locktronics™

Simplifying Electricity

Automotive Fault Finding

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Contents

Automotive fault-finding

Introduction to multimeters

Automotive fault-finding

You can buy many different types of multimeter for use in automotive fault-finding.

They may have different features, but they are used in pretty much the same way.

In these worksheets, we introduce you to the basics of multimeters.

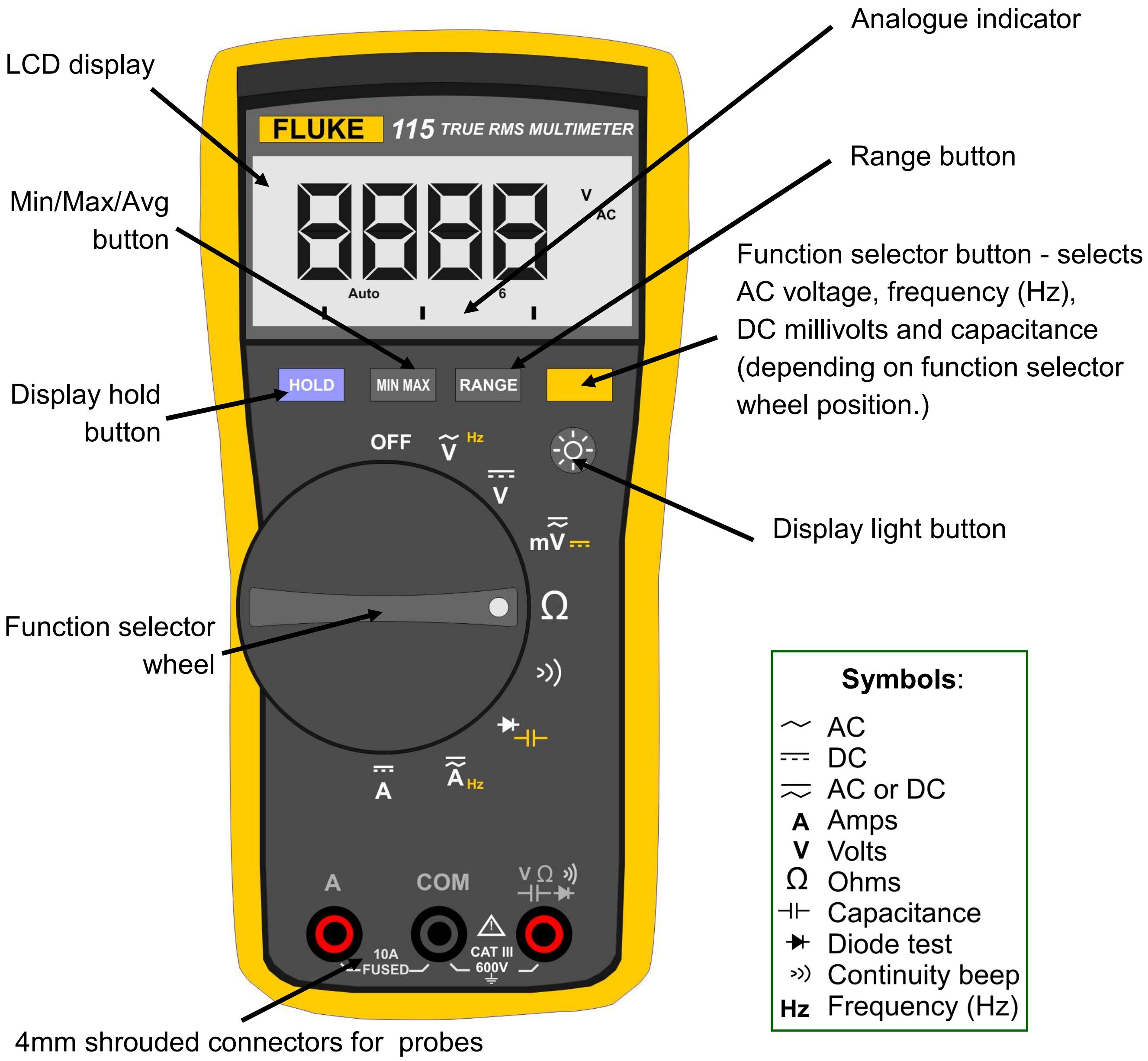
Over to you:

- Have a look at the next two pages which describe the functions of a multimeter. You can come back to these pages at any time.
- Don't worry too much if you don't understand all the details of how these devices work at this time - we will be making sure that you understand how to use your multimeter in the coming pages.
- For whatever multimeter you use, you need the manual - either in paper form or downloaded from the internet. Make sure that you have this to hand for the worksheets that follow.
- Familiarise yourself with the Locktronics kit - we will be using the parts soon.

So what?

- Most multimeters are used in the same way.
- There are lots of different types of multimeters and in your career as an automotive technician you will use many.
- Multimeters perform a variety of functions. Always check that you have the right setting on your meter before you use it.
- To be able to diagnose automotive faults, you need to understand the basics of how your multimeter works. You will learn this in the coming worksheets

Introduction to multimeters



Symbols:

- ∼ AC
- ⎓ DC
- AC or DC
- **A** Amps
- **V** Volts
- **Ω** Ohms
- Capacitance
- Diode test
- Continuity beep
- **Hz** Frequency (Hz)

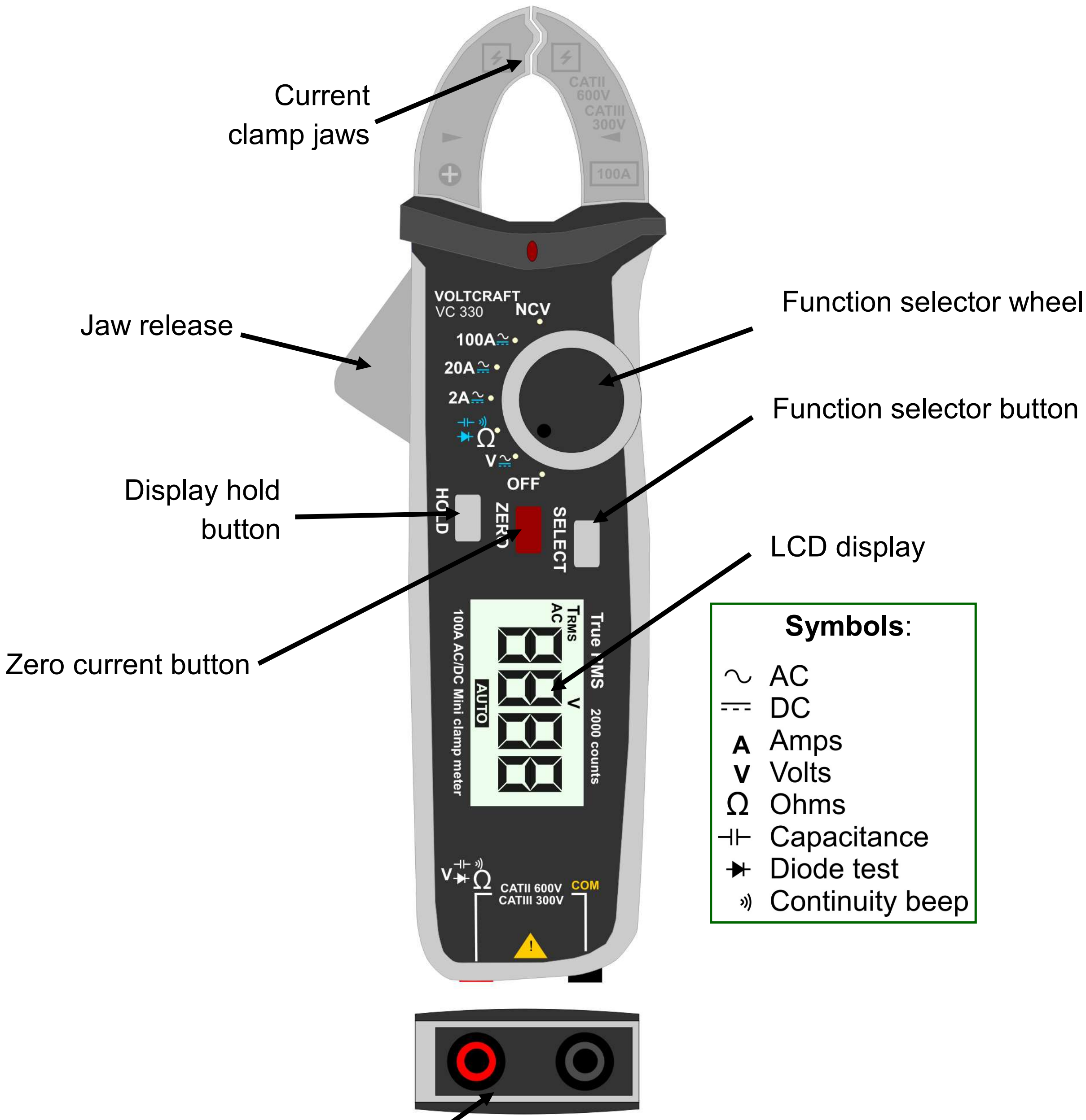
The Fluke 115 general purpose multimeter is a high quality instrument capable of measuring voltage (AC or DC), frequency, current (AC or DC), resistance, and capacitance.

To measure current, you need to use the central 'COMmon' 4mm socket and the left hand 'A' 4mm socket. For all other quantities, use the central 'COMmon' 4mm socket and the right hand 4mm socket.

After measuring current, if you forget to change the leads over, you are likely to blow the fuse in the meter when you try to measure voltage. You will then need to replace it.

Introduction to the current clamp

Automotive fault-finding



4mm shrouded connectors used for measuring voltage, current and resistance.

This Voltcraft VC330 current clamp has one big advantage over the traditional multimeter - it can measure current without the need for interrupting the circuit. You simply open the jaws and pass the wire that you are investigating through them. The clamp detects the electro-magnetic field around the wire and deduces the level of AC or DC current flowing through it.

This meter also has a special function for detecting high voltages without connecting the probes - this is called 'Non Contact Voltage Testing'. It uses a sensor in the tip of the clamp to detect high voltages.

Worksheet 1

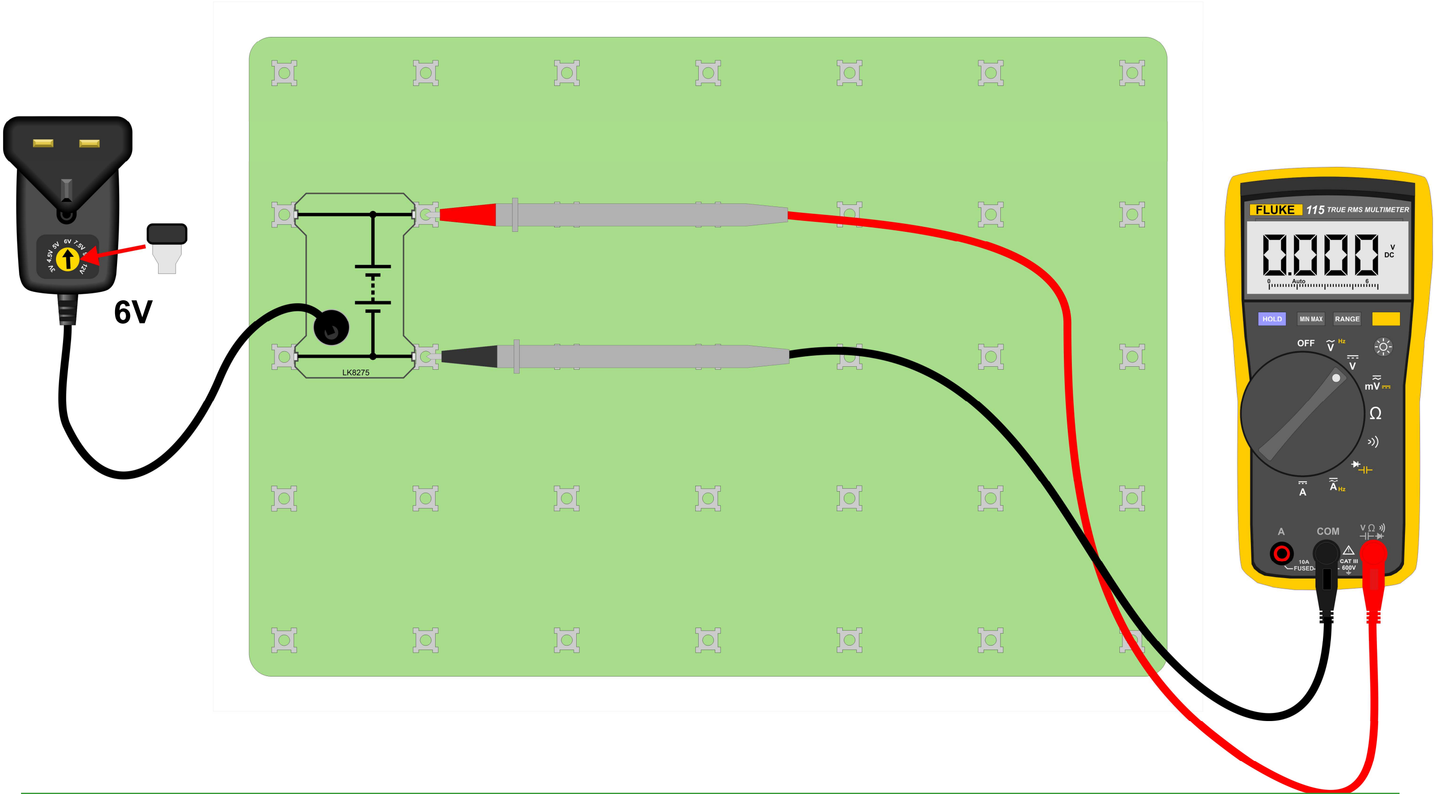
Measuring voltage

Automotive fault-finding

The majority of electrical faults in a vehicle can be detected using a standard multimeter on the voltage setting.

Here you examine how a multimeter is used to measure DC voltage.

The photograph shows the dashboard of an old car with a built-in voltmeter for monitoring battery voltage.



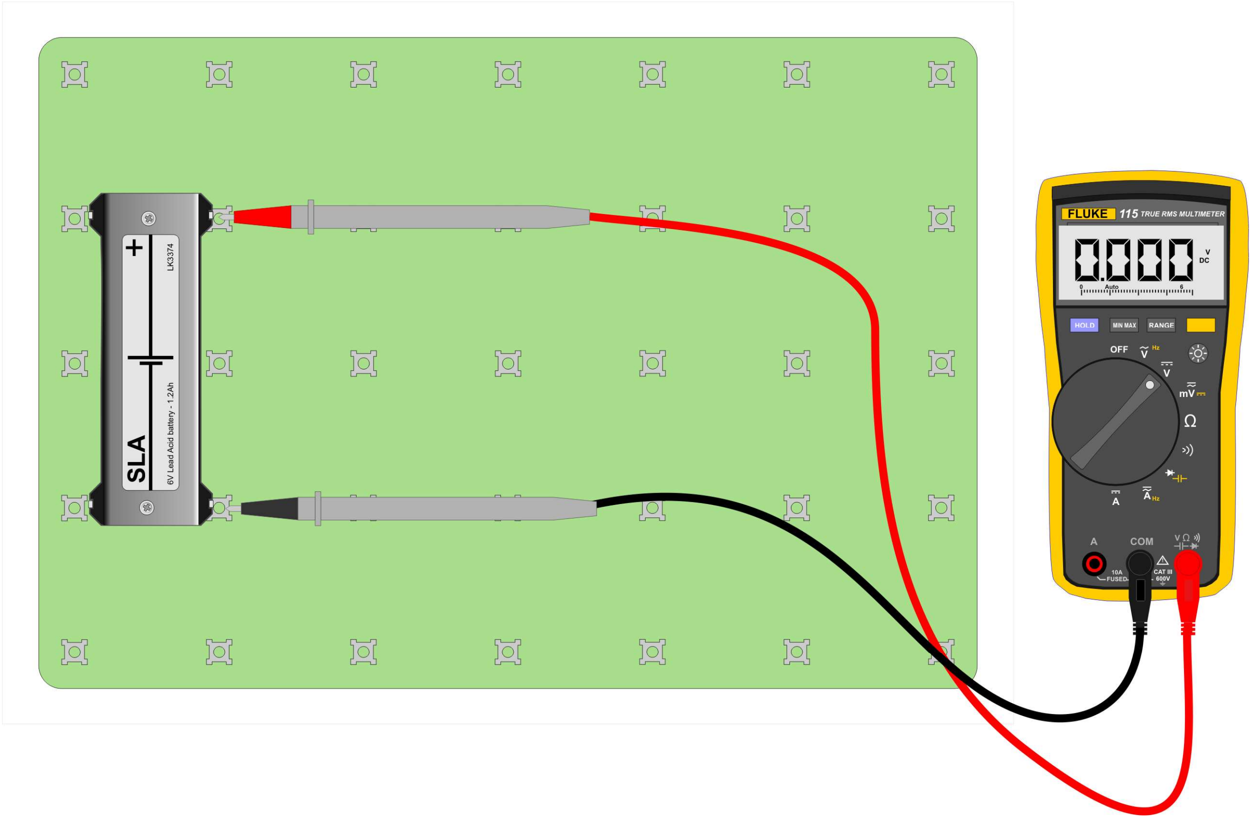
Over to you:

- Set up the Locktronics baseboard as shown.
- Adjust the plug-top power supply to 6V with the key provided . Plug it into the mains supply and turn on. Connect it to the battery carrier.
- Connect the multimeter leads to the COMmon and voltage terminals as shown.
- Set the multimeter to measure DC voltage.
- Measure the voltage across the power supply carrier and record it in the Student Handout.
- Reverse the multimeter probes on the power supply carrier. What happens?
- Put the multimeter onto the AC voltage setting. Make a note of the result.

Worksheet 1

Measuring voltage

Automotive fault-finding



Over to you:

- Exchange the plug-top power supply and battery carrier for the Sealed Lead Acid (SLA) battery as shown above.
- Measure the voltage across the battery carrier and note it in the Student Handout.

So what?

- The plug-top power supply and the 6V Lead Acid Battery look pretty much identical as far as the multimeter is concerned. They behave in in a very similar way, providing DC voltage and energy.
- Sometimes you see a battery, or power supply, described as ‘12V’. In practice it is never quite 12V - it is always slightly higher or lower.
- Always think about what you are measuring. A multimeter on the wrong setting will give in-correct results
- Make sure the display reflects the type of measurement you are making - in this case V….DC
- When on the voltage setting the multimeter measures both ways - positive and negative and it just adjusts the sign on the readout accordingly.
- When measuring voltages we talk about ‘the **voltage across ...**’.

Worksheet 1

Measuring voltage

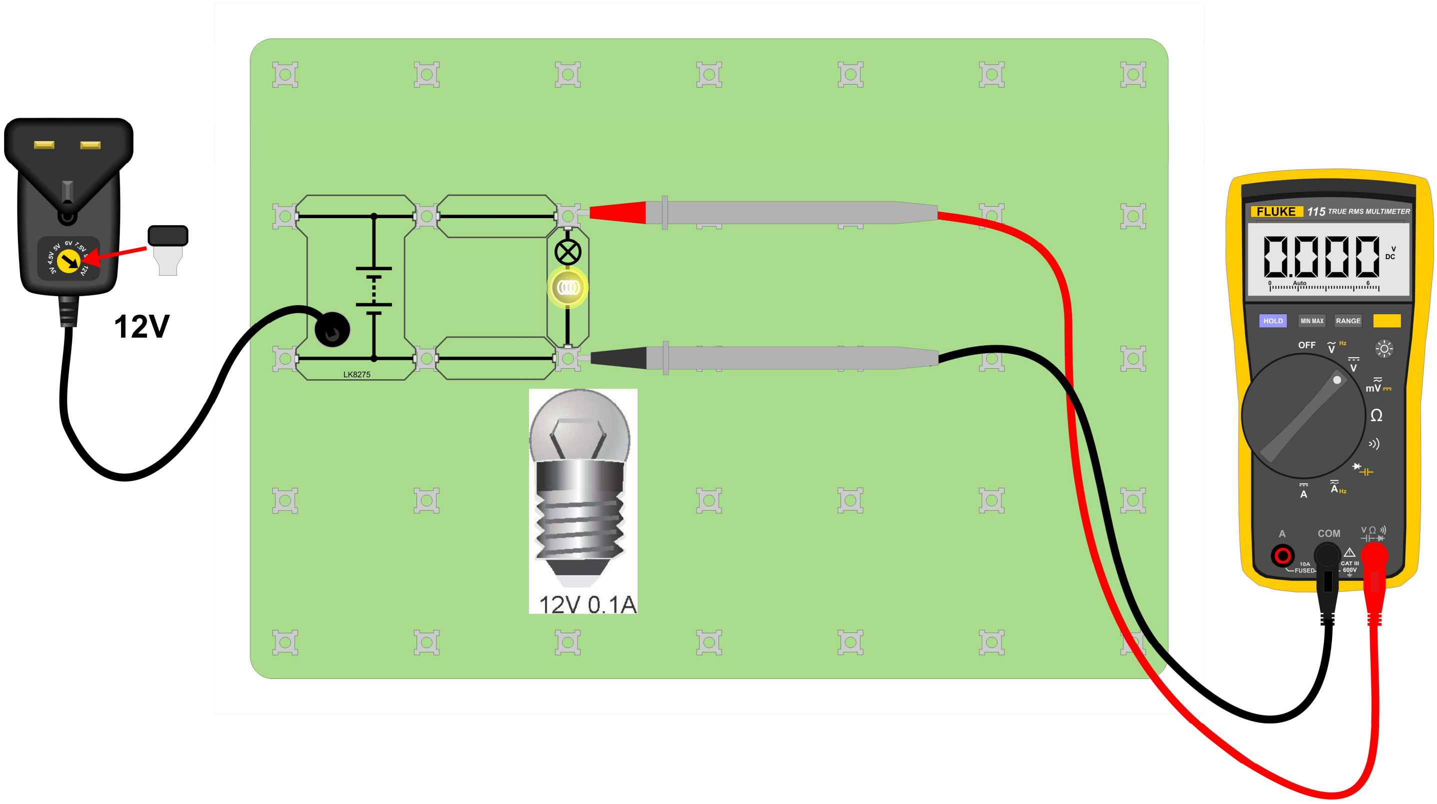
Automotive fault-finding

So what?

- You have created your first circuit. The circuit diagram for this is shown opposite. Although we used different two voltage sources the circuit for both is the same.
- The two voltage sources we have used are represented by different symbols. The Sealed Lead Acid battery is represented by a single battery symbol. The plug-top power supply is represented by two battery symbols with some dashed between them - indicating that this is a number of batteries in series. Strictly speaking this symbol is more technically correct for the Lead Acid battery as well, as it is made up of a number of cells in series. In practice, the two symbols are used interchangeably.
- A meter has its own circuit symbol - a 'V' in a circle.
- To measure the voltage **across** a component in a circuit you place a voltmeter **across** it.

Over to you:

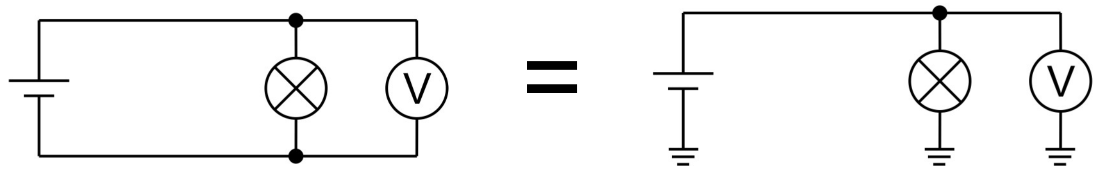
- Build the circuit shown below.
- Change the power supply to 12V and switch on.
- Measure the voltage across the bulb.
- Record its value in the Student Handout.



Worksheet 1

Measuring voltage

Automotive fault-finding



So what?

- You have built your second circuit. The 0V line is often referred to as **earth** or **ground**. As there are so many connections to 0V in a car the earth symbol, shown in the right-hand diagram, is often used to keep circuit diagrams uncluttered.
- You will find that different vehicle manufacturers represent circuit diagrams in different ways.
- In a simple circuit like this, the battery, bulb and voltmeter are all in **parallel**.
- The voltages across the battery, bulb and meter are all identical - assuming that the connections between them have zero resistance.
- To be competent in fault-finding, you need to develop the ability to read circuit diagrams and predict what your multimeter will read when connected to a particular part of the circuit.

Worksheet 2

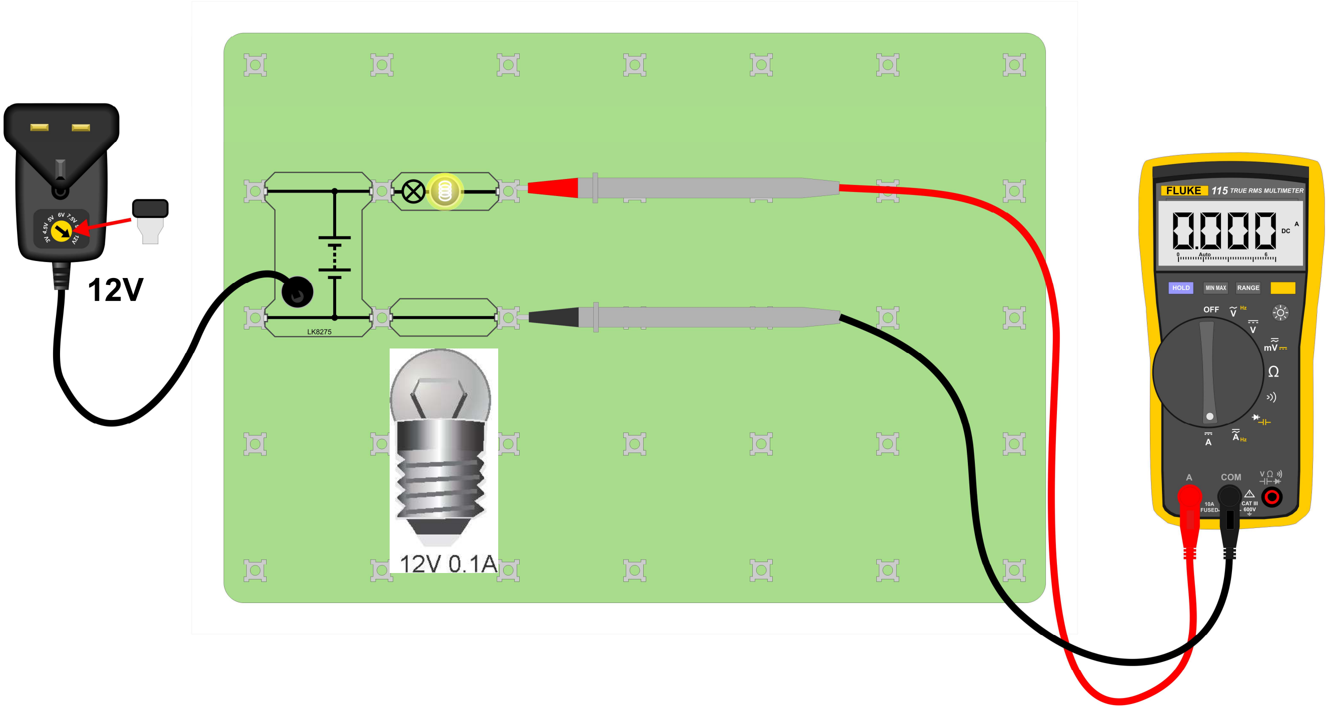
Measuring current

Automotive fault-finding

In vehicles, the current through a cable can be very large. Traditional headlights can demand 5 amps or more. Measuring current with a standard multimeter can be difficult. The modern clamp meter presents an easy solution to this problem.

The photograph shows a clamp meter monitoring the current through the wire in the jaws.

1. Using a multimeter



Over to you:

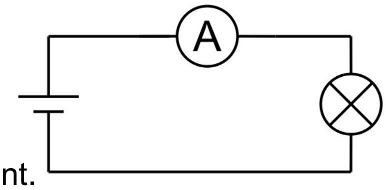
- Set up the Locktronics baseboard as shown.
- Check that the plug-top power supply is still set to 12V. Plug it into the mains supply and turn on. Connect it to the battery carrier.
- Connect the multimeter leads to the COMmon and current terminals as shown.
- Set the multimeter to measure DC current.
- Measure the current through the bulb and note it in the Student Handout.
- What reading do you get when you reverse the multimeter probes?
- What result do you get when you change the multimeter to the AC voltage setting?
- Make a note of these results in the Student Handout.

Worksheet 2

Measuring current

Automotive fault-finding

So what?



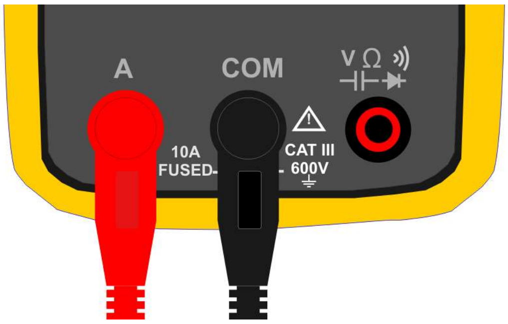
- The circuit symbol for an ammeter is an 'A' in a circle.
  You can see it in the circuit diagram opposite.
- With a voltmeter, you measured the voltage **across** a component.
- With an ammeter, you measure the current **through** the component. With a multimeter, this means that you need to interrupt the circuit. In vehicles, this can be very inconvenient as it means disconnecting or cutting a wire (and restoring it once you have taken your measurement).

WARNING

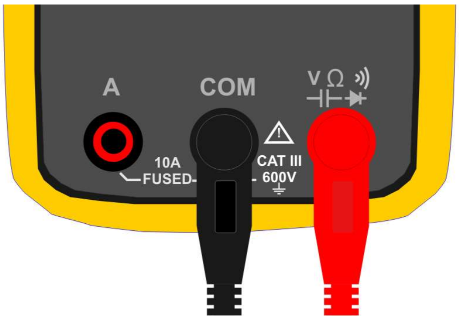
After you have measured current always change the lead positions back to the voltage measuring position:

Black to **COMmon**, **Red** to **Voltage/Ohms**.

If you try to use the meter to measure voltage when the red lead is in the 'A' socket, you will blow the fuse inside the multimeter. The multimeter will still work as far as measuring voltage and ohms is concerned - but you will no longer be able to measure current.



Never leave your multimeter like this...



...leave it like this.

Worksheet 2

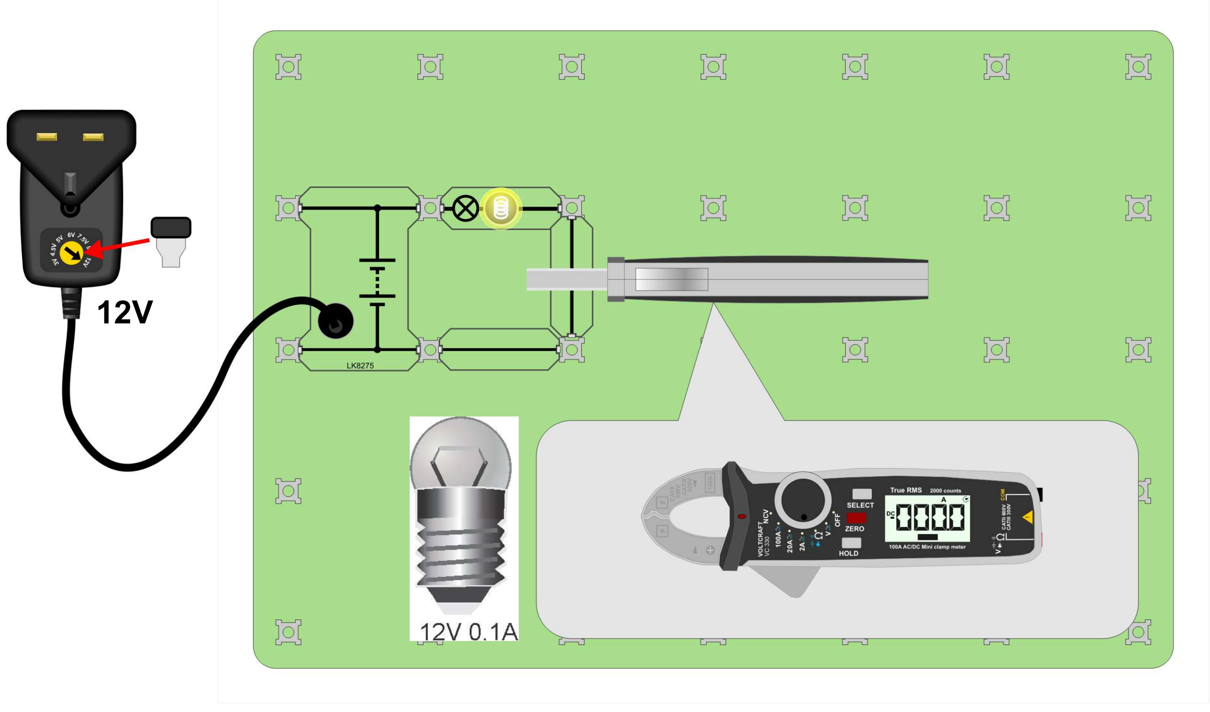
Measuring current

Automotive fault-finding

2. Using a clamp meter

Over to you:

- With the same circuit, put the link back in position to complete the circuit.
- Check that the plug-top power supply is still set to 12V. Plug it in and turn on.
- Take the clamp meter and open its jaws so that they surround a Locktronics link.
  (See the diagram below)
- Rotate the function selector on the clamp meter and select the 2A scale. Use the '**Select'** switch to select DC current. Press the '**Zero'** button on the clamp meter.
- Measure the current with the clamp meter and compare it to the results of a conventional multimeter.
- Remove the clamp and reverse the orientation of the clamp around the Locktronics link. What measurement do you get now?
- Record your results in the Student Handout.



So what?

- The clamp meter is really useful in vehicle diagnostics because it allows you to measure current without interfering with the circuit wiring.
- The clamp meter is capable of measuring AC and DC current through a wire.

Worksheet 3

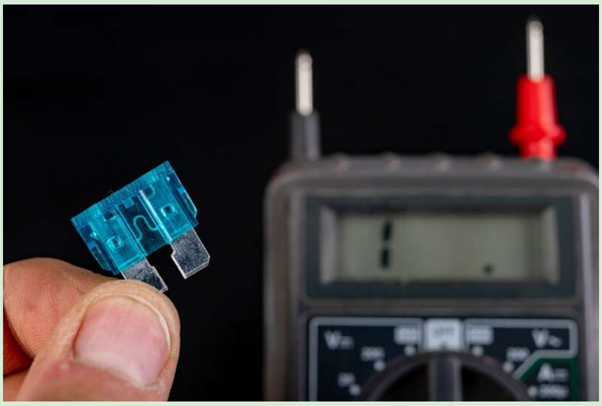
Measuring resistance

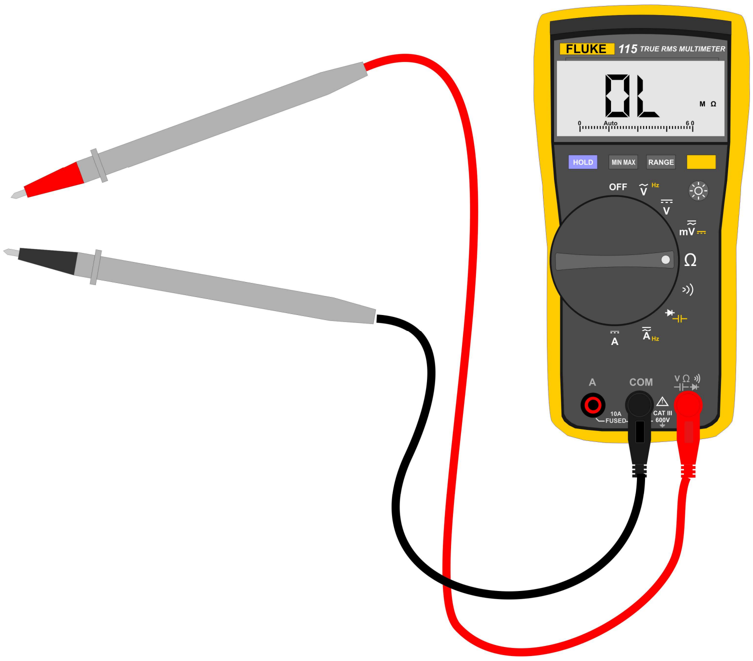
Automotive fault-finding

Multimeters are useful for testing components using the 'resistance' function.

In this worksheet, you are going to see how this resistance setting works.

The photograph shows a fuse that appears to be intact - you can still see the metal hoop encased in the plastic. But is it really intact?





Over to you:

- Return the probe leads to the 'VΩ·)))' and COMmon sockets, if you have not done so.
- Rotate the function selector on the multimeter so that it is in the 'ohmmeter' position - often indicated by the Greek letter omega Ω, the symbol for ohms.
- Firstly, verify that the ohmmeter is working. Take the two probes and touch them together. The display should change. Make a note of the reading in the Student Handout.

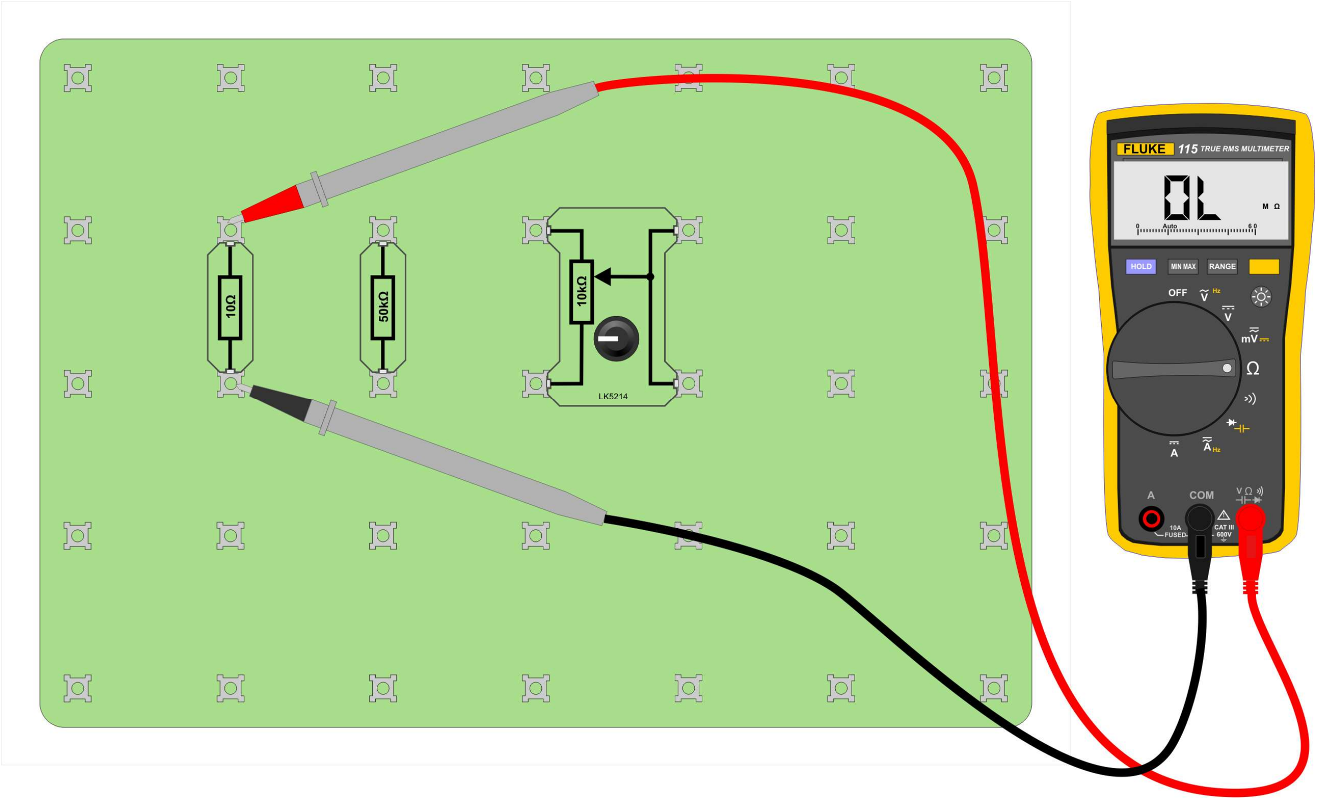
So what?

- You now know the multimeter is working.

Worksheet 3

Measuring resistance

Automotive fault-finding



Over to you:

- Arrange a 10Ω resistor, a 50kΩ resistor and a 10kΩ potentiometer on the baseboard as shown.
- Measure the 10Ω and 50kΩ resistance. Record the measurements in the Student Handout.
- Measure the resistance across the two left hand terminals on the 10kΩ potentiometer.
- Rotate the knob in the middle of the potentiometer so that it is approximately in the middle of its range. The right hand side of the potentiometer is known as the 'wiper'.
- Measure the resistance between the top terminal and the wiper. Measure the resistance between the bottom terminal and the wiper. What do you notice?

So what?

- Multimeters are really great at measuring resistance of components accurately.
- Be careful when using multimeters to test components in-circuit - there will always be something in parallel with the component you are testing which may complicate the reading.

Worksheet 3

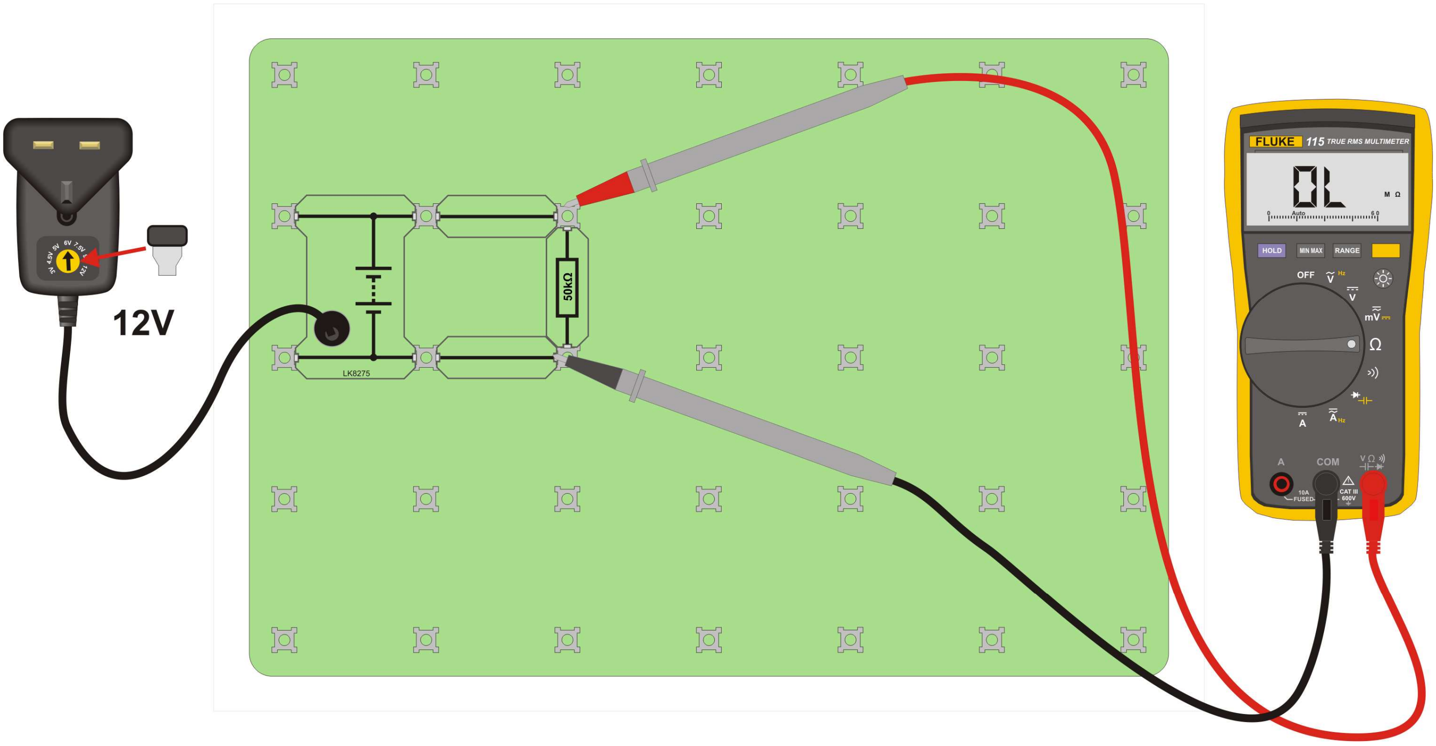
Measuring resistance

Automotive fault-finding

Over to you:

You just measured the resistance of the 50kΩ resistor 'out-of-circuit'. Now you're going to do it 'in-circuit'.

- Build the simple circuit shown below.
- Turn the power supply on.
- Measure the resistance of the 50kΩ resistor in-circuit as shown.
- What is the reading on the multimeter? Record it in the Student Handout.



So what?

- You can't use a multimeter to measure the resistance of a resistor in-circuit with the power switched on.
- On the resistance setting, the multimeter gives out a small voltage and measures the resulting current to calculate resistance.
- If there is another voltage present, then it affects the reading.

Worksheet 4

Testing diodes

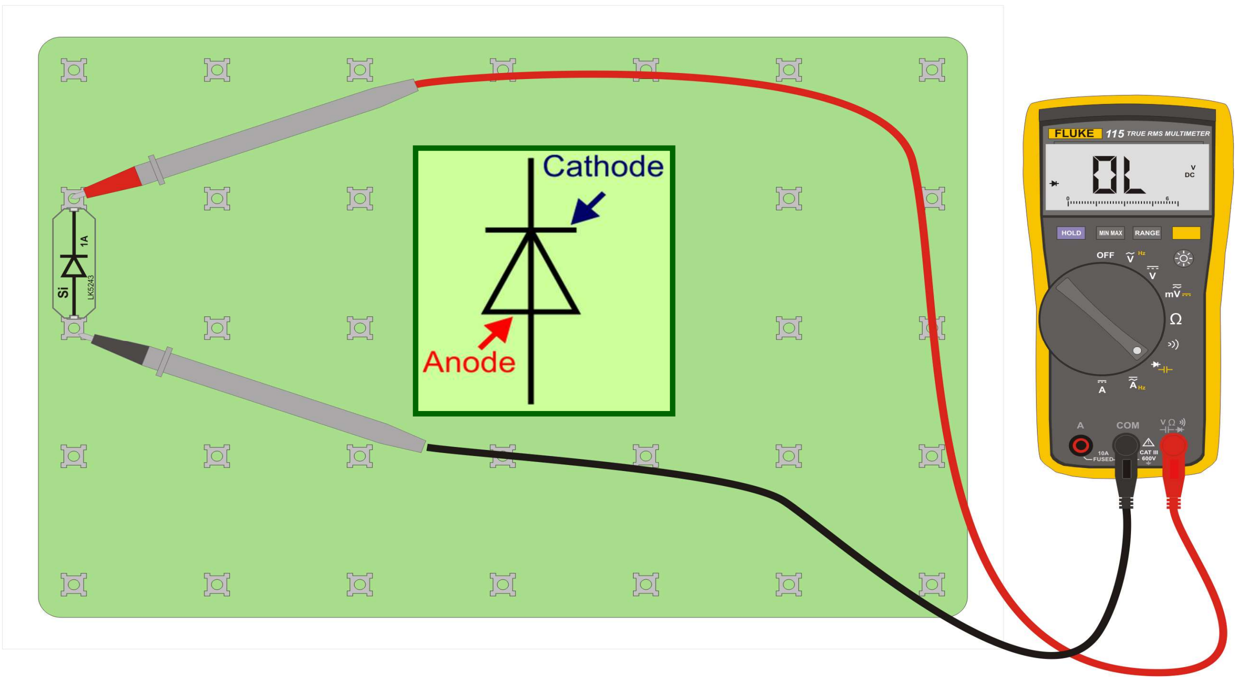
Automotive fault-finding

Every car has diodes in it. You don't always see them as individual components - they are often hidden in alternators or ECUs.

The photograph shows a BSA motorcycle bridge rectifier made up of four diodes attached to a heatsink.

Over to you:

- Rotate the function selector on the multimeter to the 'diode' test position.
- Test the diode with the terminals as shown - the negative COMmon terminal of the multimeter connected to the anode and the positive terminal to the cathode of the diode.
- Change the terminals over. If the diode is working, you should get a reading on the multimeter with this orientation.
- Comment on the significance of the readings in the Student Handout.



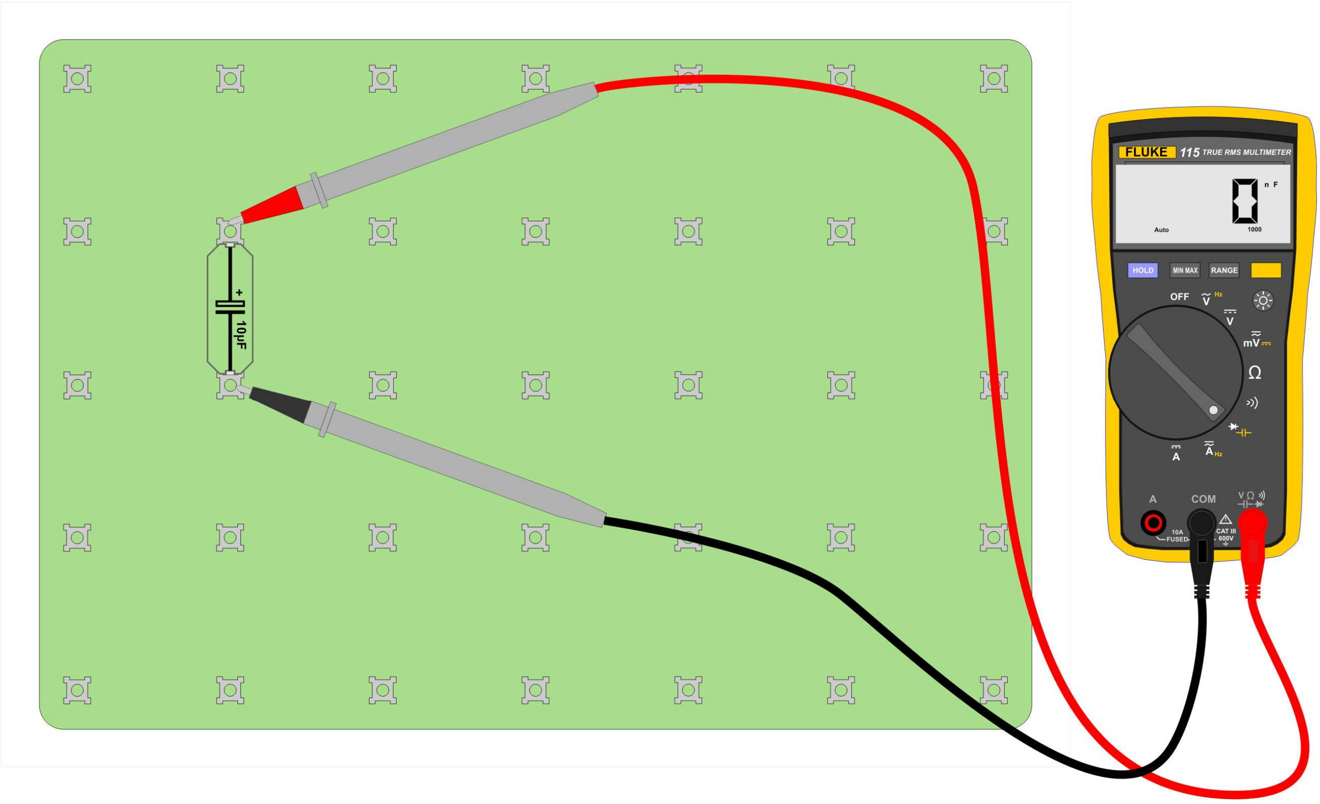
So what?

- The diode test function shows the forward-biased voltage of a functioning diode when the multimeter's positive terminal is on the Anode (the 'triangle' on the circuit symbol) and its negative terminal on the cathode (the 'bar' on the circuit symbol).
- For the Fluke multimeter, a reading of between 0.5 and 0.8V for a forward-biased diode shows that it is working correctly - like a very low value resistor. A display of 'OL' indicates that a reverse-biased diode is working correctly - like an open switch.

Worksheet 5

Measuring capacitance

Automotive fault-finding



Over to you:

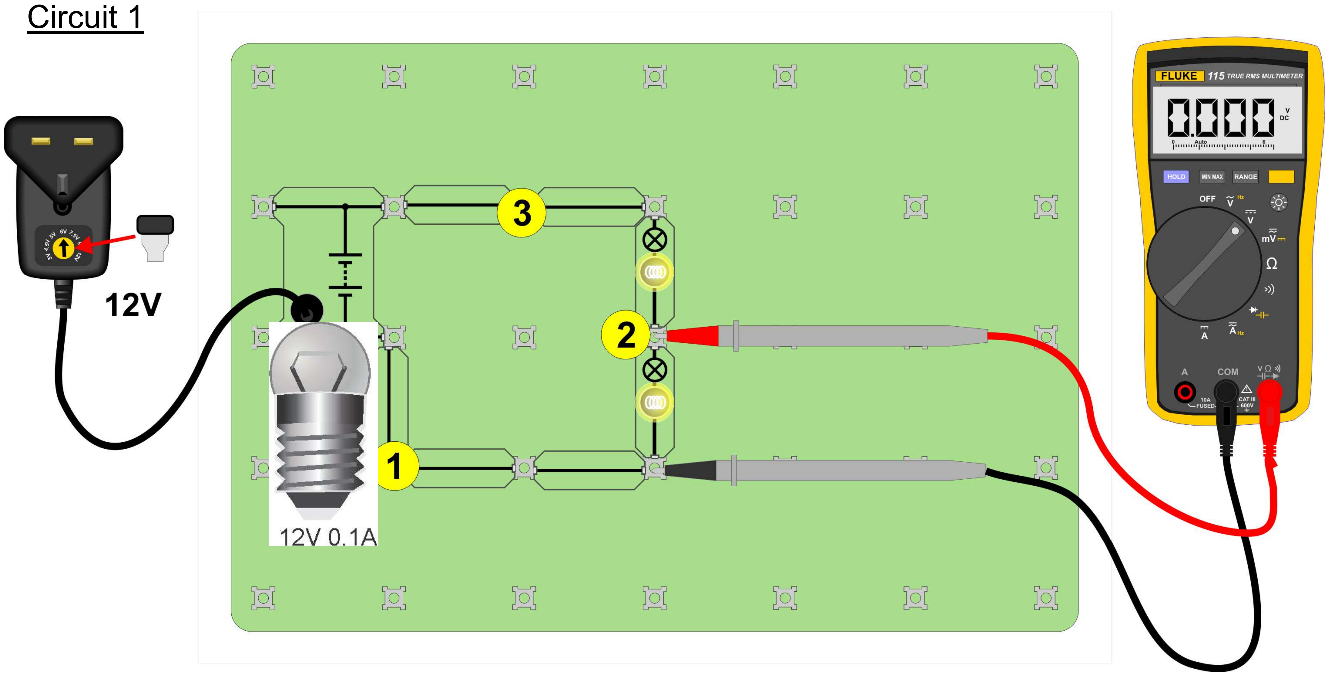
- Rotate the function selector on the multimeter to the 'diode test' position.
- Press the yellow function selector button to put the meter into 'capacitance test' mode.
- Measure the capacitance and record the result in the Student Handout.
- Reverse the probes. Is the reading any different? Again, note it in the Student Handout.

Worksheet 6

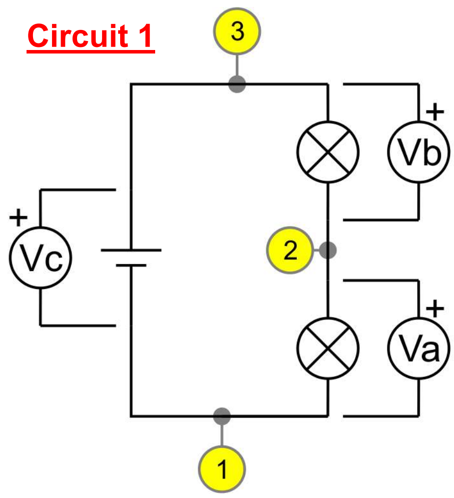
Describing voltage

Automotive fault-finding

Circuit 1



'Nodes' are junctions between components. Circuit 1, shown opposite, has three nodes, numbered 1, 2, and 3. The circuit diagram includes three voltmeters that could be connected to measure voltages Va, Vb, and Vc,



To help us to talk clearly about circuits we need a way of describing voltages. We could say '"Va is the voltage between nodes 1 and 2, Vb is the voltage between nodes 2 and 3 and Vc is the voltage between nodes 1 and 3.''

Alternatively, as most vehicles use only one battery, the voltages can be referenced to the 0V of the battery. We could then say "...the 'voltage at node 2..." etc., meaning the voltage between node 2 and the 0V terminal of the battery. Assuming that the bulbs are identical, for the circuit shown, we can say that "The voltage at node 2 is 6V. The voltage at node 3 is 12V." etc.

Over to you:

- Build circuit 1, as shown above.
- Set the power supply to 12V and switch on.
- Measure the voltages Va, Vb, and Vc.
- Note the results in the Table 1 of the Student Handout.

Worksheet 6

Describing voltage

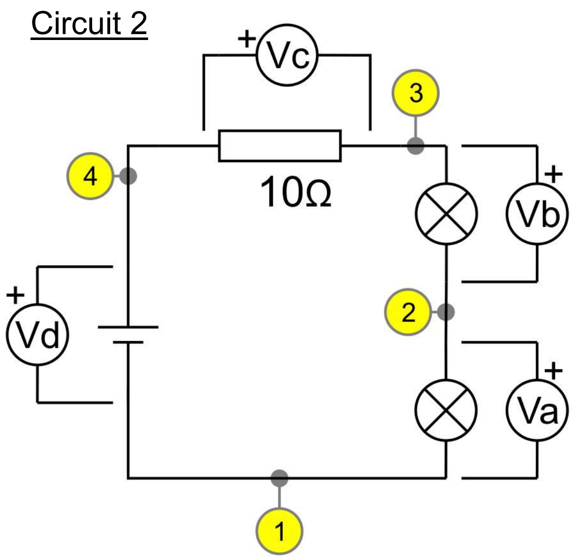
Automotive fault-finding

So what?

- The power supply supplies around 12V to the circuit.
- The voltage across the power supply equals the sum of the voltages across the two bulbs.
- We could say:
    - ‘the voltage at node 2 is around 6V’;
    - ‘the voltage drop across each bulb is around 6V’.
    - ‘the total voltage drop across both bulbs is around 12V’.
- We don’t say:
    - ‘the voltage drop across the power supply is around 12V’.

  The power supply delivers the voltage in the circuit. This is ‘dropped’ across the other components in the circuit.

Over to you:



- Modify the circuit as shown above and use it to answer the following questions:
    - What is the power supply voltage?
    - What is the voltage across the 10Ω resistor?
    - What is the voltage Vb?
    - What is the voltage drop across both bulbs together?
    - What is the voltage at node 3?
    - What is the voltage at node 2?
- Note the results in the Student Handout.

Worksheet 7

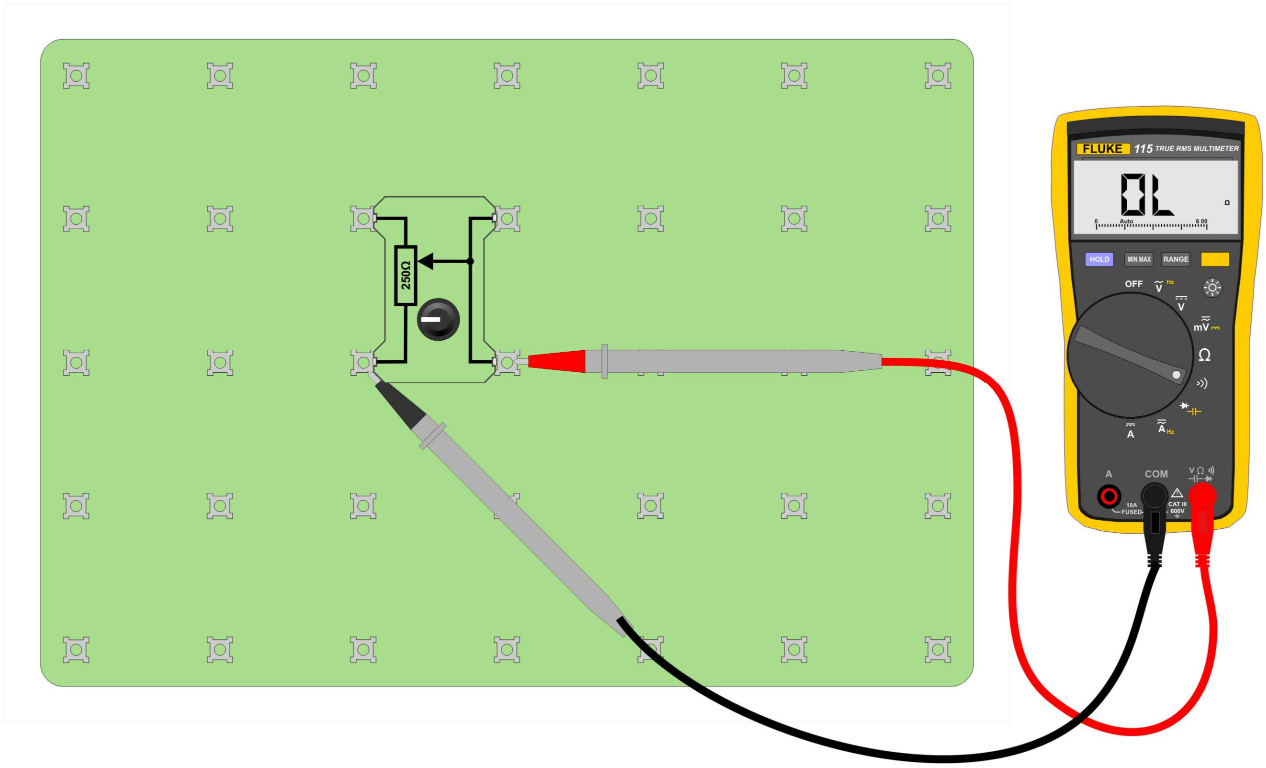
The 'continuity' beep

Automotive fault-finding

Understanding measuring instruments, how they work and what they can tell you is very important.

Otherwise, you may misinterpret the information they give.

The photograph shows automotive style circuit breakers with small reset switches.



Over to you:

- Place a 250Ω potentiometer on the Locktronics board.
- Set the multimeter onto the 'continuity' beep setting and position the probes as shown.
- Set the potentiometer to give maximum resistance between the wiper and the terminal you are using by turning the knob fully clockwise.
  (Note - most meters display resistance when on the 'continuity' beep setting.)
- Slowly reduce the resistance until you hear a beep.
- At what resistance does the beep turn on?
- Increase the resistance. At what resistance does the beep turn off?
- Record your findings in the Student Handout.

Worksheet 8

A good ground / earth

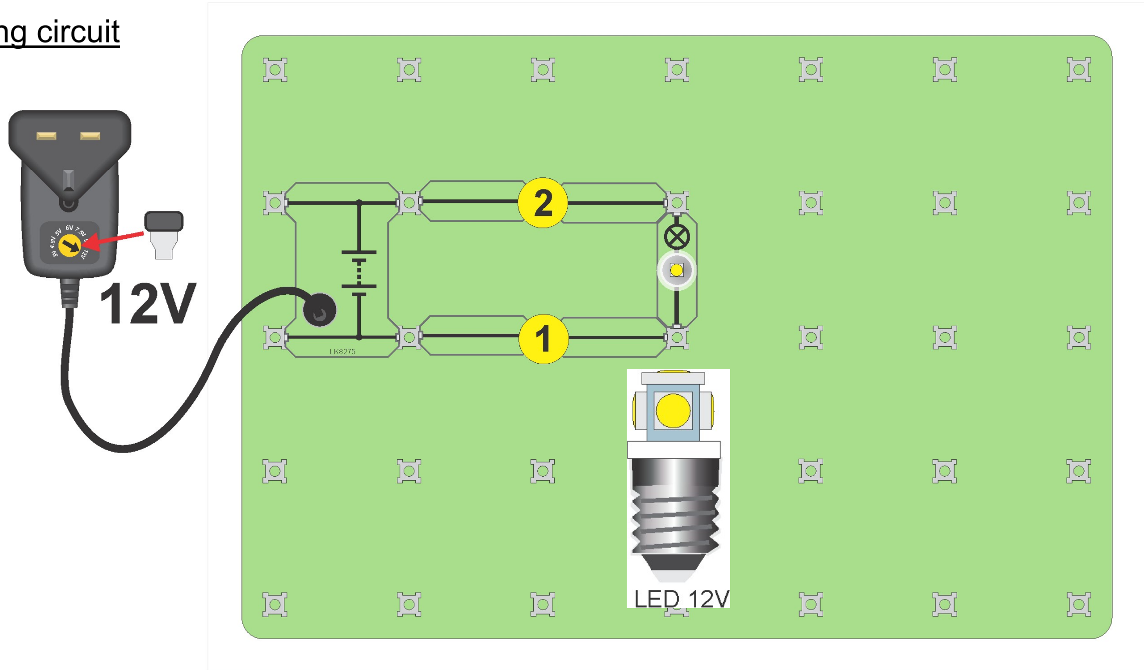
Automotive fault-finding

Electrical faults in vehicles are dangerous.

A partial short-circuit or partial open-circuit can generate huge amounts of heat in a vehicle resulting in a severe electrical fire.

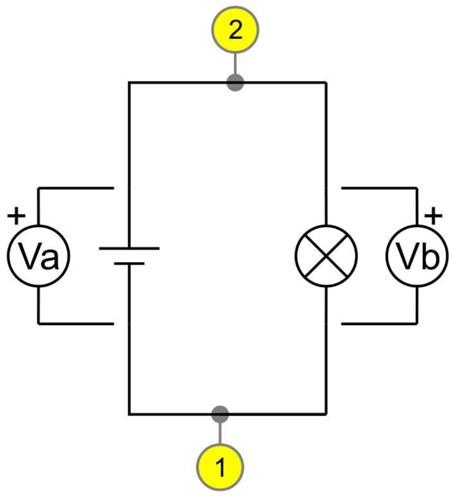
The photograph shows a burnt out car where an electrical fault in the engine compartment resulted in disaster for the owner.

Working circuit



Over to you:

- Build the circuit shown opposite using the 12V LED bulb.
- Set the power supply to 12V and switch on.
- Use it to complete Table 2 in the Student Handout.
- This table gives you the readings for the circuit in full working order.



Note that in the UK, the 0V connection on the battery is commonly referred to as the ‘Earth’ whereas in the USA the term ‘Ground ‘ is often used.

Worksheet 8

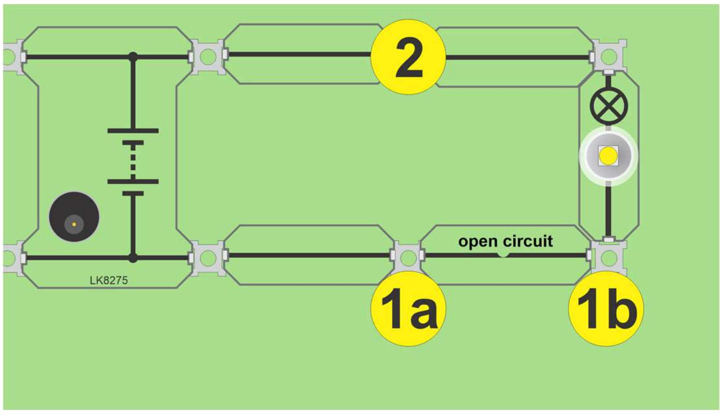
A good ground / earth

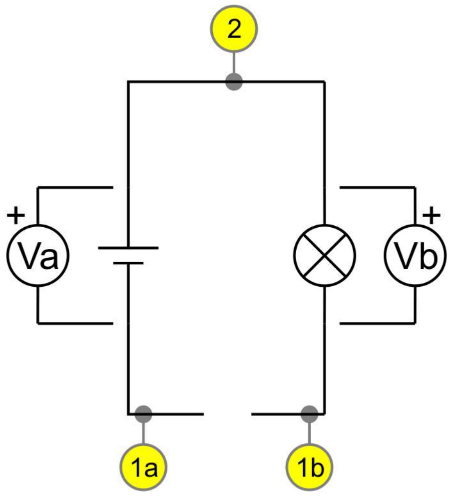
Automotive fault-finding

Over to you:

- Modify the circuit as shown in the diagram below by inserting an ‘open circuit fault’ link between the 0V of the power supply and the bulb.
- Take the same voltage measurements as before.
- Record them in Table 3 in the Student Handout.

Faulty circuit





So what?

- You know the circuit has stopped working because of the ‘open circuit fault’ link at node 1
- In practice this problem is trickier than it appears. Let’s see why……..

Worksheet 8

A good ground / earth

Automotive fault-finding

So what?

- Your results depend on where you put the COMmon terminal of the multimeter.
- You probably connected it to the negative side of the power supply, at node 1a, and got a set of readings that made sense. In a practical situation, however, you would not know exactly where the 0V line was interrupted and you might connect COMmon to the bottom connection of the bulb - at node 1b.
- You can see in the layout diagram that there are three terminals on the Locktronics board linking the negative side of the power supply to the bottom of the bulb, i.e. corresponding to node 1 in the circuit diagram.
- This gives us a rule for using a voltmeter when fault-finding:
    - first, check that your 0V connection to your multimeter is good.
- You can do this in one of two ways:
    - Check that the resistance between 0V in the circuit under test and the power supply 0V connection is zero. (Here, 0V has to mean the real terminal of the power supply.)
    - Make sure you can measure 12V somewhere in the circuit. Then you know you have a reasonable 0V connection.

Over to you:

- Repeat your measurements twice - once with multimeter COMmon on the bottom of the power supply (at node 1a) and once with the it on the bottom of the bulb (at node 1b).
- Make a note of the results in Table 4 in the Student Handout.

So what?

- 0V line or 'earth faults' are responsible for a significant number of electrical problems in motor vehicles.
- Before you start fault-finding, make sure your 0V or earth connection is connected directly back to the battery.

Worksheet 9

Open circuit faults

Automotive fault-finding

Cars are a tough environment for electrical systems:

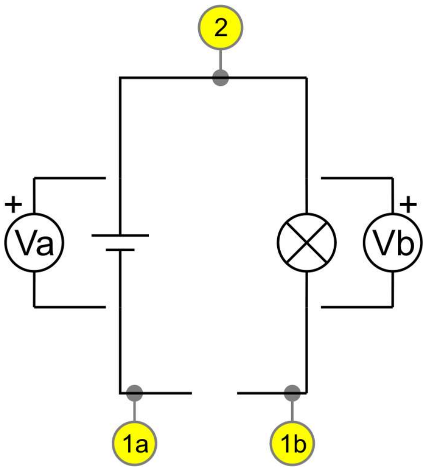
- lots of moving parts;
- large changes in temperature,
- dirt;
- and vibration!

Vehicles commonly travel hundreds of thousands of miles!

It's a wonder that they don't break down more often!

The photograph shows an open circuit in a car wiring loom.

We continue with the same circuit as in the worksheet 8.
We suppose that you know that there is a fault in the circuit, but you don't know where. You have checked the bulb and it is fine (more about this later).



Over to you:

- Connect the COMmon terminal of the multimeter to the power supply at node 1a.
- Make sure that somewhere in the circuit you get a reading of 12V. You now know that your earth connection is sound.
- Measure the voltage at node 2. If it is 12V, you know that the power supply is working and connected.
- Check that the voltage at the bulb is 12V.
- Measure the voltage at node 1b. Any reading more than 0V means that there is a problem with the earth circuit.
- Measure the voltage at node 1a. If this is 0V then you now know that there is a problem in the earth circuit between 1a and 1b.

So what?

- You can use a multimeter on the DC voltmeter function to 'chase' the fault in a circuit.
- To do this you need to understand how each component in the circuit works, how to test it and how it is connected in the circuit.
- If the meter shows a voltage drop across a part of a wire then there is a fault in that wire.

Over to you

- Change the bulb to an filament type. What is the voltage at 1b now?
  Why do you get a different reading? Write an explanation in the Student Handout.

Worksheet 10

Testing switches and bulbs

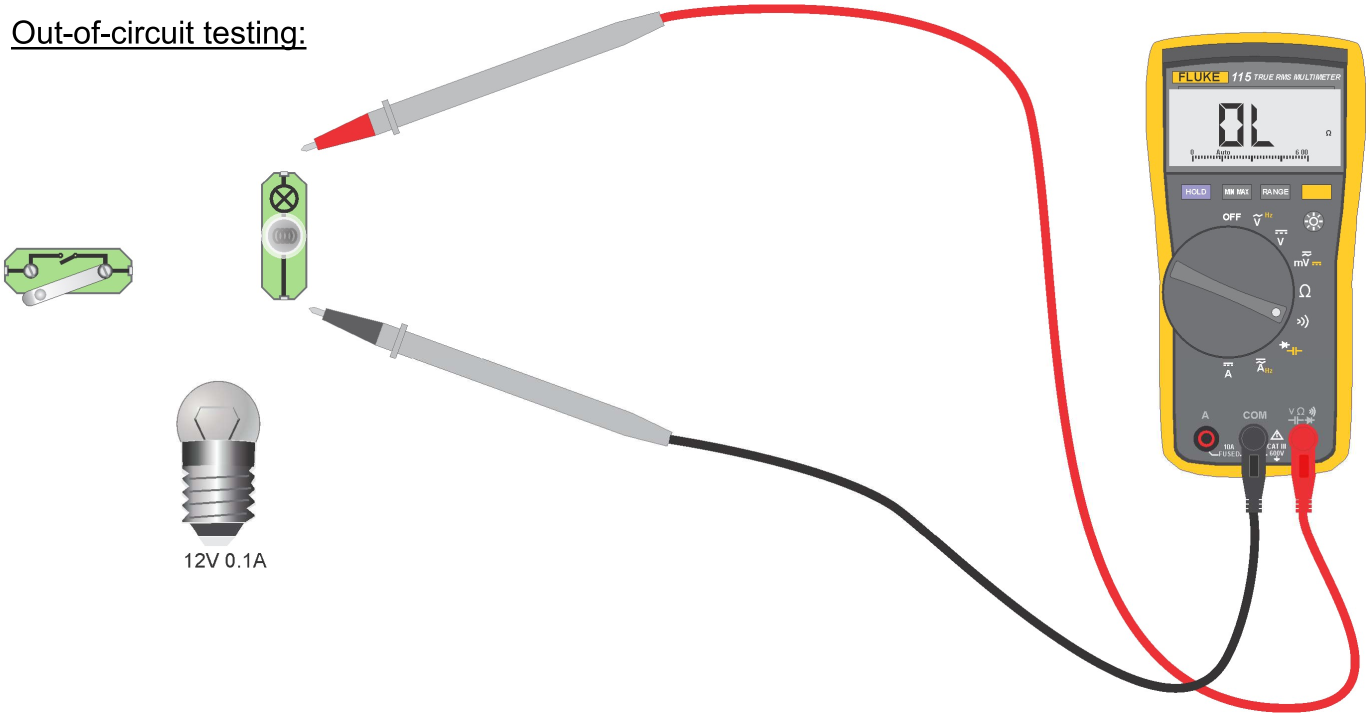
Automotive fault-finding

Sometimes you can **see** that components are broken, a missing filament in a bulb, for example. Sometimes, however, a visual check is not enough.

You need to know how to test each component in a circuit with the appropriate instrument. Here we look at testing bulbs and switches.

The photograph shows a halogen H7 light bulb.

Out-of-circuit testing:



Over to you:

- Put the multimeter onto the ‘continuity beep’ setting. Touch the probes together to test it.

Testing the switch:

- Touch the probes against the contacts at the ends of the switch.
- With the switch off (open), you should hear nothing as the switch is open circuit.
- With the switch on (closed), you should hear a continuous beep.
- If these checks are OK, the switch is working properly.

Testing the 12V filament bulb:

- Put the multimeter onto the ‘ohmmeter’ setting.
- Hold the probes against the bulb terminals and measure the resistance. A working filament should have a resistance of a few ohms.

Worksheet 10

Testing switches and bulbs

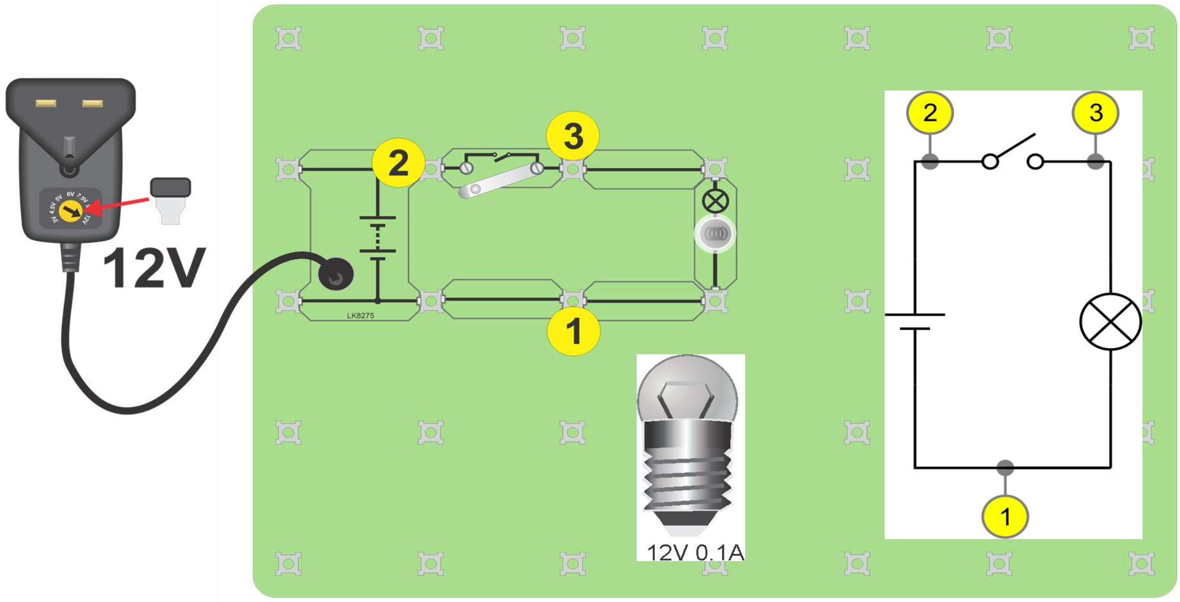
Automotive fault-finding

So what?

Out-of-circuit testing:

- A working switch has a very low resistance when closed (hence the 'beep') .
- A working filament bulb has a resistance of just a few ohms.

In-circuit testing:



Over to you:

- Build the circuit shown above.
- Change the multimeter to the 'DC voltage' setting. Connect COMmon to node 1 and check for a 12V reading somewhere in the circuit.
- For the switch open and then closed, predict the voltages you expect at nodes 2 and 3.
- Write your predictions in the first rows of Tables 5 and 6 in the Student Handout.
- Then use the multimeter to measure the voltages to check your ideas.
- Write your answers in the second rows of the tables.

So what?

In-circuit testing:

- If a bulb is working then it has 12V across it when it is lit and 0V across it when it is not .
- If the switch is working then it has 12V across it when it is off (open), and 0V across it when it is on (closed).
- You now know how to test switches and bulbs both in and out of circuit.

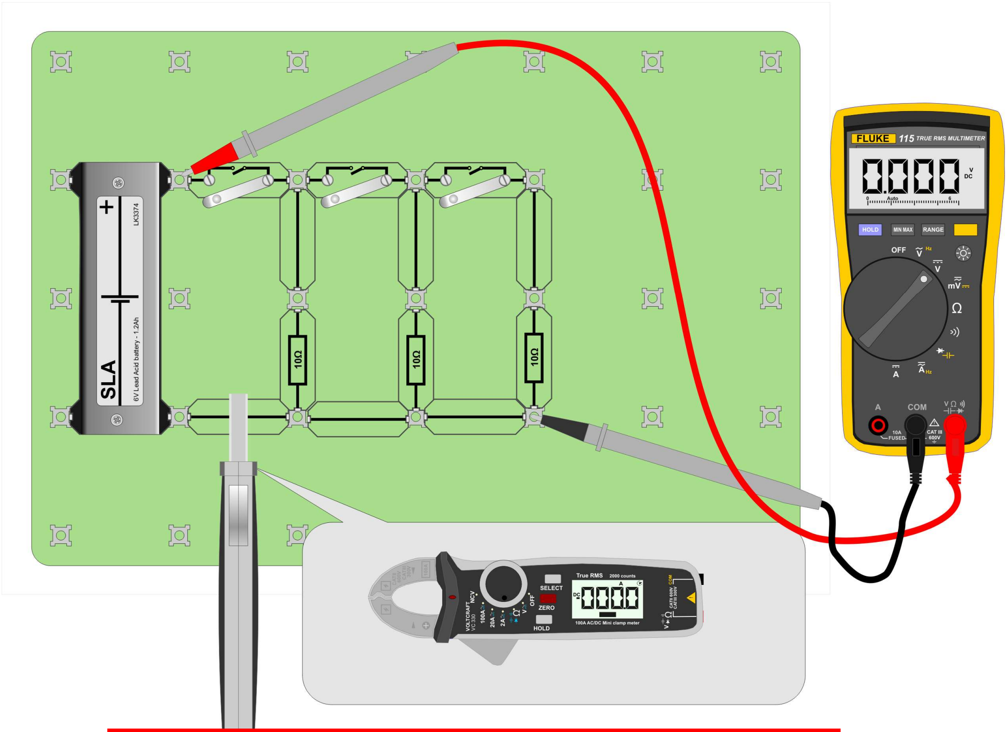
Worksheet 11

Testing batteries

Automotive fault-finding

There are number of simple ways of testing batteries but ultimately the only way to be sure a battery is working is to test its energy storage capacity. This involves charging it, then discharging it and making measurements of energy flowing in and out over a period of time.

The photograph shows a Voltcraft lead-acid battery load tester.



WARNING

Don't leave the circuit switched on for more than 10 minutes as it will damage the resistors.

Over to you:

- Build the circuit shown above, using the 6V sealed lead acid battery, three switches and three 10Ω resistors.
- Configure the multimeter to measure DC volts and the current clamp for DC amps.
- Measure the battery voltage and current as shown, with all switches open.
- Close the first switch and measure the voltage and current again.
- Repeat for the second and third switches.
- Note down all measurements in Table 7 in the Student Handout.

Worksheet 11

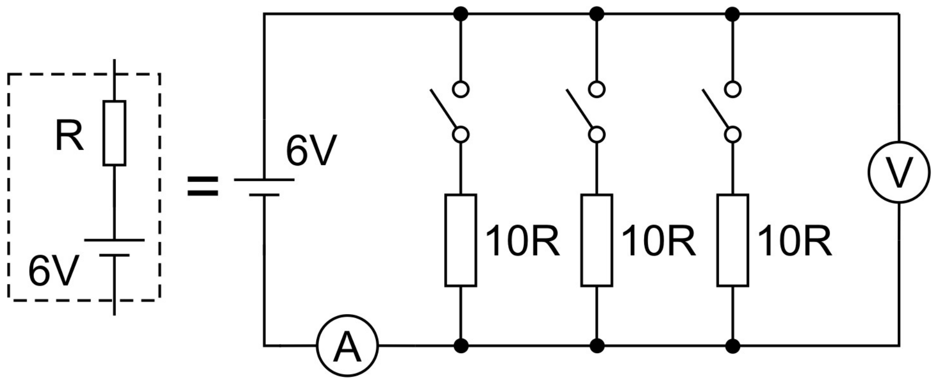
Testing batteries

Automotive fault-finding

So what?

- This battery tester, circuit diagram shown below, allows you to assess battery performance.
- Batteries are more complex than they may appear. It is as if they consist of a battery and an internal resistor.
- For many lead-acid cells, this internal resistance becomes higher when the battery starts to fail. Most lead-acid battery testers show you the effects of this internal resistance.
- As the internal resistance becomes higher, a greater voltage is dropped across it and as a result the battery output voltage falls. Eventually it falls to below an acceptable level when current is drawn.
- Eight 1.5V 'dry' cells can be connected, in series, to give an output of 12V. However, their relatively high internal resistance means that they cannot deliver the high currents needed in a vehicle's electrical system. A 12V lead-acid battery is far more expensive because of its tiny internal resistance and resulting capability to deliver high currents.
- Simply measuring the voltage with no load attached is not a good enough test for batteries.

The battery tester:



So is your battery working?

- This battery is rated at '6V 1.2Ah'. This means that, when fully-charged, it will deliver a current of 1.2A for 1 hour.
- As a rule of thumb for the 6V sealed lead acid battery, (when fully charged,) if you draw 1.2A for 5 minutes (i.e. two switches closed) the battery is probably satisfactory if the voltage stays above 5.5V .

Over to you:

- Make sure the battery is fully charged, (see Appendix 4).
- Use the 'rule of thumb, given above to show that the battery is working satisfactorily.

Worksheet 12

Short circuit faults

Automotive fault-finding

Short circuits can be very damaging in a vehicle.

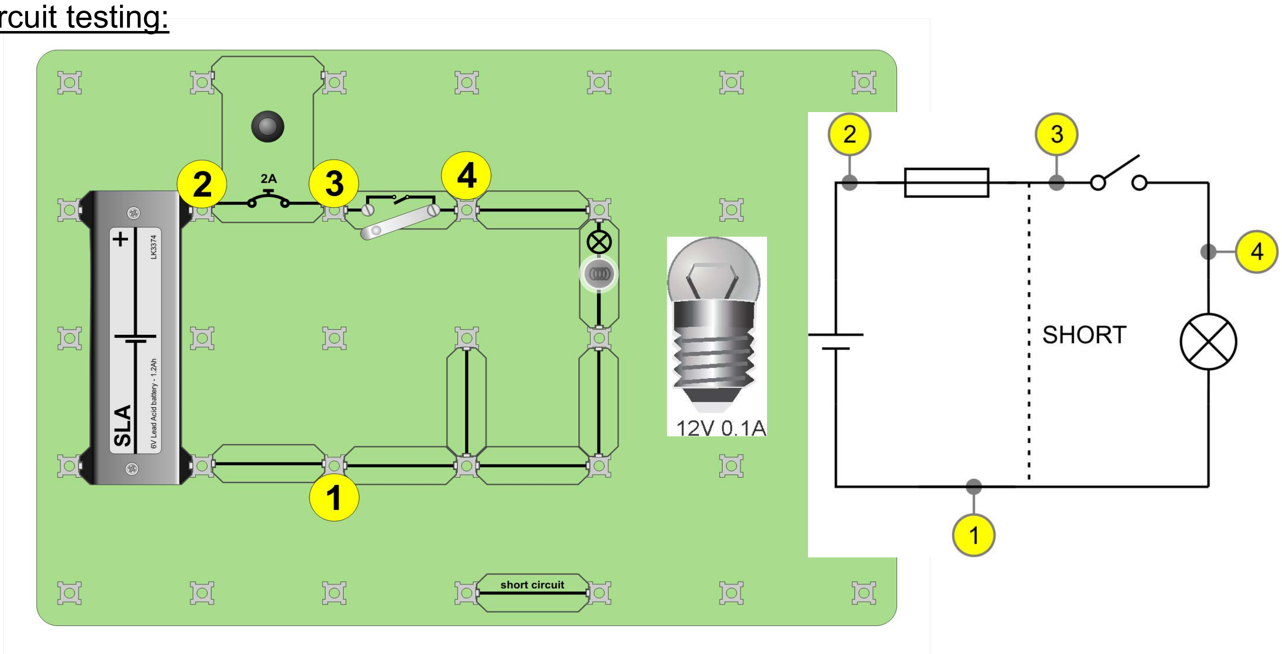
If too much current flows in a wire then the wire can burn out leading to a very expensive repair.

For this reason all circuits in a vehicle have a fuse to limit the current in a circuit.

The photograph shows a typical vehicle fuse box.

You probably know that vehicles use fuses to protect vehicle wiring and components. Once they 'blow', they need replacing - a problem for a module like this. We don't want to have to renew fuses repeatedly. Instead, the fuse has been replaced by a circuit breaker. This works in much the same way as a fuse, but can be reset by simply pressing the button.

In-circuit testing:



Over to you:

- Build the circuit shown in the diagram.
  The power source is a 6V Sealed Lead Acid battery
  The circuit breaker has such a low resistance when on that it does not affect the circuit performance.
- Turn on the switch and check that the bulb lights.
- Switch off and insert the 'short circuit' link between node 1 and node 4.
- Turn on the switch and verify that the circuit breaker trips and the bulb no longer lights.
- Switch off and press the reset on the circuit breaker.
- Turn on the switch and check that the bulb now lights again.

Worksheet 12

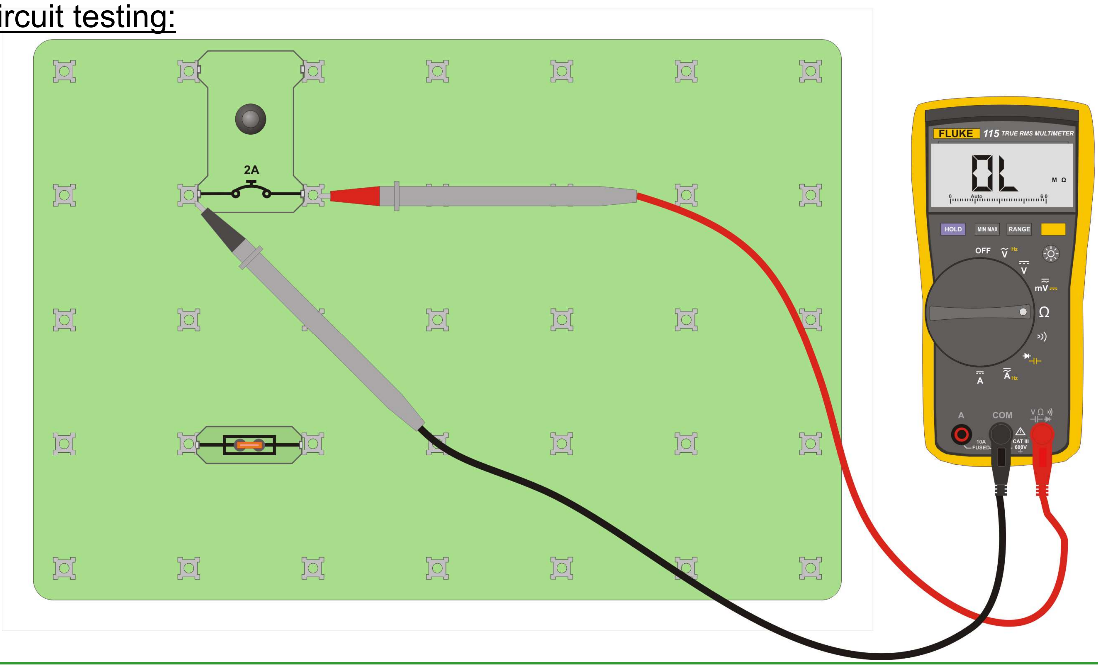
Short circuit faults

Automotive fault-finding

Over to you:

- Remove the short circuit link.
- With COMmon on the battery 0V terminal, measure the voltage at node 3:
    - with the circuit breaker tripped, i.e. circuit not working;
    - with the circuit breaker reset, i.e. circuit working.
- Record your measurements in Table 8 in the Student Handout.

Out-of-circuit testing:



Over to you:

- With the multimeter on the 'ohmmeter' setting, measure the resistance of the circuit breaker when it is tripped and when it is working.
- For comparison, measure the resistance of the real automotive fuse.
- Make a note of your readings in the Student Handout.

So what?

In-circuit testing of fuses and circuit breakers:

- If a fuse or circuit breaker is good, the full supply voltage appears at **both** terminals.
- Almost no voltage is dropped across a fuse in a working circuit.
- Once you suspect that a fuse is blown in a circuit, remove it and test it out-of-circuit.

Out-of-circuit testing of fuses and circuit breakers

- All fuses and circuit-breakers have a rating. The rating of this circuit breaker is 2A - when more than 2A flows through it, it 'trips'.
- The typical resistance of an automotive fuse is less than an ohm.

Worksheet 13

Corrosion

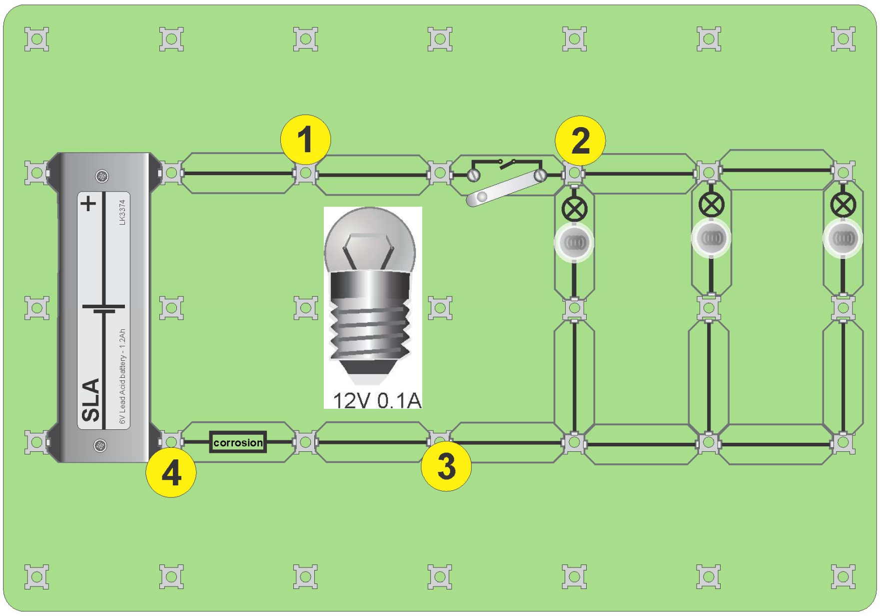
Automotive fault-finding

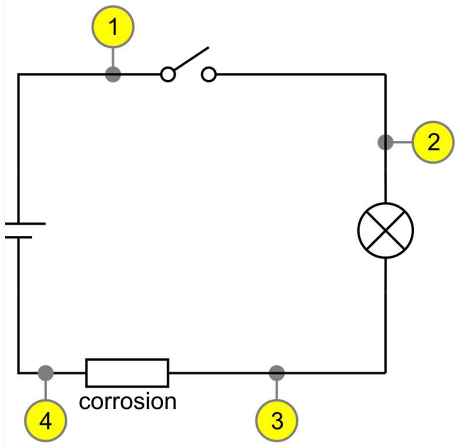
Chemicals from the vehicle battery can leak onto the battery terminals, causing corrosion.

Corrosion on the negative terminal is often a sign of undercharging the battery. Corrosion on the positive side is often a sign of over-charging.

The photograph shows a car battery with a badly corroded terminal.

Circuit 1





Over to you:

- Build the circuit shown above with the ‘corrosion’ link in the earth path of the battery.
- Set the multimeter onto the DC voltage range.
- With the COMmon lead connected to node 4, measure the voltage across the battery i.e. between nodes 1 and 4.
- Next, measure the voltage at node 2, first of all when the switch is closed and then when the switch is open.
- With the COMmon lead connected to node 3, take the same measurements - the voltage across the battery, the voltage at node 2, both when the switch is closed and then open.
- Complete Table 9 in the Student Handout with your measurements.

Worksheet 13

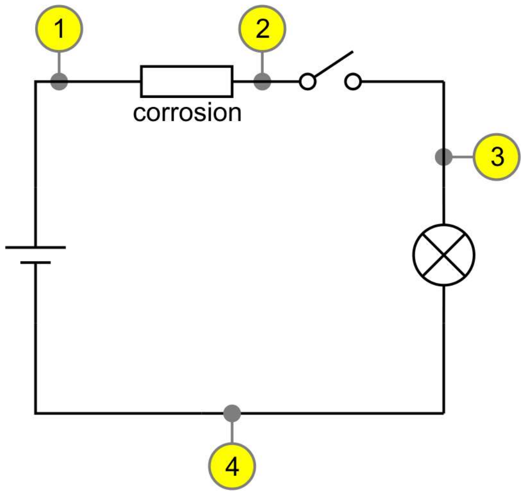
Corrosion

Automotive fault-finding

So what?

- Corrosion is equivalent to adding *a* resistor to the circuit.
- Be careful about what you assume is the 0V or earth line - as we saw in the worksheet on bad earths.
- Always make sure that you know the exact battery voltage. If you know that it is 12.7V, a measurement of under 12V in a circuit could be a sign of problems. ***1***

Circuit 2



Over to you:

- Build circuit 2, shown above, using the same components as before.
  This time, the corrosion is in the 6V line.
- Describe how you would use a multimeter to confirm that there is corrosion on the battery?
- When the bulb is lit, what is the voltage across the switch?
- Give your explanation in the Student Handout.

Worksheet 14

Fault-finding project 1

Automotive fault-finding

In the photograph, a technician is using a multimeter to test a battery.

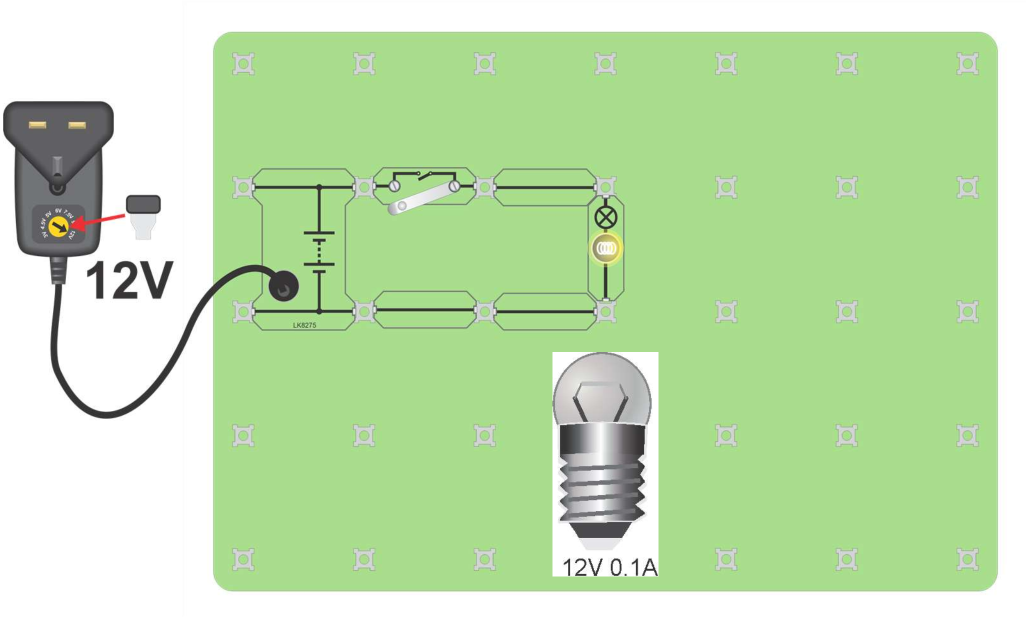
Being good at fault-finding is about being systematic:

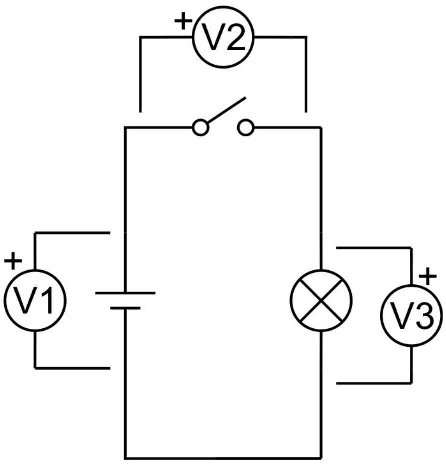
- understand the fault;
- gather information;
- formulate a theory and test it;
- repair and retest the circuit.

Developing a system of investigation is key.

Here you explore the use of fault grids on a simple

Fully-working circuit





Worksheet 14

Fault-finding project 1

Automotive fault-finding

Over to you:

- Build the circuit shown above, consisting of a battery, a switch and a bulb and switch it on.
- Switch the multimeter to the DC voltage function.
- Measure voltages V1, V2 and V3, (the voltages across each component).
- Record these measurements in the first row of the fault grid, Table 10, in the Student Handout.
- Remove the switch. This has the same effect as using a high resistance switch. Take the measurements again and record them in the second row of the fault grid.
- Next, replace the switch and instead remove the bulb. This has the same effects as a 'blown' bulb. Take the measurements again and record them in the third row of the fault grid.
- Replace the bulb and instead remove an earth link. This is an earth open circuit fault. Take the measurements again.
- Replace the earth link and instead remove the link between the switch and the bulb, creating an open circuit fault. Take the measurements again.
- Complete the last two rows of Table 10 with these measurements.

So what?

- Gathering evidence in a systematic way helps you to diagnose faults quicker.
- Several faults may produce the same test results, so that once a fault is found you may need to test several components.

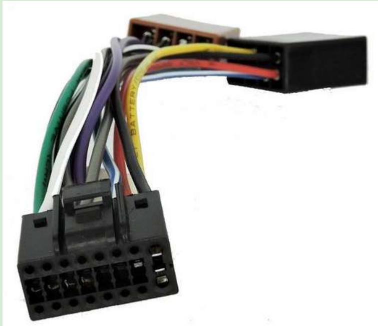
Worksheet 15

Fault-finding project 2

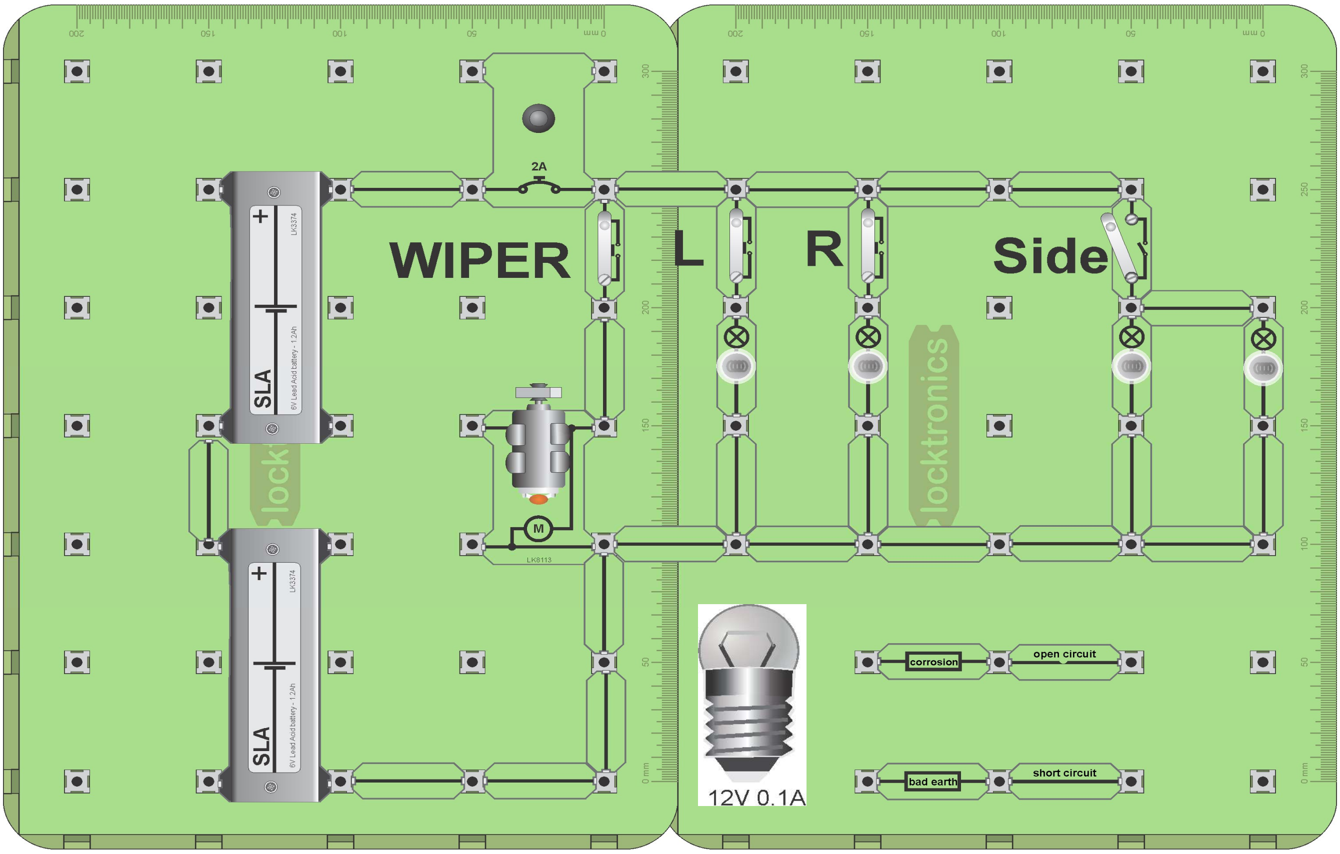
Automotive fault-finding

Faults in vehicles stem from the wires and connectors between components as often as from the components themselves.

The photograph shows a short wiring harness and connectors taken from a car.



Fully-working circuit



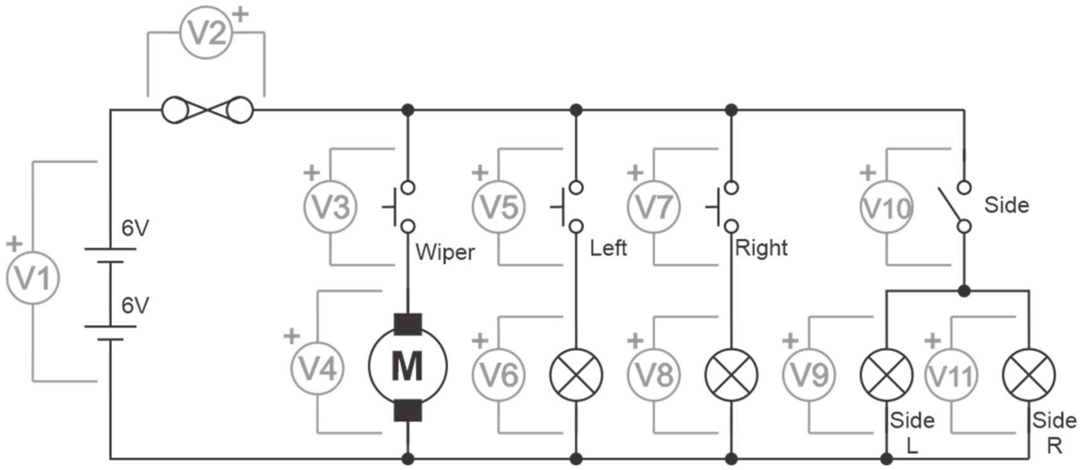
Over to you:

- Build the circuit shown above. The components represent the windscreen wiper motor and switch, the left and right indicators and switches and the side lights.
  Please note - the indicators do not flash!
- Make sure you understand the operation of the circuit.
- For this circuit, fill in the first row of the fault grid, Table 11, in the Student Handout.
- Carry out the changes necessary to the circuit and measurements to complete Table 11 for all the faults listed. At this stage, ignore the wiper motor and its switch.

Worksheet 15

Fault-finding project 2

Automotive fault-finding



So what?

- Understanding the circuit and what the voltages you should expect for all actions at all points in the circuit is the key to fault-finding.
- As a novice you will find that it help to sketch circuits and write significant voltages down. Some faults do not affect the voltage readings because of the way the circuit works. You will soon start to understand which measurements are significant.

Over to you:

- Here are four problems car problems, as described by customers.
- They are caused by one of these types of fault:
    - bad earth;
    - corrosion;
    - short circuit;
    - open circuit.
- For each problem:
    - use the customer's description of the fault to predict a possible cause;
    - modify the circuit by inserting an appropriate fault component to test your theory ;
    - describe the modification by sketching your test circuit;
    - predict voltages at significant points in that circuit;
    - use a multimeter to measure the voltage at those significant points ;
    - record your findings in the appropriate table;
    - use your measurements to confirm the cause of the problem;
    - give your verdict.

Worksheet 15

Fault-finding project 2

Automotive fault-finding

Problem 1:

A customer complains that the fuse 'blows' every time the side lights are turned on.

- What could be causing the fault?
  Predict what the effect this would have on voltages V1 to V9 and record your ideas in Table 12 in the Student Handout.
- Modify the circuit to add this fault.
  In the second line of Table 12, record the actual voltage measurements.
  Do they confirm your theory about the problem? Give your verdict in the Student Handout.
- Redraw the appropriate part of the circuit diagram including the suspected fault.

Problem 2:

- A customer complains that the left indicator is working but the right indicator is not.
- What could be causing this fault?
  Predict what the effect this would have on the voltages. Record your ideas in Table 13.
- Modify the circuit to add this fault and record the actual measurements in Table 13.
  Do they confirm your theory about the problem? Write your verdict in the Student Handout.
- Redraw the appropriate part of the circuit diagram including the suspected fault.

Problem 3:

- A customer complains that the indicators are working but the side lights are not.
- List **three** possible causes for this fault and for **each**:
  - deduce its effect on voltages V1 to V9 and record your predictions in Table 14;
  - build the faults into your circuit board;
  - measure the actual values of these voltages and record them in the table.
- Which cause seems to be behind the fault? Write your verdict in the Student Handout.
- Redraw the appropriate part of the circuit diagram including the suspected fault.

Problem 4:

- A customer complains that when both the wiper motor and side lights are turned on, the side lights are dim.
- List **two** possible causes for this fault and for **each**:
  - deduce its effect on voltages V1 to V9 and record your predictions in Table 15;
  - build the faults into your circuit board;
  - measure the actual values of these voltages and record them in the table.
- Which cause seems to be behind the fault? Write your verdict in the Student Handout.
- Redraw the appropriate part of the circuit diagram including the suspected fault.

Worksheet 16

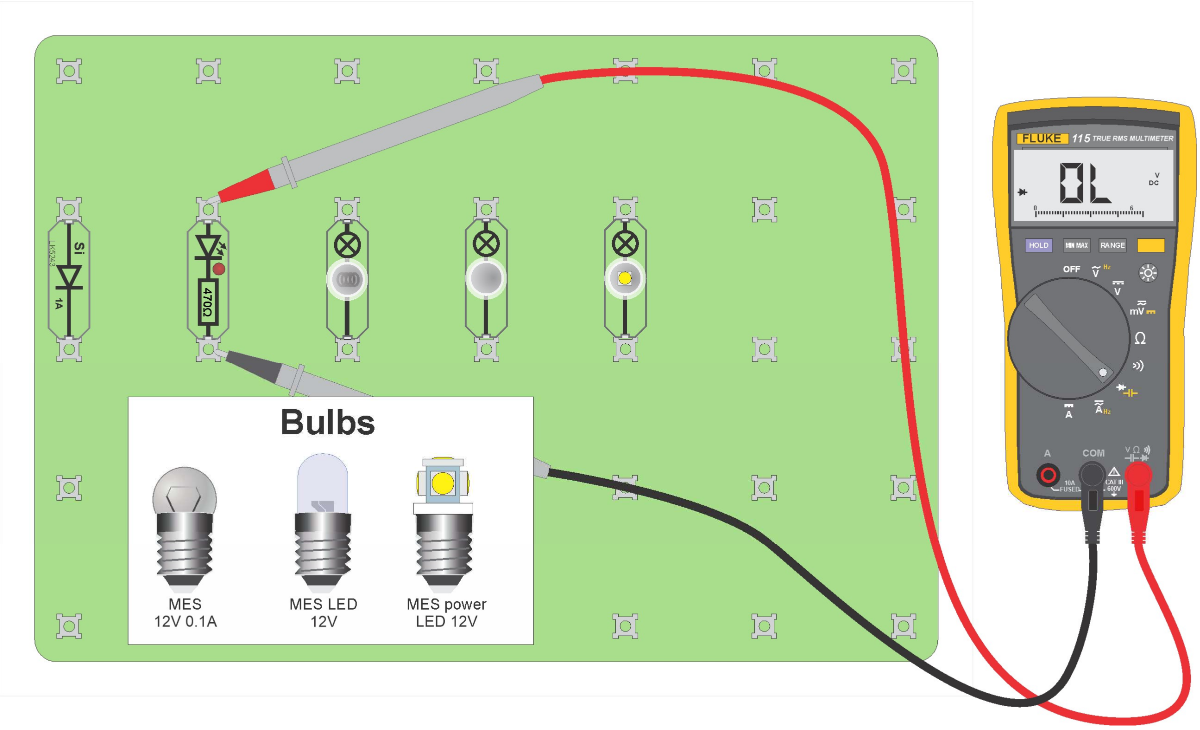
Testing diodes and LED bulbs

Automotive fault-finding

LED bulbs are a fast-changing technology in the automotive industry, with many physical and electrical variants.

This creates problems in testing, as different tests are needed for different types. Learning the principles will help you to understand why.

The photograph shows one kind of automotive cluster LED bulb.



Over to you:

- Assemble the following components on your base board:
    - a standard power diode;
    - a simple red LED with 470 ohm series resistor;
    - a small 12V MES bulb;
    - a 12V LED bulb;
    - a 12V LED power cluster bulb.
- Place the multimeter into 'diode test' mode.
- Test each component, with the positive lead on the anode, (positive side) of the device, as shown.
- Fill in Table 16 in the Student Handout with the results.

Worksheet 16

Testing diodes and LED bulbs

Automotive fault-finding

So what?

- In the ‘diode test’ mode, the multimeter puts out a low DC current and displays the resulting voltage dropped across the diode.
- For a conventional diode, with the positive multimeter lead on the anode and the negative on the cathode, this voltage is between 0.5V and 0.8V, depending on the diode type. A drop of 0.7V is typical.
- For a standard small-signal LED this forward-biased voltage drop is between 1.8 and 3.3V.
- For the two automotive LEDs, this test does not work. In these, the circuit is more complex, with other components present to limit and/or share current and voltage. These bulbs have to be tested with a 12V source

Worksheet 17

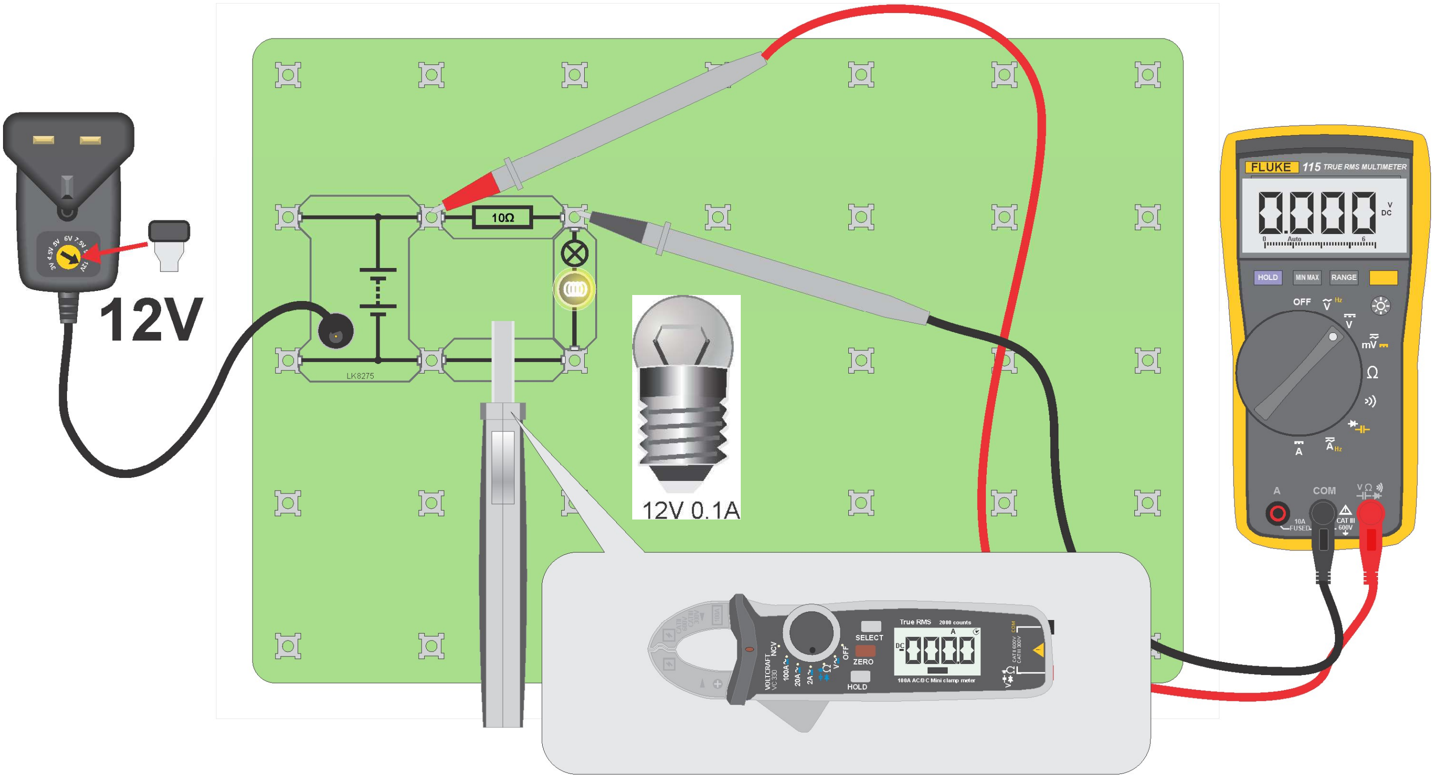
Testing resistors and potentiometers

Automotive fault-finding

Most of the standard electronic components like resistors, capacitors and transistors are buried inside ECUs in a car but it is still useful to know how they work and how to test them for fault-finding, in older vehicles, for example.

The photo shows a heater blower-motor resistor including its heatsink.

Testing resistors in-circuit with the power on:



Over to you:

- Build the circuit shown, with a 12V power supply, 10Ω resistor and a bulb.
- Set the power supply to 12V and switch on.
- With the multimeter in 'DC voltage' mode, measure the voltage across the resistor.
- Use the current clamp meter to measure the current in the circuit.
- Use the formula R=V/I. (where R is the resistance, V, the voltage drop across it and I the current through it) to calculate and verify the resistance of the resistor.
- Record your results in Table 17 in the Student Handout.

Worksheet 17

Testing resistors and potentiometers

Automotive fault-finding

So what?

In-circuit tests on resistors:

- Sometimes it is enough to verify quickly that there is a voltage drop across the resistor, so that we know that it is not short-circuited.
- In a circuit that you know, where the voltage drop is lower than 12V, you can often make a judgement that the resistor is working correctly.
- At other times, we want to know not only that the resistor is in place but also that its value has not changed. (When resistors get too hot, their resistance can become higher than the rated value). A quick calculation, like that above, is sufficient for this.

Over to you:

- Put the multimeter onto the ohmmeter setting.
- Try to measure the resistance of the resistor directly in-circuit. What do you get?
- Turn the power supply off. Try measuring resistance of the resistor again. What do you get?

So what?

- You can't measure the resistance of any device in-circuit when a circuit is powered. The circuit voltage interferes with the multimeter's measuring circuitry.

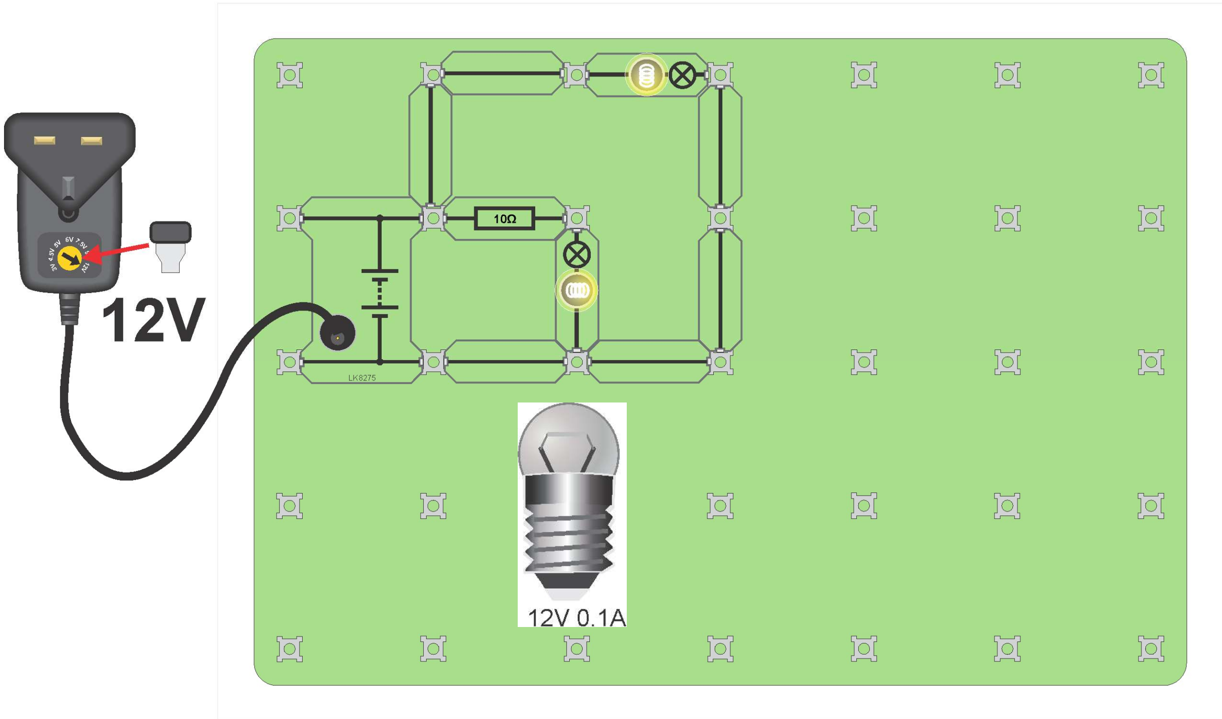
Out-of-circuit testing of resistors:

- You saw how to measure the resistance of a resistor in worksheet 3, using the multimeter's ohmmeter function.

Worksheet 17

Testing resistors and potentiometers

Automotive fault-finding



Over to you:

- Build the circuit shown above.
- Set the power supply to 12V and switch it on.
- Both bulbs should light.
- Turn the power off and put the multimeter onto the ohmmeter setting.
- Measure the resistance of the resistor by simply putting the multimeter onto the two metal pillars on the Locktronics board. What value do you get?
- Why is this not the correct value of the resistor?

So what?

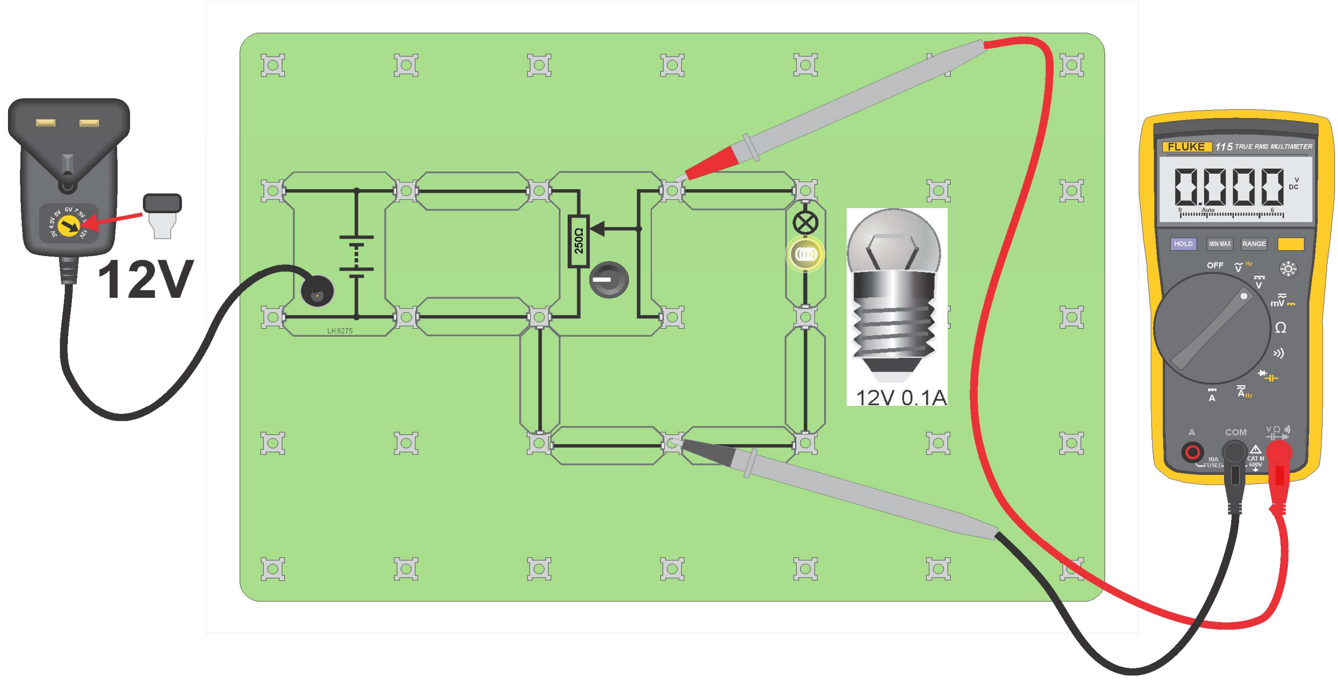
- If you are making resistance measurements on any device whilst it is in circuit, you need to be very sure that you understand the whole circuit .

Worksheet 17

Testing resistors and potentiometers

Automotive fault-finding

Testing a potentiometer in-circuit:



Over to you:

- Build the circuit shown above.
- Set the power supply to 12V and switch it on.
- Put the multimeter onto the ‘DC voltage’ setting.
- Check that the voltage at the wiper of the potentiometer varies between 0 to around 12V.

So what?

In-circuit tests on potentiometers:

- To test a potentiometer in-circuit, adjust the potentiometer and use a voltmeter to check that the output voltage varies.

Worksheet 17

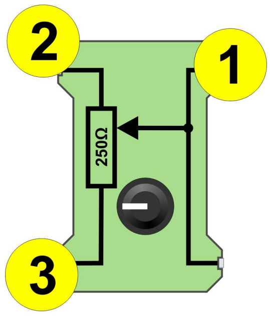
Testing resistors and potentiometers

Automotive fault-finding

Over to you:

Testing a potentiometer out-of-circuit:

- Take the potentiometer out of the circuit.
- Put the multimeter onto the ohmmeter function.
- Turn the potentiometer to its maximum anti-clockwise position.
- Measure the resistance between the wiper (1) and each of the other two terminals (2 and 3).
- Now turn the potentiometer clockwise half-way round.
- Take the resistance readings again.
- Finally, turn the potentiometer fully-clockwise.
- Take the resistance readings again.
- Measure the resistance between the two end terminals of the potentiometer (2 and 3).
- Record all your readings in Table 18 in the Student Handout.



So what?

Out-of-circuit tests on potentiometers:

- To test a potentiometer out-of-circuit, use an ohmmeter to monitor how the resistance changes.
- Many automotive potentiometers only have two terminals, a slider and an end terminal. Potentiometers in car radios and other electronic devices have three terminals like the one in this exercise.

Worksheet 18

Testing thermistors

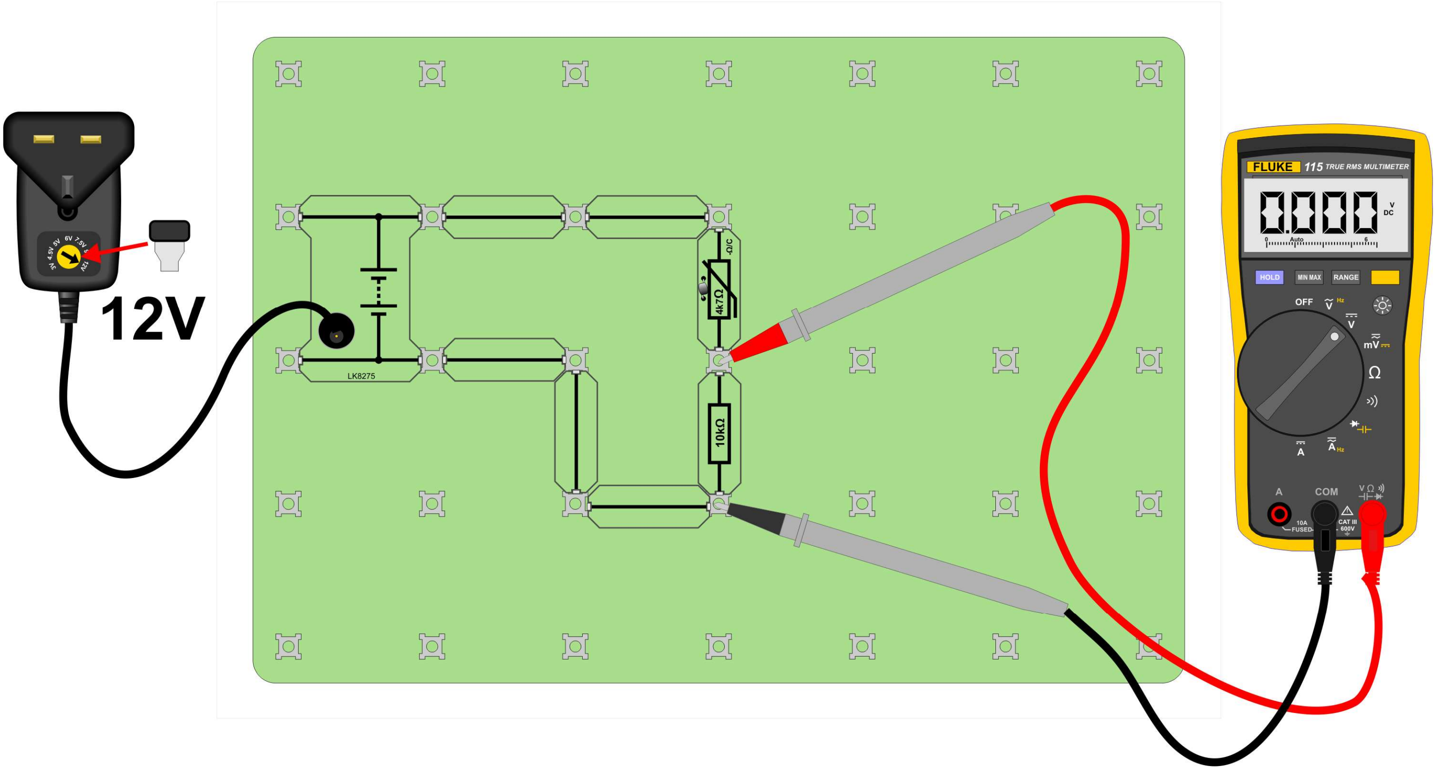
Automotive fault-finding

A thermistor is a resistor whose resistance varies with temperature.

Thermistors are used with a second resistor to make a voltage divider. An additional circuit is used to form a switch when the voltage reaches a certain point.

The photograph shows a typical vehicle thermistor in a metal housing.

Thermistor: In-circuit testing:



Over to you:

- Build the circuit shown above, using a thermistor and 10kΩ resistor.
- Set the power supply to 12V and switch it on.
- Put the multimeter onto the ‘DC voltage’ function.
- Measure the voltage at the junction of the resistor and thermistor, as shown in the diagram.
- Warm the thermistor with your fingers for 20 seconds.
- Measure the voltage again.
- Write your answers in Table 19 of the Student Handout.

Worksheet 18

Testing thermistors

Automotive fault-finding

So what?

In circuit tests of thermistors:

- Thermistors are always part of a voltage divider circuit. The voltage drop across the thermistor should be between 0V and 12V.
- When heated or cooled the thermistor resistance will change and the voltage out will rise or fall. To understand whether the voltage rises or falls with temperature you need to understand whether the thermistor has a negative temperature coefficient, (resistance falls as the temperature rises,) or a positive temperature coefficient,(resistance rises as the temperature rises) and you need to understand the rest of the circuit.

Over to you:

Out-of-circuit testing:

- Put the multimeter onto the ‘ohmmeter’ function.
- Take the thermistor out of circuit and measure its resistance.
- Warm the thermistor with your fingers and measure the resistance again.
  Record your results in Table 20 in the Student Handout.

So what?

Out-of-circuit testing of thermistors:

- Vary the temperature of the thermistor and its resistance should change.

Both in-circuit and out-of-circuit tests are simple ‘go / no go’ tests.

They prove that the thermistor is working. They do not prove that the thermistor is working to its specification. For that detailed measurements of resistance change versus temperature change would need to be made.

Worksheet 19

Testing relays

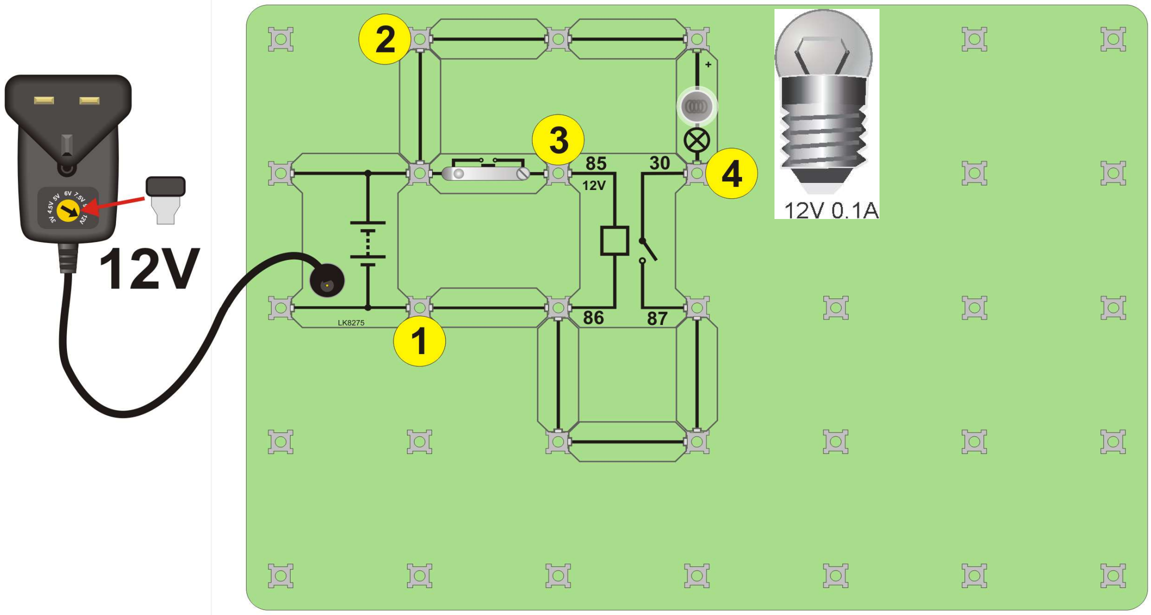
Automotive fault-finding

Relays allow small voltages and currents to switch much larger voltages and currents.

They also allow different circuits to be electrically isolated from one another - really important in modern electric vehicles where voltages above 200V are used in batteries and motors.

The photograph shows a typical vehicle fuse and relay box.

Testing a relay in-circuit:



Over to you:

- Build the circuit shown above.
- Set the power supply to 12V and switch it on.
- Select the 'DC voltage' function on the multimeter.
- Connect the COMmon terminal to node 1.
- Measure the voltages at nodes 2, 3 and 4:
  - with the switch open;
  - with the switch closed.
- Record your results in Table 21 in the Student Handout.
- Next, remove the bulb from the circuit.
- Using the multimeter on the 'ohmmeter' setting, measure the resistance between node 4 and node 1, when the relay is energised.
- Record your measurement in the Student Handout.

Worksheet 19

Testing relays

Automotive fault-finding

So what?

- A relay is made up of two separate sections:
    - a coil - which has DC electrical characteristics similar to a fuse or a resistor;
    - a switch - which has electrical characteristics just like a switch.
- The coil side of the circuit is often referred to as the **energising circuit**. The switch side of the circuit is often referred to as the **contact circuit**.

In-circuit tests on relays:

- When energised, the voltage drop across the coil should be 12V.
- When not energised, the voltage drop across the coil should be 0V.
- When energised, the voltage drop across the contacts should be 0V.
- When not energised, there should be a voltage drop across the contacts.
- When energised, the resistance between the contacts should be almost zero.

Over to you:

- Take the relay out of circuit.
- Using the multimeter on the ohmmeter setting:
    - measure the resistance across the coil;
    - measure the resistance across the contacts.
- In the Student Handout:
    - make a note of your readings;
    - comment on whether they are what you expect.

So what?

Out-of-circuit tests on relays:

- A working relay coil (pins 85 and 86) should have a measurable resistance of around a few hundred ohms.
- For a four-pin relay, the out-of-circuit contact resistance (between pins 87 and 30) should be zero, when energised, or infinite, when not energised.
- For a five-pin relay, there are three contacts: COM, Normally Open (NO) and Normally closed (NC). The out-of-circuit contact resistance between COM (pin 30) and NO (pin 87) should be zero, when energised, or infinite, when not energised. The resistance between contacts COM (pin 30) and NC (pin 87a) should be zero.

Worksheet 20

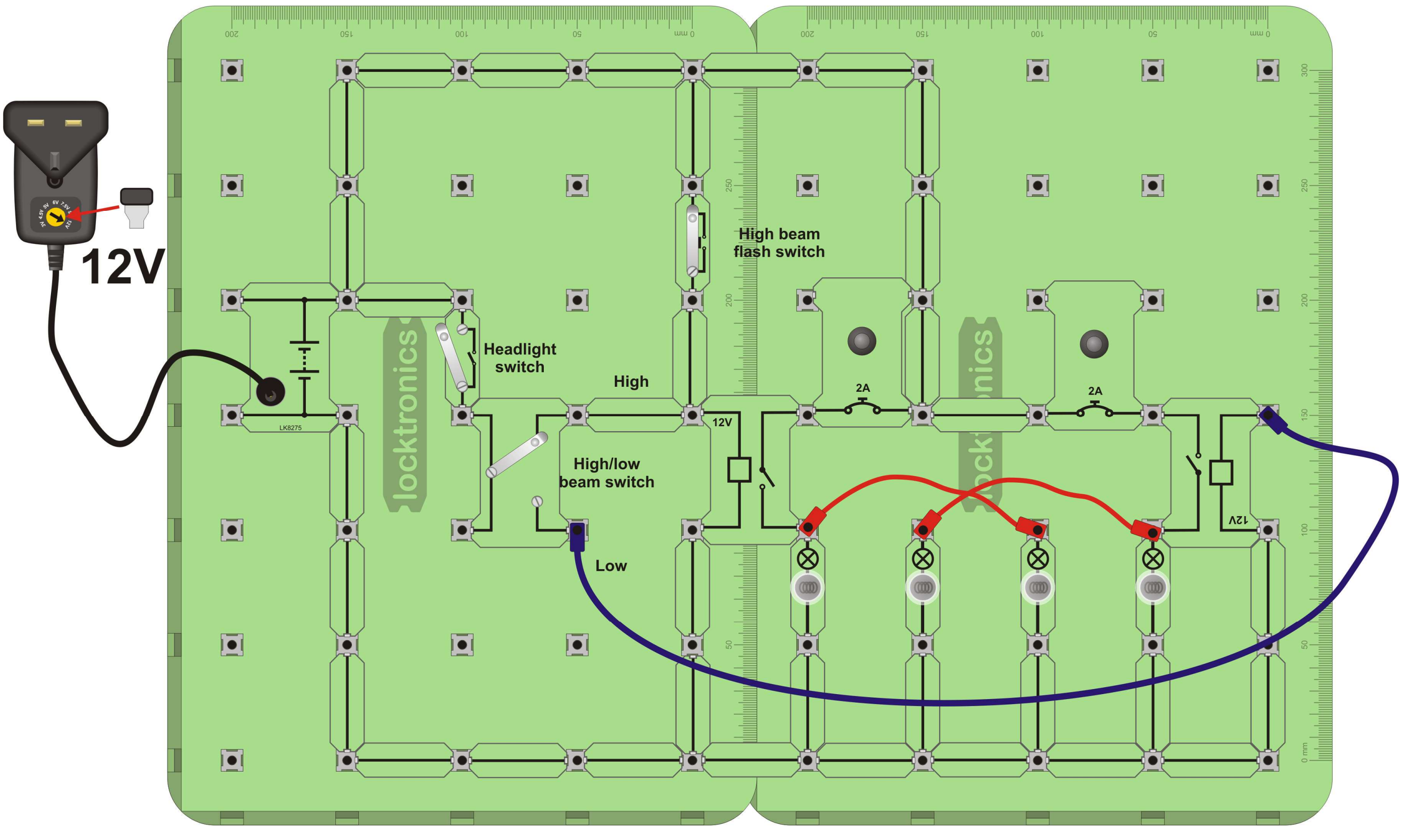
Fault-finding project 3

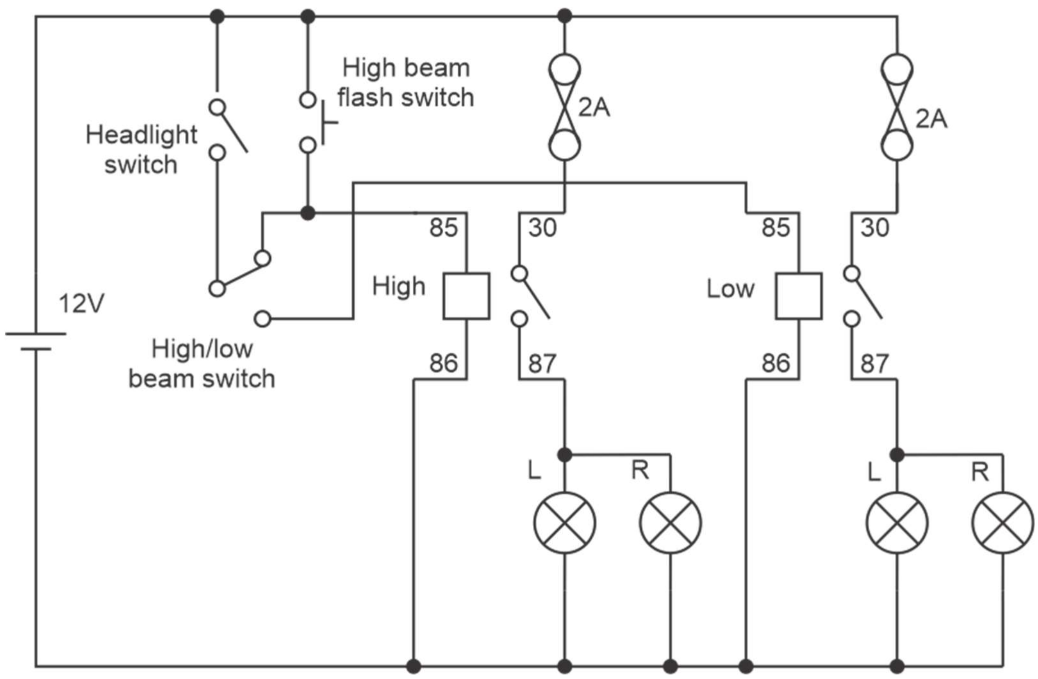
Automotive fault-finding

Over to you:

- Build the circuit shown below.
- Make sure you understand the operation of the circuit.

Fully-working circuit





Worksheet 20

Fault-finding project 3

Automotive fault-finding

Over to you:

Here are three problems relating to the car headlight circuit you just built :

Problem 1:

- A customer complains that neither high beam lights are not working, but the 'low' beam lights are. There are a number of possible causes. Identify three of them.

Problem 2:

- A customer complains that the right hand headlight (on both high and low beam) is slightly dimmer than the left. (This effect is very subtle on our layout - you need sensitive eyes!) Identify a possible cause?

Problem 3:

- A customer complains that headlights are not working at all.
- List three possible causes and test your theories.

There are four possible types of fault that could give rise to the problems outlined above:

- bad earth;
- corrosion;
- short circuit;
- open circuit.

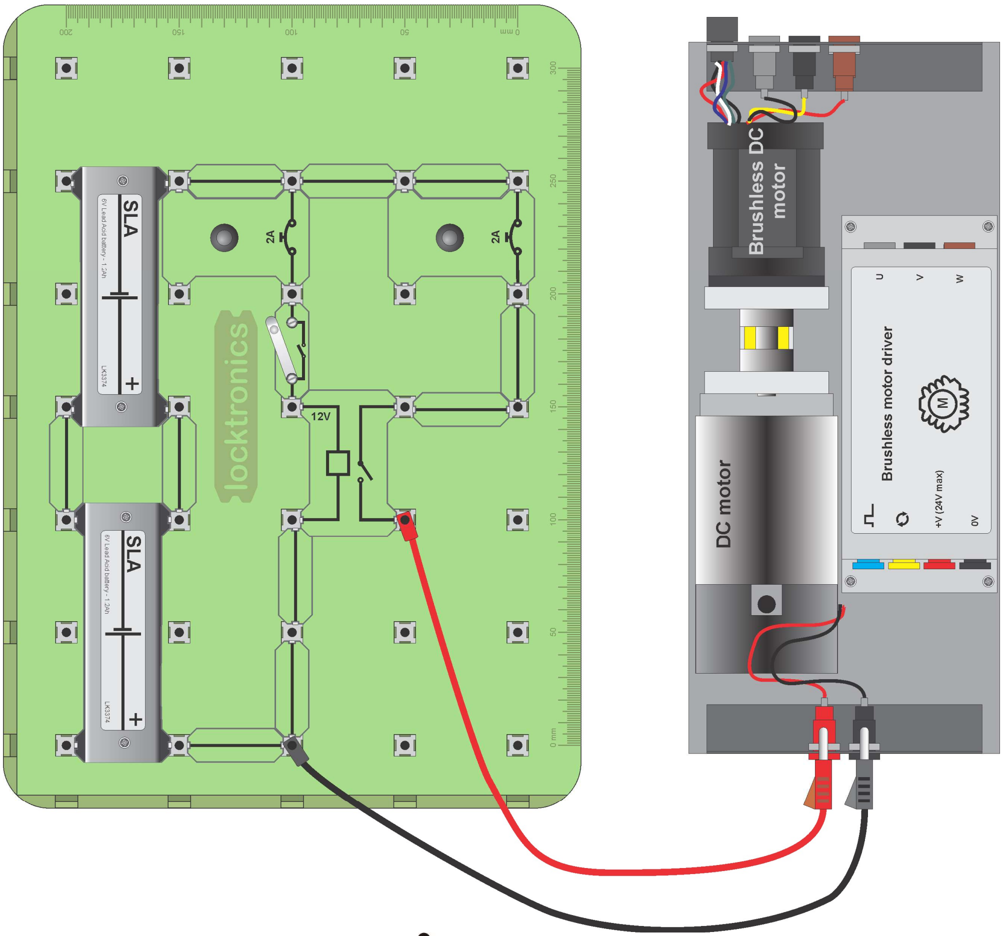
as well as broken components.

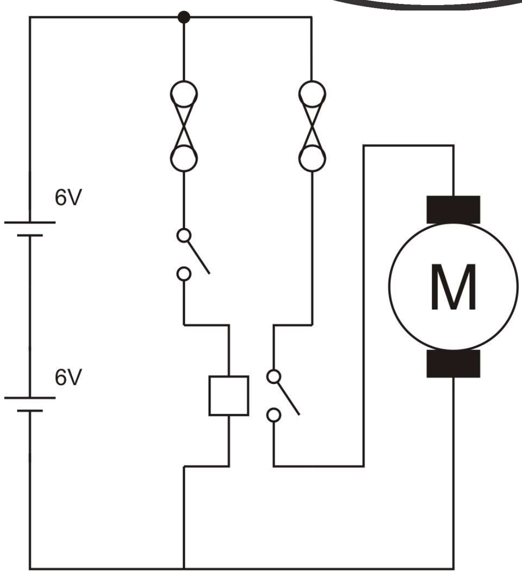
- For each of these three problems:
  - having identified possible cause(s), modify the circuit by inserting an appropriate fault component to test each theory;
  - describe the modification by sketching your test circuit;
  - predict voltages at significant points in that circuit;
  - use a multimeter to measure the voltage at those significant points ;
  - record your findings in a function grid;
  - use your measurements to confirm the likely cause of the problem;
  - give your verdict.

Worksheet 21

Fault-finding project 4

Automotive fault-finding





Over to you:

- Build the circuit shown above. It includes the HP2001 DC motor / brushless motor pair. This represents the car starter motor.
- Make sure you understand the operation of the circuit.

Worksheet 21

Fault-finding project 4

Automotive fault-finding

Over to you:

Here are two problems relating to this circuit:

Problem 1:

- A customer complains that when the battery is cold the starter motor turns slower than usual and sometimes the car does not start.
- You deduce that there are four possible causes:
    - corrosion on the battery terminals;
    - a bad earth on the starter motor;
    - a bad connection between the solenoid (here the relay) and the '+V' terminal on the starter motor;
    - a failing battery.

Problem 2:

- A customer complains that the starter motor is not functioning at all and she can not hear the click of the solenoid.
- You deduce that there are four likely culprits:
    - a faulty starter motor switch;
    - a tripped circuit breaker;
    - an open circuit between the battery positive terminal and the solenoid;
    - an open circuit between the negative terminal of the solenoid and the 0V line.

There are four possible types of fault that could give rise to the problems outlined below:

- bad earth;
- corrosion;
- short circuit;
- open circuit.;

(as well as broken components).

- For each type of fault:
    - modify the circuit by inserting an appropriate fault component to test your theory ;
    - describe the modification by sketching your test circuit;
    - predict voltages at significant points in that circuit;
    - use a multimeter to measure the voltage at those significant points ;
    - record your findings in a function grid;
    - use your measurements to confirm the cause of the problem;
    - give your verdict.

Student Handout

Automotive fault-finding

Worksheet 1 - Measuring voltage

Power supply carrier voltage: ______________

- with probes reversed ______________

- with the meter on AC ______________

6V Sealed Lead Acid battery voltage ______________

Voltage across the bulb ______________

Worksheet 2 - Measuring current

Multimeter:

current through the bulb ______________

current with probes reversed ______________

Current clamp:

current through the bulb ______________

current with current clamp reversed ______________

Worksheet 3 - Measuring resistance

Reading when probes are touched together: ______________

10Ω resistance reading ______________

50kΩ resistance reading ______________

Resistance between two left hand terminals ______________

Resistance between top terminal and wiper ______________

Resistance between bottom terminal and wiper ______________

What do you notice about these readings?

____

____

Reading for 50kΩ resistor measured in-circuit: ______________

Worksheet 4 - Testing diodes

Comment on the diode test results:

____

____

Automotive fault-finding

Worksheet 5 - Measuring capacitance

10µF capacitor reading ______________

Reading with probes reversed ______________

Worksheet 6 - Describing voltage

Circuit 1:

Va	Vb	Vc

Table 1

Circuit 2:

The battery voltage? ______________

The voltage across the 10Ω resistor? ______________

The voltage Vb? ______________

The voltage drop across both bulbs together? ______________

The voltage at node 3? ______________

The voltage at node 2? ______________

Worksheet 7 - The continuity beep

At what resistance does the beep turn on? ______________

At what resistance does the beep turn off? ______________

Worksheet 8 - Good ground / earth

Good circuit:

Va	Vb	Voltage at node 1	Voltage at node 2

Table 2

Faulty circuit:

Va	Vb	Voltage at node 1	Voltage at node 2

Table 3

Changing **COM**mon

COMmon	Va	Vb	Voltage at node 2
COMmon at 1a			
COMmon at 1b			

Table 4

Automotive fault-finding

Worksheet 9 - Open circuit faults

With **COM**mon at 1a:

voltage at node 2; ______________

voltage at node 1b. ______________

Why is the voltage different at 1b when a filament bulb replaces the LED bulb?

____

____

Worksheet 10 - Testing switches and bulbs

Circuit 1:

Voltage at node 2:

when the switch is open: ______________

when the switch is closed: ______________

Circuit 2:

Switch open:

	Node 2	*Node 3*
Predicted voltage		
Actual voltage		

Table 5

Switch closed:

	Node 2	*Node 3*
Predicted voltage		
Actual voltage		

Table 6

Worksheet 10 - Testing batteries

	No load	*1st switch closed*	*1st + 2nd switches closed*	*All three switch-es closed*
Battery voltage				
Battery current	**0**			

Table 7

Automotive fault-finding

Worksheet 11 - Short-circuit faults

	Voltage at node 3
Circuit breaker working	
Circuit breaker tripped	

Table 8

Circuit breaker:

resistance when tripped: ______________

resistance when working: ______________

Automotive fuse resistance ______________

Worksheet 13 - Corrosion

COMmon on	*Voltage between nodes 4 and 1*	*Voltage at node 2 switch open*	*Voltage at node 2 switch closed*
Node 4			
Node 3			

Table 9

Describe how you would use a multimeter to confirm that there is corrosion on the battery?

____

____

____

What is the voltage across the switch? ______________

Explain why is this not 0V?

____

Automotive fault-finding

Worksheet 14 - Fault-finding project 1

Fault grid

	V1	V2	V3
Circuit fully working			
Switch high resistance			
Bulb open circuit			
Earth open circuit			
Open circuit			

Table 10

Worksheet 15 - Fault-finding project 2

Fault grid - working circuit

	V1	V2	V3	V4	V5	V6	V7	V8	V9
All switches open									
Left indicator on									
Right indicator on									
Side lights on									
Side lights & left indicator on									
Side lights & right indicator on									

Table 11

Automotive fault-finding

Worksheet 15 (cont ...)

Fault 1

Suspected cause:

	V1	V2	V3	V4	V5	V6	V7	V8	V9
Predicted voltages									
Measured voltages									

Table 12

Sketch of the faulty circuit:

Verdict:

Fault 2

Suspected cause:

	V1	V2	V3	V4	V5	V6	V7	V8	V9
Predicted voltages									
Measured voltages									

Table 13

Sketch of the faulty circuit:

Verdict:

Automotive fault-finding

Worksheet 15 (cont ...)

Fault 3

Possible causes:

A. ____

B. ____

C. ____

Cause	*Voltage*	*V1*	*V2*	*V3*	*V4*	*V5*	*V6*	*V7*	*V8*	*V9*
A	**Predicted**									
	Measured									
B	**Predicted**									
	Measured									
C	**Predicted**									
	Measured									

Table 14

Sketch of the test circuit:

Verdict:

____

Automotive fault-finding

Worksheet 15 (cont ...)

Fault 4

Possible causes:

A. ____

B. ____

Cause	*Voltage*	*V1*	*V2*	*V3*	*V4*	*V5*	*V6*	*V7*	*V8*	*V9*
A	**Predicted**									
	Measured									
B	**Predicted**									
	Measured									

Table 15

Sketch of the test circuit:

Verdict:

____

Automotive fault-finding

Worksheet 16 - Testing diodes and LED bulbs.

Component	Diode	Red LED	6V filament bulb	12V MES LED bulb	12V MES LED cluster bulb
Voltage drop					

Table 16

Worksheet 17 - Testing resistors and potentiometers

Circuit 1:

Using Ohm's law to determine resistance:

Voltage V across it	Current I through it	Calculated resistance R using R = V / I

Table 17

In-circuit ohmmeter testing:

What happens:

when the power supply is turned on:

____

when the power supply is turned off:

____

Out-of-circuit ohmmeter testing:

Resistance measurement: ______________

Circuit 2:

Ohmmeter reading when the power is turned off: ______________

Why does this measurements give the wrong value of resistance?

____

____

Automotive fault-finding

Worksheet 17 (cont ...)

Circuit 3:

In circuit tests of potentiometers:

Maximum voltage reading: ______________

Minimum voltage reading: ______________

Out of circuit tests of potentiometers:

	Resistance between 1 and 2	*Resistance between 1 and 3*	*Resistance between 2 and 3*
Max clockwise			
Half way			
Max anticlockwise			

Table 18

Worksheet 18 - Testing thermistors

In-circuit testing:

	Voltage at junction
Cold	
Warm	

Table 19

Out-of-circuit testing:

	Thermistor resistance
Cold	
Warm	

Table 20

Worksheet 19 - Testing relays

In-circuit testing:

With **COM**mon on node 1, voltages at other nodes are:

	Node 2	*Node 3*	*Node 4*
Switch open			
Switch closed			

Table 21

Resistance of coil when the relay is energised. ______________

Out-of-circuit testing:

Coil resistance: ______________

Resistance across contacts: ______________

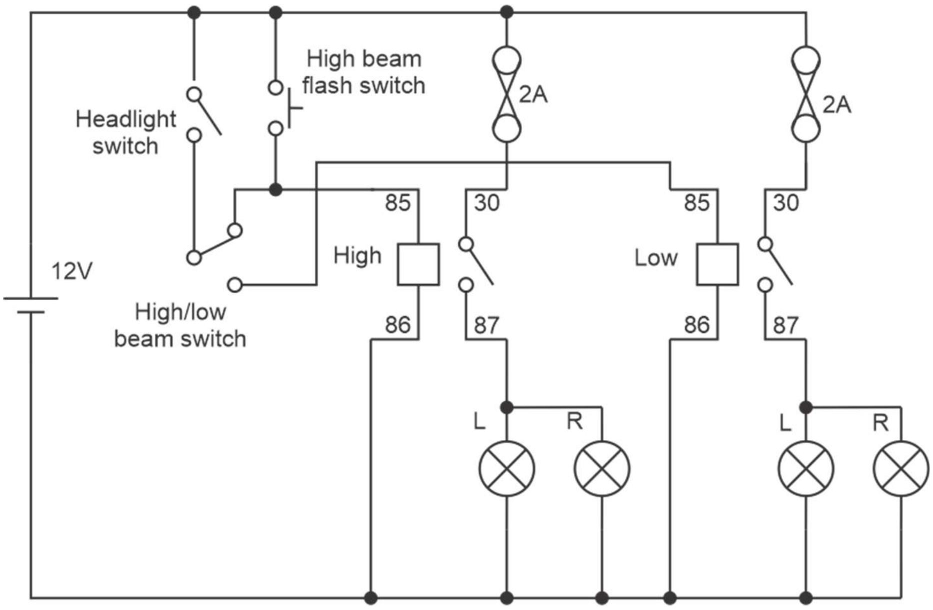
Comment on the significance of these readings.

____

____

Automotive fault-finding

Worksheet 20 - Fault-finding project 3



Problem 1:

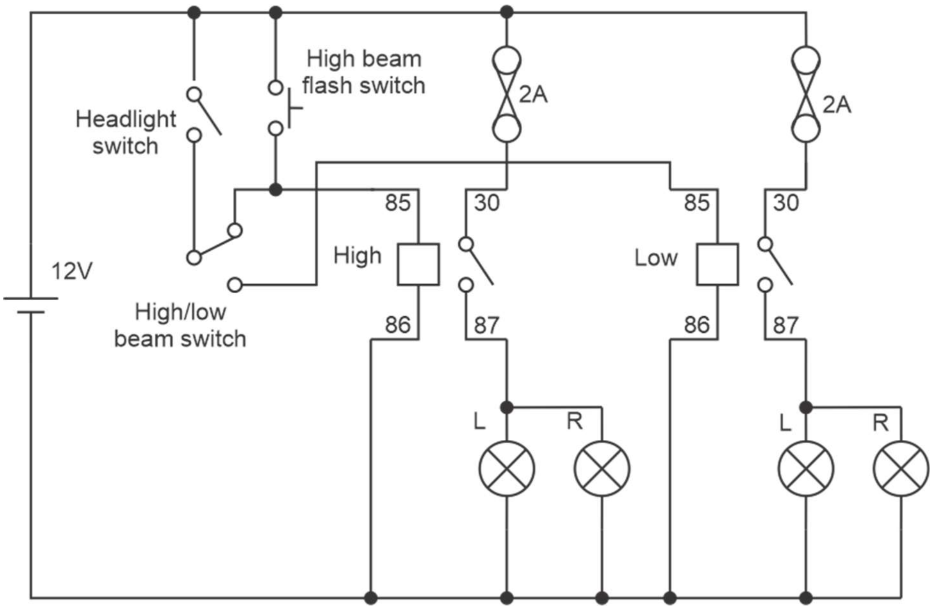
Test circuit with predicted voltages:

Fault grid with measurements:

Verdict:

Automotive fault-finding

Worksheet 20 (cont...)



Problem 2:

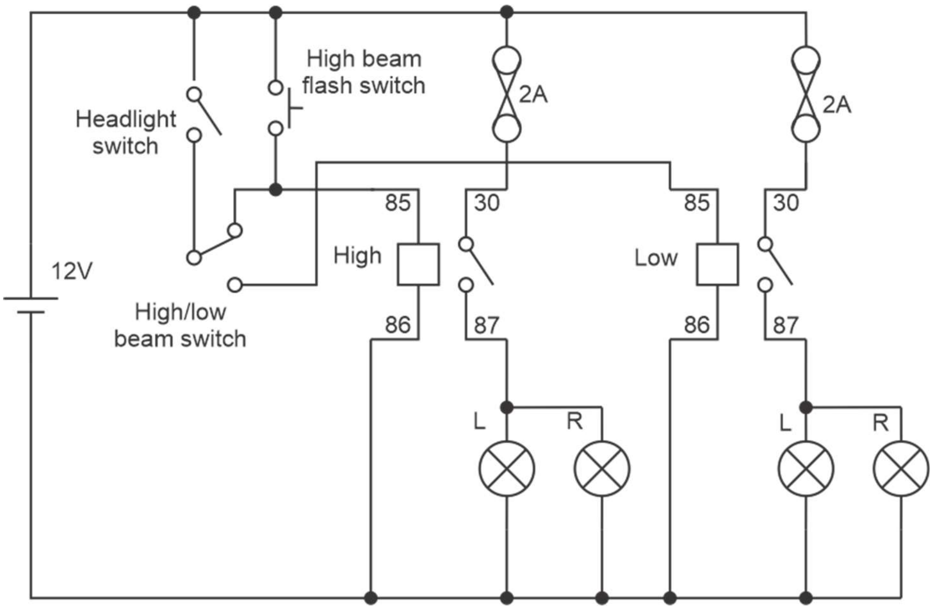
Test circuit with predicted voltages:

Fault grid with measurements:

Verdict:

Automotive fault-finding

Worksheet 20 (cont...)



Problem 3:

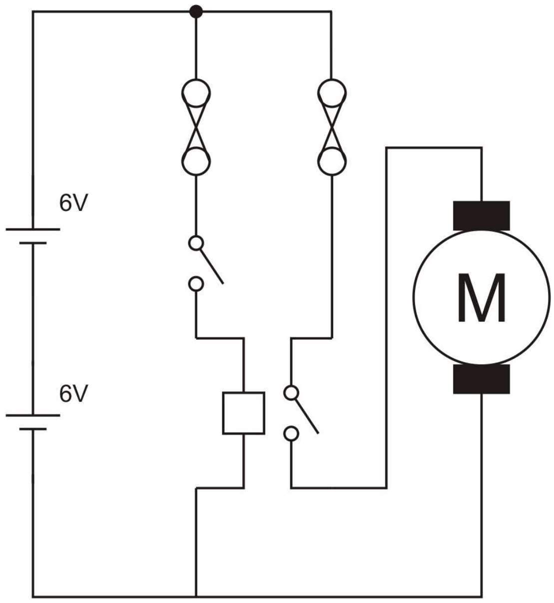
Test circuit with predicted voltages:

Fault grid with measurements:

Verdict:

Automotive fault-finding

Worksheet 21 - Fault-finding project 4



Problem 1:

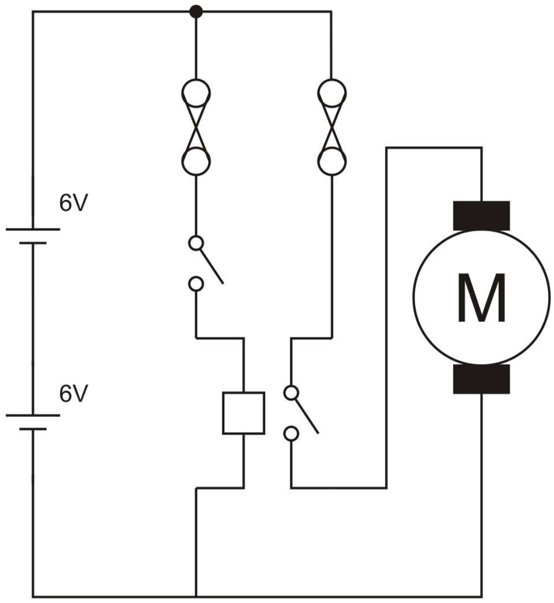
Test circuit with predicted voltages:

Fault grid with measurements:

Verdict:

Automotive fault-finding

Worksheet 21 (cont...)



Problem 2:

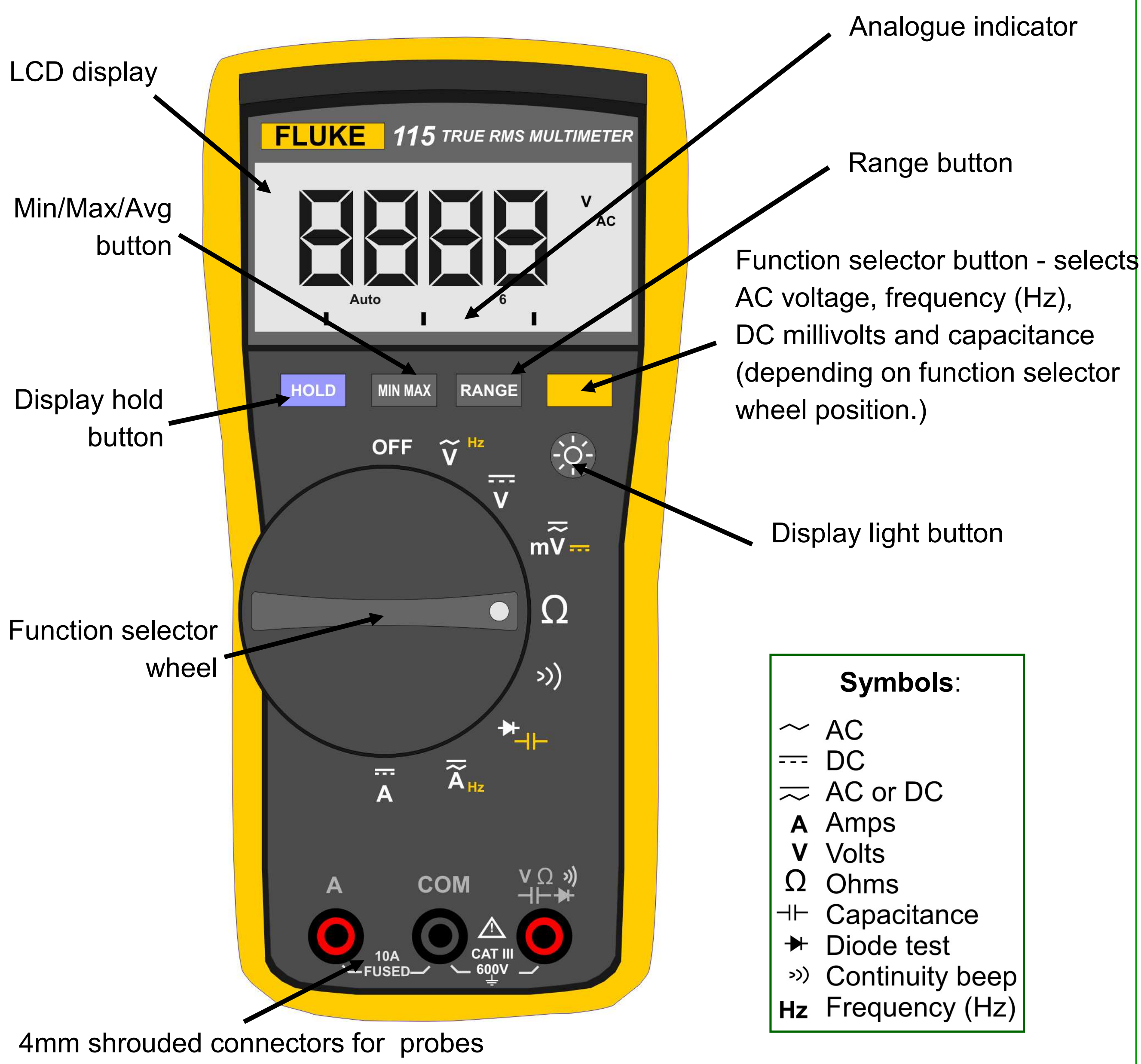
Test circuit with predicted voltages:

Fault grid with measurements:

Verdict:

Appendix 1

The multimeter



Symbols:

~	AC
⎓	DC
≂	AC or DC
A	Amps
V	Volts
Ω	Ohms
⊣⊢	Capacitance
▶|	Diode test
·)))	Continuity beep
Hz	Frequency (Hz)

The Fluke 115 general purpose multimeter is a high quality instrument capable of measuring voltage (AC or DC), frequency, current (AC or DC), resistance, and capacitance.

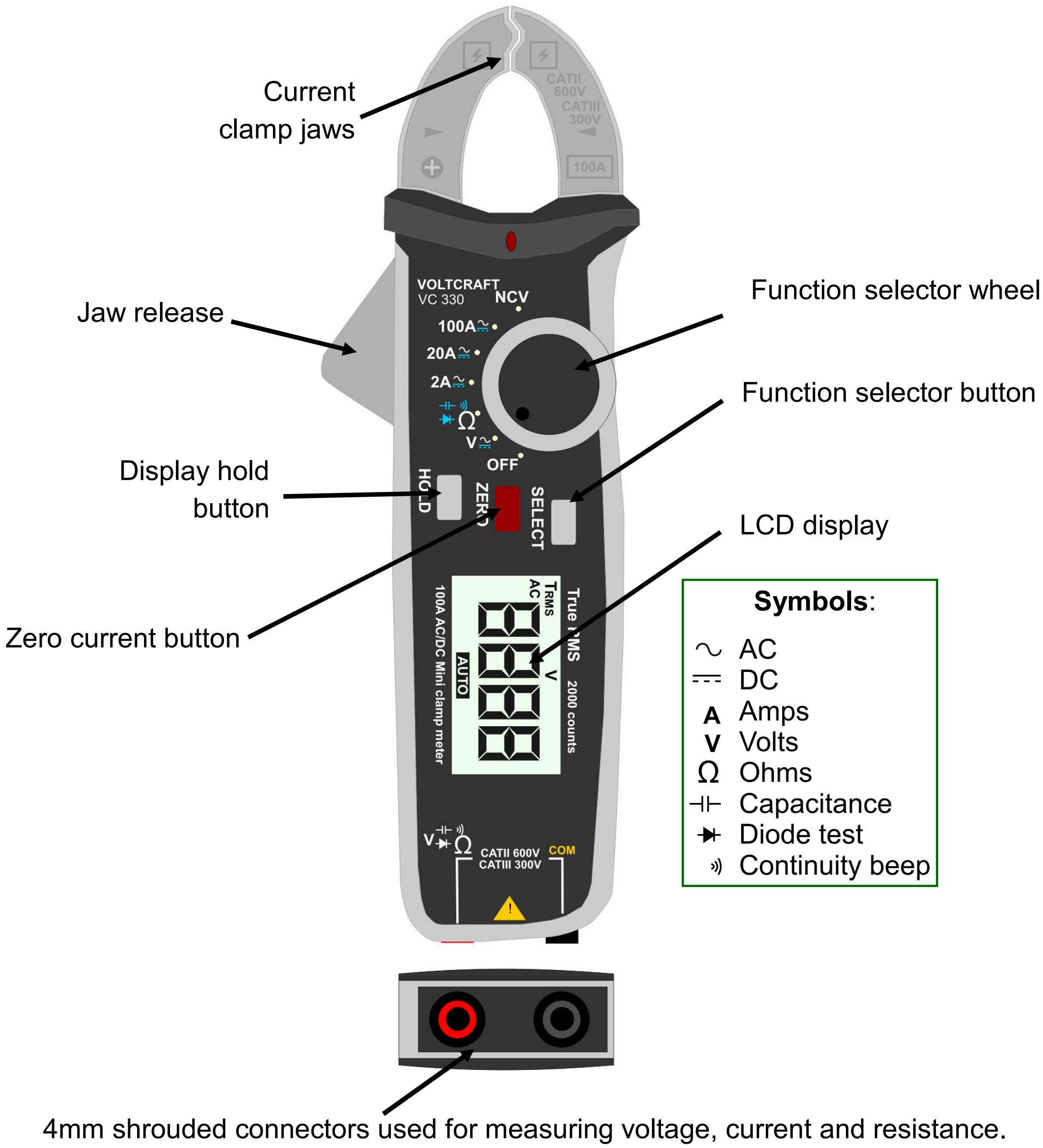
To measure current, you need to use the central 'COMmon' 4mm socket and the left hand 'A' 4mm socket. For all other quantities, use the central 'COMmon' 4mm socket and the right hand 4mm socket.

After measuring current, if you forget to change the leads over, you are likely to blow the fuse in the meter when you try to measure voltage. You will then need to replace it.

Appendix 2

The clamp meter

Automotive fault-finding



This Voltcraft VC330 current clamp has one big advantage over the traditional multimeter - it can measure current without the need for interrupting the circuit. You simply open the jaws and pass the wire that you are investigating through them. The clamp detects the electro-magnetic field around the wire and deduces the level of AC or DC current flowing through it.

This meter also has a special function for detecting high voltages without connecting the probes - this is called ‘Non Contact Voltage Testing’. It uses a sensor in the tip of the clamp to detect high voltages.

Appendix 3

Understanding faulty components

Automotive fault-finding

Terminology -

Short circuit - a connection with a resistance of ~0Ω.

Open circuit - a connection with a resistance of ~∞Ω.

Faulty components explained:

In this kit:

'corrosion' is a 3.9Ω resistor.

'bad earth' is a 3.9Ω resistor

In this workbook:

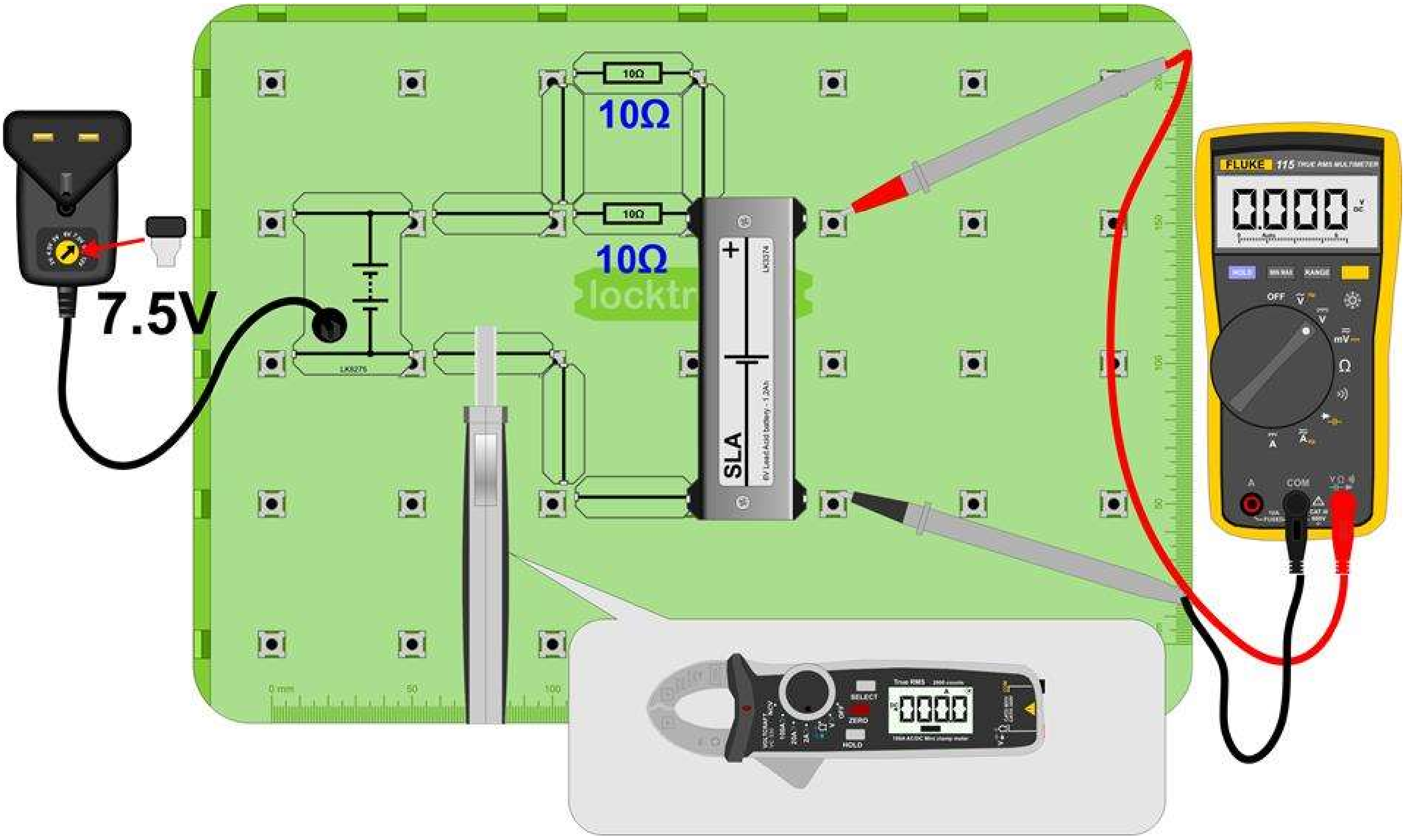
- With a 6V battery and a single bulb, the current flowing is around 0.1A and the voltage drop across a 'corrosion' or 'bad earth' link is around 0.4V - easily measurable.

In reality:

- The 'corrosion' link has a much higher resistance than corrosion in a typical battery.
- However, a typical car battery is delivering around 20A, making the effects of a corrosion resistance much more significant.

Appendix 4

Charging the lead-acid battery



- The charging time and current needed depends on the *state of charge* of your Battery. However you are unlikely to know what this is when you open your Locktronics kit.
- For the *Sealed Lead-Acid* (SLA) battery, one recommended charge method is to charge it at 0.12A for around 24 hours.
- Your kit does not include a constant current generator circuit. The circuit above offers a near equivalent. The plug-top power supply delivers 7.5V. The resistors drop between 1V and 1.5V across them, supplying around 0.2 to 0.25A to the battery.

Over to you:

- Construct the circuit shown above.
- Measure the charging current with your clamp meter.
- As the battery charges, the battery voltage rises and the charging current falls. If you charge the battery in this way for ten minutes, you will probably notice a change in the charging current as the battery voltage rises.
- Charge the battery in this way for 2 hours. Assuming that the state of charge of the battery is not zero, then that is likely to be enough.
- The battery we are using is RS Pro part number 727-0388.

Notes for the Instructor

Notes for the instructor

Automotive fault-finding

About this course

Introduction

Using the Automotive fault-finding module, students develop an approach to identifying problems that can arise in modern vehicles.

The course is essentially a practical one. It uses Locktronics equipment to show students how to test a range of devices found in automotive electrical circuits, using a multimeter. The same equipment is used to show the effects of faulty components on the behaviour of these circuits. Students analyse this behaviour, using fault grids, to identify the problem.

Aims

The course introduces students to techniques that allow faulty components and connections to be identified in vehicle electrical systems.

It encourages a methodical and systematic approach to fault-finding.

Prior Knowledge

It is recommended that students have followed the 'Automotive Electrics' course, or have equivalent knowledge and experience of building and testing simple circuits, of the meaning of electric current, voltage and resistance.

Using this course:

There are two main parts to the workbook: the worksheets and the Student Handout.

We envisage that you print (and bind) one copy of the workbook it, for each set of Locktronics equipment. This stays with the equipment. You print a Student Handout for each student.

The worksheets are written in a student-centred way. Our plan is that you give each pair of students a set of equipment, the bound workbook and a Student Handout each. You then   allow them to work through the topics in the workbook, offering help and assistance where needed. Students should not write on the worksheets but instead record their measurements in the Student Handout.

The format encourages self-study, with students working at a rate that suits their ability. It is for the instructor to monitor that their understanding is keeping pace with their progress through the worksheets. The Student Handout is one element of this. The instructor can assess progress by looking at the quality of their entries. It can be the basis for the feedback given to the students.

Knowing that multidisciplinary teaching teams are increasingly popular, the 'Notes for the instructor' aims to help instructors for whom this topic is not their principal area of experience.

Time:

It will take from ten to fifteen hours to complete the module.

Notes for the instructor

Automotive fault-finding

Learning Objectives

On successful completion of this course the student will be able to:

- state that a multimeter can be used for measuring AC and DC voltages and current, resistance, capacitance and frequency;
- state that a multimeter can be used to test diodes and check for continuity;
- connect a multimeter to measure:
    - the voltage across a component;
    - the current flowing in part of a circuit;
- recognize the units for voltage, current, resistance and capacitance;
- explain why, after measuring current, the leads should be reconnected to the ‘common’ and ‘voltage’ sockets on the multimeter;
- state an advantage of using a clamp meter instead of a multimeter to measure current;
- recognize the symbols for an ammeter and a voltmeter;
- check that an ohmmeter is functioning correctly;
- distinguish between in-circuit and out-of-circuit testing;
- connect a multimeter to measure the resistance of a component out-of-circuit;;
- explain why the resistance of a component should not be measured in-circuit;
- recognize the anode and cathode terminals of a diode on the diode circuit symbol;
- state the expected results from testing a working diode;
- use a multimeter to measure the capacitance of a capacitor;
- state that the voltage across the power supply equals the sum of the voltages across components connected in series with it;
- predict and then check the voltages at significant nodes in a functioning circuit;
- recognize that ‘earth’ and ‘ground’ can be used interchangeably when describing circuits;
- describe two tests for a faulty earth connection to the battery in a vehicle electrical system;
- describe how to use a multimeter to locate an open-circuit fault in a vehicle’s wiring;
- use a multimeter to test switches and bulbs both in-circuit and out-of-circuit;
- explain what is meant by the internal resistance of a battery and describe its significance;
- use the ‘amp-hour’ rating of a battery to calculate how long it can be used between charging;
- explain that the purpose of a fuse is to protect against the consequences of a short circuit;
- use a multimeter to test fuses and circuit breakers both in-circuit and out-of-circuit;
- use the ‘continuity’ setting on a multimeter to detect faulty components;
- use a multimeter to test for the effects of corrosion in leads and connectors;;

Notes for the instructor

Learning Objectives continued...

On successful completion of this course the student will be able to:

- create a fault-grid for a circuit and later use it to detect and identify faults caused by bad earthing, corrosion, short and open circuits and faulty components;
- use a customer's description of a problem to develop theories as to possible faults;
- devise tests to verify or discount theories on circuit faults;
- use a multimeter to test a range of different diodes;
- calculate the resistance of a resistor from readings of the voltage across it and the current through it, taken in-circuit;
- use a multimeter to test a potentiometer both in-circuit and out-of-circuit;
- use a multimeter to test a thermistor both in-circuit and out-of-circuit;
- describe the broad structure of a relay in terms of the 'energizing circuit' and 'contact circuit' and give the expected resistances in each when the relay is energised and not energised;
- explain why a relay is used in an automotive circuit such as that operating the starter motor;
- use a multimeter to test a relay both in-circuit and out-of-circuit.

Bill of Materials

Automotive fault-finding

To deliver this course you will need:

1	HP2045	Plastic shallow tray, Black
1	HP2666	Adjustable DC power supply
2	HP4039	Tray Lid
2	HP5540	Deep tray
2	HP7750	Daughter tray foam cutout
3	HP8600	Crash foam
2	HP9564	62mm daughter tray
1	LK0533	Open circuit
1	LK1316	Short circuit
4	LK2346	MES bulb 12V 0.1A
1	LK2399	MES power LED
2	LK3374	6V Sealed Lead Acid Battery
1	LK3799	Bad earth
3	LK4025	10 ohm resistor
1	LK5203	Resistor, 10K ohm, 1W, 5% (DIN)
1	LK5208	Potentiometer, 250 ohm (DIN)
1	LK5214	10K ohm potentiometer
1	LK5221	10uF electrolytic capacitor
2	LK5243	Diode, power, 1A, 50V
35	LK5250	Connecting Link
2	LK5280	Relay, 12V, normally open
4	LK5291	Lampholder, MES
1	LK5402	Thermistor, 4k7 ohm, NTC (DIN)
2	LK5603	Red 4mm to 4mm lead, 1m
2	LK5604	Black 4mm to 4mm lead, 1m
1	LK6152	Corrosion
3	LK6207	Switch, push to make, metal strip
1	LK6208	Changeover switch
3	LK6209	Switch, on/off, metal strip
1	LK6231	50Kohm ressitor
1	LK6635	LED, red, 12V (SB)
1	LK6706	Motor 3 to 12V
1	LK6841	MES LED bulb 12V
1	LK8275	Power supply carrier with battery symbol
2	LK8623	Circuit breaker
2	LK8900	7 x 5 metric baseboard with 4mm pillars

In addition to this one of the Fault Finding projects makes use of the HP2001 DC / Brushless motor pair.

Students will also need a multimeter and a clamp meter. We recommend the Fluke 115 and Voltcraft VC330 or equivalent.

Notes for the instructor

Automotive fault-finding

General checks

- *Is the plug-top power supply on the correct voltage setting?*

  If not, the results in the Student Handout will be wrong.

- *Is the multimeter connected to the power-supply carrier correctly?*

  If not, the '-' sign will appear in the wrong place.

- *Is the multimeter set on the correct range?*

  If not, the results in the Student Handout will be wrong.

- *The multimeter does not measure current.*

  The internal fuse may have blown.

- *The voltage across the SLA is not 6V.*

  The SLA battery may not be charged.

- *Are the leads connected to the correct sockets on the multimeter?*

  If not, the student will not be able to take a reading.

- *Bulbs do not light.*

  One or both of the bulbs are faulty or not screwed fully into the bulb holder.

- *Some voltage readings are negative.*

  The multimeter leads are the wrong way round.

Notes for the instructor

Automotive fault-finding

Worksheet	Notes
1 **Measuring voltage** **20 minutes**	**Points for discussion:** • What is meant by 'voltage' 'current' and 'resistance'? • Why do we need a complete circuit? • Series and parallel connections.
2 **Measuring current** **20 minutes**	**Points for discussion:** • Trace the circuit for measuring current with the multimeter (first activity). • How does the current clamp measure current? • Multimeter vs current clamp for measuring current. • Return the multimeter leads to the 'V/Ω' position when finished.
3 **Measuring resistance** **20 minutes**	**Points for discussion:** • Structure of a potentiometer. • In-circuit testing vs out-of-circuit testing.
4 **Testing Diodes** **15 minutes**	**Specific problem:** • *Student unable to take a reading.* Assuming that the multimeter is set to 'diode test' position, has the yellow button been pressed, putting it on 'capacitor test'? **Points for discussion:** • The diode as a 'one-way' valve - significance of 'anode' and 'cathode'. • Meaning of forward and reverse bias.
5 **Measuring capacitance** **10 minutes**	**Specific problem:** • *Student unable to take a reading.* Assuming that the multimeter is set to 'diode test' position, the yellow button must be pressed to put it on 'capacitor test'. **Points for discussion:** • What is a capacitor? • What precaution should you take before using a capacitor that may be charged? • Why do you need to take care when using electrolytic capacitors?

Notes for the instructor

Automotive fault-finding

Worksheet	Notes
6 **Describing voltage** **20 minutes**	**Specific problems:** • *(Va + Vb) does not equal 12V.* The plug-top power supply may be on the wrong voltage setting. The student may be placing the multimeter leads across both bulbs. • *(Va + Vb) does not equal Vc.* The student may not be placing the multimeter leads in the correct positions. **Points for discussion:** • What are nodes? • Sum of voltage drops equals battery voltage. • “Voltage across” compared to “voltage at”.
7 **The ‘continuity’ beep** **10 minutes**	**Points for discussion:** • Continuity setting vs resistance setting - relative advantages of each.
8 **Open circuit faults** **25 minutes**	**Specific problems:** • *Student unable to find a 12V reading.* • *Voltage at the bulb is not 12V.* The plug-top power supply may be on the wrong voltage setting. **Points for discussion:** • Factors that may cause open circuits in a vehicle.

9
Testing switches and bulbs
 	
20 minutes
	Specific problem:
	• *No ‘beep’ heard.*
	The multimeter is on the wrong setting.
	The multimeter battery is ‘flat’.
	Points for discussion:
	• How to predict voltages at significant points in a circuit.
	• In the in-circuit testing of the bulb, what would be the effects of an open circuit:
	  • between the battery and the bulb;
	  • between the switch and the bulb.

10 **Testing Batteries** **25 minutes**	**Specific problem:** • *Current reading does not change as more switches are closed.* The student is moving the current clamp to a new location each time. **Points for discussion:** • The significance of ‘6V 1.2Ah’. • Internal resistance of a battery and its effects.

Notes for the instructor

Automotive fault-finding

Worksheet	Notes
11 **Short circuit Faults** **25 minutes**	**Specific problem:** • *In-circuit test - the bulb does not light.* The circuit breaker is tripped or faulty. **Points for discussion:** • What is the purpose of a fuse? • Fuses vs circuit breakers.
12 **A good ground / earth** **25 minutes**	**Specific problem:** • *Identical readings in Tables 2 and 3.* 'Open circuit' link not situated in the correct position. **Points for discussion:** • In 'auto-speak', "earth" does not mean "earthed". • The significance of the position of the COMmon terminal. • How to check that you have a good earth connection. • Consequences of earth faults.
13 **Corrosion** **30 minutes**	**Points for discussion:** • Causes of corrosion and how to avoid it. • The effects of corrosion.
14 **Fault-finding project 1** **30 minutes**	**Points for discussion:** • How to use a fault grid in fault-finding.
15 **Fault-finding project 2** **40 minutes**	**Points for discussion:** • How to use a qualitative 'customer' description to focus on a possible fault. • Likely faults leading to the problems outlined by the customers.
16 **Testing diodes and LED bulbs** **15 minutes**	**Specific problem:** • *The positive lead from the multimeter must be connected to the anode of the LED.* **Points for discussion:** • Advantages of LEDs over filament lamps. • How to test a 12V automotive LED.

Notes for the instructor

Automotive fault-finding

Worksheet	Notes
17 **Testing resistors and Potentiome-ters** **30 minutes**	**Specific problem:** • *The bulb does not light.* In addition to items in the General Checks, the student may be using the wrong value resistor (10kΩ instead of 10Ω). • *When testing the potentiometer in-circuit, the output voltage is always zero.* It is easy to insert the potentiometer the wrong way round so that the common wiper terminals short-circuit the power supply. **Points for discussion:** • What is Ohm's law. • Using R = V / I. • The structure of a potentiometer.
18 **Testing Thermistors** **20 minutes**	**Specific problem:** • *The voltage is too small to measure.* The student may be using the wrong value resistor (10Ω instead of 10kΩ). **Points for discussion:** • The difference between ntc and ptc thermistors.
19 **Testing relays** **25 minutes**	**Points for discussion:** • The structure and operation of a relay. • Types of relay and their uses in automotive circuits. • Tracing the energising and contact circuits in the layout used.
20 **Fault-finding project 3** **30 minutes**	**Specific problem:** • *One of the devices does not work when the switch is pressed.* This is a complex circuit. Check the wiring. Notice that the relay at the right-hand side of the layout is connected 'upside-down'. **Points for discussion:** • Tracing through the 'sub-circuits' and deciding what they control. • Likely faults leading to the problems outlined by the customers.
21 **Fault-finding project 4** **30 minutes**	**Specific problem:** • *The motor does not work when the switch is pressed.* Check the circuit breakers to make sure that they have not tripped. **Points for discussion:** • Tracing through the energising and contact circuits. • Likely faults leading to the problems outlined by the customers.

Version control

Automotive fault-finding

01 12 20	First release
04 08 21	inserted times in Teacher's notes