Cambridge IGCSE · Physics 0625 · Notes

Electrical safety

Read online at **pastopic.com/cambridge/physics-0625/notes/electrical-safety**

Last checked 29 September 2026

Read first: Electrical quantities, **Electric circuits**

What you need to know

This topic is about using mains electricity without getting a shock or starting a fire. Every part of it is Core, so it can come up on all four theory papers. It uses $P = IV$ from the electrical quantities topic and the circuit symbols from electric circuits. By the end of it you should be able to:

1. **State the hazards** (what can go wrong, and what harm it does) of:
   - damaged insulation on a cable;
   - cables that overheat;
   - using mains electricity in damp or wet conditions;
   - too much current because a plug, an extension lead, or a single or multiple socket is overloaded.
2. **Know the three wires of a mains circuit**: the **live** wire (also called the **line** wire), the **neutral** wire and the **earth** wire, and **explain why the switch goes in the live wire**, so that switching off really makes the appliance safe.
3. **Explain what fuses and trip switches are for and how they work**, and **choose a suitable fuse rating** or trip switch setting for an appliance or circuit.
4. **Explain why the outer casing of an appliance must either be made of an insulator (double-insulated) or be earthed.**
5. **State that a double-insulated appliance has a fuse but no earth wire**, and that the fuse still protects the circuit and its cables.

Understand it

Why mains electricity is dangerous

The mains supply is about 230 V in many countries (some use 110–120 V or 240 V). That is enough to drive a current through a human body that can stop the heart. So the rules in this topic do two jobs:

- stop **people** touching anything at a high voltage (**electric shock**, or electrocution);
- stop **cables** carrying more current than they are built for, because a cable carrying too much current gets hot, melts its own plastic insulation and can start a **fire**.

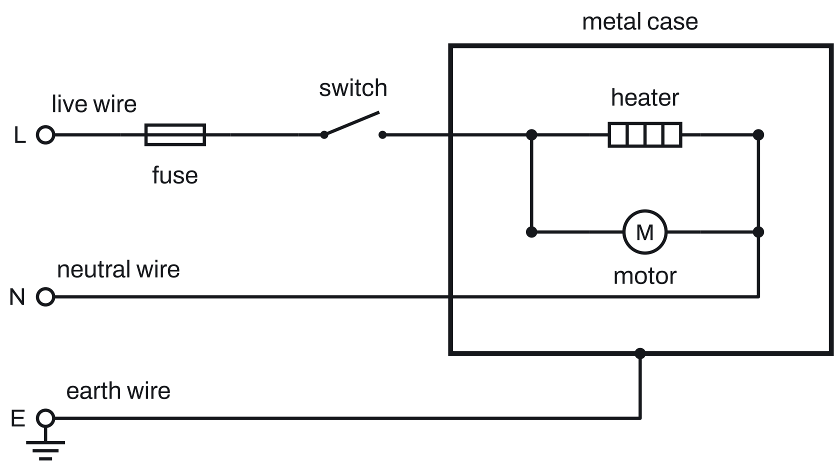
Keep those two dangers, **shock** and **fire**, in mind: nearly every answer in this topic is one of them, and the examiner wants to see which.

The three wires

A mains cable to an appliance usually has three wires inside it, each wrapped in plastic insulation.

- The **live wire** (line wire) is at a high voltage that changes all the time (a.c.). It brings the energy to the appliance. Touching it is dangerous.
- The **neutral wire** completes the circuit back to the supply. It stays close to 0 V.
- The **earth wire** is a safety wire. It joins the **metal case** of the appliance to the ground. In normal use **no current flows in it**; it only carries current when something goes wrong.

The appliance works because current flows from the live wire, through the appliance and back along the neutral wire. The earth wire plays no part in making it work. Circuit diagrams of appliances often show a **heater** (a rectangle divided into sections) and a **motor** (a circle with M inside), as in the diagram below, next to the **fuse** and the **switch**.



In normal use the current flows along the live and neutral wires only.

Why the switch goes in the live wire

A switch in **either** wire would turn the appliance on and off, because either break stops the current. The difference is what is left **live** when it is off.

- **Switch in the live wire:** when it is off, the appliance is cut off from the high voltage. Nothing inside it is live, so touching its parts is safe.
- **Switch in the neutral wire:** when it is off, no current flows, so it looks off, but the whole appliance is still joined to the live wire and is still at a high voltage. Someone changing a bulb or touching a loose part could get a shock.

The **fuse** also goes in the **live** wire, for the same reason: when it melts, it cuts the appliance off from the high voltage. (In a plug the fuse sits in the live connection; in a building, the trip switches for each circuit are in the live wire too.)

Fuses

A **fuse** is a short piece of thin wire inside a small holder, connected **in series in the live wire**. Its symbol is a rectangle with the wire running straight through it (see the diagram above). Each fuse has a **rating**, such as 3 A, 5 A or 13 A.

How it works: a current heats the fuse wire. If the current rises above the rating, the thin wire gets so hot that it **melts** (the fuse "blows"). The circuit is broken, the current stops, and the appliance is cut off from the live wire.

What it protects: the fuse protects the **cables and the circuit** from carrying too much current, so they do not overheat and start a fire. It also protects the appliance from further damage after a fault. On its own it does **not** stop you getting a shock if you touch a live wire, because the current through a body is far smaller than a fuse rating and the fuse does not melt. It does not control or "regulate" the normal current either: in normal use it is just a piece of wire.

A blown fuse must be **replaced**, and the cause of the fault found first.

Trip switches (circuit breakers)

A **trip switch** (circuit breaker) does the same job as a fuse, but with a switch. It is connected in the live wire, and the current passes through a small electromagnet inside it. If the current rises above the setting, the electromagnet becomes strong enough to pull the switch open, and the circuit is broken. The switch is said to "trip".

Compared with a fuse, a trip switch:

- **can be reset** by flicking it back on once the fault is fixed, so nothing needs replacing;
- acts **faster**;
- makes it easy to see which circuit has been switched off.

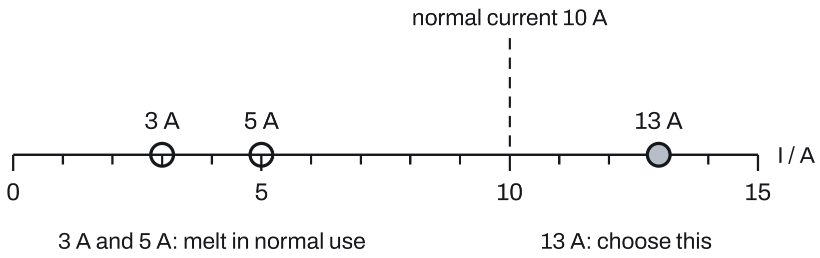
Buildings have a trip switch for each circuit (lighting, sockets, cooker) in the consumer unit, so a fault on one circuit switches off only that circuit.

Choosing a fuse rating or trip switch setting

A fuse must let the **normal** current through, but melt when the current is **too large**. So choose the **smallest rating that is larger than the normal current**. If that rating is only just above the current and a larger one is offered that the cable can still take, choose the larger one: a fuse carrying nearly its full rating all the time runs hot and can melt in normal use. The rating must also be no more than the current the cable is designed to carry, or the cable could overheat before the fuse melts.

1. Find the normal current. If you are given the power, use $I = \frac{P}{V}$ with the power in watts. If several appliances or lamps share the fuse, add their currents (or add their powers first).
2. Look at the ratings you are offered and pick the **smallest one above** that current.
3. If that one is only just above the current (within about 15%: this is our own guide, not a Cambridge rule) and the next one up is no more than the cable's rating, take the next one up instead.

For a 2.3 kW kettle on a 230 V supply, $I = \frac{2300}{230} = 10$ A. From 3 A, 5 A and 13 A fuses, the 3 A and 5 A fuses would melt as soon as the kettle was switched on, so choose 13 A.



- Not the **nearest** value: a 10 A fuse for a 10.4 A cooker, or a 3 A fuse for a 3.2 A fan, would melt in normal use.
- Not a **much larger** one: a 13 A fuse on a 0.4 A radio would let a fault current of several amps flow without melting, so the cable could overheat.
- A **trip switch setting** is chosen the same way: the smallest setting above the normal current in that circuit.

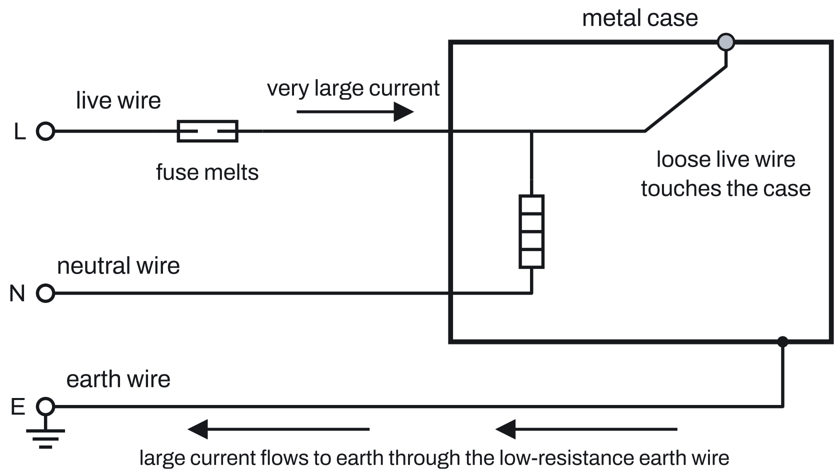
Earthing a metal case

Metal conducts. If a live wire inside an appliance works loose, or its insulation wears through, it can touch the **metal case**. The case is then live, and anyone who touches it becomes a path to the ground: an electric shock.

The **earth wire** stops this. It joins the metal case to the ground through a wire with **very low resistance**. If the live wire touches the case:

1. a **very large current** flows from the live wire, through the case and down the earth wire to the ground (much easier than through a person);
2. this large current **melts the fuse** (or trips the trip switch) in the live wire;
3. the appliance is cut off from the live supply, so the case is no longer live and **nobody gets a shock**.

The earth wire and the fuse work **together**: the earth wire gives the fault current a safe path and makes it large; the large current makes the fuse melt.



Double insulation

The other way to make the outside of an appliance safe is to make the **outer casing from an insulator**, such as plastic, with the live parts inside also insulated from anything you can touch. This is **double insulation**, shown on the appliance by the symbol of one square inside another. Even if a live wire works loose inside, the casing cannot become live, because plastic does not conduct.

A double-insulated appliance:

- **does not need an earth wire**, so it can use a cable with just two wires (live and neutral);
- **still has a fuse** (or is protected by a trip switch), because the fuse protects the **circuit and the cabling** from too much current, and that job has nothing to do with the case.

So the rule for the casing is: a **conducting** (metal) casing **must be earthed**; an **insulating** casing is **not** earthed.

The four hazards

Hazard	What goes wrong	The danger
Damaged insulation (cracked, worn, cut, or with copper showing)	A person can touch the bare live wire, or the live and neutral wires can touch each other (a **short circuit**)	**Electric shock**; a short circuit gives a huge current that **overheats** the cable and can start a **fire**
Overheating cables	The current is more than the cable is built for; a cable **too thin** for the appliance's current (such as a thin lead on a 10 A kettle); or a cable left **coiled** up, which cannot lose its heat	The insulation **melts** or burns: **fire**, and bare wires that can give a **shock**
Damp conditions (wet hands, bathrooms, kitchens, rain)	Water, especially with dissolved salts, **conducts**, so current can flow through the water to a person or between wires	**Electric shock**; short circuits

Hazard	What goes wrong	The danger
Overloading plugs, extension leads, single or multiple sockets	Too many appliances draw current through one socket or lead; their currents **add up** to more than it is designed for	The cable and plug **overheat**, melt and can start a **fire**

Some safety features come from these hazards. Bathroom lights and heaters use **pull-cord switches** so that wet hands never touch a mains switch. You must **disconnect** an appliance from the mains before opening its cover, so you cannot touch live parts inside. An extension lead's total current is the **sum** of the currents of everything plugged into it.

Key facts and formulas

There is no formula sheet for 0625: every equation must be learnt.

Formula	Status
$P = IV$, so the current in an appliance is $I = \dfrac{P}{V}$ (power in W, not kW)	Learn it
Currents of appliances on one lead or fuse add: $I_{\text{total}} = I_1 + I_2 + \ldots$	Learn it
Fuse rating (or trip setting): the **smallest** value **above** the normal current (the next one up if it is only just above), and no more than the cable's rating	Learn it
The switch and the fuse go in the **live** wire	Learn it
Metal case → **earthed**; insulating case (double-insulated) → **no earth wire**, but still a **fuse**	Learn it
Fuse: melts when the current is too large → protects the **cables** from **overheating** (fire)	Learn it
Earth wire + fuse together → protect the **user** from **shock** when the case becomes live	Learn it

How to do it

In the Paper 1–4 questions we have tagged for this topic (54 questions, 48 of them different, 2021–2025), the types came up this often. 8 of the different questions mix types, so the counts add up to more than 48.

Question type	Questions
Fuses and trip switches: what they do and how they work	14
The three wires, and where the switch and fuse go	12

Question type	Questions
Earthing and double insulation	11
Choosing a fuse rating	10
Hazards: damaged insulation, overheating, damp, overloading	10

1. Fuses and trip switches: what they do and how they work (14 questions)

1. **Purpose:** say it protects the **cables** (the wiring) from **overheating** when the current is **too large**, so there is no fire.
2. **How it works:** the current is **larger than the rating**, the fuse wire **gets hot and melts**, the **circuit is broken** and the current stops.
3. If a fault with a metal case is involved, add the earth wire's part (type 3).

Variations you will meet:

- **Multiple choice on the purpose.** The right answer is about stopping the current becoming too large or the cables overheating. Wrong answers say it prevents short circuits (a short circuit is the cause, not something the fuse prevents), saves energy, increases the resistance, makes the circuit work, or protects you from touching a live wire.
- **"Why did the fuse melt?"** Because the current became too large, not because of damp air or the room temperature.
- **A lower-rated fuse fitted by mistake**, such as a 5 A fuse in a 12 A heater: the fuse melts as soon as it is switched on and the heater simply does not work. The heater is **not** damaged.
- **Name or draw the fuse symbol** (a rectangle with a line through it).
- **Circuit breaker (trip switch) vs fuse:** the circuit breaker **can be reset**; a fuse has to be replaced. It also acts faster. Both work in a.c. circuits.
- **How a trip switch works:** too much current makes its electromagnet strong enough to open the switch.

2. The three wires, and where the switch and fuse go (12 questions)

1. **Name the three wires**: live (or line), neutral, earth.
2. **Switch: live wire.** Reason: when it is off, the appliance is **disconnected from the live wire (high voltage)**, so it is safe to touch.
3. **Fuse: live wire**, for the same reason.

Variations you will meet:

- **Where the fuse is in a circuit diagram.** A fuse that cuts off **all** the lamps must be in the main part of the circuit, in series with all of them, not in one branch.
- **A row table** "fuse in ... / switch in ...": both in the **live** wire. Never the earth wire, and never the neutral.
- **A picture of a cable** with two wires labelled and one marked X: X is the one not named (usually the **earth** wire).

- **A diagram of a plug, cable and appliance** with points P, Q, R: the switch goes at the point on the live wire.
- **Answers to reject:** "either wire, because both carry the current" (true about the current, but not safe), "in the earth wire", "positive" and "negative" (mains is a.c., and the wires are called live and neutral).

3. Earthing and double insulation (11 questions)

Explaining earthing (for a metal case, when the live wire touches it):

1. The earth wire connects the metal case to earth (it has a **low resistance**), keeping the case at 0 V.
2. If the case becomes live, a **large current** flows through the earth wire to earth.
3. This current **melts the fuse**, which disconnects the live supply.
4. So the case is not left live and the user does **not get an electric shock**.

Double insulation:

1. The outer casing is an **insulator** (plastic), so it **cannot become live**.
2. So **no earth wire** is needed: a two-core cable (live and neutral) is used.
3. A **fuse** (or trip switch) is **still needed** to protect the circuit and cable.

Variations you will meet:

- **"Which statements are correct?"** A conducting casing must be earthed; an insulating casing is not earthed.
- **"Why does one appliance have an earth wire and the other not?"** One has a metal case, the other a plastic (insulating) one. It is not about how much current they take or whether they have a switch.
- **"Which is not correct?"** "The earth wire needs a high resistance" is wrong: it needs a **low** resistance so that a large current flows and the fuse melts.
- **"Which component is not needed?"** for a double-insulated appliance: the **earth wire**. It still needs the live and neutral wires and a fuse.
- **"The purpose of earthing"** is protecting the **user from electric shock**, not completing the circuit, keeping cables dry or stopping them overheating.

4. Choosing a fuse rating (10 questions)

1. **Find the normal current.** From power: $I = \dfrac{P}{V}$, converting kW to W first. For several lamps or appliances on the same fuse, add their currents.
2. **Pick the smallest rating above it** from the list. If that one is only just above the current (within about 15%, such as 10 A for a 9.0 A current) and the next one up is still within the cable's rating, take the next one up.
3. If the cable's maximum current is given, check the fuse is **not more than** that.

Variations you will meet:

- **Current given directly** (on a label such as "230 V ~ 50 Hz 0.4 A"): skip step 1. For 0.4 A, from 1 A, 3 A, 5 A and 13 A, choose 1 A.
- **A cable rating as well:** a 6.0 A heater with a 12 A cable, from 5, 10, 15 and 20 A fuses: 10 A (above 6.0 A, and below 12 A).
- **Two settings**, such as the hair dryer in **0625/33/O/N/22 Q9**, which takes 5.2 A on low and 8.9 A on high: the fuse must pass the **higher** current. From 5, 10, 13, 15 and 30 A the mark scheme answer is 13 A. Our reason: 10 A is only just above 8.9 A, so it leaves no margin.
- **A rating given in volts** among the options (such as "250 V") is not a current rating: fuse ratings are in **amperes**.
- **Lamps in parallel** on one fuse: 5 lamps each taking 0.40 A draw 2.0 A in total.

5. Hazards: damaged insulation, overheating, damp, overloading (10 questions)

1. **Name the fault** you can see, in the syllabus words: damaged insulation, overheating cable, damp or wet conditions, overloaded socket or extension lead.
2. **State the danger:** electric **shock** (electrocution) or **fire**, and say why in a few words.

Variations you will meet:

- **A picture of a kitchen or bathroom** with several hazards (a kettle near a sink, too many plugs in one lead, a frayed cable, a cable left coiled up, a thin cable on a high-current appliance such as a kettle, a hair dryer near water): list each one separately, then each consequence (shock, fire, burns).
- **"Explain the danger of connecting too many plugs to an extension lead."** The currents add up, the total is more than the lead is designed for, the cable **overheats** and can start a **fire**.
- **"A 10 A cable carries 25 A; suggest a hazard."** The cable overheats and the insulation melts or burns.
- **Several cables in series, rated 5, 13, 20 and 32 A:** they all carry the same current, so the one with the **lowest** rating (5 A) overheats first.
- **"Why is a pull cord safer than a push switch in a bathroom?"** Damp conditions: wet hands never touch the mains switch, so there is less risk of shock.
- **"Why disconnect from the mains before removing the cover?"** So you cannot touch live parts: risk of electric shock.
- **Damp conditions** lead to electric shock, not to the insulation becoming damaged or the fuse blowing.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

An electric kettle is labelled "230 V, 2.3 kW". It is fitted with a plug that can take a 3 A, 5 A or 13 A fuse.

(a) Calculate the current in the kettle when it is working normally. **[3]**

(b) State which fuse should be fitted, and explain why the other two are unsuitable. **[2]**

(a) $P = IV$, so $I = \frac{P}{V}$. **C1** for the equation in any form.

$I = \frac{2300}{230}$ **C1** (the power converted to watts)

$I = 10$ A **A1**

(b) 13 A. **B1**

The 3 A and 5 A fuses have ratings below the normal current of 10 A, so they would melt as soon as the kettle was switched on. **B1**

Example 2

A washing machine has a metal case. It is connected to the mains by a cable with three wires.

(a) State the names of the three wires in the cable. **[2]**

(b) The switch on the washing machine is connected in one of the wires. State which wire, and explain why. **[2]**

(c) A fault occurs and the live wire touches the inside of the metal case. Explain how the earth wire and the fuse protect a person who touches the case. **[3]**

(a) Live (line), neutral and earth. **B2** (all three for 2 marks; one or two correct for 1 mark)

(b) The live wire. **M1** When the switch is off, the machine is disconnected from the live wire (the high voltage), so nothing inside it is live. **A1**

(c) The earth wire connects the case to earth, so a large current flows from the live wire through the case to earth. **B1** This large current melts the fuse, **B1** which breaks the circuit and disconnects the live supply, so the case does not stay live and the person does not get an electric shock. **B1**

Example 3

A student plugs a 2.0 kW heater and a 1.2 kW toaster into one extension lead connected to a 230 V mains supply. The cable of the extension lead is designed to carry a current of up to 10 A.

(a) Calculate the total current in the extension lead when both appliances are on. **[3]**

(b) State and explain the hazard. **[2]**

(c) The student plugs the heater on its own into a wall socket. Its plug can take a 3 A, 5 A or 13 A fuse. State which fuse should be used. **[1]**

(a) Total power $= 2000 + 1200 = 3200$ W. **C1**

$I = \frac{P}{V} = \frac{3200}{230}$ **C1**

$I = 13.9$ A (3 s.f.) **A1**

(Working out each current first, 8.70 A and 5.22 A, and adding also gives 13.9 A.)

(b) The current, 13.9 A, is more than the 10 A the cable is designed for, so the cable **overheats**. **B1** The insulation can melt and cause a **fire** (or leave bare live wires, a risk of shock). **B1**

(c) The heater takes $\frac{2000}{230} = 8.70$ A, so the 13 A fuse. **B1**

Common mistakes

- **Thinking the fuse controls the current.** Examiners report this often: a fuse does nothing in normal use. It only acts when the current becomes too large, by melting and breaking the circuit.
- **Mixing up what the earth wire and the fuse do.** The earth wire gives the current a path to earth when the case becomes live; the fuse melts because of that large current. Write both steps. "The earth wire stops the wires overheating" is wrong, and so is "the fuse stops you getting a shock" on its own.
- **Saying the earth wire carries current all the time**, or that the appliance needs it to work. It carries current only when there is a fault.
- **Choosing the nearest fuse rating** instead of the nearest one **above** the current. A 10 A fuse for a 10.4 A cooker melts in normal use.
- **Forgetting to convert kW to W** before $I = \frac{P}{V}$, giving a current 1000 times too small, or using $P = \frac{V}{I}$ by mistake. Check the answer: a mains appliance takes a few amps, not a few milliamps or thousands of amps.
- **Putting the switch in the neutral wire** "because it still turns it off". It does stop the current, but the appliance stays live.

- **Writing "it's dangerous"** for a hazard. Say what the danger is: **electric shock** or **fire**, and why (bare wire, water conducts, cable overheats).
- **Thinking a double-insulated appliance needs no fuse.** It needs no **earth wire**; it still needs a fuse to protect its cable.

How to get the marks

- **Use the key words.** Marks go to "live wire", "earth wire", "insulation", "overheating", "melts", "electric shock", "fire", "current too large". Vague phrases such as "stops the electricity" or "it's safer" score nothing.
- **"State the hazard"** needs the harm: electric shock (electrocution) or fire. **"State the fault"** needs what is wrong: for example, damaged insulation.
- **"Explain" for the switch** needs the wire (live) for one mark and the reason (the appliance is disconnected from the high voltage when off) for the second.
- **"Explain how a fuse works"** needs the chain: current too large → fuse wire heats and melts → circuit broken. "It blows" alone is not enough.
- **Earthing explanations** are marked step by step: case connected to earth, large current to earth, fuse melts, no shock. Each step you leave out is a mark lost.
- **Calculations** (such as the current for a fuse choice): write the equation, then the numbers in it, then the answer with its unit (A). Each is a separate mark, so show all three. Give answers to 2 or 3 significant figures.
- **"Suggest"** questions (such as why a pull cord is safer) accept any sensible safety reason linked to this topic, usually damp conditions and shock.
- In multiple-choice questions, **read every option**: several are often partly true (for example "both wires carry the current").

Quick check

1. A student says the switch for a lamp could go in the neutral wire because the lamp would still go off. Explain why the switch should be in the live wire.
2. A microwave oven is rated at 0.90 kW and runs on a 230 V supply. Fuses of 3 A, 5 A and 13 A are available. Calculate the current and choose the fuse.
3. A hair dryer has a plastic case. Explain why it does not need an earth wire, and state what its fuse still protects.
4. Four lamps, each taking 0.25 A, are connected in parallel and share one fuse. Fuses of 1 A, 3 A and 5 A are available. Which should be used?
5. A lighting circuit has ten 100 W lamps on a 230 V supply. Its trip switch can be set to 3 A, 6 A, 10 A or 16 A. Choose the setting.

Answers

1. With the switch in the neutral wire, the lamp goes off but is still connected to the live wire, so the lamp holder is still at a high voltage and anyone changing the bulb could get an electric shock. With the switch in the live wire, the lamp is disconnected from the high voltage when it is off.
2. $I = \frac{P}{V} = \frac{900}{230} = 3.91$ A (3 s.f.). The 3 A fuse would melt in normal use, so choose the 5 A fuse.
3. The case is an insulator, so it cannot become live even if a live wire touches it inside: there is no risk of shock from the case (double insulation). The fuse still protects the circuit and the cable from overheating if the current becomes too large.
4. Total current $= 4 \times 0.25 = 1.0$ A. A 1 A fuse is not above the normal current and would melt, so use the 3 A fuse.
5. Total power $= 10 \times 100 = 1000$ W, so $I = \frac{1000}{230} = 4.35$ A (3 s.f.). The smallest setting above this is 6 A.

Past questions to try

- **0625/12/O/N/24 Q30**: where the fuse goes and which rating, from a safety label.
- **0625/11/M/J/24 Q29**: the purpose of earthing a metal case.
- **0625/33/O/N/22 Q9**: hazards in a kitchen, the fuse, the circuit breaker and a fuse rating.
- **0625/31/M/J/22 Q10**: explaining how the fuse and an earthed case work together.