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FREE EBOOK

ROBOTICS AND ELECTRONICS

Robotics and Electronics Basics Study Book

The complete study notes, practice questions and glossary for
Robotics and Electronics Basics

INSIDE THIS BOOK

- Little Learners: What Is a Robot?
- Voltage, Current, Resistance and Ohm's Law
- Series and Parallel Circuits on a Breadboard
- Electronic Components: From Resistors to Relays
- ...and 3 more chapters, practice questions and a glossary

Beginner

School students starting robotics and electronics

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Robotics and Electronics Basics Study Book

Learn how electricity, circuits and electronic parts work, then use motors, sensors and batteries safely to understand how simple robots such as line followers and obstacle avoiders think and move.

WHO IT IS FOR	School students starting robotics and electronics
LEVEL	Beginner
SUBJECT AREA	Robotics and electronics
WHAT IS INSIDE	7 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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Little Learners: What Is a Robot?

Hello, little engineer!

This lesson is for our youngest learners, from KG to class 2. A grown-up can read it aloud with you.

A robot is a machine that can do a job by itself. Some robots clean floors. Some robots help to build cars in big factories. Some toy robots can walk, talk and even dance.

A robot has three parts

Think about your own body. You see with your eyes. You think with your brain. You move with your muscles. A robot works in the same way.

Your body	The robot	What it does
Eyes and ears	Sensors	Find out what is around
Brain	Controller, a tiny computer	Decides what to do
Muscles	Motors	Make the wheels and arms move

So a robot does three things again and again. It **senses**. It **thinks**. It **acts**.

Electricity is the robot's food

You eat roti and rice to get energy. A robot gets its energy from electricity. Small robots get electricity from a **battery**.

A battery has two ends. One end has a **plus** sign (+). The other end has a **minus** sign (-). When you put batteries into a toy, match the + and - signs on the battery with the signs inside the toy.

Electricity likes to go round and round

Electricity moves only when it has a full path, like a toy train on a round track. The path goes out of the battery, through a wire, through the bulb, and back into the battery. This round path is called a **circuit**.

- If the path is complete, the bulb glows.
- If there is a gap in the path, the bulb stays off.

A **switch** opens a gap or closes the gap. Switch on, and the path is complete, so the light comes on. Switch off, and there is a gap, so the light goes off. The fan and lights in your room work in this way too.

Stay safe, always

Never put your fingers, a wire or anything else into a wall socket. The electricity there is very strong and can hurt you badly.

- Play with batteries only when your teacher or a grown-up is with you.
- Never put a battery in your mouth, nose or ears. Small round button batteries are very dangerous if swallowed.
- If a battery or a wire feels hot, stop and tell a grown-up.
- Keep water away from anything electric.
- Wash your hands after playing with batteries.

Let us remember

Robots sense, think and act. A battery gives electricity. Electricity needs a full, round path called a circuit. A switch makes or breaks that path. And safety always comes first!

KEY POINTS

- A robot is a machine that can do a job by itself.
- A robot senses with sensors, thinks with a controller and moves with motors.
- A battery gives electricity and has a plus end and a minus end.
- Electricity flows only around a complete, round path called a circuit.
- Never touch a wall socket, and play with batteries only with a grown-up.

TRY THESE EXERCISES

1. Draw a robot and colour in its sensors (eyes), its controller (brain) and its motors (muscles), then tell a friend what each part does.
2. With your teacher, connect a battery holder, a switch and a small bulb or LED module, and turn the switch on and off to make and break the circuit.
3. With a grown-up, walk around your home and make a list of three things that run on batteries.

CHAPTER 2

Voltage, Current, Resistance and Ohm's Law

Three words every electronics student needs

Picture the water tank on the roof of a house in Jaipur. Water flows down a pipe to the tap in the kitchen. Electricity behaves in a similar way.

Quantity	Symbol	Unit	Water picture
Voltage	V	volt (V)	The pressure that pushes the water
Current	I	ampere (A)	How much water flows each second
Resistance	R	ohm (Ω)	A narrow part of the pipe that slows the flow

Voltage is the electrical push between two points. One AA cell gives about 1.5 V, and an Arduino Uno works at 5 V. **Current** is the rate at which electric charge flows. Small circuits use thousandths of an ampere, so we often write milliamperes: 1 A = 1000 mA.

Resistance is how strongly a part opposes the current.

Current flows only around a closed loop. Circuit diagrams show conventional current flowing out of the positive terminal and back into the negative terminal, although the electrons in the wire actually move the other way.

Ohm's law

The German scientist Georg Ohm found that the current through a resistor at a steady temperature is proportional to the voltage across it. We write this as $V = I \times R$.

Rearranged, it gives $I = V \div R$ and $R = V \div I$. A handy memory trick is a triangle with V on top and I and R side by side at the bottom: cover the quantity you want, and the other two show the formula.

Worked example 1: find the current

A 9 V battery is connected across a 450 Ω resistor.

$$I = V \div R = 9 \div 450 = 0.02 \text{ A, which is 20 mA.}$$

Worked example 2: find the voltage

A current of 0.5 A flows through a 12 Ω resistor.

$$V = I \times R = 0.5 \times 12 = 6 \text{ V.}$$

Worked example 3: find the resistance

Rohan wants 25 mA to flow from a 5 V supply. First change milliamperes to amperes: 25 mA = 0.025 A.

$$R = V \div I = 5 \div 0.025 = 200 \Omega.$$

Before using the formula, convert milliamperes to amperes (divide by 1000) and kilo-ohms to ohms (multiply by 1000).

Power: how hard a part is working

Power is measured in watts (W) and found with $P = V \times I$. In example 1, $P = 9 \times 0.02 = 0.18 \text{ W}$. The small resistors in most kits are rated for 0.25 W, so that resistor is safe. A part forced to handle more power than its rating gets hot and can burn out.

Measuring with a multimeter

A digital multimeter measures all three quantities.

- To measure **voltage**, touch the probes across the part (in parallel), with the dial on DC volts.
- To measure **current**, open the circuit and make the meter part of the loop (in series), with the red lead in the current socket.
- To measure **resistance**, switch the power off or take the part out of the circuit first.

KEY POINTS

- Voltage (volts) is the push, current (amperes) is the flow and resistance (ohms) opposes the flow.
- Ohm's law is $V = I \times R$, so $I = V \div R$ and $R = V \div I$.
- Convert mA to A and $k\Omega$ to Ω before you calculate.
- Power is $P = V \times I$, and every part has a maximum power rating.
- Measure voltage across a part and current in series with it.

TRY THESE EXERCISES

1. Use Ohm's law to find the current when 6 V is connected across a $300\ \Omega$ resistor, then check your answer of 20 mA with a multimeter at the centre.
2. Measure the voltage of a new AA cell and of a used one with a multimeter and compare the readings.
3. Make a table of five voltage and resistance pairs of your choice and calculate the current and the power for each.

CHAPTER 3

Series and Parallel Circuits on a Breadboard

Using a breadboard

A breadboard lets you build and change a circuit without soldering. You push component legs and jumper wires into its holes, and metal clips inside join them.

- In the main area, the holes are arranged in numbered rows. On a typical breadboard, the five holes of a row on one side of the centre gap (columns a to e, or f to j) are connected together inside.
- The centre gap separates the two halves, so the two halves of a row are **not** connected. Chips are placed across this gap.
- The long strips along the edges, marked + (red) and - (blue), are **power rails**. Connect the supply to them so every part can reach power easily. On some long breadboards the rails are split halfway along, so check with a multimeter.

Never put both legs of one component in the same connected row. That part is then shorted out and does nothing.

Series circuits

In a series circuit the parts are joined end to end, so there is only one path for the current.

- The **same current** flows through every part.
- The supply voltage is **shared**: the voltages across the parts add up to the supply voltage.
- The total resistance is the sum: $R = R_1 + R_2 + R_3$ and so on.
- If one part breaks, the whole loop stops, like a simple string of decorative lights in which one failed bulb puts all of them out.

Worked example: series

A $100\ \Omega$ and a $220\ \Omega$ resistor are in series across 5 V.

- Total resistance $R = 100 + 220 = 320\ \Omega$.
- Current $I = 5 \div 320 \approx 0.0156\ \text{A}$, about 15.6 mA.
- Voltage across the $100\ \Omega$ resistor $\approx 0.0156 \times 100 \approx 1.56\ \text{V}$, and across the $220\ \Omega$ resistor $\approx 3.44\ \text{V}$. Together they make 5 V.

Parallel circuits

In a parallel circuit each part sits on its own branch, connected directly across the supply.

- Every branch has the **same voltage**.
- The branch currents **add up** to the total current.
- The total resistance is **less than the smallest** branch resistance. For two resistors, $R = (R_1 \times R_2) \div (R_1 + R_2)$.
- If one branch breaks, the others keep working. This is why the lights and fans in your home are wired in parallel.

Worked example: parallel

A $100\ \Omega$ and a $300\ \Omega$ resistor are in parallel across 6 V.

- Current in the $100\ \Omega$ branch = $6 \div 100 = 0.06\ \text{A}$ (60 mA); in the $300\ \Omega$ branch = $6 \div 300 = 0.02\ \text{A}$ (20 mA).
- Total current = 80 mA.
- Total resistance = $(100 \times 300) \div (100 + 300) = 75\ \Omega$, and $6 \div 75 = 0.08\ \text{A}$ confirms it.

Cells in series and parallel

Two 1.5 V cells in series give 3 V, and four give 6 V. Identical cells in parallel keep the same voltage but can supply current for longer. Never connect cells of different types, ages or charge levels together.

KEY POINTS

- A breadboard joins the five holes of each row on one side of the centre gap; the edge strips are power rails.
- Series: one path, the same current everywhere, and voltages and resistances add.
- Parallel: separate branches, the same voltage on each, currents add, and the total resistance is below the smallest branch.
- Home wiring is parallel so each appliance works on its own.
- Cells in series add their voltages.

TRY THESE EXERCISES

1. On a breadboard, connect a $1\ \text{k}\Omega$ and a $2.2\ \text{k}\Omega$ resistor in series, calculate the total ($3.2\ \text{k}\Omega$), then measure it with a multimeter.
2. Calculate the total resistance of two $470\ \Omega$ resistors in parallel ($235\ \Omega$) and check it with a multimeter.
3. Build two LEDs, each with its own $220\ \Omega$ resistor, in parallel across a 5 V supply, then remove one LED and observe that the other keeps glowing.

Electronic Components: From Resistors to Relays

The resistor and its colour code

A resistor limits current. Most through-hole resistors show their value with coloured bands. Each colour stands for a digit.

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

On a four-band resistor, bands 1 and 2 are digits, band 3 tells you how many zeros to add, and band 4 is the tolerance (gold $\pm 5\%$, silver $\pm 10\%$). So red, red, brown, gold is 22 plus one zero = $220\ \Omega \pm 5\%$, and brown, black, red, gold is 10 plus two zeros = $1,000\ \Omega$, written $1\ \text{k}\Omega$.

The LED and its resistor

An LED (light-emitting diode) glows when current flows from its **anode** (+, the longer leg) to its **cathode** (-, the shorter leg, beside the flat edge of the rim). Connected the wrong way round, it stays off. Never connect an LED straight to a battery or a 5 V pin: it needs a resistor in series to limit the current.

$$R = (\text{supply voltage} - \text{LED forward voltage}) \div \text{LED current}$$

A red LED has a forward voltage of about 2 V (blue and white ones nearer 3 V). On 5 V at 15 mA: $R = (5 - 2) \div 0.015 = 200\ \Omega$. Use the next common kit value up, $220\ \Omega$.

The diode

A diode lets current pass in one direction only, like a one-way gate. The stripe marks the cathode. A silicon diode such as the 1N4007 drops about 0.7 V when it conducts. Diodes protect a circuit from a battery connected backwards, and a diode across a relay coil or motor absorbs the voltage spike produced when it switches off.

The capacitor

A capacitor stores electric charge. Its unit is the farad, and practical values are in microfarads (μF) or smaller. Capacitors smooth a wobbly supply and filter electrical noise. Electrolytic capacitors are polarised: a stripe marks the negative leg, and the longer leg is positive. Always choose a voltage rating higher than the circuit voltage.

The transistor as a switch

A small current into the **base** of an NPN transistor such as the BC547 lets a much larger current flow from its **collector** to its **emitter**. Connect the load between the positive supply and the collector, the emitter to ground, and drive the base through a resistor (around 1 k Ω from a 5 V signal is common). A weak signal can now switch a buzzer or a small relay. The BC547 handles only about 100 mA, so bigger loads need a bigger transistor.

The relay

A relay is a switch worked by an electromagnet. Current through its coil pulls a lever that connects the **COM** terminal to **NO** (normally open) and away from **NC** (normally closed). The coil side and the switched side are electrically separate, so a 5 V circuit can control a separate circuit.

Switching 230 V mains with a relay is a job only for a qualified adult. Students practise with low-voltage loads.

KEY POINTS

- Resistor bands give two digits, then the number of zeros, then the tolerance (gold is $\pm 5\%$).
- An LED needs a series resistor: $R = (\text{supply voltage} - \text{forward voltage}) \div \text{current}$.
- A diode conducts one way only, and its stripe marks the cathode.
- Electrolytic capacitors are polarised and need a voltage rating above the circuit voltage.
- A transistor or a relay lets a small signal switch a bigger load.

TRY THESE EXERCISES

1. Pick five resistors from the kit, read each colour code, and check your answers with a multimeter.
2. Calculate the resistor for a red LED (about 2 V) on a 9 V battery at 15 mA, then build the circuit with the nearest standard value above your answer (470 Ω).
3. Find the COM, NO and NC terminals on a relay module, then use the multimeter's continuity mode to see which pair is connected while the relay is off.

CHAPTER 5

Motors, Batteries and Power Safety

Motors turn electricity into movement

DC motor

A plain DC motor spins when a voltage is applied. Swap its two wires and it spins the other way. A higher voltage, or a PWM signal from a controller passed through a motor driver, changes its speed. A small DC motor spins very fast but with little turning force, called **torque**.

BO gear motor

The yellow BO (battery operated) motor found in most robot kits is a small DC motor joined to a plastic gearbox. The gears trade speed for torque, so the shaft turns slowly and strongly enough to drive a wheel directly. Check its rated voltage on the label or in the seller's details before you connect a battery.

Servo motor

A hobby servo such as the SG90 contains a motor, gears, a position sensor and a control circuit. You tell it an **angle**, usually between 0° and 180°, with a pulse sent about every 20 milliseconds; the width of the pulse, roughly 1 to 2 ms, sets the angle. It has three wires: ground (brown or black), power (red) and signal (orange, yellow or white). Servos suit steering, arms and grippers. A continuous-rotation servo is a separate type that spins like a wheel.

Stepper motor

A stepper motor turns in fixed steps, for example 1.8° per step, which is 200 steps per turn, so a controller can reach an exact position by counting steps. Steppers move 3D printers and CNC machines, and they always need a driver board; kits often pair the small 28BYJ-48 stepper with a ULN2003 driver.

A controller pin cannot power a motor. Motors need far more current, so they are driven through a motor driver such as the L298N, or through a transistor.

Batteries

Battery	Typical voltage	Notes
AA alkaline cell	1.5 V	Four in a holder give 6 V
9 V battery	9 V	Small capacity; runs down quickly with motors
Li-ion 18650 cell	3.7 V nominal, 4.2 V when full	Rechargeable; needs a proper charger and protection

Capacity is given in milliampere-hours (mAh). In theory a 2000 mAh battery could supply 200 mA for 10 hours; real use gives less.

Power safety rules

- Never short-circuit a battery by joining its terminals with a wire or a tool. A shorted Li-ion cell can get very hot and catch fire.
- Do not mix old and new cells, or different types, in one holder.
- Put a switch in the battery line, and disconnect power before changing any wiring.

- Charge Li-ion cells only with a charger made for them, never leave them charging unattended, and stop using any cell that is swollen, dented or hot.
- If a part smells hot or smokes, switch off at once.
- Never connect a student project to 230 V mains. Use batteries or a proper low-voltage adapter.

KEY POINTS

- Reversing a DC motor's wires reverses its direction; voltage or PWM sets its speed.
- A BO motor is a DC motor with a gearbox that trades speed for torque.
- A servo turns to a commanded angle; a stepper moves in exact, fixed steps.
- Motors are powered through a driver, never straight from a controller pin.
- Never short a battery, never mix cells, and keep projects away from mains.

TRY THESE EXERCISES

1. Connect a BO motor to a holder of two AA cells, note which way the wheel turns, then swap the wires and note the change.
2. Read the labels of three different batteries at the centre and write down each one's voltage and, where shown, its capacity in mAh.
3. Make a safety poster for your lab that lists the battery rules from this lesson.

CHAPTER 6

Sensors: IR, Ultrasonic, LDR and Touch

Sensors are a robot's senses

A sensor turns something in the world, such as light, distance or touch, into an electrical signal. Some sensors give a **digital** output, only HIGH or LOW, like yes or no. Others give an **analog** output, a voltage that changes smoothly.

IR sensor module

An infrared (IR) module has an IR LED that sends out invisible light and a receiver that detects light bouncing back. A white or shiny surface reflects plenty of IR; a black surface absorbs most of it. A comparator chip on the module turns the reading into a digital output, and a small potentiometer sets the sensitivity. Many modules make the

output LOW and light an indicator LED when they detect a reflection, but check your own module. IR modules are used for line following and short-range obstacle detection. Strong sunlight contains infrared and can confuse them.

Ultrasonic sensor (HC-SR04)

The HC-SR04 measures distance with sound too high-pitched for people to hear, at 40 kHz, much as a bat does.

1. The controller sends a pulse of at least 10 microseconds to the **Trig** pin.
2. The module sends out a short burst of ultrasound.
3. The sound hits an object and echoes back.
4. The **Echo** pin stays HIGH for as long as the sound took to travel there and back.

Because that time covers the journey both ways, the distance is half of $\text{time} \times \text{speed of sound}$. Sound travels at about 343 m/s in air at room temperature, which is 0.0343 cm per microsecond:

$$\text{distance (cm)} = \text{echo time } (\mu\text{s}) \times 0.0343 \div 2$$

If Echo stays HIGH for 1,166 μs , the object is about $1166 \times 0.0343 \div 2 \approx 20$ cm away. The module runs on 5 V and is rated for roughly 2 cm to 4 m. Soft cloth and steeply angled surfaces may not echo well.

LDR (light-dependent resistor)

An LDR's resistance is high in the dark and **falls** as the light gets brighter. Put it in a voltage divider with a fixed resistor, for example 10 k Ω , and the changing resistance becomes a changing voltage that a controller's analog input can read. LDRs are used in automatic night lamps and in robots that follow a torch.

Touch sensor

A capacitive touch module, many of which use the TTP223 chip, senses the small change in capacitance when a finger touches its pad, even through thin plastic, and gives a digital output. A push button does a similar job mechanically.

Sensor	Measures	Output
IR module	Reflected infrared light	Digital on most modules
HC-SR04	Distance, from echo time	A pulse on the Echo pin

Sensor	Measures	Output
LDR	Light level	Analog, through a divider
Touch module	A finger on the pad	Digital

KEY POINTS

- Digital sensors give HIGH or LOW; analog sensors give a smoothly changing voltage.
- IR modules detect reflected infrared: white surfaces reflect it and black surfaces absorb it.
- HC-SR04 distance = echo time × speed of sound ÷ 2.
- An LDR's resistance falls in brighter light, and it is read through a voltage divider.
- A capacitive touch module senses a finger and gives a digital output.

TRY THESE EXERCISES

1. Hold an IR module over white paper and then over black tape, watch its indicator LED, and adjust the potentiometer until it switches cleanly between the two.
2. Calculate the distance for echo times of 580 μ s and 2,900 μ s (about 10 cm and 50 cm).
3. Measure an LDR's resistance with a multimeter in room light, under a torch and covered by your hand, and record the three readings.

CHAPTER 7

How Simple Robots Work: Line Followers and Obstacle Avoiders

Sense, think, act

Every simple robot repeats one loop many times a second: read the sensors, decide what to do, then drive the motors. The controller, often an Arduino, runs the deciding part as a program.

Differential drive

Most kit robots have two BO motors driving the left and right wheels, plus a free castor wheel for balance. There is no steering wheel: the robot turns by running its wheels at different speeds or in different directions. This is called **differential drive**.

Left wheel	Right wheel	Robot
Forward	Forward	Goes straight
Stopped or slow	Forward	Turns left
Forward	Stopped or slow	Turns right
Backward	Forward	Spins left on the spot
Backward	Backward	Reverses

Line follower

A line follower tracks a black line on a white floor using two IR modules facing down, placed just either side of the line.

- Both sensors see white: the line is between them, so go straight.
- The left sensor sees black: the robot has drifted right, so turn left until that sensor sees white again.
- The right sensor sees black: turn right.
- Both sensors see black: the robot is at a junction or the finish, so stop, or follow a rule you choose.

As steps a controller can follow:

TEXT

```
repeat forever:
  read the left and right sensors
  if both see white: go forward
  else if left sees black and right sees white: turn left
  else if left sees white and right sees black: turn right
  else: stop, because both see black
```

Faster robots use three, five or more sensors so they can tell how far off the line they are and correct smoothly.

Obstacle avoider

An obstacle avoider carries an HC-SR04 at the front, often on a servo so it can look left and right.

TEXT

```
repeat forever:
  measure the distance ahead
  if the distance is more than 20 cm: go forward
  else:
    stop and reverse for a short time
    look left, then right, with the servo
    turn towards the side with more space
```

The 20 cm limit is a choice, not a rule. A faster robot needs a larger one, because it travels further before it can stop.

Common problems and fixes

- **Turns the wrong way:** swap the two wires of that motor, or swap the left and right rules in the program.
- **Zig-zags off the line:** lower the speed, or move the sensors closer to the line.
- **Controller resets when the motors start:** the battery is weak or shared badly; use fresh cells, a separate motor supply and a common ground.
- **Readings jump about:** press loose jumper wires home and shade IR sensors from sunlight.

Build and test one block at a time: the motors first, then each sensor on its own, then the full program.

KEY POINTS

- A robot repeats a sense, think, act loop many times a second.
- Differential drive steers by running the two wheels at different speeds or directions.
- A two-sensor line follower turns towards whichever sensor sees the line.
- An obstacle avoider stops, backs off and turns when the distance falls below a set limit.
- Test motors and each sensor separately before running the whole robot.

TRY THESE EXERCISES

1. On paper, draw a robot and a black line, and act out with a partner what the robot does in each of the four sensor cases.
2. Mark a 20 cm line with tape, push a robot towards a wall by hand, and note when its ultrasonic reading falls below 20.
3. Write your own rules, as steps, for a robot that stops when its touch sensor is pressed and starts again when it is pressed a second time.

CHECK YOURSELF

Practice questions

Choose the best answer for each question. The answers, with a short explanation, are in the next chapter.

1. In the "sense, think, act" idea, which part of a robot does the thinking?

- | | |
|-------------------|----------------|
| a) The motors | b) The battery |
| c) The controller | d) The wheels |

2. Why does the bulb in a simple battery circuit go off when the switch is turned off?

- | | |
|---|---|
| a) The battery stops making electricity as soon as the switch moves | b) The switch breaks the path, so the circuit is incomplete |
| c) The bulb cools down and stops working | d) The current starts to flow the other way round the loop |

3. Which part of a robot is like its muscles?

- | | |
|-----------------------|-------------------|
| a) Its motors | b) Its sensors |
| c) Its battery holder | d) Its controller |

4. Which is the unit of electric current?

- | | |
|-----------|---------|
| a) Ampere | b) Volt |
| c) Ohm | d) Watt |

5. A 9 V battery is connected across a 450 Ω resistor. What current flows?

- | | |
|-----------|----------|
| a) 2 mA | b) 0.5 A |
| c) 4.05 A | d) 20 mA |

6. What resistance lets a current of 25 mA flow from a 5 V supply?

- a) 125 Ω
- b) 200 Ω
- c) 20 Ω
- d) 2,000 Ω

7. How must a multimeter be connected to measure the current through an LED?

- a) In series, as part of the loop
- b) Across the LED, in parallel with it
- c) Directly across the battery terminals
- d) Anywhere, once the power is switched off

8. What power is used by a resistor with 9 V across it and 0.02 A flowing through it?

- a) 450 W
- b) 4.5 W
- c) 0.18 W
- d) 0.0022 W

9. A 100 Ω and a 220 Ω resistor are connected in series. What is their total resistance?

- a) 68.75 Ω
- b) 120 Ω
- c) 220 Ω
- d) 320 Ω

10. In a parallel circuit, which quantity is the same for every branch?

- a) The current
- b) The resistance
- c) The voltage
- d) The power

11. What is the total resistance of a 100 Ω and a 300 Ω resistor connected in parallel?

- a) 400 Ω
- b) 75 Ω
- c) 200 Ω
- d) 30 Ω

12. On a typical breadboard, which holes are connected together inside?

- a) Every hole on the board, including the power rails
- b) Holes facing each other across the centre gap
- c) None of them, because every hole is a separate socket
- d) The five holes of a row on one side of the centre gap

13. Why are the lights and fans in a home wired in parallel?

- a) So each one works on its own at the full voltage
- b) So that all of them switch on and off together
- c) So the total resistance of the house is as high as possible
- d) So the same current flows through every appliance

14. What is the value of a four-band resistor coloured red, red, brown, gold?

- a) $22\ \Omega \pm 10\%$
- b) $2,200\ \Omega \pm 5\%$
- c) $220\ \Omega \pm 5\%$
- d) $221\ \Omega \pm 5\%$

15. Which leg of an LED is the anode?

- a) The longer leg
- b) The shorter leg
- c) The leg beside the flat edge of the rim
- d) Either leg, because an LED has no polarity

16. Which resistor suits a red LED with a forward voltage of about 2 V, running at about 15 mA from a 5 V supply?

- a) $22\ \Omega$
- b) $220\ \Omega$
- c) $2.2\ \text{k}\Omega$
- d) $22\ \text{k}\Omega$

17. What does the stripe printed on a diode such as the 1N4007 mark?

- a) The anode
- b) The tolerance
- c) The cathode
- d) The maximum voltage

18. Why must an electrolytic capacitor be connected the right way round?

- a) It works only on alternating current, never on DC
- b) It has no voltage rating, so it can take any voltage
- c) It glows to show that it has been connected correctly
- d) It is polarised; a stripe marks the negative leg

19. In an NPN transistor used as a switch, what controls the larger current from collector to emitter?

- a) A small current into the base
- b) The current through the load alone
- c) The voltage of the emitter alone
- d) A magnet placed near the transistor

20. What is the main job of a relay?

- a) To store electric charge and release it when needed
- b) To measure the distance to an object ahead
- c) To change the light level into a varying voltage
- d) To switch a separate circuit using an electromagnet

21. How do you reverse the direction of a plain DC motor?

- a) Connect a bigger resistor in series
- b) Swap the two supply wires
- c) Use a battery with a higher voltage
- d) Add a capacitor across the motor

22. What does the gearbox on a BO motor do?

- a) Raises the speed and lowers the torque
- b) Turns it into a stepper motor
- c) Lowers the speed and raises the torque
- d) Lets it run from mains electricity

23. How do you tell a hobby servo such as the SG90 which angle to turn to?

- a) Change the battery voltage
- b) Send pulses whose width sets the angle
- c) Reverse its red and brown wires
- d) Count the steps it has taken

24. Which type of motor moves in fixed steps, such as 1.8° each, so its position can be set by counting steps?

- a) BO gear motor
- b) Plain DC motor
- c) Continuous-rotation servo
- d) Stepper motor

25. Why should a motor not be connected directly to a microcontroller pin?

- a) The pin cannot safely supply the current a motor needs
- b) The motor would spin far too fast for the robot to control
- c) The pin gives out alternating current only
- d) The motor would erase the program stored in the chip

26. Which of these is a safe practice with batteries?

- a) Mixing old and new cells in one holder
- b) Joining the terminals with a wire to test the battery
- c) Disconnecting power before changing the wiring
- d) Charging a Li-ion cell with any phone charger

27. On a line-following robot, what does each IR sensor module detect?

- a) Ultrasonic sound reflected back from the floor below
- b) Heat given off by the black line
- c) Infrared light reflected from the surface below
- d) The magnetic field produced by the line

28. Over which surface will an IR module receive the least reflected infrared?

- a) Black insulating tape
- b) White paper
- c) A shiny steel plate
- d) A white floor tile

- 29. The Echo pin of an HC-SR04 stays HIGH for 1,166 μ s. About how far away is the object, if sound travels 0.0343 cm per μ s?**
- a) 10 cm
 - b) 20 cm
 - c) 40 cm
 - d) 80 cm
- 30. Why is the echo time halved when calculating the distance measured by an ultrasonic sensor?**
- a) Sound slows down to half its speed in air
 - b) The sensor always sends two pulses at the same time
 - c) The Echo pin doubles the real time
 - d) The sound travels to the object and back again
- 31. What happens to an LDR's resistance as the light falling on it gets brighter?**
- a) It rises
 - b) It stays the same
 - c) It falls
 - d) It becomes exactly zero
- 32. In a two-sensor line follower, the left sensor sees the black line and the right sensor sees white. What should the robot do?**
- a) Turn left
 - b) Turn right
 - c) Stop
 - d) Reverse
- 33. How does a differential-drive robot turn?**
- a) By turning a front steering wheel left or right
 - b) By running its wheels at different speeds or directions
 - c) By switching off its sensors for a moment
 - d) By raising and lowering its battery voltage together
- 34. An obstacle-avoiding robot reads a distance of 12 cm when its set limit is 20 cm. What should its program do next?**
- a) Speed up and drive straight forward
 - b) Ignore the reading and keep going until it hits
 - c) Switch the ultrasonic sensor off and on again
 - d) Stop, back off and turn towards open space
- 35. Why does a faster obstacle-avoiding robot need a larger distance limit?**
- a) Its sensor measures less accurately at speed
 - b) It travels further before it can stop
 - c) Sound travels more slowly when the robot moves
 - d) Its motors stop working near walls

Answers

1. **(c) The controller.** The controller, a small computer, decides what to do; sensors gather information and motors carry out the action.
2. **(b) The switch breaks the path, so the circuit is incomplete.** Electricity flows only around a complete loop, and an open switch breaks that loop.
3. **(a) Its motors.** Motors make the wheels and arms move, just as muscles move the body.
4. **(a) Ampere.** Current is measured in amperes (A); the volt measures voltage, the ohm resistance and the watt power.
5. **(d) 20 mA.** By Ohm's law, $I = V \div R = 9 \div 450 = 0.02$ A, which is 20 mA.
6. **(b) 200 Ω .** $R = V \div I = 5 \div 0.025 = 200$ Ω , after converting 25 mA to 0.025 A.
7. **(a) In series, as part of the loop.** To measure current the meter must become part of the loop, in series with the LED.
8. **(c) 0.18 W.** Power is $P = V \times I = 9 \times 0.02 = 0.18$ W.
9. **(d) 320 Ω .** In series the resistances add: $100 + 220 = 320$ Ω .
10. **(c) The voltage.** Every branch of a parallel circuit is connected directly across the same supply, so each has the same voltage.
11. **(b) 75 Ω .** For two resistors in parallel, $R = (100 \times 300) \div (100 + 300) = 30,000 \div 400 = 75$ Ω .
12. **(d) The five holes of a row on one side of the centre gap.** Each short row of five holes is joined by a metal clip, and the centre gap separates the two halves of the row.
13. **(a) So each one works on its own at the full voltage.** Parallel branches share the same voltage and work independently, so switching off one does not affect the others.
14. **(c) 220 Ω $\pm 5\%$.** Red, red gives 22, brown adds one zero to make 220 Ω , and gold means a tolerance of $\pm 5\%$.
15. **(a) The longer leg.** The anode is the positive, longer leg; the cathode is the shorter leg next to the flat edge.
16. **(b) 220 Ω .** $R = (5 - 2) \div 0.015 = 200$ Ω , so 220 Ω , the next value up in the common E12 series found in most kits, is used.
17. **(c) The cathode.** The band on a diode marks the cathode, the end that current flows out of when the diode conducts.
18. **(d) It is polarised; a stripe marks the negative leg.** Electrolytic capacitors are polarised, so the negative leg, marked by the stripe, must go to the lower voltage side.
19. **(a) A small current into the base.** A small base current switches on a much larger collector-to-emitter current, which is how a weak signal controls a bigger load.

- 20. (d) To switch a separate circuit using an electromagnet.** Current in the relay's coil moves a switch contact, so a low-power circuit can control a separate one.
- 21. (b) Swap the two supply wires.** Reversing the polarity of the supply reverses the direction in which a DC motor spins.
- 22. (c) Lowers the speed and raises the torque.** The gears trade speed for torque, so the shaft turns slowly but strongly enough to drive a wheel.
- 23. (b) Send pulses whose width sets the angle.** A servo reads the width of a repeating control pulse, roughly 1 to 2 ms, and turns to the matching angle.
- 24. (d) Stepper motor.** A stepper motor turns one fixed step each time its driver switches the coils to the next position, so counting steps gives an exact position.
- 25. (a) The pin cannot safely supply the current a motor needs.** A pin can supply only a small current, so motors are driven through a motor driver or a transistor.
- 26. (c) Disconnecting power before changing the wiring.** Removing power before rewiring prevents accidental short circuits; the other three are unsafe.
- 27. (c) Infrared light reflected from the surface below.** The module sends out infrared light and senses how much reflects back: white reflects a lot and black very little.
- 28. (a) Black insulating tape.** Black surfaces absorb most infrared light, so very little is reflected back to the receiver.
- 29. (b) 20 cm.** Distance = $1166 \times 0.0343 \div 2 \approx 20$ cm; the time is halved because the sound travels there and back.
- 30. (d) The sound travels to the object and back again.** The measured time covers the journey out and the return, so the one-way distance uses half of it.
- 31. (c) It falls.** An LDR's resistance is high in the dark and falls as the light gets brighter.
- 32. (a) Turn left.** The robot has drifted right, so it turns left until the left sensor is back on white.
- 33. (b) By running its wheels at different speeds or directions.** With no steering wheel, the robot turns by making one wheel go slower, stop or reverse compared with the other.
- 34. (d) Stop, back off and turn towards open space.** A reading below the limit means an obstacle is close, so the robot stops, backs off and turns before moving on.
- 35. (b) It travels further before it can stop.** At higher speed the robot covers more ground between sensing an obstacle and stopping, so it must react earlier.

Glossary

Ampere

The unit of electric current, written A, where 1 A equals 1000 mA.

Anode

The positive leg of a diode or LED, through which conventional current enters.

Breadboard

A reusable board with connected rows of holes for building circuits without soldering.

Capacitor

A component that stores electric charge, measured in farads.

Cathode

The negative leg of a diode or LED, marked by a stripe on a diode and by the shorter leg on an LED.

Circuit

A complete, closed path around which electric current can flow.

Current

The rate of flow of electric charge, measured in amperes.

Differential drive

A way of steering a robot by running its left and right wheels at different speeds or in different directions.

Diode

A component that lets current flow in one direction only.

LDR

A light-dependent resistor, whose resistance falls as the light on it gets brighter.

LED

A light-emitting diode, which glows when current flows from its anode to its cathode.

Motor driver

A circuit, such as the L298N, that supplies the large current a motor needs under the control of a small signal.

Ohm

The unit of resistance, written with the symbol Ω .

Ohm's law

The rule $V = I \times R$ that links voltage, current and resistance.

Parallel circuit

A circuit in which each part has its own branch across the same voltage.

Relay

A switch worked by an electromagnet, which lets a small current control a separate circuit.

Resistor

A component that limits the current in a circuit.

Sensor

A device that turns something in its surroundings, such as light or distance, into an electrical signal.

Series circuit

A circuit with a single path, in which the same current flows through every part.

Servo motor

A motor with built-in control that turns to and holds a commanded angle.

Short circuit

An accidental path of very low resistance that lets a dangerously large current flow.

Stepper motor

A motor that turns in fixed, equal steps so that its position can be set exactly.

Transistor

A semiconductor device that uses a small current to switch or amplify a larger one.

Ultrasonic sensor

A sensor that measures distance by timing the echo of sound too high-pitched for people to hear.

Voltage

The electrical push between two points, measured in volts.



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