

Chapter 4: Basics of Electrical and Electronics

NICL AO 2026 Risk Engineer: Technical & Professional Knowledge

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Chapter opener

What this chapter covers

This chapter begins at electric charge and a simple lamp circuit, then builds towards DC circuit laws, power measurement, single-phase AC, balanced three-phase supply, transformers, generators and motors, safety functions, and electronic devices. The explanations assume no previous electrical-engineering course. Each circuit law comes with the physical situation in which it applies; diagrams are conceptual, not wiring instructions.

Why this matters for a risk engineer. Loads consume energy; fault paths divert current; protective devices respond to different electrical conditions. A risk engineer should be able to read the physical story behind a machine rating, fuse or protective conductor before assessing the description of an incident.

Learning objectives

After this chapter you should be able to:

1. Tell charge from current, name the electrical units, trace electron and conventional directions on a loaded circuit, and predict how wire size affects resistance.
2. Distinguish series from parallel by tracing junctions, calculate equivalent resistance, apply current and voltage conservation, and recognise an open versus a short circuit.
3. Relate power to energy and heating, choose the placement of current and voltage meters, and distinguish PMMC from moving-iron indication.
4. Read a sine-wave cycle, convert between period and frequency, interpret RMS, compare R/L/C phase, and use power factor correctly.
5. Recognise a balanced three-phase set, identify star and delta branches, relate line to phase magnitudes, and explain three-phase power and rotating fields.
6. Predict induced emf from changing flux, distinguish an open-coil voltage from current, and apply turns ratio and practical transformer loss ideas.
7. Explain how generators and motors exchange energy, compute synchronous speed and slip, and interpret the meaning of motor ratings and cogging.
8. Distinguish live, neutral and PE, assign overcurrent and residual-current protection their roles, and explain why switching is not verified isolation.
9. Distinguish p-type from n-type silicon, identify diode bias and rectification, explain NPN current gain, and read AND/NAND/NOR truth tables.

Topic map

Unit	Main theme	Practice questions
4.1	Electrical quantities and circuit basics	Q1–Q8
4.2	DC networks and circuit laws	Q9–Q22 and Q91, Q92, Q93
4.3	Electrical power and measurement	Q23–Q32 and Q94, Q99
4.4	Single-phase alternating current	Q33–Q44 and Q95, Q96

Unit	Main theme	Practice questions
4.5	Balanced three-phase systems	Q45–Q52 and Q97
4.6	Magnetism, induction and transformers	Q53–Q62 and Q98
4.7	Electrical machines	Q63–Q70
4.8	Electrical installations, protection and safety	Q71–Q80
4.9	Semiconductor devices and digital logic	Q81–Q90 and Q100

Exam context. According to the supplied NICL 2026 notice, the specialist technical/professional knowledge section has 50 one-mark questions in 35 minutes. A correct answer earns +1, a wrong answer loses 0.25 mark and a blank scores zero. Calculators are not allowed. This chapter's practice-question allocation is an editorial learning choice, not a prediction of NICL topic weights.

Should you guess?

If p is your honest chance of being right, the expected mark from answering is

$$\text{Expected mark} = p - 0.25(1 - p) = 1.25p - 0.25$$

The break-even point is $p = 20\%$, a blind pick among five options, so a blind guess is worth zero *on average*. If the options you rule out really are wrong and the rest are equally likely, one option out gives +0.063 per guess, two out +0.167, three out +0.375. Ruling out the right answer by mistake reverses the gain.

Electrical safety note. The descriptions of live, neutral, protective earth, fuse, MCB and RCD explain principles, not installation rules. No supply colour code, protective trip setting, safe-touch threshold or Indian legal-compliance value is claimed. Work on real installations requires competent personnel and verified isolation.

How to study

Read a subsection before its example; trace each load and return path. After each unit, try the matching practice set without looking at the answers. Return to the revision kit for a quick comparison of easily confused quantities. The answer grid, explanations and numerical solutions appear only after Q100.

Working conventions

A current arrow points in the direction positive charge would move. Electrons drift oppositely in a metal. For a resistor absorbing power, positive conventional current enters its positive-voltage side. Unless otherwise stated, AC power calculations use RMS magnitudes of sinusoidal waveforms, and star/delta rules assume a balanced three-phase load. Turns are N_1 and N_2 ; induction-motor speeds are n_s and n_r .

4.1 Electrical quantities and circuit basics

In a nutshell. Charge is an amount, current is a rate and voltage is energy transferred per charge. A source–load–return path permits current, and wire dimensions determine resistance.

4.1.1 Charge and conducting materials

Electric charge is a property of particles. The electron carries a negative charge, while the proton carries a positive charge of equal magnitude. The coulomb is a unit of charge, not a current. A current can be present even when a conductor remains electrically neutral overall: mobile carriers drift and an equal amount leaves as enters. A metal contains mobile conduction electrons. An insulator has far fewer available mobile carriers at everyday voltages. Silicon lies between these extremes and becomes useful in electronics when carefully doped. Do not confuse this elementary description with the chemistry of cell electrodes in Chapter 3. One coulomb is approximately 6.24×10^{18} elementary charge magnitudes; the sign depends on which charge is counted. What matters for conductivity is how easily charges move, not the total charge present in the substance.

Symbol	Quantity	Unit
Q	Electric charge	C (coulomb)
I	Current	A (ampere)
V	Potential difference	V (volt)
R	Resistance	Ω (ohm)
P	Power	W (watt)
E	Energy	J or kWh

Table 4.1. Electrical quantities, symbols and units.

Material	Free carriers under ordinary use	Typical behaviour
Copper wire	Many mobile electrons	Good conductor
Dry glass	Very few mobile carriers	Insulator
Silicon	Carrier population varies greatly with doping	Semiconductor

Table 4.2. Metal, insulator, semiconductor: conduction overview.

4.1.2 Current and potential difference

Imagine drawing an invisible cross-section through a copper wire. Current asks how much net charge crosses that section per unit time, not how much total charge is stored in the wire. For steady charge transfer, $I = \Delta Q / \Delta t$. The ampere therefore means coulomb per second. Voltage compares two points. A source that transfers more energy per unit charge between its terminals has a greater potential difference. If Q coulombs cross between two points and W joules are transferred, $V = W / Q$. Unlike energy, voltage is not a quantity that accumulates in an electricity meter. A steady unbranched circuit has the same current through each chosen wire section.

Key relationship.

$$I = \frac{\Delta Q}{\Delta t} \quad V = \frac{W}{Q}$$

Example 4.1. Find the mean current when 90 C crosses a wire section in 30 s.

Working: $I = Q/t = 90 \text{ C} / 30 \text{ s} = 3 \text{ A}$.

Answer: 3 A.

Why this method works: Use the charge-crossing time interval, not the voltage.

4.1.3 A working circuit and current direction

A battery or DC supply has a positive and a negative terminal. Connect the positive terminal through a closed switch and a lamp, then return from the lamp to the negative terminal: this is a complete loaded circuit. The lamp can use electrical energy because current can flow along the whole path. Opening the switch makes a physical gap and interrupts this steady path. Conventional current arrows on the external metal run from + through the lamp to -. Electrons drift in the opposite direction within that metal. Neither arrow can jump an open switch. A short bypass wire is not an equivalent substitute for the lamp; it can make current dangerously large. In Figure 4.1, electron drift on the lower return conductor points away from the negative terminal and toward the lamp.

Figure 4.1 Closed-source, switch and lamp circuit

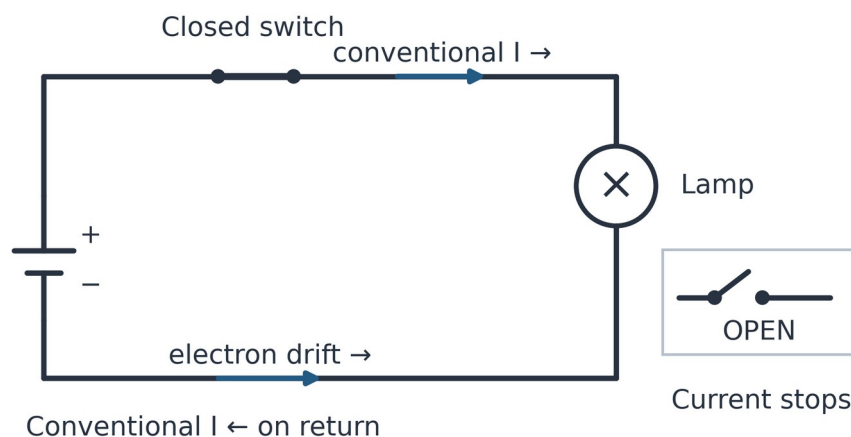


Figure 4.1. Closed-source, switch and lamp circuit. Closed-circuit schematic; not to scale.

4.1.4 Resistance and wire dimensions

Resistance describes the relation between voltage applied to a component and the resulting current. At a named temperature and nonzero current, a measured resistance is $R = V/I$. Some devices change resistance as they heat, so a single reading does not define their behaviour at every point. A uniform