10.1 Circuit diagrams, e.m.f. and p.d.

Name: _____ Class: _____ Date: _____ **Total: 27 marks**

KEY WORDS electromotive force • potential difference • ammeter • voltmeter • circuit diagram

Objective

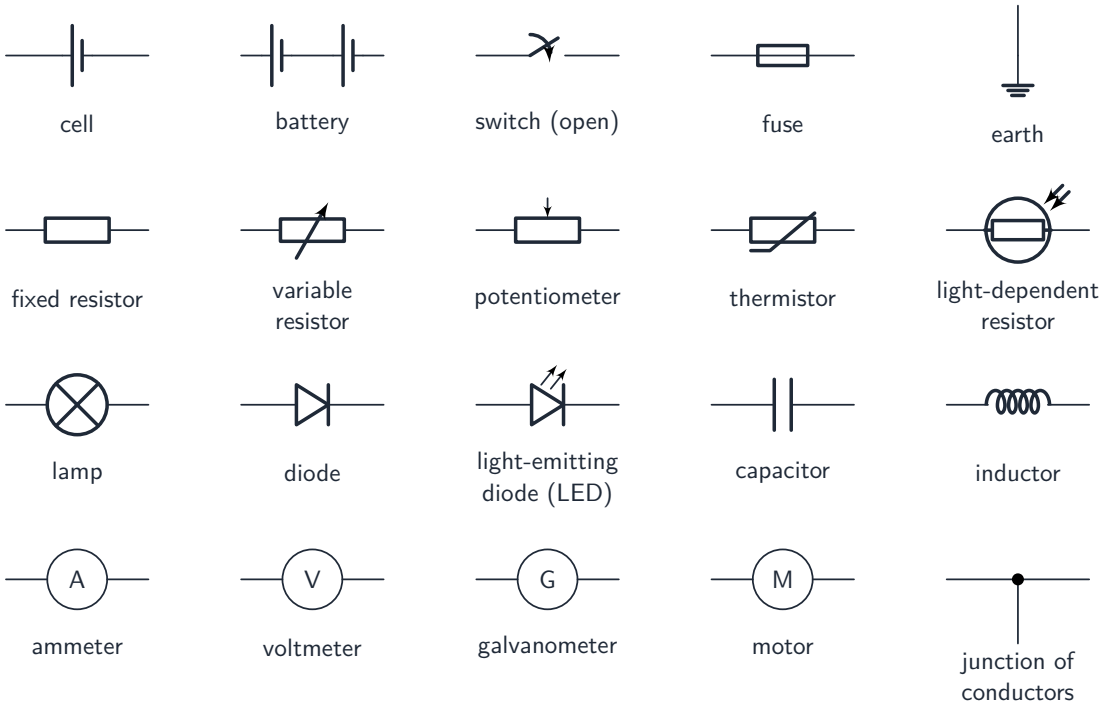
Answer exam questions on **practical circuits** : the circuit symbols, drawing and reading circuit diagrams, and the **electromotive force** (e.m.f.) of a source compared with the **potential difference** across a component. Syllabus 10.1, learning outcomes 1 to 4.

You must be able to:

- recognise and draw the circuit symbols, and draw a circuit that measures a current and a p.d.
- place an ammeter in series and a voltmeter in parallel, and read a circuit diagram
- define e.m.f. as energy transferred per unit charge in driving charge round a complete circuit
- distinguish e.m.f. from p.d. in terms of energy, and use $E = \frac{W}{Q}$

1 Key knowledge and worked examples

Key knowledge: symbols and diagrams



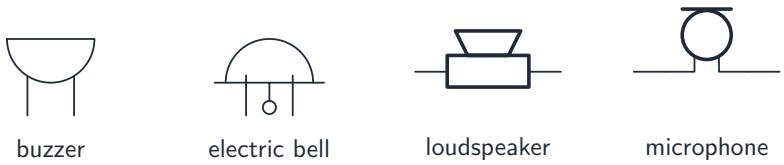
Rule	Why
an **ammeter** goes **in series** with the component	the same current must pass through it; an ideal ammeter has zero resistance
a **voltmeter** goes **in parallel** across the component	it compares the two ends; an ideal voltmeter has infinite resistance
draw with a ruler, straight wires, square corners, no gaps	a wire that stops short is a broken circuit
a dot marks a junction	wires that cross without a dot are not joined

Key knowledge: e.m.f. and p.d.

	Definition	Energy goes
e.m.f. E	the energy transferred **per unit charge** by a source in driving charge round a **complete circuit**, $E = \frac{W}{Q}$	**into** electrical energy (from chemical in a cell)
p.d. V	the energy transferred **per unit charge** passing through a component, $V = \frac{W}{Q}$	**out of** electrical energy (to thermal, light, kinetic)

- both are measured in volts, joules per coulomb: the difference is the **direction** of the energy transfer, so it must be stated in words about energy
- e.m.f. is not a force, despite its name
- round a circuit, the energy each coulomb gains from the e.m.f. equals the energy it gives up in the components

Key knowledge: recognising audio components



A buzzer and bell produce sound from electricity; a loudspeaker turns an electrical signal into sound, while a microphone converts sound into an electrical signal. In the reference chart, left to right: buzzer, bell, loudspeaker, microphone. Learn the outline as well as the function.

Worked example: drawing a measuring circuit

Draw a circuit to find the resistance of a lamp.

1. **Series loop** – cell, switch, variable resistor and lamp in one loop, with the **ammeter** in the same loop to measure the lamp's current.
2. **Voltmeter** – connected **across** the lamp only, not across the cell or the variable resistor.
3. **Result** – $R = \frac{V}{I}$ from the two readings; the variable resistor changes the current to take several readings.

■ **Worked example: energy from an e.m.f.**

A battery of e.m.f. 9.0 V drives a charge of 30 C round a circuit.

1. **Energy given to the charge** – the e.m.f. is the energy per coulomb, $E = \dfrac{W}{Q}$, so $W = EQ$; it is transferred from chemical to electrical energy:

$$W = EQ = (9.0\ \text{V})(30\ \text{C}) = 270\ \text{J}$$

2. **Where it goes** – the p.d. across the external circuit is 8.4 V, the energy each coulomb gives up there, $V = \dfrac{W}{Q}$:

$$W = VQ = (8.4\ \text{V})(30\ \text{C}) = 252\ \text{J}$$

3. **The rest** – what the charge was given but did not give up outside is transferred to thermal energy inside the battery:

$$W_{\text{inside}} = EQ - VQ = 270\ \text{J} - 252\ \text{J} = 18\ \text{J}$$

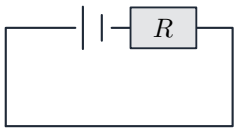
2 Practice

Now apply the methods above.

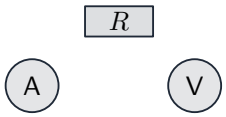
2.1 Define the **e.m.f.** of a source. [2]

e.m.f.

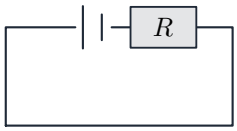
2.2 Explain, in terms of energy, the difference between the e.m.f. of a cell and the p.d. across a resistor. [2]



2.3 State how an ammeter and a voltmeter are connected to measure the current in, and the p.d. across, a resistor. [2]



2.4 A cell of e.m.f. 1.5 V drives a charge of 40 C round a circuit. Calculate the energy it transfers. [2]



1.5 V

40 C

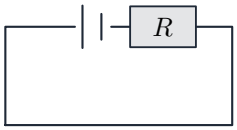
2.5 In the space below, draw a circuit containing a battery, a switch, a thermistor and a fixed resistor in series, with a voltmeter to measure the p.d. across the thermistor. [3]

2.6 Which of the four audio components converts sound into an electrical signal? Which two are commonly used to give an audible alarm? [3]

buzzer electric bell loudspeaker microphone

3 Exam-style questions

3.1 Which statement about the e.m.f. of a battery is correct? [1]



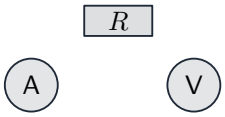
A It is the force that pushes the charges round the circuit.

B It is the energy transferred per unit charge in driving charge round a complete circuit.

C It is the energy transferred per unit charge to thermal energy in the circuit.

D It is the p.d. across the battery when it delivers a current.

3.2 An ideal voltmeter and an ideal ammeter are used in a circuit. Which row is correct? [1]



A voltmeter: zero resistance, in series; ammeter: infinite resistance, in parallel

B voltmeter: infinite resistance, in parallel; ammeter: zero resistance, in series

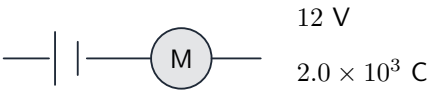
C voltmeter: infinite resistance, in series; ammeter: zero resistance, in parallel

D voltmeter: zero resistance, in parallel; ammeter: infinite resistance, in series

3.3 A 12 V battery supplies a charge of 2.0×10^3 C to a motor. The p.d. across the motor is 11 V.

(a) **Define** potential difference. [1]

(b) Calculate the energy transferred to electrical energy by the battery. [2]



(c) Calculate the energy transferred by the charge in the motor. [1]

(d) State where the rest of the energy is transferred, and explain your answer in terms of e.m.f. and p.d. [2]

3.4 A student wants to measure how the current in a filament lamp varies with the p.d. across it.

(a) In the space below, draw a circuit that the student could use, with a variable resistor to change the current. [3]

(b) State which meter reading changes if the voltmeter is wrongly connected across both the lamp and the variable resistor, and why. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- the energy transferred per unit charge (from other forms to electrical)
- in driving the charge round a complete circuit

2.2

- e.m.f.: energy transferred **to** electrical energy per unit charge, inside the source
- p.d.: energy transferred **from** electrical energy per unit charge, in the resistor (to thermal energy)

2.3

- the ammeter in series with the resistor
- the voltmeter in parallel with (across) the resistor

2.4

- from $E = \dfrac{W}{Q}$: $W = EQ$

$$W = EQ = (1.5\ \text{V})(40\ \text{C}) = \mathbf{60}\ \text{J}$$

2.5

- battery, switch, thermistor and resistor in one series loop, with correct symbols
- voltmeter drawn in parallel across the thermistor only
- a complete circuit with no gaps

2.6

Microphone; buzzer and electric bell.

3.1 B

- e.m.f. is the energy per unit charge transferred by the source round a complete circuit
- **A**: it is not a force; **C** describes a p.d.; **D** is the terminal p.d., which is less than the e.m.f. when a current flows

3.2 B

- a voltmeter goes across a component and should draw no current: infinite resistance; an ammeter goes in series and should not reduce the current: zero resistance

3.3

(a) the energy transferred per unit charge passing through a component

(b) from $E = \dfrac{W}{Q}$: $W = EQ$

$$W = EQ = (12\ \text{V})(2.0 \times 10^3\ \text{C}) = \mathbf{2.4 \times 10^4}\ \text{J}$$

(c) the p.d. across the motor is the energy each coulomb gives up there, $V = \dfrac{W}{Q}$, so $W = VQ$

$$W = VQ = (11\ \text{V})(2.0 \times 10^3\ \text{C}) = \mathbf{2.2 \times 10^4}\ \text{J}$$

(d) the rest of the energy the charge was given

$$W = EQ - VQ = 2.4 \times 10^4\ \text{J} - 2.2 \times 10^4\ \text{J} = 2.0 \times 10^3\ \text{J}$$

is transferred to thermal energy inside the battery (or in the connecting wires)

- the e.m.f. is the energy given to each coulomb, and the p.d. across the motor is the energy each coulomb gives up there; the difference is given up elsewhere in the circuit

3.4

(a) cell or power supply, variable resistor, lamp and ammeter in series

- voltmeter across the lamp only
- correct symbols, complete circuit

(b) the voltmeter reading: it now measures the p.d. across the lamp **and** the variable resistor, which is larger than the p.d. across the lamp alone

- so the lamp's p.d. is overestimated