

## Electrical power energy and mains safety

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Paper 1 | Foundation and Higher

Worked solutions and teaching prompts | Shared Foundation and Higher content

### Specification points covered

AC and DC potential difference: 8463 4.2.3.1 / 8464 6.2.3.1  
Mains wires and electrical safety: 8463 4.2.3.2 / 8464 6.2.3.2  
Electrical power: 8463 4.2.4.1 / 8464 6.2.4.1  
Appliance energy transfers: 8463 4.2.4.2 / 8464 6.2.4.2  
National Grid: 8463 4.2.4.3 / 8464 6.2.4.3

A community kitchen is choosing appliances for a weekly lunch service. You will compare their energy use and explain how the mains supply is made safer. These are paper-based problems. Do not open, wire or test a mains appliance.

Suggested timing has not been classroom-tested. Core Questions 1–6: 31 parts, 54 marks. Optional Q7: 2 parts, 3 marks; substitute for 1(c–e) if required within one lesson. All core content is shared by both routes and tiers. Accept equivalent physics and consistent follow-through. Original PhysicsUK practice, not an official AQA paper or mark scheme.

### 1 Reading appliance ratings

The kitchen uses a 2300 W hot-water urn and a 920 W toaster on a 230 V supply. For these calculations, use the stated mains potential difference and operating currents directly.

**1(a)** Explain what the urn's power rating of 2300 W means in terms of energy and time. **[1 mark]**

**Answer / mark points:** It transfers 2300 J of energy per second while operating at its rated power. [1]

**Teacher prompt:** Power is the rate of energy transfer. It is not an amount of energy and is not measured in J.

**1(b)** Calculate the current in the urn when it operates at 2300 W on the 230 V supply. **[1 mark]**

**Answer / mark points:**  $I = P / V = 2300 / 230 = 10 \text{ A}$ . [1]

**1(c)** Calculate the current in the 920 W toaster on the 230 V supply. **[1 mark]**

**Answer / mark points:**  $I = P / V = 920 / 230 = 4.0 \text{ A}$ . [1]



## 1 Reading appliance ratings continued

**1(d)** A battery-powered serving-area fan operates at 12 V and 0.25 A. Calculate its electrical input power. **[1 mark]**

**Answer / mark points:**  $P = VI = 12 \times 0.25 = 3.0 \text{ W}$ . [1]

**1(e)** A separate kitchen monitor transfers electrical energy at 120 W and draws a current of 0.50 A. Calculate the potential difference across it. **[1 mark]**

**Answer / mark points:**  $V = P / I = 120 / 0.50 = 240 \text{ V}$ . [1] Use the measurements for this separate device, not the nominal 230 V rating of the other appliances.

**1(f)** The urn's power is 2.5 times the toaster's power. Predict the ratio of their currents and explain why this ratio applies here. **[2 marks]**

**Answer / mark points:** The urn's current is 2.5 times the toaster's current. [1] Both operate at the same potential difference, so  $I = P / V$  makes current proportional to power. [1]

**Teacher prompt:** The same-potential-difference condition is essential. Do not generalise to appliances supplied at different voltages.

## 2 Checking heating elements

The kitchen receives test data for replacement heating elements. Each part describes a separate test; use only its stated values.

**2(a)** A heating element has resistance  $25 \Omega$  and carries 4.0 A. Calculate the power transferred in it. **[1 mark]**

**Answer / mark points:**  $P = I^2R = 4.0^2 \times 25 = 400 \text{ W}$ . [1]

**Teacher prompt:** Square the current before multiplying by resistance.

**2(b)** A different element transfers 900 W at a current of 6.0 A. Calculate its resistance. **[2 marks]**

**Answer / mark points:**  $I^2 = 6.0^2 = 36 \text{ A}^2$  and  $R = P / I^2$ . [1 for the correctly squared-current setup]  
 $R = 900 / 36 = 25 \Omega$ . [1]

**2(c)** In a test, the current in an element doubles while its resistance stays constant. A volunteer predicts that the power will double. Explain the correct change in power. **[2 marks]**

**Answer / mark points:** The power increases by a factor of four. [1]  $P = I^2R$ , so doubling current multiplies  $I^2$  by four when  $R$  is unchanged. [1]

**Teacher prompt:** This conclusion is conditional on constant resistance; a real element can change resistance as its temperature changes.

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## 2 Checking heating elements continued

**2(d)** Another element is measured at 230 V, 5.0 A and 46  $\Omega$ . Calculate its power using both power equations and decide whether the readings are consistent. **[2 marks]**

**Answer / mark points:**  $P = VI = 230 \times 5.0 = 1150 \text{ W}$ . [1]

$P = I^2R = 5.0^2 \times 46 = 1150 \text{ W}$ ; the results agree, so the readings are consistent. [1]

**Teacher prompt:** The agreement belongs with the second result; do not award a third mark for simply saying the values agree.

## 3 Energy used during service

The urn operates at 2300 W and a plate warmer at 300 W. Each stated time is the time the heater is actually on.

**3(a)** The 2300 W urn is on for 3.0 minutes. Calculate the electrical energy transferred in joules. **[2 marks]**

**Answer / mark points:**  $t = 3.0 \times 60 = 180 \text{ s}$ . [1]

$E = Pt = 2300 \times 180 = 414\,000 \text{ J}$ . [1]

**3(b)** The 300 W plate warmer is on for 20 minutes. Calculate its electrical energy transfer in joules. **[2 marks]**

**Answer / mark points:**  $t = 20 \times 60 = 1200 \text{ s}$ . [1]

$E = Pt = 300 \times 1200 = 360\,000 \text{ J}$ . [1]

**3(c)** For the uses in (a) and (b), which appliance transfers more electrical energy, and by how much? **[1 mark]**

**Answer / mark points:** The urn transfers more:  $414\,000 - 360\,000 = 54\,000 \text{ J}$  more. [1 for the correct named comparison and difference]

**Teacher prompt:** A larger time alone does not establish which appliance transfers more energy.

**3(d)** The urn needs to transfer 690 000 J during a different heating cycle. Calculate the time at 2300 W, in seconds. **[1 mark]**

**Answer / mark points:**  $t = E / P = 690\,000 / 2300 = 300 \text{ s}$ . [1]



### 3 Energy used during service continued

**3(e)** A service fan uses a 12 V battery. During a run, 900 C passes through the battery. Calculate the electrical energy transferred. **[1 mark]**

**Answer / mark points:**  $E = QV = 900 \times 12 = 10\,800 \text{ J}$ . [1]

**3(f)** The service fan in (e) has a constant electrical input power of 18 W. Calculate the length of the run in minutes. **[2 marks]**

**Answer / mark points:**  $t = E / P = 10\,800 / 18 = 600 \text{ s}$ . [1]  
 $600 / 60 = 10 \text{ minutes}$ . [1]

**Teacher prompt:** Use electrical input energy with electrical input power. Do not introduce an unspecified efficiency.

**3(g)** Describe the useful energy transfer when the urn heats water, and when a fan motor starts its blades moving. **[2 marks]**

**Answer / mark points:** Energy is transferred electrically to the heating element and then by heating to the water, increasing the water's internal energy. [1]  
 Electrical work increases the kinetic energy of the fan's moving blades as they start moving. [1]

**Teacher prompt:** Energy is transferred electrically; it is not stored as electricity in the water. Accept a clear thermal-energy-store description for the water.

### 4 Choosing an urn

Urn A heats a measured batch of water in 180 s at 2300 W. Urn B heats the same mass of water from the same initial temperature to the same final temperature in 300 s at 1500 W.

**4(a)** Calculate the electrical energy transferred by urn B during its 300 s heating cycle. **[1 mark]**

**Answer / mark points:**  $E = Pt = 1500 \times 300 = 450\,000 \text{ J}$ . [1]

**4(b)** A volunteer says, "Urn B has the lower power, so it must use less electrical energy to heat this batch." Evaluate the claim using both urns' energy transfers. Use 414 000 J for urn A if needed. **[2 marks]**

**Answer / mark points:** The claim is incorrect: B uses 450 000 J, more than A's 414 000 J. [1]  
 B operates for longer, so its smaller power does not mean a smaller product  $Pt$ ; it uses 36 000 J more. [1]

**Teacher prompt:** The equal mass and temperature change make this a like-for-like task. Do not claim lower power necessarily means less energy.

**4(c)** During a later 30-minute service, urn A's thermostat keeps its 2300 W heater on for only 12 minutes in total. Assume it transfers no electrical energy when off. Calculate the energy transferred during the service. **[2 marks]**

**Answer / mark points:** Use the actual on-time:  $t = 12 \times 60 = 720 \text{ s}$ . [1]  
 $E = 2300 \times 720 = 1\,656\,000 \text{ J} = 1.656 \text{ MJ}$ . [1]

**Teacher prompt:** Do not multiply the full 30-minute interval by the on-state power. The assumption excludes standby energy.

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## 5 Explaining mains protection

Figure 1 is a simplified circuit model of the metal-cased urn. Gaps in the case outline show insulated wire entries, not breaks in the metal case. The dashed connection shows a fault in which a wire touches the case. It is not present during normal operation.

**5(a)** State the approximate potential difference and the frequency of the UK domestic mains supply. **[2 marks]**

**Answer / mark points:** About 230 V. [1] 50 Hz. [1]

**5(b)** A fan battery provides direct potential difference, whereas the mains provides alternating potential difference. Describe the difference in polarity. **[2 marks]**

**Answer / mark points:** A direct potential difference has a polarity that stays the same. [1] An alternating potential difference repeatedly reverses polarity. [1]

**Teacher prompt:** Potential difference does not flow. A statement only about current direction is not a description of potential-difference polarity.

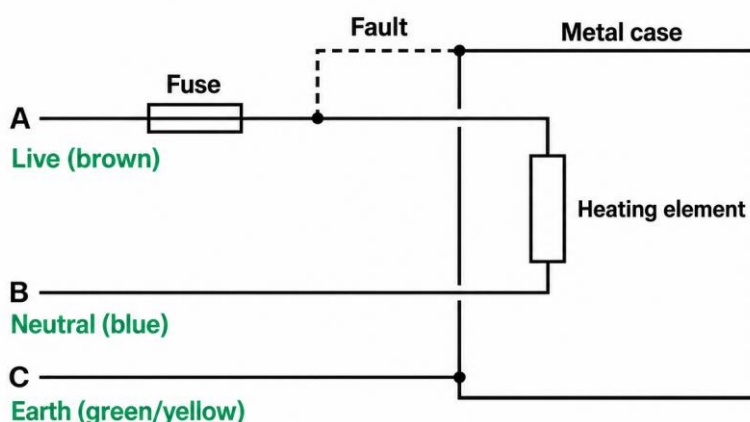


Figure 1

**5(c)** In Figure 1, identify the live wire by letter and state its insulation colour. **[1 mark]**

**Answer / mark points:** Wire A; brown insulation. [1 for both]



## 5 Explaining mains protection continued

5(d) Name wire B in Figure 1 and explain its function in normal operation. [2 marks]

**Answer / mark points:** B is the neutral wire. [1] It completes the circuit through the heating element. [1]

**Teacher prompt:** Neutral is at or close to earth potential (0 V), but it carries current in normal operation. It is not the protective earth wire.

5(e) State the insulation colours of wire C and whether it carries a current during normal, fault-free operation. [2 marks]

**Answer / mark points:** Green and yellow stripes. [1] It carries no current during normal, fault-free operation. [1]

**Teacher prompt:** C is the earth wire. Its normal potential is 0 V. Do not say it continuously carries unwanted current away.

5(f) The dashed fault in Figure 1 occurs. Explain how the earth wire and a correctly rated fuse reduce the electric-shock risk. Link the fault to the protective outcome. [4 marks]

**Answer / mark points:** The earth wire provides a low-resistance conducting path from the metal case to earth. [1]

The live-to-case fault then produces a large current through the fuse and earth path. [1]

This current heats the fuse wire until it melts, breaking the live circuit. [1]

The appliance is disconnected from the live supply, preventing the case remaining live. [1]

**Teacher prompt:** The fuse must be in the live wire. Do not say the fuse absorbs current, that current is used up, or that earth alone switches the circuit off.

5(g) The earth connection is broken before the live-to-case fault occurs. Explain why a person touching the case while connected to earth could receive an electric shock. [2 marks]

**Answer / mark points:** The case can be at a large potential difference from earth, approximately the live supply potential difference. [1]

Touching it can complete a conducting path through the person to earth, so a current passes through the person. [1]

**Teacher prompt:** Without the protective low-resistance path, the fault need not draw enough current to melt the fuse. Never test this situation.

5(h) An appliance's operating switch is open, but an exposed section of live wire on the supply side of that switch is still connected to the mains. Explain why touching it while connected to earth remains dangerous. [2 marks]

**Answer / mark points:** The open operating switch does not remove the potential difference between that live section and earth. [1]

A person touching it while connected to earth can complete a path for current through their body. [1]

**Teacher prompt:** An appliance not operating is not evidence that every internal conductor is safe. This is explanation, not instructions to inspect mains equipment.



## 6 Supplying the kitchen through the National Grid

Two proposed transmission designs transfer the same electrical power before cable losses. Design H uses a higher transmission potential difference. The total transmission-cable resistance is  $2.0\ \Omega$  in either design.

Table 1

| Transmission design | Current in cables / A | Total cable resistance / $\Omega$ |
|---------------------|-----------------------|-----------------------------------|
| L                   | 100                   | 2.0                               |
| H                   | 10                    | 2.0                               |

**6(a)** State how a step-up transformer changes the potential difference for transmission, and how a step-down transformer changes it before domestic use. **[2 marks]**

**Answer / mark points:** A step-up transformer increases the potential difference. [1] A step-down transformer decreases it to the much lower value needed for domestic use. [1]

**6(b)** Use the currents in Table 1 to calculate the power transferred by heating in the transmission cables for each design. **[2 marks]**

**Answer / mark points:** L:  $P = I^2R = 100^2 \times 2.0 = 20\ 000\ \text{W}$ . [1]  
H:  $P = 10^2 \times 2.0 = 200\ \text{W}$ . [1]

**Teacher prompt:** These are cable heating losses, not the useful power arriving at the kitchen. Use the same total cable resistance in both cases.

**6(c)** Explain why transmitting at the higher potential difference in design H makes energy transfer more efficient. Refer to the same transmitted power and the cable heating. **[3 marks]**

**Answer / mark points:** For the same transmitted power,  $P = VI$  means a higher potential difference requires a smaller current. [1]  
The smaller current reduces  $I^2R$  and therefore the rate of energy transfer by heating in the cables. [1]  
A smaller fraction of the supplied energy is transferred to the surroundings, so a larger fraction reaches consumers. [1]

**Teacher prompt:** The benefit is not a lower cable resistance. Transformer construction, turns ratios and ideal-transformer calculations are not assessed here.

## 7 Optional electricity costs

Use a hypothetical tariff of 30 p per kWh and  $1\ \text{kWh} = 3\ 600\ 000\ \text{J}$ . Ignore standing charges. Round costs to the nearest 0.01 p.

**7(a)** Using 414 000 J for urn A's heating cycle, calculate its energy use in kWh and the cost of one cycle at the supplied tariff. **[2 marks]**

**Answer / mark points:** Energy =  $414\ 000 / 3\ 600\ 000 = 0.115\ \text{kWh}$ . [1]  
Cost =  $0.115 \times 30 = 3.45\ \text{p}$ . [1]

**7(b)** Urn B uses 0.125 kWh for the same batch. Calculate its cost and how much more this is than urn A's cost. **[1 mark]**

**Answer / mark points:** B costs  $0.125 \times 30 = 3.75\ \text{p}$ ; it costs  $3.75 - 3.45 = 0.30\ \text{p}$  more per batch. [1 for the correctly compared costs]

**Teacher prompt:** The tariff is in pence per kWh, not pounds per joule. Accept equivalent £0.0375 and £0.0030 difference.

## Review and improve

Distinguish power from energy and potential difference from charge flow. The earth wire carries no current normally. In a fault, a large current can melt the fuse and break the live circuit.

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