3.1 Planning valid investigations

Name: _____ Class: _____ Date: _____ **Total: 26 marks**

KEY WORDS valid measurement • independent variable • dependent variable • control variables • resolution • Calibration • zero error

Objective

Practise the WPH13 skills in planning valid investigations. These are original training tasks grounded in the specification and reviewed assessment demand.

1 Key knowledge and worked examples

A **valid measurement** measures what you intend to measure. A precise timer does not help if it times the wrong event.

Start by naming the **independent variable** that you change and the **dependent variable** that you measure. List **control variables** that could also affect the dependent variable. Say how you will keep each important one steady.

■ Turn a description into a usable method

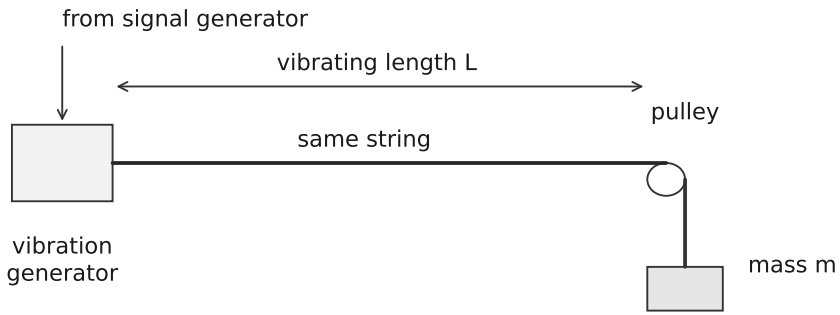
A method needs:

- named apparatus, with a suitable measuring range and **resolution** ;
- an arrangement showing where measurements are taken;
- steps that another student can follow, including the start and end events;
- several independent-variable settings over a useful range;
- repeats where they test stability and estimate variation;
- a calculation or graph that answers the investigation question;
- specific sources of uncertainty and improvements;
- realistic hazards with a practical way to reduce each risk.

Do not write only “take readings” or “use better equipment”. Name the reading, the instrument and what the improvement changes.

■ Worked planning example: string frequency and tension

Investigate how fundamental frequency depends on tension in a string.



- Use a vibration generator and signal generator. Pass the string over a pulley to a mass hanger.
- Change hanging mass m. With a freely moving pulley, tension is approximately $F_T = mg$.
- Measure vibrating length between the end nodes. Use the same string and keep that length fixed.
- Adjust frequency for the fundamental each time. The same mode is a control, not an optional detail.
- Measure the string’s mass and total length to find linear density μ. Keep it unchanged in this investigation.
- Record several tensions and their resonant frequencies. Repeat the tuning near each resonance.

The model for the fundamental is:

$$f = \frac{1}{2L}\sqrt{\frac{F_T}{\mu}} \quad \Rightarrow \quad f^2 = \frac{F_T}{4L^2\mu}$$

A graph of f^2 vertically against F_T horizontally should be straight through the origin. A large triangle gives the gradient. Secure the stand and keep your feet away from falling masses. This is stronger than saying “be careful”.

■ Calibration and zero checks

Calibration checks an instrument against known reference values. A **zero error** occurs when it does not read zero at the correct zero condition. Check closed micrometer jaws or an empty balance before measuring.

If a micrometer reads +0.03 mm with its jaws correctly closed, subtract 0.03 mm from each subsequent reading. Repeating the measurement alone does not remove

that offset. A zero check cannot prove that every point on the scale is calibrated correctly.

■ Range, spacing and repeats

Choose a range wide enough to reveal the relationship. Several measurements crowded near one setting may give a poor gradient. Use more settings near a turning point if you need to locate a maximum accurately.

Repeats are useful when conditions can be reproduced. They show scatter and help identify unstable readings. However, repeated readings of a discharging cell or a heating wire may drift because the conditions change. Reduce the current, switch off between readings, control temperature or restore conditions. Do not average a drift as though it were random variation.

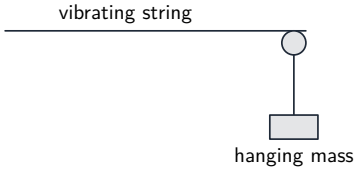
■ Control the actual cause

When varying the angle of a lamp above a solar cell, keep lamp–cell distance and lamp output fixed. Control background light, for example with shielding or a darkened room. Keep the cell and its load the same. Otherwise a change in measured power may come from distance, illumination or circuit resistance instead of angle.

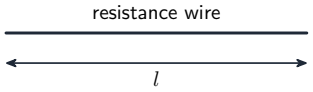
Discuss context using a physical cause. A tracking solar panel can stay closer to normal incidence and collect more energy over a day. Its motor also uses energy and adds cost or maintenance. “Better for the environment” alone does not explain either effect.

2 Practice

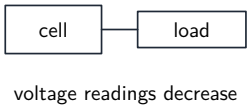
2.1 A student varies the hanging mass on a vibrating string and measures its fundamental frequency. Name the independent variable, dependent variable and one control variable. [3]



2.2 A student measures wire resistance while changing wire length. Explain why a small current, a zero-checked micrometer and secure contacts each improve the investigation. [3]

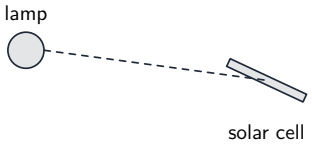


2.3 A student repeats a cell voltage measurement while the cell is supplying a large current. The readings steadily decrease. Explain why averaging alone is not enough and give two practical changes. [3]



3 Exam-style questions

3.1 A student changes the angle between light and a solar cell, using a lamp as a model source. Describe three controls with a way to maintain each. Explain how to improve the estimate of the angle giving maximum power. [5]



3.2 Plan how to measure the maximum load supported by small beams of equal dimensions but different fibre content. Include load measurement, failure detection, controls, repeatability and safety. [6]

3.3 Plan an investigation of how string fundamental frequency depends on vibrating length. Include apparatus, resonance identification, controls, graph, interpretation and a safety precaution. [6]

Solutions

Original-task allocations: B1 = one point, M1 = one method mark, A1 = one accuracy mark.

2.1 Independent: tension, varied through hanging mass. Dependent: fundamental frequency. Keep vibrating length or string linear density fixed.

2.2 Small current limits heating and changing resistivity. The zero check allows a known diameter offset to be corrected. Secure contacts reduce variable contact resistance or intermittent readings.

2.3 The drift indicates changing cell conditions, rather than only random variation. Reduce current/use a larger load resistance. Open the switch between readings and allow conditions to stabilise.

3.1 Keep lamp–cell distance fixed using a measured constant radius. Keep lamp output fixed using the same supply setting. Keep background light steady with shielding/darkened room, or keep cell load/temperature steady with a stated method. First sample a broad range to find the peak region, then add more closely spaced angle settings around the peak while maintaining controls.

3.2 Place each beam across supports with the same separation. Add measured masses at the same loading position, converting total supported mass to force using $F = mg$ or reading a suitable force sensor. Increase in small steps near failure and record the highest supported load plus the next failing load as a bracket. Keep dimensions, support arrangement and other preparation conditions fixed. Use several comparable beams per composition because failure destroys a specimen; compare spread/mean rather than reusing a broken beam. Use a shield/eye protection and a tray to catch fragments or falling masses, naming the relevant risk.

3.3 Use a vibration generator driven by a signal generator and measure the length between end nodes. Tune to the fundamental at each of several lengths; approach resonance from both sides/repeat. Keep tension and linear density fixed. Plot f against $1/L$; the model predicts a straight line through the origin with gradient $\frac{1}{2}\sqrt{F_T/\mu}$. Secure the stand/masses or protect against a named falling-mass hazard.