CARR TECHNICAL LEARNING SERIES

Practical Electrical and Electronic Technology

YEAR 2

Installation control testing fault finding and project work

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 2 COURSE MAP

Chapters and practical focus

Chapter	Learning focus
01	Generation transmission and distribution Practical: Map the supply chain
02	Plans specifications and load schedules Practical: Prepare a small-room plan
03	Cables containment and terminations Practical: Install a short conduit run
04	Lighting circuits and switching Practical: Wire one-way and two-way trainers
05	Socket outlets and fixed appliances Practical: Inspect and wire an outlet trainer
06	Earthing bonding and protective devices Practical: Demonstrate protective continuity
07	Distribution boards isolation and circuit schedules Practical: Create a circuit schedule
08	Relays contactors and control circuits Practical: Build start stop control
09	Motors and motor starting Practical: Inspect and run a motor trainer
10	Electronic control sensors and power supplies Practical: Build a light-controlled indicator
11	Inspection testing and commissioning Practical: Test an isolated training circuit
12	Fault finding maintenance and repair Practical: Find hidden faults
13	Estimating project work and examination preparation Practical: Complete a capstone project

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 ________

Generation transmission and distribution

Electrical energy moves from generating stations through high-voltage networks and local distribution before reaching consumers.

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

Learning outcomes

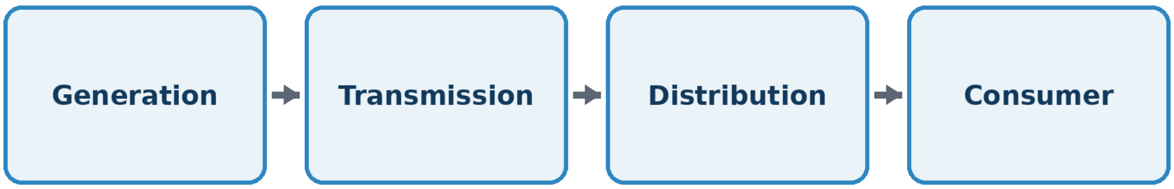
- Outline the supply chain.
- Explain why transmission uses high voltage.
- Distinguish service conductors from final circuits.
- Identify common supply hazards.

Key words

Generation	Conversion of another energy form into electrical energy.
Transmission	Bulk transfer at high voltage over distance.
Distribution	Delivery through networks nearer consumers.
Service	The supply connection between the distribution system and premises.

Move power with lower current

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

For a fixed power, increasing voltage reduces current. Lower current reduces conductor heating loss because loss depends on current squared.

Transformers raise voltage for transmission and lower it in stages for use. Protection and switching divide the network into controllable sections.

Supply arrangements and nominal values must be confirmed from local utility and current regulations.

Relationship to remember

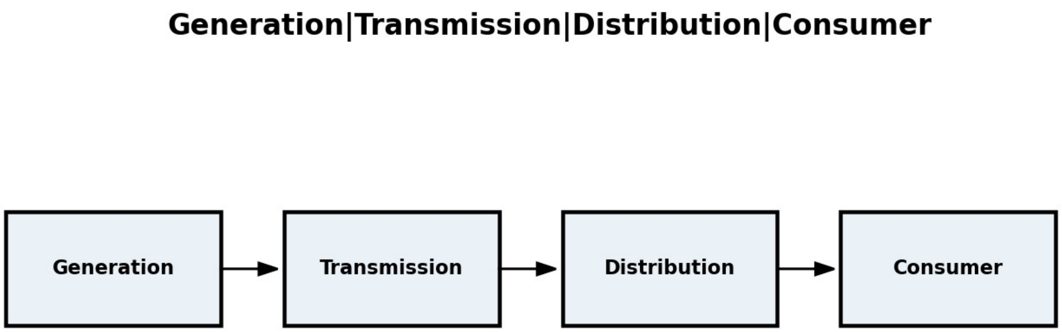
$$P = VI \qquad \text{conductor loss} = I^2R$$

These relationships explain the advantage of high-voltage transmission; they do not authorize work on supply networks.

Worked example 1 100 kW is transferred at 1 kV. Find current ignoring power factor.

Solution I = 100000 ÷ 1000 = 100 A.

Trace energy to the final circuit



Energy passes through voltage transformation, switching, protection and metering before final use.

The service enters the premises through metering and main isolation to a distribution board. Final circuits then supply lighting, socket outlets and fixed equipment.

The consumer must not interfere with sealed utility equipment or work beyond the permitted boundary.

Worked example 2 Transfer the same power at 10 kV. Find current.

Solution I = 100000 ÷ 10000 = 10 A.

Map the supply chain

Practical sequence

Arrange stages → Match function → Check order → Explain losses

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

Complete the practical in this order and record the evidence.

Identify each stage on a training diagram and match it to its function.

Equipment

supply-system chart • component cards • calculator

Method

1. Arrange generation through consumer stages.
2. Match transformers, lines, substations, meter and distribution board.
3. Calculate current at two voltages for one assigned power.
4. Explain the result to a partner.

Record your results

Test or observation	Measured result	What it means

Safety check This is a classroom model; never approach or interfere with utility equipment.

Follow the reasoning

Worked example 3 Compare I^2R losses for the two currents with the same conductor resistance.

Solution The 10 A case has one hundredth of the I^2 factor of the 100 A case.

Worked example 4 Why are substations used?

Solution They transform voltage and provide switching, protection and distribution points.

Worked example 5 Who should confirm local supply requirements?

Solution The electricity utility, current regulations and an appropriately qualified professional.

Try one without help

A 5 MW load is transferred at 5 kV and at 50 kV. Calculate current for each simplified case and compare I^2 factors.

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 generation.
2. Define distribution.
3. Why is voltage raised?
4. State the role of a substation.
5. Where does metering occur?
6. What is a final circuit?
7. Why must utility seals remain intact?
8. State one limitation of P = VI for real AC systems.

Mini project

Draw a labelled supply-chain poster for a typical Guyana community without claiming site-specific voltage levels.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Plans specifications and load schedules

Installations should be planned from user needs, drawings, circuit information and applicable rules before materials are purchased.

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

Learning outcomes

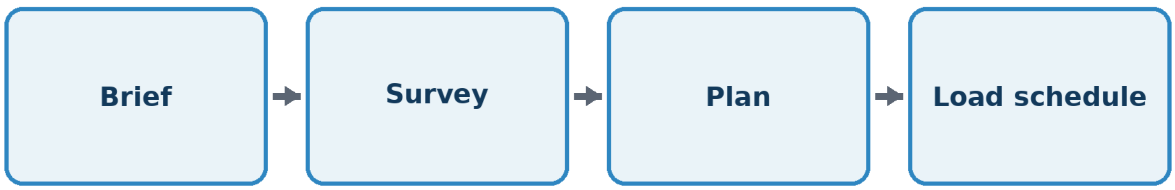
- Read basic plan symbols.
- Prepare a point schedule.
- Estimate connected load.
- Record assumptions and code checks.

Key words

Plan view	A drawing seen from above.
Specification	Written requirements for materials and workmanship.
Point schedule	A list of outlets, lights and fixed loads.
Demand	Expected load after considering realistic simultaneous use.

Turn needs into a buildable plan

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

A plan shows location; a schematic shows electrical function; a wiring diagram shows conductor connections. Each serves a different purpose.

Connected load is the sum of rated loads. Maximum demand is not automatically the same and must be determined using current local rules.

A useful schedule lists circuit reference, point type, quantity, load, control and special conditions.

Relationship to remember

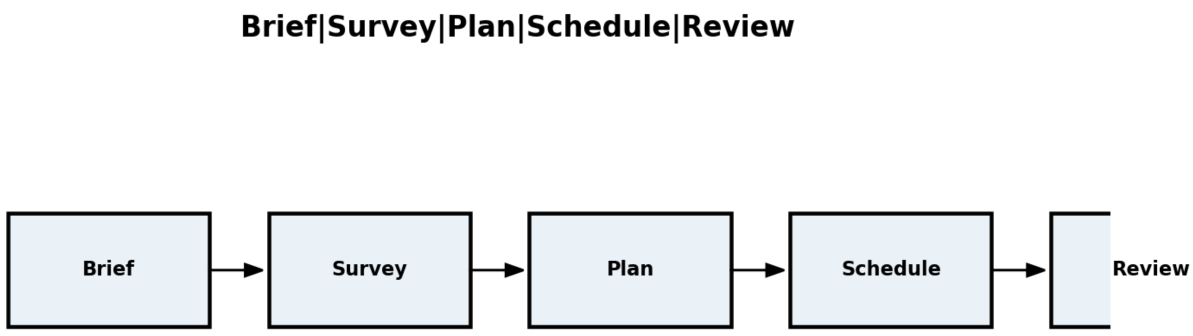
$$\text{connected load} = \text{sum of individual rated loads}$$

Do not apply invented diversity factors. Use the current code or authority guidance for a real design.

Worked example 1 Six 12 W lamps are connected. Find lighting load.

Solution $6 \times 12 = 72$ W.

Check the information path



Planning converts requirements into drawings, schedules and checks.

Begin with the client or assignment brief. Survey the space, mark points, group circuits, estimate loads and review protection and accessibility.

Revision control matters. The drawing used on site must match the latest approved issue.

Worked example 2 Add a 1200 W appliance to the 72 W lighting load.

Solution Connected load = 1272 W.

Prepare a small-room plan

Practical sequence

Measure room → Mark points → Estimate loads → Review plan

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

Complete the practical in this order and record the evidence.

Survey a training room and produce a point schedule and neat plan.

Equipment

graph paper • tape measure • symbol sheet • calculator

Method

1. Measure the room safely.
2. Mark doors and fixed features.
3. Propose light, switch and outlet points.
4. Prepare a schedule with quantities and loads.
5. Review access, control and safety with the instructor.

Record your results

Test or observation	Measured result	What it means

Safety check Do not open or inspect live accessories during the survey.

Follow the reasoning

Worked example 3 At 230 V, estimate current for 1272 W at unity power factor.

Solution I = 1272 ÷ 230 = 5.53 A.

Worked example 4 Why is this not automatically the protective-device rating?

Solution Cable capacity, installation method, demand, starting current and current rules must also be checked.

Worked example 5 A plan and schedule disagree. What should the installer do?

Solution Stop and obtain clarification through the approved revision process.

Try one without help

Prepare a connected-load schedule for eight 10 W lamps, four 100 W outlets used for training loads and one 1.5 kW appliance.

Chapter review

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

1. Distinguish plan and schematic.
2. Define specification.
3. Calculate load for ten 9 W lamps.
4. What belongs in a point schedule?
5. Why track drawing revisions?
6. Define connected load.
7. Why can demand be lower than connected load?
8. Name two site-survey observations.

Mini project

Produce a complete plan, legend and point schedule for a small electrical workshop.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Cables containment and terminations

Cable selection and installation must account for current, environment, mechanical protection and termination quality.

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

Learning outcomes

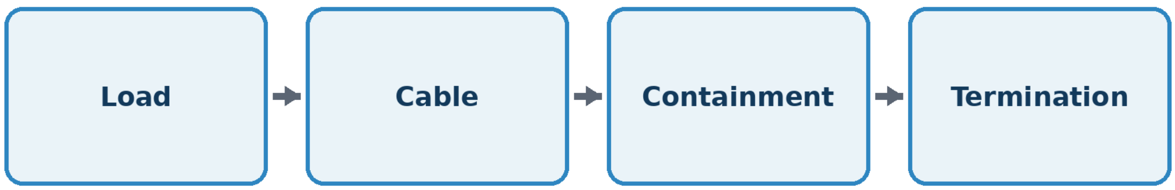
- Identify common cable features.
- Explain derating factors conceptually.
- Select containment for a stated environment.
- Inspect a completed termination.

Key words

Conductor size	Cross-sectional area of the conductive material.
Containment	Conduit, trunking or tray used to route and protect wiring.
Derating	Reduction of current capacity because of installation conditions.
Gland	A fitting that secures and seals a cable entry.

Selection involves several checks

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

A cable must carry the design current while remaining within temperature limits. Ambient temperature, grouping and thermal insulation can reduce capacity.

Containment protects and organizes conductors. Fill, bend radius, drainage, corrosion and accessibility must be considered.

A termination needs electrical contact, mechanical restraint, insulation integrity and suitable environmental sealing.

Relationship to remember

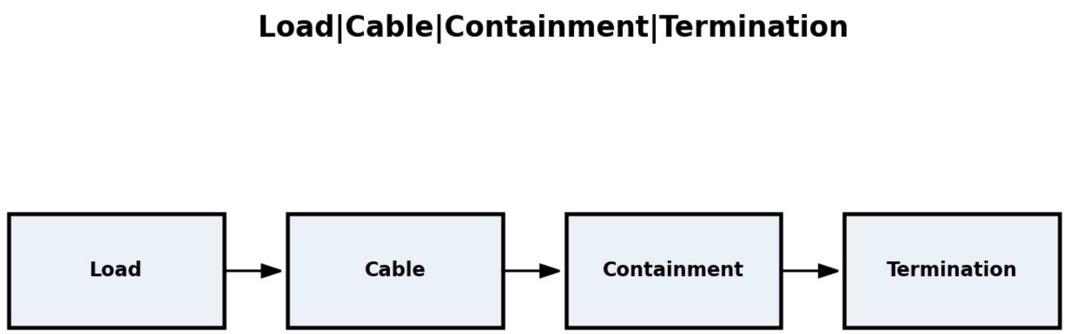
$$\text{voltage drop} = \text{current} \times \text{circuit resistance}$$

Real cable selection must follow current tables and correction factors; the simple relationship explains the trend only.

Worked example 1 Current doubles while route resistance stays constant. What happens to voltage drop?

Solution Voltage drop doubles.

Inspect the complete route



A cable route is a coordinated system, not a conductor alone.

Look beyond the conductor ends. Support spacing, bends, entries, identification and protection against sharp edges affect the installation.

Do not use arbitrary cable sizes from memory for real work. Confirm current requirements and manufacturer data.

Worked example 2 Why can grouped cables run hotter?

Solution Each cable adds heat while reduced airflow limits cooling.

Install a short conduit run

Practical sequence

Mark route → Cut and deburr → Pull conductors → Inspect

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

Complete the practical in this order and record the evidence.

Plan, cut, deburr and assemble a short trainer route with a draw-in box.

Equipment

PVC conduit • bending equipment • cutter • deburring tool • fittings

Method

1. Mark the route and bend positions.
2. Cut squarely and remove burrs.
3. Form the bend without flattening.
4. Assemble and support the route.
5. Pull approved practice conductors and inspect.

Record your results

Test or observation	Measured result	What it means

Safety check Wear eye protection and keep hands clear of cutting and bending tools.

Follow the reasoning

Worked example 3 What does a grommet protect against?

Solution It protects insulation from a sharp hole edge.

Worked example 4 Why is a gland used?

Solution It provides restraint and, where designed, sealing and earth continuity.

Worked example 5 A terminal contains cut strands. What action is required?

Solution Isolate, cut back and re-terminate correctly.

Try one without help

Explain how high ambient temperature, grouping and thermal insulation can affect cable selection.

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 containment.
2. Why remove burrs?
3. State two cable-selection factors.
4. What is derating?
5. Why protect entries?
6. State two termination checks.
7. What affects voltage drop?
8. Why consult current tables?

Mini project

Build a sample board showing correct and deliberately defective cable entries for inspection practice.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Lighting circuits and switching

Lighting circuits use switching arrangements that place control devices in the live conductor and keep the lamp return complete.

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

Learning outcomes

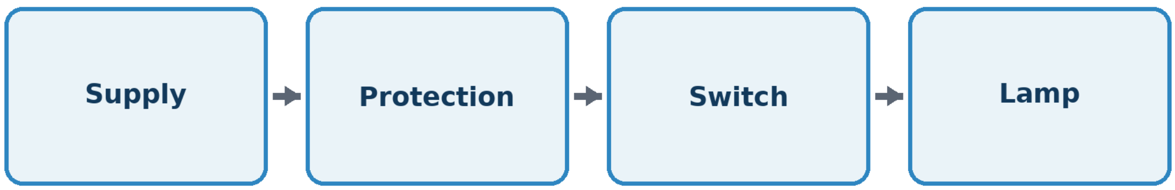
- Explain one-way switching.
- Trace a two-way switching arrangement.
- Identify switched live and neutral.
- Test a low-voltage lighting trainer.

Key words

One-way switching	Control of a light from one position.
Two-way switching	Control of a light from either of two positions.
Switched live	A live conductor controlled by a switch.
Luminaire	A complete light fitting or lighting unit.

Switch the live conductor

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

A one-way switch opens the live path to the lamp. The neutral normally runs directly to the lamp. Protective conductors continue to required exposed conductive parts.

Two-way switching uses changeover contacts and two traveller or strapper conductors. Either switch can change the selected path.

Conductor identification must remain clear, including any conductor used as a switched live.

Relationship to remember

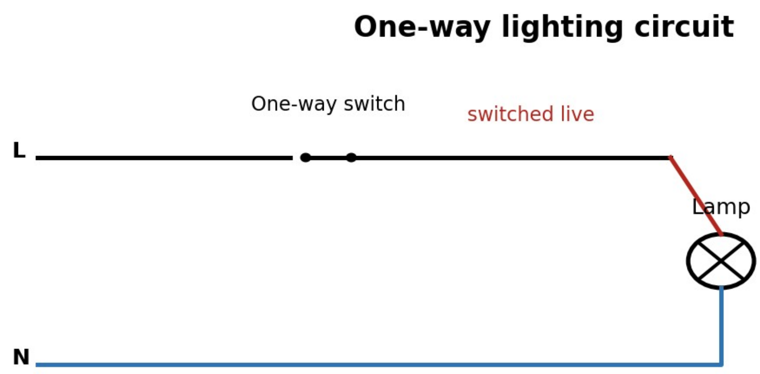
lamp current = lamp power ÷ supply voltage

This calculation estimates operating current; circuit design still requires current installation rules.

Worked example 1 A 12 W lamp operates at 230 V. Estimate current.

Solution I = 12 ÷ 230 = 0.052 A.

Trace before connecting



The switch interrupts the live conductor; neutral completes the lamp circuit.

Trace from live through the control contacts, then through the lamp to neutral. Mark each terminal from the approved diagram.

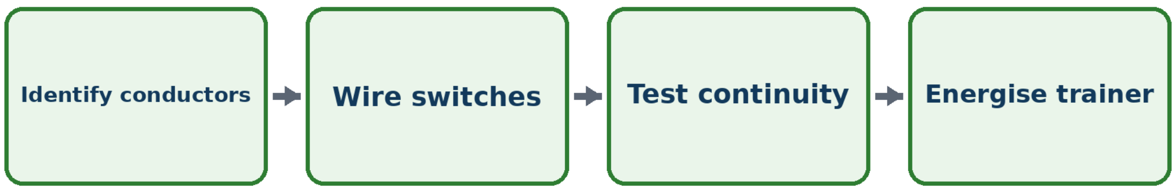
Functional testing follows inspection and safe test procedures. A lamp that does not operate may have supply, switch, lamp, neutral or connection faults.

Worked example 2 Why should the switch interrupt live rather than neutral?

Solution With live interrupted, downstream parts are not intentionally left connected to live when off.

Wire one-way and two-way trainers

Practical sequence



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

Complete the practical in this order and record the evidence.

Build and test low-voltage lighting circuits from approved diagrams.

Equipment

lighting trainer • two-way switches • lamps • multimeter • leads

Method

1. Identify all terminals.
2. Wire one-way control with power off.
3. Inspect and function-test.
4. Reconfigure to the approved two-way diagram.
5. Test every switch-position combination and record results.

Record your results

Test or observation	Measured result	What it means

Safety check Use a low-voltage trainer; isolate before changing any conductor.

Follow the reasoning

Worked example 3 What is a switched live?

Solution The conductor carrying live potential from the switch to the lamp when the switch is closed.

Worked example 4 A lamp works only when both two-way switches are in one position. What is likely?

Solution A traveller connection may be missing or incorrectly placed; test systematically while isolated.

Worked example 5 Four 10 W lamps operate together. Find total load.

Solution Ptotal = 4 × 10 = 40 W.

Try one without help

Prepare a truth table showing lamp ON or OFF for all four position combinations of two two-way switches.

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-way switching.
2. What is a switched live?
3. Why identify conductors?
4. Find current for 18 W at 230 V.
5. How many control positions does two-way switching provide?
6. What is a traveller conductor?
7. State two possible lamp faults.
8. Why inspect before functional testing?

Mini project

Create a demonstration board showing one-way and two-way lighting with a clear connection diagram.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Socket outlets and fixed appliances

Outlet and appliance circuits require correct polarity, protective continuity, suitable isolation and load assessment.

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

Learning outcomes

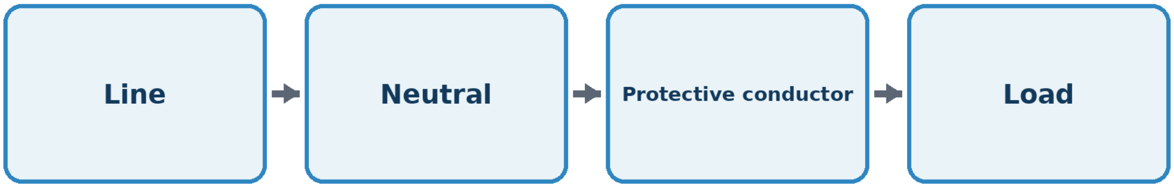
- Identify line, neutral and protective functions.
- Explain polarity checks.
- Estimate appliance current.
- Recognize isolation and switching needs.

Key words

Polarity	Correct connection of line, neutral and switched conductors.
Protective conductor	A conductor provided for safety against electric shock.
Isolation	Disconnection from all relevant live conductors.
Radial circuit	A final circuit that extends from the protective device without returning.

Connect functions correctly

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

Line supplies energy, neutral provides the intended return and the protective conductor provides a low-impedance fault path. They are not interchangeable.

Fixed appliances may require local control or isolation appropriate to the equipment and current rules.

Accessory ratings must not be exceeded. The circuit, cable, protective device and outlet are selected as a coordinated system.

Relationship to remember

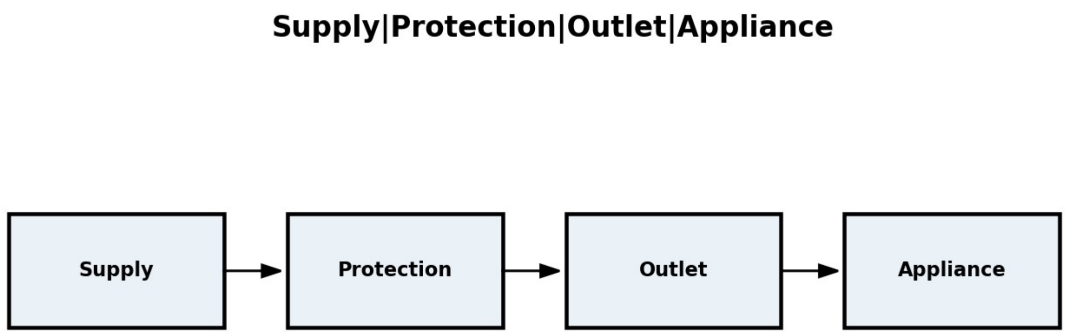
$$I = P \div V$$

For motors and electronic loads, power factor, efficiency and starting current may also matter.

Worked example 1 A 2 kW heater operates at 230 V. Estimate current.

Solution I = 2000 ÷ 230 = 8.70 A.

Inspect before energising



Every load depends on coordinated conductors, protection, connection and isolation.

Check conductor identification, terminal tightness, exposed copper, protective continuity, enclosure condition and strain relief.

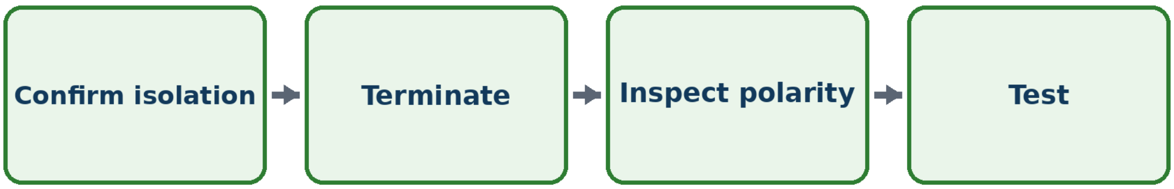
Polarity is tested using an approved sequence. A functioning appliance does not prove that polarity and protection are correct.

Worked example 2 Why is neutral not a protective conductor?

Solution Neutral carries operating current; the protective conductor is reserved for fault protection and bonding functions.

Inspect and wire an outlet trainer

Practical sequence



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

Complete the practical in this order and record the evidence.

Terminate an isolated training accessory and complete visual and continuity checks.

Equipment

outlet trainer • practice cable • hand tools • continuity tester

Method

1. Confirm isolation.
2. Identify terminals from markings.
3. Prepare conductors without damage.
4. Terminate with correct identification and restraint.
5. Inspect and complete instructor-approved continuity checks.

Record your results

Test or observation	Measured result	What it means

Safety check Do not connect the trainer to mains; testing remains under instructor control.

Follow the reasoning

Worked example 3 An outlet works with line and neutral reversed. Is it acceptable?

Solution No. Operation does not prove correct polarity or safe switching.

Worked example 4 Three appliances draw 2 A, 3 A and 4 A simultaneously. Find total current.

Solution Itotal = 2 + 3 + 4 = 9 A.

Worked example 5 Why provide strain relief on a flexible cord?

Solution It prevents pulling force from reaching the conductor terminals.

Try one without help

A 230 V circuit supplies 750 W, 1200 W and 100 W loads together. Estimate total current at unity power factor.

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 function of line.
2. State the function of neutral.
3. State the function of the protective conductor.
4. Calculate current for 1150 W at 230 V.
5. What is polarity?
6. Why is strain relief needed?
7. Define radial circuit.
8. Why does operation not prove safety?

Mini project

Prepare an accessory inspection checklist with at least twelve visible quality points.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Earthing bonding and protective devices

Protection limits shock and fire risk by providing fault paths and disconnecting dangerous conditions.

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

Learning outcomes

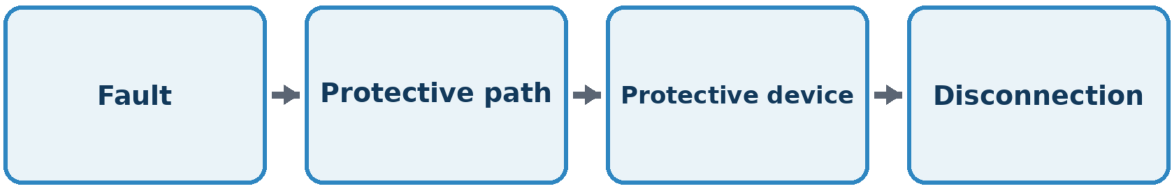
- Explain protective earthing.
- Distinguish earthing and bonding.
- Describe fuse, circuit-breaker and residual-current functions.
- Explain automatic disconnection conceptually.

Key words

Earthing	Connection of exposed conductive parts to the protective system and earth arrangement.
Bonding	Connection of conductive parts to reduce dangerous voltage differences.
Overcurrent	Current above the intended rated value.
Residual current	Difference between currents in live conductors caused by leakage or another path.

Protection uses coordinated layers

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

A protective conductor provides a low-impedance route for fault current. The protective device then disconnects within the required conditions.

A fuse or circuit-breaker responds to overcurrent. A residual-current device compares current leaving and returning and trips when the difference exceeds its operating criterion.

Bonding reduces voltage differences between accessible conductive parts. It does not replace circuit protective conductors.

Relationship to remember

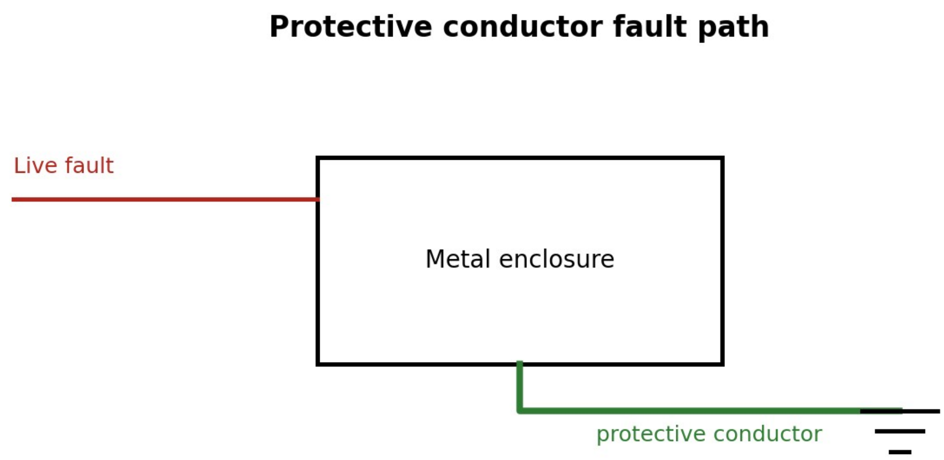
$$\text{fault current} \approx \text{supply voltage} \div \text{fault-loop impedance}$$

This simplified relation shows why a lower fault-loop impedance produces greater fault current and faster overcurrent operation.

Worked example 1 230 V is applied across a 1 Ω simplified fault loop. Estimate fault current.

Solution I = 230 ÷ 1 = 230 A.

Trace the fault path



The green path represents the intended route that supports rapid disconnection after a live-to-enclosure fault.

A live conductor touching a metal enclosure raises its potential. The protective path carries fault current back toward the source so the protective device can act.

If the protective path is missing or high resistance, the enclosure may remain dangerous. Visual inspection and approved testing are both required.

Worked example 2 What happens if loop impedance rises to 10 Ω?

Solution Estimated current falls to 23 A, which may delay or prevent the intended overcurrent operation.

Demonstrate protective continuity

Practical sequence

Isolate → Connect tester → Measure continuity → Record result

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

Complete the practical in this order and record the evidence.

Measure continuity on a de-energised metal-enclosure trainer.

Equipment

continuity tester • trainer with protective conductor • test leads

Method

1. Confirm the trainer is isolated.
2. Prove the tester as instructed.
3. Measure between the protective terminal and accessible metal points.
4. Record and compare readings.
5. Introduce an instructor-controlled open fault and identify the change.

Record your results

Test or observation	Measured result	What it means

Safety check Continuity testing is performed only on isolated equipment.

Follow the reasoning

Worked example 3 Does an RCD replace overcurrent protection?

Solution No. It provides a different protective function and must be coordinated with overcurrent protection.

Worked example 4 Why bond accessible metal services where required?

Solution To reduce dangerous potential differences during a fault.

Worked example 5 May the protective conductor be used as neutral?

Solution No. Their functions and permitted connections differ.

Try one without help

Explain how fault-loop impedance affects fault current and why protective-device selection cannot use current rating alone.

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 earthing.
2. Define bonding.
3. What does a fuse detect?
4. What does an RCD compare?
5. Calculate fault current at 230 V and 2 Ω.
6. Why must protective continuity be tested?
7. Can bonding replace earthing?
8. State one limitation of the simplified fault formula.

Mini project

Build a labelled protection demonstration board showing overcurrent and residual-current functions conceptually.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Distribution boards isolation and circuit schedules

A distribution board divides the supply into protected circuits and provides organized isolation, identification and testing points.

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

Learning outcomes

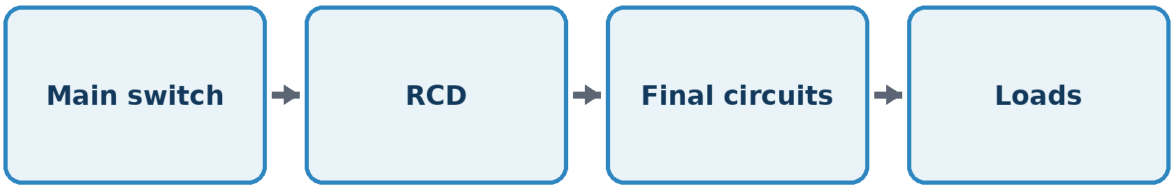
- Identify main distribution-board functions.
- Read a circuit schedule.
- Explain circuit separation and identification.
- Outline safe inspection boundaries.

Key words

Main switch	Device intended to isolate the installation or specified section.
Busbar	A conductor distributing supply to several devices.
Circuit schedule	A record matching protective devices to circuits.
Spare way	An unused position reserved for future equipment where suitable.

Organization supports safety

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

The enclosure houses main isolation, protective devices, neutral and protective terminals as appropriate to the system. Covers prevent access to live parts.

A clear schedule reduces the chance of isolating the wrong circuit and supports inspection, testing and emergency response.

Device ratings alone do not prove correct design. Cable capacity, fault level, disconnection conditions, load characteristics and local rules must agree.

Relationship to remember

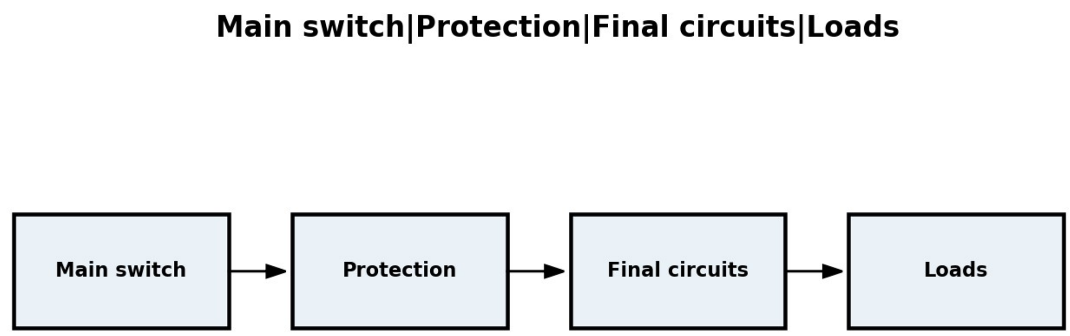
$$\text{total connected current} \neq \text{automatic main-device setting}$$

Demand, diversity, circuit design and supply conditions must be assessed using current requirements.

Worked example 1 Why is a circuit schedule important?

Solution It identifies the area or load controlled by each device and supports safe isolation.

Read before touching



A distribution board separates the incoming supply into identified protected circuits.

Begin with labels, diagrams and safe external observations. Internal access requires authorization, isolation and verification.

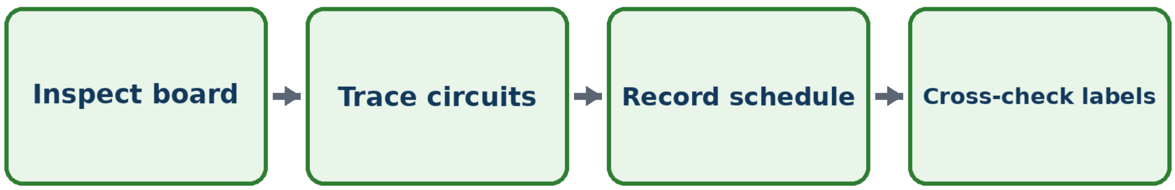
Unused openings need proper blanks. Conductors should be supported, identified and terminated without damage.

Worked example 2 Three circuit estimates are 3 A, 8 A and 12 A. Find connected current.

Solution 3 + 8 + 12 = 23 A, before any permitted demand assessment.

Create a circuit schedule

Practical sequence



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

Complete the practical in this order and record the evidence.

Inspect the outside of a training board and prepare an accurate schedule.

Equipment

de-energised training board • labels • schedule form • pencil

Method

1. Confirm the board is an isolated trainer.
2. Record device references and ratings.
3. Trace each training circuit by approved labels or continuity method.
4. Write clear circuit descriptions.
5. Have another student verify the schedule.

Record your results

Test or observation	Measured result	What it means

Safety check Do not remove covers from live equipment; internal work requires instructor authorization and safe isolation.

Follow the reasoning

Worked example 3 May a 32 A device automatically protect any cable?

Solution No. Cable size, installation conditions and disconnection requirements must be checked.

Worked example 4 What is the purpose of a main switch?

Solution It provides isolation for the installation or stated section within its design.

Worked example 5 What should cover an unused opening?

Solution A suitable secure blanking piece that maintains enclosure protection.

Try one without help

A board serves lighting, outlets, a water pump and an air-conditioning unit. Write clear schedule descriptions that avoid vague labels.

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 two distribution-board functions.
2. Define busbar.
3. Why identify every circuit?
4. What is a spare way?
5. Does device rating prove cable suitability?
6. Name two external inspection points.
7. Why use secure blanks?
8. Distinguish connected current and demand.

Mini project

Design a blank circuit-schedule form suitable for a small workshop and test it on a training board.

My reflection

One skill I can now demonstrate is:

____

____

One point I need to practise again is:

____

____

Relays contactors and control circuits

Control circuits use switches, relays and contactors to operate loads safely and logically.

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

Learning outcomes

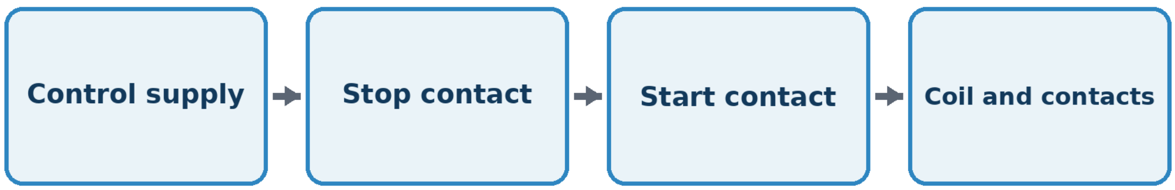
- Read a simple ladder diagram.
- Explain seal-in control.
- Distinguish power and control circuits.
- Identify overload and emergency-stop functions.

Key words

Contactor	An electrically operated switch intended for frequent control of power circuits.
Seal-in contact	An auxiliary contact that maintains coil current after the start button is released.
Interlock	A control that prevents incompatible operations.
Overload relay	A device that responds to sustained motor overcurrent according to its design.

Separate command from power

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

The control circuit carries the logic and energises a coil. The power circuit carries load current through main contacts.

A normally closed stop button is placed in series with the coil. A normally open start button energises the coil; an auxiliary contact then bypasses the start button to maintain operation.

An overload auxiliary contact can open the coil circuit. Short-circuit protection is still required separately.

Relationship to remember

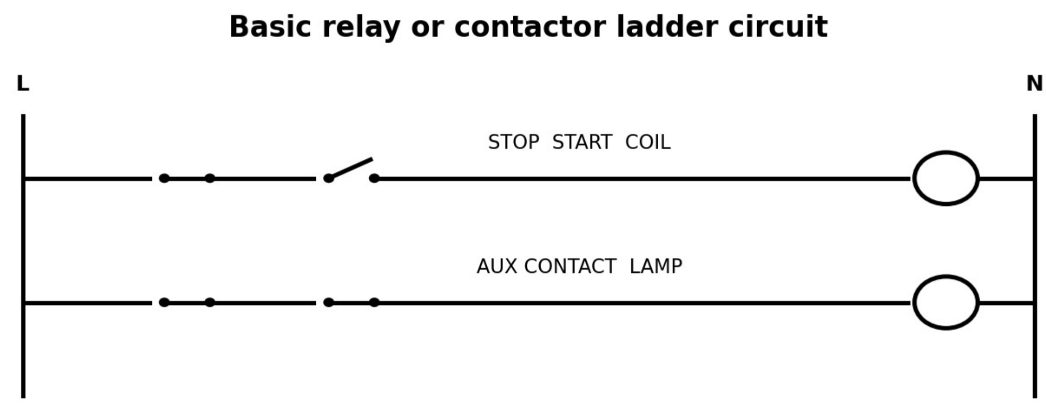
$$\text{coil current} = \text{coil power} \div \text{coil voltage}$$

Use the coil rating, not the contact rating, for this calculation.

Worked example 1 A 24 V coil consumes 6 W. Find current.

Solution $I = 6 \div 24 = 0.25$ A.

Read ladder logic left to right



The stop and start devices control a coil; an auxiliary path can maintain the command.

The two vertical rails represent the control supply. Each horizontal rung describes a condition that energises an output.

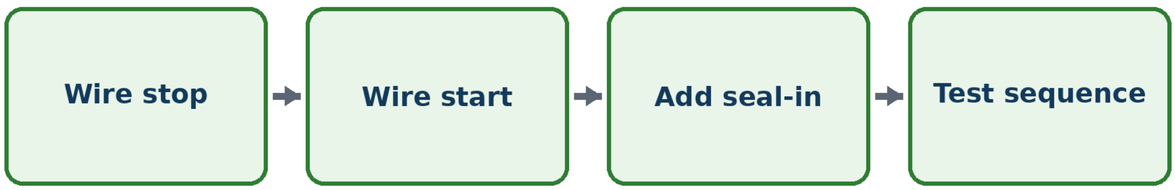
Control diagrams show contact state with coils de-energised and devices in their normal condition unless otherwise stated.

Worked example 2 Why is the stop button normally closed?

Solution A broken wire or loss of continuity tends to stop the coil rather than preventing a stop command.

Build start stop control

Practical sequence



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

Complete the practical in this order and record the evidence.

Wire a low-voltage relay trainer with stop, start and seal-in contact.

Equipment

low-voltage control trainer • relay • pushbuttons • indicator • leads

Method

1. Identify normal contact states.
2. Wire the stop contact in series with the coil.
3. Add the start contact.
4. Add the seal-in auxiliary contact.
5. Inspect, energise and test stop, start and supply-loss behaviour.

Record your results

Test or observation	Measured result	What it means

Safety check Use only the approved low-voltage trainer and isolate before rewiring.

Follow the reasoning

Worked example 3 What does a seal-in contact do?

Solution It maintains coil current after the momentary start button is released.

Worked example 4 Does an overload relay normally clear a short circuit?

Solution No. Appropriate short-circuit protection is also required.

Worked example 5 What is an interlock used for?

Solution It prevents conflicting commands, such as forward and reverse contactors energising together.

Try one without help

Draw a ladder rung for a coil controlled by a normally closed stop, normally closed overload and normally open start with seal-in contact.

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 contactor.
2. Distinguish power and control circuits.
3. Why is stop normally closed?
4. What is seal-in control?
5. Define interlock.
6. Find current of a 12 W, 24 V coil.
7. What does an overload detect?
8. Why is separate short-circuit protection needed?

Mini project

Construct a labelled low-voltage start-stop demonstration panel with status indicators.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Motors and motor starting

Motors convert electrical energy into mechanical motion and require suitable starting, protection and mechanical safety.

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

Learning outcomes

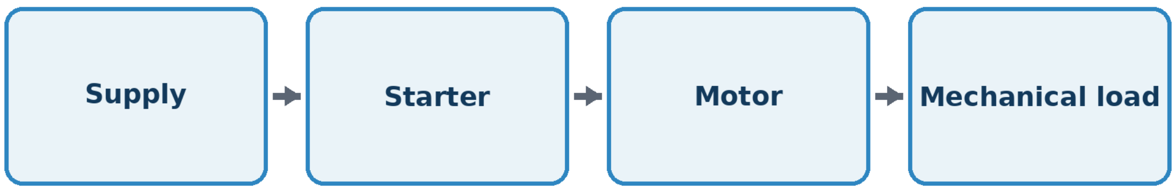
- State basic motor principles.
- Read a motor nameplate.
- Explain starting current.
- Apply safe checks before operation.

Key words

Torque	Turning effect produced by a motor.
Rated current	Current specified for rated operating conditions.
Starting current	Current drawn during acceleration, often above running current.
Overload	A sustained condition that causes excessive current or heating.

Electrical and mechanical systems interact

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

Magnetic forces create torque. The driven load determines how much torque is required and how the motor accelerates.

Nameplate voltage, phase, frequency, current, speed, power and connection information guide selection and commissioning.

Protection must address short circuit, overload, loss of phase where relevant, and unsafe mechanical conditions.

Relationship to remember

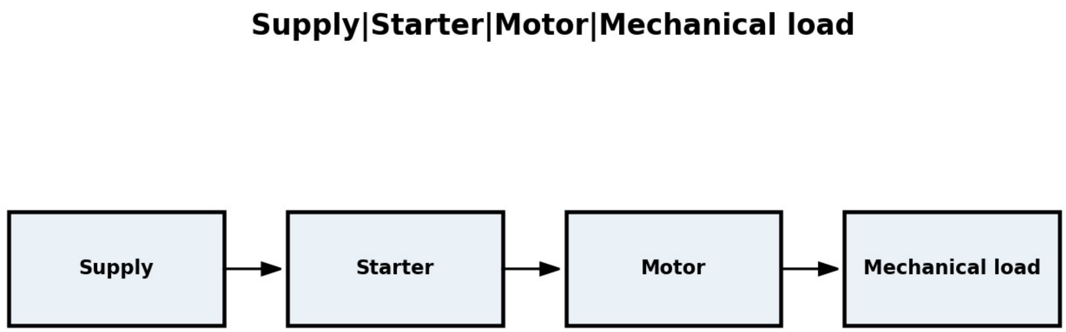
$$\text{efficiency} = \text{mechanical output power} \div \text{electrical input power} \times 100\%$$

Motor input calculations may also require power factor and phase relationships.

Worked example 1 A motor takes 1000 W and delivers 750 W. Find efficiency.

Solution Efficiency = 750 ÷ 1000 × 100% = 75%.

Start only after checks



The starter controls and protects the motor while the driven load determines torque demand.

Check mounting, guarding, coupling, free rotation, lubrication requirements, connection, insulation and protective continuity.

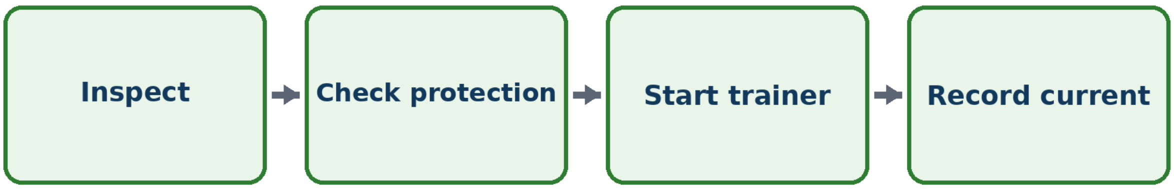
A motor that hums, overheats, vibrates or fails to accelerate should be stopped and investigated rather than repeatedly restarted.

Worked example 2 A 230 V single-phase teaching motor takes 4 A at simplified unity power factor. Find input power.

Solution $P = VI = 230 \times 4 = 920$ W.

Inspect and run a motor trainer

Practical sequence



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

Complete the practical in this order and record the evidence.

Complete pre-start checks and observe starting and running behaviour.

Equipment

low-voltage or approved motor trainer • checklist • clamp meter if approved • tachometer if available

Method

1. Read the nameplate.
2. Check mounting, guard and free movement.
3. Verify approved electrical connections.
4. Start under instructor supervision.
5. Record starting observation, running current and direction, then stop safely.

Record your results

Test or observation	Measured result	What it means

Safety check Keep clear of rotating parts and never remove a guard while the motor can start.

Follow the reasoning

Worked example 3 Why can starting current be high?

Solution Before speed builds, the motor produces little opposing electrical effect and draws greater current.

Worked example 4 A motor vibrates strongly after coupling. What should be done?

Solution Stop, isolate and check alignment, mounting, coupling and load condition.

Worked example 5 Why is a guard required?

Solution It prevents contact with moving parts and reduces risk from entanglement or ejected parts.

Try one without help

A motor has 1.5 kW output at 80% efficiency. Calculate input 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. Define torque.
2. What is rated current?
3. Why can start current exceed run current?
4. Calculate efficiency for 600 W out and 800 W in.
5. Name four pre-start checks.
6. What does overload protection address?
7. Why stop a humming motor?
8. State two mechanical hazards.

Mini project

Prepare a motor nameplate-reading worksheet using three motors or instructor-supplied data plates.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Electronic control sensors and power supplies

Sensors and electronic switches allow physical conditions to control indicators, relays and other loads.

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

Learning outcomes

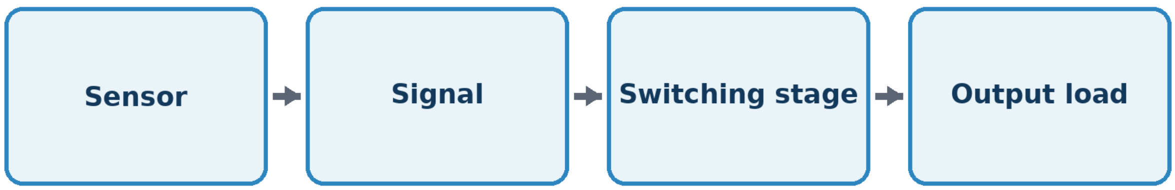
- Explain a potential divider.
- Describe common sensors.
- Use a transistor as a switch conceptually.
- Identify stages of a DC power supply.

Key words

Sensor	A component that changes an electrical property in response to a condition.
Potential divider	Series resistors used to obtain a fraction of a supply voltage.
Bias	Electrical condition applied to set device operation.
Regulation	Control that keeps output near a required value as conditions change.

Turn a condition into a voltage

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

An LDR changes resistance with light; a thermistor changes resistance with temperature. In a divider, this change alters the output voltage.

A transistor can use a small input signal to control a larger load current within its ratings. A relay coil needs a suppression diode in many DC switching circuits.

A typical isolated DC supply contains transformation, rectification, filtering and regulation.

Relationship to remember

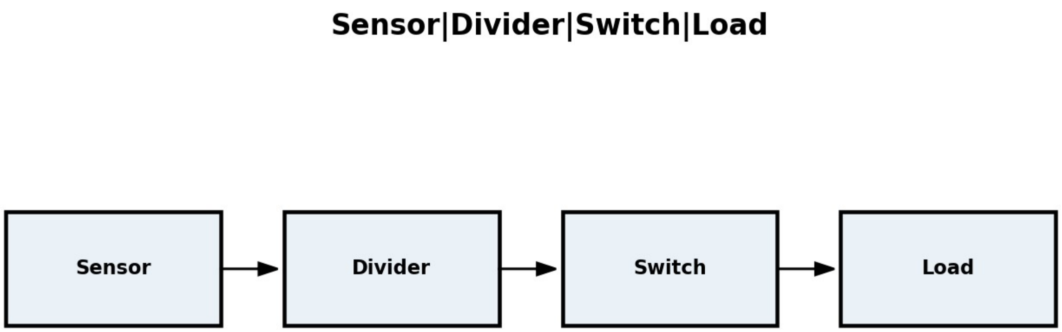
$$V_{out} = V_s \times R2 \div (R1 + R2)$$

The formula applies to an unloaded divider; a connected load can change the result.

Worked example 1 R1 = 1 kΩ and R2 = 1 kΩ on 10 V. Find Vout.

Solution Vout = 10 × 1 ÷ 2 = 5 V.

Follow signal flow



A sensor changes an electrical value; the control stages decide when to operate the load.

Start with the sensed condition, then trace the sensor voltage to the switching stage and the output load.

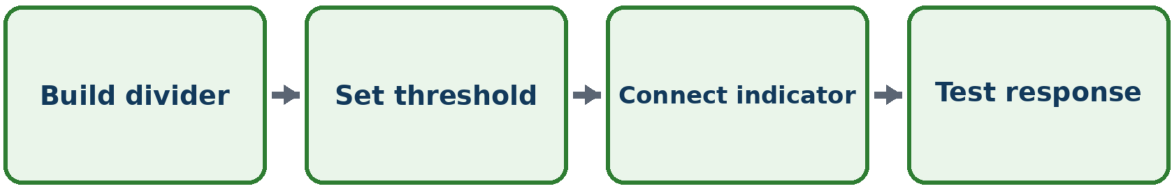
When a circuit operates at the wrong threshold, test supply, sensor values, divider voltage and switching stage in order.

Worked example 2 R2 increases while R1 stays fixed. What happens to Vout measured across R2?

Solution Vout increases toward the supply voltage.

Build a light-controlled indicator

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 LDR divider and approved transistor module to control an LED.

Equipment

breadboard • LDR • resistors • transistor module • LED • low-voltage supply • multimeter

Method

1. Build the divider with power off.
2. Measure Vout in bright and shaded conditions.
3. Connect the switching stage from the approved diagram.
4. Test the LED response.
5. Adjust one approved resistor and record the threshold change.

Record your results

Test or observation	Measured result	What it means

Safety check Use only the low-voltage supply and verify transistor and LED connections before energising.

Follow the reasoning

Worked example 3 Why place a diode across a DC relay coil?

Solution It limits the inductive voltage produced when coil current is interrupted.

Worked example 4 Name the four stages of a basic DC supply.

Solution Transformation, rectification, filtering and regulation.

Worked example 5 A transistor output is always on. Name two checks.

Solution Check the sensor/divider voltage and check for a shorted or incorrectly connected transistor.

Try one without help

A 12 V divider uses 4.7 kΩ on top and 10 kΩ to ground. Calculate unloaded output 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 sensor.
2. What changes in an LDR?
3. State the divider formula.
4. Find Vout for equal resistors on 6 V.
5. What does a transistor switch do?
6. Why suppress a relay coil?
7. Name four power-supply stages.
8. Why can loading change divider voltage?

Mini project

Design a low-voltage automatic night-light and document its input, threshold, output and test results.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Inspection testing and commissioning

Inspection and testing provide evidence that an installation or assembly matches its design and safety requirements before service.

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

Learning outcomes

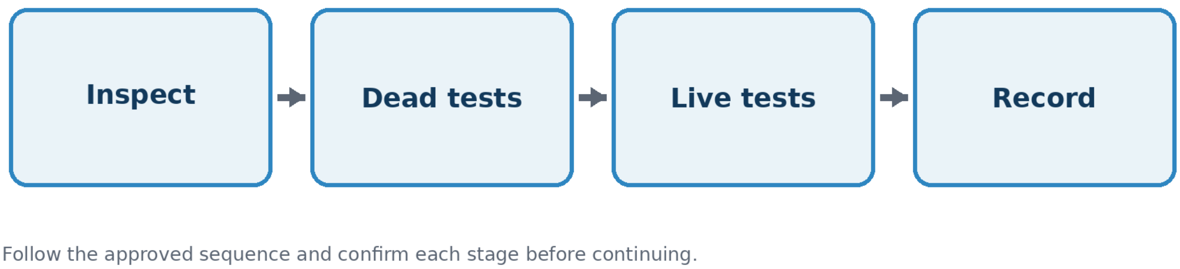
- Sequence visual inspection and tests.
- Explain continuity, insulation and polarity tests.
- Record results clearly.
- Recognize tests requiring specialized competence.

Key words

Inspection	Careful visual and physical examination.
Continuity test	Test for an unbroken conductive path.
Insulation resistance	Resistance between conductors that should be separated.
Commissioning	Final checks and controlled handover for service.

Use a planned sequence

Concept map



The main relationship for this chapter.

Visual inspection comes first because obvious defects should be corrected before instruments are connected. Dead tests are completed with the supply isolated; live tests require additional precautions and authorization.

Each test has a purpose, method, expected result and action when the result is unsatisfactory. Recording only pass or fail can hide useful evidence.

Instrument suitability, proving, lead checks and calibration status affect confidence in results.

Relationship to remember

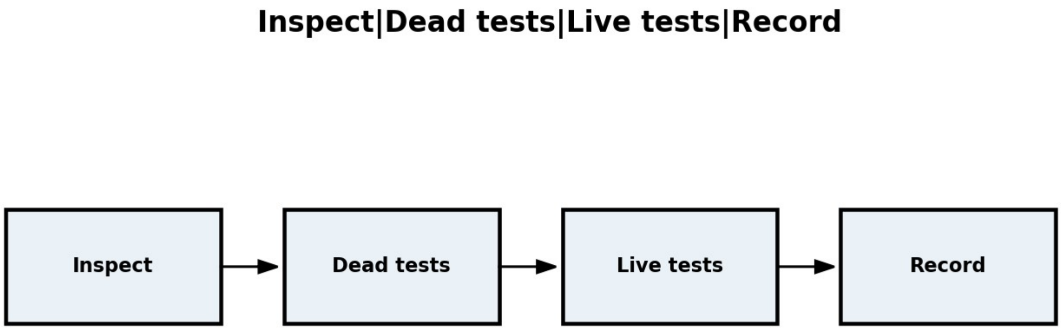
$$\text{test result} + \text{limit} + \text{instrument} + \text{circuit identity} = \text{useful evidence}$$

A number without its unit, test point or acceptance basis is incomplete.

Worked example 1 A continuity reading changes from 0.3 Ω to OL. What does this suggest?

Solution The path may have opened, a connection may be lost or the test setup may be incorrect.

Follow the test path



Testing moves from low-risk inspection to controlled verification and documentation.

A typical learning sequence is inspection, protective continuity, insulation checks, polarity checks and instructor-controlled functional tests. Exact order and methods follow current rules and system conditions.

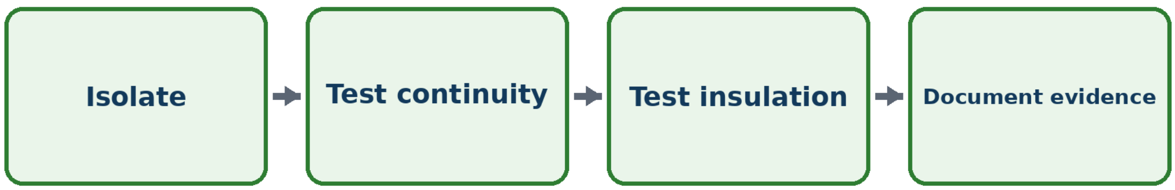
Never apply an insulation tester to connected sensitive electronics unless the approved procedure protects or disconnects them.

Worked example 2 Why record lead resistance?

Solution It can be considered when interpreting low-resistance measurements.

Test an isolated training circuit

Practical sequence



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

Complete the practical in this order and record the evidence.

Complete visual, continuity and polarity checks on a trainer containing one hidden fault.

Equipment

isolated trainer • continuity tester • inspection sheet • diagram

Method

1. Confirm isolation and prove the tester.
2. Inspect against the diagram.
3. Test protective and circuit continuity as instructed.
4. Check polarity by the approved dead-test method.
5. Locate the hidden fault, correct it and repeat affected tests.

Record your results

Test or observation	Measured result	What it means

Safety check Do not energise until the instructor accepts the dead-test results.

Follow the reasoning

Worked example 3 An insulation reading is unexpectedly low. What is the next action?

Solution Stop, keep isolated and investigate connected loads, moisture, damage and test setup.

Worked example 4 Why inspect before testing?

Solution Inspection can reveal hazards or defects that make testing unsafe or misleading.

Worked example 5 What makes a result traceable?

Solution Circuit identity, test points, value, unit, instrument and date or tester record as required.

Try one without help

Prepare a test record for a circuit with continuity readings of 0.18 Ω, 0.21 Ω and OL, and explain which needs investigation.

Chapter review

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

1. Why inspect first?
2. Define continuity.
3. What does insulation testing assess?
4. Why can electronics need disconnection?
5. What information belongs with a result?
6. When are live tests permitted?
7. Why prove a tester?
8. What follows a repaired fault?

Mini project

Create a commissioning checklist and test sheet for the low-voltage project built later in this book.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Fault finding maintenance and repair

Systematic fault finding uses evidence to narrow the problem instead of replacing parts at random.

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

Learning outcomes

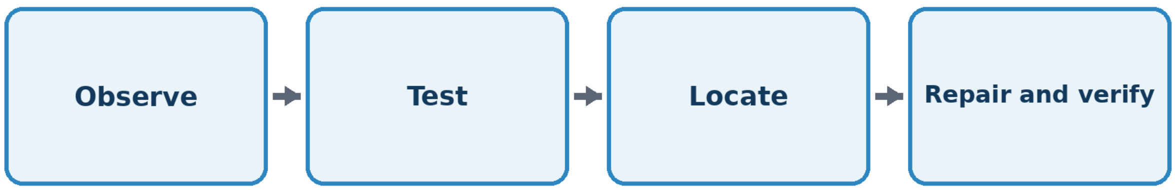
- Gather symptoms accurately.
- Divide a system into test sections.
- Select safe tests.
- Verify the repair and document it.

Key words

Symptom	An observable effect of a fault.
Cause	The condition producing the symptom.
Half-split method	Testing near the middle to reduce the search area.
Verification	Evidence that the repair restored correct and safe operation.

Diagnose from evidence

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

Begin with the reported symptom, operating conditions and any recent changes. Confirm the symptom safely instead of assuming the report is complete.

Use the diagram to identify supply, control, load and return paths. Test at a point that separates possible causes.

Replacing a part without proving the cause can waste materials and leave the real fault in place.

Relationship to remember

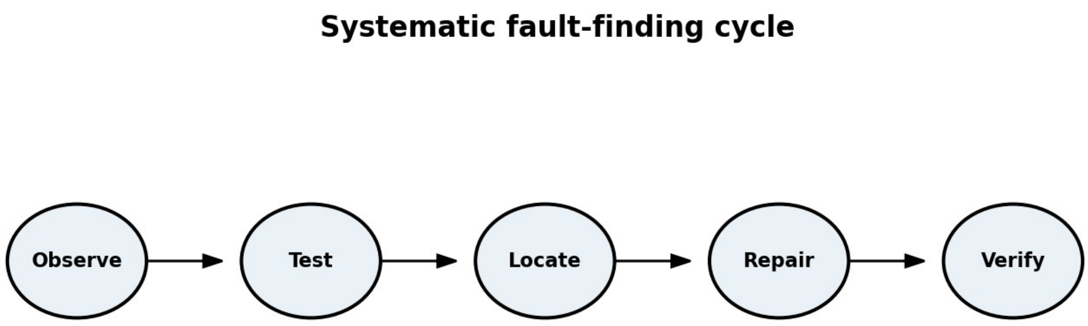
$$\text{expected value} - \text{measured value} = \text{diagnostic clue}$$

The difference is meaningful only when the expected value and test conditions are correct.

Worked example 1 A 12 V lamp is off. The supply measures 12 V but the lamp terminals measure 0 V. What section should be checked?

> **Solution** Check the control and wiring between the supply and lamp, plus the return path as indicated by the diagram.

Use a repeatable process



Each measurement narrows the possible fault location before repair.

Observe, make safe, inspect, test, locate, repair, retest and document. If evidence conflicts, recheck the test setup and assumptions.

After repair, repeat any safety tests affected by the work and conduct a controlled functional test.

Worked example 2 The lamp has 12 V across it but remains off. What is likely?

Solution The lamp may be open or defective, assuming the measurement is valid.

Find hidden faults

Practical sequence

Read symptom → Choose test → Find cause → Retest

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

Complete the practical in this order and record the evidence.

Diagnose three instructor-inserted faults on isolated low-voltage circuits.

Equipment

fault boards • schematics • multimeter • fault record

Method

1. Read the symptom card.
2. Inspect and identify likely sections.
3. Choose the first safe test and predict its result.
4. Measure, interpret and narrow the fault.
5. Repair only with approval, then retest and document.

Record your results

Test or observation	Measured result	What it means

Safety check Isolate before resistance or continuity testing and never bypass a protective device.

Follow the reasoning

Worked example 3 Why is OL across an isolated closed switch suspicious?

Solution A closed switch should have continuity; OL suggests an open contact or test problem.

Worked example 4 What is the benefit of half-split testing?

Solution Each good midpoint test can eliminate roughly half of the possible path.

Worked example 5 What must follow component replacement?

Solution Inspection, affected safety tests and controlled functional verification.

Try one without help

A relay will not energise. List a logical test sequence covering supply, stop path, start command, overload contact and coil.

Chapter review

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

1. Distinguish symptom and cause.
2. What is half-split testing?
3. Why confirm the symptom?
4. Why use a diagram?
5. What does 0 V across an open switch indicate?
6. Why avoid random replacement?
7. What tests follow a repair?
8. What belongs in a fault report?

Mini project

Create a fault library with ten symptoms, possible causes, safe tests and confirmed remedies from training circuits.

My reflection

One skill I can now demonstrate is:

One point I need to practise again is:

Estimating project work and examination preparation

A complete technical project combines planning, safe construction, testing, costing, records and clear explanation.

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

Learning outcomes

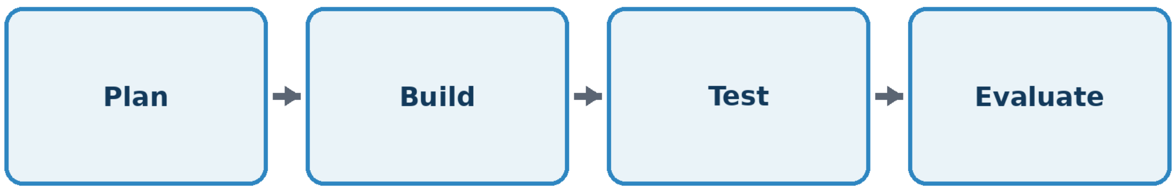
- Prepare a materials estimate.
- Calculate labour and total cost.
- Plan and document a student project.
- Use evidence-based examination revision.

Key words

Bill of materials	A list of required items, quantities and specifications.
Contingency	A planned allowance for reasonable uncertainty.
Direct cost	A cost tied directly to the job.
Portfolio	Organized evidence of planning, work, tests and reflection.

Estimate transparently

Concept map



Follow the approved sequence and confirm each stage before continuing.

The main relationship for this chapter.

Measure quantities from an approved drawing and record waste or spare allowances separately. Multiply quantity by unit cost, then add labour and other stated costs.

A quotation should state scope, exclusions, validity and payment terms. Tax and statutory requirements must follow current Guyana rules and professional advice.

Student projects need a problem statement, design, risk assessment, build record, test results, evaluation and improvement.

Relationship to remember

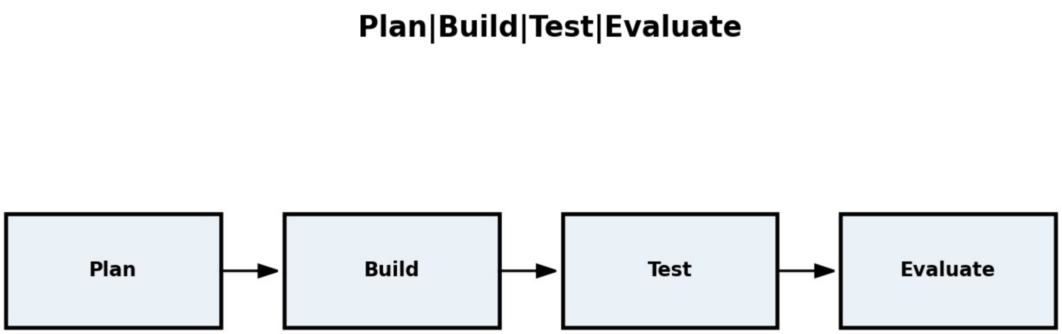
$$\text{item cost} = \text{quantity} \times \text{unit price} \qquad \text{total} = \text{materials} + \text{labour} + \text{stated additions}$$

Use current supplier quotations and identify the date and currency.

Worked example 1 20 m of cable costs GYD 320 per metre. Find item cost.

Solution 20 × 320 = GYD 6,400.

Plan build test improve



A technical project is complete only when its performance and safety evidence are recorded.

Break the project into tasks with checkpoints. Do not energise simply because construction is complete; inspection and testing come first.

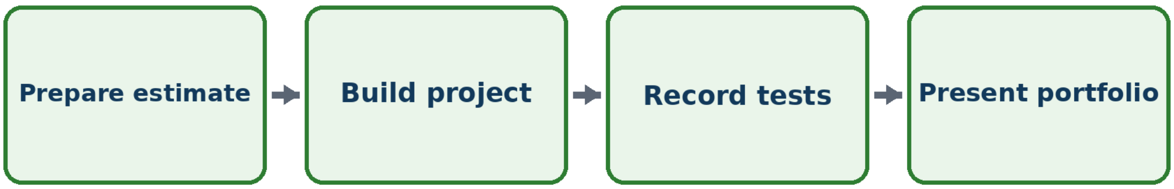
For examination revision, practise explaining diagrams and calculations, not only memorising answers. Create original questions and correct errors using the calculation method.

Worked example 2 Add GYD 4,500 accessories and GYD 8,000 labour. Find subtotal.

Solution 6400 + 4500 + 8000 = GYD 18,900.

Complete a capstone project

Practical sequence



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

Complete the practical in this order and record the evidence.

Plan, build, test and present an original low-voltage electrical control project.

Equipment

project brief • approved components • tools • test instruments • portfolio sheets

Method

1. Define the need and success criteria.
2. Draw the circuit and prepare risk and materials records.
3. Build in stages with inspection checkpoints.
4. Complete approved tests and record results.
5. Demonstrate, evaluate and propose one improvement.

Record your results

Test or observation	Measured result	What it means

Safety check All energised demonstrations must use instructor-approved supplies and procedures.

Follow the reasoning

Worked example 3 Add a stated 5% contingency to GYD 18,900.

Solution $0.05 \times 18{,}900 = 945$; total = GYD 19,845.

Worked example 4 Why date supplier prices?

Solution Prices change, so the date shows the basis of the estimate.

Worked example 5 A project works but has no test record. Is it complete?

Solution No. Safe performance and compliance claims require documented evidence.

Try one without help

Prepare a cost estimate for 30 m cable at GYD 280/m, six accessories at GYD 950 each, GYD 12,000 labour and 7% contingency.

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 bill of materials.
2. Calculate cost of 15 items at GYD 420.
3. What is contingency?
4. Name four quotation details.
5. List six project-portfolio sections.
6. Why test before demonstration?
7. State one effective revision method.
8. Why must practice questions be original?

Mini project

Complete and present a low-voltage automatic light, alarm, motor-control model or other instructor-approved project with a full portfolio.

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.

Generation transmission and distribution

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

Independent challenge solution

At 5 kV: I = 5,000,000 ÷ 5,000 = 1000 A. At 50 kV: I = 100 A. The I^2 factors are 1,000,000 and 10,000, so the higher-voltage case has one hundredth of the simplified heating factor.

Chapter review answers

1. Generation converts another form of energy into electrical energy.

2. Distribution delivers energy through networks nearer consumers.

3. Voltage is raised to reduce current and conductor heating loss for a given power.

4. A substation transforms voltage and provides switching, protection and distribution.

5. Metering normally occurs near the service entry before consumer circuits.

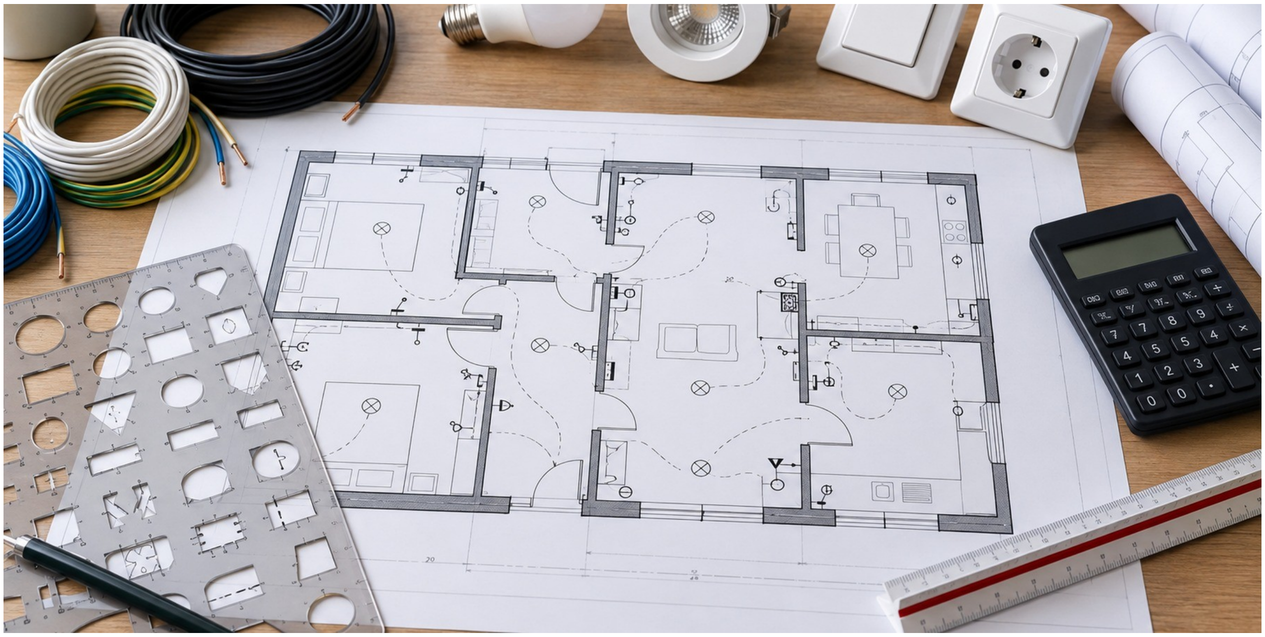
6. A final circuit directly supplies outlets, lights or fixed equipment from a distribution point.

7. Utility seals protect controlled equipment and must be handled only by authorized persons.

8. P = VI ignores power factor and phase relationships in many real AC systems.

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

Plans specifications and load schedules



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

Independent challenge solution

Lighting load = 8 × 10 = 80 W. Training outlets = 4 × 100 = 400 W. Appliance = 1500 W. Connected load = 1980 W. At 230 V and simplified unity power factor, current is about 8.61 A.

Chapter review answers

1. A plan shows location from above; a schematic shows electrical function and connections.

2. A specification states required materials, performance and workmanship.

3. Ten 9 W lamps use 90 W.

4. Include circuit reference, point type, quantity, load, control and special conditions.

5. Revision control prevents construction from an outdated drawing.

6. Connected load is the sum of rated loads.

7. Demand can be lower when not all loads operate simultaneously, subject to approved rules.

8. Examples include dimensions, access, environment, existing services and equipment positions.

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

Cables containment and terminations

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

Independent challenge solution

Higher ambient temperature reduces cooling; grouping adds nearby heat; thermal insulation restricts heat escape. Each can require derating, a larger conductor or a different installation method after checking current tables.

Chapter review answers

1. Containment routes, protects and organizes cables.

2. Burrs can cut or abrade insulation during pulling and service.

3. Consider design current, voltage drop, installation method, temperature, grouping, protection and environment.

4. Derating is reduction of permitted current capacity because of installation conditions.

5. Entries need grommets, bushes or glands to prevent sharp-edge damage and provide restraint or sealing.

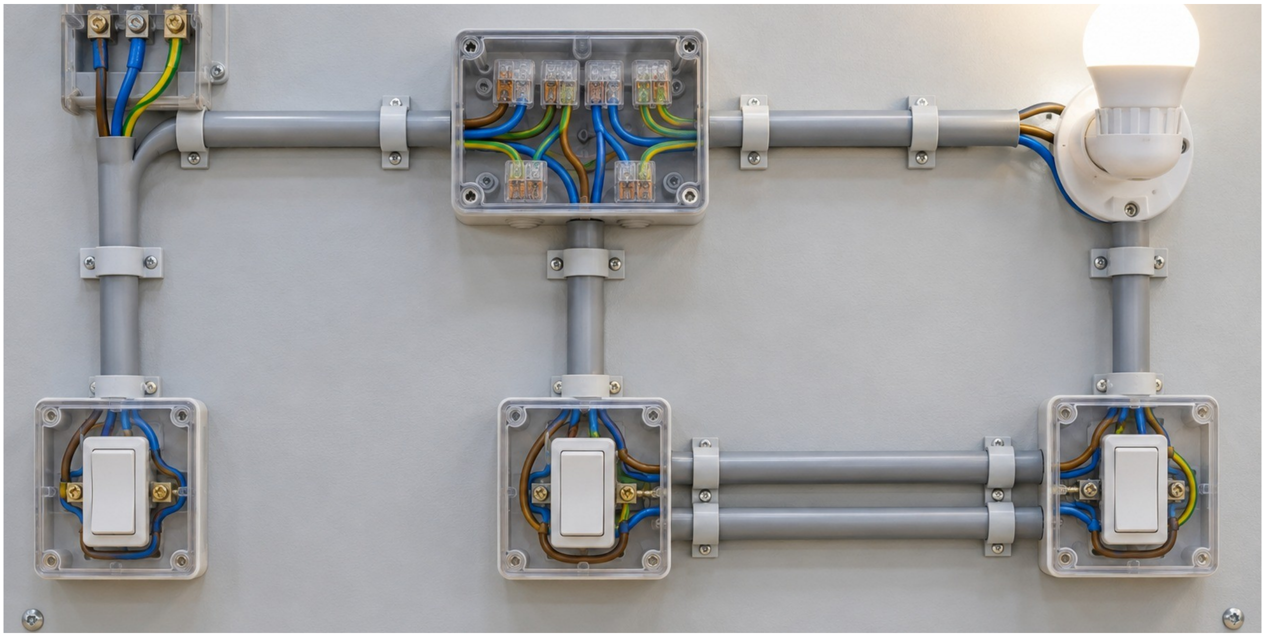
6. Check secure contact, correct strip length, intact strands, no exposed copper and suitable restraint.

7. Voltage drop increases with current and circuit resistance.

8. Current tables include conductor and installation limits that memory or a simple formula cannot replace.

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

Lighting circuits and switching


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

Independent challenge solution

For an ideal two-way arrangement, the lamp state changes whenever either switch changes position. A valid truth table has two combinations ON and two OFF; the exact labels depend on how switch positions are named.

Chapter review answers

1. One-way switching controls a light from one position.

2. A switched live carries line potential from the switch to the lamp when closed.

3. Identification prevents a switched live from being mistaken for neutral or another conductor.

4. I = 18 ÷ 230 = 0.078 A approximately.

5. Two-way switching provides control from two positions.

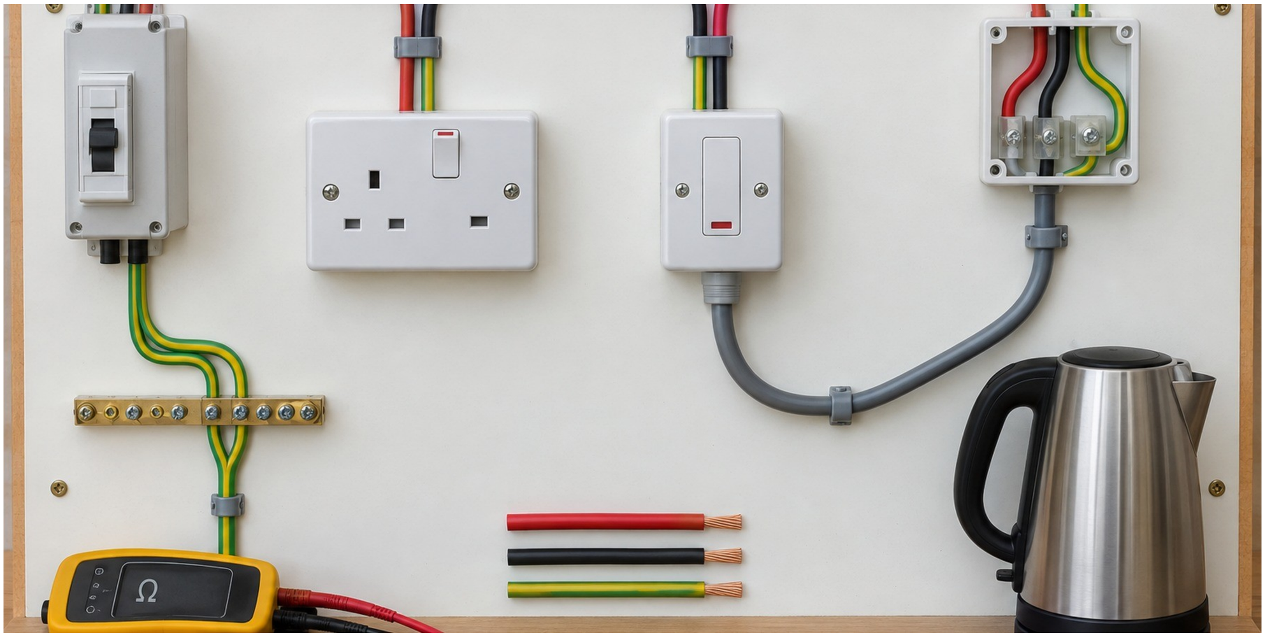
6. Traveller or strapper conductors connect the changeover switches.

7. Possible faults include failed lamp, open switch, missing supply, open neutral or loose connection.

8. Inspection can find unsafe or incorrect connections before energy is applied.

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

Socket outlets and fixed appliances



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

Independent challenge solution

Total power = 750 + 1200 + 100 = 2050 W. I = 2050 ÷ 230 = 8.91 A approximately at unity power factor.

Chapter review answers

1. Line supplies energy at live potential.

2. Neutral is the intended return conductor in the operating circuit.

3. The protective conductor provides a fault-current path for shock protection.

4. I = 1150 ÷ 230 = 5 A.

5. Polarity is correct connection of line, neutral and switched conductors to their intended terminals.

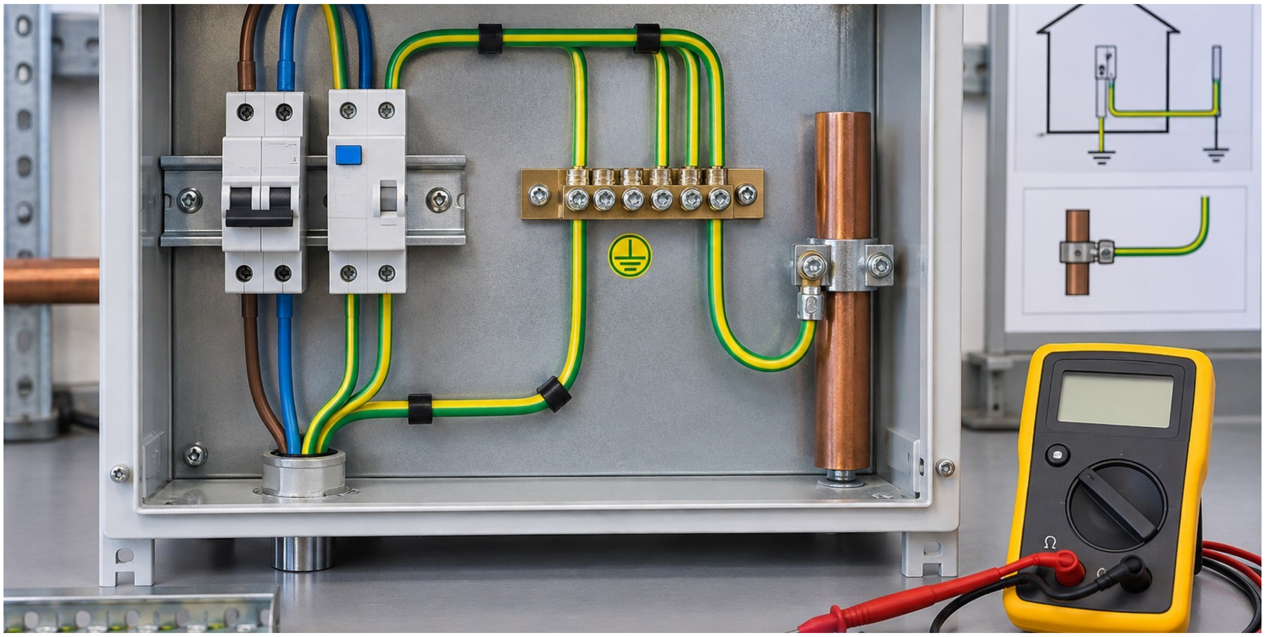
6. Strain relief prevents pulling force from reaching the conductor terminals.

7. A radial final circuit extends from its protective device without returning to it.

8. Equipment may operate with reversed polarity, missing earth or another dangerous defect.

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

Earthing bonding and protective devices



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

Independent challenge solution

Fault current ≈ 230 ÷ 2 = 115 A. Higher loop impedance lowers fault current and can slow or prevent the intended protective-device operation. Device type, rating and required disconnection conditions must all be coordinated.

Chapter review answers

1. Earthing connects exposed conductive parts to the protective system and earth arrangement.

2. Bonding connects conductive parts to reduce dangerous potential differences.

3. A fuse responds to overcurrent by melting its element.

4. An RCD compares current leaving and returning in the live conductors.

5. At 230 V and 2 Ω, fault current is approximately 115 A.

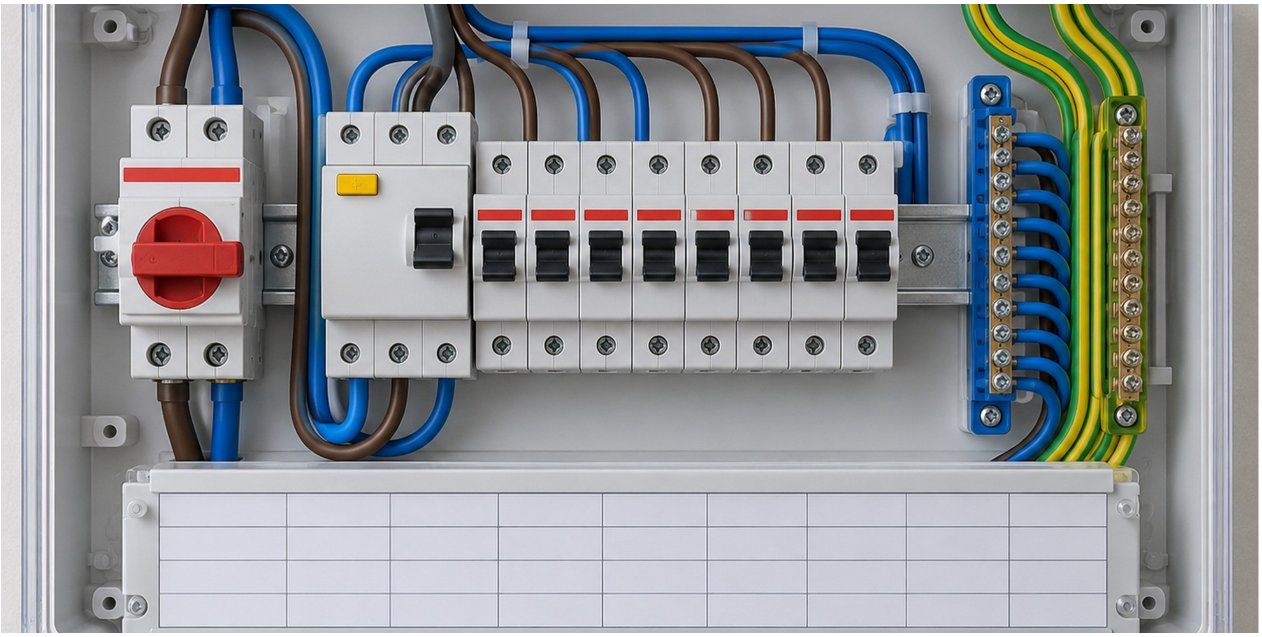
6. Testing confirms that the protective path is present and sufficiently continuous.

7. No. Bonding and earthing have related but different functions.

8. The simple formula ignores source characteristics, conductor reactance and detailed protective-device requirements.

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

Distribution boards isolation and circuit schedules



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

Independent challenge solution

Use clear descriptions such as “Workshop lighting,” “General socket outlets,” “Water pump motor,” and “Air-conditioning unit.” Add location or equipment identification where more than one similar load exists.

Chapter review answers

1. It provides isolation, distribution, protection and organized circuit connections.

2. A busbar distributes supply to several devices or circuits.

3. Identification prevents wrong-circuit isolation and supports testing and emergencies.

4. A spare way is a suitable unused position reserved for possible future equipment.

5. No. Cable capacity and disconnection conditions must also be verified.

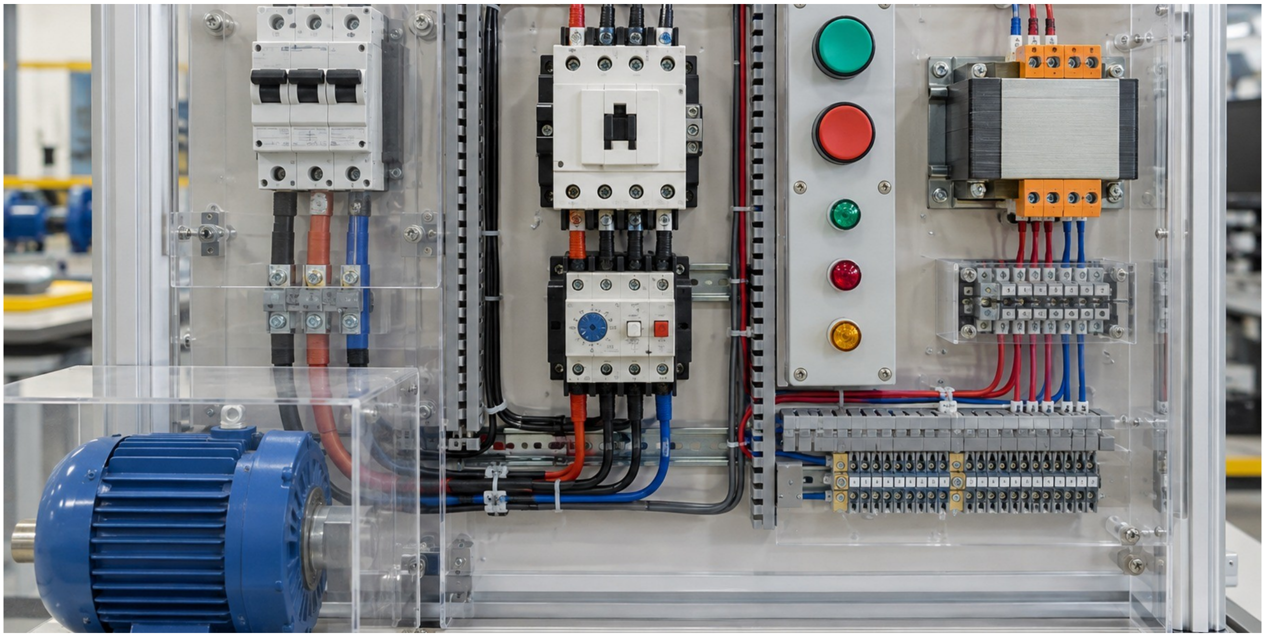
6. Check labels, blanks, enclosure condition, access, signs of heat and schedule accuracy.

7. Secure blanks prevent access to live parts and maintain enclosure protection.

8. Connected current sums loads; demand estimates the current likely under approved simultaneous-use assumptions.

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

Relays contactors and control circuits



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

Independent challenge solution

Place a normally closed stop and normally closed overload contact in series with the coil. Place the normally open start contact next, with a normally open auxiliary contact in parallel with start. When the coil energises, the auxiliary contact seals in the circuit.

Chapter review answers

1. A contactor is an electrically operated switch designed for frequent power-circuit control.

2. The control circuit carries commands; the power circuit carries load current.

3. A normally closed stop gives fail-safe behaviour for a broken control wire or lost continuity.

4. Seal-in control keeps the coil energised after the start button is released.

5. An interlock prevents conflicting operations.

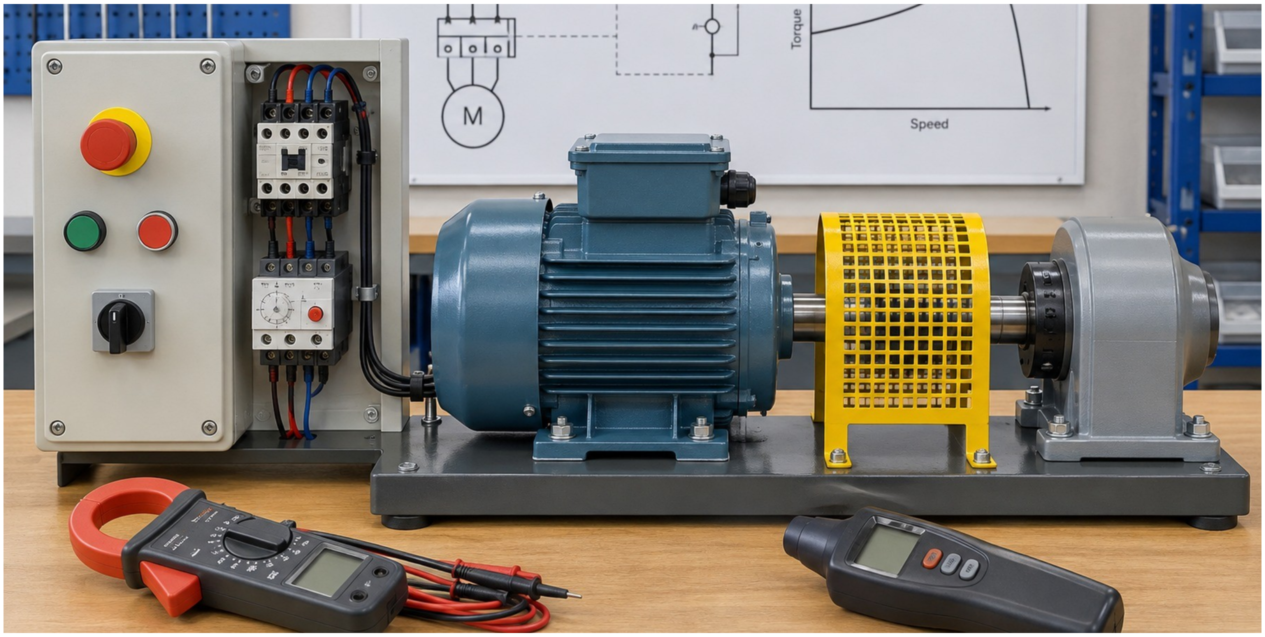
6. $I = 12 \div 24 = 0.5$ A.

7. An overload relay responds to sustained overcurrent or heating according to its design.

8. An overload device may not interrupt high short-circuit current safely or quickly enough.

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

Motors and motor starting



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

Independent challenge solution

Input power = output ÷ efficiency = 1.5 kW ÷ 0.80 = 1.875 kW.

Chapter review answers

1. Torque is the turning effect produced by the motor.

2. Rated current is the specified current at rated operating conditions.

3. During acceleration the motor has not developed its normal opposing electrical effect, so current can be high.

4. Efficiency = 600 ÷ 800 × 100% = 75%.

5. Check nameplate, mounting, guarding, coupling, free rotation, connections and protective continuity.

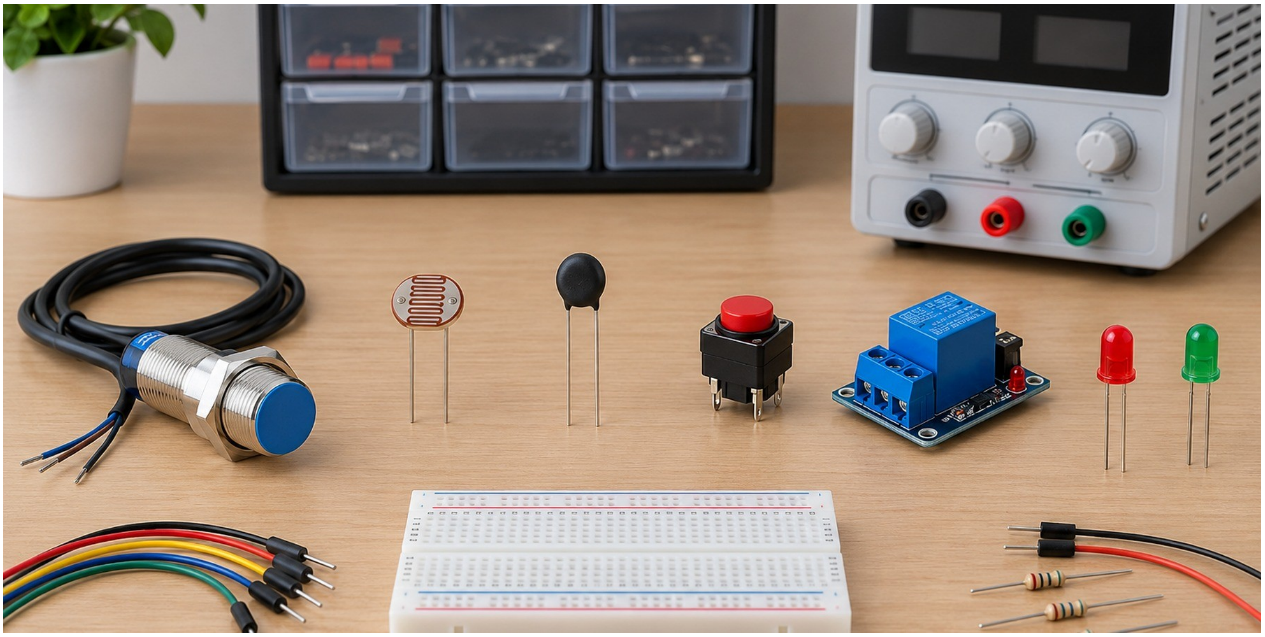
6. Overload protection addresses sustained overcurrent and overheating, not every short circuit.

7. Humming can indicate stalled operation, missing phase, low voltage or mechanical binding that quickly overheats the motor.

8. Examples include entanglement, pinch points, rotating shafts, hot surfaces and ejected parts.

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

Electronic control sensors and power supplies



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

Independent challenge solution

Vout = 12 × 10 ÷ (4.7 + 10) = 8.16 V approximately, assuming the output is unloaded.

Chapter review answers

1. A sensor changes an electrical property in response to a physical condition.

2. An LDR changes resistance with light level.

3. Vout = Vs × R2 ÷ (R1 + R2).

4. Equal resistors divide 6 V to 3 V.

5. A transistor switch lets a small input condition control a load current within its ratings.

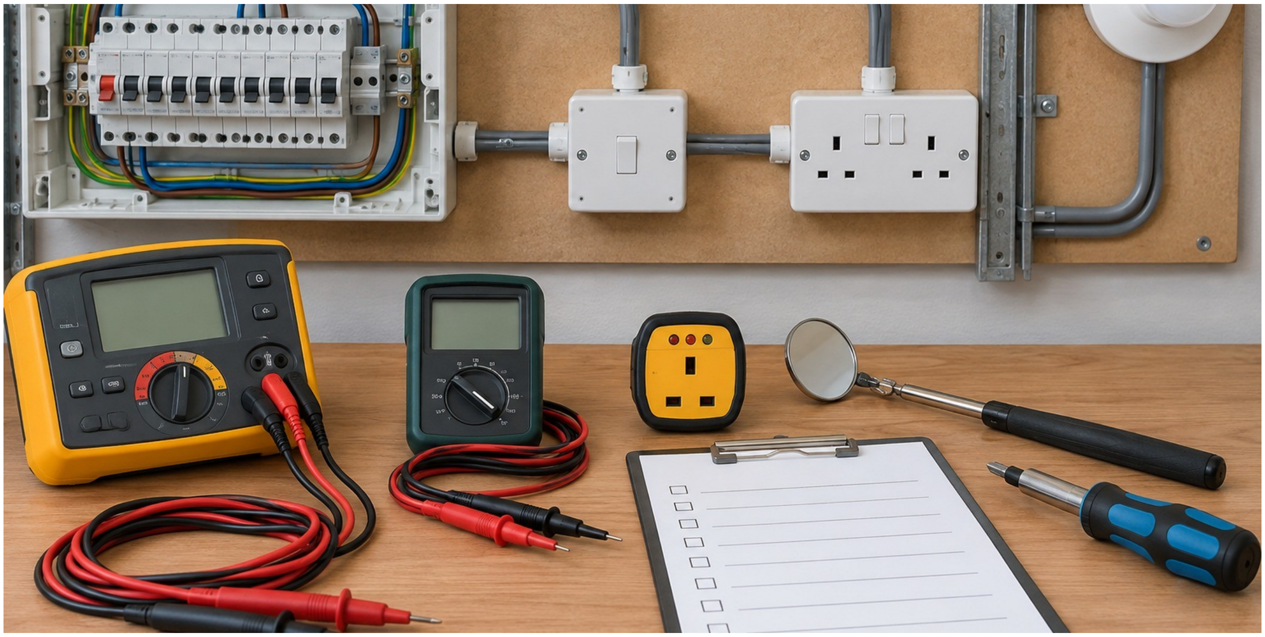
6. Suppression limits the inductive voltage produced when coil current is interrupted.

7. Transformation, rectification, filtering and regulation.

8. A load draws current from the divider and changes its effective resistance ratio.

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

Inspection testing and commissioning



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

Independent challenge solution

Record each circuit or test point, instrument, unit and result. The OL reading needs investigation because it indicates an open path or an incorrect test setup, while 0.18 Ω and 0.21 Ω indicate low-resistance continuity subject to lead resistance and the required limit.

Chapter review answers

1. Inspection can reveal damage, wrong connections or unsafe conditions before instruments or energy are applied.

2. Continuity is the presence of an unbroken conductive path.

3. Insulation testing assesses separation between conductors that should not be connected.

4. The test voltage may damage sensitive electronics or distort the reading.

5. Record circuit identity, test points, value, unit, instrument and acceptance basis.

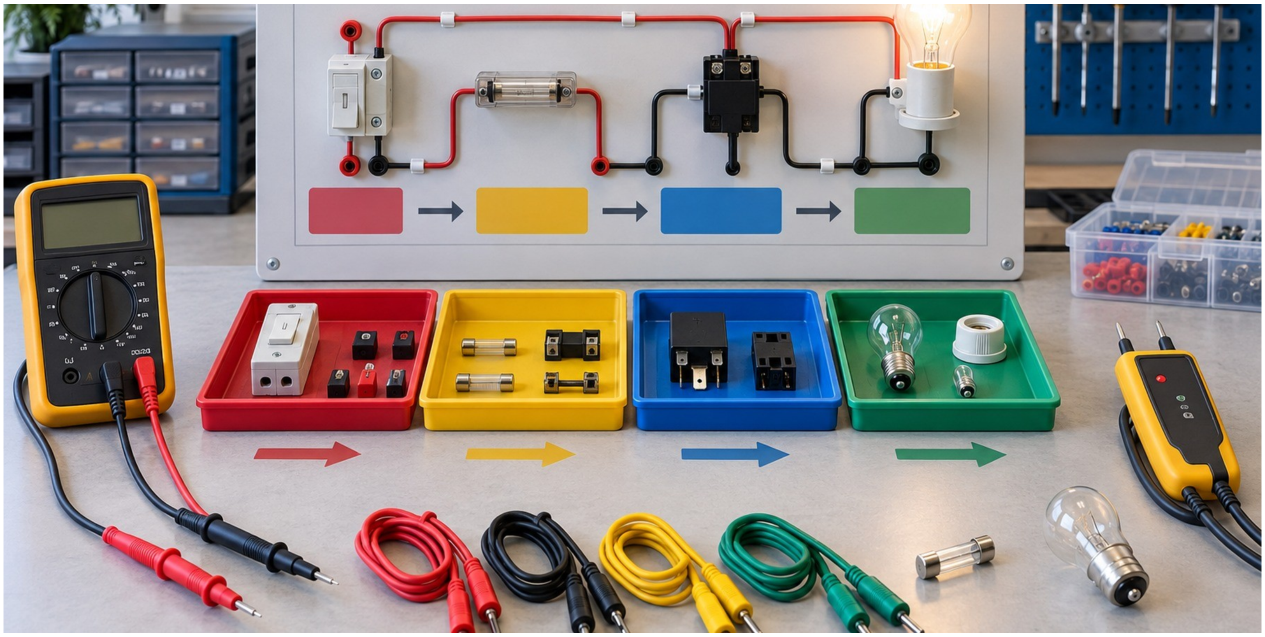
6. Live tests are permitted only when necessary, authorized and controlled by a safe procedure.

7. Proving confirms that the tester works before and after the measurement.

8. Repeat all tests affected by the repair and complete controlled functional verification.

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

Fault finding maintenance and repair



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

Independent challenge solution

Confirm control voltage first. Test through the normally closed stop and overload path, then verify the start command reaches the coil. If rated voltage is present across the coil but it does not energise, isolate and test coil continuity or resistance. If voltage is absent, work backward through the open control path.

Chapter review answers

1. A symptom is the observed effect; a cause is the condition producing it.

2. Half-split testing checks near the middle of a path to reduce the possible fault area quickly.

3. Confirming prevents diagnosis of an incomplete or inaccurate report.

4. The diagram identifies expected paths, devices and test points.

5. Across an open switch, 0 V may mean the supply is missing or both terminals are at the same potential; compare with a known reference and diagram.

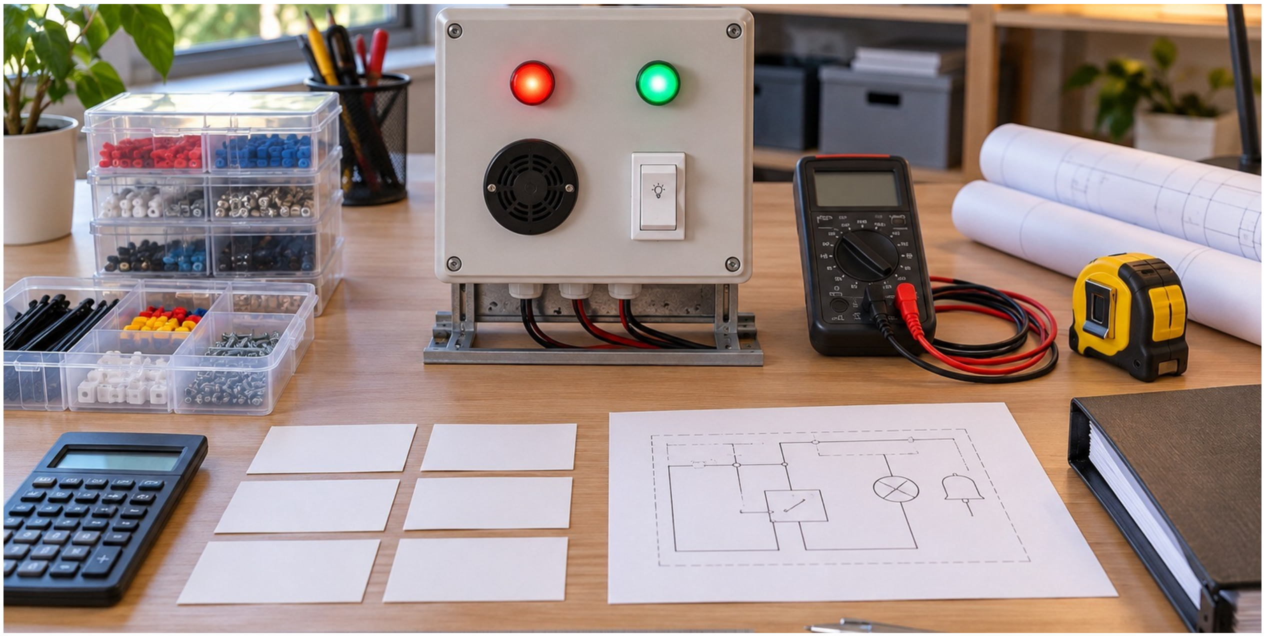
6. Random replacement wastes parts and can leave the true fault unresolved.

7. Repeat affected inspection and safety tests, then perform a controlled functional test.

8. Record symptom, conditions, measurements, fault, repair, retest results and any recommendation.

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

Estimating project work and examination preparation



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

Independent challenge solution

Cable: 30 × 280 = GYD 8,400. Accessories: 6 × 950 = GYD 5,700. Labour = GYD 12,000. Subtotal = GYD 26,100. Contingency = 0.07 × 26,100 = GYD 1,827. Total = GYD 27,927.

Chapter review answers

1. A bill of materials lists required items, specifications and quantities.

2. 15 × GYD 420 = GYD 6,300.

3. Contingency is a stated allowance for reasonable uncertainty, not hidden profit.

4. State scope, price, exclusions, validity, payment terms and any tax basis.

5. Include problem statement, design, risk assessment, materials, build record, tests, evaluation and reflection.

6. Testing provides evidence of safe and correct operation before people see or use the demonstration.

7. Effective methods include spaced practice, redrawing circuits, solving new values and correcting errors.

8. Original questions avoid copyright problems and test understanding rather than recall of a copied paper.

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

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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 Generation transmission and distribution	______________	__________
Chapter 02 Plans specifications and load schedules	______________	__________
Chapter 03 Cables containment and terminations	______________	__________
Chapter 04 Lighting circuits and switching	______________	__________
Chapter 05 Socket outlets and fixed appliances	______________	__________
Chapter 06 Earthing bonding and protective devices	______________	__________
Chapter 07 Distribution boards isolation and circuit schedules	______________	__________
Chapter 08 Relays contactors and control circuits	______________	__________
Chapter 09 Motors and motor starting	______________	__________
Chapter 10 Electronic control sensors and power supplies	______________	__________
Chapter 11 Inspection testing and commissioning	______________	__________
Chapter 12 Fault finding maintenance and repair	______________	__________
Chapter 13 Estimating project work and examination preparation	______________	__________