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FREE EBOOK

SCIENCE PROJECTS AND KITS

Physics Working Models Explained

Twenty classic models, how each works and how to make it

INSIDE THIS BOOK

- Before you start
- Motors, generators and electromagnets
- Bells, transformers and floating magnets
- Light and mirrors
- Swings, collisions and sound
- ...and 4 more chapters, practice questions and a glossary

Beginner to intermediate
Students of class 6 to 12

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Physics Working Models Explained

Twenty classic physics models, from the electric motor and periscope to the hydraulic lift and water level indicator. For each one you get the principle, a materials list, safe step-by-step making instructions using cells and batteries only, a simple way to explain it, and the viva questions examiners like to ask, with answers.

WHO IT IS FOR	Students of class 6 to 12
LEVEL	Beginner to intermediate
SUBJECT AREA	Science projects and kits
WHAT IS INSIDE	9 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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Before you start

A **working model** is a model that does something when you use it: it turns, lights up, rings, lifts or shows an effect. This book explains twenty classic physics models. Each one is set out the same way:

- **Principle:** the science idea that makes it work.
- **You need:** the materials.
- **How to make it:** numbered steps.
- **How to explain it:** what to say to a teacher or judge.
- **Viva questions:** questions examiners often ask, with short answers.

Safety rules for every model

1. Use only cells and batteries, up to 12 V. Never connect any model to a wall socket, and never open a mains appliance.
2. An adult must handle soldering, hot glue guns, sharp cutters, glass and anything hot. Younger students should always work with an adult beside them.
3. A wire joined straight across a cell, with nothing else in the circuit, is a **short circuit**. The wire and the cell get hot and the cell runs down fast. Disconnect circuits when you are not testing them.
4. An LED (light emitting diode) needs a resistor in series with it on a 9 V battery, or it burns out. A 1 k Ω (one kilo-ohm) resistor is a safe choice.
5. Strong magnets can pinch fingers. Keep small magnets away from young children, who might swallow them, and away from phones and bank cards.

A basic toolkit

Tool or material	Used for
Scissors and a ruler	Cutting and measuring card and wire
Sandpaper	Scraping the coating off enamelled wire

Tool or material	Used for
Cello tape and insulation tape	Holding parts and covering bare joints
Fevicol or other white glue	Joining card and wood
Cell holders and a 9 V battery clip	Connecting cells safely
Connecting wires with crocodile clips	Quick, solder-free joints
A multimeter (optional)	Measuring voltage and checking connections

Many parts come from home: old toys give motors, shoeboxes give bodies, and empty thread reels make pulleys. Electronics shops sell LEDs, resistors, buzzers and transistors for a few rupees each.

EXAMPLE

Simran from Ludhiana planned three models for her school fair. She bought a 9 V battery and clip (! 45), five LEDs and five resistors (! 25), enamelled copper wire (! 40) and two ceramic magnets (! 30). Everything else came from home. Her total was ! 140.

REMEMBER

A model that works every time is better than a bigger one that works now and then. Test each model at least ten times before you show it.

CHAPTER 2

Motors, generators and electromagnets

These three models show the link between electricity and magnetism.

Simple electric motor

Principle: A wire carrying a current in a magnetic field feels a force. Here the force makes a coil spin.

You need: about 1 metre of thin enamelled copper wire, a 1.5 V D cell, two large safety pins, a thick rubber band, a strong round ceramic magnet and a piece of sandpaper.

How to make it:

1. Wind the wire about 20 times around a marker pen. Slide the coil off and wrap each free end twice round the coil to hold it. Leave 3 cm of straight wire on each side.
2. Sand all the coating off one straight end.
3. Stand the coil upright like a wheel and sand only the top half of the other end.
4. Lay the cell on its side. Hold a safety pin against each end with the rubber band, eyes at the top.
5. Put the magnet on top of the cell and rest the coil in the eyes of the pins. Give it a gentle spin.

How to explain it: "Current flows through the coil, and the magnet's field pushes on it. The half-scraped end switches the current off for half of each turn, so the coil is not pushed backwards and keeps spinning."

Viva questions: What energy change happens? Electrical energy becomes the energy of movement. What would make it spin the other way? Turning the cell round, or turning the magnet over.

Electric generator (dynamo)

Principle: Electromagnetic induction. When a coil turns in a magnetic field, a voltage is produced in the coil.

You need: a small toy DC motor (the kind in toy cars), a red LED, two wires, and string or a small fan blade for the shaft.

How to make it:

1. Connect the LED's two legs to the motor's two terminals.
2. Wind string tightly around the motor shaft, or fit a fan blade on it.
3. Pull the string sharply, or blow hard on the blade, so the shaft spins fast.
4. If the LED does not glow, spin it the other way. An LED lights in one direction only.

How to explain it: "A motor and a generator are the same machine used in opposite ways. When I spin the shaft, the coil inside turns past magnets, a voltage is made, and the LED lights."

Viva questions: Why does faster spinning give a brighter light? The magnetic field through the coil changes faster, so the voltage is higher. Where are generators used? In power stations, wind turbines and bicycle dynamos.

Electromagnet

Principle: A current in a coil of wire makes a magnetic field. An iron core inside the coil makes it much stronger.

You need: a large iron nail or bolt, about 2 metres of thin insulated copper wire, a 1.5 V cell in a holder, a push switch and a box of steel pins or paper clips.

How to make it:

1. Leave 15 cm of wire free, then wind 50 neat turns along the nail, all in the same direction.
2. Remove the coating from the two wire ends and join them to the cell through the switch.
3. Press the switch and count the pins the nail head picks up. Release it and watch them fall.
4. Add 50 more turns and test again.

How to explain it: "The nail is a magnet only while current flows. More turns make a stronger magnet."

Viva questions: Why release the switch quickly? The coil is nearly a short circuit, so it heats and drains the cell. Why do some pins stay stuck after the current stops? Most nails are steel, which keeps a little magnetism; a soft iron core loses it almost completely.

TRY THIS

Record the pins picked up with 50, 100 and 150 turns in a table. A simple table of results turns a model into a small investigation.

Bells, transformers and floating magnets

Electric bell

Principle: An electromagnet that switches itself on and off very quickly makes a hammer strike a gong again and again. This is called a **make-and-break** circuit.

You need: an iron bolt wound with about 100 turns of insulated wire, a springy steel strip (cut by an adult from a clean tin, with the edges filed smooth), a small screw as a contact, a nut stuck to the strip as a hammer, a small steel bowl as the gong, a wooden base, three or four AA cells in a holder, a push switch and wires.

How to make it:

1. Fix the bolt upright on the base. Fix one end of the steel strip so its free end hangs just in front of the bolt head.
2. Place the bowl so the hammer just touches it when the strip is pulled towards the bolt.
3. Fix the contact screw so its tip rests lightly against the back of the strip.
4. Wire it in one loop: cells, switch, coil, contact screw, strip and back to the cells.
5. Press the switch and adjust the contact screw until the bell rings.

How to explain it: "Current makes the bolt a magnet, which pulls the strip and strikes the gong. That pulls the strip off the contact screw, so the current stops, the magnet lets go and the strip springs back. The contact closes again and the cycle repeats many times a second."

Viva questions: Why is the strip made of steel? It must be attracted by the magnet and springy enough to return. Are the tiny sparks dangerous? Not at this low voltage, but they slowly wear the contact.

Step-down transformer

Principle: Mutual induction. A changing current in one coil makes a changing magnetic field, which produces a voltage in a second coil wound on the same iron core.

You need: a closed iron core (a U-core and bar from a lab kit is best), thin enamelled copper wire, a sealed plug-in adapter whose label says **AC output, 12 V or less**, a 1.5 V torch bulb in a holder, and a multimeter if you have one.

How to make it:

1. Wind 300 turns on one side of the core. This is the **primary coil**.
2. Wind 30 turns on the other side. This is the **secondary coil**.
3. Join the bulb to the secondary coil.
4. Join the adapter's output wires to the primary. An adult plugs the adapter in, watches it, and switches off after a few seconds.

How to explain it: "The secondary has one tenth of the turns of the primary, so its voltage is about one tenth. From 12 V AC in, about 1.2 V comes out, which lights the torch bulb."

Viva questions: Why will a battery not work? A battery gives steady DC, which makes a steady field; a transformer needs a changing field. Why is the core made of thin sheets? It cuts down wasted currents in the core called eddy currents.

SAFETY

Never connect any part of this model to a wall socket, and never use an adapter whose output label says DC or more than 12 V. If the adapter or the coil gets warm, unplug at once. Students do not plug in or unplug the adapter; an adult does.

Magnetic levitation idea

Principle: Like poles of magnets repel each other. The push can be strong enough to hold a magnet up in the air.

You need: four or five ring magnets, a pencil or wooden dowel, and a small block of wood with a hole for the pencil.

How to make it:

1. Fix the pencil upright in the block.
2. Slide the magnets on one at a time, each turned so it repels the one below.
3. Watch them float, one above another. Press down gently and feel them push back.

How to explain it: "Each magnet floats where the push from below balances its weight. The pencil stops the magnets from flipping over and snapping together. Maglev trains use powerful electromagnets to lift the train just above its track, so there is no wheel friction."

Viva questions: Why are the gaps smaller near the bottom? The lower magnets carry the weight of all the magnets above them. Why are maglev trains rare? Their special tracks are very costly to build.

CHAPTER 4

Light and mirrors

Light travels in straight lines and bounces off shiny surfaces. These four models show both ideas.

Laws of reflection

Principle: When light reflects from a mirror, the angle of incidence equals the angle of reflection. The incident ray, the reflected ray and the **normal** (a line at 90° to the mirror) all lie in the same plane.

You need: a small plane mirror held upright in a block of wood or clay, white chart paper on a board, a protractor, a pencil and a torch with black paper over the front, cut with a narrow slit.

How to make it:

1. Stand the mirror on a line drawn on the paper. Draw the normal at 90° to the mirror.
2. In a dim room, shine the slit beam at the mirror at 30° to the normal. Mark the incoming and reflected rays with dots.
3. Join the dots and measure both angles. Repeat at 45° and 60° .

Angle of incidence	Angle of reflection (example readings)
30°	30°
45°	46°

Angle of incidence	Angle of reflection (example readings)
60°	60°

How to explain it: "Whatever angle the light comes in at, it leaves at the same angle on the other side of the normal. Small differences come from the width of the beam."

Viva questions: A ray makes 40° with the mirror surface. What is the angle of incidence? 50°, because angles are measured from the normal. Why not use a laser pointer? It can damage the eyes; a torch slit is safer.

Periscope

Principle: Two plane mirrors, parallel to each other and each at 45°, turn light through 90° twice, so you can see over a wall.

You need: a long box (two juice cartons taped end to end work well), two small mirrors (acrylic mirror sheet is safer than glass), tape and a cutter for the adult.

How to make it:

1. An adult cuts a square window near the top on the front, and another near the bottom on the back.
2. Fix the top mirror at 45° behind the top window, facing down.
3. Fix the bottom mirror at 45° behind the bottom window, facing up, parallel to the first.
4. Look into the bottom window and adjust until you see clearly.

How to explain it: "Light enters the top window, reflects down the tube from the first mirror and out to my eye from the second."

Viva questions: Is the image upright? Yes, and it is not swapped left to right, because the two reflections cancel out. Where are periscopes used? In submarines and armoured vehicles.

Kaleidoscope

Principle: Mirrors placed at an angle make many reflections of reflections, which form beautiful repeating patterns.

You need: three identical strips of acrylic mirror sheet or mirror card (about 20 cm by 4 cm), a card tube, tape, coloured plastic beads or sequins, two discs of clear plastic and a disc of tracing paper.

How to make it:

1. Tape the three strips into a triangular prism with the shiny sides inwards.
2. Slide the prism into the tube.
3. At one end, trap the beads loosely between the two clear discs, with tracing paper outside to let in soft light.
4. Cover the other end with card that has a small eyehole.
5. Look through it at a bright window and turn the tube.

How to explain it: "The three mirrors meet at 60° . Each reflects the beads and the other mirrors' reflections, so one small pattern repeats all round the circle."

Viva questions: How many images do two mirrors at 60° give? Five, from the rule $360 \div \text{angle} - 1$. Why do the patterns change? Turning the tube moves the beads, and every reflection moves with them.

Pinhole camera

Principle: Light travels in straight lines. Rays from the top of an object pass through a tiny hole and land at the bottom of the screen, so the image is upside down.

You need: a shoebox or two card tubes that slide into each other, black paper, aluminium foil, a pin, tracing paper and a dark cloth.

How to make it:

1. Cover one end with foil and make a single neat pinhole in its centre.
2. Cover the other end, or the inner tube's end, with tracing paper as a screen.
3. Paint or line the inside black.
4. Point the hole at a bright scene, such as a window. Cover your head and the screen end with the cloth and look at the screen.

How to explain it: "The image is upside down and swapped left to right, because light crosses over at the pinhole."

Viva questions: What happens with a bigger hole? The image is brighter but more blurred. What happens if you make two holes? You see two images.

SAFETY

Never point a pinhole camera, periscope or mirror at the Sun, and never look at the Sun through anything. It can damage your eyes permanently.

CHAPTER 5

Swings, collisions and sound

Simple pendulum

Principle: A pendulum's time for one complete swing, called its **time period**, depends on its length, not on the mass of the bob or on the size of a small swing.

You need: strong thread, a metal nut or bob, a stand or hook, a metre scale and a stopwatch.

How to make it:

1. Hang the bob so the length from the hook to the centre of the bob is 100 cm.
2. Pull it a little to one side, about a hand's width, and let go.
3. Time 20 complete swings (there and back). Divide by 20.
4. Repeat with lengths of 50 cm and 25 cm.

Length	Time period (approximate)
100 cm	2.0 s
50 cm	1.4 s
25 cm	1.0 s

How to explain it: "Making the pendulum four times longer doubles its time period. Changing the bob's mass makes no difference."

Viva questions: Why time 20 swings, not one? The small error in starting and stopping the watch is shared over 20 swings, so the result is more exact. What is the formula for older classes? $T = 2\pi\sqrt{L/g}$, where L is the length and g is the acceleration due to gravity, about 9.8 m/s^2 .

Newton's cradle

Principle: When moving balls collide, their momentum (mass multiplied by speed) and energy pass from ball to ball.

You need: five identical steel balls or marbles, a frame made from wooden rods or ice-cream sticks, thread and hot glue (used by an adult).

How to make it:

1. Build a frame with two parallel top rods.
2. Hang each ball from both rods with two threads in a V shape, so it can swing in one line only.
3. Adjust the threads until all the balls hang at the same height, just touching in a straight row.
4. Lift the end ball and let it go.

How to explain it: "When one ball hits the row, one ball flies out at the other end. Lift two, and two fly out. The momentum and energy pass through the middle balls."

Viva questions: Why does it stop after a while? Some energy is lost as sound, as heat and to air resistance at every hit. Why must the balls be identical? Different masses pass on the momentum unevenly and the neat pattern is lost.

Sound vibrations

Principle: Every sound is made by something vibrating. Faster vibration gives a higher **pitch**; bigger vibration gives a louder sound.

You need: a bowl, a piece of plastic sheet or a balloon, a rubber band, a pinch of dry rice, a steel plate and spoon, a 30 cm ruler and some rubber bands of different thickness.

How to make it:

1. Stretch the plastic tightly over the bowl with a rubber band to make a drum. Sprinkle rice on it.
2. Bang the steel plate near the drum. The rice jumps.
3. Hold a ruler on the table edge, twang the free end, then shorten the overhang and twang again.
4. Stretch thin and thick rubber bands over an open box and pluck them.

How to explain it: "The sound from the plate makes the air vibrate, and the air shakes the drum. A shorter ruler and a thinner, tighter band vibrate faster, so their pitch is higher."

Viva questions: Can sound travel through space? No. Sound needs a material such as air, water or a solid to travel through. What is the unit of frequency? The hertz (Hz), meaning one vibration per second. Most people hear from about 20 Hz to about 20,000 Hz.

DID YOU KNOW

In air, sound travels at roughly 340 metres per second. Light is so much faster that you see lightning before you hear its thunder.

CHAPTER 6

Simple machines

A **simple machine** makes work easier by changing the size or direction of a force. You never get something for nothing: a smaller effort means moving through a longer distance.

Lever types

Principle: A lever balances when $\text{effort} \times \text{effort arm} = \text{load} \times \text{load arm}$. Each arm is measured from the **fulcrum**, the point the lever turns on.

You need: a 30 cm ruler, a pencil as a fulcrum, and some identical ! 1 coins.

How to make it:

1. Rest the ruler on the pencil at its centre.
2. Put 4 coins at 5 cm from the centre on one side. Place 2 coins on the other side and slide them until the ruler balances. They balance at about 10 cm, because $4 \times 5 = 2 \times 10$.
3. Make cards showing the three classes, with real objects beside each.

Class	What is in the middle	Everyday examples
First	Fulcrum	See-saw, scissors, pliers
Second	Load	Nutcracker, wheelbarrow, bottle opener
Third	Effort	Chimta (kitchen tongs), tweezers, your forearm

How to explain it: "A long effort arm lets a small effort lift a big load. Third-class levers need more effort, but move the load further and faster."

Viva questions: Which class always needs more effort than the load? The third class. Which class always needs less effort? The second class.

Pulley system

Principle: A fixed pulley changes the direction of a force. A movable pulley halves the effort needed, if friction is ignored, but you pull twice as much rope.

You need: two or three empty thread reels, wire from a coat hanger as axles, strong string, a small cup with coins as the load, and a rubber band or spring balance to compare the pull.

How to make it:

1. Hang one reel on a fixed axle. Pass string over it to the cup. Pull down and the cup goes up.
2. Hang a second reel on the cup, so the cup hangs from a loop of string that passes under it. Tie one end of the string to the frame and pull up on the other end.
3. Compare the stretch of the rubber band in each case.

How to explain it: "With a movable pulley, two lengths of string hold the load, so each carries about half. In real life friction makes the effort a little more than half."

Viva questions: Why is a fixed pulley useful if it saves no effort? Pulling down is easier than lifting up, as at a village well. What decides the effort saved? The number of string lengths holding up the load.

Hydraulic lift

Principle: Pascal's law: pressure applied to a liquid in a closed system passes equally in all directions.

You need: two plastic syringes without needles (one small, one large), 30 cm of plastic tube that fits both nozzles tightly, water with a drop of food colour, and card or ice-cream sticks for a platform.

How to make it:

1. Fill the small syringe with water. Push the large syringe's piston fully in.
2. Hold both nozzles and the tube under water and join them, so no air gets in.
3. Fix the large syringe upright with a card platform on its piston.
4. Push the small piston. The platform rises.

How to explain it: "The pressure is the same everywhere in the water. The large piston has a bigger area, so the same pressure gives it a bigger force. It moves a shorter distance than the small one."

Viva questions: Why must there be no air in the tube? Air squashes, so the lift feels spongy. Where is this used? In car lifts at service stations, vehicle brakes and excavators.

TIP

Ask for needle-free syringes at a chemist. Join two pairs of syringes to the same arm and you have a hydraulic arm, like the arm of an excavator.

Energy from the sun and wind

Solar water heater

Principle: Black surfaces absorb sunlight and turn it into heat. Warm water is lighter than cold water, so it rises, and the water circulates on its own.

You need: a shallow box painted black inside, 2 to 3 metres of thin black rubber or plastic tube, a sheet of clear plastic, thermocol, a plastic bottle as a tank, glue, tape and a thermometer.

How to make it:

1. Line the bottom of the box with thermocol. Lay the tube in a zigzag on top and fix it.
2. Cover the box with the clear plastic, sealed with tape.
3. Fix the bottle tank higher than the box. Join the lower end of the tube to the bottom of the tank, and the upper end of the tube to the upper part of the tank.
4. Fill with water and remove air bubbles. Place it in strong sunlight, tilted towards the Sun.
5. Measure the tank's temperature every 15 minutes for an hour.

How to explain it: "The black tube absorbs sunlight and heats the water inside it. The warm water rises into the tank and cold water flows down to take its place. The plastic cover traps heat, and the thermocol stops it escaping from below."

Viva questions: Why must the tank be higher than the box? Warm water rises, so it must have somewhere higher to go. Where are real solar water heaters used? On the roofs of many homes, hostels and hotels.

TRY THIS

If the water circulates too slowly in your model, do a simpler test as well: fill two identical bottles with water, paint one black, leave both in the sun for an hour and compare their temperatures.

Wind turbine

Principle: Moving air has energy. The blades turn that energy into rotation, and a generator turns the rotation into electricity.

You need: a small toy DC motor, three blades cut from a plastic bottle or stiff card, a bottle cap as a hub, a red LED, wires, a tall tube or stick as a tower, and hot glue (used by an adult).

How to make it:

1. An adult glues the cap firmly to the motor shaft.
2. Fix the three blades evenly round the cap, each twisted at a slight angle, like a fan's blades.
3. Mount the motor on top of the tower and connect the LED to its terminals.
4. Test it in front of a table fan that an adult switches on, or outdoors on a windy day. If the LED does not glow, swap its legs.

How to explain it: "The wind pushes on the angled blades and turns the shaft. The motor works as a generator and lights the LED."

Viva questions: Why are blades set at an angle? So the wind's push turns them sideways instead of just pushing them backwards. What happens if the wind speed doubles? The power available rises about eight times, which is why turbines are built where winds are strong.

CHAPTER 8

Alarm circuits

Both of these models use a 9 V battery. Keep the battery and the circuit board dry and away from any water.

Burglar alarm

Principle: A buzzer sounds when a circuit is completed. Opening a door completes the circuit.

You need: a wooden clothes peg, two drawing pins, a strip of plastic or thick card, thread, a 9 V battery and clip, a buzzer rated for 9 V, and wires.

How to make it:

1. Push a drawing pin into the inside of each jaw of the peg so the pin heads touch when the peg closes.
2. Wind a bare wire end around each pin. Join one to the battery and the other to the buzzer, and the buzzer to the battery's other terminal.
3. Slip the plastic strip between the jaws. The buzzer stays silent.
4. Tie the strip to the door with thread, and fix the peg to the door frame.
5. Open the door. The strip is pulled out, the pins touch, and the buzzer sounds.

How to explain it: "The plastic strip is an insulator, so it keeps the circuit open. When the door pulls it out, the pins touch, the circuit is complete and the buzzer sounds."

Viva questions: What is the difference between an open and a closed circuit? Current flows only in a closed circuit, with no gaps. How could you improve it? Add an on/off switch, or use a magnetic switch called a reed switch with a magnet on the door.

Water level indicator

Principle: Water from a tap conducts a small current because of the substances dissolved in it. That small current can switch on a transistor, which then lights an LED.

You need: a clear plastic bottle, four stainless steel screws or wires as probes, three BC547 transistors, three LEDs, six 1 k Ω resistors, a 9 V battery and clip, a small circuit board and wires.

Connection	Where it goes
Bottom probe (common)	Battery positive (+)
Each upper probe (low, middle, high)	Through a 1 k Ω resistor to one transistor's base
Each transistor's emitter	Battery negative (-)

Connection	Where it goes
Each transistor's collector	LED's short leg; the LED's long leg goes through a 1 k Ω resistor to battery positive

How to make it:

1. Fix the common probe at the bottom of the bottle, and the other three at low, middle and high levels.
2. Build the circuit on the board as in the table. Check each transistor's pin order on its datasheet; for most BC547s, with the flat face towards you and legs down, it is collector, base, emitter.
3. Pour water in slowly. The LEDs light one by one as the water reaches each probe.

How to explain it: "When the water reaches a probe, a tiny current flows from the bottom probe, through the water, into a transistor's base. The transistor switches on and its LED lights."

Viva questions: Why use stainless steel probes? Ordinary metal corrodes quickly in water when a current flows. Why is a transistor needed? The current through water is too small to light an LED by itself.

SAFETY

Never connect this circuit to a mains-powered water pump or any wall socket. It is a battery-only model.

CHAPTER 9

Presenting your model

A good model needs a good presentation. Judges usually spend only a few minutes at each table.

Set up the table

- Put the model in the centre, with its working parts facing the visitor.
- Label each part with a small, neat card.

- Stand a chart behind it with the title, the principle, a labelled diagram and two real-life uses.
- Keep spare cells, wire and tape out of sight but within reach.

Explain in three steps

1. **What it is:** "This is a hydraulic lift."
2. **How it works:** the principle in one or two sentences, while you point at the parts and show it working.
3. **Where it is used:** two real examples.

Then stop and let the judge ask questions. Use the viva questions in this book to practise.

When something stops working

Problem	Likely cause	What to try
Motor coil will not spin	Enamel not fully scraped, or a flat cell	Sand the ends again; change the cell
LED does not light	Legs reversed, or LED burnt out	Swap the legs; try a new LED with its resistor
Electromagnet is weak	Loose turns or a weak cell	Wind the turns closer; use a fresh cell
Hydraulic lift feels spongy	Air bubbles in the tube	Refill under water
Pinhole image too dim	Too much stray light	Cover your head and the screen with a dark cloth
Bell buzzes but does not ring	Gong too far from the hammer	Move the bowl closer

REMEMBER

Be honest about what you made yourself and what an adult helped with. Judges value a student who understands a simple model far more than one who cannot explain a complicated one.

Practice questions

1. What is the highest battery voltage used for the models in this book, and what must you never connect a model to?
2. Why does an LED need a resistor when used with a 9 V battery?
3. In the simple motor, why is one end of the wire scraped only on its top half?
4. How can a toy motor be used as a generator?
5. Give two ways to make an electromagnet stronger.
6. What is a make-and-break circuit, and which model uses one?
7. A transformer has 300 turns on its primary and 30 on its secondary. If 12 V AC is fed in, about what voltage comes out?
8. Why does a transformer not work with a battery?
9. Why do ring magnets on a pencil float above each other?
10. State the two laws of reflection.
11. A ray makes an angle of 25° with a mirror surface. What is the angle of incidence?
12. How many images are formed by two mirrors at 60° to each other?
13. Why is the image in a pinhole camera upside down?
14. A pendulum 25 cm long has a time period of about 1 second. About how long must it be to have a period of 2 seconds?
15. Why does a Newton's cradle eventually stop?
16. Why can sound not travel through space?
17. Name the three classes of lever and give one example of each.
18. Four coins sit 6 cm from the fulcrum. Where must three coins be placed on the other side to balance them?

19. What does a fixed pulley do, and what does a movable pulley do?
20. State Pascal's law.
21. Why is the tank of a solar water heater placed higher than the collector?
22. In the burglar alarm, what job does the plastic strip do?
23. Why does the water level indicator need transistors?

ANSWER KEY

Answers

1. 12 V. Never connect a model to a wall socket or the mains.
2. Without a resistor, too much current flows and the LED burns out.
3. So the current flows for only half of each turn. The coil is not pushed backwards in the other half, so it keeps spinning.
4. Connect an LED to its terminals and spin its shaft fast. The spinning coil inside produces a voltage by electromagnetic induction.
5. Any two of: more turns of wire, more current, a soft iron core.
6. A circuit that keeps switching itself on and off, because the moving part breaks the contact each time it moves. The electric bell uses one.
7. About 1.2 V, because the secondary has one tenth of the primary's turns.
8. A battery gives steady DC, which makes a steady magnetic field. A transformer needs a changing field to induce a voltage.
9. Each magnet faces its neighbour with like poles, which repel. Each floats where the push balances its weight.
10. The angle of incidence equals the angle of reflection; and the incident ray, the reflected ray and the normal lie in the same plane.
11. 65° , because $90^\circ - 25^\circ = 65^\circ$, measured from the normal.
12. Five, because $360 \div 60 - 1 = 5$.
13. Light travels in straight lines, so rays from the top of the object pass through the hole and land at the bottom of the screen, and rays from the bottom land at the top.
14. About 100 cm, because four times the length doubles the time period.

15. At every collision some energy is lost as sound and heat, and air resistance slows the balls.
16. Sound needs a material to travel through, and space has almost none.
17. First class (fulcrum in the middle), such as a see-saw; second class (load in the middle), such as a nutcracker; third class (effort in the middle), such as tongs.
18. At 8 cm, because $4 \times 6 = 24$ and $24 \div 3 = 8$.
19. A fixed pulley changes the direction of the force. A movable pulley roughly halves the effort, but you pull twice as much rope.
20. Pressure applied to a liquid in a closed system passes equally in all directions.
21. Warm water rises, so the hot water from the collector must be able to flow up into the tank.
22. It is an insulator that keeps the two contacts apart, so the circuit stays open until the strip is pulled out.
23. The current through water is too small to light an LED, so it is used to switch on a transistor, which controls a larger current.

WORD LIST

Glossary

Electromagnet

a coil of wire, usually on an iron core, that acts as a magnet only while current flows.

Electromagnetic induction

the production of a voltage in a coil when the magnetic field through it changes.

Fulcrum

the fixed point on which a lever turns.

Generator

a machine that changes the energy of movement into electrical energy.

LED

a light emitting diode, a small light that works in one direction only and needs a resistor.

Make-and-break circuit

a circuit that keeps switching itself on and off, as in an electric bell.

Momentum

the mass of a moving object multiplied by its speed.

Mutual induction

the production of a voltage in one coil by a changing current in another coil nearby.

Normal

a line drawn at 90° to a mirror at the point where a ray strikes it.

Pascal's law

pressure applied to a liquid in a closed system passes equally in all directions.

Pitch

how high or low a sound is; it depends on how fast the source vibrates.

Primary coil

the coil of a transformer that receives the input voltage.

Probe

a metal wire or screw used to sense something, such as water.

Resistor

a part that limits the current in a circuit.

Secondary coil

the coil of a transformer that gives the output voltage.

Short circuit

a path with almost no resistance across a cell or battery, which makes it heat up and run down.

Simple machine

a device, such as a lever or pulley, that makes work easier by changing a force.

Time period

the time a pendulum takes to make one complete swing, there and back.

Transistor

an electronic part that uses a small current to switch or control a larger one.

Working model

a model that does something when used, such as turning, lighting up or lifting.



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