Set 13

Q and A

Q1

Name and describe the function of each conductor in a three-wire domestic general power outlet (three-pin socket).

The active or live wire is the conductor at the high potential, nominally $V_{rms} = 240$ V

The neutral wire is at a potential very close to zero relative to the active wire.

The earth wire is a safety feature which is permanently connected to ground and therefore at a potential of 0 V.

Q2

The severity of an electrical shock depends on the **current** passing through a person. Why is it impossible to say which **potential differences** are dangerous?

Even small potential differences, such as 12 V car batteries, can deliver huge currents (up to 100 A) which can be fatal. However, a school laboratory Van der Graaf generator can build up a potential of thousands of volts, but if a student touches it, thereby establishing an equivalent potential difference, it may provide a slight, but non-fatal shock. Generally, the resistance of the load (combined with the internal resistance of the supply) will determine the current, not the potential difference itself.

Q3

How many 40.0 W light globes can you operate on a 240 V circuit protected by a 15.0 A circuit-breaker?

$$I_{globe} = \frac{P}{V} = \frac{40\ \text{W}}{240\ \text{V}} = 0.166\ \text{A}$$

so the number of globes possible = $\frac{15\ \text{A}}{0.166\ \text{A}} = 90$ globes

In practice, the circuit breaker would probably not cut out at exactly 15 A, so you could probably run a few more globes than this from the lighting circuit.

Q4

A car with a 12.0 V electrical system has 2.40 Ω headlights. If you need to protect a single headlight circuit with a fuse, calculate the minimum current rating for such a fuse.

$$I_{min} = \frac{V}{R} = \frac{12\ \text{V}}{2.4\ \Omega} = 5.0\ \text{A}$$

Q5

Explain why:
[a] a short circuit is a thermal hazard instead of a shock hazard.
[b] alternating current is more dangerous than direct current at the same voltage.
[c] doubly insulated appliances reduce the need for a three wire system.

(a)	In the event of a short circuit, a huge current surge would generate significant heat energy which would melt / damage the guilty conductor and cause a break in the circuit, thereby stopping the current flow before an electric shock could occur.
(b)	'Time-current' is a combination of the magnitude of the current flow and the time for which it acts. Direct current does produce similar biological effects to that of alternating current, however the least DC time-current that will cause biological problems is greater than the corresponding AC time-current.
(c)	The Earth wire is an essential safety feature which allows the safe operation of appliances with metal casings. However, if the appliance was doubly insulated, then in the event that a casing should become 'live' due to a fault, then the higher resistance of the protective layer would result in a much lower current flowing to the outer shell.

Q6

You plug a 1200 W heater into a 240 V general power outlet.
[a] What current will that heater draw?
[b] Could you plug two such heaters in an outlet protected by a 15.0 A circuit-breaker? Explain.

(a)	$I_{heater} = \frac{P}{V} = \frac{1200\text{ W}}{240\text{ V}} = 5.0\text{ A}$
(b)	The 15 A circuit-breaker should not become an issue until the current drawn by the appliances is around 15 A. Since two heaters would only draw 10.0 A in total, then they would operate fine.

Q7

Should you operate a 1000 W iron, a 2400 W clothes drier and a 2000 W washing machine from the same 15.0 A, 240 V power point? Explain.

Total power consumption = 1000W + 2400W + 2000W = 5400 W

The resulting current flow, $I_{total} = \frac{P}{V} = \frac{5400\text{ W}}{240\text{ V}} = 22.5\text{ A}$

This would obviously trip the 15 A circuit-breaker, so you should not use these three appliances.

Q8

When electricity utilities install an electricity supply to a customer they sometimes install a fuse at the start of the line. If the wires to a customer's property have a larger than normal resistance, should the installers use a fuse with larger or smaller current rating?

The larger resistance wires can accommodate a bigger current flow and still function safely, therefore a fuse with a larger current rating should be installed.

Q9

What role, if any, do circuit-breakers, fuses and residual current devices play in preventing shock hazards?

All three safety features will ultimately break an electrical circuit and stop current flowing, although it may take anything from a fraction of a second to several seconds to do so. This may prevent a shock hazard in most cases, particularly in domestic situations, although they will not prevent all hazards.

Q10

The fuse in the lighting circuits of a house will break the circuit if the total current exceeds 10.0 A and the fuse for the power points will break those circuits if the total current exceeds 15.0 A.

[a] How many 100 W light globes can be placed into one lighting circuit before the fuse will 'blow'?

[b] A 1800 W vacuum cleaner and a 2400 W clothes drier are used simultaneously on two sockets in the same power circuit. Will the fuse 'blow'? Explain.

[c] In the above two circumstances, what is the purpose of the fuse?

[d] Explain why it is very silly to replace a blown fuse with a piece of thick copper wire.

[e] The fuse will always blow in the event of a short circuit. It is often claimed that this may prevent electrocution. Explain the circumstances under which a fuse might prevent electrocution.

Q10 continued

(a)	$I_{globe} = \frac{P}{V} = \frac{100\text{ W}}{240\text{ V}} = 0.417\text{ A}$ so the number of globes possible = $\frac{10\text{ A}}{0.417\text{ A}} = 24$ globes
(b)	Total power consumption = 1800W + 2400W = 4200 W The resulting current flow, $I = \frac{P}{V} = \frac{4200\text{ W}}{240\text{ V}} = 17.5\text{ A}$ This too great current would obviously 'blow' the 15 A fuse.
(c)	The fuse in both cases protects the user of the appliances from an electrical shock hazard or an electrical burn, however it also protects the appliances themselves from permanent damage which could prove financially costly.
(d)	Thick copper wire would have a very low resistance and therefore allow a much larger and potentially fatal current, to flow through it before 'blowing'.
(e)	In the event of a short circuit, a huge current surge would generate significant heat energy which would melt / damage the guilty conductor and cause a break in the circuit, thereby stopping the current flow before an electric shock could occur. Hence, the risk of electrocution maybe prevented.

Q11

Alec wants to connect several devices to one 240 V power board for a party. The devices are a 35 Ω heater, a 110 Ω lamp, a 750 Ω CD player, a 640 Ω cassette player, and a 350 Ω amplifier. The power board has an overload protection device that switches the board off when the total current exceeds 10.0 A. Will Alec's circuit work?

Power boards demand appliances be connected in parallel and they operate from a 240 V supply.

$$I_{heater} = \frac{V}{R} = \frac{240\ \text{V}}{35\ \Omega} = 6.86\ \text{A}$$

$$I_{lamp} = \frac{V}{R} = \frac{240\ \text{V}}{110\ \Omega} = 2.18\ \text{A}$$

$$I_{CD\ player} = \frac{V}{R} = \frac{240\ \text{V}}{750\ \Omega} = 0.32\ \text{A}$$

$$I_{cassette\ player} = \frac{V}{R} = \frac{240\ \text{V}}{640\ \Omega} = 0.375\ \text{A}$$

$$I_{amplifier} = \frac{V}{R} = \frac{240\ \text{V}}{350\ \Omega} = 0.686\ \text{A}$$

The total current drawn form the power board, $I_{total} = 10.42$ A

This exceeds the 10 A safety margin so Alec's circuit will not work.

Q12

Andrew foolishly uses a metal-handled knife to remove a burning slice of bread from his toaster. The knife touches the toaster element, which carries 240 V AC. Fortunately for him, a residual current device (RCD), also known as a 'safety switch', is installed in his home. His body resistance would allow 40.0 mA of current to pass through him to the earth. This is enough current to trip the RCD, which switches off all power in his house.

[a] What was the total resistance of Andrew's body, shoes and floor?

[b] If the current was 1.50 A in the active line, what would the 'return current' in the neutral line be for the RCD to detect the difference?

(a)	$R = \frac{V}{I} = \frac{240\text{ V}}{0.04\text{ A}} = 6.0\text{ k}\Omega$
(b)	$I_{neutral} = 1500\text{mA} - 40\text{mA} = 1460\text{ mA}$ (or 1.46 A)

Q13

It is common practice in commercial installations to have a separate circuit for a refrigerator so no other appliance can trip the circuit-breaker and shut off the fridge. However, Jill turns on a 1.50 kW griller on the same circuit at the same time as a fridge that draws 10.0 A when it starts. A 15.0 A circuit-breaker protects the fridge circuit.

[a] Calculate the current drawn by the griller.

[b] What is the resistance of the fridge as it starts up?

[c] Will the circuit breaker be activated when the fridge starts up?

(a)	$I_{griller} = \frac{P}{V} = \frac{1500\ W}{240\ V} = 6.25\ A$
(b)	$R_{fridge} = \frac{V}{I} = \frac{240\ V}{10\ A} = 24.0\ \Omega$
(c)	I_{total} = 10A + 6.25A = 16.25 A, so the circuit breaker will be activated when the fridge starts up.

Q14

Some school laboratories have EHT (Extra High Tension) power packs that can give up to 3000 V. For safety, they are provided with a 50.0 MΩ resistor in series with the supply.

[a] What is the maximum current able to be supplied by this power pack?

[b] Estimate the potential difference there would be across a 3.00 V, 500 mA torch bulb connected across such a supply.

[c] Explain how the 50.0 MΩ resistor acts as a safety device.

Q14 continued

(a)	$I_{max} = \frac{V}{R_{min}} = \frac{3000\text{ V}}{50 \times 10^6\ \Omega} = 6 \times 10^{-5}$ A or 60 µA
(b)	A typical torch bulb may be rated at 3 V, 500 mA when operating normally. This would suggest a resistance, $R = \frac{V}{I} = \frac{3\text{ V}}{0.5\text{ A}} = 6.0\ \Omega$. When competing with the 50 MΩ series safety resistor, its share of the voltage supply will be minimal: $I = \frac{V}{R} = \frac{3000\text{ V}}{(6\ \Omega + 50000006\ \Omega)} = 5.999 \times 10^{-5}$ A or 59.9 µA so $V_{torch} = I \times R_{torch} = 5.999 \times 10^{-5}\text{A} \times 6\ \Omega = 3.59 \times 10^{-4}$ V (about 360 µV)
(c)	The 50 MΩ resistor acts like an internal resistance, such that even in the event of a short circuit when the external resistance could be very close to 0 Ω, the maximum current that can result is limited to 60 µA which should be non-fatal.

Q15

John is barefoot on a wet laundry floor. His right hand accidentally touches a frayed live 240 V AC wire. John's body has a resistance of 4400 Ω to ground. He has not protected his house with a residual current device (RCD).

[a] What current will flow through him?

Carmen tries to rescue John without first switching off the power. She grabs his left wrist. Carmen has a resistance of 8000 Ω and the resistance of John's body between the wire and his left wrist is 400 Ω.

[b] Does the current through John's heart increase, decrease or stay the same?

[c] What current will flow through Carmen?

[d] What should Carmen have done?

[e] Explain why the fuse in the house circuit was no protection against electrocution.

Q15 continued

(a)	$I_{John} = \frac{V}{R} = \frac{240\ V}{4400\ \Omega} = 5.45 \times 10^{-2}$ A or 54.5 mA
(b)	Carmen is effectively joining John in parallel, so the combined resistance will now be less thereby drawing a bigger current. Although there are two separate current paths, John will effectively have both running through his heart - the original 54.5mA and now the extra current running along his arm span to Carmen.
(c)	$I_{Carmen} = \frac{V}{R} = \frac{240\ V}{(8000\ \Omega + 400\ \Omega)} = 2.86 \times 10^{-2}$ A or 28.6 mA
(d)	Carmen should have isolated the power supply initially – turned off the electricity.
(e)	The total current flowing = 54.5 mA + 28.6 mA = 83.1 mA, although potentially hazardous for John, it is not large enough to 'blow' the fuse in the power points circuit.