Question 1

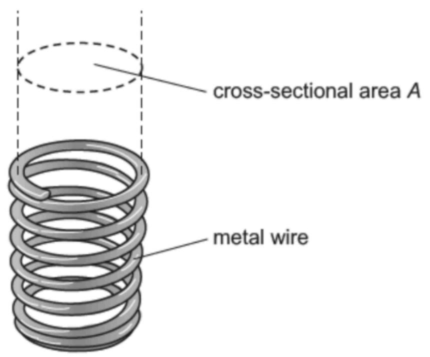
Format

1. Defining the problem – Variables
2. Diagram
3. Method of data collection
4. Method of analysis
5. Safety precaution

Method of analysis (for every question)

- Plot graph of independent variable vs. dependent variable (in correct forms)
- Relationship is valid if a straight line passing through origin is produced (when no y-intercept) OR Relationship is valid if a straight line not passing through origin is produced (when there is a y-intercept).
- Use y=mx+c to determine an expression for the desired constant in the experiment, and express this constant as the subject of the equation (in terms of the gradient and y-intercept of graph).

Spring constant



- *Several springs constructed from wire of thickness t.*
- *Each spring has a different cross-sectional area A.*
- *Investigate how spring constant k varies with A.*

$$k = \frac{\beta \rho t^4}{A^{\frac{3}{2}} N}$$

- *ρ = density of metal, N = number of turns of wire on the spring, β = constant.*
- *Test relationship between k and A.*
- *Explain how results could be used to determine value for β.*

Variables

- A = independent variable; k = dependent variable
- keep N constant

Diagram

- Spring fixed at one end to a support.
- Load attached to the other end of the spring and labelled.
- Labelled ruler drawn parallel to spring.
- Equilibrium position and displaced position indicated, and x (extension) indicated.
- Correctly positioned set square indicated at right angles between rule and horizontal surface/ plumb line shown in appropriate position.

Method of data collection

- **Thickness of spring (t)**
    - Vernier caliper/ micrometer to measure thickness of spring.
    - Repeat measurement along different positions on spring and average.
- **Density of metal (ρ)**
    - Measure mass and volume of to determine density density of spring: D = M/V
- **Area of cross section of spring (A)**
    - Rule/ vernier caliper to measure diameter of spring/ coil.
    - For external diameter: Repeat measurement in different directions and average.
    - For mean diameter: Subtract thickness from external diameter.
    - Area from diameter:

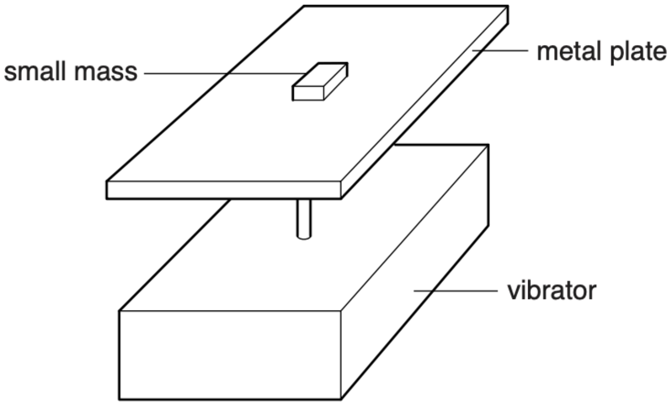
      $$A = \frac{\pi D^2}{4}$$
- **Extension (x)**
    - Metre rule used to measure equilibrium position and displaced position, and difference determined.
    - To ensure extension is vertical: Use set square at right angles between rule and horizontal surface OR plumb line, and then clamp rule.
    - Use set square when taking measurements to determine extension.
- **Load (F)**
    - Top-pan balance to measure mass of load OR newton meter to measure weight of load.
- Spring constant from extension and load:

$$k = \frac{mg}{x} \text{ or } \frac{F}{x}$$

Safety precautions

- use safety goggles/safety screen to prevent injury to eyes from moving spring/load.
- use cushion/sand box in case load falls.

SHM using electric vibrator



- *Metal plate attached to vibrator, mass placed on plate.*
- *Alternating p.d. applied to vibrator.*
- *For a given peak p.d. V, there is a maximum frequency f at which the small mass remains in contact with the plate.*
- *Contact between mass and plate is lost when frequency > f.*

$$k = \pi^2 f^2 V$$

- *k= constant*
- *Test the relationship between f and V.*
- *Explain how your results could be used to determine a value for k.*

Variables
- V = independent variable; f = dependent variable (or vice versa)
- Change V until mass leaves plate (or vice versa)
- keep position of mass constant (not keep mass constant)

Diagram
- Signal generator/a.c. supply connected to vibrator with 2 wires.
- Voltmeter/CRO connected in parallel with vibrator.

Method of data collection
- **Peak p.d. (V)**
  - Use signal generator/ a.c. supply to vary pd and cause vibration.
  - Wait for vibrator to oscillate evenly.
  - Read on CRO to determine peak voltage:

    V_{peak} = amplitude (height) × y-gain
- **Frequency of vibrator (f)**
  - Read on CRO to determine period of oscillation:

    T = no. of divisions for 1 oscillation × time-base

- Determine frequency from time period:

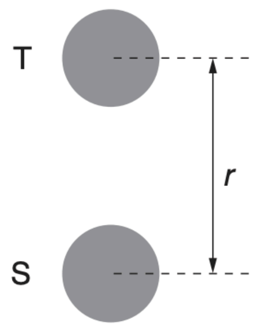
  f = 1 / T

- **To determine when mass leaves plate**
  - Listen to noise/ look for gap.
  - Use spirit level to keep plate horizontal, and view at eye level to look for gap.
  - Clean surfaces of metal plate/small mass.
- Repeat each experiment for same value of V.
- Determine maximum f by increasing and decreasing V.

Safety precautions

- use safety goggles/safety screen to prevent injury to eyes from moving mass.
- use cushion/sand box in case mass falls.

Electric force between 2 charged spheres



- *Each sphere is charged by connecting positive lead from power supply to sphere and then removing the lead.*
- *e.m.f. of power supply used to charge sphere T = V.*
- *Force F between the two charged spheres is determined by attaching sphere S to a top pan balance.*
- *For a constant charge on sphere S:*

$$F = \frac{\alpha V}{r^2}$$

- *r = distance between the centres of the spheres, α = constant.*
- *Test the relationship between F and V.*
- *Explain how your results could be used to determine a value for α.*

Variables

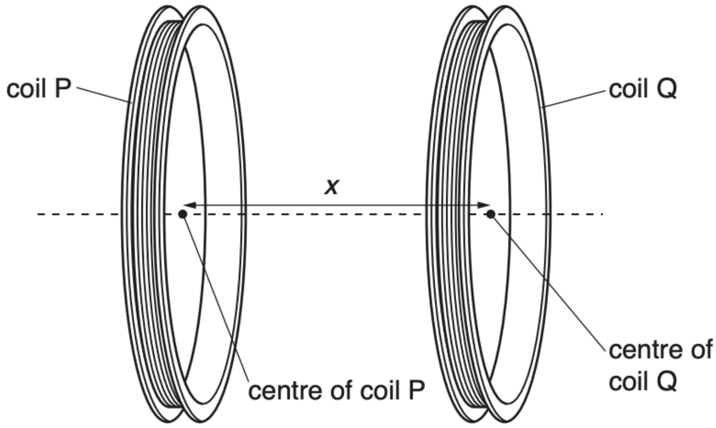
- V = independent variable, F = dependent variable.
- keep r constant

Diagram
- T suspended (clamp or ceiling).
- S on top-pan balance vertically below T.
- Sphere S and T labelled and at least one other label.
- Positive terminal of power supply to T, negative terminal grounded.
- Voltmeter across power supply.

Method of data collection
- **Distance between centres of spheres (r)**
    - r is measured using rule.
    - Calipers/micrometer to measure diameter of spheres (and halve) to determine radius OR use of fiducial mark and ruler from top of spheres.
    - Determine radius of each sphere and add to distance between spheres OR measure from top of T to top of S.
- **E.m.f. of power supply to charge T (V)**
    - Read on voltmeter connected across power supply.
- **Electric force between spheres (F)**
    - Use insulator between T and stand or between S and balance.
    - Discharge spheres by earthing or connecting to the negative of the power supply.
    - Take reading of balance quickly to avoid discharge/keep other charged objects away.
    - Avoid draughts to prevent T moving
    - To ensure charge on spheres is constant: re-charge periodically/ regularly (with initial value of p.d.)/keep it connected to a separate positive terminal.
    - Electric force = difference/ change in balance readings when spheres are charged vs. uncharged.
    - $F = \Delta mg$
- Repeat experiment for each value of V and average F.

Safety precaution
- To avoid shock/high voltages: insulating gloves to hold flying lead/to charge sphere/to avoid electrocution OR use shrouded leads/ensure that there no bare connections/avoid touching metal parts.

Induced emf between 2 coils



- *Flat circular coil P carrying a current produces a magnetic field. When a second coil Q is placed with its centre distance x from the centre of coil P, an e.m.f. V may be induced in coil Q.*

$$V = V_0 e^{-kx}$$

- *V_0 and k are constants.*
- *Design experiment to test relationship between V and x.*
- *Explain how your results could be used to determine a value for k.*

Variables
- x = independent variable, V = dependent variable.
- keep current (in the coil P) constant.
- keep the number of turns on each coil constant/frequency constant.

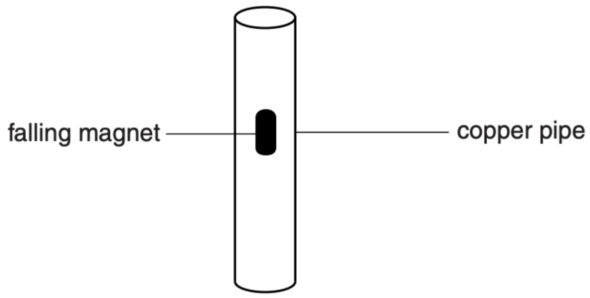
Diagram
- both coils supported.
- two correct circuit diagrams for coil P and coil Q: power supply connected to one coil and voltmeter/c.r.o. connected to other coil.
- labelled horizontal ruler adjacent to coils with x indicated.

Method of data collection
- **Distance between the coils (x)**
  - x is measured using a ruler.
  - To measure x from centre of coil P to centre of coil Q, measure width of each coil and divide by 2 and add to separation of coils.
  - Position ruler horizontally to measure x: use a spirit level or same height from bench at both ends.
  - Keep coils parallel/co-axial: adjust coil Q until maximum reading or use set square to ensure that coils are at right angles to the axis.

- **E.m.f induced in coil Q (V)**
    - Connect an a.c. power supply or signal generator to coil P, and connect a voltmeter/c.r.o to coil Q, to measure induced e.m.f.
    - Use large current/ number of turns/ iron core, to produce large magnetic field/ induced e.m.f.
    - Use high frequency, to produce larger induced e.m.f.
- **Current in coil P (I)**
    - Check that current is constant: use an ammeter and variable resistor/variable power supply.
- Repeat measurements of x for different parts of the coil and average.

Safety precaution
- Do not touch hot coil / use gloves to position hot coil / heat-proof gloves to position coil.

Falling Magnet in pipe



- *Magnet is released above copper pipe. Magnet has speed v as it leaves the pipe.*

$$v = v_0 e^{-\lambda B}$$

- *B = magnetic flux density at poles of the magnet, v0 and λ = constants.*
- *test the relationship between v and B.*
- *Explain how your results could be used to determine values of v0 and λ.*

Variables
- B= independent variable, v= dependent variable.
- Keep starting position of magnet constant/magnet always released from rest.
- Keep mass of magnet constant.

Diagram
- Labelled diagram showing magnet and the vertical copper tube supported.

Method of data collection
- **Magnetic flux density (B)**
    - Method to measure B: Hall probe. Place the Hall probe in the tube.

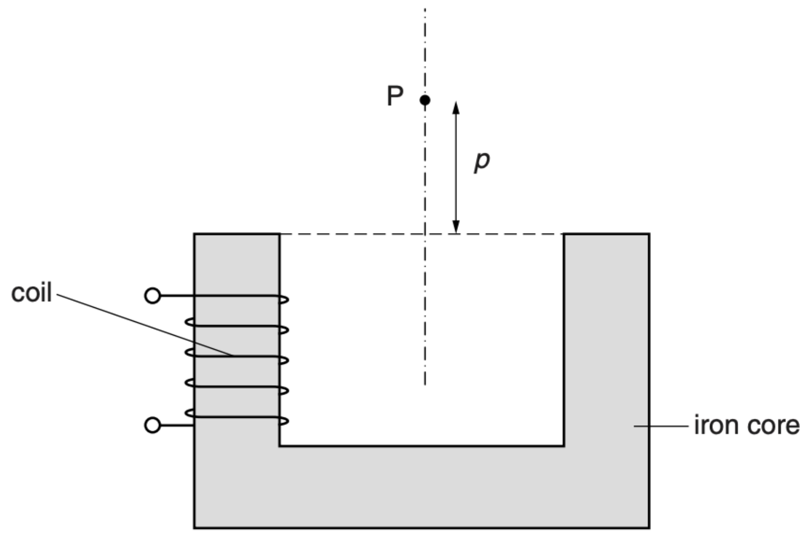
- Adjust Hall probe until maximum reading obtained (flat face of probe perpendicular to field OR take reading near north pole and near south pole, and average the two readings).
- Calibrate Hall probe by placing it in a known, uniform magnetic field.
- To vary B: re-magnetise the magnet in a coil to adjust strength.

- **Speed of magnet (v)**
    - Method to ensure that copper tube is vertical, e.g. set square, spirit level, plumb line.
    - Method to determine time at bottom of tube e.g. use of light gate(s)/motion sensor attached to timer/datalogger/computer or distance between two fixed marks at bottom of tube and stopwatch. (Do not allow time over length of tube.)
    - Use ruler to measure distance between light gates/length of magnet/between two fixed marks at bottom of tube.
    - v = d / t
- Repeat v for same B and average.

<u>Safety precaution</u>

- use sand tray/cushion to soften fall of magnet.

<u>Hall probe to investigate magnetic flux density</u>



- *Hall probe to investigate the magnetic flux density due to a U-shaped electromagnet.*
- *Point P is equidistant from the poles of the electromagnet.*
- *Distance p is the vertical distance between P and the top of the electromagnet.*
- *The magnetic flux density is B at point P.*

$$B = kNIe^{-\alpha p}$$

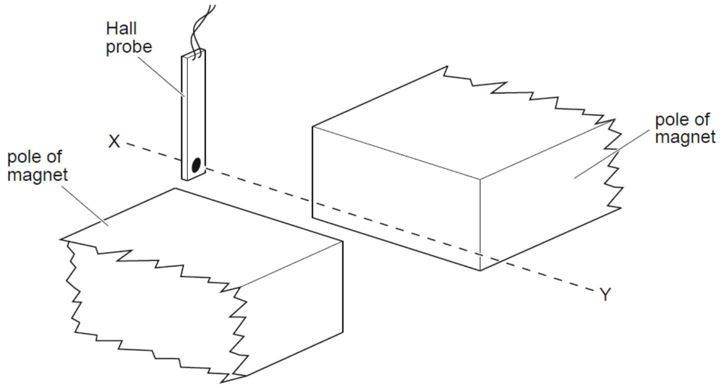
- *N = number of turns on the coil; I = current in the coil; a and k = constants.*
- *Design experiment using a Hall probe to test the relationship between B and p. Explain how your results could be used to determine values for a and k.*

Variables

- p = independent variable, B = dependent variable
- Keep the current/I in the electromagnet constant.
- Keep the number of turns/N constant.

Diagram

- Hall probe correctly positioned along p.



- Ruler correctly positioned vertically along p.
- Hall probe and rule supported.
- Circuit diagram to include d.c. power supply in series with coil and ammeter- to measure current through the coil.

Method of data collection

- **Vertical distance p**
  - Measure p with ruler.
  - To determine an accurate value of p:
    (Height of P above bench) – (height of electromagnet) OR
    Height of P measured from ruler across the top of the electromagnet.
- **Magnetic flux density (B)**
  - Calibrate Hall probe using a known field.
  - Unsure that Hall probe is equidistant from the poles: determine centre of electromagnet and use of plumb line/ruler and spirit level/set square.
  - Adjust Hall probe until maximum reading obtained/perpendicular to field.
- **Current in electromagnet (I)**
  - Use variable resistor to keep ammeter reading constant.
  - Use large number of turns/current (to increase B).

- Repeat each experiment for the same value of p and reverse the current/Hall probe and average.

Safety precaution

- Avoid overheating the coil/do not touch hot coil.

How peak alternating current varies with frequency

- *How the peak alternating current I_0 varies with frequency f in a circuit containing a coil of wire.*

$$\left(\frac{V_0}{I_0}\right)^2 = R^2 + 4\pi^2 f^2 L^2$$

- *R = resistance of the coil, V_0 = peak voltage, L = constant.*
- *Design experiment to test relationship between I_0 and f.*
- *Determine a value for L.*

Variables

- f = independent variable, I_0 = dependent variable
- Keep V_0 constant.
- Keep resistance of circuit/coil constant

Diagram

- Circuit diagram of apparatus: coil connected to power supply/signal generator.
-

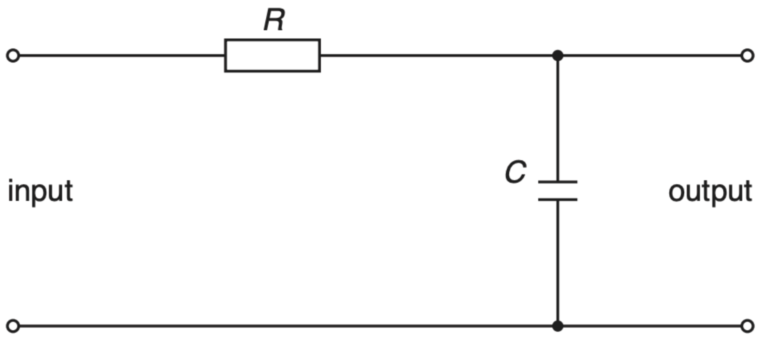
Methods of data collection

- **Frequency f**
    - Connect variable frequency ac power supply or signal generator (or method of varying frequency) to the coil.
    - Measure f using oscilloscope/read off signal generator.
    - Measure T using timebase.
    - f = 1 / period.
- **Current I_0**
    - Measure current using ammeter or p.d. across resistor.
    - Use lower frequencies to produce larger currents
- **Voltage V_0**
    - Measure V across power supply or across coil: using voltmeter or c.r.o.
    - Measuring V_0 using y-gain.
- Detail on changing r.m.s. to peak

Safety precaution

- Method to prevent overheating of coil or burns from coil.

Capacitor-resistor circuit



- *A neon lamp flashes on and off when it is connected across the capacitor with a potential difference V_F across the lamp of approximately 90 V.*
- *Student has a number of unmarked resistors.*
- *Period T of the flashes of the lamp is related to resistance R of the resistor by the expression:*

$$T = RCK$$

- *C is the capacitance of the capacitor and K is a constant.*

$$K = \ln\left(\frac{V_i - V_L}{V_i - V_F}\right)$$

- *V_i is the potential difference across the input, V_F is the potential difference required to make the lamp flash and V_L is a constant.*
- *Design a laboratory experiment to test the relationship between T and R. Explain how your results could be used to determine a value for K and V_L.*

<u>Variables</u>

- R= independent variable, T= dependent variable
- keep C constant
- input voltage or Vi is constant

<u>Diagram</u>

- labelled diagram or correct symbols of workable circuit including:
  - d.c. power supply correctly positioned
  - (neon) lamp correctly positioned
- circuit diagram to determine resistance of resistors using ammeter and voltmeter.
- circuit diagram showing voltmeter(s) or oscilloscope(s) to determine V_i and V_F.

Method of data collection

- **Capacitance (C)**
    - record value of capacitance from the capacitor or method to determine capacitance (e.g. use LCR meter - connected across capacitor OR time constant measurement).
    - Circuit diagram to measure capacitance:
        - Set up a series RC circuit with the capacitor and resistor.
        - Charge capacitor using DC supply (switch closed).
        - Disconnect the supply and let capacitor discharge through R (switch open).
        - Record voltage (V) across capacitor at different times (t).

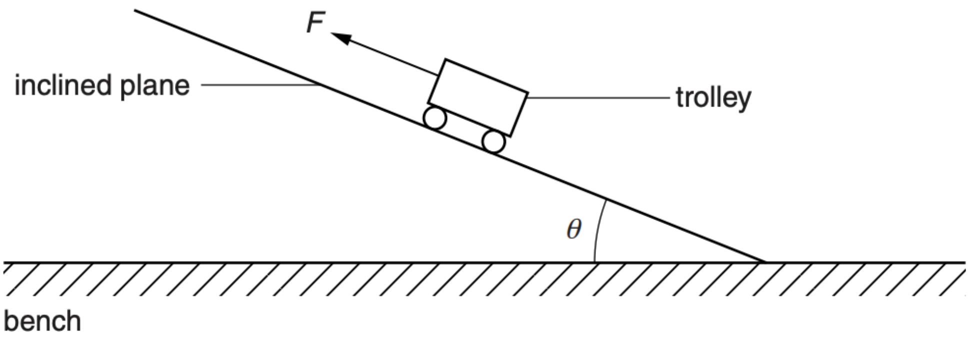
$$V = V_0 e^{-t/RC}$$

        - Rearrange to find C.
- **Resistance (R)**
    - Measure current and voltage across resistance using ammeter and voltmeter.
    - R = V/I
- **Period of flashes (T)**
    - Use a stopwatch / timer / oscilloscope.
    - For stopwatch method: time 10 or more flashes and divide by number of flashes OR for oscilloscope method: length of wave × timebase.
- Use 90 V (or larger) power supply
- repeat the experiment for each value of R and average T.
- To obtain a measurable time period: do a preliminary experiment to choose appropriate resistors OR use large values of R or C.

Safety precaution

- switch off (high voltage) circuit (before changing the resistor) / wear insulating gloves to prevent electrocution / shock

Inclined plane & Forces



- *Investigating relationship between the acceleration a of trolley and angle θ of the inclined plane when force F is applied to the trolley.*

$$ma = F - (mg\sin\theta + k)$$

- *g = acceleration of free fall, m = mass of the trolley, k = constant.*
- *test the relationship between a and θ.*
- *Explain how your results could be used to determine a value for k.*

Variables
- θ= independent variable, a= dependent variable
- Keep F constant.
- Keep mass of trolley constant/use same trolley.

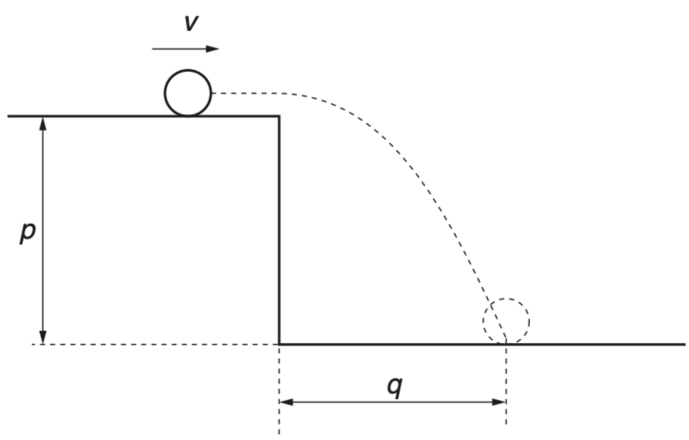
Diagram
- Diagram showing inclined plane with labelled support.

Method of data collection
- **Mass of trolley (m)**
    - Measure using top-pan balance.
- **Force (F)**
    - Take reading from newton-meter OR stretched elastic/spring (F=kx) OR falling weight (F = mg).
    - When using stretched spring/elastic, use constant extension to produce a constant force.
- **Angle of incline (θ)**
    - Use a protractor to measure θ or use a ruler to measure marked distances from which sin θ or θ may be determined.
    - Correct trigonometry relationship to determine sin θ or θ using marked lengths.

- **Acceleration of trolley (a)**
    - Use ruler to measure distance from origin to 2 light gates on slope (s1 and s2), and measure length of card of light gate.
    - Connect light gates to timer to determine times when trolley passes each gate (t1 and t2).
    - At each light gate, calculate instantaneous velocity
      $v1 = s1/t1$; $v2 = s2/t2$
    - Calculate acceleration:
      $a = (v2-v1) / (t2-t1)$
- Repeat experiment for each angle θ to find average for a.

<u>Safety precaution</u>
- use sand tray/cushion to soften fall of trolley.

<u>Projectile motion</u>



- *Small ball is rolled with velocity v along a horizontal surface.*
- *When the ball reaches the end of the horizontal surface, it falls and lands on a lower horizontal surface.*
- *Vertical displacement of the ball = p, horizontal displacement = q.*

$$gq^2 = 2pv^2$$

g= acceleration of free fall.
- *Design experiment to investigate how q is related to p.*
- *Explain how v may be determined from the results.*

<u>Variables</u>
- p = independent variable, q = dependent variable.
- Keep horizontal velocity (v) constant.

Diagram

- Labelled diagram of apparatus including method to vary p.

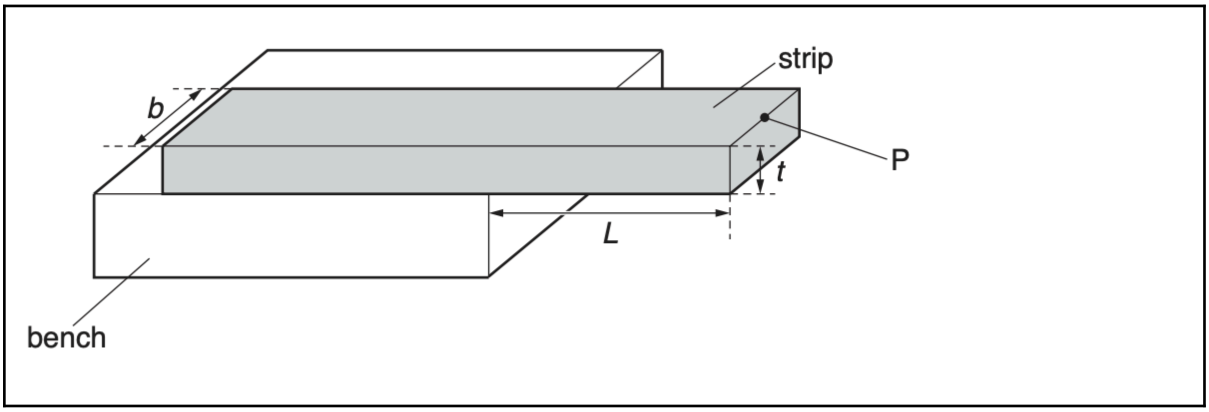
Methods of data collection

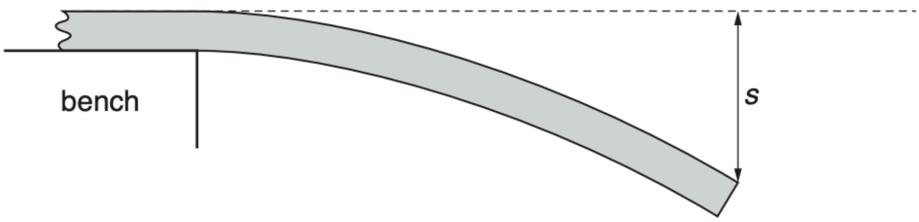
- **Vertical displacement (p)**
    - Use ruler/caliper to measure p and/or q.
    - To determine location of zero position for p and q e.g.: set square/ plumb line.
- **Horizontal displacement (q)**
    - Use carbon paper/dye/video/sand to measure position of ball on surface.
    - Location of landing position: centre of crater/start of track.
    - Method of determining position of ball: e.g. slow motion playback including scale.
- **Horizontal velocity (v)**
    - Method to ensure velocity is constant: release ball from same height on a track/spring loaded device or impulse device set to a constant value.
    - Method to ensure that the moved surface remains horizontal: spirit level/check height at different places.
    - Method to ensure that velocity of ball is horizontal only when it reaches table: e.g. curved track.
- Ensure that the ball leaves the table at 90°, e.g. set square/protractor on upper surface.
- Take many readings of q for each p and average.
- Use of high density ball to minimise the effects of air resistance.

Safety precaution

- Method to prevent ball rolling on floor: box below/storage box for balls/sand box.
- Method to prevent ball causing injury: goggles/safety screen.

Bending of wooden strip





- *Rectangular strip of width b and thickness t overhanging the edge of a bench.*
- *A length L of the strip is unsupported.*
- *A load of mass M is positioned at point P.*
- *This causes the unsupported part of the strip to bend with a deflection s.*

$$E = \frac{4MgL^3}{bst^3}$$

g = acceleration of free fall, E = Young modulus of the wood.

- *Design experiment to test the relationship between s and L.*
- *Explain how your results could be used to determine a value for E.*

<u>Variables</u>

- L = independent variable, s = dependent variable.
- keep mass of load or M constant.
- use same wooden strip or keep b and t constant.

<u>Diagram</u>

- method of fixing strip at one end, e.g. with a G-clamp or (heavy) mass placed on top of strip over bench and labelled.
- load shown touching at point P and labelled.

<u>Method of data collection</u>

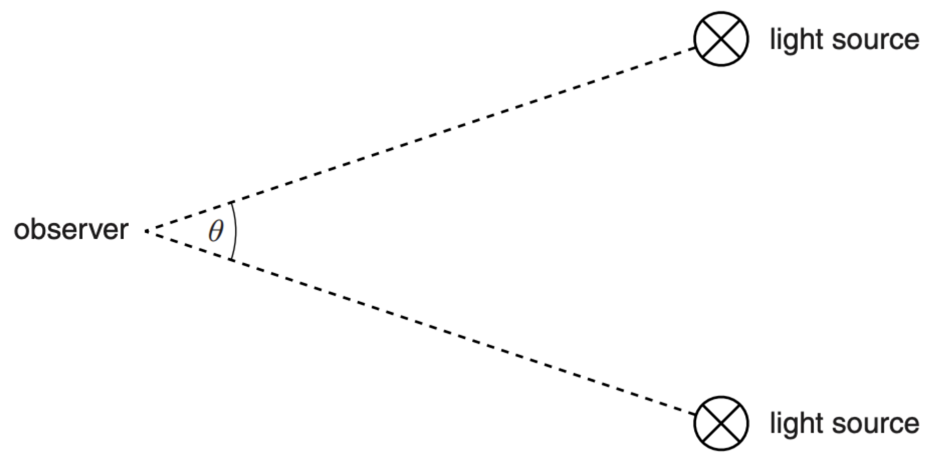
- method of attaching load to strip: use glue/tape/attach with a hook and string.
- **Length of strip unsupported (L)**
  - use a rule to measure L and s.
  - method to ensure strip is perpendicular to the bench: e.g. repeat measurements of L on each side of strip to check that L is constant or set square correctly indicated on diagram.
- **Deflection (s)**
  - clamp rule vertically to measure s.
  - method to ensure clamped rule to measure s is vertical: e.g. correctly positioned set square indicated at right angles to the horizontal surface or plumb line shown in appropriate position.

        - s = (reading of vertical rule with loaded strip) – (reading of vertical rule with no load)
- **Mass (M)**
    - use a balance to M.
- **Dimesnions of strip (b and t)**
    - use a micrometer/calipers to determine t.
    - repeat readings for b and/or t at different points along/across the strip and average.
- wait until block is stationary/in equilibrium or measure s after a fixed time.
- repeat s measurement for each L (unloading and loading strip) and average s.

<u>Safety precaution</u>

- use cushion/foam/sandbox in case mass/load falls
- wear goggles in case strip snaps or recoils

<u>Angle between light sources and wavelength</u>



- *Two identical light sources viewed from a distance.*
- *When the angle θ between the light sources is large, they are seen as separate.*
- *The sources are moved closer together.*
- *At a particular angle θ1 the two sources appear as a single source.*
- *It is suggested that θ1 is directly proportional to the wavelength λ of the light from the sources.*
- *Design experiment using 2 light sources to test the relationship between θ1 and λ.*

<u>Variables</u>

- λ = independent variable, θ = dependent variable.
- Light sources to be of similar intensity/brightness.

<u>Diagram</u>

- Labelled diagram showing observer and light sources.
- Method of producing monochromatic light: e.g. filter/coloured LED.

Method of data collection

- **Wavelength of light (λ)**
    - Record from filter/LED or Young's slit/diffraction grating method.
    - Use of equation for Young's slit/diffraction grating method:

      `d sin(θ) = mλ`

- **Angle between light sources (θ)**
    - Use a rule to measure the distances.
    - Use of vernier calipers to measure the separation of light sources.
    - Use large distances/separations.
    - Method to ensure distances are perpendicular or observer equidistant from pair of lamps: Place observer on perpendicular bisector of the line joining the two lamps so that the distances to both lamps are equal.
    - θ = sin θ = tan θ for small angles.
    - θ (or $\sin\theta$ or $\tan\theta$) = separation/distance OR

      $$\tan\left(\theta/2\right) = \frac{\text{separation}}{2 \times \text{distance}}$$

- Carry out the experiment in a dark room.
- Use vertical filament lamps. Allow vertical slits.
- View with the same eye.
- Repeat experiment for each λ and average.

Safety precautions

- Lamp becomes hot, therefore do not touch/switch off when not in use or use gloves when moving hot lamp.
- Light may damage eyes, therefore wear dark glasses or do not look at unprotected lamps.

Rate of evaporation of water

- *How the rate at which water evaporates varies with temperature.*
- *Relationship between volume of water evaporated per unit time Y and Celsius temperature θ of the water:*

  $$Y = k\theta^s$$

  k and s are constants.
- *Design experiment to test the relationship between Y and θ.*
- *Explain how your results could be used to determine values for k and s.*

Variables
- temperature of the water θ = independent variable, volume per unit time Y = dependent variable.
- keep temperature of room/surroundings constant.
- keep water temperature constant (while water is evaporating).
- keep surface area constant.

Diagram
- beaker open to air
- water, labelled
- workable method to heat water

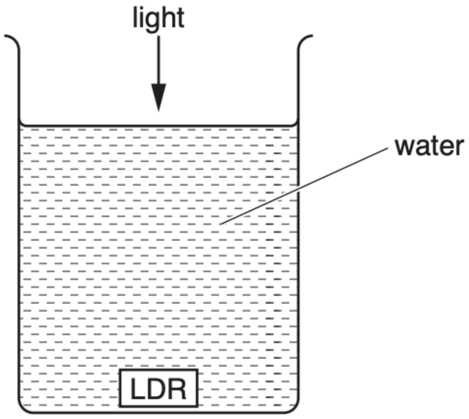
Methods of data collection
- **Change in volume/ change in mass**
    - Measuring cylinder OR top-pan balance.
- **Time**
    - Measure time with a stop-watch/timer (for change in volume/mass)

$$Y = \frac{\text{initial volume} - \text{final volume}}{\text{time}} \text{ or } \frac{\Delta V}{\text{time}}$$

- **Temperature θ**
    - Use a thermometer to measure θ or labelled thermometer in water in diagram.
- **To keep water temperature constant while it is evaporating**
    - Adjust heater/gently heat water to maintain temperature/use a water bath.
- **To keep surface area constant**
    - Use the same cylindrical container.
    - Use a large surface area to increase the rate of evaporation.
- Insulation/lagging around sides of beaker (not a lid).
- Switch off fans or close windows to avoid draughts.

Safety precaution
- use of protective gloves to handle hot beaker/water.

Resistance of LDR



- *Resistance of a light-dependent resistor (LDR) separated from a source of light by different depths of water.*
- *Relationship between the resistance R of the LDR and the depth d of the LDR in the water:*

  $$R = \frac{4\pi d^2}{K}$$

  K= constant.
- *Design experiment to test the relationship between R and d.*
- *Explain how your results could be used to determine a value for K.*

<u>Variables</u>

- d = independent variable, R = dependent variable.
- keep intensity/power of light source constant.

<u>Diagram</u>

- light source fixed above container of water with the labelled LDR positioned in the beaker.
- correct circuit diagram to measure R: e.g. V and I or ohmmeter.

<u>Methods of data collection</u>

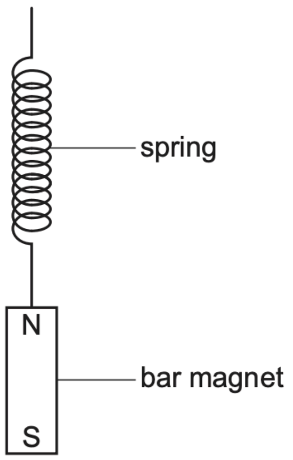
- **Resistance of LDR (R)**
    - R = p.d. across LDR / current, or read off ohmmeter.
- **Depth of LDR in water (d)**
    - use a ruler or drawn labelled vertical ruler adjacent to container.
    - method to position ruler vertically: e.g. use a set square/spirit level.
    - use horizontal fiducial mark from ruler to meniscus or middle of LDR OR d = (reading on rule at surface) – (reading at top of LDR).

- **Intensity/ power of light source**
    - method to check that current in light source is constant: e.g. use an ammeter and variable resistor / variable power supply.
    - keep position of light source constant or distance between light source and LDR constant.
    - light source is placed close to water surface to increase intensity/reduce reflections OR light source is placed further away to make it more directional.
- Carry out experiment in a dark room or shield LDR so as to avoid light from other sources.
- Use high intensity lamp or collimated beam or laser.
- use tall container to give a wide range of d or R or to reduce uncertainties OR use a wide container to reduce reflections.
- Ensure that the electrical connections/wire to the LDR are waterproof

<u>Safety precautions</u>

- dark glasses to prevent damage to eyes due to light source / do not look directly at light source.
- do not touch hot lamp/use gloves to position hot lamp/heat-proof gloves to position lamp.

<u>Movement of magnet on spring and induced emf</u>



- *The bar magnet is displaced a distance x from its equilibrium position and released.*
- *It then oscillates vertically.*
- *A student investigates how the maximum induced electromotive force (e.m.f.) E in a coil placed below the magnet depends on x.*

$$E = \alpha BNx\sqrt{\frac{k}{m}}$$

B = magnetic flux density at one of the poles of the bar magnet, N = number of turns on the coil, k = spring constant, m = mass of magnet, α = constant.

- *Design experiment to test the relationship between E and x.*
- *Explain how your results could be used to determine a value for α.*

Variables

- x= independent variable; E = dependent variable.
- Keep B or m constant and keep k or N constant.
- Keep distance between equilibrium position and coil constant.

Diagram

- Labelled spring supported by stand and clamp
- Labelled magnet
- Labelled coil positioned so that magnet is vertically above the coil by eye in the correct orientation.
- Circuit diagram showing voltmeter / oscilloscope connected to the ends of the coil.

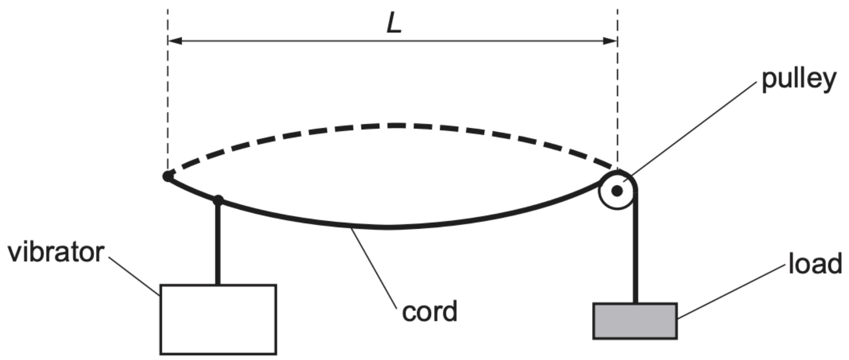
Methods of data collection

- **Displacement of spring (x)**
    - use ruler to measure equilibrium position and displaced position and determine difference.
    - method to ensure clamped rule to measure x is vertical: e.g. correctly positioned set square indicated at right angles between the rule and the horizontal surface or plumb line supported on a surface shown in appropriate position.
- **Mass of magnet (m)**
    - use balance or use newton-meter to measure weight and divide by g.
- **Spring constant (k)**
    - k = mg / extension OR gradient of F – extension graph. (Weight / force must be defined.)
- **Magnetic flux density (B)**
    - Measure B using a calibrated Hall probe.
    - adjust probe until maximum value OR measure B using Hall probe first in one direction and then in the opposite direction and average.
- **E.m.f. In coil (E)**
    - Determine max E using video and slow-motion playback.
    - Maximise E: position magnet so that equilibrium position is at the centre of the coil or use a large number of turns.
- Check that the unstretched length of the spring has not changed or is not permanently deformed after removing load/magnet.

- Repeat experiment for each x and average E.

Safety precautions
- Use safety goggles / safety screen to prevent injury to eyes from detached spring/magnet.
- oscillating magnet or use cushion / sand box in case magnet falls.
- use g clamp / weights on stand to prevent toppling.

Standing wave on string



- *Stationary waves with an elastic cord of circular cross-section attached to a load.*
- *When the frequency of the vibrator is f, the cord vibrates with the stationary wave pattern shown.*
- *The student investigates how f varies with the cross-sectional area A of the cord.*

$$f = \frac{1}{2L}\sqrt{\frac{M}{kA}}$$

L= distance between the 2 nodes, M= mass of load, k=constant
- *Design a laboratory experiment to test the relationship between f and A.*
- *Explain how your results could be used to determine a value for k.*

Variables
- A = independent variable; f = dependent variable
- Keep M constant
- Keep L constant
- use cords of the same material/density

Diagram
- elastic cord fixed at one end to a support
- other end passed over a pulley
- labelled pulley
- labelled load
- vibrator connected to signal generator

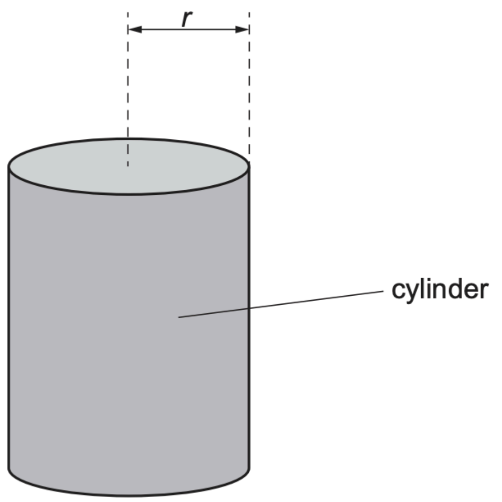
Methods of data collection

- vibrator connected to signal generator.
- increase/decrease the frequency of the signal generator until stationary wave pattern is observed.
- **Cross-sectional area of cord (A)**
    - measure diameter of cord with micrometer/calipers.
    - repeat measurement of diameter along cord and average.
    - $A = \frac{\pi d^2}{4}$
- **Frequency of vibrator (f)**
    - Use CRO to determine T.
    - period = time base × length of one wave.
    - Calculate f from T: f = 1 / T.
    - Method to determine frequency at the maximum amplitude: increase frequency until the amplitude starts to decrease, then decrease frequency.
- **Mass of load (M)**
    - measure mass of the load on top-pan balance.

Safety precautions

- use safety goggles/safety screen to prevent injury to eyes from (moving) elastic cord/load.
- use cushion/sand box in case load falls.

Oscillating cylinder in oil



- *The student places the cylinder of mass m in the oil.*
- *The cylinder is displaced vertically from its equilibrium position and released so*

that it oscillates.
- *The period T of the oscillations is determined.*
- *A number of cylinders of different mass are available.*

$$T = 2\sqrt{\frac{\pi m}{\sigma K r^2}}$$

σ = density of the oil; K = constant.
- *Design experiment to test the relationship between T and m.*
- *Explain how your results could be used to determine a value for K.*

Variables
- Mass of cylinder m = independent variable, period T = dependent variable. Keep radius of cylinder constant.
- Keep density / temperature of the (cooking) oil constant OR keep σ constant.

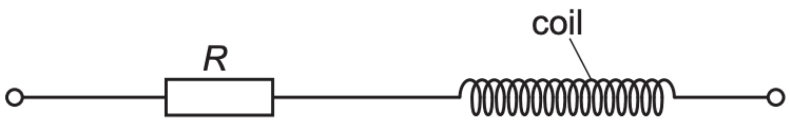
Diagram
- beaker with cooking oil on a bench or container supported by stand where stand is on a bench.
- cylinder partially submerged in (cooking) oil
- cylinder and (cooking) oil labelled.

Methods of data collection
- **Mass of cylinder (m)**
  - use a top pan balance.
- **Period of oscillations (T)**
  - use a stopwatch / timer to time oscillations.
  - Time n oscillations and divide nT by n (where n ⩾ 5).
  - Count oscillations with position of fiducial mark / mark on cylinder / beaker / fixed point shown in diagram.
  - wait for oscillations to become even / steady.
- **Radius of cylinder (r)**
  - Measure diameter of cylinder using micrometer or calliper.
  - r= diameter / 2.
  - repeat measurements of diameter in different directions and average.
- **Density of oil (σ)**
  - Determine mass of oil = mass of beaker and oil – mass of beaker, and measure volume of oil: use a measuring cylinder.
  - Density σ = mass / volume.
- Repeat experiment for each value of m and average T.

Safety precautions

- Use gloves to prevent oil contacting skin / slippery hands
- Perform experiment in a tray to prevent oil spillage

<u>Resistor and coil series circuit</u>



- *The student connects a high-voltage d.c. power supply and a switch across the series combination.*
- *When the switch is closed, it takes time t for the current in the resistor of resistance R to reach a maximum value. The time t is a few milliseconds.*
- *There are a number of different unmarked resistors available.*

  $$t = \frac{KN^2A}{LR}$$

  N = number of turns of wire on the coil, A = cross-sectional area of the coil, L = length of the coil, K = constant.
- *Design a laboratory experiment to test the relationship between t and R.*
- *Explain how your results could be used to determine a value for K.*

<u>Variables</u>

- R = independent variable, t = dependent variable
- keep the number of turns on the coil/N constant
- Keep A and L constant

<u>Diagram</u>

- labelled d.c. power supply
- switch in series with power supply, resistor and coil
- complete workable circuit

<u>Methods of data collection</u>

- **Resistance (R)**
  - ammeter and voltmeter correctly positioned OR R connected to ohmmeter with no other connections (not ohmmeter in main circuit).
  - R = V / I.
- **Time (t)**
  - use storage oscilloscope or current/voltage sensor connected to datalogger/computer to measure t of few milliseconds.
  - use time-base from oscilloscope to measure t OR use time axis of output from data logger/computer.

- **Cross-sectional area of coil (A)**
    - micrometer/calipers to determine diameter of coil and A = πd2 /4.
    - repeat measurements of diameter in different directions/at points along the coil and average.
- **Length of coil (L)**
    - use ruler/calipers to measure L.
- repeat experiment for each value of R and average t.
- use smaller values of R to increase I.
- reduce L or increase N or increase A to increase t.

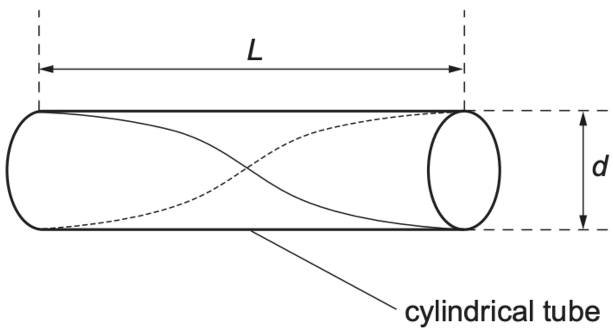
<u>Safety precautions</u>

- open switch/switch off circuit before changing the resistor/touching components OR ensure no bare wires/use shrouded connectors.
- wear insulating gloves to prevent electric shock/electrocution.

NOTE:
A student places a metal cylinder and an electrical heater in a beaker of water. The electrical heater is switched on and the student measures the time t for the temperature of the water to increase by Δθ.
Things to remember:

- check that/ensure/keep initial temperature of the water constant or volume/mass of water constant.
- ensure heater and cylinder are fully submerged/immersed OR stir water (using a glass rod/stirrer.
- method to insulate beaker: e.g. use of a lid on the beaker or foam/insulation around outside of beaker.
- Calculate power of heater using P=VI (connect ammeter and voltmeter to heater).

<u>Standing sound wave in air column</u>



- *Stationary wave pattern in a tube which is open at both ends.*
- *The tube has length L and diameter d.*
- *The frequency of the sound for the stationary wave pattern shown is f.*

- *There are a number of different tubes available.*

$$\frac{v}{f} = 2L + kd$$

v = speed of sound in air, k = constant.
- *Design a laboratory experiment to test the relationship between f and d.*
- *Explain how your results could be used to determine values for k and v.*

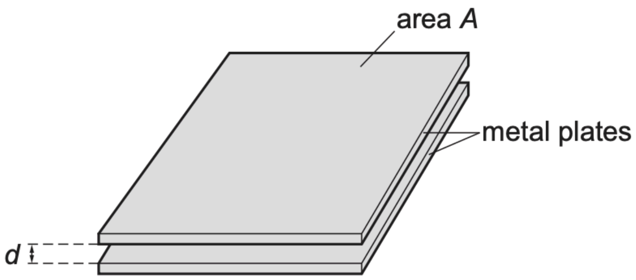
Variables
- diameter/d = independent variable, frequency/f = dependent variable.
- Keep L constant or length (of tube) constant.

Diagram
- tube supported
- loudspeaker positioned in line with the tube and labelled
- signal generator connected to loudspeaker in diagram
- labelled microphone, positioned outside tube in line with tube, connected to labelled oscilloscope or correct circuit symbol.

Methods of data collection
- **Frequency of sound (f)**
    - adjust/change frequency until maximum amplitude detected.
    - increase frequency from a low frequency to the first maximum amplitude.
    - To determine f at maximum amplitude: increase frequency to f, then continue increasing frequency, and then decrease frequency until value of f determined.
    - determine period from oscilloscope: no. of divisions × time-base.
    - determine frequency from time period, f = 1 / T.
- **Diameter of tube (d)**
    - use calipers to measure d.
- **Length of tube (L)**
    - use a rule to measure L.
- repeat measurements of d and average in different directions/positions or along the tube.
- perform experiment in a quiet room

Safety precaution
- wear ear defenders to prevent damage to hearing/to avoid loud sounds OR use a low volume to prevent damage to hearing/to avoid loud sounds.

<u>Parallel plates pd and separation</u>



- *The plates are initially charged using a power supply.*
- *The plates are then connected to an uncharged capacitor.*
- *The potential difference V across the capacitor is measured.*

$$\frac{W}{V} = 1 + \frac{Cd}{KA}$$

C = capacitance of the capacitor, K and W = constants.

- *Plan experiment to test the relationship between V and d.*
- *Explain how the results could be used to determine values for K and W.*

<u>Variables</u>

- d= independent variable, V = dependent variable
- Keep A or area (of overlap) of plates constant
- keep the initial p.d. across plates or initial charge constant

<u>Diagram</u>

- circuit diagram with voltmeter connected in parallel with the capacitor, and their correct symbols.
- capacitor and voltmeter connected to the metal plates with no power supply in discharge part of the circuit.
- Method to charge plates: separate circuit diagram showing plates connected to a d.c. power supply or combined circuit with switches and d.c. power supply

<u>Methods of data collection</u>

- **Distance between plates (d)**
    - use calipers to measure d OR use micrometer/calipers to measure thickness of spacers.
- **Area of plates (A)**
    - use ruler to measure lengths to determine A <u>and</u> A = length x breadth.
- **Capacitance (C)**

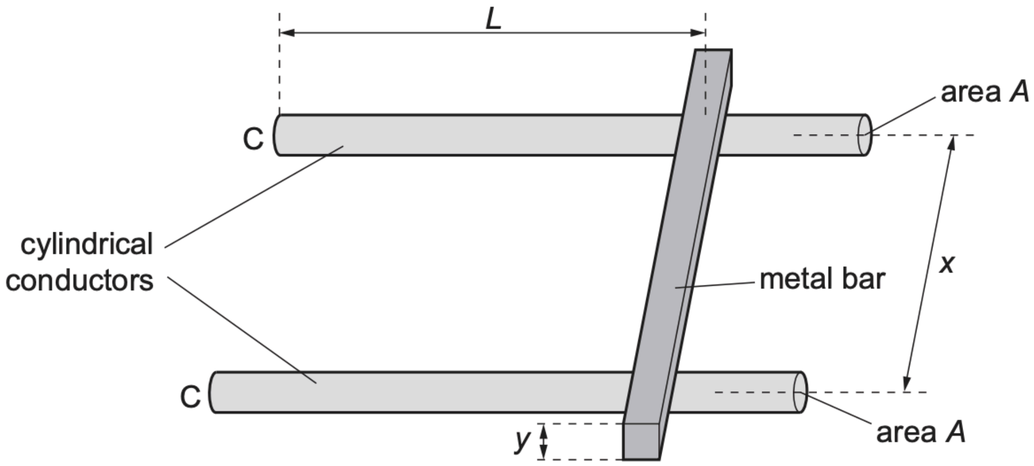
- measure the p.d. (or current) across the capacitor at regular time intervals, as it discharges through a known resistor, to determine capacitance.

- operation of circuits using switches, between charging and discharging.
- fully discharge capacitor between experiments: short-circuit the capacitor or use of switch in parallel with capacitor.
- repeat measurements of d at different points across plates and average.
- repeat measurements of V for same d and average V.
- Ensure bottom plate rests on insulating material OR top plate is supported by strings.
- use high voltage power supply to increase charge on plates OR use a very small value of capacitance to increase voltmeter reading.

<u>Safety precautions</u>

- use gloves to prevent electric shock OR do not touch metal plates to avoid shocks.

<u>Sliding rail current</u>



- *Two parallel cylindrical conductors each have a small cross-sectional area A.*
- *A thin metal bar connects the two conductors.*
- *The metal bar has a square cross-section with sides of length y.*
- *For each conductor, the distance between its end C and the centre of the metal bar is L.*
- *The distance between the centres of the conductors is x.*
- *The ends C are connected to a power supply and the current I in the conductors is measured.*

$$\frac{E}{I} = \frac{2PL}{A} + \frac{Qx}{y^2}$$

- *E = electromotive force (e.m.f.) of the power supply, P and Q = constants.*

- *Plan experiment to test the relationship between I and L.*
- *Explain how the results could be used to determine values for P and Q.*

<u>Variables</u>

- L = independent variable, I = dependent variable
- Keep E constant
- keep A and y constant
- Keep x constant

<u>Diagram</u>

- circuit diagram with power supply connected to ends C
- ammeter in series with power supply and conductors
- voltmeter correctly positioned to measure E across the power supply

<u>Methods of data collection</u>

- **Length of sides of metal bar (y)**
    - use a micrometer/calipers to measure y.
    - repeat measurements of y in different (perpendicular) directions/different points/along bar and average.
- **Cross-sectional area of conductor (A)**
    - use micrometer/calipers to measure diameter of conductor and A = πd2 / 4.
    - repeat measurements of diameter along conductors and average.
- **L and x**
    - use a ruler to measure L and x.
    - method to ensure that L is the same for each conductor: e.g. check both lengths.
    - method to keep x constant with reason: adhesive/plasticine/blocks one either side of each conductor, to prevent cylindrical conductors from moving.
    - method to determine L: measure to edge and add y / 2.
      method to determine x: measure between the conductors and add diameter.
- method of ensuring good electrical contact: e.g. clean metal bar/cylindrical conductors or use of solder or crocodile clips to connect circuit to the conductors.

<u>Safety precautions</u>

- do not touch/ use (heat resistant) gloves to avoid hot conductors/metal bar OR use a protective resistor/small e.m.f. to reduce the current OR switch off when not in use/when moving ba

Additional Details

Physical Quantity	**Instrument**	**Additional Detail**
Height – Vertical height	Metre rule	- Clamp rule + ensure vertical using plumb line or set-square. - Clearly state distance and equation if relevant
Length of strings, spring, stretch/moving things.	Metre rule	- Repeat measurements and average. - Use a marker. - If movement involved while measuring, clamp rule, view video playback frame by frame - Use safety goggles to prevent injury (to eyes) from moving spring/load - Use cushion/sand box in case load falls.
Time / period	Stop watch/ light gate	- View video playback frame by frame - Clearly indicate start and stop of timing - Indicate position of light gate - For oscillation, take 5, 10, or 20 complete cycles.
Current/ Voltage/ Power/ Heat energy/ Resistance	Ammeter Voltmeter	- Draw Circuit Diagram - Include equation
Temperature	Thermometer	
Pressure	Manometer/ pressure gauge	- Sealed bell jar/conical flask
Force	Newton meter/ weighing balance (Vertical force)	- Example of top pan balance
Angle	Protractor/ruler	- Use relevant trigo identity - Use plumb line for alignment if needed - Cannot be measured directly
Volume/ surface area of regular shapes	Metre rule to measure appropriate lengths	- State equation used to calculate volume/area

Volume of irregular shapes	Measuring cylinder	- Water displacement method
Volume (Liquid)	Measuring Cylinder	
Volume (Gas)	Measuring Cylinder	
Average velocity/ acceleration	Measure time & displacement of object	- Use relevant equation of motion
Wavelength of light	Determined using Young double slit/ diffraction grating.	- Use filter / different LED - Include relevant equation
Frequency / Intensity of sound wave	Read on CRO	- Use signal generator to vary - Include Mic and loudspeaker
Magnetic Flux Density	Hall Probe	- to vary, change current in coils - to measure, calibrate hall probe with a known field - to set-up, rotate hall probe until max reading on voltmeter.
Alternating Current Frequency/peak values	Read on CRO	- to vary, use signal generator, use small frequency.

Question 2

Relationship	Graph to plot	Gradient	Y-intercept
$y = mx + c$	y vs. x	m	c
$y = ae^{kx}$	$\ln y$ vs. x	k	$\ln a$
$y = ax^n$	$\lg y$ vs. $\lg x$	n	$\lg a$

UNCERTAINTIES

1) If $a = b \pm c$

$$\Delta a = \Delta b + \Delta c$$

2) If $a = \frac{bc}{d}$

$$\frac{\Delta a}{a} = \frac{\Delta b}{b} + \frac{\Delta c}{c} + \frac{\Delta d}{d}$$

3) If $a = b^n$

$$\frac{\Delta a}{a} = n\left(\frac{\Delta b}{b}\right)$$

4) for logs:

$$\Delta \log_a x = \frac{1}{\ln a}\left(\frac{\Delta x}{x}\right)$$

$a = 10$ → $\Delta \lg x = \frac{1}{\ln 10}\left(\frac{\Delta x}{x}\right)$

$a = e$ → $\Delta \ln x = \frac{\Delta x}{x}$

* $$\Delta a = \frac{a_{max} - a_{min}}{2}$$

↳ half range of readings

↓

can be used for all

* If raw values are given to 2 s.f in table, calculated values should be 2-3 s.f.

Be consistent in s.f. (not d.p.)

* If calculated value is given to 3d.p, uncertainty can be given to 2-4 d.p. → match value d.p to unc. d.p.
Usually, uncertainty is given to precision equal to 1 small box on graph (in MS)

GRAPHS

Plots & Error Bars

→ Plot at corners, no larger than size of one small box.
use crosses

→ Bars – symmetrical, horizontal / vertical

* no anomalous points!!

* if uncertainty = 0.01, but smallest box = 0.1, take uncertainty as 0.1 ∵ all error bars have to be shown, and only corner plots allowed – no in-between!!

Best & Worst fit Lines

→ label lines
→ BF should be close to all points with balanced points above and below line.
→ WF with steepest / shallowest slope → should pass all error bars.

* LHS of top error bar to RHS of bottom error bar (or vice versa)

Gradient & Uncertainty

→ clear gradient triangle (dotted line)
→ coordinates taken and shown substitution ↘ label coordinates
→ find gradient of BF & WF

absolute uncertainty in gradient = gradient of BF – gradient of WF

y-intercept & Uncertainty

→ substitute into $y = mx + c$ for BF and WF

absolute uncertainty in y-intercept = y-intercept of BF – y-intercept of WF