6.1 Planning A2 investigations

Name: _____ Class: _____ Date: _____ **Total: 31 marks**

KEY WORDS linearisation • range • control variables • ammeter • voltmeter • data logger

Objective

Practise the WPH16 planning skills: turn a predicted relationship into a method whose data feeds a chosen graph, control what actually changes, place meters correctly and justify improvements. These are original training tasks grounded in the specification and reviewed assessment demand.

1 Key knowledge and worked examples

Choose the graph before the method

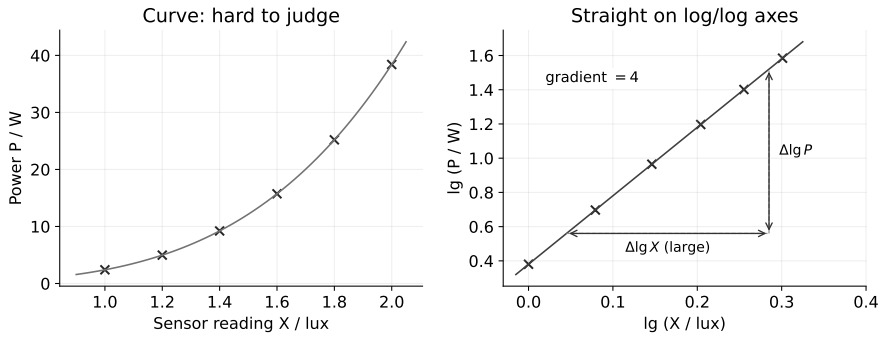
Decide how the data will be processed **before** writing the method. **Linearisation** turns a model into the straight-line form $y = mx + c$:

Model	Plot	Read off
$V = V_0 e^{-t/RC}$	$\ln V$ against t	gradient $-1/RC$, intercept $\ln V_0$
$P = kX^n$	$\lg P$ against $\lg X$	gradient n, intercept $\lg k$
$p = c/V$	p against $1/V$	straight through origin, gradient c
$T^2 = (4\pi^2/k)m$	T^2 against m	gradient $4\pi^2/k$, intercept 0

A method that never names its graph is unfinished. State what proves the model: the expected gradient, or a straight line through the origin.

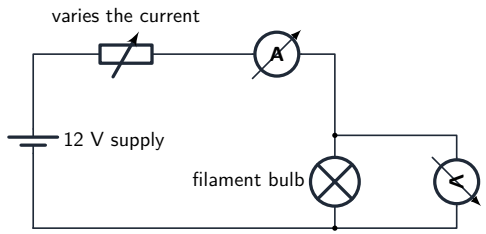
The method skeleton

- named apparatus with measuring **range** and **resolution** ;
- the quantity you change, set to at least five well-spread values;
- **control variables** with the physical reason each one matters;
- repeats that test stability, and new settings rather than repeats when mapping a relationship;
- realistic hazards with a specific action for each;
- the calculation or graph that answers the question.



Meters belong where the measurement is

An **ammeter** is in series with the component under test; a **voltmeter** is in parallel with that component **only**. A variable resistor in series changes the current through it. If a voltmeter straddles two components, its reading belongs to neither.



Worked planning example: the spring constant from oscillations

A loaded spring oscillates with $T = 2\pi\sqrt{m/k}$. Plan an investigation to determine k.

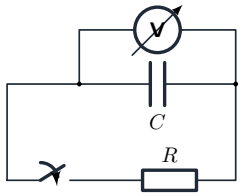
- Known: the period depends on the load. Why this route: $T^2 = (4\pi^2/k)m$, so a T^2 against m graph is straight through the origin and its gradient finds k without a stopwatch calibration.
- Hang mass increments on the same spring from a clamped stand. Record m from the labelled masses.
- Displace the mass a small distance, time 10 oscillations past a marker at the centre of the motion, and repeat. Divide by 10 for T, then square.
- Control the spring, the amplitude (small) and the environment. Keep feet clear of falling masses; use a clamp with a heavy base.
- Plot T^2 against m for at least five loads, draw the best-fit line and take its gradient g_T with a large triangle. Then $k = 4\pi^2/g_T$.

■ **Improvements name their mechanism**

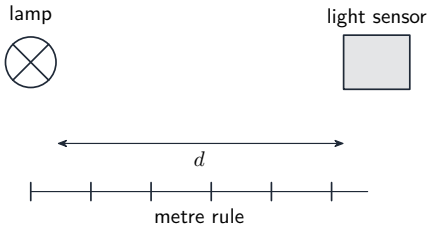
A **data logger** with probes takes paired readings simultaneously, removes **parallax** and improves resolution; say which of these the investigation gains. Safety answers name the hazard and the action: hot water burns, so move glass with tongs; a heater's leads can topple a beaker, so clamp it.

2 Practice

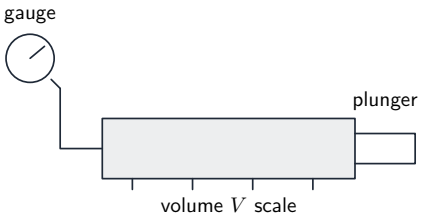
2.1 A charged capacitor discharges through a resistor. State the quantities you would measure, the graph you would plot to test $V = V_0 e^{-t/RC}$, and what its gradient and intercept would represent. [3]



2.2 A lamp shines onto a light sensor whose reading is X. Name two variables that must be controlled when investigating how X varies with the lamp–sensor distance d, and give the physical reason each one matters. [4]



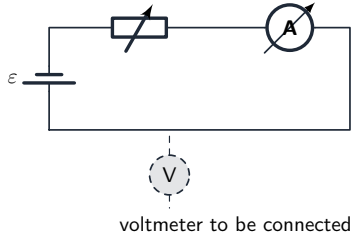
2.3 Air is compressed slowly in a sealed syringe at constant temperature. The model is $pV =$ constant. State the graph you would plot to test this model and what a straight line through the origin would show. [3]



3 Exam-style questions

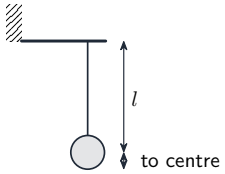
3.1 A student investigates a battery of e.m.f. ε and internal resistance r. The terminal potential difference V and current I follow $\varepsilon = V + Ir$.

Devise a method to determine ε and r using a suitable graph. Your answer should include the circuit with both meters, how the readings are varied, the graph axes, and what the gradient and intercept represent. [7]



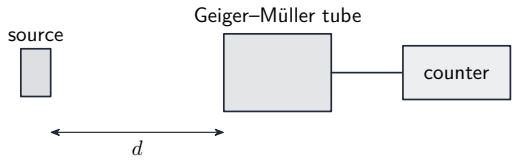
3.2 A student times a pendulum for different lengths l, using $T = 2\pi\sqrt{l/g}$. The student measures l from the support to the **top** of the bob, but the effective pendulum length is $l + \delta l$, because the bob's centre of mass is a fixed distance δl below its top.

Show that a graph of T^2 against l still gives g from the gradient, explain what the intercept would reveal, and state one control variable and one timing technique. [6]



3.3 A gamma source is placed at different distances d from a Geiger–Müller tube. The corrected count rate R is predicted to follow an inverse-square law, $R = c/d^2$, where c is constant.

Devise a method to test this prediction with a suitable graph. Include the treatment of background radiation, the number and spread of distances, two safety points and what would confirm the prediction. [8]



Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 Measure V (across the capacitor) at known times t after switching. Plot $\ln V$ against t. Gradient $= -1/RC$ and intercept $= \ln V_0$, so a straight line with negative gradient supports the exponential model.

2.2 Any two of: lamp current/supply voltage, since brightness and therefore X change with it; background illumination, since it adds to the sensor reading; alignment/angle of sensor to lamp, since the received fraction depends on it; same sensor and rule position. Physical reason required for each mark pair.

2.3 Record p from the gauge for a series of volumes V read from the syringe scale. Plot p against $1/V$. A straight line through the origin shows pV is constant, so the model holds over the range tested.

3.1 Circuit: battery in series with an ammeter and a variable resistor; voltmeter in parallel with the battery terminals only. Vary the resistance to obtain at least five well-spread current values; record paired I and V. Rearranged model: $V = \varepsilon - Ir$. Plot V vertically against I horizontally. Gradient $= -r$; intercept on the V axis $= \varepsilon$. Switch off between readings to avoid heating the cell.

3.2 With the effective length $l + \delta l$ and a constant δl:

$$T^2 = \frac{4\pi^2}{g}(l + \delta l) = \frac{4\pi^2}{g}\, l + \frac{4\pi^2}{g}\, \delta l$$

This is the straight-line form $y = mx + c$: the plot of T^2 against l is straight with gradient $4\pi^2/g$, so $g = 4\pi^2/\text{gradient}$ whatever the length offset. The intercept on the T^2 axis is $(4\pi^2/g)\,\delta l$, so $\delta l = \text{intercept/gradient}$ – the graph reveals the systematic length error. Control: same bob and small amplitude. Technique: time many oscillations past a marker at the centre of the swing and divide by the count.

3.3 Measure the background count rate with the source removed and repeat it. Subtract it from every gross rate to get R. Take readings at a series of at least five distances spread over a wide range, each counted for the same long time, repeating each count. Linearise: $R = c(1/d^2)$, so plot R against $1/d^2$ and expect a straight line through the origin, or plot $\lg R$ against $\lg d$ and expect gradient -2. Confirmation: the line passes through the origin (or gradient -2) within scatter. Safety: hold the source in tongs/holder and point it away from people; minimise handling time and return it to its box immediately, keeping distance.