CARR TECHNICAL LEARNING SERIES

# Practical Electrical and Electronic Technology

## YEAR 1

Foundations circuits measurement and introductory electronics

*Original equipment illustration for the CARR illustrated student edition.*

**STUDENT BOOK**

**Original diagrams • Worked solutions • Supervised practicals**

For CSEC preparation and technical institute foundation programmes in Guyana

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ABOUT THIS BOOK

# A practical course for student electricians

This student book develops the electrical knowledge, workshop habits and problem-solving skills needed for secondary technical studies, CSEC preparation and entry-level technical institute programmes in Guyana. Each chapter moves from a clear idea to a worked solution, a diagram, a supervised practical and an independent review.

## Safety boundary

Practical work must be supervised by a qualified instructor. Students must use isolated training supplies or approved extra-low-voltage equipment unless the instructor has established a safe workshop procedure. Students must never work on an energised building installation.

## Originality and examination use

The explanations, worked examples, exercises and diagrams in this book were written and drawn for this course. They do not reproduce CXC past-paper questions or third-party textbook artwork. This book is designed to support study; it does not claim endorsement or authorization by CXC or the Ministry of Education.

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# Use the six-step chapter routine

| 1 Preview | Read the chapter purpose, outcomes and key words. |
| --- | --- |
| 2 Learn | Study each idea in a short section and connect it to the diagram. |
| 3 Follow | Work through each calculation one line at a time. |
| 4 Practise | Complete the practical only with the instructor’s approval. |
| 5 Solve | Attempt the additional problems before checking the method. |
| 6 Review | Complete the chapter questions and explain any error you made. |

## Calculation method

1. Write the quantity required.
2. List the known values with units.
3. Choose the correct relationship.
4. Substitute the values.
5. Calculate and write the final unit.
6. Ask whether the answer is reasonable.

YEAR 1 COURSE MAP

# Chapters and practical focus

| Chapter | Learning focus |
|---|---|
| 01 | Electrical safety and workshop practice<br>Practical: Workshop hazard survey |
| 02 | Tools materials and good workmanship<br>Practical: Prepare and terminate conductors |
| 03 | Electrical quantities units and symbols<br>Practical: Symbol and circuit reading |
| 04 | Measuring voltage current and resistance<br>Practical: Measure a low-voltage lamp circuit |
| 05 | Ohms law and basic DC circuits<br>Practical: Test Ohm’s law |
| 06 | Series circuits<br>Practical: Verify series-circuit rules |
| 07 | Parallel and series parallel circuits<br>Practical: Verify parallel-circuit rules |
| 08 | Electrical power energy efficiency and cost<br>Practical: Measure lamp power |
| 09 | Cells batteries and DC supplies<br>Practical: Compare cells in series |
| 10 | Magnetism electromagnetism and relays<br>Practical: Operate a low-voltage relay |
| 11 | Alternating current fundamentals<br>Practical: Observe safe AC waveforms |
| 12 | Transformers and power transfer<br>Practical: Measure a step-down transformer |
| 13 | Introduction to electronic components<br>Practical: Build an LED indicator |

# Rules that apply throughout the course

- Obtain permission before energising any training circuit.
- Inspect tools, test leads and insulation before use.
- Keep hands dry and remove jewellery before electrical work.
- Isolate, secure and verify dead before touching conductors.
- Use the correct meter function, range and terminal.
- Keep the bench orderly and protect conductors from sharp edges.
- Report damaged equipment, overheating, smoke or unusual smell immediately.
- Know the emergency stop, fire equipment and first-aid procedure.

## Student safety agreement

I understand that practical work is supervised. I will stop when instructions are unclear or when a condition appears unsafe.

Student name ____________________________ Signature ___________________ Date __________

# Electrical safety and workshop practice

Electrical work begins with hazard control, disciplined behaviour and correct emergency action.

**Take this chapter one step at a time. Accuracy grows with careful practice.**

## Learning outcomes

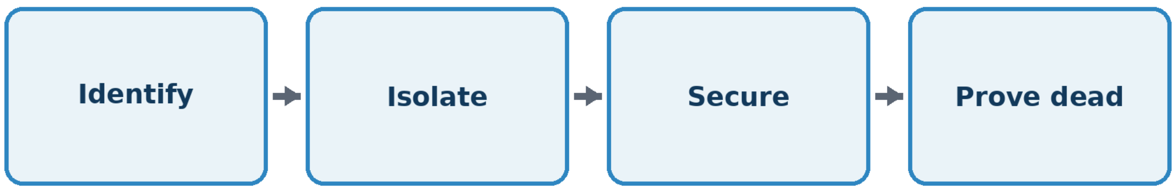
- Distinguish a hazard from a risk.
- Select suitable personal protective equipment.
- Describe safe isolation.
- Respond correctly to common workshop emergencies.

## Key words

| Hazard | A source with the potential to cause harm. |
| --- | --- |
| **Risk** | The likelihood and possible severity of harm. |
| **Isolation** | Separation of equipment from every energy source. |
| **PPE** | Equipment worn to reduce exposure to a hazard. |

# Control hazards before work starts

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

A safe worker identifies the danger before choosing a control. The best control removes the hazard; PPE is a final protective layer.

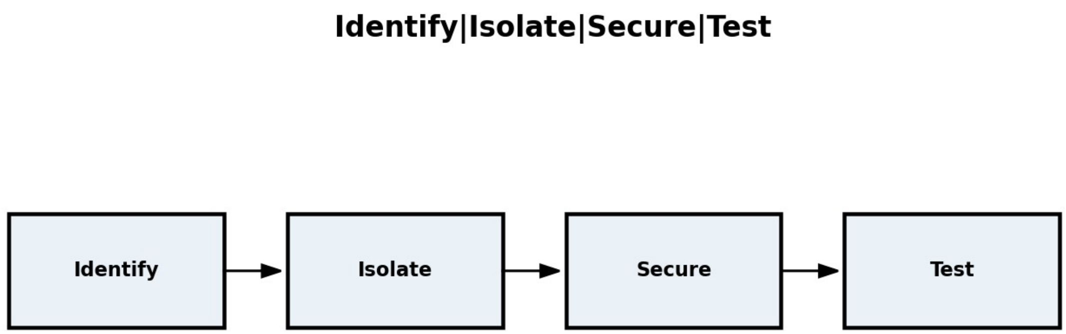
Isolation must prevent accidental reconnection. A warning tag alone is not enough when a lock can be fitted.

Electrical shock may stop breathing or the heart. Do not touch a casualty who is still connected to the supply. Isolate the source and call for trained help.

**Worked example 1** A frayed extension lead still operates a lamp. May it be used?

**Solution** No. Operation does not prove safety. Remove it from service, label it and report the damage.

# A safe sequence




*A safe-isolation sequence reduces the chance of contact with dangerous voltage.*

Identify the correct circuit, inform affected persons, shut down normally, isolate, secure, prove the tester, test for absence of voltage and re-prove the tester.

The sequence matters because a tester can fail and an incorrect isolator can be selected.

**Worked example 2** Why is a test instrument proved before and after testing?

**Solution** The first proof confirms operation. The second proof confirms that the tester did not fail during the test.

# Workshop hazard survey

## Practical sequence

Inspect area → Record hazards → Rank risk → Choose control

Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Identify hazards and recommend controls before practical work begins.

## Equipment

clipboard • pencil • PPE • approved work area

## Method

1. Walk through the area without touching equipment.
2. Record four hazards and the harm each could cause.
3. Rank each risk as low, medium or high using the instructor’s method.
4. Recommend a control and report urgent hazards.

## Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Do not approach exposed live parts, smoke, damaged equipment or wet electrical areas.

# Follow the reasoning

**Worked example 3** A 230 V conductor is touched while standing on a damp floor. What two factors increase danger?

**Solution** The voltage can drive current through the body, and the damp floor lowers resistance and improves the return path.

**Worked example 4** Which control is stronger: gloves or disconnecting the source?

**Solution** Disconnecting and securing the source removes the electrical energy. Gloves only reduce exposure.

**Worked example 5** A small electrical fire begins at a trainer. What is the first action?

**Solution** Raise the alarm and isolate power if this can be done safely. Use only the approved extinguisher and follow the emergency plan.

## Try one without help

Write a safe-isolation sequence for an instructor-approved single-phase trainer. Explain why each step is necessary.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. Define hazard.
2. Define risk.
3. State two reasons for good housekeeping.
4. Why must jewellery be removed?
5. Place the safe-isolation steps in order.
6. State the first action when a person is receiving an electric shock.
7. Name two items of PPE and their limitations.
8. Explain why switching off is not the same as isolation.

## Mini project

Create a one-page safety inspection sheet for your electrical workshop.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Tools materials and good workmanship

Correct tools and sound joints make electrical work safer, quicker and easier to inspect.

**You do not need to solve everything at once. Start with what is known.**

## Learning outcomes

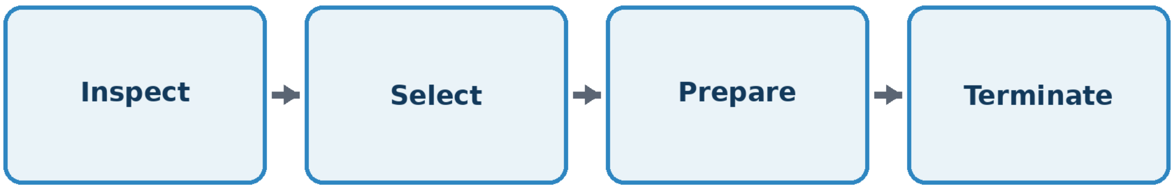
- Identify common hand tools.
- Choose a tool for a stated task.
- Prepare conductors without damage.
- Recognize conductors, insulators and semiconductors.

## Key words

| Conductor | A material that allows charge to move readily. |
|---|---|
| **Insulator** | A material that strongly opposes charge movement. |
| **Termination** | The prepared end connection of a conductor. |
| **Calibration** | Comparison or adjustment to maintain measurement accuracy. |

# Choose and inspect tools

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

Insulated screwdrivers reduce exposure but do not authorize live work. Pliers grip and cut; side cutters are not stripping tools unless designed for that purpose.

A good termination has correct strip length, no cut strands, secure mechanical contact and no exposed copper outside the terminal.

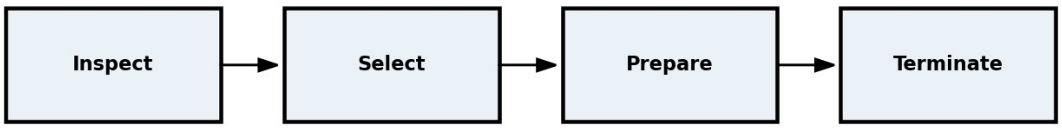
Copper is widely used because it conducts well and can be formed. PVC and similar polymers provide insulation but may be damaged by heat, oil or sharp edges.

**Worked example 1** Which tool should remove insulation from a small copper conductor?

**Solution** Use an adjustable wire stripper sized for the conductor.

# Quality can be inspected

**Inspect|Select|Prepare|Terminate**




*Tool selection and conductor preparation form a simple quality-control process.*

Before use, check handles, jaws, blades, insulation and adjustment. A damaged tool must be removed from service.

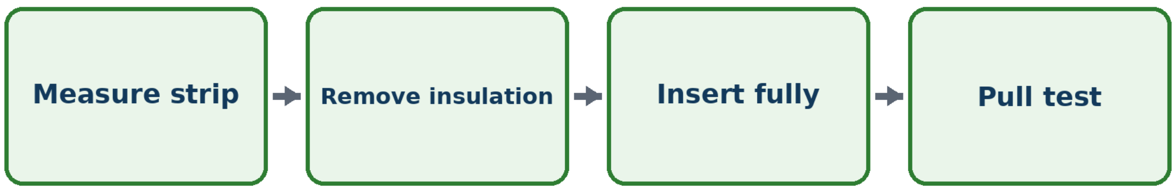
Good workmanship is repeatable. Two students following the same preparation dimensions should produce similar terminations.

**Worked example 2** A screw terminal has copper visible outside it. What is wrong?

> **Solution** The strip length is excessive or the conductor is not fully inserted. Re-terminate it with the supply isolated.

# Prepare and terminate conductors

## Practical sequence




Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Produce three consistent conductor ends and inspect them against a quality checklist.

## Equipment

wire stripper • side cutters • screwdriver • practice cable • terminal block

## Method

1. Confirm the trainer is isolated.
2. Measure the required strip length.
3. Strip without cutting strands.
4. Twist only as instructed and insert fully.
5. Tighten to the instructor’s requirement and perform a gentle pull test.

## Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Use tools only for their intended purpose and keep cutting edges away from the body.

# Follow the reasoning

**Worked example 3** Why should pliers not be used as a hammer?

**Solution** The jaws and pivot can be damaged, creating a tool that grips poorly or fails.

**Worked example 4** A cable has 1 broken strand out of 7. Should it be used?

**Solution** No. The reduced cross-section and uneven clamping can cause heating. Cut back and prepare the end again.

**Worked example 5** Classify copper, PVC and silicon.

**Solution** Copper is a conductor, PVC is an insulator, and silicon is a semiconductor.

## Try one without help

A seven-strand conductor loses two strands during stripping. Explain the electrical and mechanical consequences.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. Name four electrician’s hand tools.
2. State one inspection point for each tool.
3. Why must conductor strands remain intact?
4. What makes a termination mechanically sound?
5. Classify aluminium as conductor or insulator.
6. State two properties of insulation.
7. Explain why tool size matters.
8. Describe a safe pull test.

## Mini project

Make an illustrated tool-identification chart using tools available in your workshop.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Electrical quantities units and symbols

Electrical calculations become manageable when every quantity, symbol and unit is used consistently.

**A wrong answer is useful when you find the step that caused it.**

## Learning outcomes

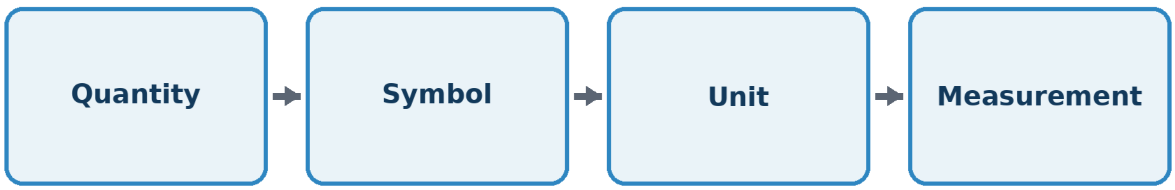
- Match common quantities to symbols and units.
- Convert engineering prefixes.
- Read basic schematic symbols.
- Rearrange simple formulas.

## Key words

| Voltage V | Electrical potential difference measured in volts. |
|---|---|
| **Current I** | Rate of charge flow measured in amperes. |
| **Resistance R** | Opposition to current measured in ohms. |
| **Power P** | Rate of energy transfer measured in watts. |

# Use units carefully

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

The quantity symbol belongs in a formula; the unit follows the numerical answer. For example, current uses I in equations and A after the value.

Prefixes shorten very large or small numbers. One kilo-ohm is 1000 ohms; one milliampere is 0.001 ampere.

A schematic symbol represents a function rather than the physical appearance of a component.

### Relationship to remember

$$1\ \mathrm{k\Omega} = 1000\ \Omega \qquad 1\ \mathrm{mA} = 0.001\ \mathrm{A}$$

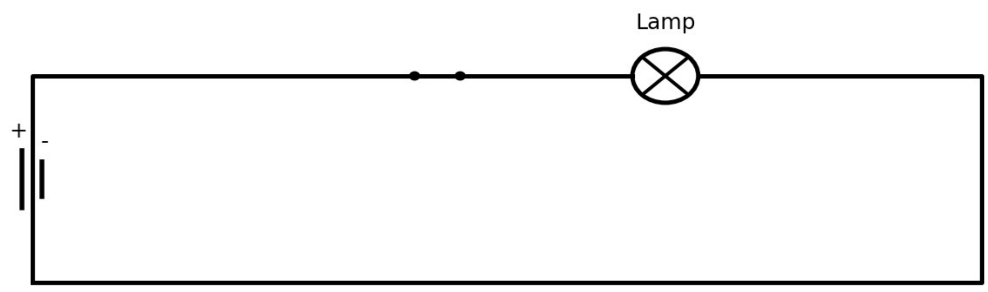
Convert prefixes before substituting values unless the chosen formula and calculator entry use consistent units.

**Worked example 1** Convert 4.7 kΩ to ohms.

**Solution** $4.7 \times 1000 = 4700\ \Omega$.

# Read a simple schematic

**Source switch and lamp circuit**




*The closed loop includes a source, a control device and a load.*

A circuit diagram shows electrical connections. Wires that join normally have a marked junction; crossing lines without a junction are not automatically connected.

Read from the source through control and load, then trace the return path.

**Worked example 2** Convert 250 mA to amperes.

**Solution** 250 ÷ 1000 = 0.250 A.

# Symbol and circuit reading

## Practical sequence

Read symbols → Trace path → Build circuit → Isolate safely

Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Build a low-voltage lamp circuit from a supplied schematic.

### Equipment

extra-low-voltage supply • lamp • switch • leads • symbol sheet

### Method

1. Identify each symbol.
2. Trace the complete current path.
3. Assemble with the supply off.
4. Ask the instructor to inspect.
5. Energise, operate the switch and isolate.

### Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Use only the approved extra-low-voltage supply.

# Follow the reasoning

**Worked example 3** A value is 0.006 A. Express it in milliamperes.

**Solution** 0.006 × 1000 = 6 mA.

**Worked example 4** Which symbol represents resistance in a formula and which unit follows the answer?

**Solution** R represents resistance; Ω follows the numerical answer.

**Worked example 5** A lamp is marked 12 V, 6 W. Identify the two quantities.

**Solution** 12 V is rated voltage and 6 W is rated power.

## Try one without help

Convert 2.2 kΩ, 680 mA and 0.015 MW to base units and show the multiplier used.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. Give the unit of voltage.
2. Give the symbol for current.
3. Convert 3.3 kΩ to ohms.
4. Convert 75 mA to amperes.
5. What does a junction dot show?
6. Distinguish a component symbol from a physical layout.
7. Name the source, control and load in the diagram.
8. Why must units be written with answers?

## Mini project

Create a personal symbol sheet with twenty circuit symbols drawn neatly and labelled.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Measuring voltage current and resistance

Meters provide evidence only when they are connected correctly and set to the right function.

**Good electrical work comes from patient checks, not rushed guesses.**

## Learning outcomes

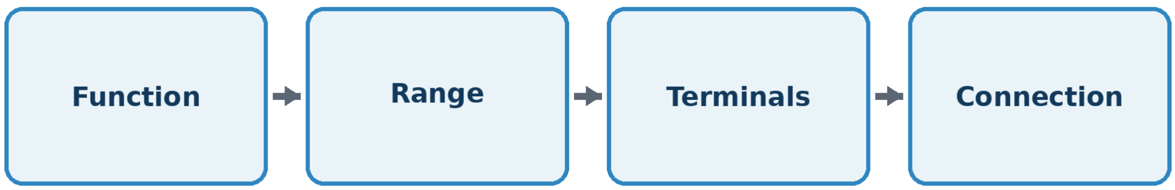
- Select voltage, current or resistance mode.
- Connect an ammeter in series.
- Connect a voltmeter in parallel.
- Apply safe multimeter checks.

## Key words

| Range | The span of values an instrument can measure. |
| --- | --- |
| **Series connection** | Components share one current path. |
| **Parallel connection** | Components share the same two connection points. |
| **Continuity** | A low-resistance path between test points. |

# Prepare the meter before connection

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

Check the case, leads, probes, terminals, function and range. Begin on a higher range when the value is uncertain.

Voltage is measured across two points, so the voltmeter is connected in parallel. Current passes through the ammeter, so the circuit must be opened and the meter inserted in series.

Resistance and continuity tests are performed only on isolated circuits after stored energy is discharged.

### Relationship to remember

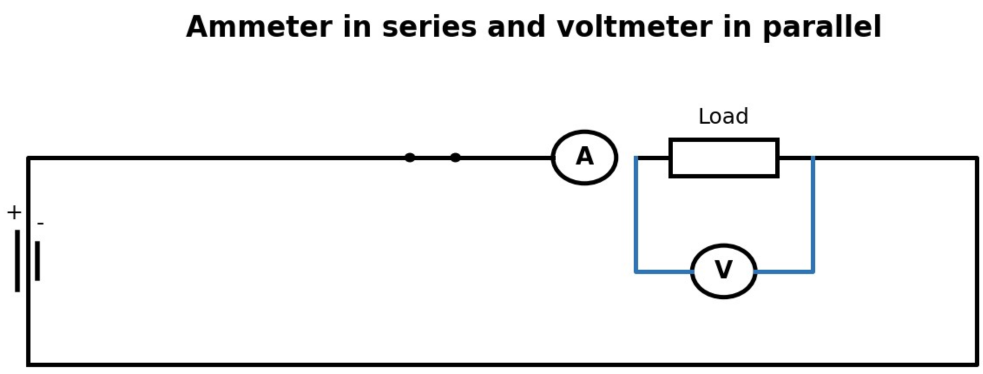
$$\text{Reading} = \text{scale indication} \times \text{range factor}$$

Digital meters normally display the value directly, but the selected prefix and decimal point must still be read.

**Worked example 1** Where is the voltmeter connected to measure lamp voltage?

**Solution** Across the lamp terminals, in parallel.

# Correct meter positions




*The ammeter carries load current while the voltmeter measures the potential difference across the load.*

An ammeter has low internal resistance and can cause a short circuit if placed across a source. A voltmeter has high resistance and draws little current.

Return the current lead to the voltage terminal after current testing to prevent the next user from making an unsafe connection.

**Worked example 2** Where is the ammeter connected?

**Solution** Open the circuit and insert it in series with the load.

# Measure a low-voltage lamp circuit

## Practical sequence

Inspect meter → Select mode → Connect correctly → Record result

Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Measure source voltage, lamp voltage and circuit current.

## Equipment

digital multimeter • extra-low-voltage supply • lamp • switch • leads

## Method

1. Inspect and set the meter.
2. Measure supply voltage in parallel.
3. Isolate and move the lead for current measurement.
4. Insert the meter in series and energise briefly.
5. Isolate, return leads to the voltage terminals and record results.

## Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Never move the selector or leads carelessly while the circuit is energised.

# Follow the reasoning

**Worked example 3** A display shows 0.018 A. Express it in mA.

**Solution** $0.018 \times 1000 = 18$ mA.

**Worked example 4** Why is resistance mode unsafe on an energised circuit?

**Solution** The meter applies its own test source; external voltage can damage it and create a hazard.

**Worked example 5** The meter reads OL in resistance mode. What can this mean?

**Solution** The resistance is above the selected range or the path is open.

## Try one without help

A student places a meter set to current directly across a battery. Predict the result and state the correct procedure.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. List five pre-use meter checks.
2. How is voltage measured?
3. How is current measured?
4. Why start on a high range?
5. What does OL commonly mean?
6. When may continuity be tested?
7. Why return the current lead after use?
8. Convert 35 mA to amperes.

## Mini project

Prepare a meter-use flowchart that another student can follow before every measurement.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Ohms law and basic DC circuits

Ohm’s law links voltage, current and resistance and provides a first test of whether a circuit value is reasonable.

**Draw the circuit, label the values and let the diagram guide you.**

## Learning outcomes

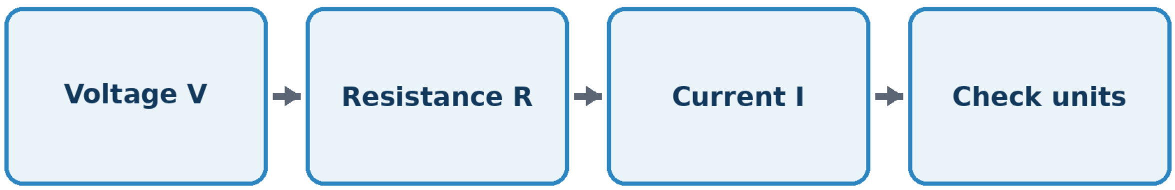
- State Ohm’s law.
- Calculate voltage, current or resistance.
- Plot a simple V-I relationship.
- Check answers using units and estimation.

## Key words

| Ohmic conductor | A conductor whose resistance remains approximately constant under stated conditions. |
|---|---|
| **Load** | A component that converts electrical energy. |
| **Open circuit** | An incomplete path with negligible current. |
| **Short circuit** | An unintended very low-resistance path. |

# Relate voltage current and resistance

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

For a constant resistance, current increases when voltage increases. For a constant voltage, current decreases when resistance increases.

Ohm’s law applies under constant physical conditions, especially temperature. A filament lamp may not remain ohmic as it heats.

Use the formula triangle only as a reminder. Understanding which quantity increases or decreases is more valuable than memorising a picture.

### Relationship to remember

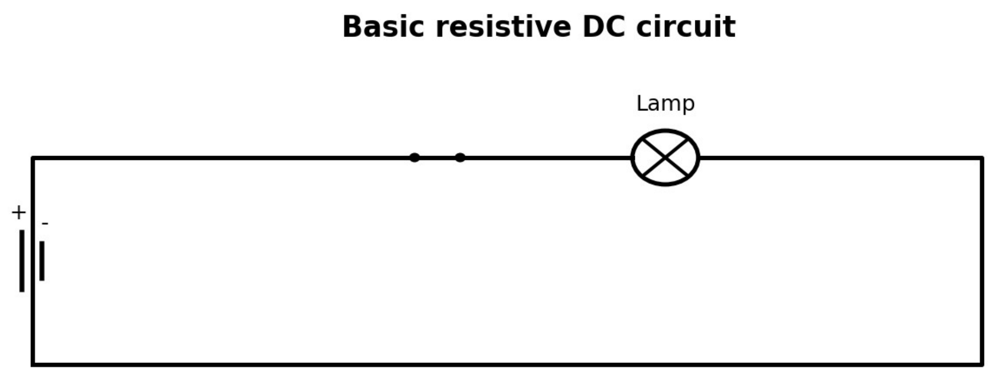
$$V = I \times R \qquad I = V \div R \qquad R = V \div I$$

Use volts, amperes and ohms together. Convert milliamperes and kilo-ohms before calculation.

**Worked example 1** A 12 V supply is connected to 6 Ω. Find current.

**Solution** $I = V \div R = 12 \div 6 = 2$ A.

# A complete DC circuit




*A closed switch completes the path from the positive terminal through the load and back to the source.*

The source creates potential difference, the switch controls the path and the resistor or lamp limits current while converting energy.

An open switch makes the current approximately zero. A short across the load can produce excessive current.

**Worked example 2** A resistor carries 0.25 A at 10 V. Find resistance.

**Solution** $R = V \div I = 10 \div 0.25 = 40\ \Omega$.

# Test Ohm's law

## Practical sequence

**Build circuit** → **Measure V** → **Measure I** → **Compare V = IR**

Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Measure voltage and current for three safe supply settings and compare V ÷ I.

### Equipment

variable extra-low-voltage supply • resistor • two meters • switch • leads

### Method

1. Measure the resistor value with power off.
2. Build the circuit and obtain inspection.
3. Set a low approved voltage and record V and I.
4. Repeat for two higher approved settings.
5. Calculate V ÷ I for each row and compare.

### Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Stay within the resistor's power rating and stop if it becomes hot.

# Follow the reasoning

**Worked example 3** A 15 Ω resistor carries 0.4 A. Find voltage.

**Solution** $V = I \times R = 0.4 \times 15 = 6$ V.

**Worked example 4** A 2.2 kΩ resistor is connected to 11 V. Find current.

**Solution** R = 2200 Ω. $I = 11 \div 2200 = 0.005$ A = 5 mA.

**Worked example 5** Current doubles while resistance stays constant. What happens to voltage?

**Solution** From $V = IR$, voltage also doubles.

## Try one without help

A 9 V circuit should draw 30 mA. Calculate the required resistance and select a nearby standard value.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. State Ohm's law.
2. Calculate current for 24 V and 12 Ω.
3. Calculate resistance for 6 V and 20 mA.
4. Calculate voltage for 0.5 A and 8 Ω.
5. Explain an open circuit.
6. Explain a short circuit.
7. Why can a lamp depart from Ohm's law?
8. State one reasonableness check.

## Mini project

Collect five safe V-I readings for a resistor and draw a graph by hand.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Series circuits

A series circuit has one current path, so every component carries the same current.

**If a result looks unusual, pause and check the units before starting again.**

## Learning outcomes

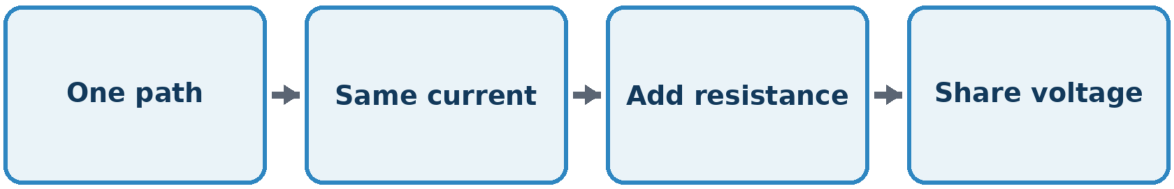
- Recognize a series connection.
- Calculate total resistance.
- Apply the voltage-divider rule.
- Diagnose an open series circuit.

## Key words

| Series circuit | A circuit with one current path. |
|---|---|
| **Total resistance** | The equivalent resistance seen by the source. |
| **Voltage drop** | Potential difference across a component. |
| **Kirchhoff voltage law** | The sum of voltage changes around a closed loop is zero. |

# Add resistance and share voltage

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

Series resistances add because the same current meets each opposition in turn. The largest resistance normally has the largest voltage drop.

The source voltage equals the sum of the individual voltage drops. A missing voltage indicates either a measurement error or an incorrect assumption.

One open component stops current everywhere in the series path.

### Relationship to remember

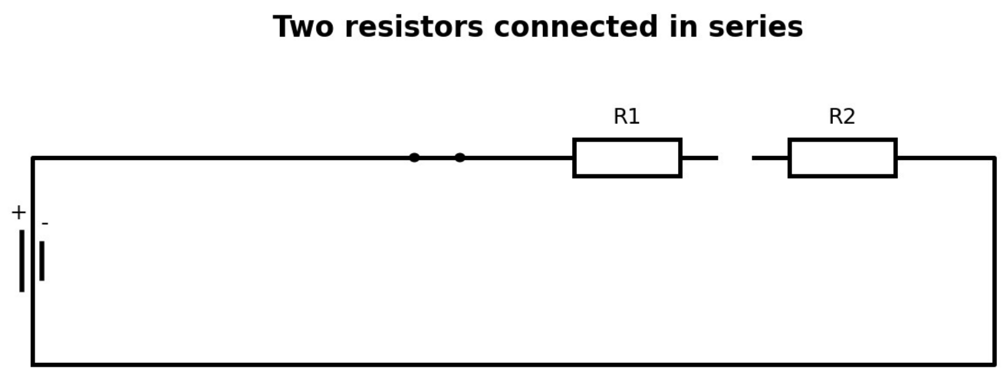
$$R_t = R_1 + R_2 + \ldots \qquad V_s = V_1 + V_2 + \ldots$$

Current is the same at every point in an ideal series circuit.

**Worked example 1** Find total resistance for 10 Ω and 20 Ω in series.

**Solution** $R_t = 10 + 20 = 30\ \Omega$.

# Trace the single path




*Both resistors carry the same current; their voltage drops add to the supply voltage.*

Begin at the source and follow the line through every component. If there is no branch, the circuit is series.

Meters can confirm the rule: current readings should agree at different positions within measurement tolerance.

**Worked example 2** A 12 V source supplies 30 Ω. Find current.

**Solution** I = 12 ÷ 30 = 0.4 A.

# Verify series-circuit rules

## Practical sequence

Connect R1 and R2 → Measure current → Measure drops → Confirm total

Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Measure resistance, current and voltage drops in a two-resistor series circuit.

### Equipment

extra-low-voltage supply • two resistors • multimeter • switch • leads

### Method

1. Measure each resistor with power off.
2. Connect both resistors in one path.
3. Measure total resistance while isolated.
4. Energise and measure current.
5. Measure both voltage drops and compare their sum with the supply.

### Record your results

| Test or observation | Measured result | What it means |
| --- | --- | --- |
| | | |
| | | |
| | | |

**Safety check** Observe component power ratings and isolate before changing connections.

# Follow the reasoning

**Worked example 3** The current is 0.4 A through 10 Ω. Find its voltage drop.

**Solution** $V_1 = 0.4 \times 10 = 4$ V.

**Worked example 4** Find the voltage across 20 Ω in the same circuit.

**Solution** $V_2 = 0.4 \times 20 = 8$ V. Check: $4 + 8 = 12$ V.

**Worked example 5** One resistor becomes open. What current flows?

**Solution** Ideally 0 A because the only path is broken.

## Try one without help

Three series resistors are 12 Ω, 18 Ω and 30 Ω on 12 V. Find total resistance, current and every voltage drop.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. State the current rule for series circuits.
2. Find total resistance of 4 Ω, 6 Ω and 10 Ω.
3. Find current from 20 V through 20 Ω.
4. Find the drop across 6 Ω at 1 A.
5. What happens if one lamp opens?
6. Why does the largest resistance get the largest drop?
7. State the voltage-sum rule.
8. How can meter tolerance affect results?

## Mini project

Design a three-resistor series voltage divider that provides approximately one-third of the supply voltage at one tap.

## My reflection

One skill I can now demonstrate is:

________________________________________

________________________________________

One point I need to practise again is:

________________________________________

________________________________________

# Parallel and series parallel circuits

Parallel branches share the same voltage while dividing the source current.

**Take this chapter one step at a time. Accuracy grows with careful practice.**

## Learning outcomes

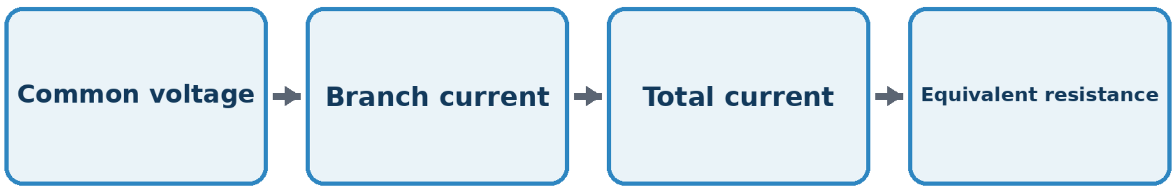
- Recognize parallel branches.
- Calculate current in each branch.
- Calculate equivalent parallel resistance.
- Reduce a series-parallel network in stages.

## Key words

| Branch | A separate path between two junctions. |
|---|---|
| **Node** | A connection point shared by conductors. |
| **Branch current** | Current through one parallel path. |
| **Equivalent resistance** | One resistance that draws the same total current. |

# Voltage is common current divides

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

Each branch connects to the same two nodes, so every branch has the same voltage. Lower resistance draws more current.

The source current equals the sum of branch currents. Adding a branch reduces total resistance and increases source current.

For two resistors, the product-over-sum relationship is convenient.

### Relationship to remember

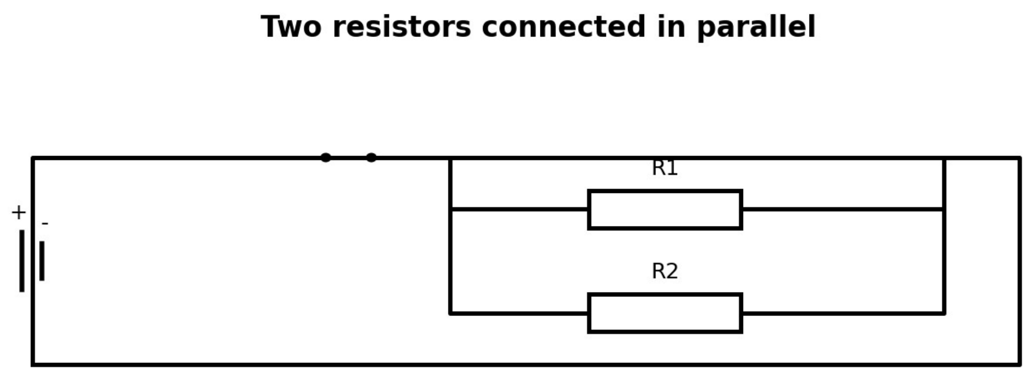
$$I_t = I_1 + I_2 + \ldots \qquad R_t = (R_1 R_2) \div (R_1 + R_2)$$

The equivalent resistance of a parallel network is less than its smallest branch resistance.

**Worked example 1** Find 12 Ω in parallel with 6 Ω.

**Solution** $R_t = (12 \times 6) \div (12 + 6) = 72 \div 18 = 4\ \Omega$.

# Reduce networks in stages




*Both branches receive the source voltage; their currents combine at the junction.*

Identify the pure parallel group first and replace it with its equivalent resistance. Then add any series resistance.

Redraw the simplified circuit after each step. This prevents a series resistor from being added to only one branch by mistake.

**Worked example 2** Both branches are on 12 V. Find current through 12 Ω.

**Solution** $I_1 = 12 \div 12 = 1$ A.

# Verify parallel-circuit rules

## Practical sequence

Build branches → Measure voltage → Measure currents → Compare totals

Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Measure common voltage and branch currents in a two-branch network.

### Equipment

extra-low-voltage supply • two resistors • multimeter • switch • leads

### Method

1. Build two branches between the same nodes.
2. Obtain inspection before energising.
3. Measure voltage across each branch.
4. Measure each branch current safely.
5. Add branch currents and compare with source current.

### Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Current in the source lead may be larger than either branch current; select the range accordingly.

# Follow the reasoning

**Worked example 3** Find current through 6 Ω.

**Solution** $I_2 = 12 \div 6 = 2$ A.

**Worked example 4** Find total current.

**Solution** $I_t = 1 + 2 = 3$ A. Check: $12 \div 4 = 3$ A.

**Worked example 5** A 2 Ω resistor is in series with the 4 Ω equivalent. Find total resistance.

**Solution** Rtotal = 2 + 4 = 6 Ω.

## Try one without help

A 30 Ω branch and 60 Ω branch are connected to 12 V. Find each branch current, total current and equivalent resistance.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. State the voltage rule for parallel circuits.
2. State the current rule.
3. Find 8 Ω in parallel with 8 Ω.
4. Which branch draws more current: 5 Ω or 10 Ω?
5. What happens to total resistance when a branch is added?
6. Find total current when branches draw 2 A and 3 A.
7. Describe a node.
8. Outline the reduction method for a mixed network.

## Mini project

Build a model lighting board with two independently controlled low-voltage lamps in parallel.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Electrical power energy efficiency and cost

Power describes the rate of energy conversion, while energy measures the total used over time.

**You do not need to solve everything at once. Start with what is known.**

## Learning outcomes

- Calculate electrical power.
- Calculate energy in watt-hours and kilowatt-hours.
- Calculate efficiency.
- Estimate operating cost.

## Key words

| Power | Rate of energy transfer in watts. |
| --- | --- |
| **Energy** | Capacity transferred or used over time. |
| **Efficiency** | Useful output divided by total input. |
| **Kilowatt-hour** | Energy used by one kilowatt for one hour. |

# Connect power with voltage and current

## Concept map

Voltage → Current → Power → Energy and cost

Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

Electrical power rises when either voltage or current rises. For a resistor, Ohm's law gives two additional forms.

Energy depends on both power and time. Electricity bills normally use kilowatt-hours, not kilowatts.

Efficiency is below 100 percent because some input becomes unwanted heat, sound or mechanical loss.

### Relationship to remember

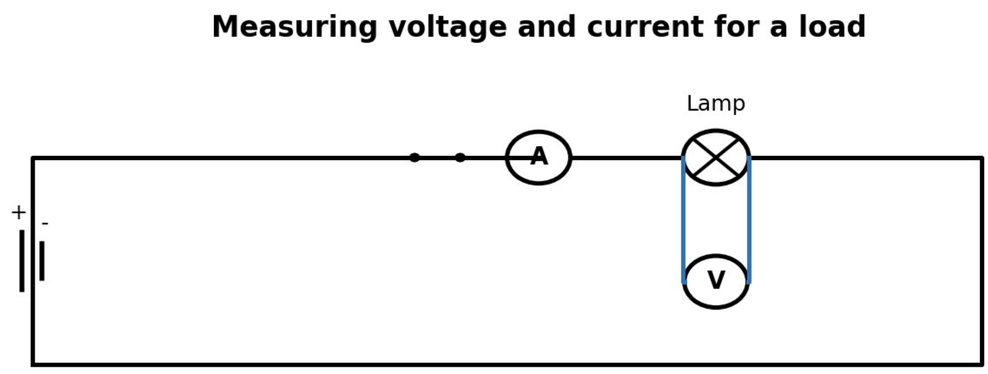
$$P = VI \qquad E = Pt \qquad \text{efficiency} = \text{useful output} \div \text{input} \times 100\%$$

For billing, use power in kilowatts and time in hours to obtain kilowatt-hours.

**Worked example 1** A 12 V lamp draws 0.5 A. Find power.

**Solution** $P = VI = 12 \times 0.5 = 6$ W.

# Measure a load safely




*Multiply the ammeter reading by the voltmeter reading to estimate DC load power.*

Current is measured in series and voltage in parallel. Their product estimates the input power for a DC resistive load.

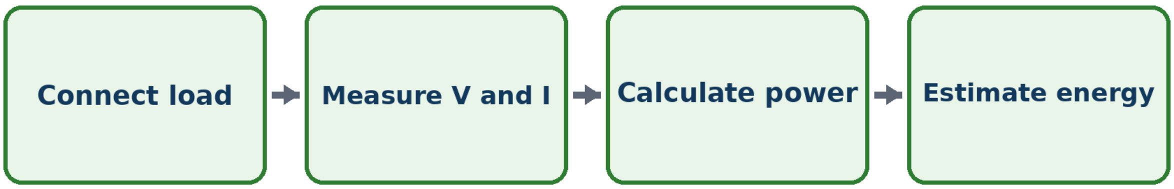
Compare calculated power with the component rating. A rating states the safe or intended operating condition, not the energy used in every situation.

**Worked example 2** A 60 W lamp operates for 5 h. Find energy.

**Solution** E = 60 × 5 = 300 Wh = 0.30 kWh.

# Measure lamp power

## Practical sequence




Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Measure voltage and current of an approved low-voltage lamp and calculate input power.

## Equipment

low-voltage lamp • supply • two meters • switch • leads

## Method

1. Record the lamp rating.
2. Connect the ammeter in series and voltmeter in parallel.
3. Obtain inspection.
4. Energise and record steady readings.
5. Calculate VI and compare with the rating.

## Record your results

| Test or observation | Measured result | What it means |
| --- | --- | --- |
| | | |
| | | |
| | | |

**Safety check** Do not exceed the lamp rating or touch a hot lamp.

# Follow the reasoning

**Worked example 3** Energy costs GYD 70 per kWh. Find the cost of 0.30 kWh.

**Solution** Cost = 0.30 × 70 = GYD 21.

**Worked example 4** A device takes 100 W and gives 75 W useful output. Find efficiency.

**Solution** Efficiency = 75 ÷ 100 × 100% = 75%.

**Worked example 5** Find power in a 10 Ω resistor carrying 2 A.

**Solution** $P = I^2R = 2^2 \times 10 = 40$ W.

## Try one without help

A 1.5 kW appliance operates 3 h per day for 30 days. Find energy and cost at GYD 68 per kWh.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. Calculate power at 24 V and 2 A.
2. Convert 750 W to kilowatts.
3. Find energy used by 2 kW for 4 h.
4. Distinguish kW from kWh.
5. Calculate 80% of 500 W.
6. Name two common energy losses.
7. Why may measured power differ from the label?
8. State two ways to reduce energy use safely.

## Mini project

Prepare a one-week energy estimate for five appliances used at home or in a workshop.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Cells batteries and DC supplies

Cells convert chemical energy to electrical energy and may be combined to meet voltage and current needs.

**A wrong answer is useful when you find the step that caused it.**

## Learning outcomes

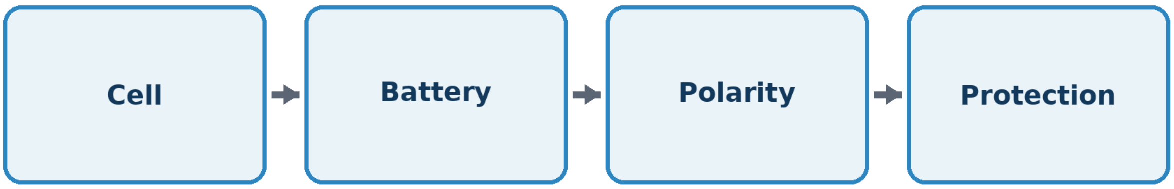
- Distinguish cells and batteries.
- Calculate series battery voltage.
- Explain capacity in ampere-hours.
- Apply safe charging and storage practices.

## Key words

| Cell | A single electrochemical source. |
|---|---|
| **Battery** | One or more cells connected as a source. |
| **Capacity** | Available charge commonly stated in ampere-hours. |
| **Polarity** | The positive and negative terminal relationship. |

# Combine and care for cells

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

Series cells add voltage when connected with correct polarity. Parallel connection can increase available capacity but should use compatible cells at similar states of charge.

Capacity in ampere-hours estimates current multiplied by time; actual capacity depends on discharge rate, temperature and battery condition.

Short circuits can cause very high current, heating, fire or rupture. Correct fusing, insulation and charging are essential.

### Relationship to remember

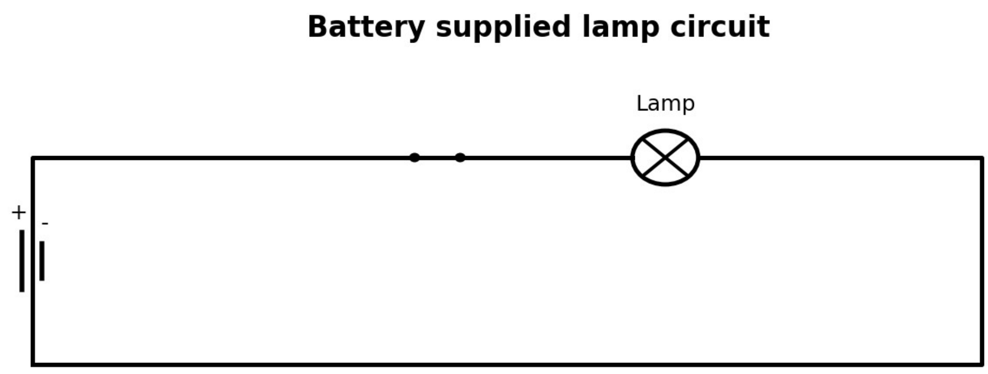
$$V_{battery} = \text{number of series cells} \times \text{cell voltage} \qquad \text{time} \approx \text{Ah} \div \text{A}$$

The time relationship is an estimate, not a guarantee.

**Worked example 1** Four 1.5 V cells are in series. Find voltage.

**Solution** $V = 4 \times 1.5 = 6$ V.

# A practical DC source




*The battery provides DC voltage; the switch controls current through the lamp.*

A switch controls the circuit and the load limits current. Protection should be placed close to the source where practical.

Observe polarity for electronic loads, meters and chargers. Reversed polarity can damage semiconductor devices.

**Worked example 2** A 12 Ah battery supplies 2 A ideally. Estimate time.

**Solution** t = 12 ÷ 2 = 6 h.

# Compare cells in series

## Practical sequence

Inspect cells → Connect series → Measure voltage → Disconnect safely

Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Measure one cell and a correctly assembled series group.

### Equipment

identical low-voltage cells • holders • multimeter • small lamp • leads

### Method

1. Inspect cells for damage or leakage.
2. Measure each cell voltage.
3. Connect two cells in series with correct polarity.
4. Measure total voltage and compare with the sum.
5. Connect the approved lamp briefly and observe.

### Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Never short the terminals or mix damaged, different or rechargeable and non-rechargeable cells.

# Follow the reasoning

**Worked example 3** Two identical 12 V, 20 Ah batteries are in parallel. State nominal voltage and capacity.

**Solution** Voltage remains 12 V; ideal combined capacity is 40 Ah.

**Worked example 4** Why is polarity marked?

**Solution** Correct polarity guides connection and prevents reverse-voltage damage.

**Worked example 5** A terminal becomes hot. State two possible causes.

**Solution** A loose high-resistance joint or excessive current can create heating.

## Try one without help

Six 1.2 V rechargeable cells supply 0.6 A to a load. Find nominal voltage and estimate operating time for 2.4 Ah capacity.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. Define a cell.
2. Define a battery.
3. Find the voltage of three 1.5 V cells in series.
4. What stays constant for identical batteries in parallel?
5. What does Ah describe?
6. Why is a fuse placed near a battery?
7. Name two signs of battery damage.
8. Why must the correct charger be used?

## Mini project

Design a labelled low-voltage battery box with switch, fuse, output terminals and polarity markings.

## My reflection

One skill I can now demonstrate is:

______________________________

______________________________

One point I need to practise again is:

______________________________

______________________________

# Magnetism electromagnetism and relays

Current produces a magnetic field that can create motion and operate contacts.

**Good electrical work comes from patient checks, not rushed guesses.**

## Learning outcomes

- Describe magnetic poles and fields.
- Explain an electromagnet.
- State factors affecting coil strength.
- Explain relay operation.

## Key words

| Magnetic field | The region in which magnetic force can act. |
|---|---|
| **Electromagnet** | A magnetic field produced by current in a coil. |
| **Relay** | An electrically operated switch. |
| **Armature** | A moving iron part acted on by magnetic force. |

# Current creates a magnetic field

## Concept map

**Coil current** → **Magnetic field** → **Armature** → **Contacts**

Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

The field surrounds a conductor and becomes stronger when current increases. Winding the conductor into a coil concentrates the field.

A soft-iron core increases flux and releases magnetism readily when current stops. Coil turns, current and magnetic path affect strength.

A relay allows one circuit to control another while maintaining separation between their conductive paths.

### Relationship to remember

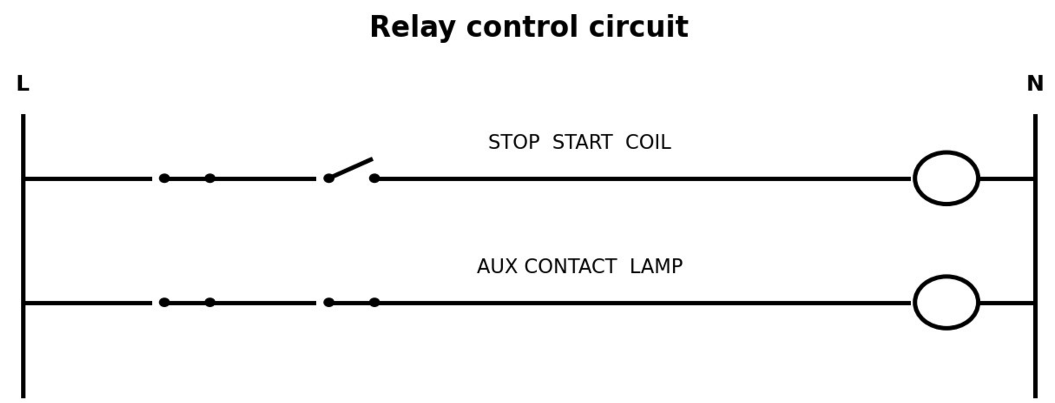
$$\text{magnetising effect} \propto \text{coil turns} \times \text{current}$$

This proportional statement is qualitative unless the magnetic circuit and geometry are known.

**Worked example 1** What happens when current through a coil increases?

**Solution** The magnetic field generally becomes stronger, provided the coil remains within its rating.

# Control with a relay




*A low-power control path operates a coil whose contact can control another load.*

When the coil is energised, the armature moves and changes contact state. Normally open contacts close; normally closed contacts open.

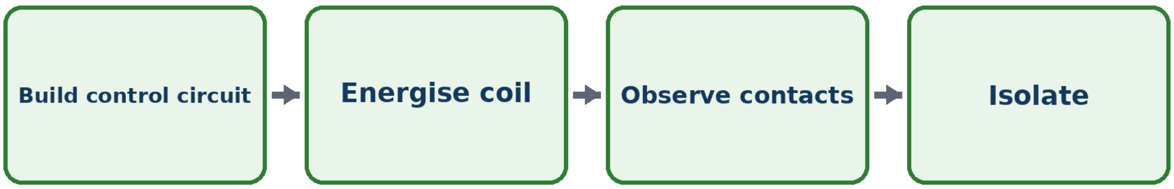
The coil voltage rating and contact current rating describe different parts of the relay and must both be respected.

**Worked example 2** A coil has 200 turns at 0.1 A. Find ampere-turns.

**Solution** $NI = 200 \times 0.1 = 20$ ampere-turns.

# Operate a low-voltage relay

## Practical sequence




Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Use a pushbutton to energise a relay and switch a separate low-voltage lamp.

### Equipment

low-voltage relay • two safe supplies or trainer • pushbutton • lamp • leads

### Method

1. Identify coil and contact terminals from the approved data.
2. Build the coil circuit with power off.
3. Build the lamp circuit through a normally open contact.
4. Obtain inspection and energise.
5. Press the button and record the contact action.

### Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Use only instructor-approved low-voltage trainers; do not exceed coil or contact ratings.

# Follow the reasoning

**Worked example 3** Why use soft iron for an electromagnet core?

**Solution** It magnetises strongly and loses most magnetism when current is removed.

**Worked example 4** A relay coil is 12 V but contacts are rated 5 A at 230 V. May 230 V be applied to the coil?

**Solution** No. The coil must receive its rated 12 V; the contact rating applies to the switched circuit.

**Worked example 5** What is the state of a normally open contact with the coil off?

**Solution** It is open.

## Try one without help

A 12 V relay coil has 240 Ω resistance. Find coil current and explain why the switch must carry at least this value.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. Name the poles of a magnet.
2. What produces a field around a conductor?
3. State two ways to strengthen an electromagnet.
4. Define relay.
5. Distinguish coil and contact ratings.
6. Define normally open.
7. Find ampere-turns for 300 turns at 0.2 A.
8. Give one relay application.

## Mini project

Construct a low-voltage relay alarm in which a sensor switch energises a buzzer.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Alternating current fundamentals

Alternating voltage changes magnitude and polarity repeatedly and is described by frequency, period and RMS value.

**Draw the circuit, label the values and let the diagram guide you.**

## Learning outcomes

- Distinguish AC and DC.
- Identify cycle, frequency and period.
- Use T = 1/f.
- Explain the meaning of RMS voltage.

## Key words

| Cycle | One complete repetition of a waveform. |
|---|---|
| **Frequency** | Number of cycles per second in hertz. |
| **Period** | Time for one cycle. |
| **RMS value** | Effective AC value based on heating effect. |

# Describe a waveform

## Concept map

Cycle → Period → Frequency → RMS value

Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

A sine wave passes through positive and negative half-cycles. Its instantaneous value changes continuously.

Frequency is measured in hertz. Period and frequency are reciprocals, so high frequency has a short period.

RMS voltage is the AC value compared with an equivalent DC heating effect for a resistor.

### Relationship to remember

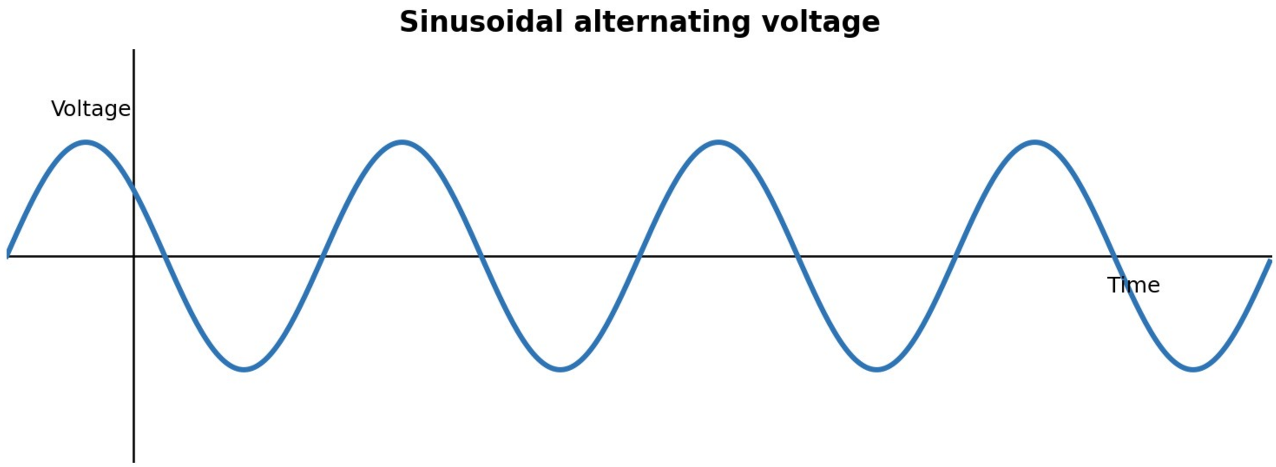
$$T = 1 \div f \qquad f = 1 \div T$$

Use seconds for period and hertz for frequency.

**Worked example 1** Find the period of 50 Hz AC.

**Solution** $T = 1 \div 50 = 0.020$ s = 20 ms.

# Read the AC graph




*One cycle includes a positive half-cycle and a negative half-cycle.*

The vertical axis represents instantaneous voltage and the horizontal axis represents time. Peak-to-peak value spans from the positive peak to the negative peak.

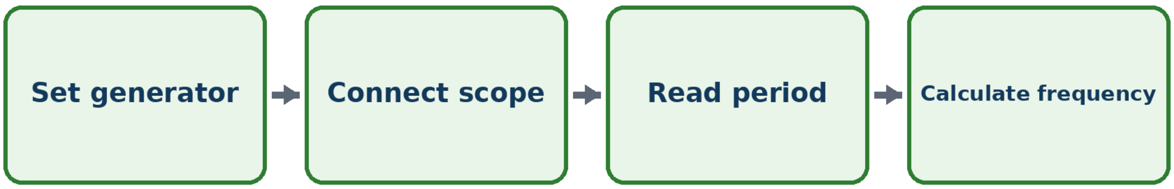
A DC waveform of constant polarity would appear as a horizontal line above or below zero.

**Worked example 2** Find frequency when period is 10 ms.

**Solution** T = 0.010 s. f = 1 ÷ 0.010 = 100 Hz.

# Observe safe AC waveforms

## Practical sequence




Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Use an instructor-approved signal generator and oscilloscope trainer to measure period.

### Equipment

signal generator • oscilloscope or safe waveform trainer • test leads

### Method

1. Set the generator to the approved low voltage.
2. Connect with power off where required.
3. Display one or more cycles.
4. Measure one period from the time scale.
5. Calculate frequency and compare with the generator setting.

### Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Never connect an oscilloscope to mains unless the instructor has approved suitable isolated equipment and procedure.

# Follow the reasoning

**Worked example 3** A sine wave has 12 V peak. Find peak-to-peak voltage.

**Solution** Vpp = 2 × 12 = 24 V.

**Worked example 4** Does an ordinary AC voltmeter normally show peak value?

**Solution** No. It is normally calibrated to indicate RMS value for its intended waveform range.

**Worked example 5** What changes in AC?

**Solution** Magnitude changes and polarity reverses periodically.

## Try one without help

An oscilloscope shows 2.5 cycles in 50 ms. Calculate frequency.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. Define one cycle.
2. Give the unit of frequency.
3. Find period at 25 Hz.
4. Find frequency for 5 ms.
5. Define RMS value.
6. Find peak-to-peak value for 8 V peak.
7. Distinguish AC and DC.
8. Why must oscilloscope grounding be understood?

## Mini project

Draw and label two cycles of a sine wave, including period, positive peak and negative peak.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Transformers and power transfer

A transformer transfers AC energy between windings by electromagnetic induction.

**If a result looks unusual, pause and check the units before starting again.**

## Learning outcomes

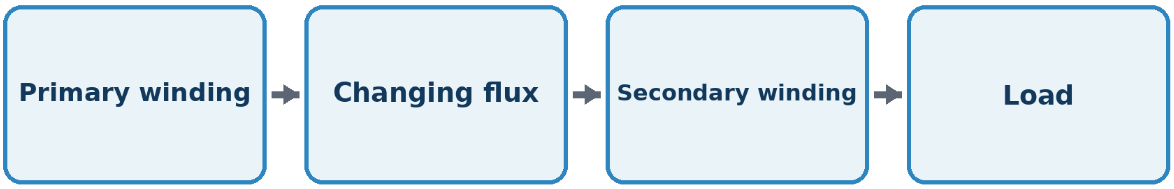
- Identify transformer parts.
- Use the turns and voltage ratio.
- Distinguish step-up and step-down operation.
- Explain common losses and safety concerns.

## Key words

| Primary winding | The winding connected to the input supply. |
|---|---|
| **Secondary winding** | The winding delivering output. |
| **Mutual induction** | Induction in one winding caused by changing flux from another. |
| **Turns ratio** | Ratio of winding turns or ideal voltages. |

# Changing flux links the windings

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

AC in the primary produces changing magnetic flux in the core. The changing flux induces voltage in the secondary.

More secondary turns than primary turns give a step-up voltage; fewer give a step-down voltage. An ordinary transformer does not operate continuously from steady DC.

Real transformers lose energy through winding resistance, eddy currents, hysteresis and stray flux.

### Relationship to remember

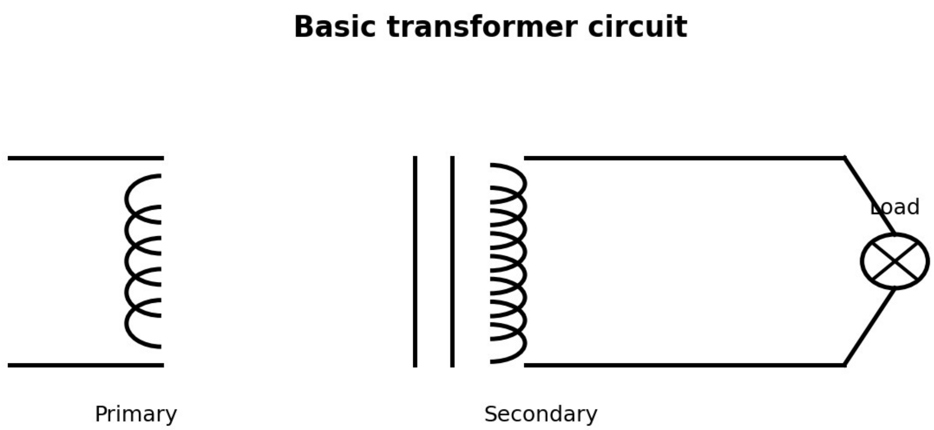
$$V_p \div V_s = N_p \div N_s$$

For an ideal transformer, input power approximately equals output power.

**Worked example 1** $N_p = 500$, $N_s = 100$ and $V_p = 230$ V. Find $V_s$.

**Solution** $V_s = V_p \times N_s \div N_p = 230 \times 100 \div 500 = 46$ V.

# Read the windings and load




*The primary receives AC; magnetic coupling transfers energy to the secondary load.*

The primary and secondary are electrically separate in an isolating transformer but magnetically linked by the core.

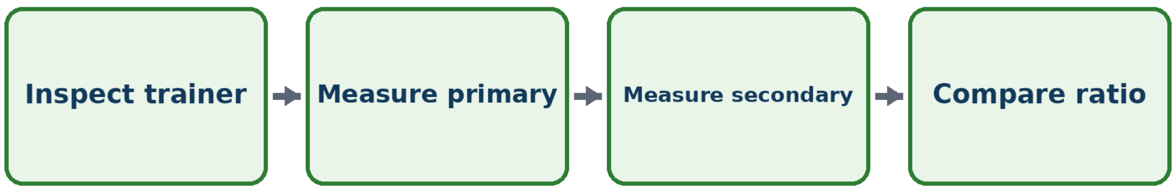
A step-down transformer can still deliver dangerous current. Safe voltage does not remove the need for overcurrent protection.

**Worked example 2** A 230 V to 12 V transformer is step-up or step-down?

**Solution** Step-down because secondary voltage is lower.

# Measure a step-down transformer

## Practical sequence




Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Measure approved primary and secondary voltages and compare their ratio.

## Equipment

isolated low-voltage AC transformer trainer • AC voltmeter • leads

## Method

1. Read all transformer ratings.
2. Connect only the approved primary supply.
3. Obtain instructor inspection.
4. Measure primary and secondary voltages.
5. Calculate Vp/Vs and compare with the stated turns ratio.

## Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Use only an isolated trainer; never improvise a connection to the public supply.

# Follow the reasoning

**Worked example 3** An ideal transformer supplies 12 V at 2 A. Find output power.

**Solution** Pout = 12 × 2 = 24 W.

**Worked example 4** If ideal input is 230 V, estimate primary current.

**Solution** Ip = 24 ÷ 230 = 0.104 A approximately.

**Worked example 5** Why are transformer cores laminated?

**Solution** Laminations reduce eddy-current paths and heating.

## Try one without help

A transformer has 1200 primary turns and 200 secondary turns. The primary is 120 V. Find secondary voltage.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. Define primary winding.
2. Define mutual induction.
3. Use the turns ratio for 600:100 at 240 V.
4. Why will steady DC not sustain transformer action?
5. Name two losses.
6. State one reason for laminations.
7. What does isolation mean?
8. Why can low voltage still cause heating?

## Mini project

Prepare a labelled transformer data card showing voltage, current, apparent power and winding identification.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# Introduction to electronic components

Semiconductor devices control current and form the basis of rectifiers, indicators, sensors and switching circuits.

**Take this chapter one step at a time. Accuracy grows with careful practice.**

## Learning outcomes

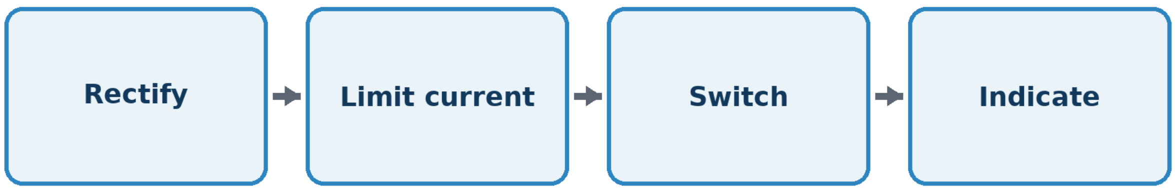
- Identify resistor, capacitor, diode, LED and transistor functions.
- Explain diode polarity.
- Calculate an LED series resistor.
- Describe a simple rectifier.

## Key words

| Diode | A semiconductor device that conducts mainly in one direction. |
|---|---|
| **LED** | A diode that emits light when correctly biased. |
| **Capacitor** | A component that stores charge and energy in an electric field. |
| **Transistor** | A semiconductor device used for switching or amplification. |

# Protect semiconductor devices

## Concept map




Follow the approved sequence and confirm each stage before continuing.

*The main relationship for this chapter.*

A diode has an anode and cathode. Forward bias allows conduction after the device's forward-voltage requirement is met.

An LED requires a series resistor to limit current. Reverse polarity or excessive current can damage it.

Capacitors may retain charge after power is removed. Polarised capacitors must be connected with correct polarity and voltage rating.

### Relationship to remember

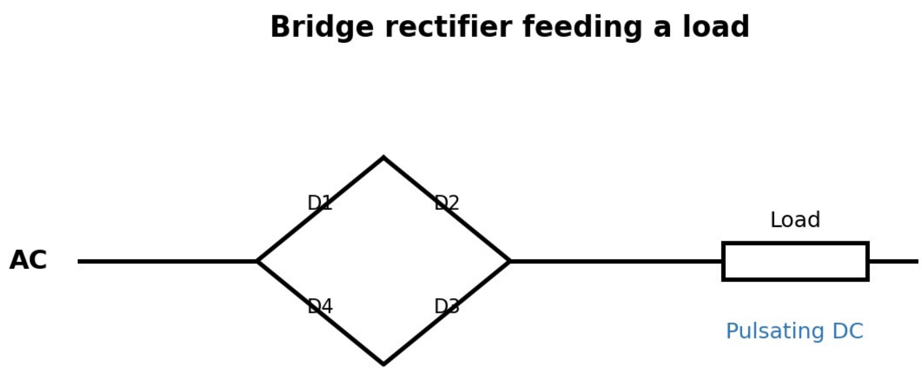
$$Rseries = (Vsupply - VLED) \div ILED$$

Convert LED current from milliamperes to amperes before calculating resistance.

**Worked example 1** A 9 V supply powers a 2 V LED at 10 mA. Find resistance.

**Solution** $R = (9 - 2) \div 0.010 = 700\ \Omega$. Select a suitable nearby standard value such as 680 Ω or 750 Ω after checking current.

# Convert AC to pulsating DC




*Four diodes steer both AC half-cycles through the load in the same direction.*

A bridge rectifier uses four diodes so load current flows in one direction during both AC half-cycles. A filter capacitor can reduce ripple.

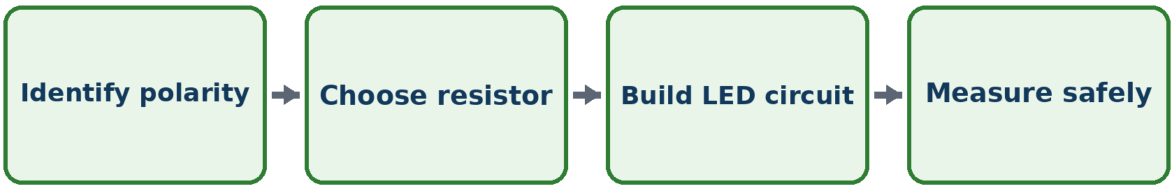
Rectification does not automatically produce a regulated or touch-safe supply. Transformer isolation and protection remain important.

**Worked example 2** What happens if an LED is reversed in a low-voltage DC circuit?

**Solution** It normally does not light and excessive reverse voltage may damage it.

# Build an LED indicator

## Practical sequence




Use an isolated trainer and complete every step under instructor supervision.

*Complete the practical in this order and record the evidence.*

Calculate, select and test an LED series resistor on an approved DC supply.

## Equipment

LED • resistors • breadboard • low-voltage supply • multimeter

## Method

1. Identify LED polarity.
2. Calculate the required series resistance.
3. Choose an approved standard value.
4. Build with power off and obtain inspection.
5. Energise and measure current.

## Record your results

| Test or observation | Measured result | What it means |
|---|---|---|
| | | |
| | | |
| | | |

**Safety check** Use a current-limiting resistor and do not exceed component voltage or power ratings.

# Follow the reasoning

**Worked example 3** Why is a resistor used with an LED?

**Solution** It limits current to a safe value.

**Worked example 4** A capacitor is rated 16 V. May it be used across 24 V?

**Solution** No. The applied voltage exceeds its rating.

**Worked example 5** What is the output of an unfiltered bridge rectifier?

**Solution** Full-wave pulsating DC.

## Try one without help

Design a 12 V indicator for an LED with 2.1 V forward drop at 15 mA. Calculate resistor value and resistor power.

# Chapter review

Try every question before checking the answer section. If an answer is different, identify the first step where your method changed.

1. State a diode function.
2. Identify LED polarity.
3. Why is a series resistor needed?
4. Calculate resistance for 5 V, 2 V and 10 mA.
5. What can a capacitor store?
6. State one capacitor hazard.
7. What does a rectifier do?
8. Name two transistor uses.

## Mini project

Create a small component-identification board with symbols, actual parts and safe handling notes.

## My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

# End of year practical assessment

Complete one instructor-approved integrated task. Your evidence should include the diagram, risk controls, materials, build record, measurements, calculations, test results and evaluation.

| Assessment area | Evidence expected |
|---|---|
| **Planning** | Diagram, sequence, materials and risk controls are complete. |
| **Workmanship** | Connections are secure, identified and mechanically sound. |
| **Testing** | The selected tests are safe, suitable and recorded with units. |
| **Problem solving** | Measured evidence supports each conclusion. |
| **Communication** | The student explains operation, limitations and improvements. |

## Final written review

1. Draw and label one important circuit from memory, then compare it with the book.
2. Select five worked examples and solve them again using different values.
3. Explain one practical procedure as if teaching a new student.
4. List three common errors you now know how to detect.
5. Write a study plan for the topics that remain difficult.

# How to use the answer section

The answers are placed at the back so you can attempt each question independently. Mark the exact step that needs correction, solve the question again without looking, and then explain the method aloud. A corrected attempt shows progress.

Equivalent wording is acceptable for explanation questions when the technical meaning is correct. Numerical answers should include units and working.

# Electrical safety and workshop practice

*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

Identify the circuit and every source; inform affected persons; shut down normally; isolate; lock and tag; prove the tester; test the required conductor combinations; re-prove the tester. Each step prevents selection error, reconnection or reliance on a failed tester.

## Chapter review answers

**1.** A hazard is something with the potential to cause harm.

**2.** Risk combines how likely the harm is with how serious its result could be.

**3.** Good housekeeping prevents trips and keeps tools or conductors from creating unsafe contact.

**4.** Metal jewellery can bridge conductors, heat rapidly and increase shock or burn injury.

**5.** Identify, inform, shut down, isolate, secure, prove, test and re-prove.

**6.** Isolate the electrical source without touching the casualty, raise the alarm and obtain trained emergency help.

**7.** Examples include eye protection and insulated gloves. PPE reduces exposure but does not make live work safe.

**8.** A switch may control only part of a circuit or may be wrongly identified. Isolation separates every relevant source and prevents reconnection.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Tools materials and good workmanship

*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

Two broken strands reduce conductor area, increase resistance and heating, weaken the conductor and make clamping uneven. Cut back and prepare the end again.

## Chapter review answers

**1.** Examples are an insulated screwdriver, wire stripper, side cutters and combination pliers.

**2.** Check screwdriver insulation, stripper adjustment, cutter edges and plier jaws or pivot.

**3.** Missing strands reduce current capacity and mechanical strength.

**4.** A sound termination is secure, fully inserted, correctly tightened and free from exposed copper or damaged strands.

**5.** Aluminium is a conductor.

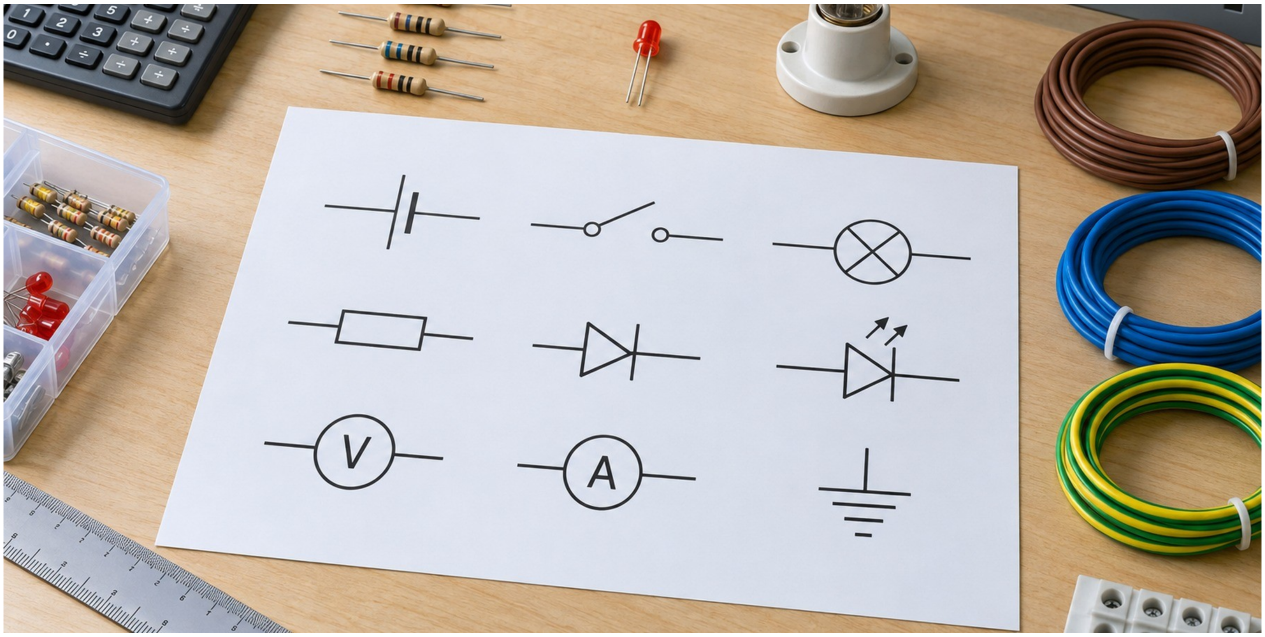
**6.** Insulation should have high resistance and withstand the expected voltage, temperature and environment.

**7.** The correct size grips or cuts the work without slipping, crushing or damaging it.

**8.** With power isolated, pull gently enough to check that the conductor is secure without damaging the terminal.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Electrical quantities units and symbols




*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

2.2 kΩ = 2200 Ω. 680 mA = 0.680 A. 0.015 MW = 15,000 W.

## Chapter review answers

**1.** The volt is the unit of voltage.

**2.** I represents current.

**3.** 3.3 kΩ = 3300 Ω.

**4.** 75 mA = 0.075 A.

**5.** A junction dot shows that conductors are electrically connected.

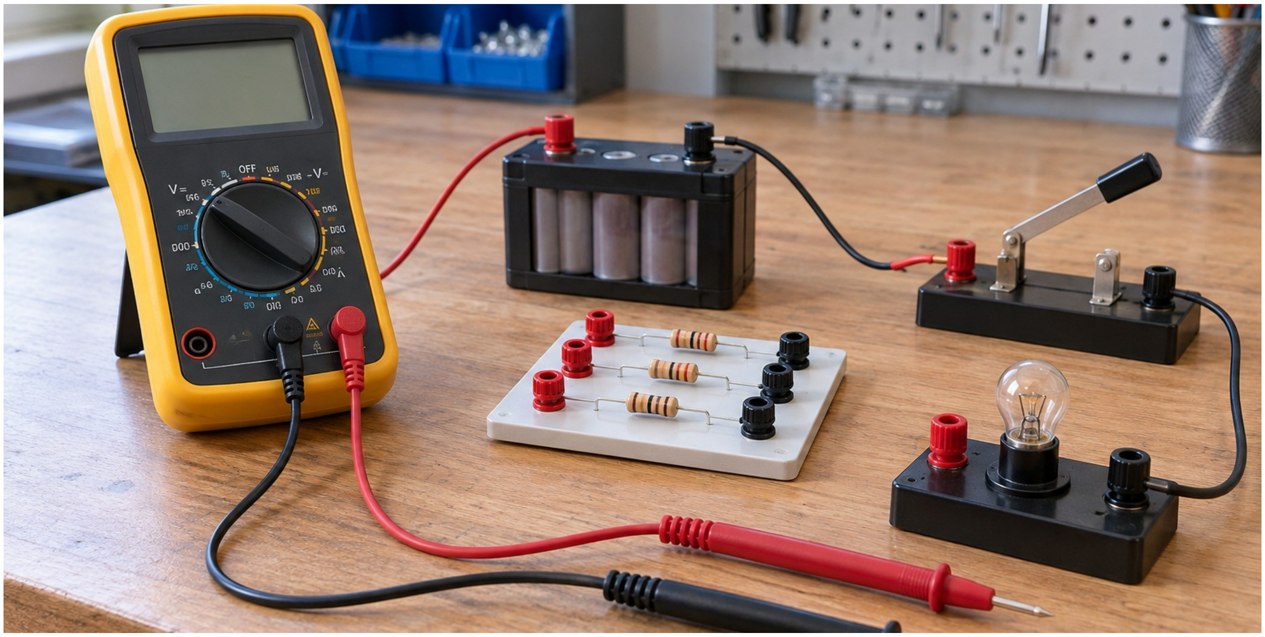
**6.** A schematic shows function and connections; a physical layout shows actual position and appearance.

**7.** The battery is the source, the switch is the control and the lamp is the load.

**8.** Units show what the number represents and allow the result to be checked.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Measuring voltage current and resistance



*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

The current range has very low resistance. Across a battery it can form a short circuit, damage the meter or leads and cause heating. Isolate, open the circuit, select the correct current terminal and range, insert the meter in series, inspect, then energise briefly.

## Chapter review answers

**1.** Check the case, leads, probe insulation, terminals, selector function and range.

**2.** Voltage is measured in parallel across two points.

**3.** Current is measured by opening the circuit and inserting the ammeter in series.

**4.** A high starting range reduces the chance of overload when the value is unknown.

**5.** OL often means open circuit or a value above the selected resistance range.

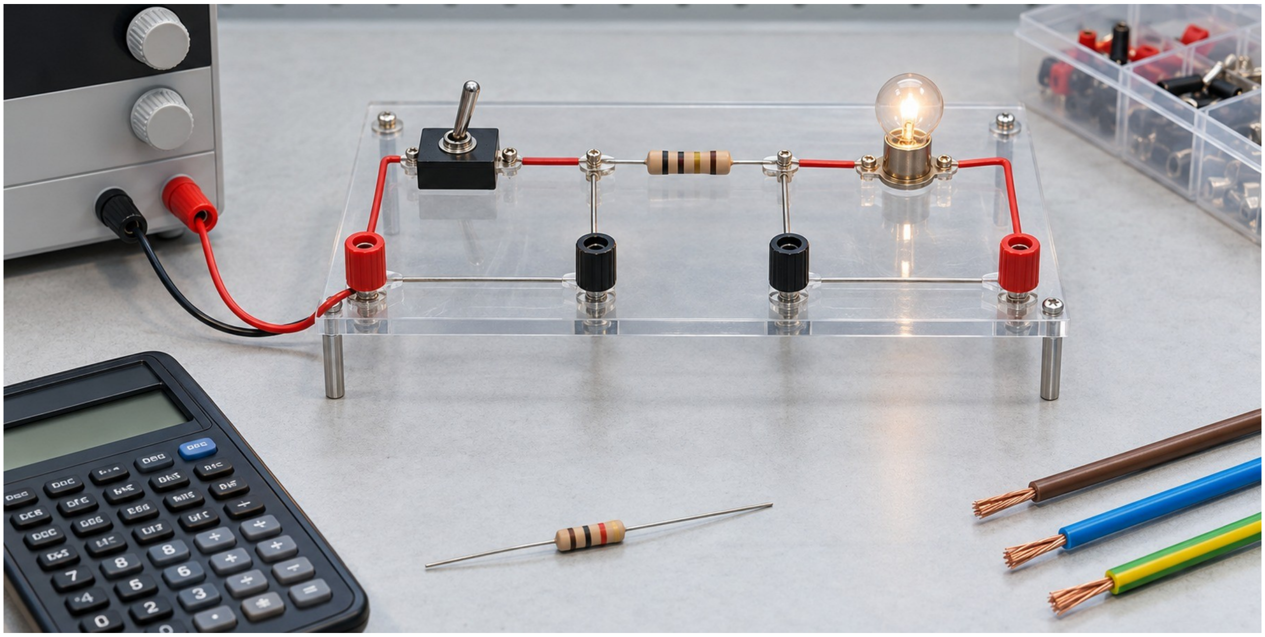
**6.** Continuity may be tested only on an isolated circuit after stored energy is discharged.

**7.** It prevents the next voltage measurement from being attempted with the lead still in the current terminal.

**8.** 35 mA = 0.035 A.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Ohms law and basic DC circuits



*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

R = V ÷ I = 9 ÷ 0.030 = 300 Ω. A standard 300 Ω value is suitable if its power rating is adequate.

## Chapter review answers

**1.** For constant conditions, voltage equals current multiplied by resistance.

**2.** I = 24 ÷ 12 = 2 A.

**3.** R = 6 ÷ 0.020 = 300 Ω.

**4.** V = 0.5 × 8 = 4 V.

**5.** An open circuit has an incomplete current path, so current is approximately zero.

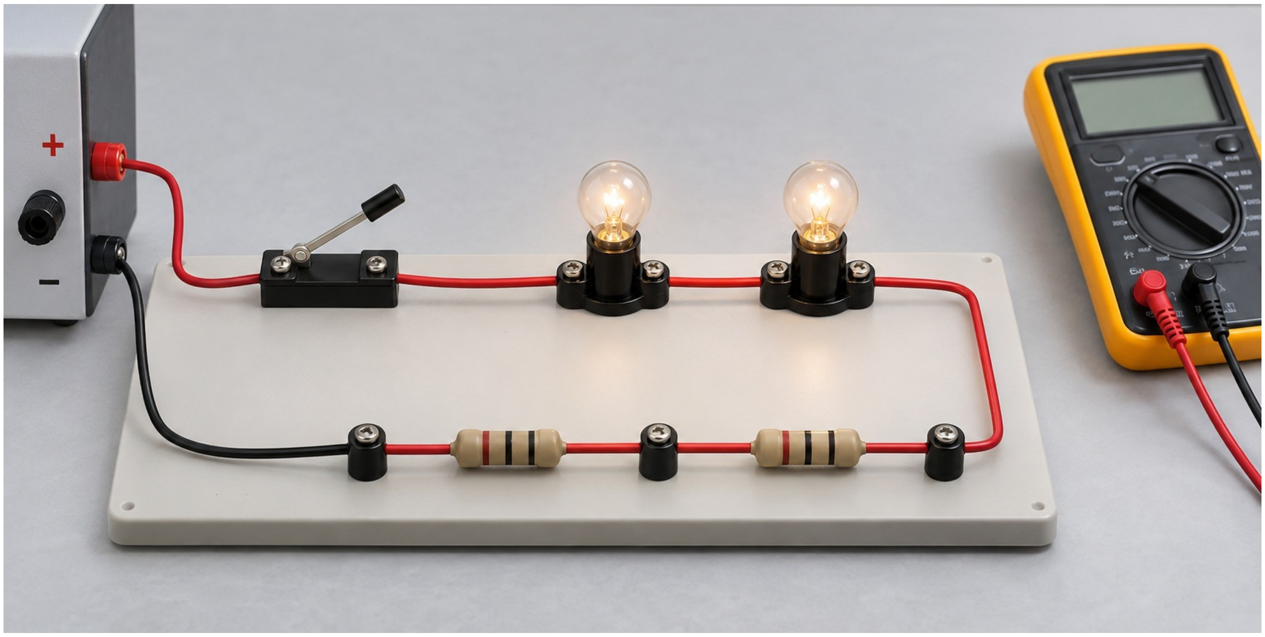
**6.** A short circuit is an unintended very low-resistance path that can cause excessive current.

**7.** Its filament heats, so its resistance changes.

**8.** Check the unit, order of magnitude and whether the result follows the expected trend.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Series circuits




*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

Rtotal = 12 + 18 + 30 = 60 Ω. I = 12 ÷ 60 = 0.2 A. Drops are 2.4 V, 3.6 V and 6.0 V. Their sum is 12 V.

## Chapter review answers

**1.** The same current flows through every component in a series circuit.

**2.** Rtotal = 4 + 6 + 10 = 20 Ω.

**3.** I = 20 ÷ 20 = 1 A.

**4.** V = 1 × 6 = 6 V.

**5.** Current stops throughout the single path.

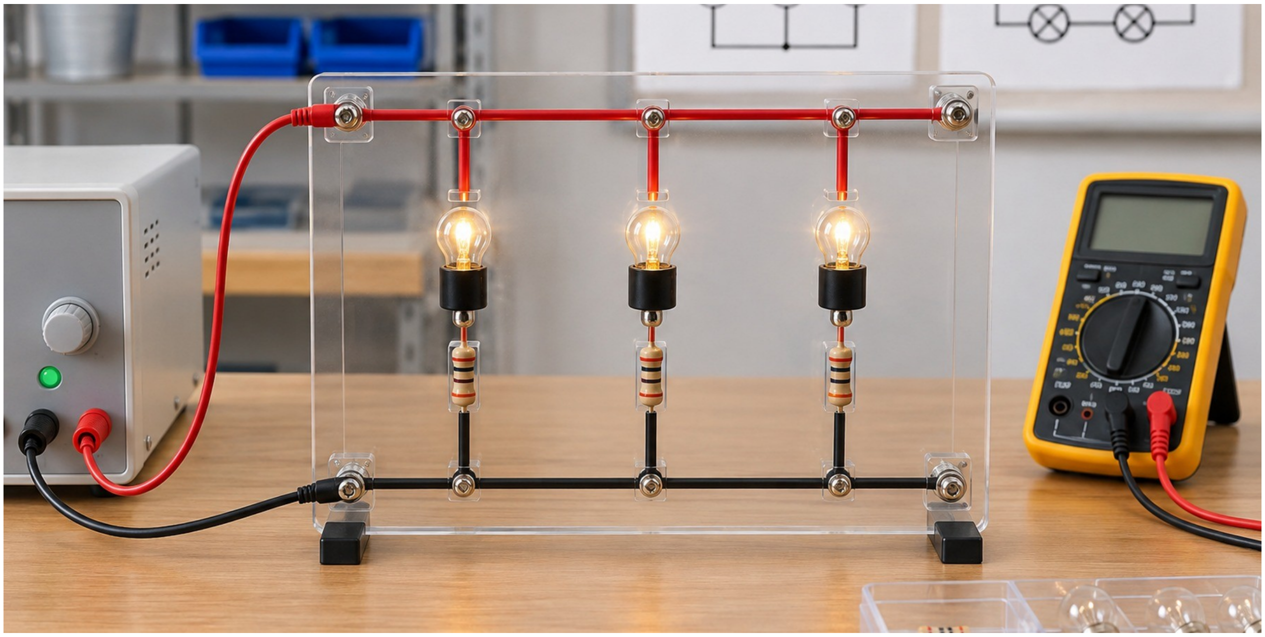
**6.** With common current, V = IR makes voltage drop proportional to resistance.

**7.** The individual voltage drops add to the source voltage.

**8.** Small differences can come from component tolerance, meter accuracy, lead resistance and supply variation.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Parallel and series parallel circuits



*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

Branch currents are 12 ÷ 30 = 0.4 A and 12 ÷ 60 = 0.2 A. Total current is 0.6 A. Equivalent resistance is 12 ÷ 0.6 = 20 Ω.

## Chapter review answers

**1.** Every parallel branch has the same voltage because it connects to the same two nodes.

**2.** The source current equals the sum of the branch currents.

**3.** 8 Ω in parallel with 8 Ω gives 4 Ω.

**4.** The 5 Ω branch draws more current at the same voltage.

**5.** Total resistance decreases when another parallel path is added.

**6.** Total current is 2 + 3 = 5 A.

**7.** A node is a connection point shared by two or more conductors or components.

**8.** Reduce a clear parallel or series group to an equivalent value, redraw, and repeat until one resistance remains.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Electrical power energy efficiency and cost

*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

Daily energy = 1.5 kW × 3 h = 4.5 kWh. For 30 days: 135 kWh. Cost = 135 × GYD 68 = GYD 9,180.

## Chapter review answers

**1.** P = 24 × 2 = 48 W.

**2.** 750 W = 0.75 kW.

**3.** E = 2 × 4 = 8 kWh.

**4.** kW measures power; kWh measures energy used over time.

**5.** 80% of 500 W is 400 W.

**6.** Examples include unwanted heat, sound, friction and magnetic losses.

**7.** Supply voltage, actual load, tolerance, temperature and measurement accuracy can change operating power.

**8.** Switch off unused loads and choose efficient equipment suited to the task.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Cells batteries and DC supplies

*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

Nominal voltage = 6 × 1.2 = 7.2 V. Estimated time = 2.4 Ah ÷ 0.6 A = 4 h. Actual time may be lower or higher with conditions.

## Chapter review answers

**1.** A cell is one electrochemical source.

**2.** A battery is one or more cells connected as a source.

**3.** Three 1.5 V cells in series provide 4.5 V.

**4.** For identical compatible batteries in parallel, nominal voltage stays the same.

**5.** Ampere-hours describe available charge capacity under stated conditions.

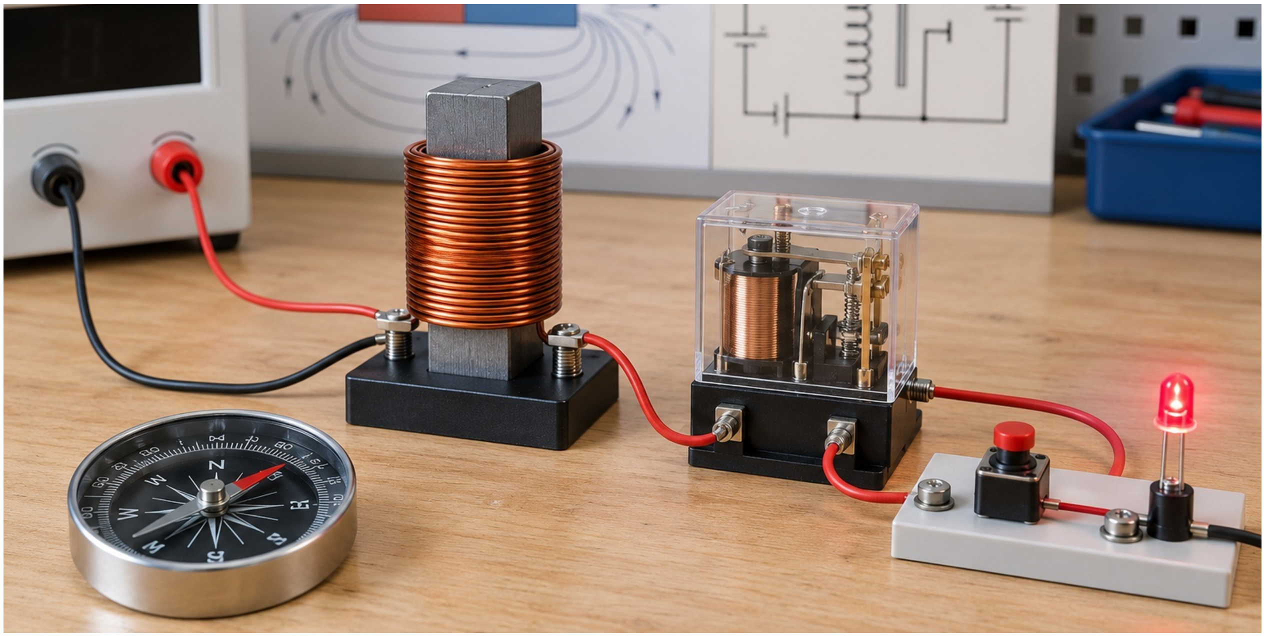
**6.** A nearby fuse limits energy released if the downstream wiring develops a short circuit.

**7.** Swelling, leakage, cracks, corrosion, heat or unusual smell are warning signs.

**8.** The correct charger controls voltage and current for the battery chemistry and configuration.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Magnetism electromagnetism and relays



*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

I = V ÷ R = 12 ÷ 240 = 0.05 A or 50 mA. The control switch must safely carry at least the coil current and withstand the switching conditions.

## Chapter review answers

**1.** Magnetic poles are north and south.

**2.** Current in a conductor produces a magnetic field.

**3.** Increase coil turns or current, or improve the magnetic core path within ratings.

**4.** A relay is an electrically operated switch.

**5.** The coil rating controls coil supply; the contact rating controls the load that contacts may switch.

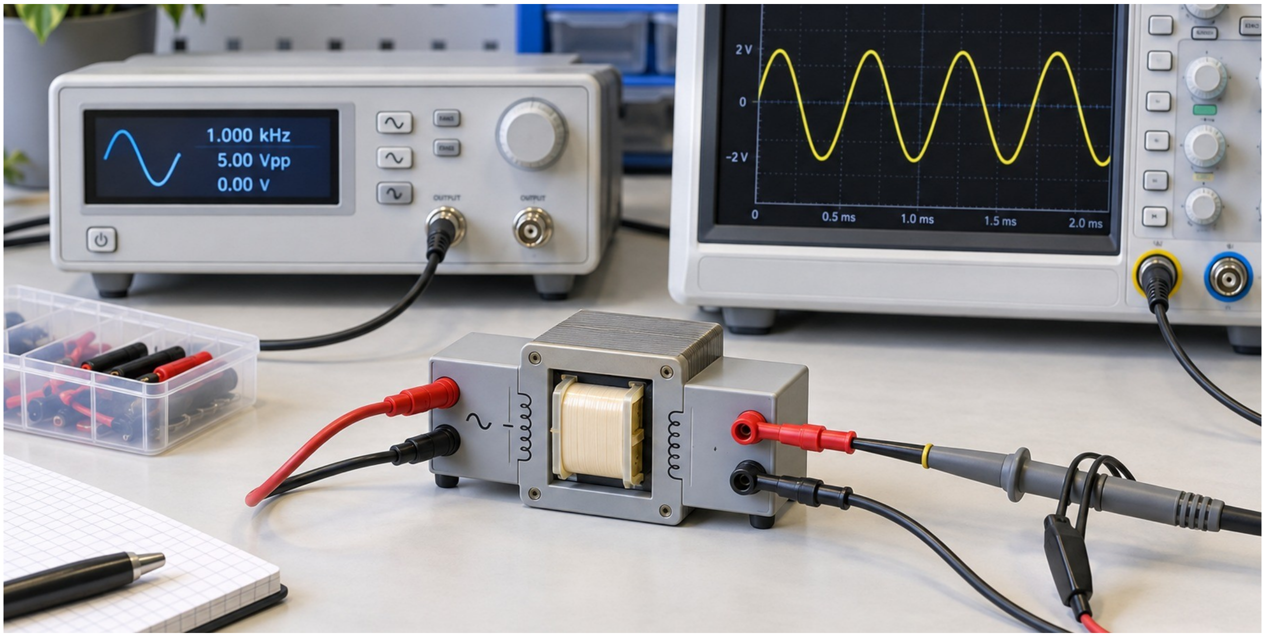
**6.** Normally open means open when the coil is de-energised.

**7.** 300 × 0.2 = 60 ampere-turns.

**8.** Examples include alarms, motor control, lighting control and electrical isolation between control and load circuits.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Alternating current fundamentals




*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

2.5 cycles occur in 0.050 s. Frequency = 2.5 ÷ 0.050 = 50 Hz.

## Chapter review answers

**1.** A cycle is one complete repetition of a waveform.

**2.** Frequency is measured in hertz.

**3.** T = 1 ÷ 25 = 0.040 s or 40 ms.

**4.** f = 1 ÷ 0.005 = 200 Hz.

**5.** RMS is the effective AC value based on equivalent heating in a resistor.

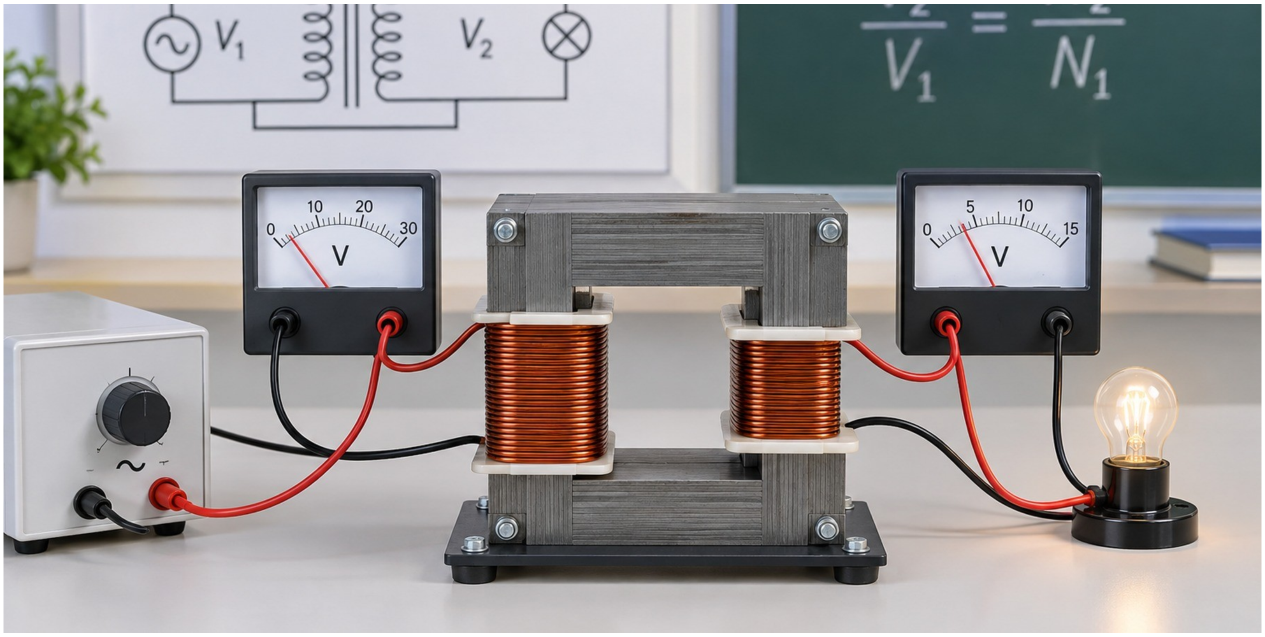
**6.** Peak-to-peak voltage = 2 × 8 = 16 V.

**7.** DC keeps one polarity; AC reverses polarity periodically.

**8.** An oscilloscope ground can create an unintended current path or short if connected incorrectly.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Transformers and power transfer




*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

Vs = Vp × Ns ÷ Np = 120 × 200 ÷ 1200 = 20 V.

## Chapter review answers

**1.** The primary winding receives the input.

**2.** Mutual induction is voltage induced in one winding by changing flux produced by another.

**3.** Vs = 240 × 100 ÷ 600 = 40 V.

**4.** Steady DC does not create continuously changing flux after the initial transient.

**5.** Examples are copper loss, eddy-current loss, hysteresis loss and stray-flux loss.

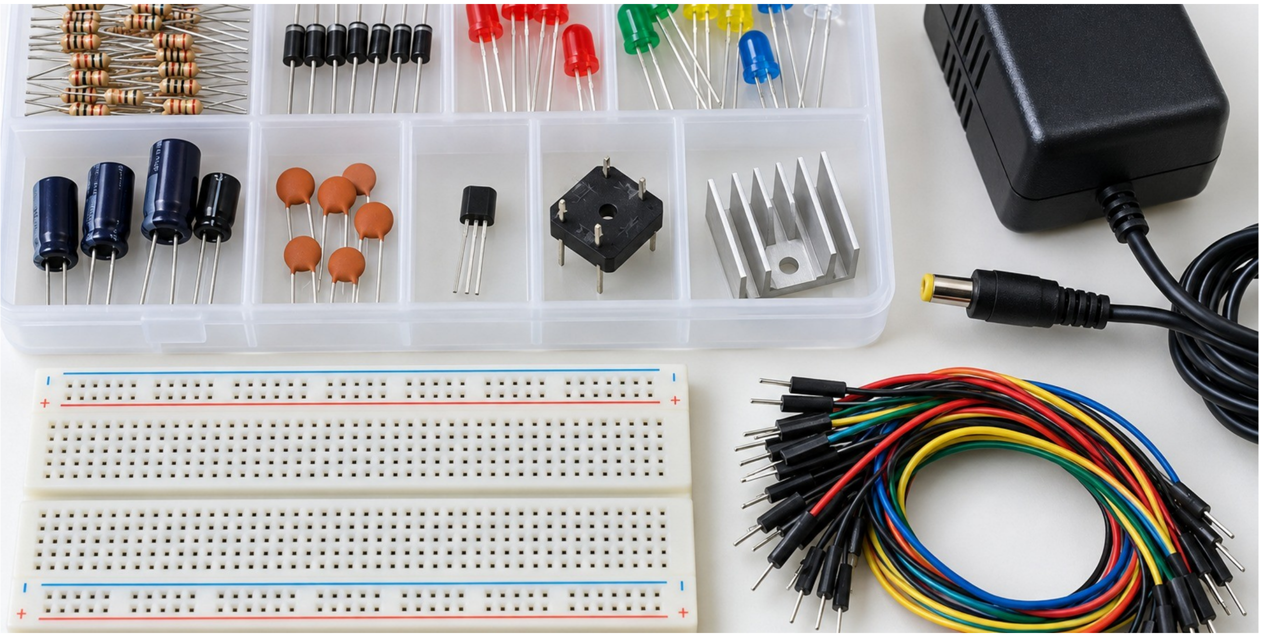
**6.** Laminations restrict eddy-current paths and reduce heating.

**7.** Isolation means there is no direct conductive connection between the windings.

**8.** Low voltage can still drive high current, causing burns, heating or fire.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Introduction to electronic components




*Representative training equipment. Use the accompanying schematic and approved procedure for exact connections.*

## Independent challenge solution

R = (12 − 2.1) ÷ 0.015 = 660 Ω. A nearby standard value such as 680 Ω gives slightly less current. Resistor power is approximately $I^2R = 0.015^2 \times 680 = 0.153$ W, so a 0.25 W or higher suitable resistor is required.

## Chapter review answers

**1.** A diode conducts mainly in one direction and can be used for rectification or protection.

**2.** The longer lead often indicates anode and the body mark identifies cathode; confirm with the data sheet or meter.

**3.** The resistor limits LED current.

**4.** R = (5 − 2) ÷ 0.010 = 300 Ω.

**5.** A capacitor stores charge and energy in an electric field.

**6.** It can retain dangerous charge after power is removed or rupture if voltage or polarity is wrong.

**7.** A rectifier converts AC to unidirectional pulsating current.

**8.** Transistors are used for switching and amplification.

*Keep going. Rework any question that was difficult, then ask your instructor to check your method.*

# Core relationships

| Topic | Relationship | Typical units |
|---|---|---|
| **Ohm's law** | $V = IR$ | V, A, Ω |
| **Power** | $P = VI$ | W, V, A |
| **Energy** | $E = Pt$ | Wh or kWh |
| **Series resistance** | $R_t = R_1 + R_2 + \ldots$ | Ω |
| **Two parallel resistors** | $R_t = R_1R_2 \div (R_1 + R_2)$ | Ω |
| **Efficiency** | useful output ÷ input × 100% | % |
| **Frequency and period** | $f = 1/T$ | Hz, s |
| **Transformer ratio** | $Vp/Vs = Np/Ns$ | ratio |
| **Cost** | energy × tariff | currency |

## Six-line solution format

1. Required quantity
2. Known values and units
3. Relationship
4. Substitution
5. Calculation
6. Answer with unit and reasonableness check

ACKNOWLEDGEMENT AND PUBLICATION STATUS

# Course authorship and use

Mr. R.A. Singh holds a Bachelor of Science degree in Electrical Engineering from the University of Guyana and graduated in 2009. He brings 20 years of private-sector electrical engineering experience to this practical student series. The books are independently published by CARR Consultancy and Engineering Services and are available free for non-commercial educational use. Contact: carrces592@gmail.com.

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## STUDENT PROGRESS RECORD

## Student completion record

| Chapter and topic | Date completed | Instructor initials |
|---|---|---|
| Chapter 01 Electrical safety and workshop practice | ________ | ______ |
| Chapter 02 Tools materials and good workmanship | ________ | ______ |
| Chapter 03 Electrical quantities units and symbols | ________ | ______ |
| Chapter 04 Measuring voltage current and resistance | ________ | ______ |
| Chapter 05 Ohms law and basic DC circuits | ________ | ______ |
| Chapter 06 Series circuits | ________ | ______ |
| Chapter 07 Parallel and series parallel circuits | ________ | ______ |
| Chapter 08 Electrical power energy efficiency and cost | ________ | ______ |
| Chapter 09 Cells batteries and DC supplies | ________ | ______ |
| Chapter 10 Magnetism electromagnetism and relays | ________ | ______ |
| Chapter 11 Alternating current fundamentals | ________ | ______ |
| Chapter 12 Transformers and power transfer | ________ | ______ |
| Chapter 13 Introduction to electronic components | ________ | ______ |