HOLIDAY HOMEWORK 假期作业

AP Physics 2

Exercise sheets, topic by topic.

每个单元：练习卷。

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

Contents 目录

9 Temperature, gases, and heat – 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)		
Thermodynamics	热力学			
kinetic theory	分子运动论			
Temperature	温度			
pressure	压强			
ideal gas	理想气体			
Heat	热量			
thermal equilibrium	热平衡			
conduction	传导			
convection	对流			
radiation	辐射			
specific heat	比热容			

Recall

You already know a lot about heat and gases:

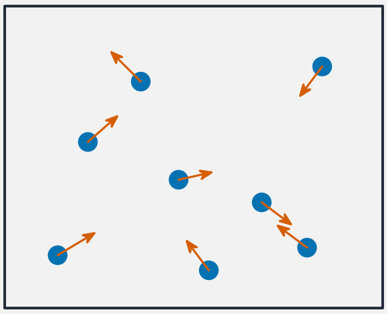
- Hot things feel hot because their tiny particles move fast; cold things move slowly.
- A gas pushes out on its container –a balloon stays full because the air pushes on it.
- Heat always flows from the hot object to the cold one, never the other way.

This sheet gives these ideas exact formulas. Each idea has a worked example.

New ideas

■ 1 Temperature and moving particles

Thermodynamics 热力学 is the study of heat and energy in large groups of particles. The **kinetic theory** 分子运动论 says a gas is countless tiny particles in fast, random motion.



1. many identical molecules, in continuous **random motion**
2. their own volume is **tiny** next to the container
3. straight lines between hits - intermolecular forces **ignored**
4. collisions are **elastic**: no kinetic energy is lost

poor at very high pressure (volume matters) or very low temperature (forces matter)

Temperature 温度 measures the **average kinetic energy** of those particles: hotter means faster-moving. The **pressure** 压强 a gas makes comes from its particles hitting the container walls.

■ 2 The ideal gas law

An **ideal gas** 理想气体 obeys

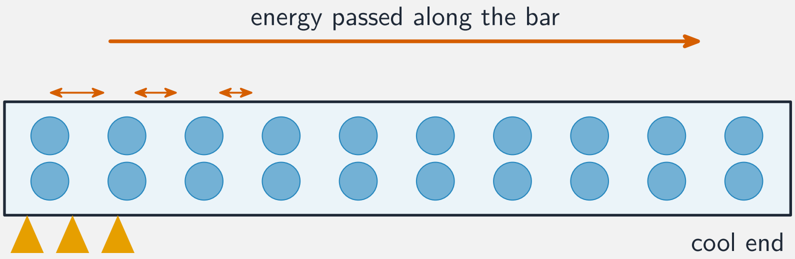
$$PV = nRT,$$

linking pressure P, volume V, amount n, and temperature T (always in **kelvin**). Change one quantity and the law tells you how another responds.

Worked example. A sealed rigid can of gas is at 1.0×10^5 Pa and 300 K. Heated to 450 K at fixed volume, $\frac{P}{T}$ stays constant, so $P_2 = P_1\frac{T_2}{T_1} = 1.0 \times 10^5 \times \frac{450}{300} = 1.5 \times 10^5$ Pa.

■ 3 Heat and how it moves

Heat 热量 Q is energy that flows because of a temperature difference –always from hot to cold. When two objects reach the same temperature they are in **thermal equilibrium** 热平衡 and the flow stops. Heat travels by **conduction** 传导 (through solids), **convection** 对流 (moving fluids), and **radiation** 辐射 (waves, even through empty space).



4 Specific heat

The **specific heat** 比热容 c is the heat needed to warm 1 kg of a substance by 1 °C:

$$Q = mc\,\Delta T.$$

Worked example. Heating 2.0 kg of water ($c = 4200$) from 20 °C to 80 °C needs $Q = mc\,\Delta T = 2.0 \times 4200 \times 60 = 5.0 \times 10^5$ J.

Watch out: always convert temperatures to **kelvin** ($T_K = T_C + 273$) before using a gas law –using Celsius gives nonsense.

Practice

Try these in order. The methods are all above.

2.1 State what temperature measures, in terms of the particles of a gas. [1]

2.2 Convert 27 °C to kelvin. [1]

2.3 A rigid can of gas at 2.0×10^5 Pa and 300 K is cooled to 150 K. Find the new pressure. [3]

2.4 Name the three ways heat can travel, and give the one that works through empty space. [2]

2.5 How much heat warms 0.50 kg of water ($c = 4200$) by $30\,°\mathrm{C}$? [2]

2.6 Explain why coastal towns have milder temperatures than inland ones (think about water's specific heat). [2]

9 The laws of thermodynamics – 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)		
internal energy	内能			
first law of thermodynamics	热力学第一定律			
Entropy	熵			
second law of thermodynamics	热力学第二定律			

Recall

In Part A you met temperature, gases, and heat. Now connect heat to energy:

- Energy is never lost –it only moves or changes form (you saw this with work and kinetic energy).
- Heating a gas can warm it **or** make it push out and do work.
- Heat only ever flows hot → cold on its own. This sheet says why.

Each idea has a worked example before the Practice.

New ideas

■ 1 Internal energy

The **internal energy** 内能 U of a gas is the total energy of its particles' motion. More internal energy means a higher temperature.

■ 2 The first law of thermodynamics

The **first law of thermodynamics** 热力学第一定律 is just energy conservation for a gas:

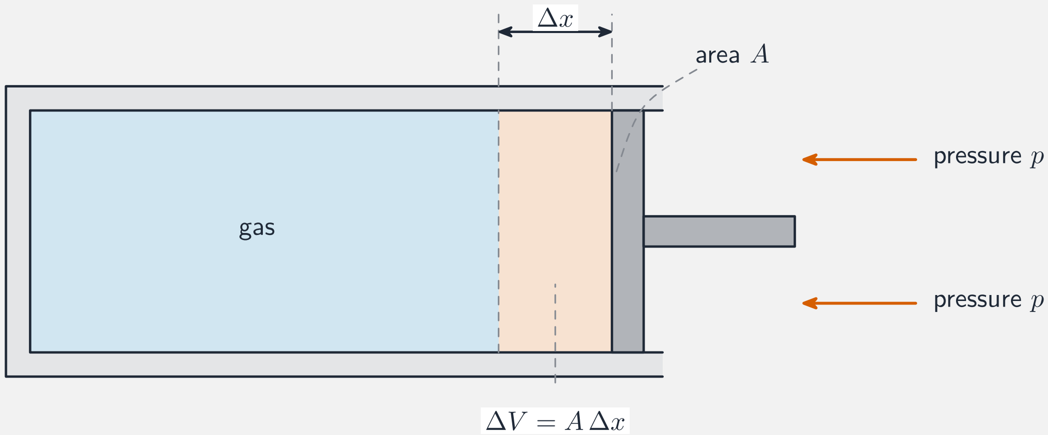
$$\Delta U = Q + W,$$

where Q is the heat added **to** the gas and W is the work done **on** the gas. Add heat and the gas warms up or does work (or both).

Worked example. A gas absorbs 500 J of heat and does 200 J of work on its surroundings (so work done **on** the gas is $W = -200$ J): $\Delta U = Q + W = 500 + (-200) = 300$ J. Its internal energy rises by 300 J, so it ends up hotter.

■ 3 Work when a gas expands

When a gas expands and pushes a piston, it does work on the outside world.



Compressing a gas does **positive** work on it (raising its energy); letting it expand does **negative** work on it (it gives energy away).

■ 4 Entropy and the second law

Entropy 熵 measures how spread-out or disordered energy is. The **second law of thermodynamics** 热力学第二定律 says the total entropy of an isolated system never decreases –energy naturally spreads out. This is why heat flows hot $\to$ cold by itself, and never cold $\to$ hot.

Watch out: in $\Delta U = Q + W$, the sign of W matters most. Work done **on** the gas is positive; when the gas does work on its surroundings, W is **negative**. Get the sign right and these problems are easy.

Practice

Try these in order. The methods are all above.

2.1 State what the internal energy of a gas depends on. [1]

2.2 A gas gains 400 J of heat and 100 J of work is done **on** it. Find the change in internal energy. [2]

2.3 A gas absorbs 600 J of heat and does 250 J of work on its surroundings. Find the change in its internal energy. [3]

2.4 State the direction heat naturally flows between a hot and a cold object, and name the law that sets this direction. [2]

2.5 Explain why energy naturally spreads out rather than gathering into one place, using the idea of entropy. [2]

10 Electric charge, force, and field – 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			
conductor	导体			
insulator	绝缘体			
conduction	接触起电			
induction	感应起电			
electric field	电场			

Recall

You have already seen electric charge in action:

- Rub a balloon on your hair and it sticks to the wall –that is static electricity.
- Like charges push apart; opposite charges pull together.
- A metal wire lets charge flow; plastic does not.

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

New ideas

■

Electric charge 电荷 comes in two kinds, positive and negative. Like charges **repel**, opposite charges **attract**. Charge is carried by electrons moving from one object to another.

■ 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 $k = 9.0 \times 10^9$. Like gravity it is an inverse-square law, but it can push **or** pull.

Worked example. Two charges of 3.0 μC and 2.0 μC sit 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, insulators, and charging

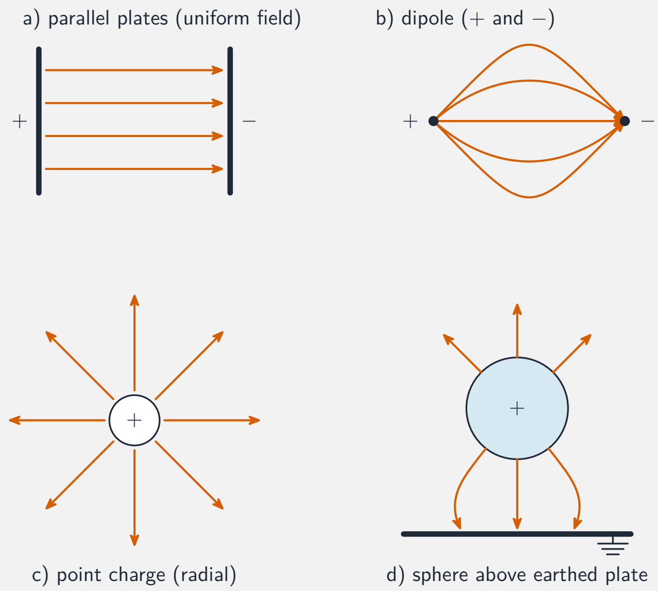
A **conductor** 导体 lets charge move freely (metals); an **insulator** 绝缘体 holds it in place (plastic, rubber). Objects charge up by **friction** (rubbing), by **conduction** 接触起电 (touching), or by **induction** 感应起电 (a nearby charge pushes charge around inside a neutral object).

■ 4 The electric field

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

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

Field lines point away from positive charges and toward negative ones.



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.

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 positive charges, (b) a positive and a negative charge. [2]

2.2 Two charges of 4.0 μC and 1.0 μC are 0.20 m apart. Find the force between them ($k = 9.0 \times 10^9$). [3]

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

2.4 A field of 500 N/C acts on a 2.0×10^{-6} C charge. Find the force on it. [2]

2.5 Two charges are moved from 0.10 m apart to 0.20 m apart. State what happens to the force between them, and by what factor. [2]

10 Electric potential and capacitors – 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	电势			
voltage	电压			
capacitor	电容器			
capacitance	电容			

Recall

In Part A you met electric charge, force, and field. Now two ideas you use every day without noticing:

- **Voltage** is written on every battery (1.5 V, 9 V). It is really "electric potential."
- A **capacitor** stores charge –it is inside phones, cameras, and flashes.

Each idea has a worked example before the Practice.

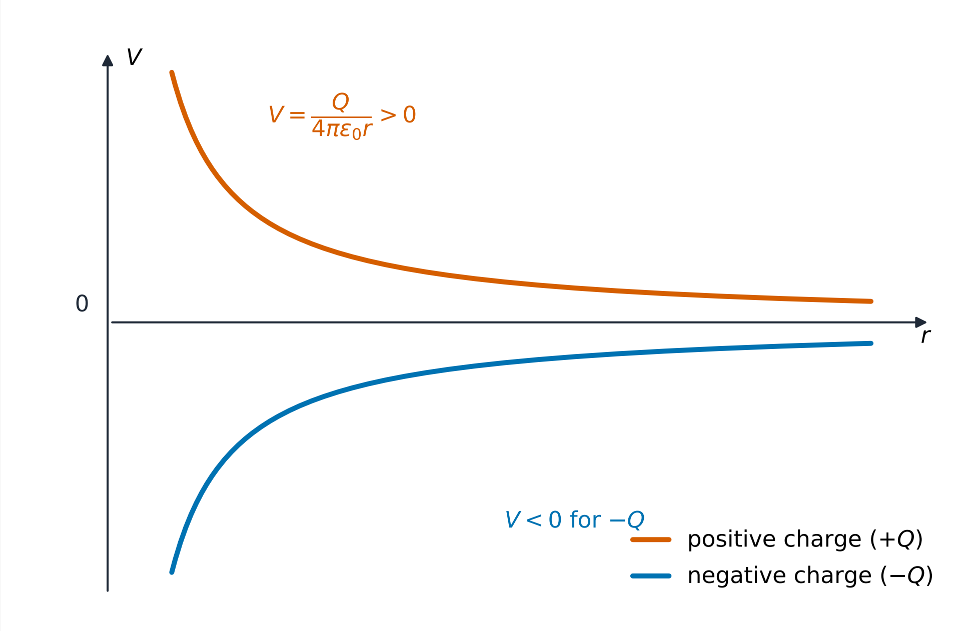
New ideas

■ 1 Electric potential

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

$$V = \frac{U}{q}.$$

Unlike the field (a vector), potential is a simple number (a scalar), so it is easier to work with.



2 Voltage

The **voltage** 电压 (potential difference) between two points is the work done per unit charge to move a charge between them: $U = qV$. A positive charge moves from high to low potential on its own –like a ball rolling downhill.

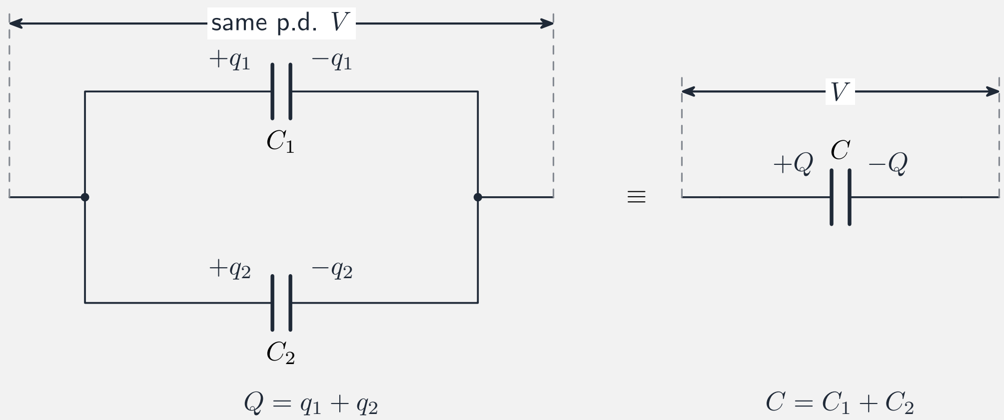
Worked example. Moving a charge of 2.0 C through a potential difference of 6.0 V transfers $U = qV = 2.0 \times 6.0 = 12$ J of energy.

3 Capacitors

A **capacitor** 电容器 stores charge on two plates. Its **capacitance** 电容 links charge to voltage:

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

and it stores energy $U = \frac{1}{2}CV^2$.



Worked example. A 100 μF capacitor charged to 12 V holds $Q = CV = 100 \times 10^{-6} \times 12 = 1.2 \times 10^{-3}$ C and stores $U = \frac{1}{2}CV^2 = \frac{1}{2} \times 100 \times 10^{-6} \times 12^2 = 7.2 \times 10^{-3}$ J.

■ **4 Charges gain energy from voltage**

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

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

Watch out: electric potential V is a **scalar** (just a number), so potentials from several charges simply **add** –much easier than adding field arrows, which are vectors.

Practice

Try these in order. The methods are all above.

2.1 State what electric potential (voltage) measures, in words. [1]

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

2.3 A 50 μF capacitor is charged to 10 V. Find the charge it stores. [2]

2.4 For the capacitor in 2.3, find the energy stored ($U = \frac{1}{2}CV^2$). [3]

2.5 Explain why electric potential is easier to add up than the electric field, when several charges are present. [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			
amperes	安培			
series	串联			
parallel	并联			
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 of wire to light a bulb.
- More **voltage** pushes a bigger current; more **resistance** holds it back.
- You have wired bulbs in a line (series) and side by side (parallel).

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

New ideas

■

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

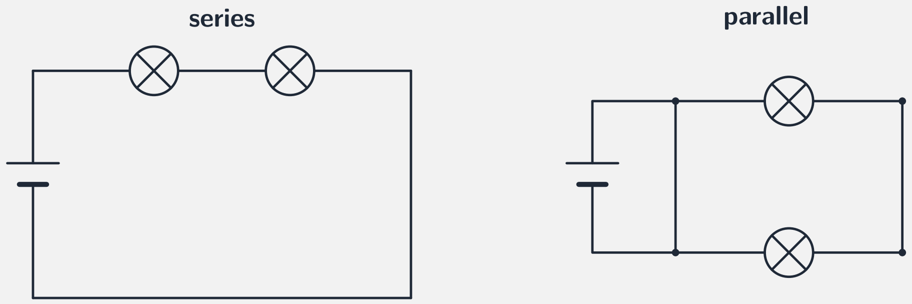
$$I = \frac{\Delta q}{\Delta t}.$$

A current needs a complete loop and a source (a battery) to push it.

Worked example. If 6.0 C of charge flows past a point in 3.0 s, the current is $I = \frac{\Delta q}{\Delta t} = \frac{6.0}{3.0} = 2.0$ A.

■ 2 Series and parallel

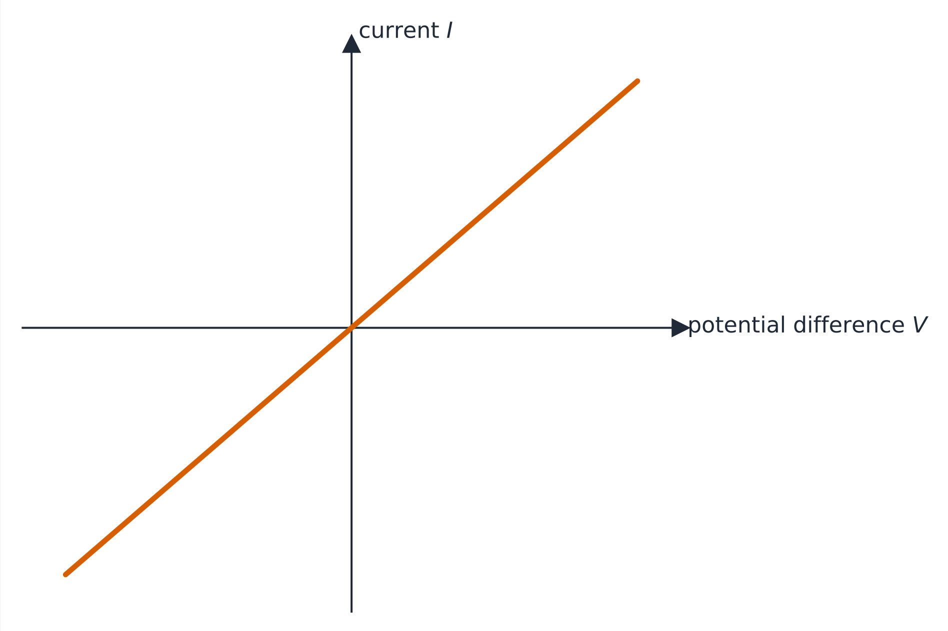
- In a **series** 串联 circuit the components are in one line, so the **same current** flows through each.
- In a **parallel** 并联 circuit they sit on separate branches, so the **same voltage** is across each.



■ 3 Resistance and Ohm's law

Resistance 电阻 R (in ohms) 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 a voltage $V = IR = 2.0 \times 6.0 = 12$ V.

■ 4 Electric power

Electric power 电功率 is the rate a component turns electrical energy into heat, light or motion:

$$P = IV = I^2R = \frac{V^2}{R}.$$

Pick the form that uses what you know.

Worked example. The 6.0 Ω resistor carrying 2.0 A uses $P = I^2R = 2.0^2 \times 6.0 = 24$ W.

Watch out: in **series** the current is the same everywhere; in **parallel** 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 State what is the same for every component in (a) a series circuit, (b) a parallel circuit. [2]

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

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

2.5 A 12 V battery drives a current of 2.0 A through a bulb. Find the bulb's resistance and its power. [3]

11 Combining resistors and circuit rules – 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)		
equivalent resistance	等效电阻			
Kirchhoff's junction rule	基尔霍夫电流定律			
Kirchhoff's loop rule	基尔霍夫电压定律			

Recall

In Part A you used $V = IR$ and $P = IV$ for single components. Now handle circuits with **several** resistors:

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

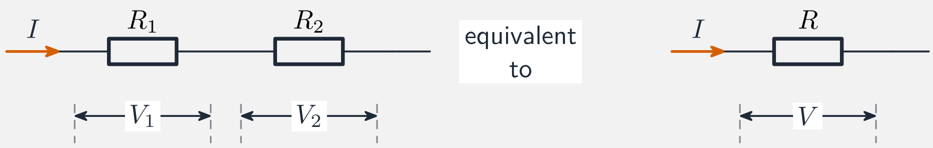
Each idea has a worked example before the Practice.

New ideas

■ 1 Combining resistors

Replace several resistors with one **equivalent resistance** 等效电阻:

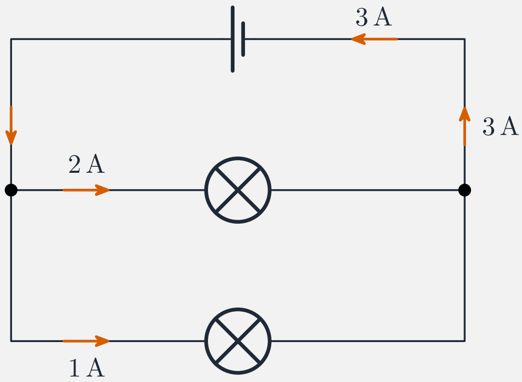
- **Series:** $R_{\text{eq}} = R_1 + R_2 + \cdots$ (they add).
- **Parallel:** $\dfrac{1}{R_{\text{eq}}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \cdots$ (the total is **less** than the smallest one).



Worked example. A 4.0 Ω and a 12 Ω resistor in **parallel**: $\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{12} = \frac{4}{12}$, so $R_{eq} = 3.0\ \Omega$ –smaller than either one.

■ 2 The junction rule

Kirchhoff's junction rule 基尔霍夫电流定律 says the current flowing **into** a junction equals the current flowing **out** (charge is conserved).



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

Worked example. If 4.0 A enters a junction and one branch carries 3.0 A, the other branch must carry $4.0 - 3.0 = 1.0$ A.

■ 3 The loop rule

Kirchhoff's loop rule 基尔霍夫电压定律 says that, going around any complete loop, the voltage gains (from the battery) and drops (across resistors) add up to **zero** (energy is conserved).

■ 4 Capacitor circuits

An **RC circuit** has a resistor and a capacitor. The capacitor charges up (or discharges) gradually, over a time set by $\tau = RC$. Right at the start it acts like a plain wire; once fully charged it blocks the current.

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 5.0 A enters a junction. One branch carries 2.0 A. Find the current in the other branch. [2]

2.4 State the two conservation ideas behind Kirchhoff's junction rule and loop rule. [2]

2.5 State whether the total resistance of two resistors in parallel is larger or smaller than the smallest resistor, and explain briefly. [2]

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 before:

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

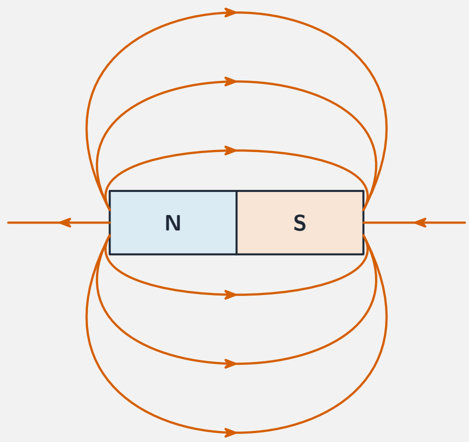
This sheet adds the forces that magnetic fields make. Each idea has a worked example.

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, and closer lines mean a stronger field. Poles always come in pairs –cut a magnet in half and you get two smaller magnets, never a single pole.

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**:

$$F = qvB\sin\theta,$$

where θ is the angle between the velocity and the field. The force is at right angles to the motion, so it bends the charge into a **circle** without changing its speed.

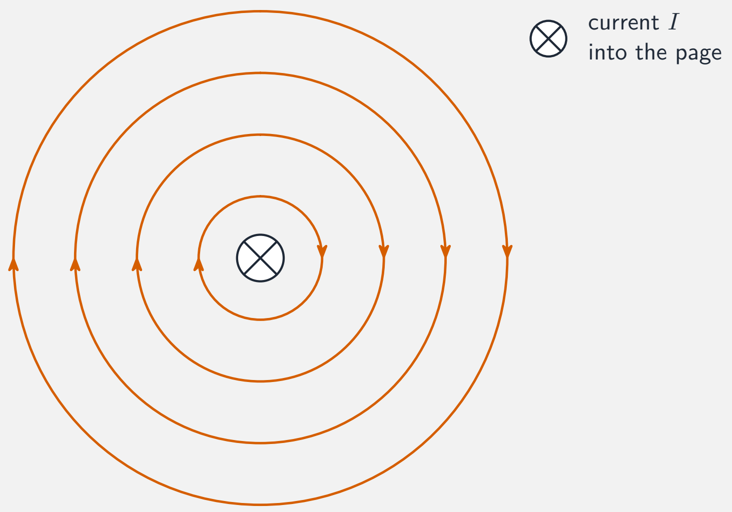
Worked example. A charge of 1.6×10^{-19} C moving at 2.0×10^5 m/s across a 0.50 T field feels $F = qvB = 1.6 \times 10^{-19} \times 2.0 \times 10^5 \times 0.50 = 1.6 \times 10^{-14}$ N.

■ 3 Force on a current-carrying wire

A current is moving charge, so a magnetic field pushes on a **current-carrying wire**:

$$F = BIL.$$

This push is what turns the coil in an electric motor.



circular field lines (right-hand grip rule)

Worked example. A 0.30 m wire carrying 4.0 A across a 0.20 T field feels $F = BIL = 0.20 \times 4.0 \times 0.30 = 0.24$ N.

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 what happens when you cut a bar magnet in half. [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 magnetic force on it. [3]

2.3 A 0.50 m wire carries 3.0 A at right angles to a 0.10 T field. Find the force on it. [2]

2.4 State the direction of the magnetic force on a moving charge, relative to its velocity. [1]

2.5 Explain why a charge moving straight along a magnetic field line feels no magnetic force. [2]

12 Electromagnetic induction – 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)		
electromagnetic induction	电磁感应			
magnetic flux	磁通量			
Faraday’s law	法拉第定律			
Lenz’s law	楞次定律			

Recall

In Part A you saw that a current makes a magnetic field. The reverse is just as important:

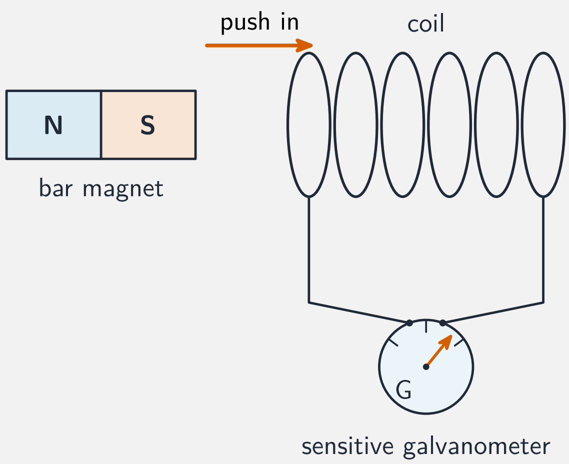
- Move a magnet near a coil of wire and a current appears –with no battery at all.
- This is how every generator and power station makes electricity.

Each idea has a worked example before the Practice.

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 a coil, or out of it, 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 strength, the area, or the loop's angle changes.

■ 3 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 the flux through a single loop drops from 0.020 Wb to 0.008 Wb in 0.030 s: $\varepsilon = \dfrac{\Delta\Phi}{\Delta t} = \dfrac{0.020 - 0.008}{0.030} = 0.40$ V.

■ 4 Lenz's law

Lenz's law 楞次定律 says the induced current flows in the direction that **opposes** the change that caused it. This is really energy conservation –you must do work to push the magnet, and that work becomes the electrical energy.

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

2.3 A coil has 50 turns. If one turn would give 0.40 V, what voltage does the whole coil give? [2]

2.4 State what Lenz's law tells you about the direction of an induced current. [1]

2.5 A student holds a magnet still inside a coil and expects a current. Explain why none flows. [2]

13 Reflection and refraction – 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)		
Geometric optics	几何光学			
law of reflection	反射定律			
angle of incidence	入射角			
angle of reflection	反射角			
refraction	折射			
index of refraction	折射率			
Snell's law	斯涅尔定律			
total internal reflection	全反射			

Recall

You have watched light behave in these ways:

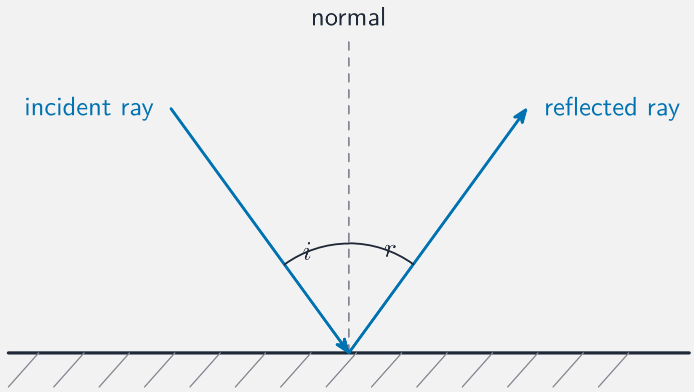
- A mirror bounces light back –you see your reflection.
- A straw in a glass of water looks bent where it enters the water.
- Fibre-optic cables carry light for long distances.

This sheet gives these effects exact laws. Each idea has a worked example.

New ideas

■

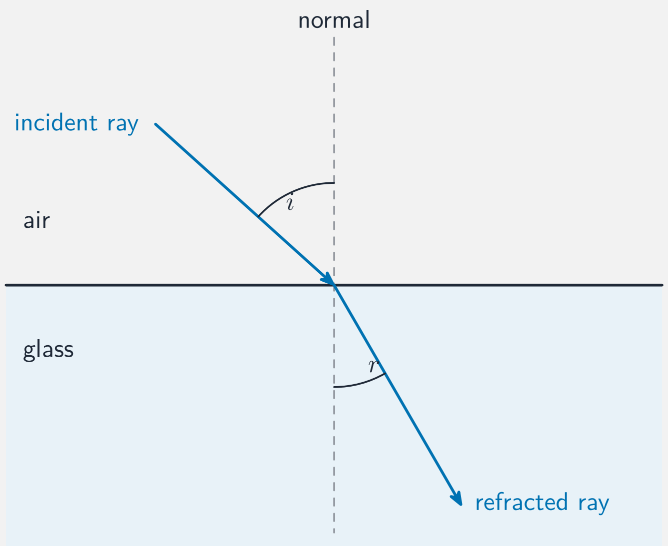
Geometric optics 几何光学 treats light as straight rays. The **law of reflection** 反射定律 says the **angle of incidence** 入射角 equals the **angle of reflection** 反射角, both measured from the **normal** (the line at right angles to the surface).



plane mirror $(i = r)$

■ 2 Refraction

When light passes from one material into another its speed changes, so it bends – **refraction** 折射. Each material has an **index of refraction** 折射率 $n = \frac{c}{v}$ (how much it slows light). Light entering a denser material (larger n) bends **toward** the normal.



bends towards the normal $(i > r)$

■ 3 Snell's law

The bending follows **Snell's law** 斯涅尔定律:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2.$$

Worked example. A ray in air ($n_1 = 1.00$) enters water ($n_2 = 1.33$) at 40°: $\sin\theta_2 = \frac{1.00}{1.33}\sin 40° = 0.483$, so $\theta_2 = 29°$ –it bends toward the normal, as expected going into the denser medium.

■ 4 Total internal reflection

When light tries to leave a dense material at a steep enough angle, it reflects **entirely** back inside –**total internal reflection** 全反射. This is how optical fibres trap light and carry it for kilometres.

Watch out: all these angles are measured from the **normal**, not from the surface. Measuring from the surface is the most common error in optics.

Practice

Try these in order. The methods are all above.

2.1 A ray hits a mirror at 30° to the normal. State the angle of reflection. [1]

2.2 State what happens to the direction of light entering a denser material (bends toward or away from the normal). [1]

2.3 A ray in air ($n_1 = 1.00$) enters glass ($n_2 = 1.50$) at 30° to the normal. Use Snell's law to find the angle in the glass. [3]

2.4 Glass has an index of refraction of 1.5. Find the speed of light in the glass ($c = 3.0 \times 10^8$ m/s). [2]

2.5 State what total internal reflection is used for, and why it works. [2]

13 Images from mirrors and lenses – 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)		
converging	会聚			
diverging	发散			
real image	实像			
virtual image	虚像			

Recall

In Part A you saw light reflect and refract. Now those effects form **images**:

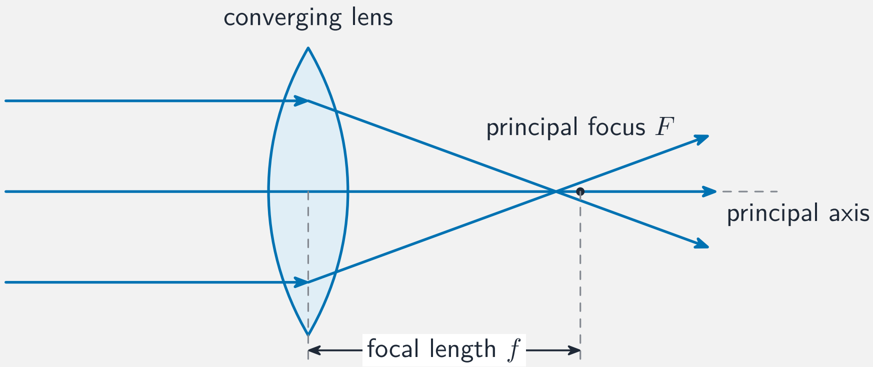
- A magnifying glass makes small print look bigger.
- A camera lens makes a small picture on its sensor.
- A curved mirror can focus light to a point.

Each idea has a worked example before the Practice.

New ideas

1 A converging lens

A **converging** 会聚 (convex) lens bends parallel rays to meet at its **focal point**, a distance f away.



A **diverging** 发散 (concave) lens spreads rays out instead.

■ 2 The thin-lens equation

For an object a distance d_o from a lens, the image forms at d_i where

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}.$$

Worked example. An object 30 cm from a converging lens with $f = 10$ cm: $\frac{1}{d_i} = \frac{1}{10} - \frac{1}{30} = \frac{2}{30}$, so $d_i = 15$ cm.

■ 3 Magnification

The **magnification** is

$$m = -\frac{d_i}{d_o},$$

where the size tells you how much bigger, and the sign tells you upright (+) or inverted (−).

Worked example. For the lens above, $m = -\frac{15}{30} = -0.5$ –the image is half-size and inverted (a camera picture).

■ 4 Real and virtual images

- A **real image** 实像 forms where rays actually meet –you can catch it on a screen (a camera, a projector).
- A **virtual image** 虚像 only appears to be there –you see it by looking through the lens (a magnifying glass).

Watch out: a **positive** image distance means a real image (on a screen); a **negative** one means a virtual image (seen by looking through). Keep the signs straight.

Practice

Try these in order. The methods are all above.

2.1 State what a converging lens does to parallel rays of light. [1]

2.2 An object is 20 cm from a converging lens of focal length $f = 5.0$ cm. Find the image distance. [3]

2.3 For the lens in 2.2, find the magnification. [2]

2.4 State whether the image in 2.2 is upright or inverted, and how you can tell. [1]

2.5 Give one everyday device that uses a real image and one that uses a virtual image. [2]

14 Waves, sound, and the wave equation – 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)		
wave	波			
Transverse	横波			
Longitudinal	纵波			
wavelength	波长			
frequency	频率			
amplitude	振幅			
wave speed	波速			
Electromagnetic waves	电磁波			
Doppler effect	多普勒效应			

Recall

Waves are all around you:

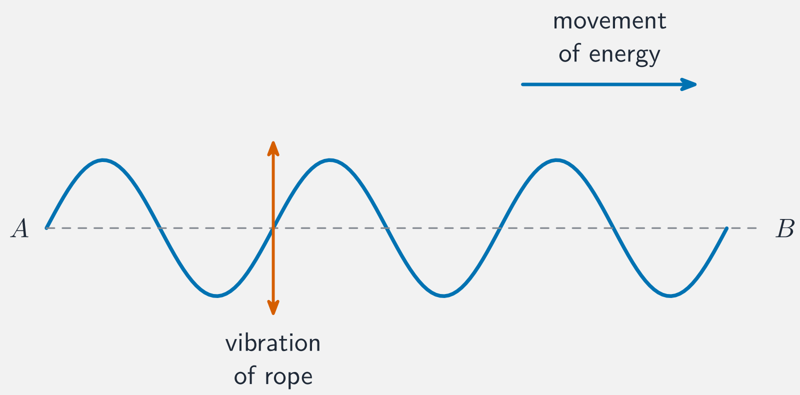
- Ripples spread across a pond; sound travels through the air; light reaches you from a lamp.
- A wave carries **energy** from place to place, but the water or air itself stays put.
- You have used speed = frequency × wavelength before.

This sheet lines up the wave ideas the AP course builds on. Each idea has a worked example.

New ideas

1 What a wave is

A **wave** 波 carries energy without carrying the material along. There are two kinds:



- **Transverse** 横波: the material moves at right angles to the wave (a rope wave, light).
- **Longitudinal** 纵波: the material moves back and forth along the wave (sound).

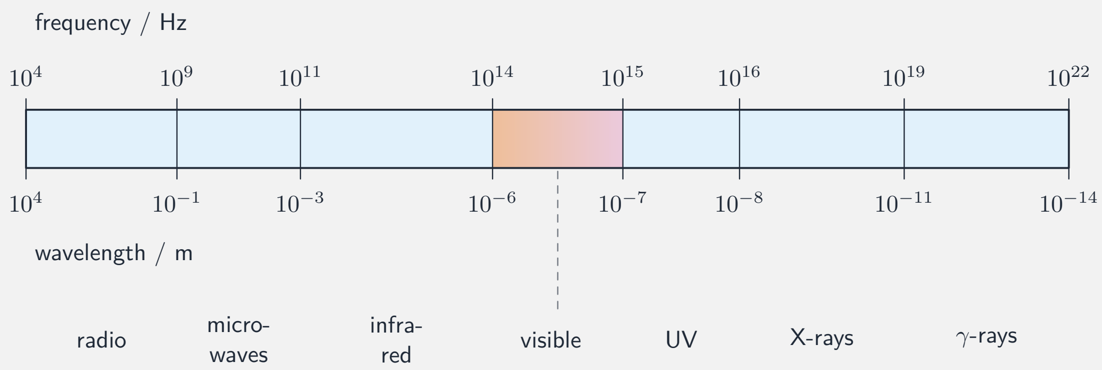
2 Describing a wave

- **wavelength** 波长 λ –the distance between repeats,
- **frequency** 频率 f –cycles per second,
- **amplitude** 振幅 A –the largest displacement (linked to energy),
- **wave speed** 波速: $v = f\lambda$, set by the material the wave travels in.

Worked example. A note of frequency 340 Hz travels through air at 340 m/s, so its wavelength is $\lambda = \dfrac{v}{f} = \dfrac{340}{340} = 1.0$ m.

3 Electromagnetic waves

Electromagnetic waves 电磁波 (radio, light, X-rays) are made of oscillating electric and magnetic fields. They all travel through empty space at the speed of light $c = 3.0 \times 10^8$ m/s and need no material.



■ **4 The Doppler effect**

The **Doppler effect** 多普勒效应 is the change in the frequency you hear when a source moves toward or away from you: approaching sounds higher-pitched, moving away sounds lower. It is why a passing siren drops in pitch.

Watch out: when a wave moves into a new material, its **frequency stays the same** (set by the source) but its **speed and wavelength change**. Do not assume the wavelength is fixed.

Practice

Try these in order. The methods are all above.

2.1 State the difference between a transverse and a longitudinal wave, with one example of each. [2]

2.2 A wave has frequency 50 Hz and wavelength 0.40 m. Find its speed. [2]

2.3 A radio wave travels at 3.0×10^8 m/s with frequency 1.0×10^8 Hz. Find its wavelength. [2]

2.4 A siren passes you at speed. Describe how the pitch you hear changes as it approaches and then moves away. [2]

2.5 A sound of frequency 200 Hz passes from air (speed 340 m/s) into water (speed

1500 m/s). State what happens to its frequency and to its wavelength. [2]

14 Interference, standing waves, and diffraction – 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)		
Constructive interference	相长干涉			
Destructive interference	相消干涉			
standing wave	驻波			
nodes	波节			
antinodes	波腹			
Diffraction	衍射			

Recall

In Part A you described single waves. Now see what happens when **two** waves meet:

- Two sets of ripples cross and make a criss-cross pattern.
- A guitar string vibrates in a fixed shape and sounds a clear note.
- Waves bend around a corner so you hear sound from another room.

Each idea has a worked example before the Practice.

New ideas

■ 1 Adding waves (superposition)

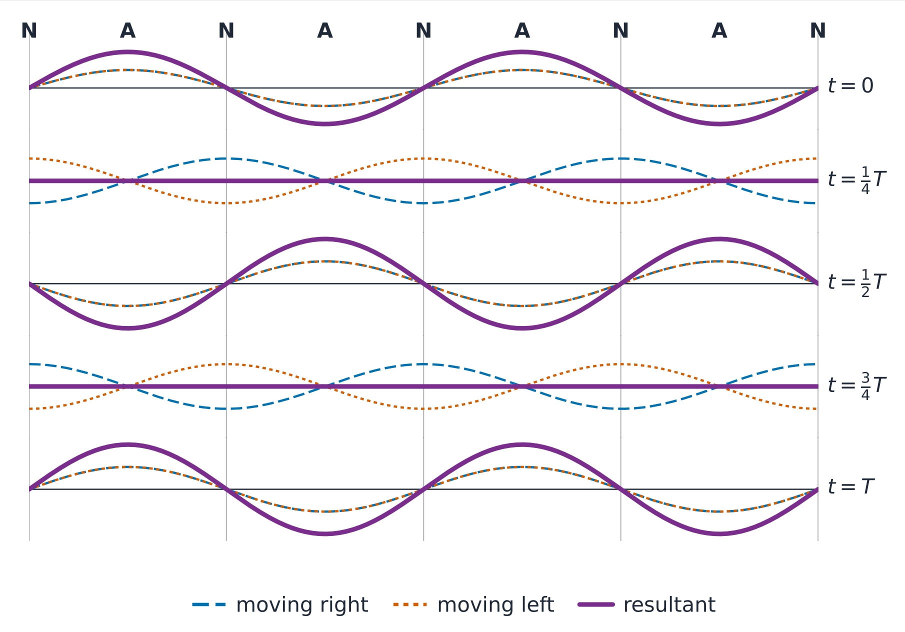
When two waves overlap they simply **add**:

- **Constructive interference** 相长干涉–crest meets crest –makes a bigger wave.

- **Destructive interference** 相消干涉–crest meets trough –cancels out.

■ 2 Standing waves

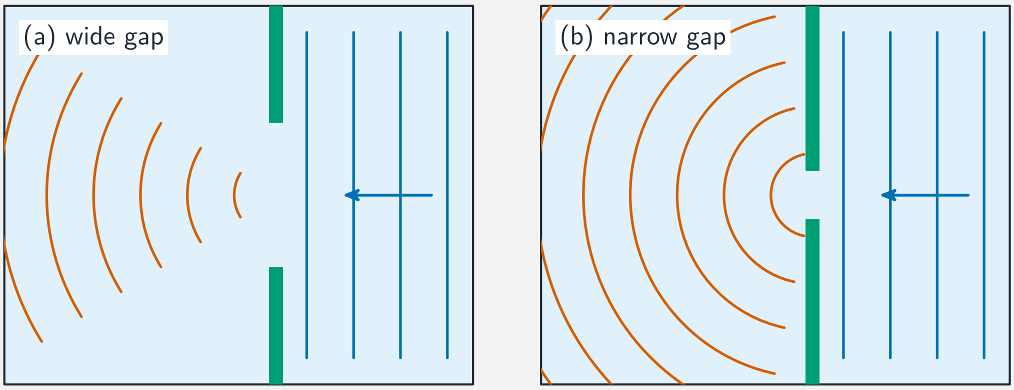
Two waves travelling in opposite directions in a fixed space form a **standing wave** 驻波, with **nodes** 波节 (points that never move) and **antinodes** 波腹 (points that move the most). This is how a guitar string or a pipe makes a note.



Worked example. A string 0.65 m long, fixed at both ends, fits half a wavelength in its simplest note, so $\lambda = 2L = 1.30$ m. If waves travel at 260 m/s, the note is $f = \dfrac{v}{\lambda} = \dfrac{260}{1.30} = 200$ Hz.

■ 3 Diffraction

Diffraction 衍射 is the bending and spreading of waves around edges or through gaps. It is largest when the gap is about the same size as the wavelength.



gap $\gg \lambda$: little spreading

gap $\approx \lambda$: strong spreading

■ 4 The double slit

Light passing through two close slits makes a pattern of bright and dark **fringes**, where the waves interfere. Bright fringes appear where the two paths differ by a whole number of wavelengths.

Watch out: diffraction is only obvious when the gap is close to the wavelength. Sound (long wavelength) bends around a doorway easily; light (tiny wavelength) needs a very narrow slit to spread noticeably.

Practice

Try these in order. The methods are all above.

2.1 State what happens when a crest of one wave meets (a) a crest of another, (b) a trough of another. [2]

2.2 On a standing wave, state what a node is and what an antinode is. [2]

2.3 A string 0.50 m long, fixed at both ends, has $\lambda = 2L$ in its simplest note. Waves travel at 300 m/s. Find the frequency of the note. [3]

2.4 Explain why you can hear sound coming from around a corner, but cannot see around it. [2]

2.5 State what you would see on a screen when light passes through two closely spaced slits. [1]

15 Photons and the atom – 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)		
quanta	量子			
photons	光子			
Wave–particle duality	波粒二象性			
energy levels	能级			
photoelectric effect	光电效应			
work function	逸出功			

Recall

You have heard some surprising ideas about light and atoms:

- Light comes in tiny packets called photons, not just a smooth wave.
- Atoms give off particular colours –think of the orange glow of a street lamp.
- Shining light on some metals can knock electrons out.

This sheet makes these quantum ideas exact. Each idea has a worked example.

New ideas

■ 1 Photons

At tiny scales, energy comes in packets called **quanta** 量子. Light is carried by **photons** 光子, each with energy set by its frequency:

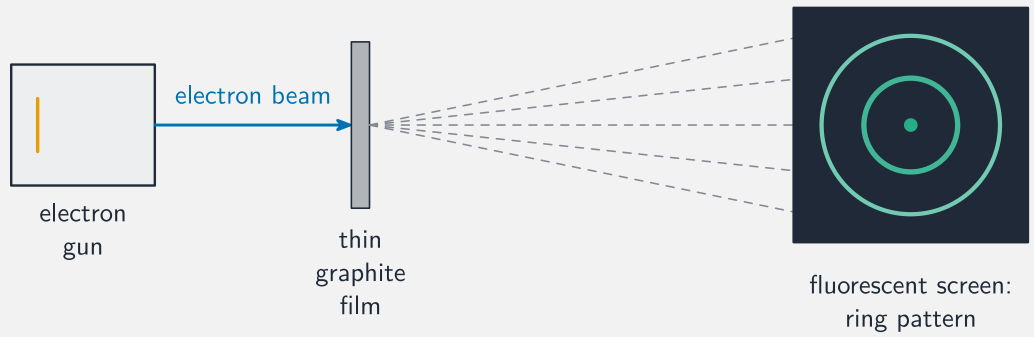
$$E = hf,$$

where $h = 6.63 \times 10^{-34}$ J s is Planck's constant. Higher-frequency light means higher-energy photons.

Worked example. A green-light photon of frequency 5.0×10^{14} Hz carries $E = hf = 6.63 \times 10^{-34} \times 5.0 \times 10^{14} = 3.3 \times 10^{-19}$ J.

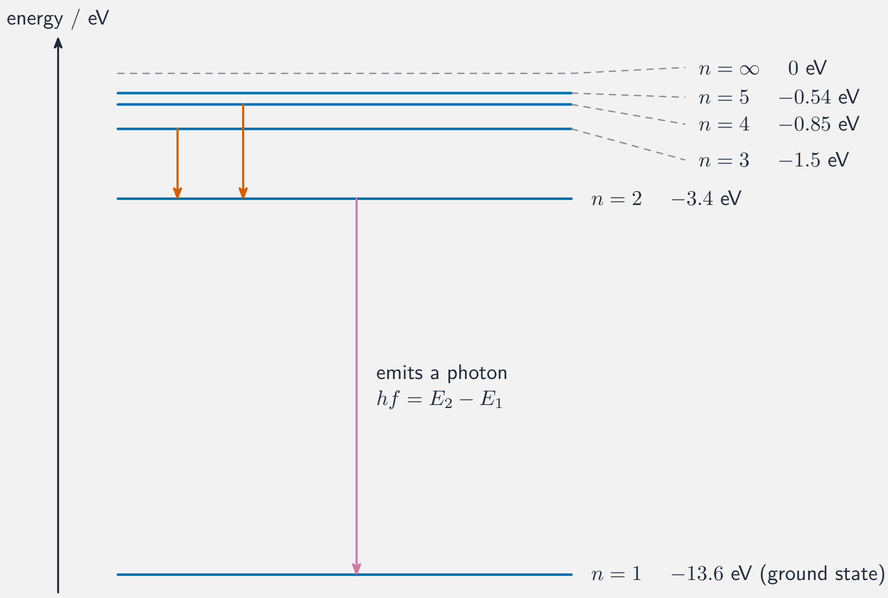
■ 2 Wave–particle duality

Wave–particle duality 波粒二象性 means light (and even matter) shows **both** wave behaviour (interference, diffraction) and particle behaviour (photons, single hits).



■ 3 Energy levels

An atom's electrons can sit only in certain **energy levels** 能级. An electron jumps between levels by absorbing or emitting a photon whose energy exactly matches the gap. Because the gaps are fixed, each element gives off its own set of colours –a fingerprint.



■ 4 The photoelectric effect

Shining light on a metal can eject electrons –the **photoelectric effect 光电效应**–but only if the photon's frequency is high enough. The escaping electron's energy is

$$K_{\text{max}} = hf - \phi,$$

where ϕ is the **work function 逸出功** (the energy needed to free an electron).

Watch out: below the threshold frequency, **no** electrons come out, no matter how bright the light. Brightness adds more photons, but each one must individually be energetic enough.

Practice

Try these in order. The methods are all above.

2.1 Find the energy of a photon of frequency 4.0×10^{14} Hz ($h = 6.63 \times 10^{-34}$ J s). [2]

2.2 State what ”wave–particle duality” means, in one sentence. [1]

2.3 An electron drops between two energy levels, emitting a photon. State what decides the photon's energy. [1]

2.4 Light of frequency 9.0×10^{14} Hz hits a metal with work function $\phi = 4.0 \times 10^{-19}$ J. Find the maximum kinetic energy of an ejected electron. [3]

2.5 A very bright red light shines on a metal but ejects no electrons, while a dim blue light does. Explain why. [2]

15 The nucleus - fission, fusion, and decay – 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)		
nucleus	原子核			
Fission	裂变			
Fusion	聚变			
radioactive decay	放射性衰变			
alpha	阿尔法衰变			
beta	贝塔衰变			
gamma	伽马衰变			
half-life	半衰期			

Recall

You already know some nuclear physics:

- Atoms have a tiny, dense **nucleus** of protons and neutrons.
- Some atoms are **radioactive** and give off radiation.
- Nuclear power and the Sun both release huge amounts of energy.

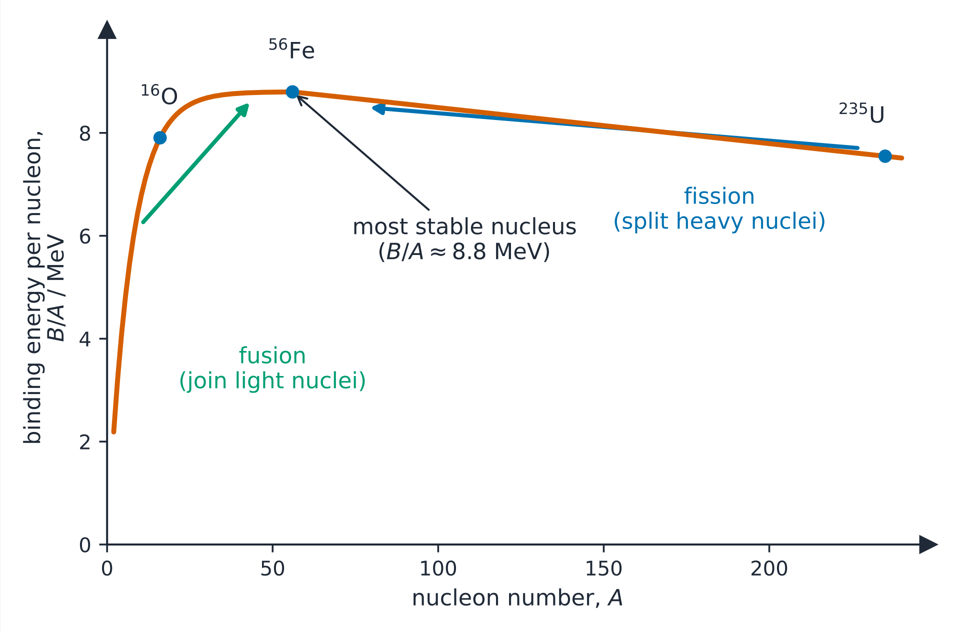
This sheet explains where that energy comes from. Each idea has a worked example.

New ideas

1 Energy from the nucleus

The **nucleus** 原子核 stores enormous energy. Two processes release it:

- **Fission** 裂变 splits a heavy nucleus into lighter pieces (nuclear reactors).
- **Fusion** 聚变 joins light nuclei into a heavier one (the Sun).



2 Mass becomes energy

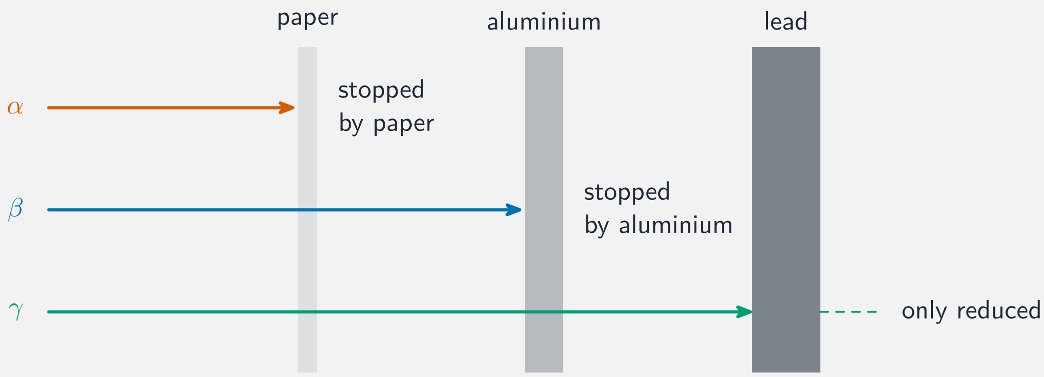
Both release energy because the products have slightly **less mass** than the starting materials, converted by Einstein's equation

$$E = mc^2.$$

Worked example. If a reaction loses 1.0×10^{-3} kg of mass, it releases $E = mc^2 = 1.0 \times 10^{-3} \times (3.0 \times 10^8)^2 = 9.0 \times 10^{13}$ J –a tiny mass, an enormous energy.

3 Radioactive decay

Unstable nuclei undergo **radioactive decay** 放射性衰变, emitting three kinds of radiation:



- **alpha** 阿尔法衰变–a helium nucleus (stopped by paper),
- **beta** 贝塔衰变–a fast electron (stopped by aluminium),
- **gamma** 伽马衰变–a high-energy photon (needs thick lead).

■ 4 Half-life

Decay is random, but a sample halves every **half-life** 半衰期: after each half-life, half of the remaining nuclei have decayed.

Worked example. A sample has a half-life of 8.0 days. After 24 days that is $24/8.0 = 3$ half-lives, so the fraction left is $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$ (about 12.5%).

Watch out: in every decay, the total **mass number** and total **charge** are conserved –use this to balance a decay equation and find the new nucleus.

Practice

Try these in order. The methods are all above.

2.1 State the difference between nuclear fission and nuclear fusion. [2]

2.2 A nuclear reaction loses 2.0×10^{-4} kg of mass. Find the energy released ($c = 3.0 \times 10^8$ m/s). [3]

2.3 Name the three types of radioactive decay, in order of increasing penetrating power. [2]

2.4 A sample has a half-life of 5.0 years. What fraction remains after 15 years? [3]

2.5 State the two quantities that are always conserved in a radioactive decay. [1]