# H2 Physics
# (Practical)

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## Format

**Total duration**: 2 h 30 mins

**Total marks**: 55 marks

| Component | Time | Marks |
|---|---|---|
| **2 short experiments** | 1 h | 20-23 |
| **1 long experiment** (including mini planning) | 1 h | 20-23 |
| **Planning** | 0.5 h | 12 |

### Experiments

Strategy

1. Linearise expression
2. Collect data (quantitative questions: refer to section 1)
3. Answer all other questions (qualitative questions: refer to section 2)

> **Remark.** Do not be bothered by accuracy (whether data collected is correct or not) when doing experiment; accuracy is only one mark.

Always take note of

- d.p. / s.f.
- units
- presentation of work
  Define any undefined variables e.g. "let $t$ be ..."

**Mini planning**: refer to section 3.

### Planning

**Long planning**: refer to section 3.

# §1 Quantitative Questions

## §1.1 Decimal places and significant figures

Decimal places are henceforth known as "d.p.", significant figures as "s.f.".

- Addition and subtraction: follow least d.p.
- Multiplication and division: follow least s.f.
- Percentage uncertainty: 2 s.f.
- Logarithm: # d.p. = # s.f. of raw data

For recording d.p. of instruments, refer to appendix A.

## §1.2 Measure and record

1. Explicitly state what you are measuring and/or number of measurements.
2. Show evidence of repeated measurements and find average.

**Example.** Let $t$ be time taken for 20 oscillations.

$$\begin{aligned} t_1 &= 50.4 \text{ s} \\ t_2 &= 49.4 \text{ s} \\ t_{\text{avg}} &= \frac{50.4 + 49.4}{2} = 49.9 \text{ s} \\ T &= \frac{49.9}{20} = 2.50 \text{ s} \end{aligned}$$

**Remark.** s.f. of $T$ follows s.f. of $t_{\text{avg}}$.

## §1.3 Estimate percentage uncertainty

Use minimum $2 \times \Delta R$ for actual uncertainty:

$$\% \text{ uncertainty} = \frac{2\Delta R}{R} \times 100\%$$

## §1.4 Table for recording readings

Presentation:

- Solidus notation (symbol + notation) to denote physical quantities.
- Header in the order of experiment, record raw data followed by processed data (calculated values).
- Follow d.p. for raw data, s.f. for processed data.
- Correct number of data sets: minimum 6 for straight line, 8 for curve.

Format of table:

| $n$ | $t_1/\text{s}$ | $t_2/\text{s}$ | $t_{\text{avg}}/\text{s}$ | $T/\text{s}$ | $\sqrt{n}$ |
|---|---|---|---|---|---|
| 6 | 20.0 | 20.2 | 20.1 | 1.05 | 2.45 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

## §1.5 Graph

### §1.5.1 Linearising

1. Manipulate given equation such that independent variable is on one side, dependent variable on the other side.
2. **Linearising statement**: Plot $Y$ against $X$. If the relationship is valid, a straight line graph with gradient $P$, $y$-intercept $Q$ will be obtained.

### §1.5.2 Graph plotting

1. **Scale**

   No odd scale; the acceptable ratios of big squares to small squares are only **1:1, 1:2, 1:5**. Awkward scales (e.g. 3:10) are not allowed.

   Label all bold lines (do not skip any).

   Scales must be chosen so that plotted points occupy at least half the graph grid in both $x$ and $y$ directions.

   Axes must be labelled (with units if any).

2. **Line**

   Line of best fit, (roughly) equal number of points on both sides.

3. **Points**

   Points plotted to half the smallest square.

   Circle and label any anomalies (max 1 allowed).

### §1.5.3 Gradient and y-intercept

**Gradient**:

- Hypotenuse of gradient triangle must be greater than half the length of best-fit line.
- Do NOT use "X" to mark points used for gradient calculation; use a small circle instead.
- Read offs must be accurate to half the smallest square. E.g. if one big square is 0.50, then 0.50/20=0.025 so record to 3 d.p.
- Correct units

**y-intercept**:

- Calculated from $Y = mX + c$ using a point <u>on the line</u> (use gradient coordinates for substitution, NOT values from data collected!)
- Correct units

Calculation: do +/− first (follow least d.p.), then ×/÷ (follow least s.f.)

## §1.6 Calculations

Show all steps of working, d.p. and s.f.

Do not use intermediate values, just use final answers

## §2 Qualitative Questions

- **Support suggested relationship**
  1. My measurements do (do not) support the relationship because
  2. % difference is smaller (larger) than % uncertainty.

$$\% \text{ difference} = \left| \frac{x_1 - x_2}{(x_1 + x_2)/2} \right| \times 100\%$$

  (Percentage uncertainty would have already been calculated in an earlier question.)

- **Point agrees with pattern**

  (If plot this point, is it considered anomalous?)
  1. Since point $X$ is close to (far from) the best fit line, it agrees (does not agree) with the pattern of the other points.
  2. Show that $\Delta l_1 \leq \Delta l_2$ ($\Delta l_1 > \Delta l_2$)

     For a value $l$ on the best fit line, there is an error bar of $\pm\Delta l$.

$$\Delta l = \frac{l_{\text{max}} - l_{\text{min}}}{2}$$

  $l_{\text{max}}$ and $l_{\text{min}}$ can be found from data points collected during experiment.

- **Source of error + improvement**

  **Sources of error** are factors inherent within the experimental set-up and procedures that cannot be "fixed´´, no matter how hard you try to reduce them.

| Source of error | Improvement |
|---|---|
| Time of fall too short, making % uncertainty of $t$ very large. | Allow helicopter to fall through greater height to increase duration of fall. |
| Difficult to start and stop timing at the precise position (moving too fast), making the values of $t$ and $h$ unreliable. | Use light gates and electronic timer / high speed video recording to track the motion for more precise fall timing. |
| Difficult to read two instruments simultaneously, resulting in random errors in readings. | |

- **Anomalous data**

  There is no anomalous data as no data point deviates substantially from the linear trend set by the other data points. All data points are closely and evenly scattered about the best-fit line. **OR**

  $(X, Y)$ is an anomalous point because it deviates substantially from the linear trend set by the other data points.

- **Comment on value obtained**
  1. The value is correct / wrong.
  2. (How it affects graph)

- **Comment on trend**

  Specify 1) direction 2) linear/non-linear.

  > **Example.** Value of $t$ increases non-linearly with value of $x$.

- **Choose same value of x to be used throughout**

  Largest value of x has lowest % uncertainty.

> **Example.** At $x$ = 20.0 cm, values of $t$ are the largest, thus % uncertainty of $t$ will be the smallest (least error).

- **Justify number of s.f.**

> **Example.** $k = ty$
>
> 1. (list out all precisions of variables used in calculation) $y$ recorded to 2 s.f., $t$ recorded to 3 s.f.
> 2. (type of operation) $k$ is product of $y$ and $t$.
> 3. Record to least s.f. based on those of $y$ and $t$.

- **Estimate area under the graph**

  Use trapezium rule.

# §3 Planning

Format

1. **Diagram**
   - Big, clear, well-labelled, 2D
   - Show relative positions of apparatus, include lab bench, retort stand (to ensure apparatus are not floating in the air)
2. **Objective**

   To investigate how (dependent variable) varies with (independent variable)
   - **Independent** variable
   - **Dependent** variable
   - **Controlled** variables - ensure same throughout experiment

   For each type of variable,
   - *direct* measurement: state what (physical quantity) you measure and the apparatus you use.
   - *indirect* measurement: state what (physical quantity) you want to determine and describe how (the physical quantities to be measured; apparatus, techniques and equations used; illustrate if necessary).
3. **Procedure**
   (a) Set up the apparatus as shown in Fig. 1.
   (b) [clearly describe procedure to determine dependent variable]
   (c) Repeat steps xxx to xxx by [describe method] of varying [independent variable; give range of values] to obtain xxx sets of readings.
4. **Analysis**

   Mini planning (1 independent variable)
   (a) Given (or assume) that $y = kx^n$,
   (b) Taking log on both sides, $\log y = n \log x + \log k$.
   (c) Plot graph of $\log y$ against $\log x$.
   (d) If the relationship $y = kx^n$ is true, straight-line graph will be obtained where gradient equals to $n$, y-intercept equals to $\log k$.

   Long planning (2 independent variables)
   (a) Experiment 1 (vary $p$): Given (or assume) that $y = kp^m q^n$, taking log on both sides, $\log y = m \log p + n \log q + \log k$. Plot graph of $\log y$ against $\log p$. If the relationship $y = kp^m q^n$ is true, straight-line graph will be obtained where gradient equals to $m$, y-intercept equals to $\log kq^n$.
   (b) Experiment 2 (vary $q$): Plot graph of $\log y$ against $\log q$. If the relationship $y = kp^m q^n$ is true, straight-line graph will be obtained where gradient equals to $n$, y-intercept equals to $\log kp^m$.

   > **Remark.** Show full linearisation steps.
5. **Safety precautions**

   How to prevent injuries/accidents

   Pressure:
   - Use safety screens in case of implosion/explosion.
   - Container must be strong enough to withstand high pressure.
   - Water flow rate should not be too high to avoid water from splashing on the floor, as a wet floor might cause slipping.
   - e.g. safety goggles can be worn to protect eyes in case a piece of something breaks off during experiment.

   Sound:
   - Wear ear plugs to protect against loud sound.
   - Switch on sound source only for short period of time

to protect against loud sound.

Electricity:

- Switch off power supply between readings to avoid overheating of apparatus.
- When handling high voltage, wear rubber gloves to avoid electric shock.
- To minimise risk from high current, connect rheostat/protective resistor in series.
- Prevent electrical circuit from coming into contact with water to prevent short circuit.

Light:

- To minimise ambient light, perform experiment in dark room OR black coloured container large enough to house apparatus.
- Do not look into bright light source / wear dark glasses to protect eyes.
- Do not touch hot light source.

Mechanics:

- Heavy mass clamped to retort stand: use G-clamp to secure retort stand / place weights/bricks on base of retort stand.
- Falling mass: keep well away, use sand trays to catch falling object.

Magnetic field:

- Switch off hall probe when not in use to avoid overheating coil.
- Do not touch coil because it is hot.

Heat:

- Use gloves/tongs when handling hot container.
- Wait to cool down.

Radioactivity:

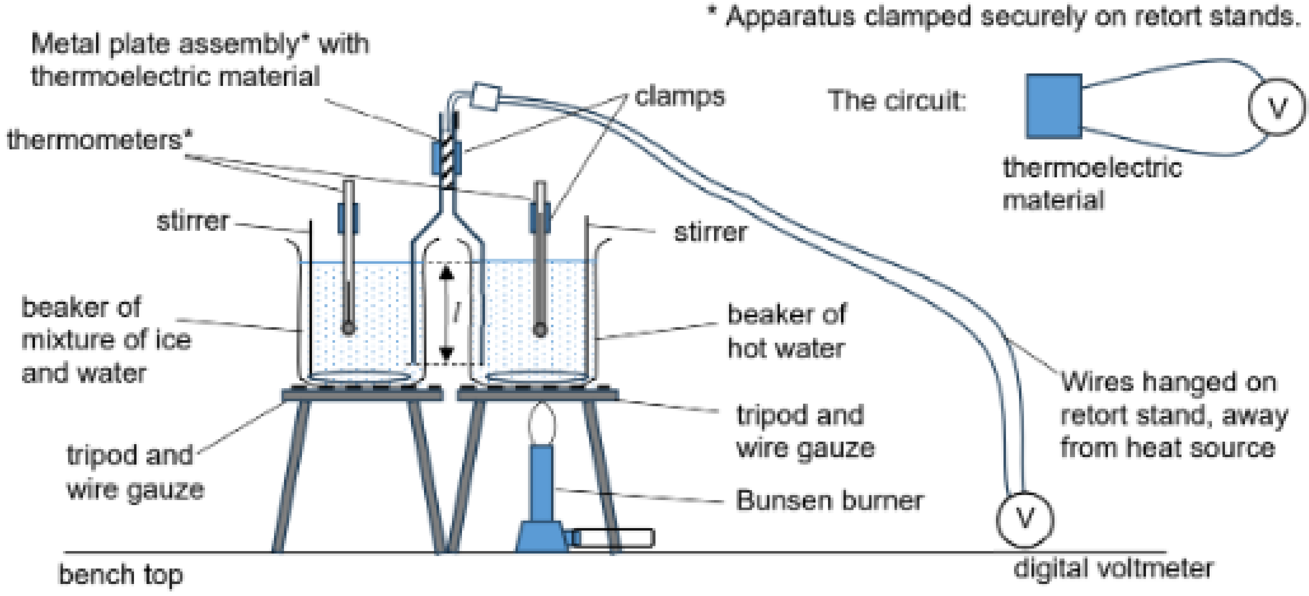
- Use forceps or tongs when handling source, to avoid contact with radioactive material.
- Do not point the source at people / do not look directly at source.
- Store source in lead-lined box when not in use.

6. **Improve accuracy/reliability**

   Potential significant systematic & random error + apparatus/method to eliminate/reduce

   - e.g. heat loss + use jacket
   - e.g. % uncertainty + reduce by using larger volume of water / larger time / larger distance, average more

**A-Level 2022 planning question**:




**Procedure**

1. Using a fine permanent marker and a ruler, calibrate the ends of the metal plates to be immersed in water in cm. When immersed the plates in water, $l$ can be read from the scale created on each plate.
2. Set up the apparatus as shown above, with the metal-plate assembly, vertical half-metre rules, and the thermometers securely clamped on separate retort stands. Fill the beakers separately with ice water and room temperature water, to the same level.

Vary $l$, keep $\theta$ constant to obtain $\beta$:

3. Adjust the metal-plate assembly vertically such that both metal plates are immersed to the same depth of minimum $l$.
4. Check that the beaker of mixture of ice and water is maintained at 0°C, using the thermometer. Stir the water using the stirrer to ensure uniformity of temperature of the metal plate. Record the temperature $T_L$.
5. Turn on the Bunsen burner and heat the other beaker of water to $T_H$ = 40°C; stir the water in the process to ensure uniformity of temperature of the metal plate. Record $T_H$ and calculate $\theta = T_H - T_L$.
6. Record the voltmeter reading $\varepsilon$.
7. Repeat steps 3 to 6, each time incrementally increase $l$ in step 3, for ten sets of $l$ and $\varepsilon$, keeping $\theta$ constant.
8. Plot a graph of lg $\varepsilon$ against lg $l$. Since $\lg \varepsilon = \beta \lg l + \alpha \lg \theta + \lg k$, the plots will yield a straight line. The gradient is equal to $\beta$.

Vary $\theta$, keep $l$ constant to obtain $\alpha$:

9. Repeat steps 3 to 6, keeping $l$ constant at maximum in step 3, each time increasing $T_H$ in step 5 incrementally, for ten sets of $\theta$ and $\varepsilon$. Check the value of $l$ after each set, replenish water accordingly if there is evaporation.
10. Plot a graph of lg $\varepsilon$ against lg $\theta$. The gradient of the straight line is the value of $\alpha$.

Precautions

11. A preliminary trial could be done to determine a suitable range of $\theta$ for appreciable variations in $\varepsilon$.
12. Wear goggles, rubber gloves and covered shoes while working with the Bunsen burner, to protect one's eyes hands and feet from accidental spillage of hot water and breakage of the beakers.
13. Hang the wires tidily on the retort stand, keeping them away from the tripod and Bunsen burner, to avoid fire hazards.

## §A Common Apparatus

| Instrument | Resolution | Used for measurement of |
|---|---|---|
| Metre rule | 0.1 cm | height/length of object |
| Half metre rule | 0.1 cm | height/length of object |
| 30-cm rule | 0.1 cm | height/length of object |
| Measuring tape | 0.1 cm | long distances |
| Vernier caliper | 0.01 cm | Outer jaws: coins or rod<br>Inner jaws: interior of hollow pipe<br>Depth rod (tail): holes or steps |
| Micrometer | 0.01 mm | diameter of ball bearings, thickness of wires |
| Travelling microscope | 0.01 mm | short lengths that cannot be measured by micrometer e.g. holes, indents, writings, biological specimens |
| Stopwatch | 0.01 s (**record to 0.1 s**) | experiments in which human reaction time (0.3 s) has low percentage uncertainty e.g. 20 oscillations |
| High speed camera on a tripod | 1 $\mu s$ | experiments in which human reaction time has high percentage uncertainty |
| Electronic balance / weighing machine | 0.001 g | mass |
| Spring balance | depends | small (tensional) forces between 1 N and 30 N |
| Strain gauge | depends | relatively large forces |
| Measuring cylinder | depends | volume of liquid |
| Barometer | depends | atmospheric pressure |
| Nanometer | depends | pressure near atmospheric pressure |
| Pressure gauge | depends | gauge pressure (difference between absolute gas pressure and atm pressure) |
| Mercury-in-glass thermometer | depends | temperature of liquid between −10°C and 110°C, room temperature, body temperature |
| Thermocouple | depends | temperature range between −200°C and 1300°C |
| Digital multi-meter | based on setting | all purpose |
| Voltmeter | depends | e.m.f./p.d. |
| Ammeter | depends | current |
| Cathode ray oscilloscope (c.r.o.) | depends | period of sound wave by connecting c.r.o. to microphone |
| Photometer / light sensor connected to data logger | depends | intensity of incident UV, visible, infrared |
| Stroboscope | depends | frequency of oscillating object, typically a stationary mechanical wave formed by transverse waves |
| Diffraction grating | depends on $1/d$, usually number of lines per mm | (indirect) measurement of frequency of visible light (use $d\sin\theta = n\lambda$, $c = f\lambda$, and small angle approx $x/D \approx \tan\theta \approx \sin\theta$) |
| Gaussmeter connected to hall probe | depends | magnetic flux density [use of current balance is too complicated to describe] |
| Geiger counter | depends | ionising radiation (in counts per minute) |

# §B Common Experiments

**Mechanics**

- Determine centre of gravity
- Oscillation of pendulum
- Moments
- Waves
- Diffraction grating

**Electricity**

- Measure potential difference / current / resistance using digital multi-meter

**Thermal**

- Measure temperature change