

There is no practical exam: Papers 1 and 2 ask you to plan, read instruments, process results and evaluate experiments you have done in class. The marks are for the routine – the instrument and its resolution, the repeat, the table, the graph, the matching improvement.

Measuring well

Read every scale with your eye level with the mark, at right angles to it. Looking from an angle gives a parallax error.

Metre rule – resolution 1 mm. Use a set square to line the object up with the scale, and check whether the rule starts at its end or a little in

Stopwatch – reads to 0.01 s, but human reaction time is about 0.2 s. Time many oscillations or a long run, or use light gates and a data logger

Thermometer – read to 1 °C, or 0.5 °C on a finer scale; stir the liquid and keep the bulb in it while reading

Balance – zero (tare) it before use; a reading with a zero error is wrong by the same amount every time

Ammeter and voltmeter – ammeter in series, voltmeter in parallel across the component; check that both read zero with the switch open

Repeat each measurement at least three times, leave out any anomalous reading, and calculate the mean. Repeats reduce random error; they do nothing for a zero error or heat loss.

Tables, graphs and gradients

The independent variable goes in the first column and on the x-axis. Head every column and axis with the quantity and its unit: ‘extension / cm’.

Choose scales so the points cover more than half the grid in both directions, with easy steps (1, 2, 5 or 10 per large square).

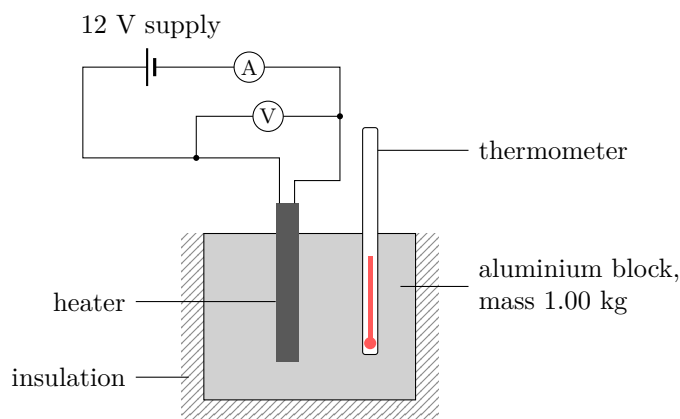
Plot each point to within half a small square, then draw one smooth line of best fit – straight or curved, never dot-to-dot – with points scattered evenly on both sides.

Directly proportional means a straight line **THROUGH THE ORIGIN**. A straight line that misses the origin shows a linear relationship, but not a proportional one.

Find a gradient from a large triangle drawn on the line (over half the line’s length), not from two data points; give it a unit – °C/s, N/cm.

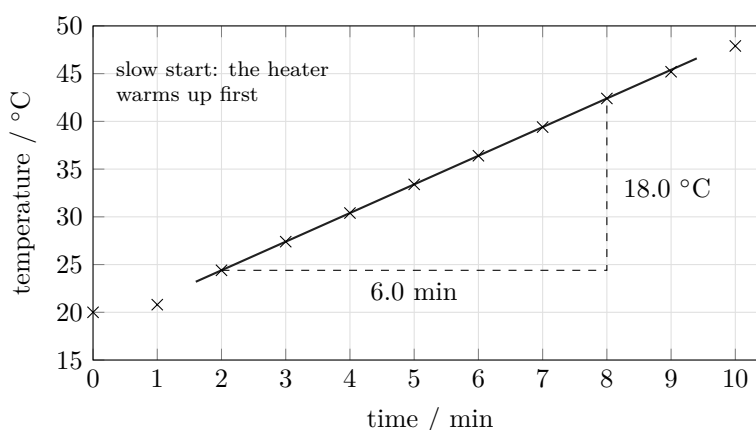
Worked analysis: specific heat capacity of aluminium :

A 12 V, 4.0 A heater (power 48 W) and a thermometer were placed in holes drilled in a 1.00 kg aluminium block, which was wrapped in insulation. The temperature was read every minute for 10 minutes.



The ammeter is in series with the heater and the voltmeter across it, so power = 12 V $\times$ 4.0 A = 48 W. A joulemeter in place of both meters reads the energy directly.

time / min	0	1	2	3	4	5	6	7	8	9	10
temp. / °C	20.0	20.8	24.4	27.4	30.4	33.4	36.4	39.4	42.4	45.2	47.9



The straight section is used; the first minute (heater warming up) and the last (more heat lost as the block gets hotter) are left out.

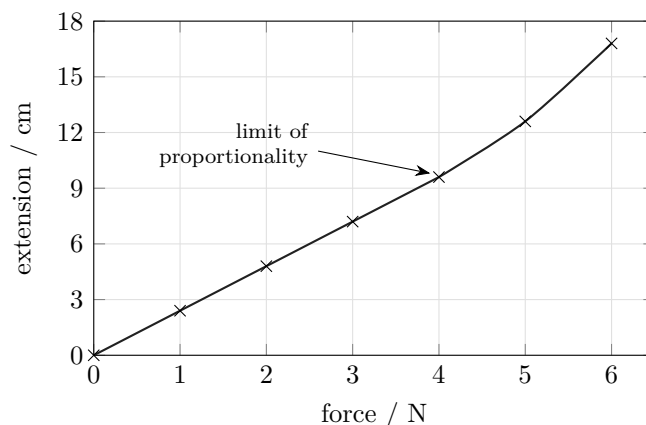
1. Gradient = 18.0 °C $\div$ 6.0 min = 3.0 °C/min = 0.050 °C/s.
2. Each second the heater supplies 48 J, so $\Delta Q = m \times c \times \Delta T$ gives 48 J = 1.00 kg $\times$ c $\times$ 0.050 °C.
3. $c = 48 \div (1.00 \times 0.050) = 960 \text{ J/kg } ^\circ\text{C}$.

The data-book value for aluminium is 900 J/kg °C, so the result is 7% too HIGH. Some of the energy supplied heats the air rather than the block, so more energy seems to be needed per degree. Improvements: thicker insulation and a lid; a drop of oil in each hole so the heater and thermometer touch the metal.

Worked analysis: stretching a spring :

Masses were hung on a spring in 1.0 N steps and the extension measured against a vertical metre rule, using a pointer fixed to the bottom of the spring to avoid parallax.

force / N	0	1.0	2.0	3.0	4.0	5.0	6.0
extension / cm	0	2.4	4.8	7.2	9.6	12.6	16.8



Straight through the origin up to 4.0 N: extension is directly proportional to force (Hooke's law). Beyond it the line curves.

Spring constant = force $\div$ extension on the straight part = 4.0 N $\div$ 9.6 cm = 0.42 N/cm (42 N/m).

Remove the masses at the end: a spring stretched past its elastic limit does not return to its original length.
Wear eye protection and keep feet clear of the masses.

The specification's practicals – what each one needs

Motion of everyday objects – a toy car or ball over a measured distance; average speed = distance $\div$ time. Light gates remove reaction time; for a falling object, a longer drop gives a smaller percentage error in the time

Springs, metal wires and rubber bands – force against extension (above). A wire needs a long length and a fine scale because its extension is tiny; a rubber band's curve does not return the same way when unloaded

Current and voltage characteristics – a variable resistor to change the current, readings in both directions for a diode. Resistor: straight line through the origin; filament lamp: curve, as resistance rises with temperature; diode: current in one direction only. $R = V \div I$

Refraction of light – a ray box with a narrow slit, a rectangular block, semicircular block or prism on paper; mark the rays with crosses, draw the normal, and measure the angles from it with a protractor. $n = \sin i \div \sin r$. A semicircular block, rays aimed at the centre of its flat face, shows the critical angle and total internal reflection

Frequency of sound with an oscilloscope – a microphone connected to an oscilloscope; read the period from several complete waves using the time-base setting, then $f = 1 \div T$

Thermal energy transfer – conduction along rods of different metals; convection shown by a coloured crystal in heated water; radiation from the faces of a Leslie cube (matt black emits most, shiny silver least), measured with an infrared thermometer at the same distance

Density – mass on a balance; volume of a regular solid from its measured sides, of an irregular one by displacement in a measuring cylinder or eureka can; of a liquid from a measuring cylinder. $\rho = m \div V$

Change of state – stearic acid (or ice) heated or cooled with readings every 30 s; the temperature–time graph is flat while it melts or freezes, at the melting point

Specific heat capacity – the block (above) or water; energy supplied by a joulemeter or $E = \text{power} \times \text{time}$; $\Delta Q = m \times c \times \Delta T$. Heat loss makes c come out too high

Magnetic field patterns – plotting compasses moved along the field, marking where each points; or iron filings on paper over the magnet. Show the field of one magnet and between two, attracting and repelling

Penetration of radiation – measure the background count first and subtract it; then the count with paper, aluminium and lead between source and detector. Alpha is stopped by paper, beta by a few millimetres of aluminium, gamma reduced by lead. Sources are handled with tongs, kept at arm's length and returned at once – or use a simulation

What examiners keep reporting

A method with no measuring instrument, or an instrument with nothing about how it is used: 'measure the length with a metre rule, eye level with the pointer' scores; 'measure the length' does not.

A control variable with no way of keeping it constant. Say how: the same volume of water, measured in the same measuring cylinder.

'Repeat to make it accurate'. Repeats and a mean make a result more reliable and reduce random error; they do not remove a systematic error.

A gradient read from two plotted points instead of from the line, or given without a unit.