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FREE EBOOK

HARDWARE, NETWORKING AND REPAIR

Using a Digital Multimeter

Measure voltage, current, resistance and continuity safely

INSIDE THIS BOOK

- Meet the digital multimeter
- Probes, sockets, the dial and ranges
- Measuring DC voltage
- AC voltage, mains danger and CAT ratings
- Measuring resistance
- ...and 5 more chapters, practice questions and a glossary

Beginner

Electronics, hardware and mobile repair students

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Using a Digital Multimeter

Learn every part of a digital multimeter and use it safely on battery circuits. You will measure DC voltage, resistance and current, check continuity, test diodes, LEDs, switches, fuses, wires, batteries and transistors, understand CAT safety ratings, avoid the common mistakes and practise with low-voltage activities.

WHO IT IS FOR	Electronics, hardware and mobile repair students
LEVEL	Beginner
SUBJECT AREA	Hardware, networking and repair
WHAT IS INSIDE	10 chapters, practice questions with answers, and a glossary

HOW TO USE IT

Read one chapter at a time and try the examples as you go: on a computer, at your workbench or in your notebook. The boxes give tips, safety points and short activities. When you finish, test yourself with the practice questions and check your answers at the end. Words you may not know are explained in the glossary.



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Meet the digital multimeter

A **multimeter** is one tool that does the work of many meters. It measures **voltage** (the push that drives electricity, in volts, V), **current** (the flow of electricity, in amperes or amps, A) and **resistance** (how much a part resists the flow, in ohms, Ω). A **digital multimeter**, often called a **DMM**, shows the result as numbers on a screen.

Every electronics student, hardware technician and mobile repairer uses one. With it you can tell a good battery from a flat one, find a broken wire, check a fuse, test an LED and much more.

The main parts

Part	What it does
Display	Shows the reading as numbers, with a minus sign and symbols where needed
Rotary dial	A knob you turn to choose what to measure and the range
Sockets (jacks)	Holes where the test leads plug in
Test leads and probes	A red and a black wire with pointed metal tips
Buttons	Extra features such as HOLD, backlight or a range button
hFE socket	Small holes for testing transistors, on many meters

Symbols on the dial

The dial is covered in symbols. Learn them once and you can use almost any meter.

Symbol	Meaning
V with a straight line and a dashed line	DC volts, from batteries and cells
V with a wavy line (~)	AC volts, as in mains wiring
A with a straight line	DC current

Symbol	Meaning
A with a wavy line	AC current
Ω	Resistance
A sound-wave or speaker sign	Continuity test (beeps)
A triangle pointing at a bar	Diode test
hFE	Transistor gain test

DC means direct current, which flows one way only, as from a battery. **AC** means alternating current, which keeps changing direction many times a second, as in the mains supply.

What the display tells you

A meter's screen has a limit on the biggest number it can show. A common basic meter is a **2000-count** meter: it can show up to 1999. When the reading is too large for the range you chose, the display shows **over-range**. On many basic meters this is a single **1** at the left of the screen; others show **OL**.

A **minus sign** in front of a DC reading means the probes are the wrong way round. The value is still correct.

DID YOU KNOW

Many meters have a **HOLD** button that freezes the reading on the screen. It is handy when you must look at the probes, not the display, while you measure.

SAFETY

Every activity in this book uses cells and batteries of 12 V or less. The mains supply in Indian homes is 230 V AC and can kill. Students must never measure mains, open sockets, or work on anything plugged into the wall.

REMEMBER

Before every measurement, ask three questions. What am I measuring? Is the dial in the right place? Are the leads in the right sockets?

Probes, sockets, the dial and ranges

Many mistakes with a multimeter, and many damaged meters, come from leads in the wrong socket or the dial in the wrong place. This chapter helps you avoid both.

The test leads

The **test leads** are a red and a black wire. Each has a plug at one end and a **probe** at the other: a pointed metal tip with an insulated handle. Good probes have a **finger guard**, a raised ring that stops your fingers sliding onto the metal tip. Some kits include **crocodile clips** that grip a wire so your hands stay free.

Check the leads before use. Cracked insulation or a loose plug means the leads must be replaced.

The sockets

A typical meter has four sockets.

Socket	Lead	Used for
COM	Black, always	The common return for every measurement
VΩ	Red	Voltage, resistance, continuity and diode tests
mA	Red	Small currents, protected by a fuse inside
10A	Red	Large currents up to 10 A, for short times only

The black lead stays in **COM** all the time. Only the red lead moves. On many low-cost meters, VΩ and mA share one socket, marked **VΩmA**, so there are only three sockets.

SAFETY

On many cheap meters the 10A socket has **no fuse** inside. The label beside it often gives a time limit for large currents. Never connect it straight across a battery: the meter becomes a short circuit, and a large battery can make wires and probes dangerously hot.

Manual ranging and auto ranging

A **manual-ranging** meter has many positions for each quantity. For DC volts you might see 200m, 2000m, 20, 200 and 600. Each number is the most that position can show, and the unit comes from the label. So 200m means up to 200 millivolts, and 20 means up to 20 volts.

Choose the **lowest range that is still higher** than what you expect:

1. If you do not know what to expect, start at the highest range.
2. Turn down one step at a time for more digits.
3. If you see over-range (**1** or **OL**), turn back up one step.

An **auto-ranging** meter picks the range for you. You choose only "V DC" or " Ω ", and the meter shows the unit, such as mV, V, k Ω or M Ω , on the screen. Auto-ranging is easier, but check the small unit letters every time.

EXAMPLE

Aman wants to measure a 9 V battery on a manual meter. The 2000m range is too small, because 9 V is 9,000 mV. The 200 range shows 9.4. The 20 range shows 9.42, with one more digit. He uses the 20 range.

The meter's own battery

The meter runs on its own battery, often a 9 V battery or two small cells. When it is weak, a battery sign appears, and readings may become wrong. Replace it as soon as the sign shows. Turn the dial to **OFF** after use; many meters also switch off by themselves after some minutes.

TIP

Before you take the meter to a job, test it on something known: a new cell for voltage, or the two probes touched together for continuity. If it reads as expected, you can trust it.

TRY THIS

Turn the dial slowly through every position on your meter. For each one, say aloud what it measures and which socket the red lead needs.

Measuring DC voltage

Voltage is measured **across** a part: one probe on each side. The circuit stays as it is, and power stays on. This is called measuring in **parallel**.

Measuring a battery

1. Put the black lead in **COM** and the red lead in **VΩ**.
2. Turn the dial to **DC volts**. On a manual meter, choose the range just above the battery's printed voltage.
3. Touch the red probe to the battery's **positive (+)** end and the black probe to its **negative (-)** end.
4. Read the display.

What the reading means

A battery's reading with nothing connected is a rough guide to how much charge is left. These are typical figures for batteries at rest; they vary a little between makers.

Battery	New or full	About half	Low
1.5 V AA or AAA alkaline	About 1.5 to 1.6 V	About 1.3 V	About 1.2 V or less
9 V alkaline	About 9.5 V	About 8 V	About 7.2 V or less
3.7 V lithium-ion cell	About 4.2 V	About 3.7 V	About 3.3 V or less
12 V sealed lead-acid	About 12.7 V	About 12.2 V	12.0 V or less: charge it soon

A **rechargeable** AA cell is usually rated 1.2 V, so do not throw it away just because it reads less than an alkaline cell.

REMEMBER

A battery can show a good voltage with nothing connected and then drop sharply when it has to drive a motor or a bulb. If a device fails with a battery that "reads fine", measure it again while the device is switched on.

Measuring inside a circuit

You can also measure the voltage across any part of a working circuit. Touch the probes to the two ends of the part. In a circuit of an LED and a resistor on a 9 V battery, you might read about 2 V across a red LED and about 7 V across the resistor. Together they add up to the battery's voltage.

The black probe is often kept on the battery's negative, called **ground** or **0 V**. Then the red probe can be moved from point to point to see the voltage at each place.

EXAMPLE

Tanvi's toy car in Chennai will not run. Its two AA cells read 1.52 V and 1.14 V with nothing connected, so the second cell is low. She fits a new pair, because a pair with one old cell runs down quickly and the old cell can leak, and puts the 1.52 V cell in the wall clock, which needs very little current. Her brother had wanted to replace every cell in the house, about ! 200 worth in this example. Testing showed that one new pair was enough.

SAFETY

Never short a battery by touching both of its ends with one metal object. Lithium-ion phone batteries can catch fire if shorted, punctured or bent. If a lithium battery is swollen, do not charge or press it; give it to an adult for safe disposal.

TRY THIS

Collect old and new cells from home. Measure each one and write the readings in a table with three columns: full, about half and low. Take used cells to an e-waste or battery collection point, never to a fire.

CHAPTER 4

AC voltage, mains danger and CAT ratings

Your meter has an **AC volts** position, marked V with a wavy line. It is there for trained electricians, who use it on mains wiring. This chapter explains what it is and why you must leave it alone for now.

Why mains is different

The mains supply in Indian homes is about 230 V AC. That is many times the voltage of the batteries in this book, and enough to drive a deadly current through a human body. A mistake with a 9 V battery may blow a fuse in your meter. The same mistake on mains can kill you, start a fire or make the meter burst in your hand.

SAFETY

Students must not measure mains voltage, open switchboards, or put probes into wall sockets, even "just to see". Measuring mains is a job for a trained electrician, or for a student only under a trained supervisor during a proper course, with the right meter and leads.

What can go wrong

- The dial is on current or resistance by mistake. The meter acts like a short circuit across the mains, and a flash of extremely hot, glowing gas called an **arc** can burn the hands and face.
- A probe slips and touches two wires, or your finger slides onto the metal tip.
- Old leads with cracked insulation let current reach your hand.
- A sudden high-voltage spike on the line, called a **transient**, breaks through a meter that was not built for it.

CAT safety ratings explained simply

Meters meant for mains work carry a **measurement category**, or **CAT rating**, printed near the sockets, such as **CAT III 600 V**. The rating tells you where the meter can safely be used. The idea is simple: the closer you are to where electricity enters a building, the bigger the spikes on the line, and the tougher the meter must be.

Category	Where it can be used
CAT II	Plug-in appliances and circuits at ordinary wall sockets
CAT III	Fixed wiring inside a building, such as distribution boards
CAT IV	Where the supply enters the building, such as the electricity meter

The voltage after the category is the highest working voltage that rating covers. A higher category is not "more volts": it means the meter can survive larger spikes. A set is only as safe as its lowest-rated part, so the test leads need a rating at least as high as the meter's.

The battery circuits in this book are not connected to mains at all, so they fall outside these categories. Older meters may show **CAT I** for circuits like these.

REMEMBER

A CAT rating protects a trained person who is also following safe working methods. It never makes mains work safe for a beginner.

DID YOU KNOW

Mains electricity in India goes through 50 complete back-and-forth cycles every second. This is written as 50 Hz (hertz). Some meters have an Hz position on the dial for measuring how often a signal repeats.

EXAMPLE

Rahul, a student in Ranchi, sees a 230 V reading on a video and wants to try it on his home socket. His teacher explains the arc risk, shows him that his practice meter's leads have no rating printed at all, and gives him a 12 V battery activity instead.

CHAPTER 5

Measuring resistance

Resistance is measured with the **power off**. The meter sends its own small current through the part and works out the resistance from it. Any voltage from a battery in the circuit spoils the reading and can damage the meter.

Measuring a resistor

1. Black lead in **COM**, red lead in **VΩ**.
2. Turn the dial to **Ω**. On a manual meter, choose a range above the value you expect.

3. Touch one probe to each leg of the resistor. A resistor has no plus or minus, so either way round is fine.
4. Read the display. On a manual meter, the range tells you the unit: on the 20k range, a reading of 4.68 means 4.68 k Ω , or 4,680 Ω .

Remember the prefixes: **k** (kilo) means a thousand, so 1 k Ω = 1,000 Ω , and **M** (mega) means a million, so 1 M Ω = 1,000,000 Ω .

Checking the colour code

Small resistors show their value with coloured bands. On a four-band resistor, the first two bands are digits, the third is the multiplier (how many zeros to add), and the fourth, usually gold or silver, is the **tolerance**: how far the real value may be from the marked value.

Colour	Digit	Colour	Digit
Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Grey	8
Yellow	4	White	9

A gold fourth band means $\pm 5\%$ and silver means $\pm 10\%$.

EXAMPLE

Lakshmi picks a resistor marked yellow, violet, red, gold. That is 4, 7 and two zeros: 4,700 Ω , or 4.7 k Ω , at $\pm 5\%$. Five per cent of 4,700 is 235, so any reading from 4,465 Ω to 4,935 Ω is fine. Her meter shows 4.68 k Ω , so the resistor is good.

Getting an honest reading

- **Keep your fingers off both metal tips.** Your body also has resistance. Holding both tips adds a second path, which lowers the reading of large values such as 100 k Ω and above.
- **Take the part out of the circuit,** or lift one leg. Other parts joined to it give the current another path, so the meter reads too low.

- **Subtract the leads.** Touch the probes together on the lowest range. The meter may show a small value, often below $1\ \Omega$. For very small resistances, subtract this from your reading.

SAFETY

Disconnect the battery before measuring resistance in any circuit. Large capacitors can hold a charge for a short while after the power is removed, so wait a moment before touching probes to the board.

TIP

An over-range reading on the highest range means the resistance is too large to measure, or the path is broken. This is useful: a fuse or a wire that reads over-range is broken.

TRY THIS

Take ten mixed resistors. Write the value from the colour code for each, then measure it. Mark each one as within tolerance or not.

CHAPTER 6

Continuity and diode tests

Repair technicians use these two quick tests all the time. On many meters they share one position on the dial.

Continuity: is there a path?

Continuity means an unbroken path for electricity. In continuity mode, the meter **beeps** when the resistance between the probes is very low, below a small value set by the maker, often a few tens of ohms. You can keep your eyes on the probes and listen.

1. **Switch off and disconnect the power** to whatever you test.
2. Black lead in **COM**, red lead in **V Ω** .
3. Turn the dial to the continuity sign (sound waves). If it shares a position, press the button that selects it.

- 4. Touch the probes together. The meter should beep. This proves the test works.
- 5. Touch one probe to each end of the path you are checking.

Result	Meaning
Beep, reading near 0	Good path: a wire, a fuse or a closed switch
No beep, over-range	Broken path: a cut wire, a blown fuse or an open switch

EXAMPLE

Ayesha's old charging cable in Hyderabad works only when bent one way, so it is going to be thrown away. Her teacher cuts off both plugs and strips the ends of the wires inside. Ayesha clips the probes to the two ends of one wire and bends the cable gently along its length. The beep stops and starts at one spot near a plug, showing exactly where the wire has broken.

The diode test

A **diode** lets current flow one way only. Its two legs are the **anode** (+) and the **cathode** (-); the cathode is marked with a band. The **diode test** sends a small current through the diode and shows the **forward voltage**: the voltage needed to push current through it.

- 1. Black lead in **COM**, red lead in **VΩ**, dial on the diode sign.
- 2. Put the red probe on the anode and the black probe on the cathode (the band side).
- 3. Read the display, then swap the probes and read again.

Reading forward	Reading reversed	Meaning
About 0.5 to 0.7 V (500 to 700)	Over-range	Good silicon diode
Over-range	Over-range	Diode is open (broken inside)
Near 0	Near 0	Diode is shorted (failed)

Many meters show the forward voltage in millivolts, so a reading of 589 means 0.589 V.

REMEMBER

Continuity and diode tests, like resistance, are done with the power off. Never press the probes onto a powered circuit in these modes.

DID YOU KNOW

You can use the diode test to find which way round an unmarked diode goes. The direction that gives a reading has the red probe on the anode.

TRY THIS

Test a 1N4007 diode both ways and write down both readings. Then, in continuity mode, try a piece of wire, a thick pencil line drawn on paper, and a dry cloth. Notice which ones beep. Then measure the pencil line in the Ω mode: it does conduct, but far too poorly to beep.

CHAPTER 7

Measuring current in series

Current is the flow through a circuit, so the meter must become **part of** the circuit. The current flows in through one probe, through the meter and out through the other. This is called connecting in **series**.

Steps for measuring current

1. **Switch off** the circuit.
2. **Open the circuit** at one point. For example, take the wire off the battery's positive terminal.
3. Black lead in **COM**. Move the red lead to the **mA** socket, or to **10A** if you expect more than a few hundred milliamps or do not know.
4. Turn the dial to **DC current**, choosing a range above what you expect.
5. Touch the red probe to the battery's positive terminal and the black probe to the loose wire. The meter now fills the gap.
6. Switch on and read the display.

7. Switch off, remove the meter, rejoin the circuit and **move the red lead back to $V\Omega$** .

SAFETY

In current mode the meter has almost no resistance. Never put the probes across a battery or across a part, as you would for voltage. That makes a short circuit, which blows the meter's fuse at best, and on the 10A socket can make a big battery heat the leads dangerously.

A worked example

Gurpreet builds a circuit in Ludhiana: a 9 V battery, a $470\ \Omega$ resistor and a red LED. First she works out what to expect. A red LED needs about 2 V, so about 7 V is left across the resistor.

Current $I = V \div R = 7 \div 470 = 0.0149\text{ A}$, which is about 15 mA.

She puts the red lead in **mA**, sets the dial to the 20m (20 mA) range and connects the meter in series. The display shows 14.60, which means 14.6 mA. Her calculation and her measurement agree closely. The small difference comes from the battery voltage, the LED and the resistor's tolerance.

Units of current

Unit	Value	Typical example
A (amp)	1 A	A toy motor starting up
mA (milliamp)	1/1,000 A	An LED, about 10 to 20 mA
μA (microamp)	1/1,000,000 A	A circuit in sleep mode

To change mA to A, divide by 1,000: $15\text{ mA} = 0.015\text{ A}$.

When the reading is always zero

If the meter reads 0 in current mode every time, even in a circuit that works, the fuse inside the mA socket may be blown. It must be replaced with a fuse of exactly the same type and rating, as the meter's manual says. Ask your teacher to do this the first time.

TIP

A small motor takes a much bigger current for a moment as it starts. Use the 10A socket for motors, keep the test short, and read the current once the motor is running steadily.

REMEMBER

One of the commonest ways to damage a multimeter is to measure current, forget to move the red lead back, and then try to measure a battery's voltage. Make "red lead back to V Ω " the last step every time.

TRY THIS

Measure the current through an LED with a 1 k Ω resistor and then with a 470 Ω resistor on the same battery. Which gives more current, and which LED is brighter?

CHAPTER 8

Testing everyday parts

With voltage, resistance, continuity and diode tests, you can check most of the parts in a toy, torch or project kit.

LEDs

An **LED** is a diode that gives light. Its longer leg is the **anode** (+), and the cathode side often has a flat edge on the rim.

1. Set the dial to the **diode test**.
2. Put the red probe on the longer leg and the black probe on the shorter leg.
3. Many red, green and yellow LEDs glow faintly and the meter shows about 1.6 to 2.2 V.

Blue and white LEDs need about 3 V, which is more than many meters give in diode mode. They may stay dark and show over-range even when they are good. Test them in a circuit with a battery and a resistor instead.

Switches and push buttons

Use **continuity**, with the switch out of the circuit or the power off.

- **On/off switch:** it should beep when on and stay silent when off.
- **Tactile push button** (the small four-legged button in kits): inside, each leg is joined to one other leg, making two pairs. Find the pairs first, because they beep all the time. Then check that pressing the button joins one pair to the other.
- **Slide or toggle switch with three legs:** the middle leg is usually the common one. It joins one outer leg in one position and the other outer leg in the other.

Fuses

A **fuse** is a thin wire that melts and breaks the circuit when too much current flows. Take it out of its holder and test it with **continuity**. A good fuse beeps. A blown fuse shows over-range. A glass fuse can look fine and still be blown, so always test it.

SAFETY

If a fuse has blown, something drew too much current. Find the fault before fitting a new fuse, and always fit the same rating.

Wires and cables

Test each core end to end with **continuity**. To find a break that comes and goes, bend the wire gently along its length while listening to the beep. This works well on breadboard jumper wires, which often break inside their plastic cover.

Batteries

Measure **DC volts**, as you learnt earlier. Compare the reading with the printed voltage and with the table in the DC voltage chapter.

Other parts

Part	Test	Good result
Small DC motor	Resistance	A few ohms; over-range means a broken coil
Small speaker (marked 8 Ω)	Resistance	A little less than 8 Ω

Part	Test	Good result
Torch bulb (filament type)	Continuity	Beep; silence means the filament is broken
Buzzer	Join it to a battery of its rated voltage	It sounds

DID YOU KNOW

A speaker marked $8\ \Omega$ often measures about 6 to 7 Ω on a multimeter. The 8 Ω figure describes how it behaves with the changing signals of sound, not with the steady current from the meter.

EXAMPLE

Manoj's torch in Bhubaneswar does not light. He checks in order: the cells read 1.55 V each, so they are fine; the switch beeps when on; the bulb shows over-range. A new bulb fixes the torch in two minutes, with no guessing.

CHAPTER 9

Checking transistors and the hFE socket

A **transistor** is a small part that acts as a switch or an amplifier. A small current into one leg, the **base** (B), controls a bigger current between the other two legs, the **collector** (C) and the **emitter** (E). Common transistors in kits are the **BC547**, an **NPN** type, and the **BC557**, a **PNP** type.

Finding the legs

For the BC547 and BC557, hold the transistor with the **flat face towards you** and the legs pointing down. From left to right the legs are **collector**, **base**, **emitter**. Other transistors can have a different order, so always check the **datasheet**, the maker's information sheet, for any new part.

The hFE socket

hFE is the transistor's **current gain**: how many times bigger the collector current is than the base current. Many meters have a small socket with holes marked **E**, **B** and **C**, in one group labelled **NPN** and another labelled **PNP**.

1. Turn the dial to **hFE**. The test leads are not used.
2. Push the transistor's legs into the group for its type (NPN for BC547), matching each leg to its letter.
3. Read the number. A BC547 usually reads somewhere in the hundreds.

A reading of 0, or a very small number, usually means a leg is in the wrong hole, the wrong group is used, or the transistor is damaged. The meter's figure is only a rough guide, because gain changes with current and temperature.

The diode test on a transistor

You can also test a transistor without an hFE socket. Inside, it behaves like two diodes joined at the base. For an **NPN** transistor such as the BC547, with the dial on the **diode test**:

Red probe	Black probe	Good NPN result
Base	Emitter	About 0.6 to 0.7 V
Base	Collector	About 0.6 to 0.7 V
Emitter	Base	Over-range
Collector	Base	Over-range
Collector	Emitter (either way)	Over-range

For a **PNP** transistor, such as the BC557, the probes are the other way round: the black probe goes on the base to get the two readings.

A reading near 0 between any two legs means the transistor is **shorted**. Over-range in every direction means it is **open**. Either way, replace it.

EXAMPLE

Riya's robot in Bengaluru has a motor that will not switch on. She takes out the BC547 driving it and does the diode test. Base to emitter shows over-range both ways: the junction is open. A new transistor brings the motor back to life.

TIP

Some multimeters do not have an hFE socket. That is fine. The diode test tells you whether a transistor is working, which is all most repairs need.

TRY THIS

Test a BC547 in the hFE socket and with the diode test. Then put it in the hFE socket the wrong way round and note what happens to the reading.

CHAPTER 10

Common mistakes and practice activities

You now know every main job a multimeter does. This last chapter collects the mistakes that catch beginners, then gives you practice activities using only low-voltage batteries.

Common mistakes

Mistake	What happens	How to avoid it
Red lead left in mA or 10A, then measuring volts	Short circuit; fuse blows, leads heat	Red lead back to $V\Omega$ after every current test
Measuring resistance with power on	Wrong reading; meter can be damaged	Disconnect the battery first
Meter across a battery in current mode	Short circuit	Current is always measured in series
Range too low	Over-range (1 or OL) shown	Start high, then go down

Mistake	What happens	How to avoid it
Misreading the unit	4.7 read as 4.7 Ω instead of 4.7 k Ω	Check the range label or unit letters
Holding both probe tips	Low readings on large resistances	Hold the insulated handles only
Weak meter battery	Readings drift or are wrong	Replace when the battery sign shows
DC setting on an AC circuit	Wrong or zero reading	Check the symbol before measuring
Leaving the meter on	Meter battery runs flat	Turn to OFF after use

REMEMBER

Most mistakes happen in the few seconds between two measurements. Stop, check the dial, check the sockets, then measure.

Practice activities

Use only cells and batteries of 12 V or less. Keep a notebook and write every reading with its unit.

Activity 1: Battery survey. Measure ten cells from home or the lab. Sort them into full, about half and low, using the table in the DC voltage chapter.

Activity 2: Resistor check. Read the colour code of ten resistors, measure each one and work out whether it is within its tolerance.

Activity 3: Voltage map. Build a circuit with a 9 V battery, a 470 Ω resistor and a red LED. Measure the battery, the resistor and the LED. Check that the resistor and LED voltages add up to about the battery voltage.

Activity 4: Current check. In the same circuit, calculate the current, then measure it in series. Compare the two.

Activity 5: Broken wire hunt. Your teacher mixes a few faulty jumper wires into a bundle of good ones. Use continuity to find every faulty wire.

Activity 6: Switch map. Use continuity to find which legs of a four-legged push button are always joined and which join only when pressed. Draw a diagram in your notebook.

Activity 7: Torch repair. Your teacher prepares a torch with one fault. Find it using voltage and continuity tests, in a sensible order.

EXAMPLE

Sneha in Guwahati records Activity 3: battery 9.21 V, resistor 7.17 V, LED 2.02 V. The two parts add up to 9.19 V, very close to the battery reading. Her notebook shows her teacher that she measured carefully and understands how voltage divides around a circuit.

SAFETY

Keep drinks away from your workbench, never work with wet hands, and put the meter away with the dial on OFF and the leads coiled loosely, not wrapped tightly round the meter.

CHECK YOURSELF

Practice questions

1. Name the three main quantities a multimeter measures and their units.
2. What does a dial symbol of V with a wavy line mean?
3. Which socket does the black lead always go in?
4. On a manual meter, which range would you use to measure a 9 V battery: 2000m, 20 or 200? Why?
5. What does a single 1 at the left of the display usually mean?
6. A DC voltage reading shows a minus sign. What does this tell you?
7. Why must voltage be measured in parallel?
8. A battery reads 9.4 V with nothing connected, but the toy does not work. What should you check next?

9. Why must students not measure mains voltage?
10. In simple words, what does a higher CAT rating mean?
11. Why must the power be off when you measure resistance?
12. What is the value and the allowed range of a resistor marked brown, black, red, gold?
13. Why should you not hold both probe tips while measuring a large resistance?
14. When does a meter beep in continuity mode?
15. A diode reads over-range in both directions. What is wrong with it?
16. How is a meter connected to measure current?
17. What is the last step after measuring current, and why?
18. A 9 V battery drives a red LED through a $470\ \Omega$ resistor. About what current do you expect?
19. Why might a good blue LED show over-range in the diode test?
20. How can you find which legs of a four-legged push button are joined?
21. What are the legs of a BC547, from left to right, with the flat face towards you?
22. In a diode test on an NPN transistor, what should base-to-emitter read?

ANSWER KEY

Answers

- | | |
|---|---|
| 1. Voltage in volts (V), current in amperes (A) and resistance in ohms (Ω). | 5. Over-range: the value is too large for the chosen range. |
| 2. AC volts, as in mains wiring. | 6. The probes are the wrong way round; the value is still correct. |
| 3. COM. | 7. Voltage is the difference between two points, so the probes must touch both ends of the part while the circuit works normally. |
| 4. 20, because it is the lowest range higher than 9 V; 2000m is too small and 200 gives fewer digits. | |

8. Measure the battery again while the toy is switched on, because a weak battery can drop sharply under load.
9. Mains is about 230 V AC and can kill or cause an arc, fire or a burst meter; it is work for trained people only.
10. The meter can survive bigger voltage spikes, so it can be used closer to where the supply enters a building.
11. Any voltage in the circuit spoils the reading and can damage the meter, which uses its own small current to measure.
12. 10 followed by two zeros: 1,000 Ω (1 k Ω) at $\pm 5\%$, so 950 Ω to 1,050 Ω .
13. Your body adds a second path, which makes the reading too low.
14. When the resistance between the probes is very low, showing an unbroken path.
15. It is open, broken inside.
16. In series: the circuit is opened and the meter fills the gap, so the current flows through it.
17. Move the red lead back to V Ω , so the next voltage measurement does not short the battery through the meter.
18. About $(9 - 2) \div 470 = 0.015$ A, which is about 15 mA.
19. Blue LEDs need about 3 V, which is more than many meters give in diode mode.
20. Use continuity on each pair of legs: two pairs beep all the time, and pressing the button joins one pair to the other.
21. Collector, base, emitter.
22. About 0.6 to 0.7 V, with the red probe on the base and the black probe on the emitter.

WORD LIST

Glossary

AC

alternating current, which changes direction many times a second, as in mains.

Auto-ranging

a meter that chooses the measuring range by itself.

CAT rating

a safety rating that shows where a meter may be used on mains circuits.

COM

the common socket, where the black lead always goes.

Continuity

an unbroken path for electricity.

Current

the flow of electricity, measured in amperes.

DC

direct current, which flows one way only, as from a battery.

Diode test

a meter mode that shows the forward voltage of a diode.

Forward voltage

the voltage needed to push current through a diode or LED.

Fuse

a thin wire that melts to break a circuit when too much current flows.

hFE

the current gain of a transistor.

Manual ranging

a meter on which you choose the range with the dial.

Open

a broken path, through which no current can flow.

Over-range

the display sign that the value is too large for the range.

Parallel

connected across a part, as when measuring voltage.

Probe

the pointed metal tip of a test lead, with an insulated handle.

Resistance

how much a part resists the flow of current, measured in ohms.

Series

connected in the path of the current, as when measuring current.

Short circuit

an unwanted path with almost no resistance.

Tolerance

how far a part's real value may be from its marked value.

Transient

a sudden, short spike of high voltage on a line.

Voltage

the push that drives current, measured in volts.



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