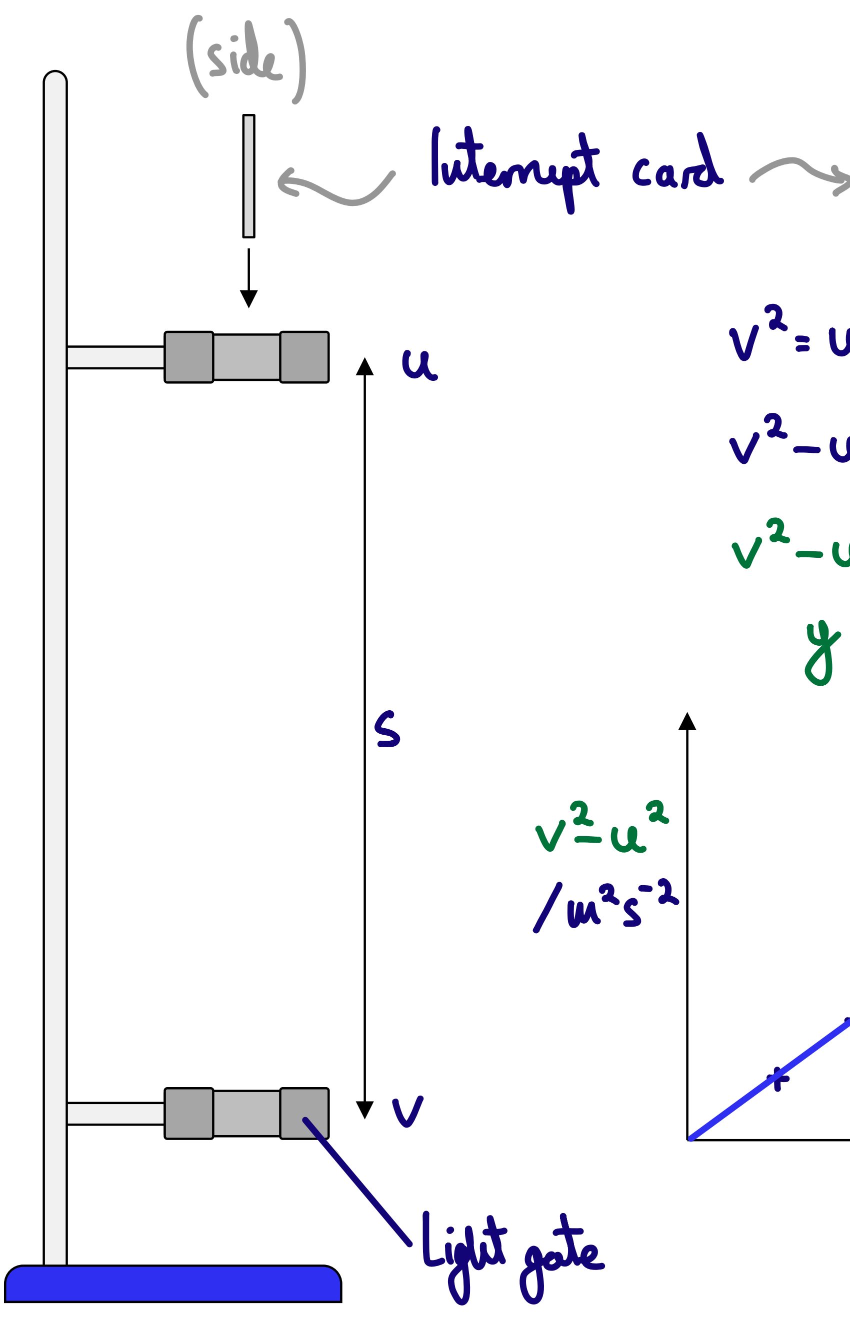
Gradient = acceleration = g

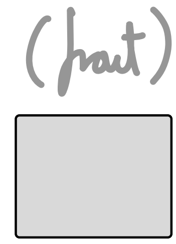
Find the supporting video and other practical experiments at:
ALevelPhysicsOnline.com

Method 2. Two Light Gates and Single Interrupt Card

A card of known length interrupts a light gate connected to a data logger. By recording the time the beam is interrupted for, the average velocity of the falling card is calculated at that point.

If two light gates are used, then you can record values of **initial** and **final velocity** for a range of **heights** (including repeats).



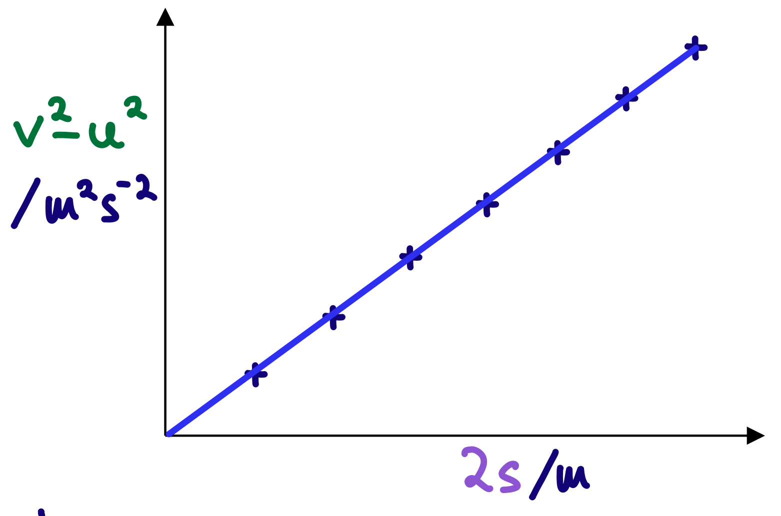


$$v^2 = u^2 + 2as$$

$$v^2 - u^2 = 2as$$

$$v^2 - u^2 = a\,2s$$

$$y = m\,x + c$$



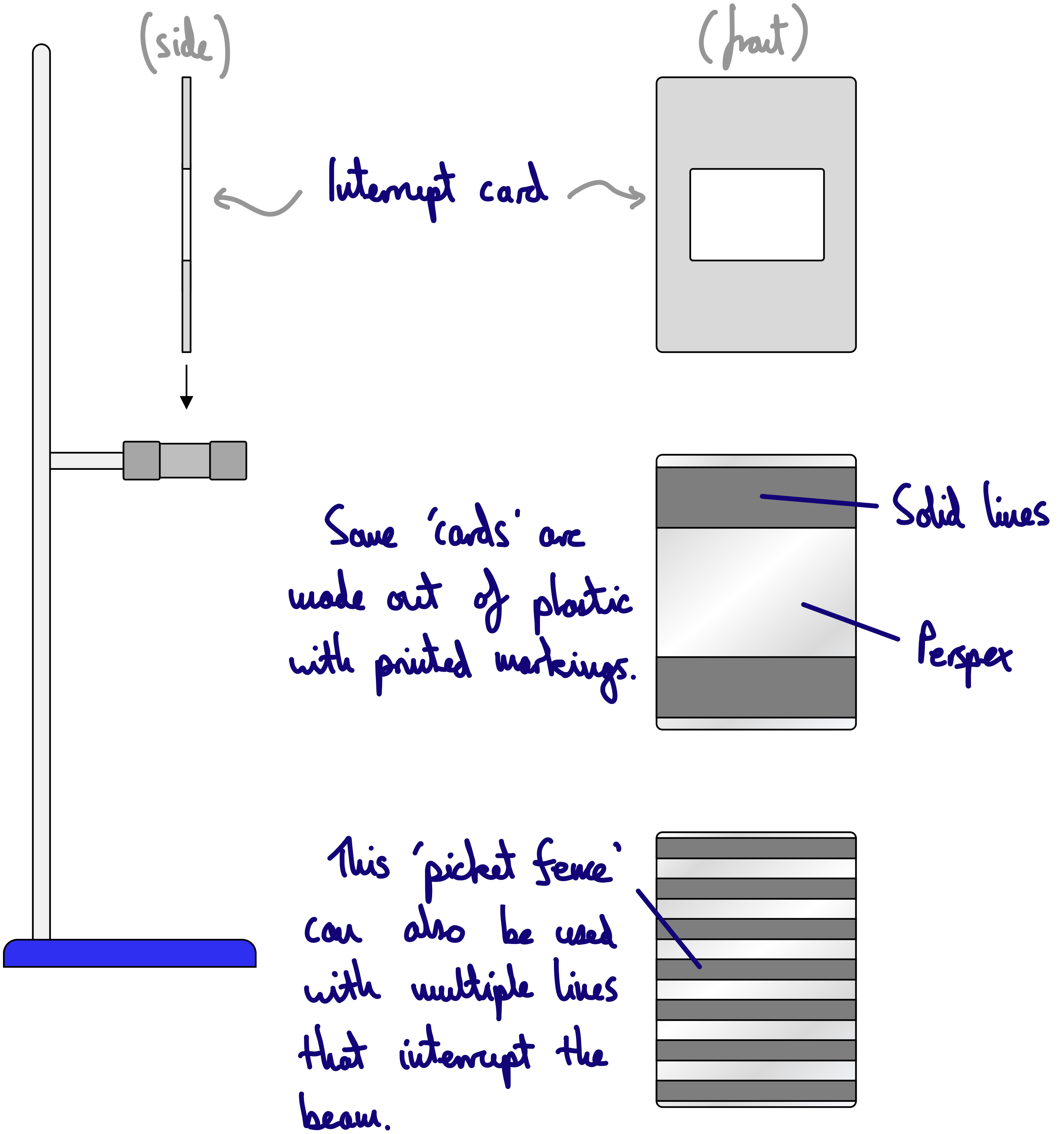
gradient = acceleration = g

Method 3. One Light Gate and Double Interrupt Card

A double interrupt card falls through a single light gate, so it cuts the beam twice.

This can be set up (depending on the software and the type of light gates available) to record the time that the lower and upper parts of the card interrupt the beam and the time between interruptions.

This raw data can be used to calculate initial and final velocities, or combined with the time between interruptions to give a final value for the acceleration of the card.

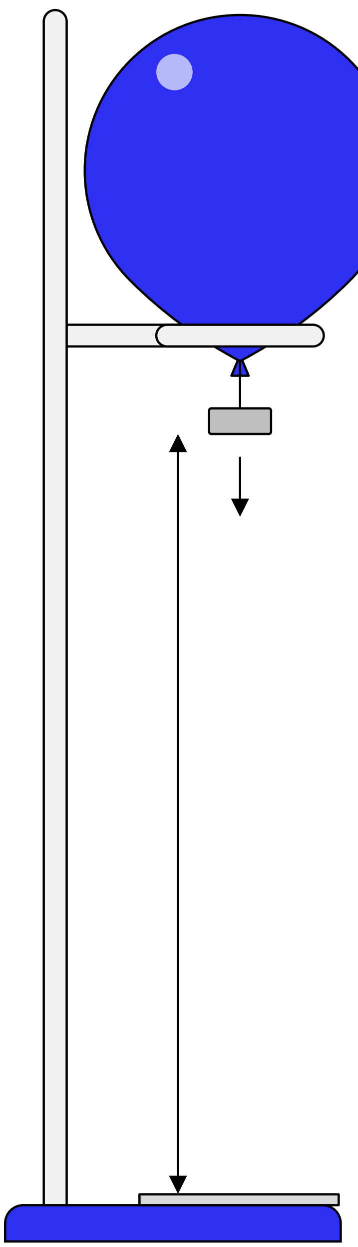


Method 4. Acoustic Stopwatch

This method follows the same principal as the falling ball bearing explained in **Method 1**, with the digital timer replaced with the acoustic stopwatch in phyphox.

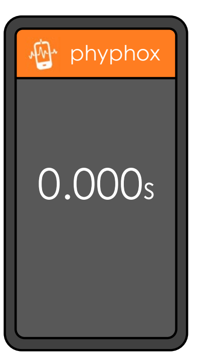
This acoustic stopwatch starts and stops when it detects a loud sound.

A metal mass is suspended from a balloon that is held lightly in a clamp. When the balloon is burst with a pin, the mass starts falling and the timer begins. When the mass hits a metal tray on the floor it causes a further sound that stops the timer.



The time to fall through various heights can be measured.

A graph of **height** against **½time²** is plotted with the gradient equal to the acceleration of the mass, as explained in **Method 1**.



$s = ut + \frac{1}{2}at^2$

if $u = 0$ then $s = \frac{1}{2}at^2$

$s = a\frac{t^2}{2}$

$y = mx + c$

Teacher and Technician Notes

- There are multiple ways that students can measure a value for ‘g’. This could start with simply dropping a ball from various heights and measuring the time with a stopwatch, allowing the students to focus on the physics principles underlying this experiment.
- Identifying sources of error and discussing ways to minimise these may lead to the falling ball bearing (**Method 1**). Depending on the equipment you have at your school, this can be developed by the students so the range of heights is large enough to ensure meaningful data.
- This practical provides a great opportunity for students to see how light gates can speed up data collection. The exact setup depends on the equipment and software your school has (e.g. PASCO, Data Harvest) so it is worth spending time before the lesson becoming familiar with how this can be set up and the data exported.
- An alternative could be to use two BeeSpi V light gates that record speed. This allows the initial and final velocities of a falling object to be measured, for example, a ball bearing that falls through a clamped glass tube to ensure it falls vertically through the light gates every time.
- The free phyphox app may provide a further way to record the time. If phones are allowed, then students could potentially download this before the lesson, or it could be installed on departmental tablets. To find out more about this approach search for ‘phyphox freefall’ for detailed instructions direct from phyphox.

Suitable Equipment

Philip Harris ‘g’ by Freefall

A simple mechanical clip releases a ball bearing that falls onto a trip plate, the time is recorded with a Unilab fast timer.

findel-education.co.uk

FINDEL