Introduction to Planning Question

Scheme of Assessment (from Syllabus 9749)

Planning question is part of the GCE A-level H2 Physics examination and it carries a weightage of 5%. Planning question will be assessed as part of Paper 4 and you should complete it within 30 minutes. Your procedure must allow another person to conduct the experiment and evaluate the results of the experiment.

Paper	Type of Paper	Weighting	Marks	Duration
1	Multiple Choice	15%	30	1 h
2	Structured Questions	30%	80	2 h
3	Longer Structured Questions	35%	80	2 h
4	Practical • Planning (P) • MMO, PDO, ACE	 5% 15%	55	2 h 30 m

Paper 4

Candidates will be allocated a specified time for access to apparatus and materials of specific questions. Candidates will not be permitted to refer to books and laboratory notebooks during the assessment. This paper will assess appropriate aspects of the following skill areas:

- Planning (P)
- Manipulation, measurement and observation (MMO)
- Presentation of data and observations (PDO)
- Analysis, conclusions and evaluation (ACE)

Note that the assessment of PDO and ACE may also include questions on data-analysis, which do not require practical equipment and apparatus.

Skills Requirements (from Syllabus 9749)

Candidates should be able to define clearly the question/problem using appropriate knowledge and understanding. The plan should show a sense of coherence with a detailed sequence, providing a clear logical account of the experimental procedure to be followed.

Candidates should describe how the data is used in order to reach a conclusion. The risks involved in the experiment should be assessed and precautions to keep these risks to a minimum should be described. Below is a brief summary of the requirements.

(a) Defining the problem

Students should be able to
- identify the independent and the dependent variables;
- identify those variables that must be controlled;
- give a clear precise statement as to what is being investigated.

(b) Methods of data collection

Students should be able to give a clear logical account of the experimental procedure to be followed, including a description of
- how the independent variable is to be varied;
- how the independent and the dependent variables are measured;
- how the other variables are controlled;
- the arrangement of the apparatus.

(c) Method of analysis

Students should be able to describe the main steps by which their data would be analysed in order to draw valid conclusions. This may well include the proposal of graphical methods to analyse data.

(d) Safety considerations

Students should be able to identify areas of risk and suggest suitable safety precautions to be taken.

Question Structure

The question is usually loosely structured and requires you to design an experiment to reach some conclusions. You may need to integrate knowledge from the syllabus, and know how to use the correct instruments and techniques to collect data.

The format of a planning question usually includes:
- background information;
- instruction to "design an experiment ...";
- list of available apparatus and materials;
- areas to be included in the answer.

Details to Include in Report

The background information given at the start of the question provides context to the question. Such information may or may not be useful in answering the question. There is usually more than 1 way of answering a planning question and the marking scheme varies from year to year.

a. **Problem Definition**

- Identify the quantifiable independent variable x of the experiment.
- Identify the quantifiable dependent variable y of the experiment.
- Identify the control variables (preferably quantifiable) of the experiment, i.e. variables to be kept constant in order for the experiment to be valid.

b. **Experimental Set-up**

- Draw clearly labelled 2D diagram(s) – top and/or side view - that show the relative positions of the apparatus in workable arrangements.
- All apparatus should be supported by clamps and stands, and be laid on the table top (draw line for table top). They should not be hanging in the air.
- Apparatus which are in danger of toppling (such as motor, pulley, retort stands) must be firmly clamped to the workbench.
- Conventional circuit symbols must be used for circuit diagrams.
- You may use some or all of the apparatus suggested in the question, as well as any other equipment usually found in a Physics laboratory.

c. **Procedure**

The procedure must be logically sequenced and clearly numbered. Leave a line between each step for amendments. Students may use any typical apparatus found in the Physics laboratory. The procedure should include:

- descriptions of the setup, if the diagrams cannot fully explain the intentions.
- how the independent and dependent variables are measured using the correct instruments and methods, and how the readings would be used.
- equations used to determine the independent and dependent variables, if they cannot be measured directly.
- taking preliminary readings to determine the range of the independent variable which will produce a valid range of dependent variable. Do NOT state specific values or trends.
- values that are not given must be measured and not assumed (e.g. cannot assume that diameter of wire is uniform, temperature of ice is 0 °C).
- definitions of all symbols used.
- steps to be repeated to find the average of the dependent variable.
- steps to be repeated to obtain at least 5 additional sets of data.
- methods to vary the independent variable.
- methods to measure and keep the control variables constant for a valid experiment.

***d.* Analysis**

Describe how the data obtained should be used to achieve the objective(s) of the experiment.

Case 1: If relationship is given or known:
Linearise equation and explain how unknown constants or relationship can be determined from the equation or graph.

E.g.: $s = vt$

Plot a graph of s against t.

The speed v can be obtained from the gradient of the graph.

Case 2: If relationship is NOT given and NOT known.
Assume that $y = k\,x^n$,

where k and n are constants.

$\Rightarrow \lg(y) = n\lg(x) + \lg(k)$.

Plot a graph of $\lg(y)$ against $\lg(x)$.
If the above relationship is true, a straight line graph will be obtained, where the gradient is n and the vertical-intercept is $\lg(k)$.
Hence, $k = 10^c$ where c is the vertical-intercept.

Safety Precautions

- State reasonable hazards that are specific to the experiment **AND** how to avoid them, even if question did not ask.
- State actions to be taken, **NOT** actions to avoid (e.g. "wear glove to handle hot beaker", **NOT** "do not handle beaker with bare hands").
- Rationale must be given for the steps taken.
- Hazards can be due to apparatus (e.g. high-voltage supply), material (e.g. mercury) or procedures (e.g. oscillation of a heavy mass).

***e.* Additional Details**

Include details which improve the reliability (i.e. accuracy and precision) of the results, even if the question did not explicitly ask for them. These may include:

- Taking preliminary readings to determine a suitable range of the independent variable is investigated. By suitable, we mean the range of values of the dependent variable will be large and measurable.
- crucial arrangement of apparatus,
- steps to reduce/eliminate sources or error,
- proper use and calibration of equipment.
- Environment control
  - Optics experiment: Conduct experiment in a dark room
  - Sound experiment: Conduct experiment in a sound-proof, isolated room. Or, lay the workbench and surround the experimental setup with sound absorbing board (any soft board will do)
  - Heat experiment: Keep the temperature of the room constant by using an air-conditioner. Ensure all fans are switched off or surround the setup with boards to minimise air draft.

Template of Report

Problem Definition

Independent variable:	<*x*>	
Dependent variable:	<*y*>	
Control variables:	1.	....
	2.	....

Experimental Set-up

Diagram of set-up
- must be detailed and clearly labelled.
- must show relative positions of apparatus in a workable arrangement.
- must support and secure apparatus, not hanging in the air (except circuit diagrams).
- must use conventional symbols for circuit diagrams.

Note:
**You need not use all suggested apparatus. You may use common laboratory apparatus.*
**If you choose to use data-loggers, include relevant details (e.g. type of sensor used, type of graph/data obtained on the computer, how to interpret the graph/data, e.t.c. in the procedure).*

Procedure

1. **"Set up the apparatus as shown in Fig 1."**
   Describe the setup only if the diagram cannot fully explain intentions.

2. Describe the steps required to conduct the experiment.

3. "**Measure** <*x*> **using** <apparatus to measure *x*> **and record**."
   Describe how the independent variable it is to be measured.

4. "**Measure** <*y*> **using** <apparatus to measure *y*> **and record**."
   Describe how the dependent variable it is to be measured.

5. **"Calculate <*y*> (or <*x*>) can be calculated using the equation ________________."**
   Describe how <*y*> or <*x*> is determined from a measured value in step 3 or 4.

6. … …
   Describe a method to determine the range of <*x*> to be investigated (sometimes just determining the min or max value is sufficient), OR state the range if it is obvious.

7. "**Repeat steps ___ to ___ to obtain the average value of** <*y*>."

8. "**Repeat steps ___ to ___ to obtain 5 further sets of** <*x*> **by** <u><method to vary x></u>."

9. … …
   Describe how the control variables listed above are measured and kept constant.

Analysis

Read the question again. Answer the question accordingly. Refer to page 4 for the different possibilities.

Safety Precautions

1. There is a risk that.... and we can prevent that by...
2. ....

Additional Details

1. Preliminary investigation of ....
2. ....

Tips!!

- *Write legibly, using short, clear and complete sentences.*
- *Number each step, and leave a line between steps for amendments and additions.*
- *Give sufficient details so that another person can conduct the experiment and evaluate the results of the experiment BUT* do not waste too much time in one particular section of the report.
- *Read the question carefully and check that all parts of the question have been addressed.*
- *Read through your report to ensure that it flows logically and answers all parts of the question.*
- *When unsure, give 2 good control variables, 2 good safety precautions and 2 good additional details. It is not important where they are written. However, do NOT spend time duplicating what had already been written.*

Sample Question

Nylon is a material very much suitable for fabrics because of its smoothness, light weight and high strength. It is commonly blended with cotton to make the fabric "slippery". The "slipperiness" of a nylon-cotton blend fabric can be specified in terms of the minimum force that is required to move an object from rest on the fabric.

Design an experiment to investigate the "slipperiness" of different blends of nylon-cotton fabric.

You are provided with different blends of nylon-cotton fabrics where the percentage of nylon in the fabrics is known. You may also use any other equipment usually found in a Physics laboratory.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,
(b) the equipment you would use,
(c) the procedure to be followed,
(d) how the relationship between "slipperiness" and percentage of nylon is determined from your readings,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

[12]

Suggested Solution

Problem Definition

Independent variable:	percentage *P* of nylon in a fabric
Dependent variable:	minimum force *F* required to move a wooden block, from rest, placed on a fabric
Control variables:	mass of the wooden block surface roughness of the wooden block angle of force to the horizontal

Experimental Set-up

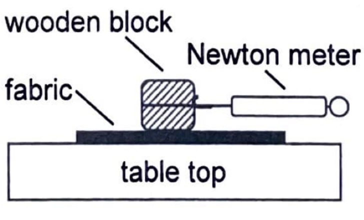


Fig. 1

Procedure

1. Set up the apparatus as shown in Fig. 1. Tie a thread tightly around the wooden block and hook the Newton meter onto the thread. Check that the wooden block is suitable by pulling it from rest with the Newton meter on fabrics with the maximum and minimum percentage *P* of nylon. The force required to move it should be within the range of the Newton meter. If not, use a wooden block with a different surface roughness.
2. Secure the fabric to the table top using double-sided tape. Record the percentage *P* of

nylon in the fabric.

3. With the wooden block at rest, pull the Newton meter horizontally with increasing force.
4. When the wooden block just starts to move, record the reading on the Newton meter as the minimum force F.
5. Repeat steps 3 to 4 to obtain an average value for the minimum force F.
6. Repeat steps 2 to 5 to obtain 5 further sets of readings for P and F by replacing the fabric with one of a different percentage P of nylon.
7. The mass and surface roughness of the wooden block is kept constant by using the same wooden block throughout the experiment.

8. Ensure that the angle of the force applied is always horizontal by checking using a ruler that the Newton meter is always parallel to the table.

Analysis

Assume that $F = k\, P^n$,

where k and n are constants.

$\Rightarrow \lg(F) = n\lg(P) + \lg(k)$.

Plot a graph of lg(F) against lg(P).

If the above relationship is true, a straight line graph will be obtained, where the gradient is n and the vertical-intercept is lg (k).

Hence, $k = 10^c$ where c is the vertical-intercept.

Safety Precautions

1. When pulling on the Newton meter, increase the force slowly to prevent the block from being thrown off the table and causing injury.

Additional Details

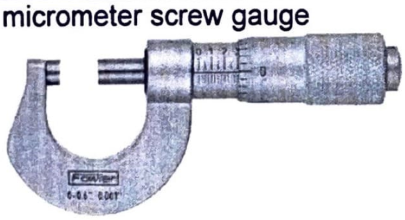
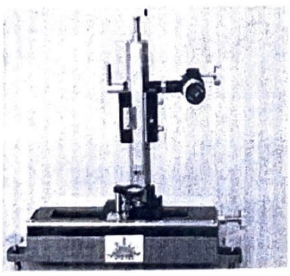
1. When attaching the fabric to the table top, the fabric should be taut so that the minimum force required to start the block moving is not affected by loose fabric.

APPENDIX

<u>List of Common Measuring Instrument</u>

Here are some common data that you may need to collect and the apparatus used to measure them.

1. Length

Apparatus	Details
metre rule	Short range: < 1 m Precision: ± 1 mm
measuring tape 	Long range: > 1 m Precision: ± 1 mm
vernier callipers 	Range: 0 to 150 mm Precision: ± 0.1 mm Take note of zero error.
micrometer screw gauge 	Range: 0 to 25 mm Precision: ± 0.01 mm Take note of zero error.
travelling microscope 	Range: 0 to 180 mm horizontal 0 to 100 mm vertical Precision: ± 0.01 mm Subtract one reading from another to determine length (e.g. diameter of cylindrical bore and small extension in metal wire).

2. Time

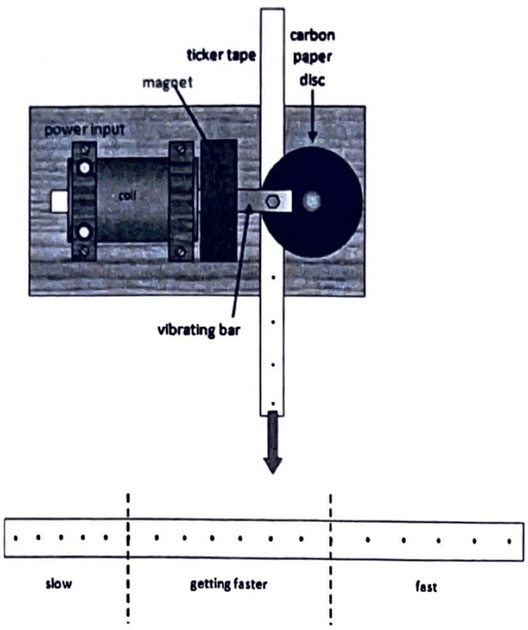
Apparatus	Details
digital stopwatch 	Use of the split function to record several timings as object passes through several positions. Precision: ± 0.01 s (but data is restricted to 1 dp due to human reaction time of ± 0.2 s)
light-gates + electronic timer light-gates  electronic timer	When an object passes through the first light-gate, the electronic timer switches on. When the object subsequently passes through the second light-gate, the electronic timer switches off to record the time taken to travel from the first to the second light-gate. Precision: ± 0.001 s

3. Frequency of Oscillation or Rotation

Apparatus	Details
stroboscope 	The stroboscope or strobe emits brief and rapid flashes of light. The frequency of the flash is reduced from its highest setting until the oscillating or rotating object appears stationary. When this happens, the frequency of the flash is equal to the object's frequency.

4. Speed

Apparatus	Details
metre rule + stopwatch	Measure the distance which the object travels using a metre rule. Measure the time taken for the object to travel through that distance using a stopwatch. Ave velocity = distance / time taken
metre rule + light-gates + electronic timer	Measure the distance between the two light-gates using a metre rule. Measure the time taken for the object to travel from one light gate to the other using an electronic timer. Average velocity = distance between light-gates / time taken

ticker-tape timer 	A long paper tape is attached to a moving object and threaded through a device that places a dot on the tape at regular intervals of time. As the object moves, it drags the tape through the "ticker," thus leaving a trail of dots. The distance between dots on a ticker tape represents the change in the object's position. If the ticker-tape timer operates at 50 Hz, there will be 50 dots on the tape as it is pulled through the timer in one second. Since the time interval between consecutive dots is short (1/50 s), the ticker-tape timer is very useful for measuring high speeds or short intervals of time. To determine the average speed of the object, divide the distance between the first and last dot by the corresponding time interval between them.

5. Acceleration

Apparatus	Details
Obtain from corresponding velocity-time graph	Use any method above to obtain the velocity-time graph. The acceleration of an object at any instant is the gradient of the velocity-time graph at that instant.

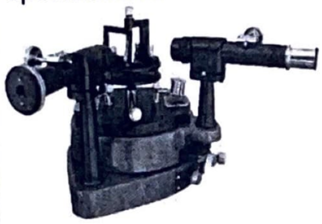
6. Mass

Apparatus	Details
beam balance + standard masses 	The mass of an object may be determined by balancing it against known standard masses.
electronic balance 	Tare the balance before use in a draft-free environment.

7. Force

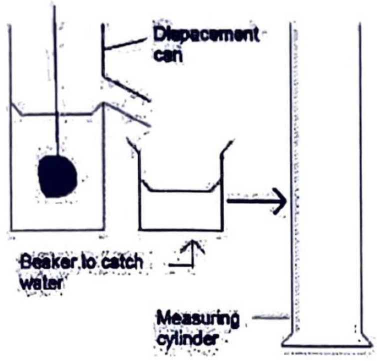
Apparatus	Details
spring balance 	The scale-markings on the spring balance are equally spaced if the proportionality limit of the spring is not exceeded. The spring can be permanently stretched if it is extended beyond its elastic limit. A spring balance can be labelled in both Newtons and kilograms.

8. Angle

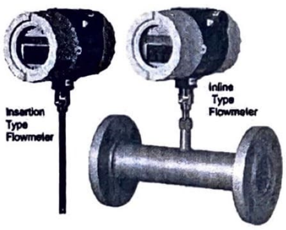
Apparatus	Details
protractor	Most protractors measure angles in degrees.
spectrometer 	A spectrometer consists of an entrance slit, collimator, a dispersive element (such as a grating or prism), focusing optics and detector. Its basic function is to take in light and break it into its spectral components at different angles. The spectral components are viewed through a telescope fixed to a turntable with an angular scale. By rotating the telescope from one spectral component to the next, the angle of deviation between the spectral components may be determined from the scale.

9. Volume

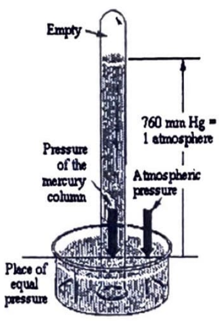
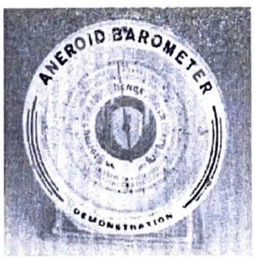
Apparatus	Details
measuring cylinder or burette for liquids	Range: 10 ml – 500 ml
calculation for regularly shaped solids	Vol. of cuboid = length x breadth x height Vol. of cylinder = $\pi r^2 h$ Vol. of sphere = $\frac{4}{3}\pi r^3$ Measure the relevant dimensions with an appropriate instrument.

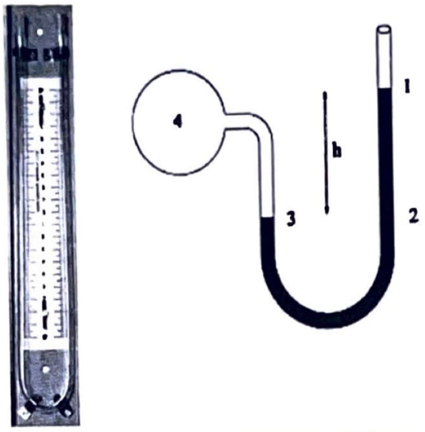
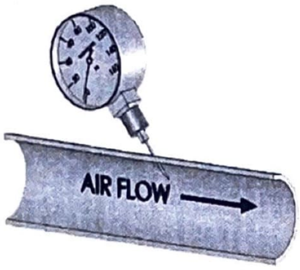
displacement can + measuring cylinder for irregularly shaped objects  	Fill the displacement can with water up to the sprout. Immersed object into water and collect overflowing water in a beaker. The displaced water can then be accurately measured using a measuring cylinder.

10. Volume and Mass Flow Rate

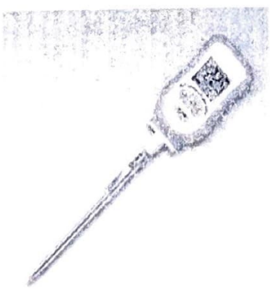
Apparatus	Details
beaker + measuring cylinder + stopwatch (for volume flow rate) beaker + weighing scale + stopwatch (for mass flow rate)	The volume of liquid flowing out in a fixed duration of time may be collected in a beaker at the outlet. The volume of the liquid collected may be determined using a measuring cylinder or the mass of the liquid collected may be determined using a weighing scale. Volume flow rate = volume of liquid / time Mass flow rate = mass of liquid / time
mass flowmeter  	Mass flowmeters measure the mass flow rate directly. Mass measurements are usually not sensitive to changes in density, pressure and viscosity. Volume flow rate = mass flow rate / fluid density

11. Pressure

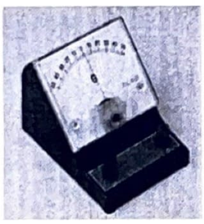
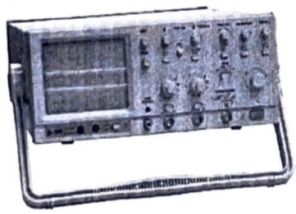
Apparatus	Details
barometer   	A barometer is used to measure atmospheric pressure. There are two common types of barometers – mercury barometer and aneroid barometer.

manometer 	A manometer uses a column of liquid to measure pressure. The pressure in 4 to be measured = pressure at 3 = pressure at 2 = [h × (density of fluid in manometer) × g] + pressure at 1
pressure gauge 	A device that measures the pressure of a gas or liquid.

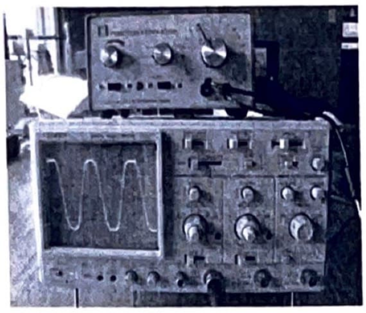
12. Temperature

Apparatus	Details
mercury-in-glass thermometer	Range: –38°C to 356°C (high temperatures) Mercury is naturally opaque, does not wet glass, has high thermal conductivity making it more sensitive. However, it is toxic.
alcohol-in-glass thermometer	Range: –200°C to 80°C (low temperatures) Alcohol is transparent so it needs to be coloured and it wets glass.
thermocouple thermometer  	Range: –200°C to 1600°C Thin (can reach narrow and deep spaces), low heat capacity (does not change temperature of object), sensitive (produces a reading quickly). It consists of two dissimilar conductors which produces a voltage when the temperature of one of junction differs from the reference junction. Thermocouples are normally calibrated to give readings in °C or °F instead of V.

13. Current, Potential Difference, Resistance

Apparatus	Details
Current: digital multimeter set as an ammeter to measure either direct or r.m.s. alternating current 	Connect in series to the branch whose current is to be measured.
Potential difference: digital multimeter set as a voltmeter to measure either direct or r.m.s. alternating voltage	Connect in parallel to the electrical component whose p.d. is to be measured.
Resistance: digital multimeter set as an ohmmeter to measure resistance	Connect in parallel to the electrical component whose resistance is to be measured.
Resistance: ammeter + voltmeter	Resistance may be found from the ratio $\frac{\text{potential difference across the component}}{\text{current through the component}}$
 galvanometer	A galvanometer is a sensitive instrument used to determine the presence or direction of a small electric current. It is commonly used to determine the null or balance point in a potentiometer circuit.
 cathode ray oscilloscope (CRO)	The CRO may be thought of as a "graphing voltmeter". Because of its ability to display the waveform of the voltage, it can be used to determine the peak voltage and frequency of an alternating signal.

14. Period, Frequency and Amplitude of Electrical Signals

Apparatus	Details
signal generator connected to a CRO 	A signal generator is able to generate repeating electrical signals. These signals can be analysed by connecting the signal generator to a CRO. The waveform produced by the signal generator will be displayed on the screen of the CRO. Using the grid on the screen, measure the horizontal distance occupied by as many complete waveforms as possible. Multiply this distance by the time-base scale to obtain time. Divide this time by the number of complete waveforms to obtain the period of the waveform. To obtain the frequency, take the reciprocal of the period. Measure the vertical peak-to-peak distance on the screen and multiply it by the y-sensitivity scale to obtain the peak-to-peak voltage. The amplitude voltage is half that of the peak-to-peak voltage.

15. Magnetic Flux Density

Apparatus	Details
Gauss meter / Tesla meter (used with a Hall probe) 	It is used to measure magnetic flux density.

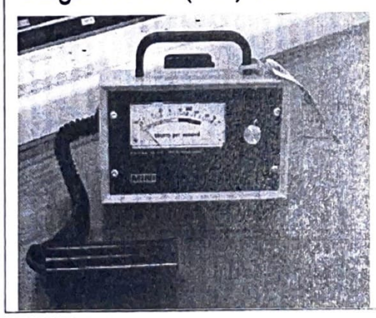
16. Light Intensity

Apparatus	Details
 photometer / light-meter	Most photometers use photoresistors, photodiodes or photomultipliers to detect light. To measure the intensity of light of a specific wavelength, a filter is placed in front of the detector so that only the intended wavelength is incident on the detector. Intensity of light is normally measured in *lux*.

17. Sound Intensity

Apparatus	Details
sound-level meter 	The sound-level meter is used for measuring the intensity of noise, music and other sounds. A typical meter consists of a microphone for picking up the sound and converting it into an electrical signal, followed by electronic circuitry for operating on this signal so that the desired characteristics can be measured. The electronic circuitry can be adjusted to read the level of most frequencies in the sound being measured or the intensity of selected bands of frequencies. The meter is usually calibrated to read the sound level in decibels.

18. Radioactive Count-rate or Counts

Apparatus	Details
Geiger-Muller (GM) counter 	The Geiger-Muller counter detects radiation such as alpha particles, beta particles and gamma rays through the ionisation produced in a Geiger–Muller tube. It can be set to measure count-rate or counts.

Data Logger

A data logger is an electronic device which collects data at fixed interval of time. It can record a wide variety of signals from different probes, including temperature, relative humidity, pressure, force, acidity, distance, speed, AC/DC current and voltage, light and sound intensity, and many more.

Typically, data loggers are compact, battery-powered devices equipped with a screen, internal microprocessor, data storage, and one or more sensors.

To analyse the data in greater detail, the data logger can be connected to a computer. A software is then used to download the data and display the measurements in graphical or tabular form.

Types of sensors that may be used with a data logger include:
- Light-gates or photogates
- Motion sensor (a sonar – which also measures distance)
- Temperature sensor (a thermocouple)
- Magnetic field sensor (a Hall probe)

Details like the type of sensors used, data collected and interpretation of graphs/data must be included in the procedure.

Circuit Symbols of Typical Electrical Components