Week 23

A-Level Physics

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

A-Level Physics Name: ______________ Score: ______

1. The e.m.f. is the energy given to each unit of charge by the ______.

   ____

2. 5.0 A flows into a junction and splits into two branches; one carries 2.0 A. What does the other carry?

   ____________ A

3. A 12 V supply is across $R_1 = 2.0\ \text{k}\Omega$ and $R_2 = 4.0\ \text{k}\Omega$ in series. What is the output across R_2?

   ____________ V

4. A cell of e.m.f. 12 V and internal resistance 0.50 Ω drives a current of 2.0 A. What is the terminal p.d.?

   ____________ V

5. A 3.0 Ω and a 6.0 Ω resistor are in series. What is the total resistance?

   ____________ Ω

6. In a potential divider, the p.d. across each resistor is proportional to its resistance.

   ☐ True ☐ False

7. A cell of e.m.f. 6.0 V and internal resistance 0.50 Ω is short-circuited. What current flows?

   ____________ A

8. Replacing one resistor in a divider with an LDR makes the output voltage depend on:

   ☐ the light level

   ☐ the temperature

   ☐ the time of day only

   ☐ nothing

9. An ideal ammeter has:

   ☐ zero resistance, connected in series

   ☐ infinite resistance, connected in series

   ☐ zero resistance, connected in parallel

   ☐ infinite resistance, connected in parallel

10. A parallel combination is always smaller than the smallest resistor in it.

    ☐ True ☐ False

A-Level Physics

1. **source**

   The source (battery, cell, generator) supplies energy to the charge; a component takes it back out (the p.d.).

2. **3 A**

   Current in = current out: $5.0 = 2.0 + I$, so $I = 3.0$ A.

3. **8 V**

   $V_{\text{out}} = V_{\text{in}} \dfrac{R_2}{R_1 + R_2} = 12 \times \dfrac{4.0}{2.0 + 4.0} = 8.0$ V.

4. **11 V**

   $V = \varepsilon - Ir = 12 - 2.0 \times 0.50 = 11$ V.

5. **9 Ω**

   $R = R_1 + R_2 = 3.0 + 6.0 = 9.0\ \Omega$.

6. **True**

   The same current flows through both, so $V = IR$ means the bigger resistor takes the bigger share.

7. **12 A**

   With $R_{\text{ext}} \to 0$, $I = \dfrac{\varepsilon}{r} = \dfrac{6.0}{0.50} = 12$ A.

8. **the light level**

   An LDR's resistance changes with light, so its share of the voltage — the output — tracks the brightness.

9. **zero resistance, connected in series**

   An ammeter goes in series and should add no resistance, so an ideal one has zero resistance.

10. **True**

    Yes — adding a parallel path gives the current another route, lowering the overall resistance.

A-LEVEL PHYSICS • EXERCISE SHEET

10.1 Practical circuits

Name: ____________ Class: ________ Date: __________ **Total: 14 marks**

KEY WORDS resistance 电阻 • internal resistance 内阻 • terminal p.d. 端电压 • open circuit 开路 • cell 电池

Objective

Build the skills to answer exam questions on **practical circuits** — e.m.f., p.d., and internal resistance.

You must be able to:

- define **e.m.f.** and distinguish it from **p.d.**
- explain **internal resistance** and use $V = \varepsilon - Ir$
- describe how to measure internal resistance

1 Worked examples

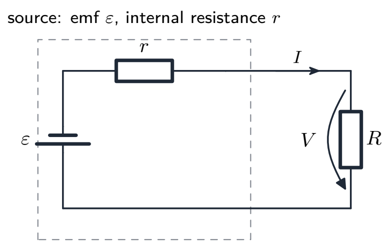
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

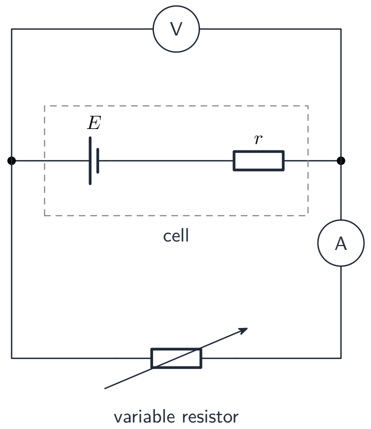
e.m.f. and p.d.

e.m.f. ε = energy given to each coulomb by the source (in driving it round the whole circuit). **p.d.** = energy transferred from electrical form by each coulomb in a component. Both in volts.

Internal resistance

A real cell has **internal resistance** r. When current flows, Ir is "lost" inside it, so the **terminal p.d.** is:





Internal resistance in a practical cell

$$V = \varepsilon - Ir.$$

- $I = 0$ (open circuit): $V = \varepsilon$;
- larger current $\to$ smaller terminal p.d.

Worked example. $\varepsilon = 1.5$ V, $r = 0.50\ \Omega$, $R = 2.5\ \Omega$: $I = \dfrac{\varepsilon}{R + r} = \dfrac{1.5}{3.0} = 0.50$ A; $V = \varepsilon - Ir = 1.5 - 0.25 = 1.25$ V.

To **measure** r: vary R, plot V against I — the intercept is ε and the gradient is $-r$.

2 Practice

Now apply the methods above.

2.1 Define the **e.m.f.** of a source. [1]

2.2 Write the equation linking **terminal p.d.**, e.m.f., current and internal resistance. [1]

2.3 State the terminal p.d. of a cell when **no current** flows. [1]

2.4 State **one** cause of a cell's internal resistance. [1]

3 Exam-style questions

3.1 A battery of e.m.f. 9.0 V drives two resistors, of 12 Ω and 6.0 Ω, connected in **parallel** with each other. The terminal p.d. is measured as 8.0 V. **Determine** the internal resistance of the battery, and the energy wasted inside it each second. [5]

3.2 As the current drawn from a cell **increases**, the terminal p.d.: [1]

- **A** increases
- **B** decreases
- **C** stays the same
- **D** becomes equal to the e.m.f.

3.3 Explain, in terms of **energy**, the difference between e.m.f. and p.d. [2]

3.4 Describe how a graph can be used to find the **internal resistance** of a cell. [2]

Solutions

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

2.1

- the **energy transferred per unit charge** by the source in driving charge **around the complete circuit**

2.2

- $V = \varepsilon - Ir$

2.3

- equal to the **e.m.f.** ε

2.4

- any one: the resistance of the **electrolyte** in a cell; the resistance of the **wire windings** in a generator

3.1

- the 12 Ω and 6.0 Ω are in parallel

$$\frac{1}{R} = \frac{1}{12\ \Omega} + \frac{1}{6.0\ \Omega} = \frac{1}{4.0\ \Omega} \Rightarrow R = 4.0\ \Omega$$

- the terminal p.d. 8.0 V is across that combination, so $I = V/R$

$$I = \frac{8.0\ \text{V}}{4.0\ \Omega} = 2.0\ \text{A}$$

- lost volts $= \varepsilon - V = 9.0\ \text{V} - 8.0\ \text{V} = 1.0\ \text{V}$, and $r = (\varepsilon - V)/I$

$$r = \frac{1.0\ \text{V}}{2.0\ \text{A}} = \mathbf{0.50}$$

- energy wasted per second $= I^2 r$

$$P = (2.0\ \text{A})^2(0.50\ \Omega) = \mathbf{2.0}\ \text{W} = 2.0\ \text{J s}^{-1}$$

3.2 B

- $V = \varepsilon - Ir$: a larger current means a larger Ir drop inside the cell, so the terminal p.d. **decreases**
- **A** is the opposite; **C** would need $r = 0$; **D** is the open-circuit case ($I = 0$)

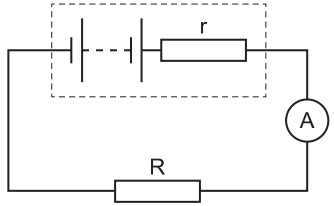
3.3

- **e.m.f.** is energy put **into** the circuit per coulomb by the source
- **p.d.** is energy taken **out** of the electrical form per coulomb in a component

3.4

- vary the external resistance and measure V and I
- plot V against I: the magnitude of the **gradient** is r (and the intercept is ε)

35 The diagram shows a circuit with a battery connected to a resistor R. The battery has an internal resistance represented by resistor r.



A second resistor, identical to R, is connected in parallel with R.

Which row describes the changes to the potential difference (p.d.) across r and the current shown on the ammeter when the second resistor is connected?

	p.d. across r	current shown on ammeter
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

34 A cell of electromotive force (e.m.f.) E delivers a charge Q to an external circuit.

Which statement is correct?

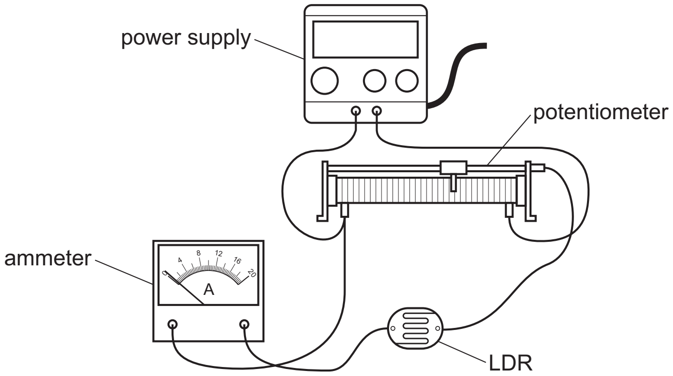
A The energy dissipated in the external circuit is EQ.

B The energy dissipated within the cell is EQ.

C The external resistance is EQ.

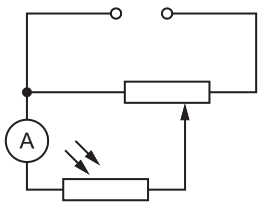
D The total energy dissipated in the cell and the external circuit is EQ.

33 The diagram shows an electrical circuit containing a light-dependent resistor (LDR).

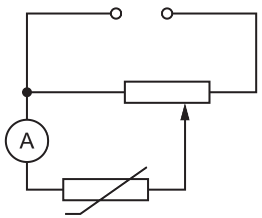


What is the circuit diagram for this circuit?

A



B



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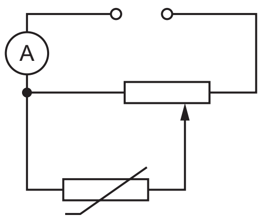
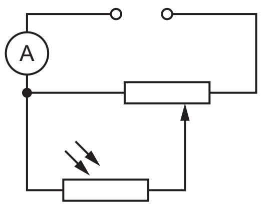
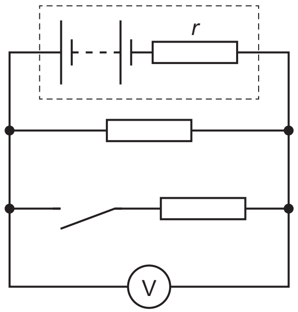


D



37 The circuit diagram shows a battery with internal resistance *r*, two resistors, a switch and a voltmeter. The switch is open.



The switch is now closed.

What happens to the current in the battery, and what happens to the reading on the voltmeter, when the switch is closed?

	current in battery	reading on voltmeter
A	increases	decreases
B	increases	remains the same
C	remains the same	decreases
D	remains the same	remains the same

5 Fig. 5.1 shows a circuit containing a battery, two fixed resistors X and Y, and a light-dependent resistor (LDR) Z.

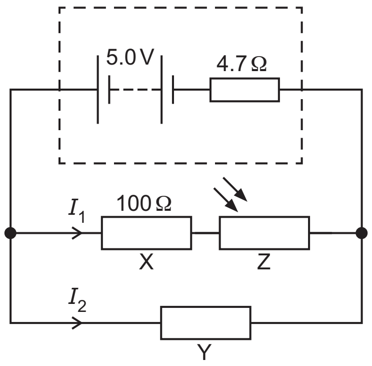
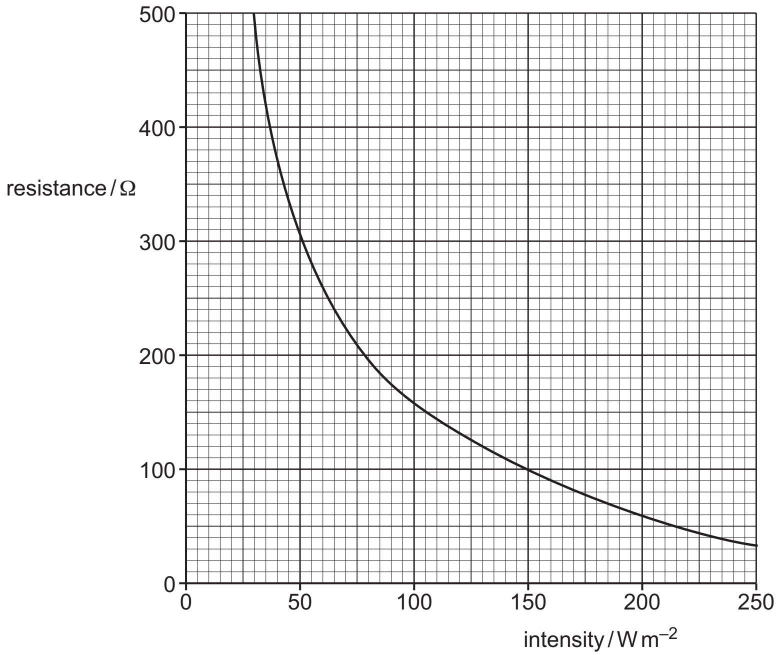


Fig. 5.1

The battery has electromotive force (e.m.f.) 5.0 V and internal resistance 4.7 Ω. The current in X is I_1 and the current in Y is I_2.

The resistance of X is 100 Ω. The resistance of Z varies with the intensity of light incident on it as shown in Fig. 5.2.



Fig

(a) State Kirchhoff's first law.

....

.... [1]

(b) The intensity of light incident on Z is 130 W m^{-2}. The current in the battery is 38 mA.

(i) Show that the terminal potential difference of the battery is 4.8 V.

[2]

(ii) Calculate the current I_2 in Y.

I_2 = ... A [3]

(iii) Calculate the power dissipated in Y.

power = ... W [2]

(iv) The intensity of the light incident on Z decreases.

State and explain the effect on the terminal potential difference of the battery.

....

....

....

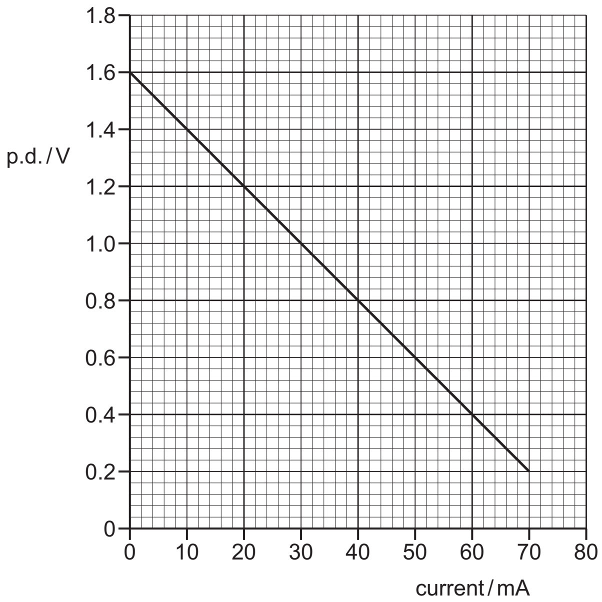
....

.... [3]

[Total: 11]

37 A cell is connected in series with an ammeter and a variable resistor. A voltmeter is used to measure the p.d. across the variable resistor. The resistance of the variable resistor is varied, and the p.d. and the current are recorded.

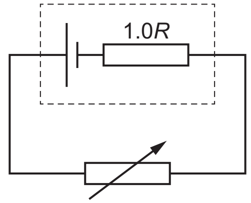
The graph shows the variation with current of the p.d. across the variable resistor.



What is the internal resistance of the cell?

A 0.050 Ω **B** 1.6 Ω **C** 20 Ω **D** 23 Ω

35 The diagram shows a cell of internal resistance 1.0*R* connected to a variable resistor.



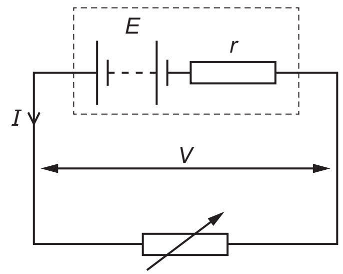
When the variable resistor has an initial resistance of 2.0*R*, the current in the cell is I_1 and the terminal potential difference (p.d.) across the cell is V_1.

The variable resistor is now adjusted to a new resistance of 4.0*R*.

What is the new current in the cell and the new terminal p.d. across the cell?

	current	terminal p.d.
A	$0.50I_1$	$1.0V_1$
B	$0.50I_1$	$1.2V_1$
C	$0.60I_1$	$1.0V_1$
D	$0.60I_1$	$1.2V_1$

36 A battery has an e.m.f. *E* and internal resistance *r*. The battery delivers a current I to a variable resistor and the p.d. across its terminals is *V*.



The variable resistor is adjusted so that I increases.

Why does *V* decrease?

A The e.m.f. *E* decreases.

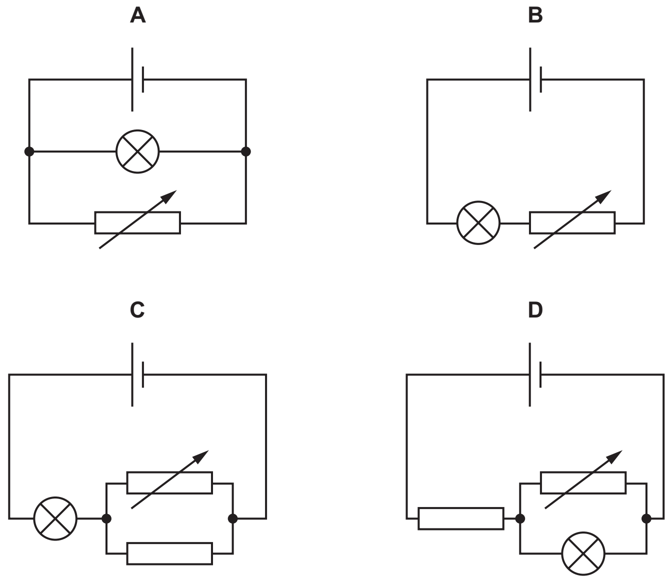
B The internal resistance *r* increases.

C The p.d. across *r* increases.

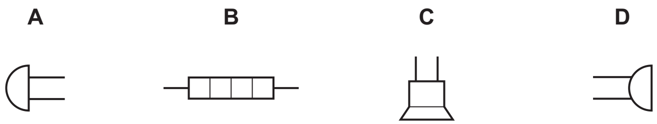
D The resistance of the variable resistor increases.

33 A cell of constant electromotive force (e.m.f.) and negligible internal resistance is separately connected into four different circuits.

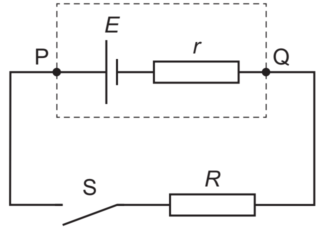
In which circuit does the power dissipated by the lamp stay the same as the variable resistor is adjusted?



34 Which circuit symbol does **not** represent an electric component that is designed to emit sound waves?



36 A cell of electromotive force (e.m.f.) E and internal resistance r is connected in series with a switch S and an external resistor of resistance R.



The potential difference (p.d.) between P and Q is V.

Which statement is correct when S is changed from open to closed?

A V increases because there is a p.d. across R.

B V decreases because there is a p.d. across r.

C V remains the same because the decrease of p.d. across r is balanced by the increase of p.d. across R.

D V remains the same because the sum of the p.d.s across r and R is still equal to E.

7 **(a)** Fig. 7.1 shows two resistors connected in series with a cell of electromotive force (e.m.f.) 1.50 V and internal resistance 0.28 Ω.

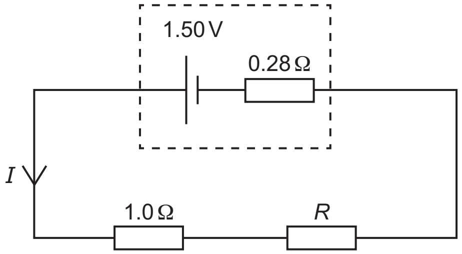


Fig. 7.1

One of the resistors has resistance 1.0 Ω. The other resistor has resistance R.
The terminal potential difference (p.d.) across the cell is 1.36 V.

(i) Show that the current I in the circuit is 0.50 A.

[2]

(ii) Calculate the combined resistance of the two resistors.

resistance = ... Ω [2]

(iii) Use your answer in **(a)(ii)** to determine resistance R.

R = ... Ω [1]

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(b) The circuit in Fig. 7.1 is disconnected and the two resistors are reconnected to the cell, now in parallel with each other.

(i) On Fig. 7.2, complete the circuit diagram to show this arrangement.

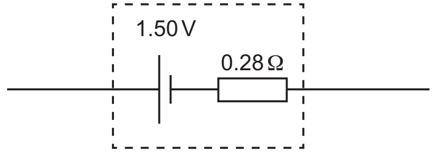


Fig. 7.2

[1]

(ii) Explain, without calculation, whether the terminal p.d. across the cell is now less than, equal to or greater than 1.36 V.

....

....

.... [2]

[Total: 8]

A-LEVEL PHYSICS • EXERCISE SHEET

10.2 Kirchhoff's laws

Name: ______________ Class: __________ Date: ____________ **Total: 19 marks**

KEY WORDS kirchhoff's first law 基尔霍夫第一定律 • kirchhoff's second law 基尔霍夫第二定律 • resistance 电阻 • internal resistance 内阻 • parallel 并联

Objective

Build the skills to answer exam questions on **Kirchhoff's laws** and analysing **combined** circuits.

You must be able to:

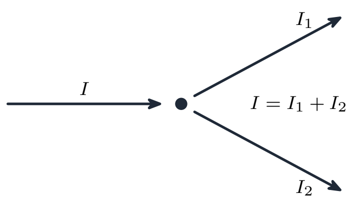
- state both **Kirchhoff's laws** and the conservation law each follows from
- combine resistors in **series** and **parallel**
- analyse a **combined** circuit: total resistance, total current, then each **branch** current and p.d.

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Kirchhoff's laws

First law (junction): current **in** = **current out** — from conservation of **charge**:



Second law (loop): around any closed loop, the **total e.m.f.** = **total p.d.** — from conservation of **energy**.

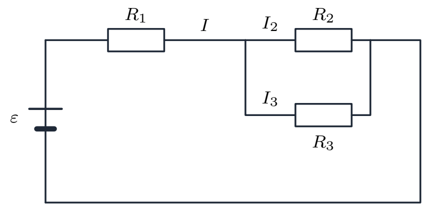
Combining resistors

- **Series** (same current): $R = R_1 + R_2 + \ldots$
- **Parallel** (same p.d.): $\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

Worked example. 3.0 Ω and 6.0 Ω in parallel: $\dfrac{1}{R} = \dfrac{1}{3.0} + \dfrac{1}{6.0} = \dfrac{1}{2.0}$, so $R = 2.0\ \Omega$.

Analysing a combined circuit

Real exam circuits mix series and parallel. Work in **steps**: collapse the parallel part, find the total current, then split it.



Worked example. $\varepsilon = 12$ V (negligible internal resistance), $R_1 = 4.0\ \Omega$ in series with $R_2 = 6.0\ \Omega$ and $R_3 = 3.0\ \Omega$ in parallel.

1. Parallel pair: $\dfrac{1}{R_\text{p}} = \dfrac{1}{6.0} + \dfrac{1}{3.0} = \dfrac{1}{2.0}$, so $R_\text{p} = 2.0\ \Omega$.
2. Total: $R = R_1 + R_\text{p} = 4.0 + 2.0 = 6.0\ \Omega$; current $I = \dfrac{\varepsilon}{R} = \dfrac{12}{6.0} = 2.0$ A.
3. P.d. across the parallel part: $V_\text{p} = IR_\text{p} = 2.0 \times 2.0 = 4.0$ V.
4. Branch currents: $I_2 = \dfrac{V_\text{p}}{R_2} = \dfrac{4.0}{6.0} = 0.67$ A, $I_3 = \dfrac{V_\text{p}}{R_3} = \dfrac{4.0}{3.0} = 1.33$ A (check: $0.67 + 1.33 = 2.0$ A ✓).

2 Practice

Now apply the methods above.

2.1 State **Kirchhoff's first law** and which conservation law it follows from. [2]

2.2 State **Kirchhoff's second law** and which conservation law it follows from. [2]

2.3 Find the combined resistance of 4.0 Ω and 6.0 Ω in **series**. [1]

2.4 Find the combined resistance of two 4.0 Ω resistors in **parallel**. [2]

3 Exam-style questions

3.1 Three 6.0 Ω resistors in **parallel** have a combined resistance of: [1]

- **A** 2.0 Ω
- **B** 6.0 Ω
- **C** 18 Ω
- **D** 0.50 Ω

3.2 A 12 V battery drives current through a 3.0 Ω and a 6.0 Ω resistor in **series**. Calculate the current and the p.d. across each resistor. [4]

3.3 A battery of e.m.f. 6.0 V and negligible internal resistance is connected to $R_1 = 2.0\ \Omega$ in series with two resistors $R_2 = 4.0\ \Omega$ and $R_3 = 4.0\ \Omega$ in **parallel** (as in the worked example).

(a) Calculate the total resistance and the current from the battery. [3]

(b) Calculate the current in **each** of R_2 and R_3. [3]

3.4 At a junction, 5.0 A enters and one branch carries 2.0 A away. Find the current in the other branch. [1]

Solutions

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

2.1

- the **total current into a junction equals the total current out**
- it follows from conservation of **charge**

2.2

- around any closed loop, the **total e.m.f. equals the total p.d.**
- it follows from conservation of **energy**

2.3

- series: $R = R_1 + R_2$

$$R = 4.0\ \Omega + 6.0\ \Omega = \mathbf{10}$$

2.4

- parallel: $1/R = 1/R_1 + 1/R_2$

$$\frac{1}{R} = \frac{1}{4.0\ \Omega} + \frac{1}{4.0\ \Omega} = \frac{1}{2.0\ \Omega} \Rightarrow R = \mathbf{2.0}$$

3.1 A

- three equal resistors in parallel: $R = R_1/3$

$$R = \frac{6.0\ \Omega}{3} = \mathbf{2.0}$$

- **B** is one resistor; **C** is series; **D** would be twelve in parallel

3.2

- series: $R = 3.0\ \Omega + 6.0\ \Omega = 9.0\ \Omega$

$$I = \frac{12\ \text{V}}{9.0\ \Omega} = \mathbf{1.33}\ \text{A}$$

- $V = IR$

$$V_3 = (1.33\ \text{A})(3.0\ \Omega) = \mathbf{4.0}\ \text{V}$$

$$V_6 = (1.33\ \text{A})(6.0\ \Omega) = \mathbf{8.0}\ \text{V}$$

3.3

(a) parallel pair

$$\frac{1}{R_\text{p}} = \frac{1}{4.0\ \Omega} + \frac{1}{4.0\ \Omega} = \frac{1}{2.0\ \Omega} \Rightarrow R_\text{p} = 2.0\ \Omega$$

- total $R = R_1 + R_\text{p} = 2.0\ \Omega + 2.0\ \Omega = \mathbf{4.0}$

$$I = \frac{6.0\ \text{V}}{4.0\ \Omega} = \mathbf{1.5}\ \text{A}$$

(b) $V_\text{p} = IR_\text{p}$

$$V_\text{p} = (1.5\ \text{A})(2.0\ \Omega) = 3.0\ \text{V}$$

- each branch

$$I = \frac{3.0\ \text{V}}{4.0\ \Omega} = \mathbf{0.75}\ \text{A}$$

- the two currents are equal because $R_2 = R_3$

3.4

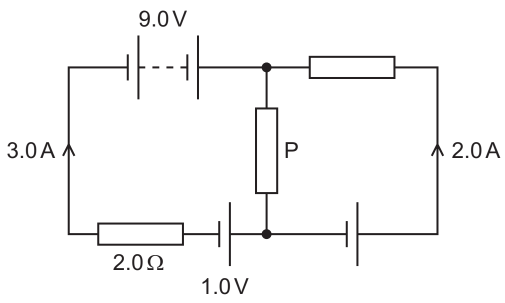
- Kirchhoff 1: current in = current out

$$I = 5.0\ \text{A} - 2.0\ \text{A} = \mathbf{3.0}\ \text{A}$$

34 The diagram shows a circuit containing a battery and cells with negligible internal resistance.

Some values of current, electromotive force (e.m.f.) and resistance are shown.

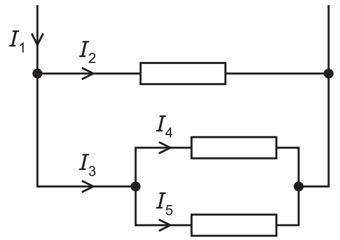
One resistor is labelled P.



What is the resistance of resistor P?

A 0.40 Ω **B** 0.80 Ω **C** 2.0 Ω **D** 2.8 Ω

37 The diagram shows the currents in part of an electric circuit.



The resistors are identical.

Which equation is **not** correct?

A $I_1 = I_2 + I_4 + I_5$

B $I_2 = I_1 - I_3$

C $I_2 = I_3 + I_4 + I_5$

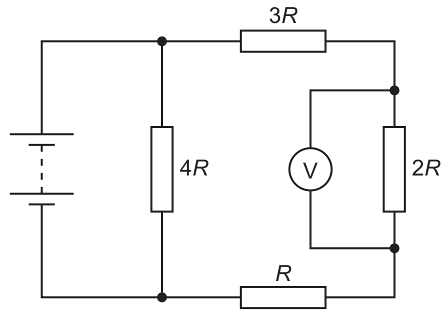
D $I_4 = I_3 - I_5$

37 The principles of conservation of which two quantities are associated with Kirchhoff's first and second laws?

	first law	second law
A	charge	energy
B	charge	voltage
C	energy	charge
D	voltage	charge

36 Four resistors of resistance R, $2R$, $3R$ and $4R$ are connected to form a network.

A battery of negligible internal resistance and a voltmeter are connected to the resistor network as shown.



The voltmeter reading is 2 V.

What is the electromotive force (e.m.f.) of the battery?

A 2 V **B** 4 V **C** 6 V **D** 10 V

5 **(a)** State Kirchhoff's first law.

....

.... [1]

(b) Fig. 5.1 shows a circuit containing a thermistor T that has a negative temperature coefficient.

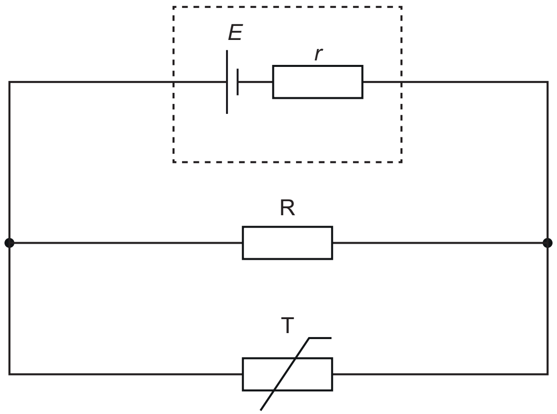


Fig. 5.1

(i) The thermistor has resistance R_0 at a temperature of 0 °C.

On Fig. 5.2, sketch a possible variation of the resistance of the thermistor with temperature between 0 °C and 100 °C.

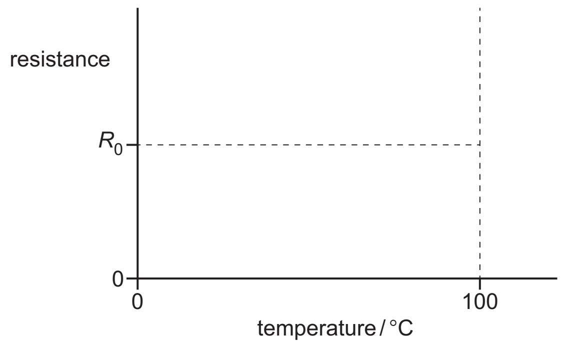


Fig. 5.2

[2]

(ii) With reference to the current in the cell, explain why the current in **resistor R** decreases with increasing temperature of the thermistor.

....

....

....

....

.... [3]

(c) The electromotive force (e.m.f.) *E* of the cell in Fig. 5.1 is 1.50 V. The internal resistance *r* of the cell is 0.12 Ω.

Resistor R has a resistance of 6.00 Ω.

At a particular temperature of the thermistor, the current in R is 0.200 A.

For this temperature of the thermistor, determine:

(i) the current in the cell

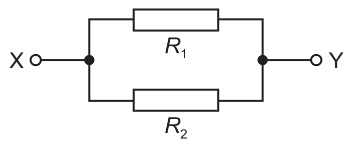
current = ...A [2]

(ii) the resistance of the thermistor.

resistance = ... Ω [2]

[Total: 10]

36 Two resistors of resistances R_1 and R_2 are connected in parallel.



What is the combined resistance between X and Y?

A $R_1 + R_2$ **B** $\dfrac{R_1 R_2}{R_1 + R_2}$ **C** $\dfrac{R_1 + R_2}{R_1 R_2}$ **D** $\dfrac{R_1}{R_2}$

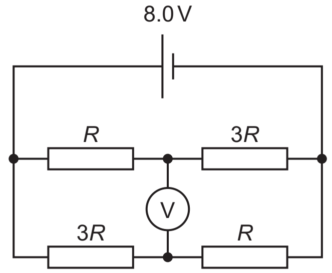
37 Each of Kirchhoff's two laws presumes that some quantity is conserved.

Which row states Kirchhoff's **first** law and names the quantity that is conserved?

	statement	quantity
A	The algebraic sum of currents at a junction is zero.	charge
B	The algebraic sum of currents at a junction is zero.	energy
C	The e.m.f. in a loop is equal to the algebraic sum of the product of current and resistance round the loop.	charge
D	The e.m.f. in a loop is equal to the algebraic sum of the product of current and resistance round the loop.	energy

35 Two resistors of resistance R and two resistors of resistance $3R$ are connected to a cell of e.m.f. 8.0 V as shown.

The cell has negligible internal resistance.



What is the reading on the voltmeter?

A 0.0 V **B** 2.0 V **C** 4.0 V **D** 6.0 V

34 The sum of the electrical currents into a point in a circuit is equal to the sum of the currents out of the point.

Which statement is correct?

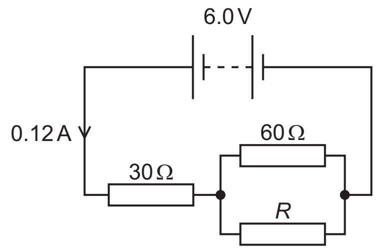
A This is Kirchhoff's first law, which results from the conservation of charge.

B This is Kirchhoff's first law, which results from the conservation of energy.

C This is Kirchhoff's second law, which results from the conservation of charge.

D This is Kirchhoff's second law, which results from the conservation of energy.

35 A battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance is connected to three resistors, as shown.



The current in the battery is 0.12 A.

What is resistance R?

A 12 Ω **B** 30 Ω **C** 50 Ω **D** 60 Ω

6 A battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance is connected in series with a variable resistor and a uniform resistance wire XY, as shown in Fig. 6.1.

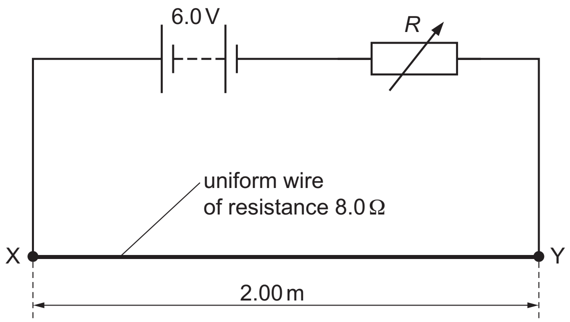


Fig. 6.1

Wire XY has length 2.00 m and resistance 8.0 Ω. The resistance *R* of the variable resistor is adjusted so that the potential difference across wire XY is 2.4 V.

(a) Determine *R*.

R = ... Ω [2]

(b) Explain why the potential difference *V* between any two points on wire XY is proportional to the distance *L* between those points.

....

....

....

.... [2]

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(c) A cell of e.m.f. *E* and internal resistance *r* is connected to the circuit, as shown in Fig. 6.2.

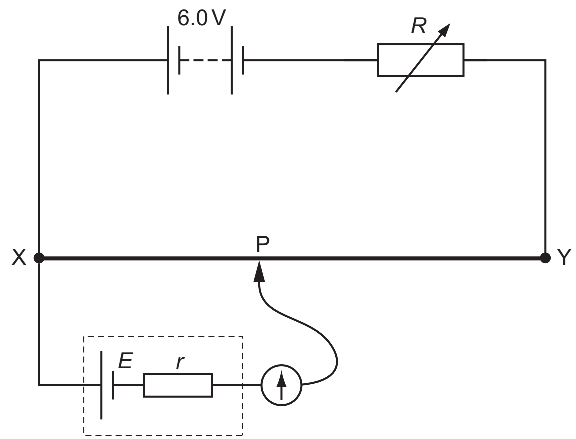


Fig. 6.2

Resistance *R* is unchanged.
The movable connection P is positioned on wire XY so that the galvanometer reading is zero.
Distance XP is 1.24 m.

(i) Calculate *E*.

E = ... V [2]

(ii) The value of *R* is now decreased.

State and explain the change that must be made to the position of P on wire XY so that the galvanometer reads zero again.

....

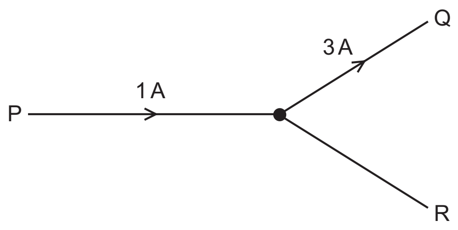
....

....

.... [2]

[Total: 8]

35 The diagram shows a junction in a circuit where three wires, P, Q and R, meet. The currents in P and Q are 1 A and 3 A respectively, in the directions shown.



How much charge passes a given point in wire R in a time of 5 s?

A 0.4 C **B** 2 C **C** 10 C **D** 20 C

A-LEVEL PHYSICS • EXERCISE SHEET

10.3 Potential dividers

Name: ____________ Class: ________ Date: __________ **Total: 19 marks**

KEY WORDS null method 零点法 • potential divider 分压器 • galvanometer 检流计 • potentiometer 电位差计 • thermistor 热敏电阻

Objective

Build the skills to answer exam questions on **potential dividers** — the divider equation, the uniform wire, and sensor circuits.

You must be able to:

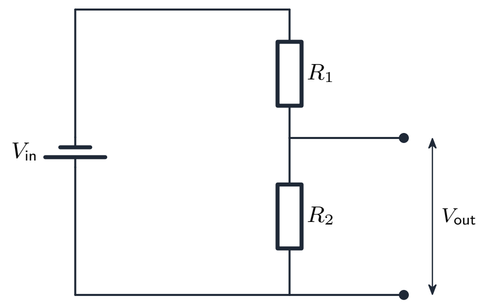
- use the **potential divider** equation
- explain why p.d. is proportional to **length** on a **uniform** wire ($V \propto L$)
- explain **thermistor** and **LDR** divider circuits, and the potentiometer null method

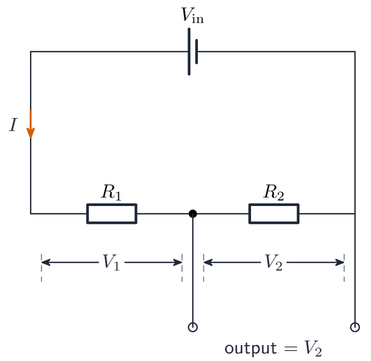
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Potential divider

Two resistors in series share V_{in} in proportion to their resistances. The output across R_2 is:





A potential divider splits the voltage

$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}.$$

Worked example. 6.0 V across 2.0 kΩ + 4.0 kΩ, output across the 4.0 kΩ: $V_{out} = 6.0 \times \frac{4.0}{6.0} = 4.0$ V.

■ **Uniform wire:** $V \propto L$

A **uniform** resistance wire has the same resistance per unit length, so resistance is proportional to length ($R = \rho L/A$ with ρ, A constant). A length of wire is just a potential divider, so the **p.d. across a length is proportional to that length**:

$$V = V_{wire} \cdot \frac{L}{L_{total}}.$$

Worked example. A 2.0 V supply is across a uniform wire of length 100 cm. The p.d. across the first 30 cm is $V = 2.0 \times \frac{30}{100} = 0.60$ V. This $V \propto L$ rule is the basis of the **potentiometer**.

■ **Sensor circuits**

Replace a resistor with a **sensor**: a **thermistor** (R falls as temperature rises) or an **LDR** (R falls as light rises). The output voltage then changes with temperature or light, and can switch a load.

■ **Potentiometer**

A uniform wire with a sliding contact compares e.m.f.s by a **null method**: slide until a **galvanometer** reads **zero** (no current), so the balance lengths are in the ratio of the e.m.f.s.

2 Practice

Now apply the methods above.

2.1 State what a **potential divider** does. [1]

2.2 A 6.0 V supply is across a 2.0 kΩ and a 4.0 kΩ resistor in series. Find the p.d. across the 4.0 kΩ resistor. [2]

2.3 A uniform wire of length 80 cm has 4.0 V across its ends. Find the p.d. across the first 20 cm. [2]

2.4 State what happens to a **thermistor's** resistance as temperature rises. [1]

3 Exam-style questions

3.1 A 12 V supply is across $R_1 = 3.0$ kΩ and $R_2 = 1.0$ kΩ in series. Find V_{out} taken across R_2. [2]

3.2 A 6.0 V supply of negligible internal resistance is connected to a variable resistor R in series with a uniform resistance wire XY of resistance 8.0 Ω.

(a) R is adjusted so the p.d. across XY is 2.4 V. Calculate R. [3]

(b) Explain why the p.d. between any two points on wire XY is **proportional to the distance** between them. [2]

3.3 In a divider, a thermistor is in series with a fixed resistor and the output is taken across the **thermistor**. The temperature **rises**. Explain what happens to the output voltage. [3]

3.4 Explain how an **LDR** in a potential divider can be used to switch a lamp **on** when it gets dark. [3]

Solutions

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

2.1

- splits an input voltage into a chosen smaller output voltage, sharing it between resistors in proportion to their resistances

2.2

- $V_{\text{out}} = V_{\text{in}} \cdot R_2/(R_1 + R_2)$

$$V = (6.0\ \text{V}) \times \frac{4.0\ \text{k}\Omega}{2.0\ \text{k}\Omega + 4.0\ \text{k}\Omega} = \mathbf{4.0}\ \text{V}$$

2.3

- a uniform wire: $V \propto L$

$$V = (4.0\ \text{V}) \times \frac{20\ \text{cm}}{80\ \text{cm}} = \mathbf{1.0}\ \text{V}$$

2.4

- it **decreases**

3.1

- $V_{\text{out}} = V_{\text{in}} \cdot R_2/(R_1 + R_2)$

$$V_{\text{out}} = (12\ \text{V}) \times \frac{1.0\ \text{k}\Omega}{3.0\ \text{k}\Omega + 1.0\ \text{k}\Omega} = \mathbf{3.0}\ \text{V}$$

3.2

(a) the wire and R form a potential divider

$$V_{\text{XY}} = \varepsilon \cdot \frac{R_{\text{XY}}}{R + R_{\text{XY}}} \Rightarrow 2.4\ \text{V} = (6.0\ \text{V}) \times \frac{8.0\ \Omega}{R + 8.0\ \Omega}$$

$$R + 8.0\ \Omega = \frac{(6.0\ \text{V})(8.0\ \Omega)}{2.4\ \text{V}} = 20\ \Omega$$

- $R = 20\ \Omega - 8.0\ \Omega = \mathbf{12}$

(b) the wire is **uniform**, so its resistance is **proportional to length**

- the same current flows along it, so by $V = IR$ the p.d. across a length is proportional to that length

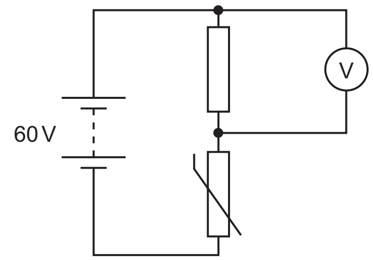
3.3

- as temperature rises, the thermistor's resistance **decreases**
- it now takes a **smaller share** of the total voltage
- so the output voltage across the thermistor **decreases**

3.4

- put the **LDR** in series with a fixed resistor and take the output across the **fixed resistor** (so the output rises in the dark)
- as it gets dark the LDR's resistance **rises**, so a larger share of the voltage is across the fixed resistor and the output **rises**
- the output crosses a **threshold** that switches the lamp on (e.g. via a transistor/comparator)

35 The diagram shows a circuit with a battery of electromotive force (e.m.f.) 60 V and negligible internal resistance, a 20 kΩ resistor, a thermistor and a voltmeter. The resistance of the thermistor is 20 kΩ.



The temperature of the thermistor decreases, and this causes its resistance to change by 50%.

After this change, what is the reading on the voltmeter?

A 20 V **B** 24 V **C** 36 V **D** 40 V

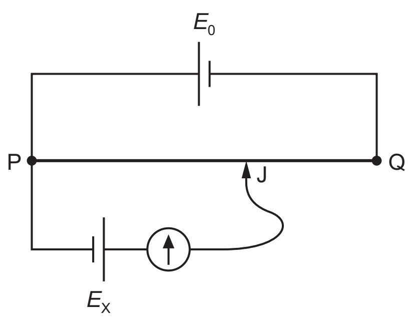
36 A potentiometer circuit is used to determine the electromotive force (e.m.f.) E_X of a cell. The circuit includes a second cell of known e.m.f. E_0 and negligible internal resistance, and a uniform resistance wire PQ of known length.

E_X is less than E_0.

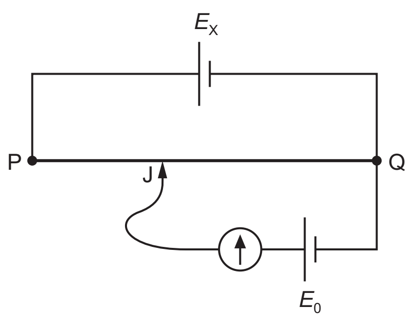
The movable connection J can be positioned anywhere along the length of the resistance wire.

Which circuit is suitable for determining E_X?

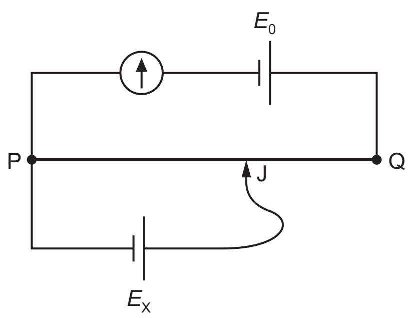
A



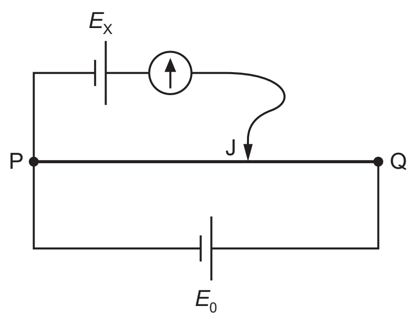
B



C



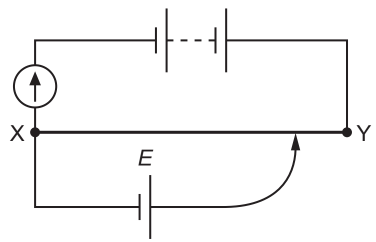
D



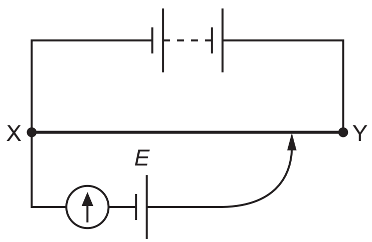
36 A potentiometer circuit may be used to determine the unknown electromotive force (e.m.f.) E of a cell. The circuit diagrams shown include a battery of known e.m.f. and negligible internal resistance, a uniform resistance wire XY and a galvanometer.

Which circuit diagram shows a suitable arrangement for determining E?

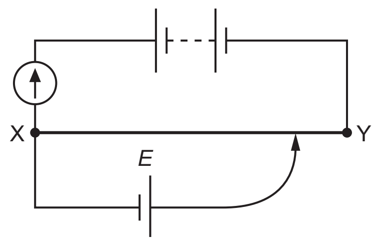
A



B



C



D