HOLIDAY HOMEWORK 假期作业

AP Physics C: Electricity and Magnetism

Exercise sheets, topic by topic.

每个单元：练习卷。

For class or self-study • no answer keys included.

Contents 目录

8 Electric charge and Coulomb's law – Part 1

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
Electric charge	电荷			
Coulomb's law	库仑定律			

Recall

You have seen electric charge in everyday life:

- Rub a balloon on your hair and it sticks to a wall.
- Like charges push apart; opposite charges pull together.
- Static shocks are charge jumping across a gap.

This sheet makes the force between charges exact. Each idea has a worked example.

New ideas

■ 1 Electric charge

Electric charge 电荷 comes in two kinds, positive and negative. Like charges **repel**; opposite charges **attract**. Charge is carried by electrons moving between objects.

■ 2 Coulomb's law

The force between two point charges is **Coulomb's law** 库仑定律:

$$F = \frac{kq_1q_2}{r^2},$$

with $k = 9.0 \times 10^9$. It is an inverse-square law –like gravity, but it can push or pull.

Worked example. Two charges of 3.0 μC and 2.0 μC, 0.10 m apart: $F = \dfrac{9.0 \times 10^9 \times (3.0 \times 10^{-6})(2.0 \times 10^{-6})}{(0.10)^2} = 5.4$ N.

3 Conductors and insulators

A **conductor** lets charge move freely (metals); an **insulator** holds it in place (plastic, rubber).

4 Charge is conserved

Charge is never created or destroyed, only moved from one object to another.

Watch out: Coulomb's law is inverse-square –**doubling** the distance makes the force **four times smaller**, not two times. Always square the distance.

Practice

Try these in order. The methods are all above.

2.1 State whether the force is a push or a pull between (a) two negative charges, (b) a positive and a negative charge. [2]

2.2 Two charges of 2.0 μC and 2.0 μC are 0.20 m apart. Find the force ($k = 9.0 \times 10^9$). [3]

2.3 Give one example of a conductor and one of an insulator. [2]

2.4 Two charges are moved from 0.10 m to 0.30 m apart. State the factor by which the force changes. [2]

2.5 State what "charge is conserved" means. [1]

8 The electric field – Part 2

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)
electric field	电场	______ ______ ______

Recall

In Part A you met the force between charges. Now the **field** that carries that force:

- A charge seems to reach across empty space to push another.
- We describe this with an ”electric field” filling the space around a charge.

Each idea has a worked example before the Practice.

New ideas

1 The electric field

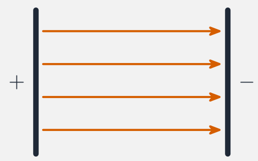
An **electric field** 电场 E is the force felt per unit of charge at a point:

$$E = \frac{F}{q}, \qquad \text{so a charge in a field feels} \qquad F = qE.$$

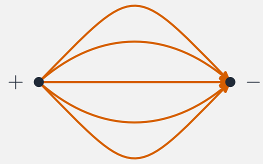
2 Field lines

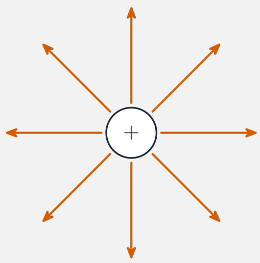
Field lines point **away** from positive charges and **toward** negative ones. Where the lines are denser, the field is stronger.

a) parallel plates (uniform field)

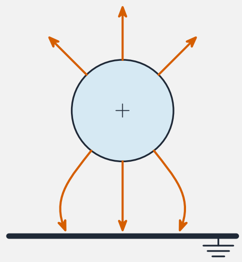


b) dipole (+ and −)





c) point charge (radial)



d) sphere above earthed plate

■ 3 Force on a charge

Worked example. A field of 2000 N/C acts on a 3.0×10^{-6} C charge: $F = qE = 3.0 \times 10^{-6} \times 2000 = 6.0 \times 10^{-3}$ N.

■ 4 The field of a point charge

A single point charge Q makes a field $E = \dfrac{kQ}{r^2}$ –stronger close in, weaker far away (inverse-square, like the force).

Watch out: the field points the way a **positive** test charge would be pushed. A negative charge in the same field feels a force in the **opposite** direction to the field.

Practice

Try these in order. The methods are all above.

2.1 State what an electric field is, in words. [2]

2.2 State which way field lines point around a positive charge. [1]

2.3 A field of 500 N/C acts on a 4.0×10^{-6} C charge. Find the force. [2]

2.4 State what a denser pattern of field lines means. [1]

2.5 State the direction of the force on a negative charge placed in a field. [2]

9 Electric potential and voltage – Part 1

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	**中文**	**Write it 3 times** (English)
Electric potential	电势	______ ______ ______
voltage	电压	______ ______ ______

Recall

You use "voltage" all the time:

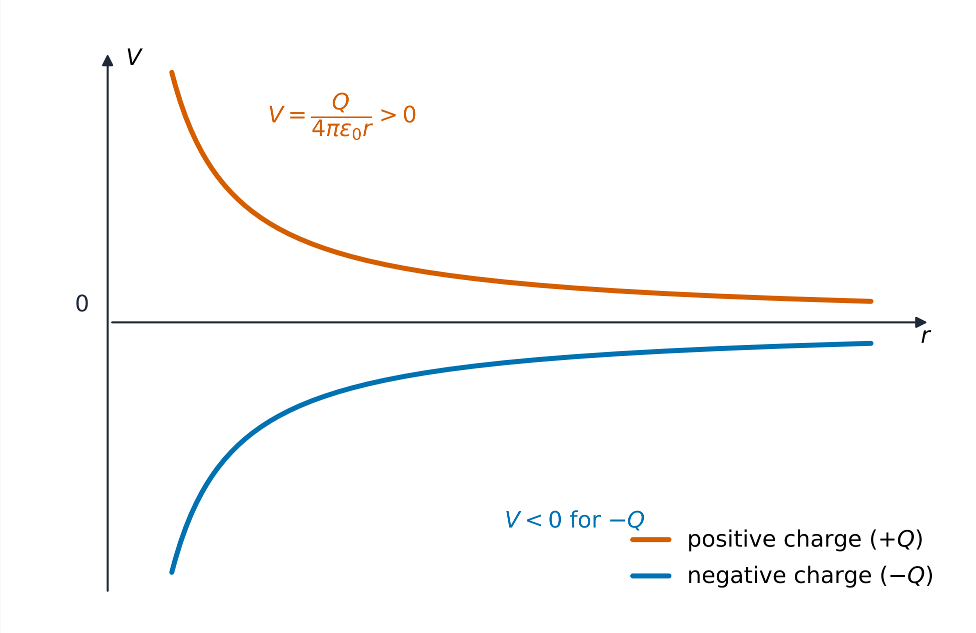
- Batteries are labelled 1.5 V, 9 V, and so on.
- Voltage is what pushes current around a circuit.
- It is really a measure of electric energy.

This sheet lines up electric potential and voltage. Each idea has a worked example.

New ideas

■ 1 Electric potential

Electric potential 电势 V is the electric potential energy per unit of charge, measured in volts.



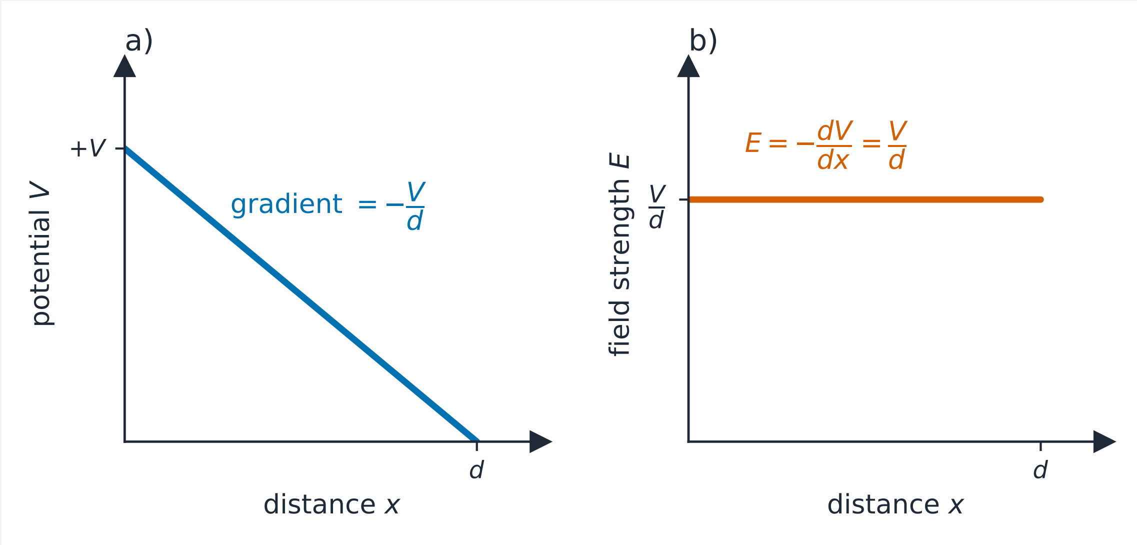
2 Voltage

The **voltage** 电压 (potential difference) between two points is the work done per unit charge to move a charge between them: $U = qV$.

Worked example. Moving a charge of 2.0 C through 6.0 V transfers $U = qV = 2.0 \times 6.0 = 12$ J.

3 Downhill for positive charge

A positive charge moves from **high** to **low** potential on its own –like a ball rolling downhill.



■ 4 A scalar

Potential is just a number (a scalar), so potentials from several charges simply **add** –much easier than adding field vectors.

Watch out: electric potential (V, a scalar) and electric field (E, a vector) are different things. Potentials add as plain numbers; fields must be added by direction as well as size.

Practice

Try these in order. The methods are all above.

2.1 State what electric potential measures. [2]

2.2 Moving a 3.0 C charge through 4.0 V –find the energy transferred. [2]

2.3 State which way a positive charge moves on its own (high to low potential, or low to high). [1]

2.4 Moving a 0.5 C charge through 12 V –find the energy transferred. [2]

2.5 State why potential is easier to add than the electric field. [2]

9 Accelerating charges with voltage – Part 2

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)
electric potential energy	电势能	______ ______ ______

Recall

In Part A you met potential and voltage. Now use voltage to give charges energy:

- A voltage can speed up a charged particle.
- This is how old TV tubes and electron microscopes work.

Each idea has a worked example before the Practice.

New ideas

1 Electric potential energy

Two charges have **electric potential energy** 电势能 stored in their arrangement – like a stretched spring stores energy.

2 Energy from voltage

A charge released across a voltage speeds up, turning electric energy into kinetic energy:

$$qV = \frac{1}{2}mv^2.$$

3 A worked example

Worked example. A charge of 2.0 C falls through 10 V, gaining $qV = 2.0 \times 10 = 20$ J of kinetic energy.

■ **4 Conservation of energy**

This is just energy conservation for charges: the electric potential energy lost equals the kinetic energy gained.

Watch out: a **positive** charge gains energy moving from high to low potential (downhill), while a **negative** charge gains energy moving the opposite way. The sign of the charge decides which way is ”downhill”.

Practice

Try these in order. The methods are all above.

2.1 State what electric potential energy is stored in. [1]

2.2 A charge of 3.0 C falls through 5.0 V. Find the kinetic energy it gains. [2]

2.3 A charge of 0.20 C is accelerated through 50 V. Find the energy gained. [2]

2.4 State the energy conversion when a charge is accelerated through a voltage. [2]

2.5 State which way a positive charge must move to gain energy. [1]

10 Conductors and capacitors – Part 1

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)
capacitor	电容器	
capacitance	电容	

Recall

Many devices store electric charge:

- A camera flash charges up, then releases energy in a burst.
- Phones and computers are full of tiny components called capacitors.

This sheet lines up conductors and capacitors. Each idea has a worked example.

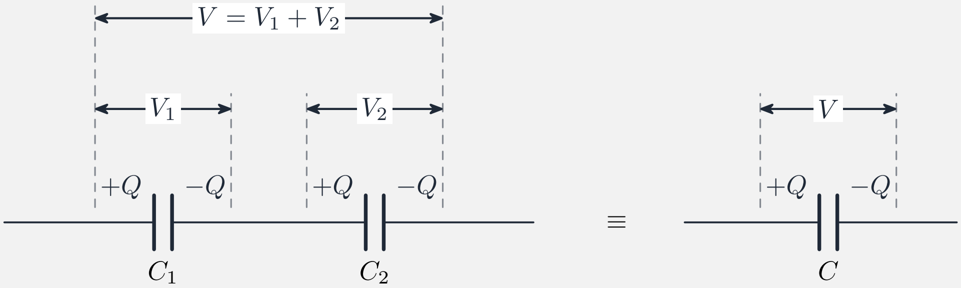
New ideas

1 Conductors

In a **conductor**, charge moves freely. Any extra charge spreads out over the **surface**, and inside the metal the field is zero.

2 Capacitors

A **capacitor** 电容器 stores charge on two conducting plates separated by a gap.



■ 3 Capacitance

The **capacitance** 电容 links the charge stored to the voltage across it:

$$C = \frac{Q}{V}.$$

Worked example. A capacitor holds $Q = 1.2 \times 10^{-3}$ C at $V = 12$ V, so $C = \dfrac{Q}{V} = \dfrac{1.2 \times 10^{-3}}{12} = 1.0 \times 10^{-4}\ \text{F} = 100\ \mu\text{F}$.

■ 4 Finding the charge

Rearranged, $Q = CV$: a bigger capacitance or a bigger voltage stores more charge.

Watch out: capacitance depends on the plates' **size and spacing**, not on how much charge you put on. Adding charge raises the voltage in step, keeping $C = Q/V$ fixed.

Practice

Try these in order. The methods are all above.

2.1 State where extra charge sits on a conductor. [1]

2.2 State what a capacitor does. [2]

2.3 A capacitor stores 6.0×10^{-4} C at 12 V. Find its capacitance. [2]

2.4 A 50 μF capacitor is charged to 10 V. Find the charge stored ($Q = CV$). [2]

2.5 State what capacitance depends on. [2]

10 Capacitor energy and dielectrics – Part 2

Name: ____________ Class: ________ Date: __________

Recall

In Part A you saw a capacitor stores charge. It also stores **energy**:

- A charged capacitor can release energy in a quick burst (a camera flash).
- The more you charge it, the more energy it holds.

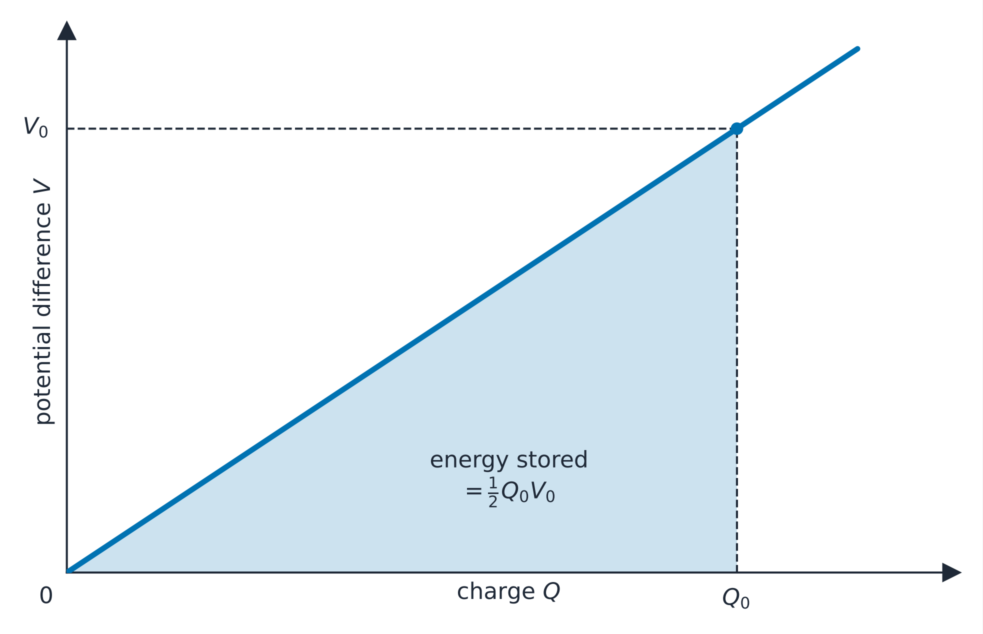
Each idea has a worked example before the Practice.

New ideas

1 Stored energy

A charged capacitor stores energy

$$U = \tfrac{1}{2}CV^2.$$



Worked example. A 100 μF capacitor at 12 V stores $U = \frac{1}{2} \times 100 \times 10^{-6} \times 12^2 = 7.2 \times 10^{-3}$ J.

■ **2 Energy depends on V squared**

Because of the V^2, **doubling** the voltage stores **four times** the energy.

■ **3 A quick release**

A capacitor can release its stored energy very quickly –far faster than a battery – which is why it powers a camera flash.

■ **4 Dielectrics**

Putting an insulating material (a **dielectric**) between the plates increases the capacitance, so more charge and energy can be stored at the same voltage.

Watch out: the stored energy depends on the **square** of the voltage ($U = \frac{1}{2}CV^2$), so a small rise in voltage gives a large rise in energy –double the voltage, quadruple the energy.

Practice

Try these in order. The methods are all above.

2.1 Write the formula for the energy stored in a capacitor. [1]

2.2 A 200 μF capacitor is charged to 10 V. Find the energy stored. [3]

2.3 A capacitor's voltage is doubled. State the factor by which the stored energy changes. [1]

2.4 State one everyday use of a capacitor's quick energy release. [1]

2.5 State what adding a dielectric between the plates does. [2]

11 Current, resistance, and power – Part 1

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
Electric current	电流			
Resistance	电阻			
Ohm’s law	欧姆定律			
Electric power	电功率			

Recall

You have built simple circuits before:

- A battery pushes a current around a loop to light a bulb.
- More voltage pushes more current; more resistance holds it back.
- You have wired components in a line and side by side.

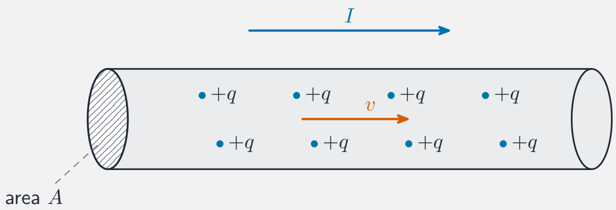
This sheet lines these up with formulas. Each idea has a worked example.

New ideas

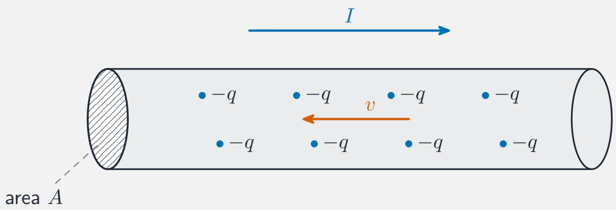
■ 1 Electric current

Electric current 电流 is the rate at which charge flows past a point, measured in amperes (A):

$$I = \frac{\Delta q}{\Delta t}.$$



(a) positive carriers drift with I



(b) electrons drift against I

Worked example. If 6.0 C flows past a point in 3.0 s, the current is $I = \dfrac{6.0}{3.0} = 2.0$ A.

■ 2 Resistance and Ohm's law

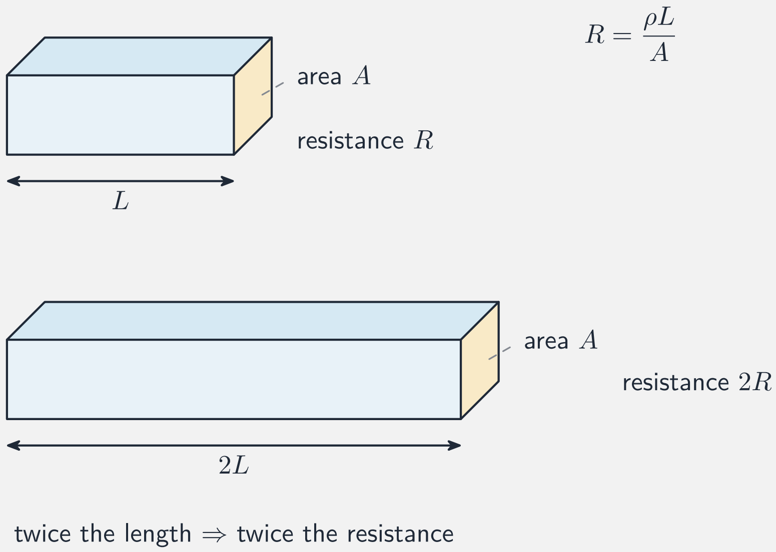
Resistance 电阻 R opposes the current. **Ohm's law** 欧姆定律 links voltage, current, and resistance:

$$V = IR.$$

Worked example. A 2.0 A current through a 6.0 Ω resistor needs $V = IR = 2.0 \times 6.0 = 12$ V.

■ 3 What sets the resistance

A wire's resistance grows with its **length** and shrinks with its **thickness** (cross-section).



4 Electric power

Electric power 电功率 is how fast a component uses energy: $P = IV = I^2R$.

Watch out: in a **series** circuit the current is the same everywhere; in a **parallel** circuit the voltage is the same across each branch. Mixing these up is the most common circuit mistake.

Practice

Try these in order. The methods are all above.

2.1 A charge of 10 C flows past a point in 5.0 s. Find the current. [2]

2.2 A 3.0 A current flows through a 4.0 Ω resistor. Find the voltage across it. [2]

2.3 State how a wire's resistance depends on its length and thickness. [2]

2.4 A resistor carries 0.50 A with 6.0 V across it. Find the power it uses. [2]

2.5 State what is the same for every component in a series circuit. [1]

11 Combining resistors and circuit rules – Part 2

Name: ______________ Class: __________ Date: ____________

Recall

In Part A you used $V = IR$ for a single resistor. Now handle circuits with **several**:

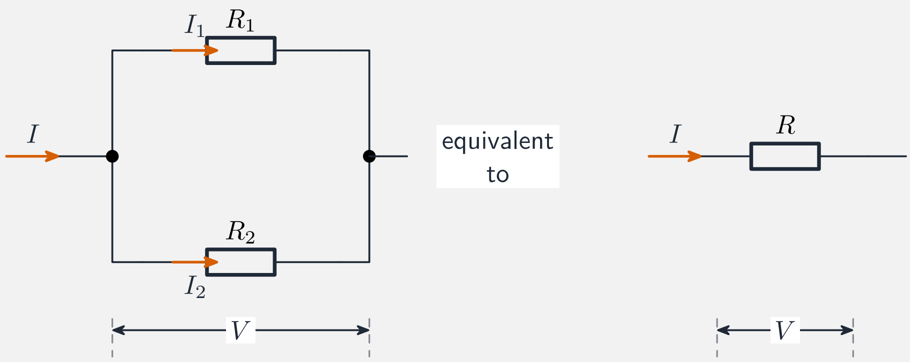
- Resistors in a line add up; resistors side by side share the current.
- Whatever current flows into a junction flows out again.

Each idea has a worked example before the Practice.

New ideas

1 Combining resistors

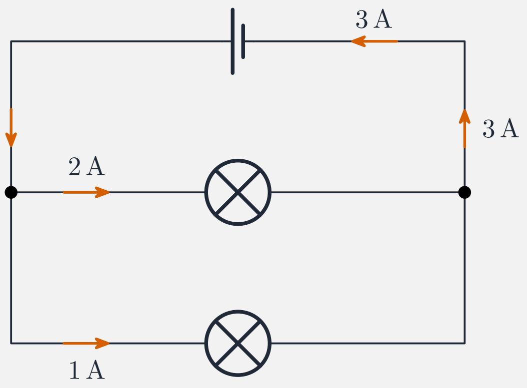
- **Series:** $R_{\text{eq}} = R_1 + R_2 + \cdots$ (they add).
- **Parallel:** $\dfrac{1}{R_{\text{eq}}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \cdots$ (the total is **less** than the smallest).



Worked example. A 4.0 Ω and a 12 Ω in parallel: $\dfrac{1}{R_{\text{eq}}} = \dfrac{1}{4} + \dfrac{1}{12} = \dfrac{4}{12}$, so $R_{\text{eq}} = 3.0\ \Omega$.

2 The junction rule

The current flowing **into** a junction equals the current flowing **out** (charge is conserved).



at each junction: $3\,\mathrm{A} = 2\,\mathrm{A} + 1\,\mathrm{A}$

■ 3 The loop rule

Going around any complete loop, the voltage gains (from the battery) and drops (across resistors) add up to **zero** (energy is conserved).

■ 4 Solving a circuit

Worked example. If 5.0 A enters a junction and one branch carries 2.0 A, the other carries $5.0 - 2.0 = 3.0$ A.

Watch out: putting resistors in **parallel** makes the total resistance **smaller** than the smallest one –because you have opened extra paths for the current. Series makes it larger.

Practice

Try these in order. The methods are all above.

2.1 Find the equivalent resistance of a 3.0 Ω and a 5.0 Ω resistor in **series**. [2]

2.2 Find the equivalent resistance of a 6.0 Ω and a 3.0 Ω resistor in **parallel**. [3]

2.3 A current of 4.0 A enters a junction; one branch carries 1.5 A. Find the current in the other branch. [2]

2.4 State the conservation idea behind the loop rule. [1]

2.5 State whether two resistors in parallel give a total larger or smaller than the smallest one. [1]

12 Magnetic fields and forces – Part 1

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)
magnetic field	磁场	_________ _________ _________
magnetic force	磁力	_________ _________ _________

Recall

You have played with magnets:

- A magnet has a north and a south pole; like poles repel, opposite attract.
- Magnets pull on iron and steel.
- A coil of wire carrying a current becomes a magnet.

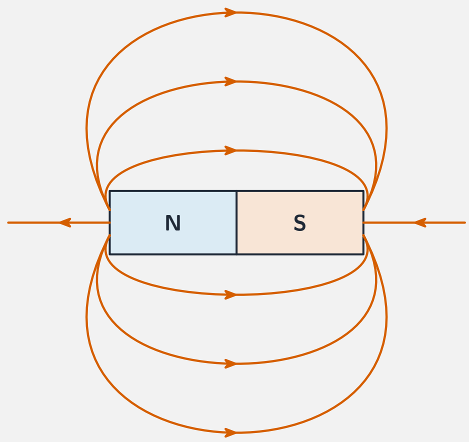
This sheet adds the forces magnetic fields make. Each idea has a worked example.

New ideas

■ 1 Magnetic fields

A **magnetic field** 磁场 B surrounds every magnet. Field lines run from the **north** pole to the **south** pole outside the magnet.

field lines run from **N** to **S** outside the magnet

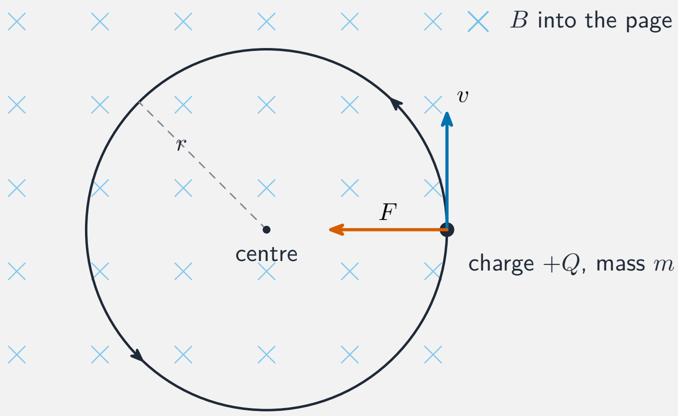


2 Force on a moving charge

A charge moving **across** a magnetic field feels a **magnetic force** 磁力:

$$F = qvB\sin\theta.$$

The force is at right angles to the motion, so it bends the charge into a **circle**.



$$BQv = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{BQ}$$

Worked example. A charge of 1.6×10^{-19} C moving at 2.0×10^5 m/s across a 0.50 T field feels $F = qvB = 1.6 \times 10^{-19} \times 2.0 \times 10^5 \times 0.50 = 1.6 \times 10^{-14}$ N.

3 Force on a wire

A current is moving charge, so a magnetic field pushes on a **current-carrying wire**: $F = BIL$. This push turns an electric motor.

■ **4 No force when parallel**

Watch out: a charge that is **not moving**, or one moving **along** the field lines, feels **no** magnetic force. The charge must move **across** the field to feel a push.

Practice

Try these in order. The methods are all above.

2.1 State the direction field lines run outside a bar magnet. [1]

2.2 A charge of 2.0×10^{-19} C moves at 1.0×10^{5} m/s across a 0.40 T field. Find the force. [3]

2.3 State the shape of the path of a charge moving across a uniform magnetic field. [1]

2.4 A 0.50 m wire carries 3.0 A across a 0.10 T field. Find the force on it ($F = BIL$). [2]

2.5 State when a moving charge feels no magnetic force. [2]

12 Magnetic fields from currents – Part 2

Name: ______________ Class: __________ Date: ____________

Recall

In Part A a magnetic field pushed on a moving charge. Now the reverse link:

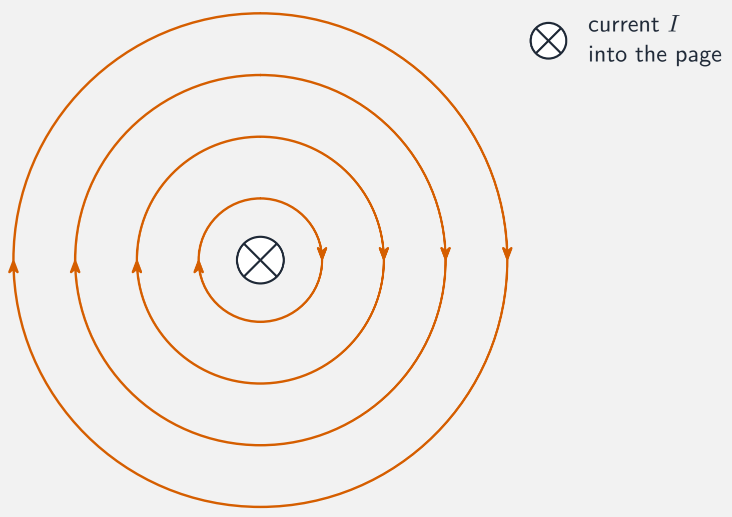
- A current does not just feel magnetic forces –it **creates** a magnetic field.
- This is how electromagnets work.

Each idea has a worked example before the Practice.

New ideas

1 A current makes a field

A current in a straight wire creates a magnetic field that **circles around** the wire.



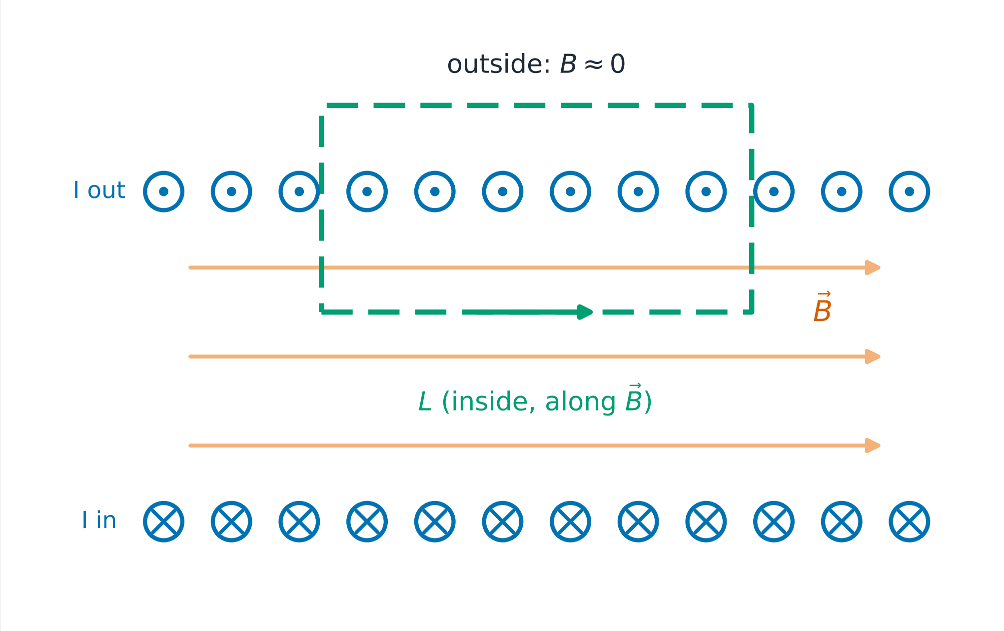
circular field lines (right-hand grip rule)

2 Stronger with more current

The field is stronger with a bigger current and weaker further from the wire.

3 Coils and solenoids

Winding the wire into a coil (a **solenoid**) makes the fields add up, giving a strong, uniform field inside –just like a bar magnet.



■ 4 Electromagnets

Because the field comes from the current, you can **switch it off** by cutting the current –the basis of electromagnets used in scrapyard cranes and doorbells.

Watch out: the magnetic field circles **around** the wire, not along it. The field lines form closed loops around the current, so there is no ”north end” of a straight wire.

Practice

Try these in order. The methods are all above.

2.1 State the shape of the magnetic field around a straight current-carrying wire. [2]

2.2 State two things that make the field around a wire stronger. [2]

2.3 State what a solenoid produces inside it. [2]

2.4 State one advantage of an electromagnet over a permanent magnet. [2]

2.5 Give one everyday device that uses an electromagnet. [1]

13 Electromagnetic induction and flux – Part 1

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
electromagnetic induction	电磁感应			
magnetic flux	磁通量			

Recall

You saw that a current makes a magnetic field. The reverse is just as important:

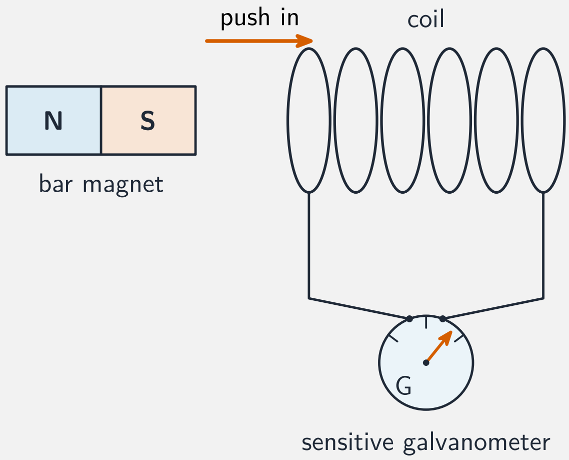
- Move a magnet near a coil of wire and a current appears –with no battery.
- This is how every generator and power station makes electricity.

This sheet lines up electromagnetic induction. Each idea has a worked example.

New ideas

■ 1 Electromagnetic induction

A **changing** magnetic field through a coil drives a current –**electromagnetic induction** 电磁感应. Move a magnet into or out of a coil and a current flows while the magnet is moving.

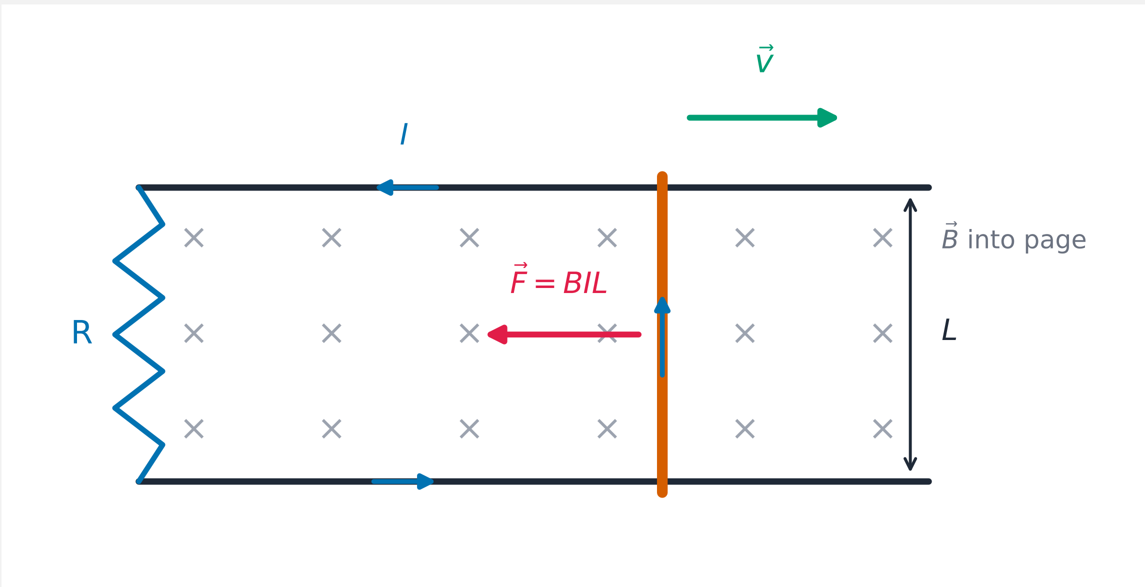


2 Magnetic flux

The **magnetic flux** 磁通量 $\Phi = BA$ measures how much field passes through a loop of area A. The flux changes if the field, the area, or the loop's angle changes.

3 A moving rod

A rod sliding along rails through a field also has a changing flux, so it generates a voltage.



4 The size of the effect

Worked example. If the flux through a single loop changes from 0.020 Wb to 0.008 Wb in 0.030 s, the average voltage is $\dfrac{0.020 - 0.008}{0.030} = 0.40$ V.

Watch out: it is the **change** in flux that induces a current, not the flux itself. A magnet sitting still inside a coil induces **nothing** –the magnet has to be moving.

Practice

Try these in order. The methods are all above.

2.1 State what must happen for a coil to have a current induced in it. [1]

2.2 State what magnetic flux measures. [2]

2.3 The flux through a single loop rises from 0.010 Wb to 0.030 Wb in 0.040 s. Find the induced voltage. [3]

2.4 Name two things that could change the flux through a loop. [2]

2.5 Explain why a magnet held still inside a coil induces no current. [2]

13 Faraday's and Lenz's laws – Part 2

Name: ______________ Class: __________ Date: ____________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
Faraday's law	法拉第定律	______	______	______
Lenz's law	楞次定律	______	______	______

Recall

In Part A you saw that a changing magnetic flux drives a current. Now the two laws that describe it:

- One law gives the **size** of the induced voltage.
- The other gives its **direction**.

Each idea has a worked example before the Practice.

New ideas

■ 1 Faraday's law

Faraday's law 法拉第定律 says the induced voltage equals how fast the flux changes:

$$\varepsilon = \frac{\Delta\Phi}{\Delta t}.$$

A coil of N turns gives N times as much.

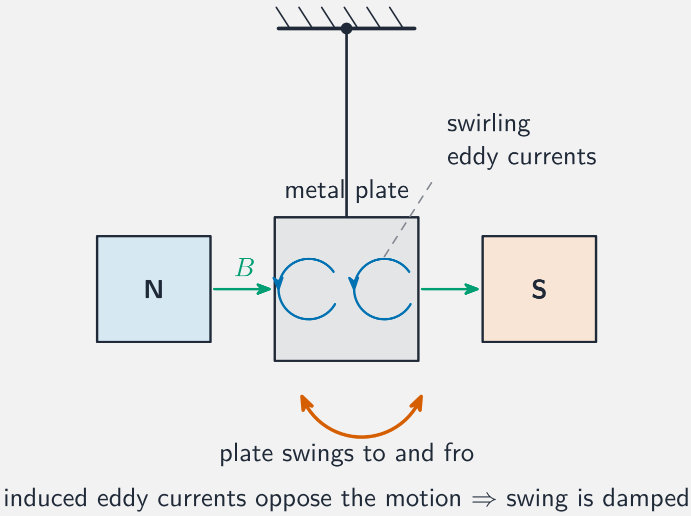
Worked example. If one turn would give 0.40 V, a 50-turn coil gives $50 \times 0.40 = 20$ V.

■ 2 Lenz's law

Lenz's law 楞次定律 gives the direction: the induced current flows so as to **oppose** the change that caused it.

■ **3 It is energy conservation**

Lenz's law is really energy conservation –you must do work to push the magnet against this opposing effect, and that work becomes the electrical energy.



■ **4 Generators**

Spinning a coil in a magnetic field constantly changes the flux, inducing a current – this is how a **generator** turns motion into electricity.

Watch out: the induced current always **opposes** the change (Lenz's law). If it helped the change instead, you would get energy for free –which is impossible.

Practice

Try these in order. The methods are all above.

2.1 State what Faraday's law says the induced voltage depends on. [2]

2.2 A coil has 20 turns; one turn would give 0.30 V. Find the coil's voltage. [2]

2.3 State what Lenz's law tells you about the direction of an induced current. [2]

2.4 Explain why Lenz's law is really a statement of energy conservation. [2]

2.5 State how a generator produces electricity. [2]