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FREE EBOOK

SCIENCE PROJECTS AND KITS

Investigatory Projects for Class 11 and 12

Topics, method and report structure for physics, chemistry and biology

INSIDE THIS BOOK

- What an investigatory project is
- Choosing a topic you can finish
- Aim, hypothesis and variables
- Physics projects
- ...and 6 more chapters, practice questions and a glossary

Intermediate

Students of class 11 and 12 (CBSE, ICSE and state boards)

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Investigatory Projects for Class 11 and 12

A step-by-step guide to planning, doing and writing up an investigatory project in physics, chemistry or biology. You will learn to choose a topic you can finish, write an aim, hypothesis and variables, record and graph readings, work out errors, write a neat report and face the viva with confidence.

WHO IT IS FOR	Students of class 11 and 12 (CBSE, ICSE and state boards)
LEVEL	Intermediate
SUBJECT AREA	Science projects and kits
WHAT IS INSIDE	10 chapters, practice questions with answers, and a glossary

HOW TO USE IT

Read one chapter at a time and try the examples as you go: on a computer, at your workbench or in your notebook. The boxes give tips, safety points and short activities. When you finish, test yourself with the practice questions and check your answers at the end. Words you may not know are explained in the glossary.



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What an investigatory project is

An investigatory project is a small piece of real science that you plan and carry out yourself. You ask a question, design a fair test, take careful readings and use them to reach an answer. The answer is not printed at the back of a textbook. You find it.

Many students confuse an investigation with a model. A model shows how something works. An investigation finds something out. Both are useful, but only one of them is an investigatory project.

A model or demonstration	An investigatory project
"Making a transformer"	"How does the type of core change a transformer's efficiency?"
"Showing fermentation"	"How does temperature affect the rate at which yeast ferments sugar?"
"Onion root tip slide"	"Is the share of dividing cells higher near the tip of an onion root than further back?"
Ends with "it works"	Ends with readings, a graph and a conclusion

What your teacher and examiner look for

- A clear question that can be answered by measuring something.
- A method that you planned and understood.
- Honest readings, taken more than once.
- A graph or table that shows a pattern.
- A conclusion that matches your readings, even if it surprised you.
- Your ability to explain every step in the viva (the oral questions at the end).

REMEMBER

A project that "failed" can still score well. If your result went against your hypothesis and you explain why, that is good science.

A sensible timeline

Most schools give you a few weeks. Here is a plan you can stretch or squeeze to fit your school's dates.

Stage	What you do
Weeks 1 to 2	Choose a topic, read the theory, write the aim
Week 3	Plan the method, collect materials, do a trial run
Weeks 4 to 6	Take the real readings, at least three times each
Week 7	Draw tables and graphs, do calculations and error analysis
Week 8	Write the report
Week 9	Practise the viva

TIP

Keep a rough notebook from day one. Write the date, what you did, every reading (even odd ones) and any problem. This notebook saves you when you write the report.

CHAPTER 2

Choosing a topic you can finish

A good topic is one you can actually complete with the time, money and equipment you have. A grand idea that you cannot finish is worth less than a small idea done well.

Five questions to ask about any topic

- 1. Can I measure something?** You need numbers: a voltage, a volume, a time, a count or a length.
- 2. Is it safe?** No mains electricity, no growing bacteria, no strong chemicals without a teacher.
- 3. Can I get the materials?** Check your school laboratory and the local market before you decide.

- 4. Can I finish it in time?** Seeds take days to germinate. Root tips take nearly a week to grow.
- 5. Do I understand the theory?** You should be able to explain it in your own words.

Narrowing a big idea

Most first ideas are too broad. Turn them into a question of the form "How does ___ affect ___?"

EXAMPLE

Kavya from Kochi wanted to do a project on "food safety". That is a whole subject, not a project. She narrowed it to "Which of six common kitchen items from three local shops show signs of adulteration in simple chemical tests?" Now she knew exactly what to buy, what to test and what to record.

Too broad	Narrowed and measurable
Electricity	How does light intensity affect the resistance of an LDR?
Vitamins	How does boiling change the vitamin C content of lemon juice?
Plants	How does the pH of water affect the germination of moong seeds?
Soaps	How does water hardness affect the foaming of different soaps?

Things to avoid

SAFETY

Do not choose a project that needs mains electricity, open flames without supervision, concentrated acids handled by you alone, harm to animals, or growing bacteria and moulds on plates. A teacher must approve every chemical and every piece of electrical equipment you use.

- Topics where the result is a matter of opinion ("Which soap smells best?").
- Topics that need costly instruments your school does not have.
- Copying a project report from a senior or from the internet. Examiners spot this quickly, and you will not be able to answer the viva.

TRY THIS

Write down three possible questions. For each, list the thing you will change, the thing you will measure and the equipment you need. Pick the one with the shortest equipment list that still interests you.

CHAPTER 3

Aim, hypothesis and variables

These three ideas are the skeleton of your project. Get them right and everything else becomes easier.

The aim

The aim is one sentence that says what you will investigate. It usually starts with "To study" or "To investigate".

Aim: To investigate how boiling time affects the vitamin C content of lemon juice.

The hypothesis

A hypothesis is a testable prediction with a reason. A good pattern is "If ... then ... because ...".

Hypothesis: If lemon juice is boiled for longer, then its vitamin C content will fall, because vitamin C breaks down when heated and when it reacts with oxygen in the air.

A hypothesis does not have to be right. It has to be clear enough that your readings can support it or go against it.

Variables

A variable is anything that can change during the experiment. There are three kinds.

Kind	Meaning	In the lemon juice project
Independent variable	The one thing you change on purpose	Boiling time (0, 2, 4, 6, 8 minutes)

Kind	Meaning	In the lemon juice project
Dependent variable	The thing you measure	Volume of iodine solution used in titration
Controlled variables	Everything you keep the same	Volume of juice, same lemons, same iodine solution, same flask

A fair test

A test is fair when only the independent variable changes. If you boil one sample in a steel pan and another in an open glass beaker, you have changed two things, and you cannot tell which one caused the difference.

REMEMBER

Change one thing. Measure one thing. Keep everything else the same.

Range, repeats and control

- **Range:** Use at least five values of the independent variable, spread well apart.
- **Repeats:** Take each reading at least three times and find the mean (average). Repeats show whether your results are reliable.
- **Control:** Keep one set-up where nothing is changed, such as unboiled juice. It gives you something to compare against.

DID YOU KNOW

Scientists call a result reliable when repeating the experiment gives nearly the same reading again. They call it accurate when it is close to the true value. A ruler with a worn-out end gives readings that are reliable but not accurate, because every reading is off by the same amount.

CHAPTER 4

Physics projects

Each topic below gives the question, the apparatus, the method in short, and what to plot. Choose one and build on it.

SAFETY

Physics projects here use batteries up to 12 V or a low-voltage AC supply that your teacher sets up and switches on. Never take power from a wall socket. Never connect a small mains transformer "backwards" by feeding its low-voltage winding: the other winding then produces a dangerous high voltage.

Resistance of an LDR and light intensity

An LDR (light dependent resistor) is a resistor whose resistance falls as more light falls on it.

- **Question:** How does the resistance of an LDR change with light intensity?
- **Apparatus:** LDR, digital multimeter, a small torch bulb or a single LED run from cells, metre scale, a dark cardboard box. Avoid a torch with a shiny reflector, because it focuses the light into a beam.
- **Method:** Fix the LDR at one end of the box. Place the light source at distances of 10, 15, 20, 25, 30 and 40 cm. Measure the resistance at each distance. For a small source, light intensity is roughly proportional to $1/d^2$, where d is the distance.
- **Plot:** Resistance against distance, and resistance against $1/d^2$. Class 12 students can also plot $\log R$ against $\log d$, which often gives a straight line.

Factors affecting the emf induced in a coil

Electromotive force (emf) is the "push" that drives current. Faraday's law says the emf induced in a coil depends on how fast the magnetic flux through it changes, and on the number of turns.

- **Question:** How do the number of turns and the strength of the magnet affect the induced emf?
- **Apparatus:** Plastic tube, enamelled copper wire, centre-zero galvanometer, bar magnets.
- **Method:** Wind coils of 100, 200, 300 and 400 turns. Drop the magnet through each coil from the same height. Note the first swing (throw) of the galvanometer. Repeat with two magnets stacked together.
- **Plot:** Galvanometer throw against number of turns.

DID YOU KNOW

For a very quick pulse, a galvanometer's swing depends on the total charge that flows, not on the peak emf. The total charge does not change much with the magnet's speed. So if you want to study speed, ask your teacher for an oscilloscope, which shows the height of the pulse directly.

Full-wave rectifier

A rectifier changes alternating current (AC), which keeps reversing, into direct current (DC), which flows one way. A bridge rectifier uses four diodes.

- **Battery demonstration first:** Build the bridge with four 1N4007 diodes and connect an LED with a $1\text{ k}\Omega$ resistor as the load. Connect a 9 V battery to the input one way, then the other way. The LED glows both times. This shows that the bridge sends current through the load in one direction whichever way the input is connected.
- **Waveforms:** In the lab, with a low-voltage AC source and oscilloscope set up by your teacher, view the output with and without a filter capacitor. The ripple (the small wave left on the DC) has twice the frequency of the input.
- **Investigation:** How do the capacitor value and the load resistance affect the ripple?

Logic gates

A logic gate gives an output of 1 (high voltage) or 0 (low voltage) depending on its inputs.

- **Question:** Can all the basic gates be built from NAND gates alone?
- **Apparatus:** 7400 quad NAND chip, breadboard, LEDs with resistors, switches, 9 V battery with a 7805 regulator to give 5 V. On these 14-pin chips, pin 14 is usually the supply and pin 7 is ground, but always check the datasheet.
- **Method:** Build NOT, AND and OR from NAND gates. Test every input combination and record the output.
- **Result:** Compare each truth table with the expected one.

Transformer efficiency

- **Question:** How does the core material affect a transformer's efficiency?

- **Apparatus:** Two coils of enamelled wire (the primary coil takes the input and the secondary coil gives the output), cores (air, a bundle of iron nails, thin laminated iron strips), AC voltmeter, a known small resistor for current, low-voltage AC supply set up by the teacher.
- **Method:** Measure primary voltage and current, and secondary voltage and current, for each core. Keep the secondary turns equal to or fewer than the primary turns, so the output never rises above the input. Many basic multimeters cannot measure AC current, so measure the AC voltage across a small known resistor in series and use $I = V/R$.
- **Calculation:** Efficiency = $(V_s \times I_s) \div (V_p \times I_p) \times 100$.

EXAMPLE

Imran in Bhopal measured $V_p = 6.0 \text{ V}$, $I_p = 0.40 \text{ A}$, $V_s = 2.8 \text{ V}$ and $I_s = 0.50 \text{ A}$ with the nail core. Input = 2.4 W , output = 1.4 W , so efficiency = $1.4 \div 2.4 \times 100 = 58\%$. With laminated strips his efficiency rose, because thin insulated strips reduce eddy currents (small loops of current that heat the core).

Refractive index of liquids

Refractive index (μ) tells you how much a material bends light. One method uses real and apparent depth: $\mu = \text{real depth} \div \text{apparent depth}$.

- **Question:** How does the concentration of sugar solution affect its refractive index?
- **Apparatus:** Travelling microscope, beaker, a mark on paper or chalk dust, sugar solutions of 0%, 10%, 20%, 30% and 40%.
- **Method:** Focus the microscope on the mark with the beaker empty, then on the mark through the liquid, then on the liquid surface. Use the three readings to find real and apparent depth.
- **Plot:** Refractive index against concentration. For water you should get a value close to 1.33.

Chemistry projects

SAFETY

Wear goggles and a lab coat. Your teacher should prepare or hand out acids, alkalis, Fehling's solution and iodine solution. Never taste anything in the laboratory, even food samples. Wash hands after every session.

Adulterants in food

An adulterant is a cheaper or harmful substance mixed into food. The food regulator FSSAI has published simple tests for this. Buy small samples of the same items from different shops and test each one.

Food	Possible adulterant	Simple test	Positive sign
Milk, paneer, khoya	Starch	Add a few drops of iodine solution	Blue-black colour
Sugar	Chalk powder	Dissolve in water, then add dilute HCl to the settled part	Insoluble powder settles; fizzing with acid
Turmeric, arhar dal	Metanil yellow (a banned dye)	Shake with water, add a few drops of conc. HCl (teacher only)	Pink or violet colour
Chilli powder	Brick powder	Stir in water	Gritty particles sink quickly
Tea leaves	Added colour	Sprinkle on wet filter paper	Coloured streaks spread

Record the shop (as A, B, C, not by name), the result and how strong the colour was.

Rate of fermentation

Fermentation is the breakdown of sugar by yeast, without oxygen, into alcohol and carbon dioxide:



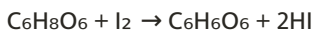
- **Question:** How does temperature affect the rate of fermentation of glucose solution by yeast?
- **Method:** Put equal volumes of the same glucose solution and equal amounts of baker's yeast into identical bottles. Stretch a balloon over each mouth. Keep them in water baths at different temperatures, for example 20, 30, 40 and 50 °C. Measure the balloon's circumference every 15 minutes.
- **Another method:** Test a few drops with Fehling's solution at intervals. While glucose remains, it gives a red-brown precipitate on heating. When fermentation is complete, it no longer does. The time taken is your result. Use glucose here, because table sugar (sucrose) does not react with Fehling's solution until it has been broken down.

DID YOU KNOW

Baker's yeast cannot ferment starch directly. Starch must first be broken into sugars by enzymes. That makes "glucose versus starch" an interesting comparison.

Vitamin C content of juices

Vitamin C (ascorbic acid) reacts with iodine and turns it into colourless iodide. When all the vitamin C is used up, extra iodine turns starch indicator blue-black. That colour change is the end point of the titration.



1. Make a standard solution from a vitamin C tablet of known strength, for example 1 mg of vitamin C per mL.
2. Put 10 mL of it in a flask with a few drops of starch solution. Add iodine solution from a burette until a blue-black colour just stays, and note the volume used.
3. Repeat with 10 mL of each strained fruit juice.

EXAMPLE

Neha in Jaipur found that 10 mL of standard solution (10 mg vitamin C) needed 12.5 mL of iodine. 10 mL of fresh orange juice needed 6.0 mL. Vitamin C in 10 mL of juice = $6.0 \div 12.5 \times 10 = 4.8$ mg, which is 48 mg per 100 mL. After boiling the juice for five minutes, it needed only 4.0 mL. These are sample figures to show the working, not standard values.

Foaming capacity of soaps

Take equal masses of different soaps and dissolve each in the same volume of distilled water. Put the same volume of each solution in identical test tubes, shake each one the same number of times, and time how long the foam lasts. Repeat with tap water or hard water. Hard water contains calcium and magnesium salts, which react with soap to form scum and reduce foam.

Casein in milk

Casein is the main protein in milk. It separates out as curd when milk is made slightly acidic.

1. Warm 20 mL of milk with 20 mL of water to about 40 °C.
2. Add dilute acetic acid drop by drop, stirring, until white casein separates.
3. Filter, wash with water, dry between filter papers and weigh.
4. Percentage of casein (grams per 100 mL) = $\text{mass} \div \text{volume of milk} \times 100$.

Compare cow, buffalo, toned and skimmed milk. Check the protein figure printed on packets and discuss it in your report. The curd also traps some fat, so your figure is "crude casein".

Comparing antacids

An antacid neutralises excess stomach acid. Use back titration: dissolve one tablet in a known excess of standard HCl, then titrate the leftover acid with standard NaOH. Your teacher will tell you which indicator to use.

EXAMPLE

Arjun in Patna added 50.0 mL of 0.10 M HCl (5.0 mmol) to a tablet. The leftover acid needed 18.0 mL of 0.10 M NaOH (1.8 mmol). Acid neutralised = $5.0 - 1.8 = 3.2$ mmol per tablet. If the tablet costs ₹ 2, that is 1.6 mmol per rupee. Comparing per rupee makes a good discussion point.

CHAPTER 6

Biology projects

SAFETY

Do not grow bacteria or moulds on plates at school or at home. You cannot tell harmless microbes from harmful ones by looking, and a plate can hold billions of them. Hydrochloric acid, glacial acetic acid and stains must be handled by your teacher. Wash hands after handling plants and soil.

Effect of pH on seed germination

pH is a scale that shows how acidic or alkaline a solution is. Below 7 is acidic, 7 is neutral and above 7 is alkaline.

- **Question:** How does the pH of water affect the germination of moong (green gram) seeds?
- **Method:** Make five solutions from about pH 3 to about pH 11: diluted vinegar at two strengths for acidic, distilled water for neutral, baking soda solution (about pH 8) and washing soda solution (about pH 11) for alkaline. Check each with pH paper. Place 20 seeds on wet cotton in each Petri dish and moisten them only with their own solution. Keep all dishes in the same place.
- **Readings:** Each day for five days, count germinated seeds and measure the length of the radicle (the first root).
- **Calculation:** Germination % = $\text{seeds germinated} \div \text{seeds sown} \times 100$.

Antibiotic sensitivity: the idea, studied safely

In hospitals, a sample of bacteria is spread on a jelly-like medium called agar. Paper discs soaked in different antibiotics are placed on it. After incubation, clear rings appear around discs where the bacteria could not grow. These rings are called zones of inhibition. A bigger zone usually means the bacteria are more sensitive to that antibiotic, though the zone size also depends on how easily the drug spreads through the agar.

You should not repeat this with real bacteria. Instead you can study the idea safely:

- **Diffusion model:** With an adult handling the hot liquid, make agar from agar-agar (china grass) with a little washing soda solution and phenolphthalein, so it sets pink. Place paper discs soaked in vinegar of different strengths on it. A colourless ring forms where the acid spreads out. Measure ring diameter against concentration. This models how a substance spreads from a disc.
- **Yeast activity:** Yeast is a harmless fungus used in baking. Compare its gas production with and without small amounts of salt, clove, garlic or turmeric. Remember that yeast is not a bacterium, so the results cannot be applied directly to bacteria.
- **Survey:** Ask families how they use antibiotics. Do they finish the course? Do they take antibiotics for colds? Antibiotics do not work against viruses, and misuse helps bacteria become resistant.

Pollen germination

When a pollen grain lands on a suitable surface, it grows a pollen tube. You can make this happen on a slide.

1. Prepare sugar solutions of 0%, 5%, 10%, 15% and 20%.
2. Put a drop of each on a separate cavity slide.
3. Dust pollen from a fresh flower, such as sadabahar (Vinca) or hibiscus, onto each drop.
4. Keep the slides in a covered dish with wet filter paper, so they do not dry out.
5. After a fixed time, count germinated and non-germinated grains under the microscope. A grain is often counted as germinated when its tube is longer than the grain's width.

Plot germination percentage against sugar concentration.

Mitosis in onion root tip

Mitosis is cell division that gives two identical cells. It happens fast near the tip of a growing root.

1. Grow roots by keeping an onion over a jar of water for 4 to 6 days.
2. Cut 1 cm root tips and fix them in acetic alcohol (your teacher prepares this).
3. Your teacher warms the tips briefly in dilute HCl to soften them.
4. Stain with acetocarmine, place under a cover slip and press gently to spread the cells.
5. Count cells in each stage: interphase, prophase, metaphase, anaphase and telophase.

Mitotic index = (number of dividing cells ÷ total cells counted) × 100.

TRY THIS

Make the project an investigation by comparing the mitotic index of the first 2 mm of the root with the next 2 mm. Count at least 200 cells in each region.

CHAPTER 7

Observations, tables and graphs

Your readings are the evidence for your conclusion. Record them neatly and present them clearly.

Rules for a good table

- Give every table a number and a title.
- Put the independent variable in the first column.
- Write the quantity and unit in the column heading, for example "Distance d (cm)". Do not write units beside every number.
- Record every repeat, then a column for the mean.
- Use the same number of decimal places in a column.

EXAMPLE

Sample readings for the LDR project.

Distance d (cm)	R ₁ (k Ω)	R ₂ (k Ω)	R ₃ (k Ω)	Mean R (k Ω)
10	1.2	1.3	1.2	1.2
15	2.1	2.0	2.1	2.1
20	3.2	3.3	3.1	3.2
25	4.3	4.2	4.4	4.3
30	5.6	5.5	5.7	5.6
40	8.4	8.5	8.3	8.4

Rules for a good graph

1. Use graph paper and a sharp pencil.
2. Put the independent variable on the x-axis and the dependent variable on the y-axis.
3. Choose a scale that uses more than half the sheet. Use easy steps such as 1, 2, 5 or 10 units per centimetre.
4. Label both axes with quantity and unit.
5. Mark points with a small cross or a dot inside a circle.
6. Draw a smooth best-fit line or curve. Do not join the dots point to point.
7. Give the graph a title.

Reading meaning from a graph

- A straight line through the origin means the two quantities are directly proportional.
- A curve means the relationship is not simple proportion. Try plotting something else, such as $1/d$ or log values, to get a straight line.
- The slope (gradient) of a straight line = $\text{rise} \div \text{run}$. Find it using two points far apart on the line, not two of your readings.

DID YOU KNOW

If $R = k \times d^n$, then $\log R = \log k + n \log d$. So a graph of $\log R$ against $\log d$ is a straight line with slope n . For the sample LDR readings above, the slope comes out close to 1.4.

REMEMBER

A point far away from the line is called an outlier. Check it, repeat it if you can, and mention it honestly in the report. Never quietly delete it.

CHAPTER 8

Errors and how to handle them

No measurement is perfect. An error is the difference between a measured value and the true value. Showing that you understand your errors is a sign of a mature project.

Least count

The least count is the smallest value an instrument can measure. A metre scale has a least count of 1 mm. A vernier caliper often has 0.1 mm. Your reading cannot be more precise than the least count.

Two kinds of error

Systematic errors	Random errors
Push every reading the same way	Scatter readings above and below
Caused by a faulty instrument, zero error or a wrong method	Caused by small, unpredictable changes and judgement
Not reduced by repeating	Reduced by taking the mean of repeats
Example: a voltmeter that reads 0.2 V with nothing connected	Example: judging the exact end point colour in titration

Absolute, relative and percentage error

- **Absolute error:** the size of the uncertainty, such as ± 0.1 cm.
- **Relative error:** absolute error $\div$ measured value.
- **Percentage error:** relative error $\times 100$.

Combining errors

- When you **add or subtract** quantities, add their absolute errors.
- When you **multiply or divide**, add their relative errors.
- When a quantity is **raised to a power n**, multiply its relative error by n.

EXAMPLE

Sana in Lucknow measured real depth = 12.0 ± 0.1 cm and apparent depth = 9.0 ± 0.1 cm. $\mu = 12.0 \div 9.0 = 1.333$. Relative error = $0.1/12.0 + 0.1/9.0 = 0.0083 + 0.0111 = 0.0194$. Absolute error = $1.333 \times 0.0194 = 0.026$. She wrote her result as $\mu = 1.33 \pm 0.03$.

Comparing with a standard value

If a standard value exists, find:

Percentage difference = (your value – standard value) $\div$ standard value $\times 100$

Sana's water result of 1.33 matched the standard value of about 1.33, so her difference was close to zero.

Writing the sources of error

List real, specific sources, not "human error". For example: "Parallax while reading the microscope scale", "Temperature of the solutions rose during the session", "The galvanometer pointer did not return exactly to zero."

TIP

Next to each source of error, write how you reduced it. This turns a weakness into evidence of careful work.

Writing the report

The report tells the full story of your project. Follow your school's or board's format if it gives one. Otherwise, this order works well.

Section	What goes in it
Certificate	A page for your teacher to sign, confirming the work is yours
Acknowledgement	A short thank-you to those who helped
Contents	Section names with page numbers
Introduction and theory	The science behind your question, in your own words
Aim and hypothesis	One sentence each
Apparatus and materials	A list with quantities and specifications
Procedure	Numbered steps someone else could follow
Observations	Tables with units, and diagrams of the set-up
Calculations	One worked example shown in full, then the rest in a table
Graphs	On graph paper, labelled and titled
Result and conclusion	What you found, and whether it supports the hypothesis
Precautions and sources of error	What you did to keep it fair and what limited accuracy
Bibliography	Books and sources you used

Writing well

- Write the procedure in the past tense: "The coil was connected to the galvanometer."
- Draw labelled diagrams of your apparatus in pencil.
- Keep the theory short and relevant. Two pages of copied theory add nothing.

- The conclusion must come from your readings. "Vitamin C content fell from 48 mg to 32 mg per 100 mL after five minutes of boiling" is far better than "Vitamin C is destroyed by heat."

EXAMPLE

A bibliography entry can look like this: Author's surname, initials. Title of book. Publisher, year, pages used. Use the same style for every entry.

REMEMBER

Copying text from websites or a senior's file is easy to detect and hard to defend. Write every line yourself.

CHAPTER 10

Facing the viva

The viva voce, or viva, is a short oral test. The examiner asks about your project to check that you did it and understood it. It is a conversation, not an attack.

How to prepare

1. Read your own report twice, aloud.
2. Be able to explain the theory with a simple diagram on rough paper.
3. Know why you chose each value, each instrument and each precaution.
4. Ask a friend or parent to question you for ten minutes.

Questions you are likely to be asked

Question	What a good answer includes
Why did you choose this topic?	A real reason: curiosity, a news story, something at home
What is your independent variable?	Name it, and the dependent and controlled variables
Why did you repeat readings?	To reduce random error and check reliability

Question	What a good answer includes
What is the least count of this instrument?	The number, with its unit
Which reading are you least sure of, and why?	Honest and specific
What would you change if you did it again?	A sensible improvement, such as a better instrument or more values
What is the practical use of your result?	A real-life link, such as food safety or a better power supply

TIP

If you do not know an answer, say so calmly, then say how you would find out. "I am not sure, but I would check it by repeating the test at a fixed temperature" shows scientific thinking.

On the day

- Carry your report, rough notebook and any small apparatus your teacher allows.
- Speak slowly and look at the examiner.
- Use the words from your project: hypothesis, variable, end point, least count.

TRY THIS

Explain your whole project in exactly two minutes, using a watch. This is often the examiner's first request, and a confident start sets the tone for the rest.

CHECK YOURSELF

Practice questions

1. How is an investigatory project different from a working model?
2. Turn the broad topic "magnets" into a measurable question.
3. Write a hypothesis for "How does temperature affect the rate of fermentation?"

4. Name the independent, dependent and controlled variables in the pH and germination project.
5. Why should each reading be taken at least three times?
6. How does the resistance of an LDR change as light intensity increases?
7. Why is a galvanometer not ideal for studying the effect of a magnet's speed on induced emf?
8. How can a 9 V battery show the working of a bridge rectifier without AC?
9. What is the frequency of the ripple from a full-wave rectifier when the input is 50 Hz?
10. Why must students never feed a mains transformer through its low-voltage winding?
11. A transformer has an input of 3.0 W and an output of 2.1 W. Find its efficiency.
12. What is the end point in the iodine titration for vitamin C?
13. 10 mL of standard solution containing 10 mg vitamin C needs 10.0 mL of iodine. 10 mL of juice needs 4.5 mL. Find the vitamin C in 100 mL of juice.
14. Why does soap produce less foam in hard water?
15. Why is the casein you collect called "crude casein"?
16. Why should students not grow bacteria on agar plates for an antibiotic project?
17. Define mitotic index.
18. State two rules for drawing a good graph.
19. What is the difference between a systematic error and a random error?
20. Length = 20.0 ± 0.1 cm and width = 10.0 ± 0.1 cm. Find the percentage error in the area.
21. Why should "human error" not be written as a source of error?
22. Give three questions you are likely to face in a viva.

Answers

1. A working model shows how something works, while an investigatory project asks a question and answers it with planned measurements, readings and a conclusion.
2. For example: "How does the number of turns in a coil affect the strength of an electromagnet, measured by the number of pins it lifts?"
3. If the temperature is raised from cool to warm, then the rate of fermentation will increase, because yeast enzymes work faster when warm, up to a point beyond which heat damages them.
4. Independent: pH of the solution.
Dependent: number of seeds germinated and radicle length. Controlled: type and number of seeds, volume of solution, temperature, light and time.
5. Repeats reduce the effect of random errors when you take the mean, and they show whether your results are reliable.
6. The resistance falls as light intensity increases.
7. For a quick pulse, the galvanometer's swing depends on the total charge that flows, which changes little with speed, so it does not show the peak emf.
8. Connect the battery to the bridge input one way and then the other. The load LED glows both times, showing that the output current through the load always flows the same way.
9. 100 Hz, which is twice the input frequency.
10. The other winding then steps the voltage up to a dangerous high level.
11. Efficiency = $2.1 \div 3.0 \times 100 = 70\%$.
12. The first permanent blue-black colour, which appears when all the vitamin C has reacted and extra iodine meets the starch indicator.
13. Vitamin C in 10 mL = $4.5 \div 10.0 \times 10 = 4.5$ mg, so 100 mL contains 45 mg.
14. Calcium and magnesium salts in hard water react with soap to form insoluble scum, so less soap is left to make foam.
15. The curd also traps some milk fat and other substances, so it is not pure casein.
16. You cannot tell harmful microbes from harmless ones by sight, the plate multiplies them to huge numbers, and safe disposal needs special equipment.
17. Mitotic index is the number of dividing cells divided by the total number of cells counted, multiplied by 100.

- 18.** Any two of these: put the independent variable on the x-axis; label axes with quantity and unit; use a scale that fills more than half the sheet; draw a best-fit line rather than joining the dots.
- 19.** A systematic error pushes every reading in the same direction and is not removed by repeating. A random error scatters readings both ways and is reduced by averaging repeats.
- 20.** Relative errors add: $0.1/20.0 + 0.1/10.0 = 0.005 + 0.010 = 0.015$, so the percentage error is 1.5%.
- 21.** It is too vague. A good report names the actual cause, such as parallax or a change in temperature, and says how it was reduced.
- 22.** Any three, such as: why you chose the topic; what your variables were; why you repeated readings; what the least count of your instrument is; what you would improve.

WORD LIST

Glossary

Investigatory project

a small scientific study in which you ask a question and answer it with planned measurements.

Aim

one sentence stating what you will investigate.

Hypothesis

a testable prediction with a reason, often written as "if ... then ... because ...".

Independent variable

the one factor you change on purpose.

Dependent variable

the factor you measure to see the effect.

Controlled variables

the factors you keep the same so the test is fair.

Fair test

an experiment in which only the independent variable changes.

Mean

the average of repeated readings.

LDR

a light dependent resistor, whose resistance falls as light increases.

Emf

electromotive force, the "push" that drives current in a circuit, measured in volts.

Rectifier

a circuit that changes alternating current into direct current.

Ripple

the small leftover variation in the output of a rectifier.

Truth table

a table listing every input combination of a logic gate and its output.

Refractive index

a number that shows how much a material bends light.

Titration

adding one solution to another, step by step, until a reaction is just complete.

End point

the moment in a titration when a colour change shows the reaction is complete.

Adulterant

a cheaper or harmful substance mixed into food.

Fermentation

the breakdown of sugar by yeast, without oxygen, into alcohol and carbon dioxide.

Casein

the main protein in milk, which separates as curd in mild acid.

Zone of inhibition

a clear ring around an antibiotic disc where bacteria could not grow.

Mitotic index

the percentage of cells in a sample that are dividing.

Least count

the smallest value an instrument can measure.

Systematic error

an error that shifts every reading in the same direction.

Random error

an error that scatters readings above and below the true value.

Viva

a short oral test about your project.



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