HOLIDAY HOMEWORK 假期作业

AS-Level Physics

Exercise sheets and past-paper practice, topic by topic.

每个单元：练习卷 + 历年真题。

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

Contents 目录

1 Physical quantities and units – 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)		
physical quantity	物理量			
magnitude	大小			
unit	单位			
base quantity	基本量			
derived unit	导出单位			
prefix	词头			
homogeneous	量纲一致			
scalar	标量			
vector	矢量			
resultant	合矢量			
perpendicular	垂直			

Recall

You already did a lot of this at IGCSE. Bring it with you:

- You measured things: **length** in metres (m), **time** in seconds (s), **mass** in kilograms (kg).
- Every measurement is a number together with a unit — “5” means nothing, “5 m” is a length.
- You met speed, force and energy. At AS we look more carefully at **units** and at **direction**.

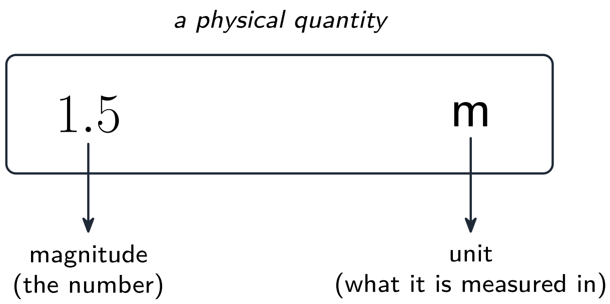
This sheet gets you ready. Nothing here is harder than IGCSE — it just lines up the ideas the AS course starts with.

New ideas

Read these first. Each idea has a short worked example. Once you have read them you can do the Practice below.

1 Every quantity = magnitude + unit

A **physical quantity** 物理量 is anything you can measure. It always has two parts: a **magnitude** 大小 (the number) and a **unit** 单位 (what it is measured in).



So “the mass is 60” is not complete. “The mass is 60 kg” is a real physical quantity.

2 Base units and derived units

The whole SI system is built from a few **base quantity** 基本量 measures. You only need these:

base quantity	unit	symbol
mass	kilogram	kg
length	metre	m
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol

Every other unit is a **derived unit** 导出单位 — built by multiplying or dividing base units.

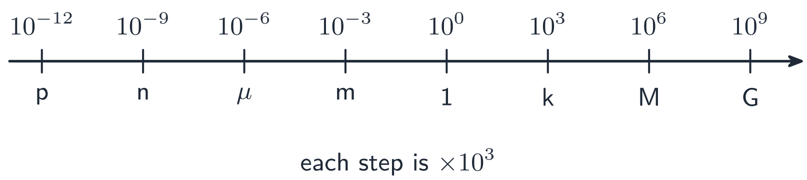
Worked example. Speed $= \dfrac{\text{distance}}{\text{time}}$, so its unit is $\dfrac{\text{m}}{\text{s}} = \text{m s}^{-1}$. Force is $F = ma$, so its unit is $\text{kg} \times \text{m s}^{-2} = \text{kg m s}^{-2}$. We give this the name **newton** (N).

3 Prefixes and powers of ten

A **prefix** 词头 is a letter put in front of a unit. It multiplies the unit by a power of ten.

prefix	symbol	factor
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}

Worked example. $45\ \mu\text{m} = 45 \times 10^{-6}\ \text{m} = 4.5 \times 10^{-5}\ \text{m}$. And $2\ \text{GW} = 2 \times 10^{9}\ \text{W}$.



Watch out: a prefix changes only the size, not the quantity — 1 km and 1000 m are the same length. Convert prefixes to powers of ten *before* calculating.

4 Checking units (homogeneous equations)

An equation is **homogeneous** 量纲一致 when both sides have the **same units**. If the units do not match, the equation must be wrong — a quick and powerful check.

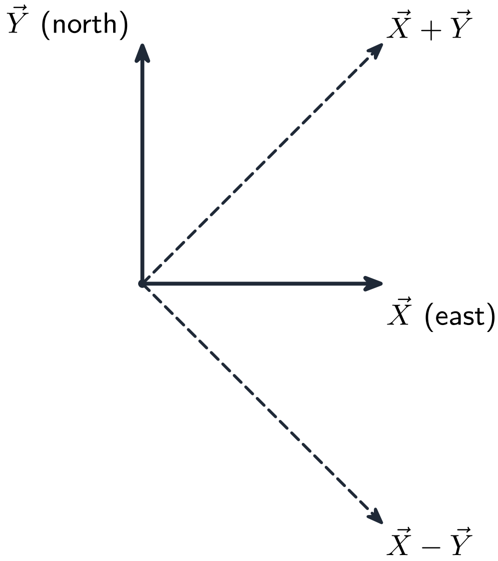
Worked example. Check $v = u + at$. Left side v: a velocity, units m s^{-1}. Right side: u is m s^{-1}, and $at = (\text{m s}^{-2})(\text{s}) = \text{m s}^{-1}$. Both sides are m s^{-1}, so the equation is homogeneous.

5 Scalars and vectors

A **scalar** 标量 has magnitude only — mass, time, energy, temperature. A **vector** 矢量 has magnitude **and** direction — force, velocity, displacement.

When two vectors act at right angles, their combined effect is the **resultant** 合矢量. Because they are **perpendicular** 垂直 (at 90°), you find its size with Pythagoras:

$$R = \sqrt{a^2 + b^2}.$$



Worked example. A force of 3.0 N east and 4.0 N north:

$$R = \sqrt{3.0^2 + 4.0^2} = \sqrt{25} = 5.0 \text{ N}.$$

Practice

Try these in order. They get a little harder. The methods are all above.

2.1 A student writes "the time is 12". State what is missing to make it a physical quantity. [1]

2.2 Give the SI base unit of (a) mass, (b) length, (c) time. [3]

2.3 Show that the derived unit of speed is m s^{-1}, starting from speed = distance ÷ time. [1]

2.4 Write each length in metres, using a power of ten: (a) 3 km, (b) 25 mm, (c) 7 μm. [3]

2.5 The kinetic energy equation is $E_k = \frac{1}{2}mv^2$. The unit of energy is the joule, J = kg $m^2 s^{-2}$. Show that the right-hand side mv^2 has these same units (so the equation is homogeneous). [2]

2.6 State whether each quantity is a scalar or a vector: (a) mass, (b) velocity, (c) energy, (d) force. [2]

2.7 A swimmer heads north at 1.2 m s^{-1} across a river. The current flows east at 0.5 m s^{-1}. These velocities are perpendicular. Find the magnitude of the swimmer's resultant velocity. [2]

15 A man of weight 600 N stands with both feet flat on the ground.

What is a reasonable estimate of the pressure exerted on the ground by the weight of the man?

A 1×10^0 Pa **B** 1×10^2 Pa **C** 1×10^4 Pa **D** 1×10^6 Pa

A-Level Physics: **w25 12**

1 What is a reasonable estimate of the weight of an adult human?

A 7×10^0 N **B** 7×10^2 N **C** 7×10^4 N **D** 7×10^6 N

A-Level Physics: **s25 12**

1 What must all physical quantities have?

A a direction and a magnitude

B a direction and a unit

C a magnitude and a prefix

D a magnitude and a unit

A-Level Physics: **s25 14**

1 The number of atoms in a mobile phone handset may be estimated by dividing the approximate volume of the handset by the approximate volume of an atom.

What is a reasonable estimate of the number of atoms in a mobile phone handset?

A 10^{17} **B** 10^{26} **C** 10^{32} **D** 10^{37}

3 What are the SI base units of the watt?

A $\mathrm{J\,s^{-1}}$ **B** $\mathrm{kg\,m^{2}\,s^{-3}}$ **C** $\mathrm{kg\,m^{2}\,s^{-1}}$ **D** $\mathrm{N\,m\,s^{-1}}$

22 What are the SI base units of stress?

A $\mathrm{kg\,m\,s^{-2}}$ **B** $\mathrm{kg\,m^{-1}\,s^{-2}}$ **C** $\mathrm{kg\,m^{-2}\,s^{-2}}$ **D** $\mathrm{kg\,m^{-3}\,s^{-2}}$

A-Level Physics: **w25 12**

3 Which physical quantity could have units of $\mathrm{N\,s^{2}\,m^{-1}}$?

A acceleration

B force

C mass

D momentum

A-Level Physics: **s25 12**

2 What is $0.25\,\mathrm{kN\,mm^{-2}}$ expressed in $\mathrm{N\,m^{-2}}$?

A $0.00025\,\mathrm{N\,m^{-2}}$

B $0.25\,\mathrm{N\,m^{-2}}$

C $250\,000\,\mathrm{N\,m^{-2}}$

D $250\,000\,000\,\mathrm{N\,m^{-2}}$

A-Level Physics: **s25 14**

2 Which unit is **not** equivalent to a unit of energy?

A $\mathrm{N\,m}$ **B** $\mathrm{V\,C}$ **C** $\mathrm{W\,s}$ **D** $\mathrm{kg\,m\,s^{-2}}$

1 Physical quantities and units – 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)		
measurement	测量			
uncertainty	不确定度			
systematic error	系统误差			
zero error	零点误差			
accuracy	准确度			
random error	随机误差			
mean	平均值			
precision	精密度			
absolute uncertainty	绝对不确定度			
perpendicular	垂直			
components	分量			

Recall

In **Part 1** you wrote quantities in SI base units, checked an equation is homogeneous, and added two perpendicular vectors. Keep ready:

- Every quantity is a number **and** a unit; a vector has size **and** direction.
- Two perpendicular vectors add to a resultant of size $\sqrt{X^2+Y^2}$.

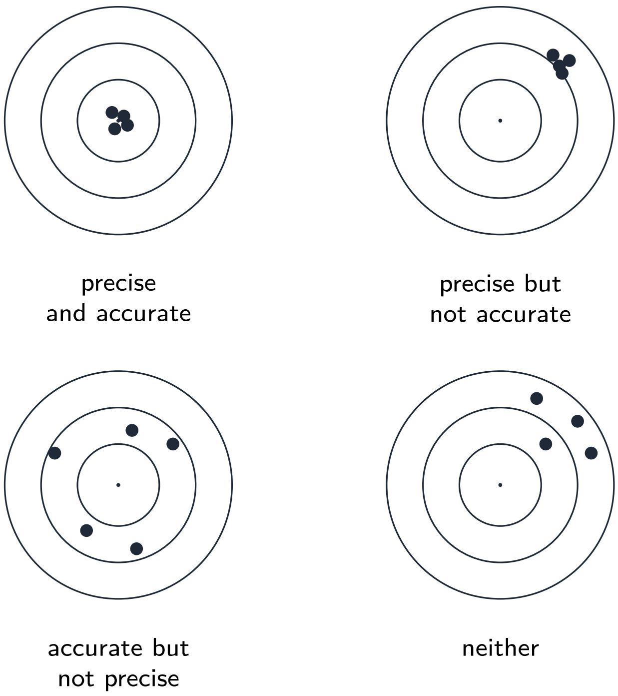
Part 2 looks at how *sure* we are of a measurement (uncertainty), and at splitting a vector into parts.

New ideas

1 Systematic and random errors

Every **measurement** 测量 has some **uncertainty** 不确定度 — we are never perfectly sure of the value. Errors come in two kinds:

- a **systematic error** 系统误差 shifts every reading the same way (e.g. a **zero error** 零点误差 — the scale doesn't read zero at the start). Repeating does **not** remove it; it harms the **accuracy** 准确度.
- a **random error** 随机误差 scatters readings above and below the true value. Taking the **mean** 平均值 of many repeats reduces it; it harms the **precision** 精密度.



Precise = readings close together; *accurate* = readings near the true value.

Watch out: repeating a measurement reduces *random* error but never a *systematic* one — a zero error stays however many times you repeat.

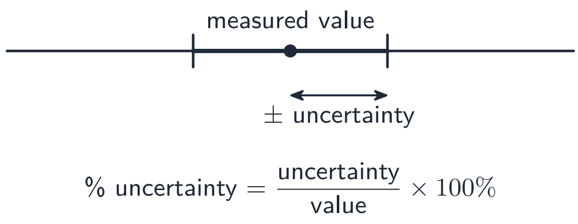
■ 2 Absolute and percentage uncertainty

A measurement is written $x \pm \Delta x$, where Δx is the **absolute uncertainty** 绝对不确定度. The

$$\text{percentage uncertainty} = \frac{\Delta x}{|x|} \times 100\%.$$

To combine uncertainties in a calculated value: **add or subtract** → add the *absolute* uncertainties; **multiply or divide** → add the *percentage* uncertainties; a **power** n → multiply the percentage by n.

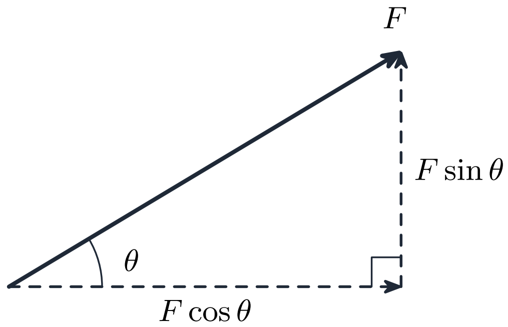
Worked example. A diameter is $d = 5.0 \pm 0.1$ cm, so its percentage uncertainty is $\frac{0.1}{5.0} \times 100\% = 2\%$. An area $A \propto d^2$, so the percentage uncertainty in A is $2 \times 2\% = 4\%$.



■ 3 Resolving a vector into components

Any vector can be split into two **perpendicular** 垂直 **components** 分量. For a vector of size v at angle θ to the horizontal:

$$v_{\mathrm{H}} = v\cos\theta, \qquad v_{\mathrm{V}} = v\sin\theta.$$



Worked example. A force of 50 N acts at 30° above the horizontal: $v_{\mathrm{H}} = 50\cos 30° = 43$ N, $v_{\mathrm{V}} = 50\sin 30° = 25$ N.

Practice

1.1 State whether each is a systematic or a random error: (a) a balance that reads 2 g with nothing on it; (b) readings that scatter each time you repeat them. [2]

1.2 A set of readings is grouped very close together but far from the true value. State whether they are (a) precise, (b) accurate. [2]

1.3 A length is measured as 20.0 ± 0.5 cm. Find its percentage uncertainty. [2]

1.4 A quantity $y = ab$, where a has a percentage uncertainty of 2% and b of 3%. Find the percentage uncertainty in y. [1]

1.5 A force of 12 N acts at 60° to the horizontal. Find its horizontal and vertical components. [3]

1.6 Challenge. The side of a cube is measured with a percentage uncertainty of 1%. State the percentage uncertainty in its volume, and explain why. [2]

2 What describes a set of data with a high precision?

A data measured using equipment with small scale divisions

B data that is close to the accepted value

C data with each value having a low uncertainty

D data with repeats that are close to each other

A-Level Physics: **w25 14**

3 A stone is released from rest and falls vertically to the ground.

The time taken to fall to the ground and the distance travelled are measured. The measurements are used to determine the acceleration of free fall.

The percentage uncertainty in the measured time is 0.05%. The percentage uncertainty in the measured distance fallen is 0.6%.

What is the percentage uncertainty in the calculated value of the acceleration of free fall?

A 0.5% **B** 0.7% **C** 1.1% **D** 1.3%

A-Level Physics: **s25 11**

3 The diameter of a ball is measured as (5.26 ± 0.02) cm.

What is the absolute uncertainty in the volume of the ball?

A $0.29\,cm^3$ **B** $0.87\,cm^3$ **C** $1.1\,cm^3$ **D** $7.0\,cm^3$

A-Level Physics: **m25 12**

2 What is the effect of a systematic error on the measurement of a physical quantity?

A It limits the precision of the measured value.

B It limits the range of values obtained in repeated measurements.

C It results in repeated measurements having different values from each other.

D It results in the measured value being different from the correct value.

1 Which quantity is a vector?

A pressure

B temperature

C weight

D work

A-Level Physics: **s25 13**

3 Which statement about errors in measurements is correct?

A An accurate set of measurements always has a small random error.

B A precise set of measurements always has a small systematic error.

C A random error can be reduced by taking an average of several measurements.

D A systematic error creates a random set of measurements spread out about the true value.

A-Level Physics: **m25 12**

1 Which quantity is a scalar quantity?

A force

B momentum

C velocity

D work

2 Kinematics – 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)		
Speed	速率			
distance	距离			
velocity	速度			
scalar	标量			
vector	矢量			
displacement	位移			
uniform acceleration	匀加速			
acceleration	加速度			
free fall	自由落体			
gradient	斜率			

Recall

You measured motion at IGCSE. Bring this with you:

- **Speed** 速率 tells you how fast something moves: speed = distance ÷ time.
- A **distance** 距离 is how far you travel; **velocity** 速度 is speed in a stated direction.
- You read simple distance–time and speed–time graphs.

At AS we sharpen these ideas and add four equations that solve almost any straight-line motion problem.

New ideas

Read these first, then do the Practice.

■ 1 Scalars and vectors

A **scalar** 标量 has size only (distance, speed, time). A **vector** 矢量 has size **and** direction. A **displacement** 位移 is the straight-line distance in a direction — the vector version of distance.

So if you walk 3 km east then 3 km back, your distance is 6 km but your displacement is 0.

■ 2 The equations of motion

For motion with **uniform acceleration** 匀加速 (a steady **acceleration** 加速度 a), five quantities link up: displacement s, start velocity u, end velocity v, acceleration a, time t. Four equations connect them:

$$v = u + at \qquad s = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2as \qquad s = \tfrac{1}{2}(u + v)\,t$$

The general method: write down the quantities you **know** and the one you **want**; choose the equation that uses only those letters; substitute.

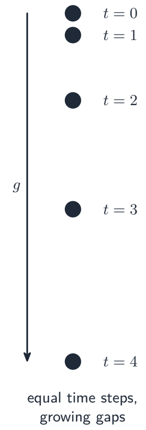
Worked example. A car speeds up from $u = 8$ m s^{-1} at $a = 2$ m s^{-2} for $t = 5$ s. Find v: use $v = u + at = 8 + (2)(5) = 18$ m s^{-1}. Find s: use $s = ut + \frac{1}{2}at^2 = (8)(5) + \frac{1}{2}(2)(5^2) = 40 + 25 = 65$ m.

Watch out: these four equations only work for *uniform* (constant) acceleration — do not use them when the acceleration changes.

■ 3 Free fall

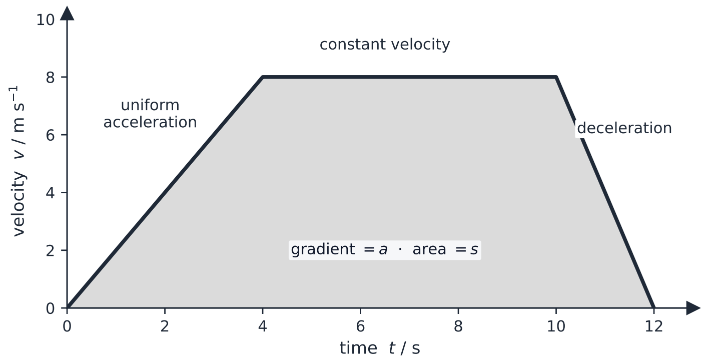
An object falling freely has acceleration $g = 9.81$ m s^{-2} downward (often rounded to 9.8). This is **free fall** 自由落体. Use the same four equations with $a = g$.

Worked example. A stone is dropped ($u = 0$). After $t = 2.0$ s: $v = u + at = 0 + (9.81)(2.0) = 19.6$ m s^{-1}.



■ 4 Velocity–time graphs

On a velocity–time graph the **gradient** 斜率 (steepness) is the acceleration, and the **area** under the line is the displacement.



Practice

2.1 A runner jogs 100 m north, then 100 m back south. State (a) the total distance, (b) the final displacement. [2]

2.2 State whether each is a scalar or a vector: (a) time, (b) velocity, (c) speed, (d) displacement. [2]

2.3 A cyclist starts at $u = 4$ m s^{-1} and accelerates at $a = 1.5$ m s^{-2} for $t = 6$ s. Find the final velocity v. [2]

2.4 Using the same cyclist, find the distance s travelled in those 6 s. [2]

2.5 A ball is dropped from rest. Taking $g = 9.8$ m s^{-2}, find its speed after 1.5 s. [2]

2.6 A car speeds up uniformly from 0 to 20 m s^{-1} in 8.0 s. (a) Find its acceleration. (b) On its velocity–time graph the area under the line is a triangle; find the distance from area $= \frac{1}{2} \times$ base $\times$ height. [3]

2.7 Challenge. A ball is thrown straight up. At its highest point it is momentarily still. State its acceleration there, and explain your answer. [2]

2 Kinematics – 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)		
gradient	斜率			
tangent	切线			
projectile	抛体			
Horizontal	水平			
Vertical	竖直			

Recall

In **Part 1** you used the four equations of motion and read velocity–time graphs. Keep these ready:

- A **vector** has size *and* direction; free fall has acceleration $g = 9.8 \text{ m s}^{-2}$ downward.
- On a velocity–time graph, the gradient is the acceleration and the area is the displacement.

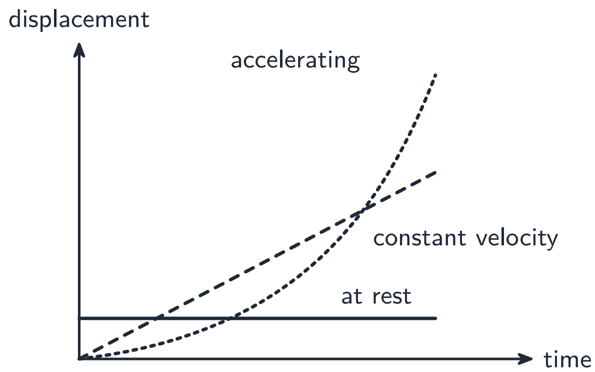
Part 2 looks at motion graphs more closely, and at motion in **two directions** at once.

New ideas

■ 1 Displacement–time graphs

On a displacement–time graph the **gradient** 斜率 (steepness) is the **velocity**.

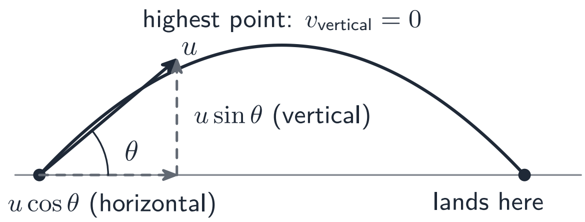
- a straight slope → constant velocity;
- a flat line → at rest (not moving);
- a curve → changing velocity. The velocity at one instant is the gradient of the **tangent** 切线 (a straight line just touching the curve) at that point.



■ 2 Projectile motion

A **projectile** 抛体 moves horizontally and vertically at the same time. The trick: treat the two directions **separately**, sharing the same time t.

- **Horizontal** 水平: no force, so the velocity stays constant — distance $= u_x\, t$.
- **Vertical** 竖直: free fall, so use the equations of motion with $a = g$.

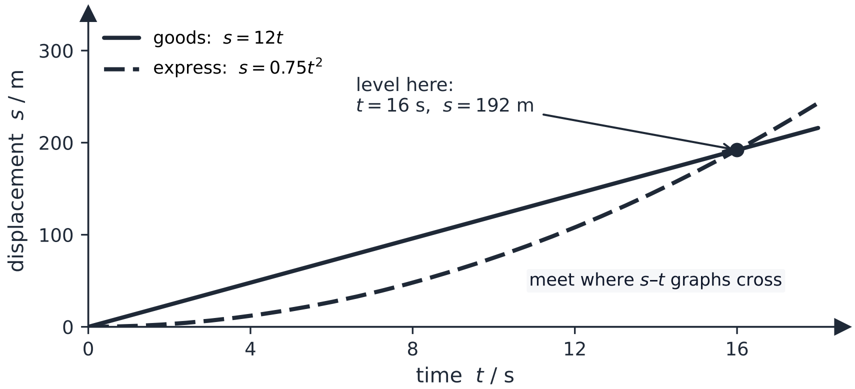


Worked example. A ball is thrown horizontally at 5.0 m s^{-1} from a height of 1.8 m. *Vertical:* $1.8 = \frac{1}{2}gt^2 \Rightarrow t = \sqrt{2(1.8)/9.8} = 0.61$ s. *Horizontal:* range $= u_x t = 5.0 \times 0.61 = 3.0$ m.

Watch out: the horizontal and vertical parts are independent — they share only the *time*. The horizontal speed never changes how fast the projectile falls.

■ 3 Two objects meeting

When two objects move along the same line, write a displacement equation for **each**, then set them equal to find when they meet.



Worked example. Car A starts from rest-point 0 at 20 m s^{-1}. Car B is 100 m ahead going 12 m s^{-1} the same way. A catches B when $20t = 100 + 12t$, so $8t = 100$, $t = 12.5$ s (at 250 m).

Practice

2.1 A displacement–time graph is a straight slope for 5 s, then a flat horizontal line. State what the object does in (a) the first 5 s, (b) after 5 s. [2]

2.2 A stone is thrown horizontally at 8.0 m s^{-1} from a cliff 20 m high ($g = 9.8$ m s^{-2}). (a) Find the time to reach the ground. (b) Find how far from the cliff base it lands. [4]

2.3 A ball rolls off a table 0.80 m high at 2.0 m s^{-1}. Find the time it takes to hit the floor. [2]

2.4 Runner A passes a post at 6.0 m s^{-1}. At the same moment runner B is 30 m ahead going 4.0 m s^{-1} the same way. After what time does A catch B? [2]

2.5 Challenge. Two balls leave a table at the same instant — one is simply dropped, the other is rolled off fast. Explain why they hit the floor at the same time. [2]

5 A car has an initial velocity u. The car then moves with constant acceleration a in a straight line through a displacement d. The car reaches a final velocity v.

Which expression gives the initial velocity u of the car?

A $v - ad$ **B** $\sqrt{v^2 - 2ad}$ **C** $v + ad$ **D** $v - \frac{1}{2}ad^2$

A-Level Physics: **s25 11**

5 A ball is projected vertically downwards with an initial velocity of $20\,\mathrm{m\,s^{-1}}$. Air resistance is negligible.

What is the displacement from its initial position of the ball after a time of 1.5 s?

A 11 m **B** 19 m **C** 37 m **D** 41 m

6 A surveyor's device emits a pulse of light. The light is reflected from a wall 150 m away.

What is the total time taken for the pulse to travel from the device to the wall and then back to the device?

A 0.05 ns **B** 0.10 ns **C** 0.50 μs **D** 1.0 μs

A-Level Physics: **s25 14**

6 A ball is released from rest from a window at a height of 12 m above the ground. Air resistance is negligible.

What is the time taken after release for the ball to reach the ground?

A 1.1 s **B** 1.2 s **C** 1.6 s **D** 2.4 s

A-Level Physics: **m25 12**

4 An aircraft, initially stationary on a runway, takes off with a speed of $85\,\mathrm{km\,h^{-1}}$ in a distance of no more than 1.20 km.

What is the minimum constant acceleration necessary for the aircraft?

A $0.23\,\mathrm{m\,s^{-2}}$ **B** $0.46\,\mathrm{m\,s^{-2}}$ **C** $3.0\,\mathrm{m\,s^{-2}}$ **D** $6.0\,\mathrm{m\,s^{-2}}$

3 Dynamics – 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)		
force	力			
Weight	重力			
resultant force	合力			
mass	质量			
acceleration	加速度			
friction	摩擦力			
linear momentum	动量			
collision	碰撞			
conservation of momentum	动量守恒			

Recall

At IGCSE you learned that forces change motion. Bring this with you:

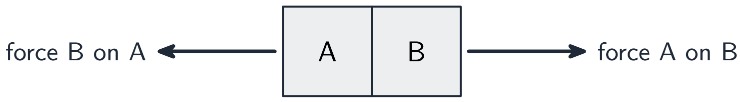
- A **force** 力 is a push or a pull, measured in newtons (N).
- A bigger force gives a bigger push; a heavier object is harder to speed up.
- **Weight** 重力 is the downward pull of gravity: weight $= mg$.

At AS we state these ideas exactly with Newton's laws, and add momentum.

New ideas

■ 1 Newton's three laws

- **First law:** an object stays at rest, or keeps moving at constant velocity, unless a **resultant force** 合力 (the single force left after adding all the forces) acts on it.
- **Second law:** the resultant force equals **mass** 质量 times **acceleration** 加速度: $F = ma$.
- **Third law:** if A pushes B, then B pushes A back with an equal and opposite force.

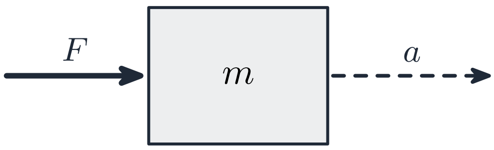


equal size, opposite direction

■ 2 Using F = ma

Method: add up the forces to get the resultant, then use $a = F/m$.

Worked example. A box of mass 3.0 kg is pushed with 20 N, while **friction** 摩擦力 pushes back with 5.0 N. Resultant force $= 20 - 5.0 = 15$ N, so $a = \frac{F}{m} = \frac{15}{3.0} = 5.0$ m s^{-2}.



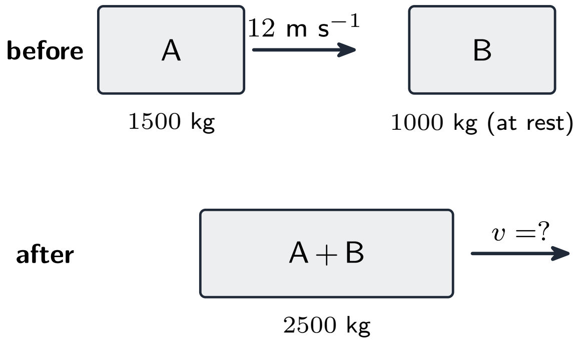
$F = ma$

Watch out: in $F = ma$, the F is the *resultant* force (all forces added together), not just the push you apply — subtract friction first.

■ 3 Momentum

The **linear momentum** 动量 of an object is $p = mv$ (mass × velocity); it is a vector.

In any **collision** 碰撞 or explosion with no outside force, **conservation of momentum** 动量守恒 holds: the total momentum **before = after**.



Worked example. A 2.0 kg trolley at 3.0 m s^{-1} hits a stationary 1.0 kg trolley and they stick together. Before: $p = (2.0)(3.0) + 0 = 6.0$ kg m s^{-1}. After: combined mass 3.0 kg, so $v = \dfrac{6.0}{3.0} = 2.0$ m s^{-1}.

Practice

3.1 State Newton's second law as an equation and say what each symbol means. [2]

3.2 A resultant force of 12 N acts on a 4.0 kg mass. Find the acceleration. [2]

3.3 A 1500 kg car moves at 20 m s^{-1}. Find its momentum. [2]

3.4 A 0.50 kg ball at 4.0 m s^{-1} hits a stationary 0.50 kg ball and they stick together.

Find their common velocity afterwards. [3]

3.5 Find the weight of a 6.0 kg bag (take $g = 9.8$ m s^{-2}). [1]

3.6 Challenge. A rocket in empty space has nothing to push against, yet it speeds up. Explain how, using Newton's third law (or conservation of momentum). [2]

12 A rocket has a weight of W and an initial acceleration of a as the rocket leaves the ground vertically. The acceleration of free fall is g.

Which expression gives the initial upward force exerted on the rocket due to the engine?

A $\dfrac{Wa}{g} + W$ **B** $\dfrac{Wa}{g}$ **C** $\dfrac{Wa}{g} - W$ **D** $Wa + W$

A-Level Physics: **s25 12**

7 A solid object of mass 1.0 kg falls vertically downwards in a vacuum.

When the speed of the object is $60\,m\,s^{-1}$, an additional constant force of 50 N suddenly starts to act vertically upwards on the object.

What is the speed of the object 2.0 s after the additional force starts to act?

A $20\,m\,s^{-1}$ **B** $40\,m\,s^{-1}$ **C** $80\,m\,s^{-1}$ **D** $100\,m\,s^{-1}$

9 A rocket engine ejects 90 kg of exhaust gas per second at a velocity of $190\,m\,s^{-1}$ relative to the rocket.

What is the force acting on the rocket due to the ejected gas?

A 2.1 kN **B** 17 kN **C** 18 kN **D** 162 kN

A-Level Physics: **m25 12**

8 An astronaut of mass m in a spacecraft experiences a gravitational force $F = mg$ when stationary on the launchpad.

What is the gravitational force on the astronaut when the spacecraft is launched vertically upwards with an acceleration of $0.2g$?

A $1.2mg$ **B** mg **C** $0.8mg$ **D** 0

3 Dynamics – 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)		
impulse	冲量			
friction	摩擦力			
drag	阻力			
terminal velocity	收尾速度			
elastic collision	弹性碰撞			
kinetic energy	动能			
relative speed	相对速率			
inelastic collision	非弹性碰撞			
deformation	形变			

Recall

In **Part 1** you used $F = ma$, Newton's three laws, and conservation of momentum. Keep ready:

- Momentum $p = mv$; the total momentum is conserved when no outside force acts.
- Weight $W = mg$.

Part 2 looks at force as the *rate of change* of momentum (impulse), motion with air resistance, and the two kinds of collision.

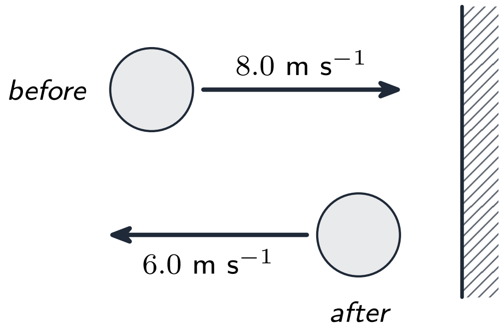
New ideas

■ 1 Impulse — force as change of momentum

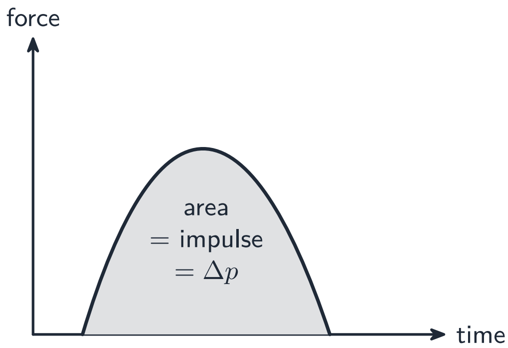
Newton's second law, in full: the resultant force equals the rate of change of momentum,

$$F = \frac{\Delta p}{\Delta t}.$$

So $\Delta p = F\,\Delta t$ — this change of momentum is the **impulse** 冲量. In a bounce the momentum **reverses**, so use signed (+/−) values.



Worked example. A 0.20 kg ball hits a wall at 8.0 m s^{-1} and bounces back at 6.0 m s^{-1}; contact lasts 0.050 s. Taking the rebound way as positive, $\Delta p = 0.20\,(6.0 - (-8.0)) = 2.8$ kg m s^{-1}, so $F = \dfrac{2.8}{0.050} = 56$ N.



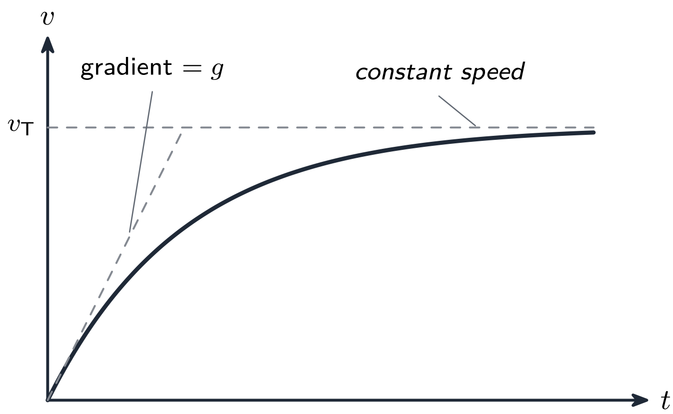
Watch out: in a bounce the momentum *reverses*, so use signed values — the change is the rebound velocity *minus* the (negative) incoming one, which is bigger than the speed change alone.

■ 2 Friction, drag and terminal velocity

A **friction** 摩擦力 force opposes sliding; a fluid (air, water) gives a **drag** 阻力 force that grows with speed. For an object dropped through air:

1. at first only weight acts → it speeds up at g;
2. as it speeds up, drag grows → the resultant force, and so the acceleration, get smaller;

3. when drag = weight the resultant is zero → it falls at a constant **terminal velocity** 收尾速度.



■ **3 Elastic and inelastic collisions**

Momentum is conserved in **every** collision. An **elastic collision** 弹性碰撞 *also* conserves **kinetic energy** 动能 (the **relative speed** 相对速率 of approach equals that of separation). An **inelastic collision** 非弹性碰撞 loses kinetic energy (to heat, sound or **deformation** 形变); if the objects stick together it is perfectly inelastic.

Worked example. A 1500 kg car at 12 m s^{-1} hits a stationary 1000 kg car and they lock together: $1500(12) = 2500\,v$, so $v = 7.2$ m s^{-1} (inelastic — kinetic energy is lost).

Practice

3.1 A steady force of 20 N acts on a trolley for 3.0 s. Find the impulse (the change in momentum). [2]

3.2 A 0.15 kg ball hits the floor at 4.0 m s^{-1} and bounces up at 3.0 m s^{-1}. Find the magnitude of its change in momentum. [2]

3.3 An object falling through air has reached its terminal velocity. State the resultant force on it, and explain why its speed stays constant. [2]

3.4 State whether each collision is elastic or inelastic: (a) two balls stick together; (b) two balls bounce apart with no loss of kinetic energy. [2]

3.5 A 2.0 kg trolley moving at 3.0 m s^{-1} hits a stationary 4.0 kg trolley and they couple together. Find their common velocity. [2]

3.6 Challenge. A car's crumple zone and air bag make a crash last *longer*. Using $F = \Delta p/\Delta t$, explain why this reduces the force on the passengers. [2]

20 A parachutist is falling at constant (terminal) velocity.

Which statement is **not** correct?

A Gravitational potential energy is converted into kinetic energy of the air.

B Gravitational potential energy is converted into kinetic energy of the parachutist.

C Gravitational potential energy is converted into thermal energy of the air.

D Gravitational potential energy is converted into thermal energy of the parachutist.

A-Level Physics: **s25 14**

8 A skydiver is falling vertically with terminal velocity when their parachute opens fully.

Which statement describes the motion of the skydiver for the first few seconds after the parachute opens fully?

A falling with non-uniform acceleration and increasing speed

B falling with non-uniform acceleration and decreasing speed

C falling with uniform acceleration and increasing speed

D falling with uniform acceleration and decreasing speed

9 In which situation is total linear momentum **always** conserved?

A in all collisions between two objects

B in collisions between two objects moving at equal and opposite velocity

C in collisions between two objects that form an isolated system

D in collisions between two objects with the same mass

10 An object of mass m moving with velocity $9.0\,\text{m}\,\text{s}^{-1}$ has a head-on elastic collision with a stationary object of mass $2m$.

After the collision, both objects are moving. No external forces act on the system.

What is the velocity of the object of mass $2m$ after the collision?

A $-6.0\,\text{m}\,\text{s}^{-1}$ **B** $-3.0\,\text{m}\,\text{s}^{-1}$ **C** $4.5\,\text{m}\,\text{s}^{-1}$ **D** $6.0\,\text{m}\,\text{s}^{-1}$

A-Level Physics: **w25 12**

9 What is a statement of the principle of conservation of momentum?

A In an elastic collision, momentum is constant.

B Momentum is the product of mass and velocity.

C The force acting on a body is proportional to its rate of change of momentum.

D The momentum of an isolated system is constant.

A-Level Physics: **s25 11**

19 The momentum of a car of mass m increases from p_1 to p_2.

What is the increase in the kinetic energy of the car?

A $\dfrac{(p_2^2 - p_1^2)}{2m}$ **B** $\dfrac{(p_2 - p_1)^2}{2m}$ **C** $\dfrac{p_2 - p_1}{2m}$ **D** $\dfrac{p_1 - p_2}{2m}$

4 Forces, density and pressure – 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)		
pivot	支点			
Density	密度			
pressure	压强			
moment	力矩			
perpendicular distance	垂直距离			
clockwise	顺时针			
anticlockwise	逆时针			
equilibrium	平衡			
principle of moments	力矩原理			
centre of gravity	重心			
hydrostatic pressure	流体静压强			
upthrust	浮力			

Recall

At IGCSE you met turning forces, density and pressure. Bring this with you:

- A force can turn an object about a **pivot** 支点 (a fixed turning point).
- **Density** 密度 is mass per unit volume; **pressure** 压强 is force per unit area.

At AS we calculate turning effects exactly and look at pressure inside a liquid.

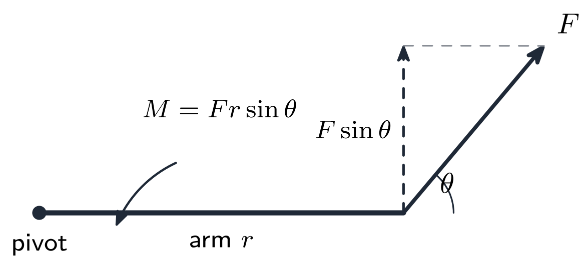
New ideas

1 Moments

The **moment** 力矩 of a force measures its turning effect:

$$\text{moment} = F \times d,$$

where d is the **perpendicular distance** 垂直距离 from the pivot to the line of the force. The unit is the newton metre (N m). A moment turns either **clockwise** 顺时针 or **anticlockwise** 逆时针.



Watch out: d is the *perpendicular* distance from the pivot to the line of the force — not the distance measured along the force itself.

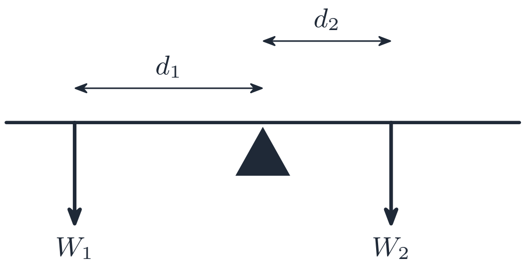
2 The principle of moments

When an object is balanced (in **equilibrium** 平衡), the **principle of moments** 力矩原理 says:

$$\text{total clockwise moment} = \text{total anticlockwise moment}.$$

The object's whole weight acts at one point, its **centre of gravity** 重心.

Worked example. A 300 N child sits 1.5 m left of a seesaw's pivot. How far right must a 450 N child sit to balance? Anticlockwise = clockwise: $300 \times 1.5 = 450 \times d$, so $d = \dfrac{450}{450} = 1.0$ m.



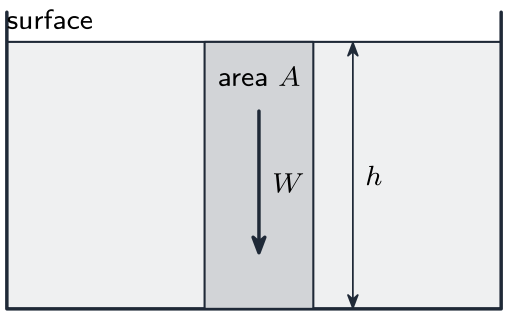
balanced when $W_1 d_1 = W_2 d_2$

3 Density and pressure

Density $\rho = \dfrac{m}{V}$, and pressure $p = \dfrac{F}{A}$.

Inside a liquid, pressure grows with depth — this is **hydrostatic pressure** 流体静压强:

$$p = \rho g h.$$



$\Delta p = \rho g h$

This pressure also pushes a submerged object upward, giving it an **upthrust** 浮力.

Worked example. Water pressure 2.0 m below the surface ($\rho = 1000$ kg m^{-3}, $g = 9.8$ m s^{-2}):

$$p = \rho g h = 1000 \times 9.8 \times 2.0 = 1.96 \times 10^4 \text{ Pa}.$$

Practice

4.1 A spanner is turned by a 25 N force acting 0.20 m from the bolt. Find the moment. [2]

4.2 A light beam balances on a pivot. A 40 N weight sits 0.30 m to the left; a weight W sits 0.20 m to the right. Find W. [3]

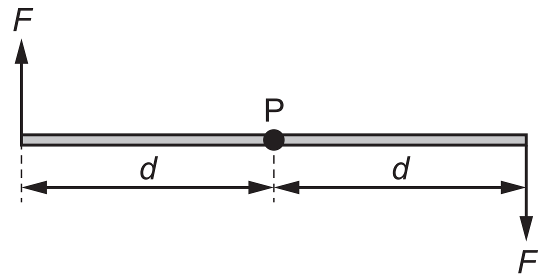
4.3 A block has mass 240 g and volume 30 cm^3. Find its density in g cm^{-3}. [2]

4.4 A force of 50 N presses on an area of 0.25 m^2. Find the pressure. [1]

4.5 Find the water pressure 5.0 m down ($\rho = 1000$ kg m^{-3}, $g = 9.8$ m s^{-2}). [2]

4.6 Challenge. A dam is built much thicker at the bottom than at the top. Using $p = \rho g h$, explain why. [2]

14 Two forces, each of magnitude F, act in opposite directions on a rod.



Each force acts on the rod at a distance d from the pivot P.

What is the torque of this couple about P?

A 0 **B** $F \times d$ **C** $2F \times d$ **D** $2F \times 2d$

13 Which row describes a pair of forces that forms a couple?

	direction of the forces	magnitude of the forces
A	opposite	different
B	opposite	equal
C	same	different
D	same	equal

10 Which statement about a couple is correct?

A It acts to produce both translational motion and rotation.

B It acts to produce rotation only.

C It acts to produce translational motion only.

D It acts to produce neither rotation nor translational motion.

4 Forces, density and pressure – 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)		
couple	力偶			
torque	力偶矩			
equilibrium	平衡			
vector triangle	矢量三角形			
upthrust	浮力			
Archimedes' principle	阿基米德原理			
displaced	排开			
floats	漂浮			

Recall

In **Part 1** you found the moment of a force ($M = F \times d$), used the principle of moments to balance a beam, and met density, pressure and hydrostatic pressure ($p = \rho g h$). Part 2 adds a special pair of forces, the full rules for balance, and why things float.

New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

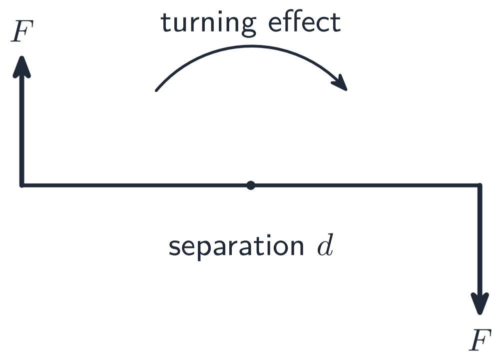
1 Couples and torque

A **couple** 力偶 is a pair of forces that are equal in size, opposite in direction, and have their lines of action a distance apart. A couple makes an object **turn only** — it gives no straight-line push.

Its turning effect is the **torque** 力偶矩:

$$\tau = F \times d,$$

where d is the perpendicular distance between the two forces. (Two equal forces in the *same* direction are **not** a couple.)

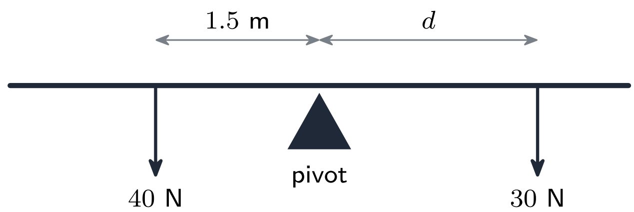


Worked example. Two hands turn a steering wheel with 10 N each in opposite directions, their lines 0.30 m apart: torque $\tau = 10 \times 0.30 = 3.0$ N m — a pure turn, no push.

2 The two conditions for equilibrium

A body is in **equilibrium** 平衡 only when **both** of these hold:

1. the resultant force is zero (no straight-line acceleration), **and**
2. the resultant moment about any point is zero (no turning).



Three forces in equilibrium can be drawn tip-to-tail as a closed **vector triangle** 矢量三角形 (the arrows return to the start) — a neat way to find an unknown force.

Worked example. A ladder resting against a wall is in equilibrium: the upward forces balance its weight (force condition), *and* the moments about its foot balance (moment condition) — both must be true at once.

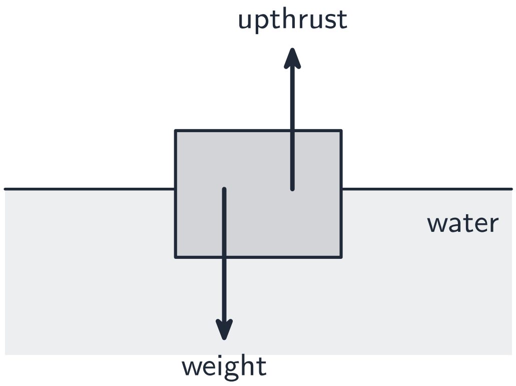
Watch out: a body can have zero resultant *force* yet still spin — equilibrium also needs the resultant *moment* to be zero. Both conditions must hold.

3 Floating and upthrust

A submerged object feels an upward **upthrust** 浮力 because the water pressure is greater on its bottom than its top. By **Archimedes' principle** 阿基米德原理, the upthrust equals the weight of fluid **displaced** 排开:

$$F = \rho_{\text{fluid}}\, g\, V.$$

An object **floats** 漂浮 when the upthrust equals its weight (only the volume below the surface counts).



Worked example. A block of volume 2.0×10^{-3} m^3 is fully under water ($\rho = 1000$ kg m^{-3}): $F = 1000 \times 9.8 \times 2.0 \times 10^{-3} = 20$ N.

Practice

4.1 State the two features that make a pair of forces a couple. [2]

4.2 A spanner is turned by a couple of two 6.0 N forces whose lines are 0.40 m apart. Find the torque. [2]

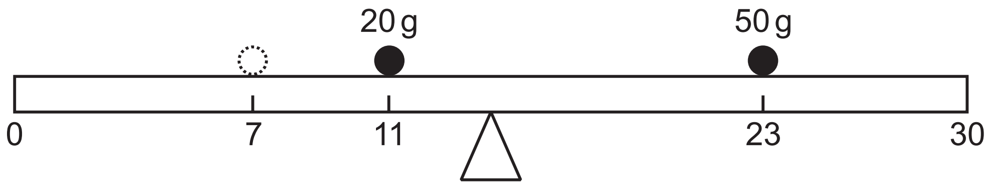
4.3 State the two conditions for a body to be in equilibrium. [2]

4.4 A stone of volume 5.0×10^{-4} m^3 is fully submerged in water ($\rho = 1000$ kg m^{-3}, $g = 9.8$ m s^{-2}). Find the upthrust on it. [2]

4.5 A steel ship floats on water even though steel is denser than water. Explain why. [2]

4.6 Explain *why* a ship sits *lower* in the water when it is loaded with heavy cargo. [2]

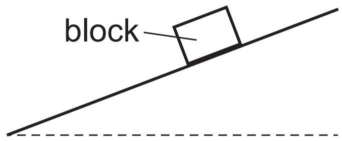
15 A student balances a 30 cm ruler on a fulcrum set at the 15 cm mark. She then places a 50 g mass on the 23 cm mark and a 20 g mass on the 11 cm mark, as shown.



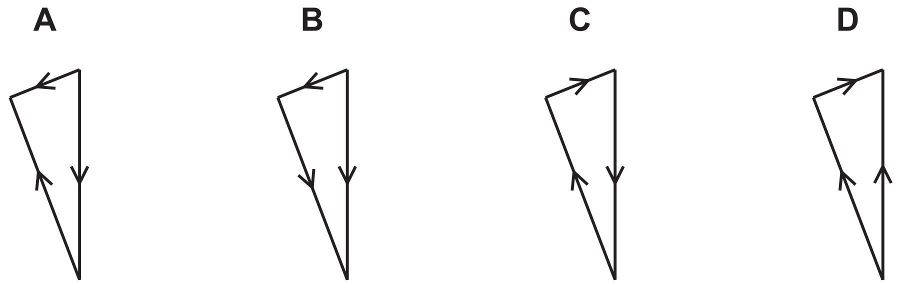
Which mass should she place on the 7 cm mark to restore the balance?

A 30 g **B** 40 g **C** 47 g **D** 133 g

14 A block is in equilibrium on a slope.



Which vector triangle represents the three forces acting on the block?



15 A man of weight 600 N stands with both feet flat on the ground.

What is a reasonable estimate of the pressure exerted on the ground by the weight of the man?

A 1×10^0 Pa **B** 1×10^2 Pa **C** 1×10^4 Pa **D** 1×10^6 Pa

A-Level Physics: **w25 14**

9 A sphere moves vertically downwards at terminal (constant) velocity in a liquid.

Which statement about the magnitude of the upthrust acting on the sphere is correct?

A It is proportional to the acceleration of free fall.

B It is equal to the weight of the sphere.

C It is proportional to the density of the sphere.

D It is proportional to the square of the radius of the sphere.

A-Level Physics: **s25 13**

13 What is the definition of density?

A mass of one cubic metre

B mass of a unit volume

C mass per cubic metre

D mass per unit volume

15 A measuring cylinder contains 80 cm^3 of a liquid.

The pressure due to the liquid at the 60 cm^3 mark is 1200 Pa.

What is the pressure due to the liquid at the base of the measuring cylinder?

A 1200 Pa **B** 1600 Pa **C** 3600 Pa **D** 4800 Pa

5 Work, energy 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)		
Energy	能量			
Work	功			
component	分量			
Kinetic energy	动能			
Gravitational potential energy	重力势能			
conservation of energy	能量守恒			
Power	功率			
Efficiency	效率			

Recall

At IGCSE you met energy and its types. Bring this with you:

- **Energy** 能量 is measured in joules (J) and can change from one form to another.
- Energy is never made or destroyed — the total always stays the same.
- You used kinetic energy and gravitational potential energy.

At AS we define work and power precisely, and use energy conservation to solve problems.

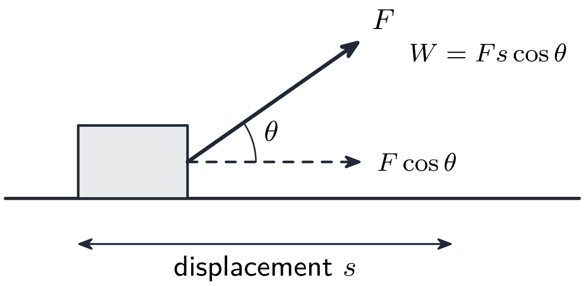
New ideas

■ 1 Work done by a force

Work 功 is energy transferred when a force moves something:

$$W = F \times (\text{distance moved in the force's direction}).$$

If the force acts at an angle θ to the motion, use the **component** 分量 along the motion: $W = Fs\cos\theta$. Work is measured in joules.



Worked example. A rope pulls a box 4.0 m with a force of 50 N at 30° above the ground:

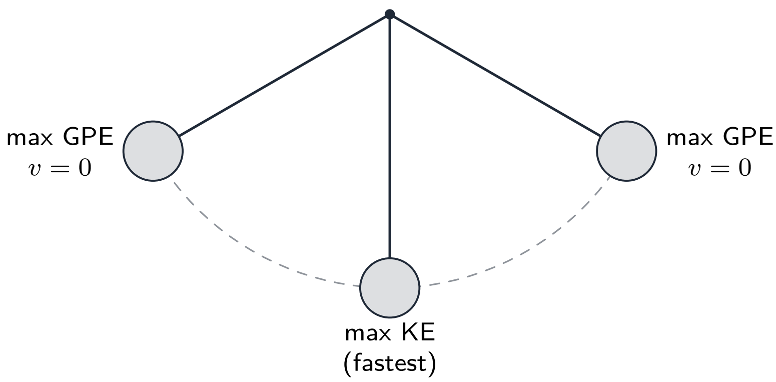
$$W = Fs\cos\theta = 50 \times 4.0 \times \cos 30° = 173 \text{ J}.$$

Watch out: a force does *no* work if it acts at right angles to the motion ($\cos 90° = 0$) — carrying a bag along a flat floor does no work against gravity.

■ 2 Kinetic and potential energy

Kinetic energy 动能 (energy of motion): $E_k = \frac{1}{2}mv^2$. **Gravitational potential energy** 重力势能 (energy of height): $E_p = mgh$.

By **conservation of energy** 能量守恒, the total stays constant — so as something falls, E_p turns into E_k.



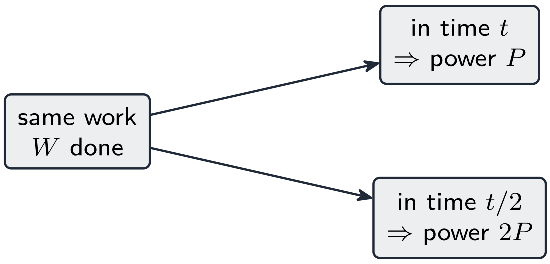
Worked example. A ball falls from rest through $h = 1.8$ m. All E_p becomes E_k:

$$mgh = \frac{1}{2}mv^2 \;\Rightarrow\; v = \sqrt{2gh} = \sqrt{2(9.8)(1.8)} = 5.9 \text{ m s}^{-1}.$$

(The mass cancels, so every object reaches the same speed.)

■ 3 Power and efficiency

Power 功率 is work done per second: $P = \dfrac{W}{t}$, measured in watts (W).



$P = \dfrac{W}{t}$ — less time, more power

Efficiency 效率 is how much of the input energy is usefully transferred:

$$\text{efficiency} = \frac{\text{useful energy out}}{\text{total energy in}}.$$

Worked example. A motor lifts a 200 N load 3.0 m in 5.0 s: $W = 200 \times 3.0 = 600$ J, so $P = \dfrac{600}{5.0} = 120$ W.

Practice

5.1 A trolley is pushed 6.0 m by a steady 30 N force in the same direction. Find the work done. [2]

5.2 A rope pulls a sledge 10 m with 40 N at 60° to the ground. Find the work done. [2]

5.3 Find the kinetic energy of a 1200 kg car moving at 15 m s^{-1}. [2]

5.4 A stone falls from rest through 5.0 m. Using $\frac{1}{2}mv^2 = mgh$, find its speed ($g =$ 9.8 m s^{-2}). [2]

5.5 A pump does 4500 J of work in 30 s. Find its power. [1]

5.6 A lamp takes in 60 J of electrical energy and gives out 9 J of light. Find its efficiency. [2]

5.7 **Challenge.** A car's kinetic energy is $\frac{1}{2}mv^2$. If its speed doubles, explain what happens to its braking distance (for the same braking force). [2]

20 The motor of a crane lifts a load of mass 600 kg. The load rises vertically at a constant speed of 12 m per minute.

What is the useful power output of the motor?

A 0.12 kW **B** 1.2 kW **C** 7.2 kW **D** 71 kW

A-Level Physics: **w25 14**

18 The total energy supplied to an electric motor is E. Energy Q is wasted and the remaining energy does useful work.

What is the efficiency of the motor?

A $\dfrac{Q}{E}$ **B** $\left(\dfrac{Q}{E}\right) - 1$ **C** $1 - \left(\dfrac{Q}{E}\right)$ **D** $\dfrac{(1 - Q)}{E}$

A-Level Physics: **s25 13**

17 An electric motor uses 1.7 kW of power when operating normally.

The efficiency of the motor is 53%.

What is the useful output power of the motor?

A 0.032 kW **B** 0.90 kW **C** 3.2 kW **D** 90 kW

A-Level Physics: **s25 14**

14 In which situation is work done on an object?

A The object slides with a constant velocity along a horizontal frictionless surface in a vacuum.

B A person holds the object at arm's length and at a fixed height above the ground.

C A person pushes the object up a frictionless ramp.

D The stationary object floats partially submerged in water.

5 Work, energy and power – 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)		
velocity	速度			
power	功率			
drag	阻力			
compression	压缩			
elastic potential energy	弹性势能			
spring constant	劲度系数			

Recall

In **Part 1** you used work ($W = Fs\cos\theta$), kinetic and gravitational potential energy, conservation of energy, and power as energy per second ($P = W/t$). Part 2 adds a faster way to find power, efficiency in real machines, and using energy ideas to solve problems.

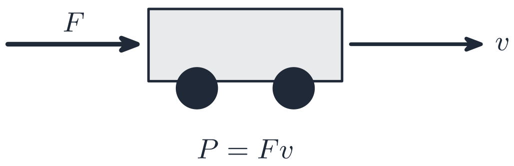
New ideas

■ 1 Power, force and velocity

For a force F that moves an object along at **velocity** 速度 v, the **power** 功率 is

$$P = Fv.$$

Worked example. A car drives at a steady 25 m s^{-1} against a total resistive force of 600 N. At constant speed the driving force equals the resistance, so $P = Fv = 600 \times 25 = 1.5 \times 10^4$ W $= 15$ kW. (At higher speed the **drag** 阻力 is larger, so more power is needed.)

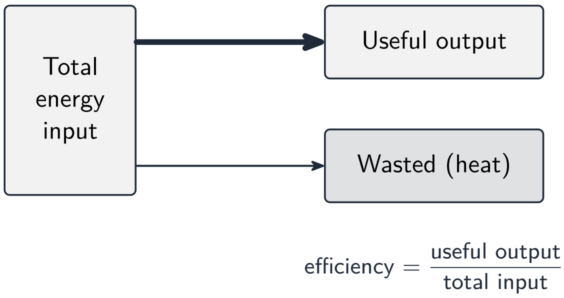


Watch out: $P = Fv$ uses the force *along* the motion. At a steady speed the driving force equals the total resistance, so use that value for F.

■ 2 Efficiency of a machine

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}} \times 100\%.$$

It is always below 100% — some input energy is wasted, usually as heat.



Worked example. A motor lifts a 50 kg load at a steady 0.40 m s^{-1} using 250 W of electrical power. Useful output $= mgv = 50 \times 9.8 \times 0.40 = 196$ W, so efficiency $= \frac{196}{250} \times 100\% \approx 78\%$.

■ 3 Solving problems with energy

Energy is conserved: *start energy + work put in = end energy + energy lost.* A handy case — a moving block runs into a spring on a smooth surface; at greatest **compression** 压缩 x all its kinetic energy has become **elastic potential energy** 弹性势能 $\frac{1}{2}kx^2$ (where k is the **spring constant** 劲度系数).

Worked example. A block with 2.0 J of kinetic energy compresses a spring of $k = 100$ N m^{-1}. At greatest compression $\frac{1}{2}(100)x^2 = 2.0$, so $x^2 = 0.040$ and $x = 0.20$ m.

Practice

5.1 A locomotive pulls with a force of 800 N at a steady 15 m s^{-1}. Find its output power. [2]

5.2 A crane lifts a load of weight 200 N straight up at a steady 0.50 m s^{-1}. Find the useful power output. [2]

5.3 A device gives 150 W of useful power for 200 W of input power. Find its efficiency. [1]

5.4 A spring of spring constant 40 N m^{-1} is compressed by 0.30 m. Find the elastic potential energy stored. [2]

5.5 A block with 4.5 J of kinetic energy slides into a spring ($k = 100$ N m^{-1}) on a smooth surface. Find the greatest compression. [2]

5.6 Challenge. Explain *why* a car needs much more engine power to drive at 30 m s^{-1} than at 15 m s^{-1}, even on a flat road. [2]

17 An object with a mass of 100 g falls a vertical distance of 10 m.

What is the change in the gravitational potential energy of the object?

A 1 J **B** 10 J **C** 100 J **D** 10 000 J

A-Level Physics: **s25 12**

18 A ball of mass 1.2 kg travels horizontally at a speed of 3.0 m s^{-1}.

The ball hits a cushion and comes to rest over a horizontal distance of 0.020 m.

What is the work done by the cushion on the ball to bring the ball to rest?

A 0.24 J **B** 1.8 J **C** 5.4 J **D** 11 J

A-Level Physics: **s25 13**

19 An object travelling with a speed of 10 m s^{-1} has kinetic energy of 1500 J.

The speed of the object is increased to 40 m s^{-1}.

What is the new kinetic energy of the object?

A 4500 J **B** 6000 J **C** 24 000 J **D** 1 350 000 J

A-Level Physics: **m25 12**

18 A projectile is launched at 45° to the horizontal with initial kinetic energy *E*.

Assuming air resistance to be negligible, what will be the kinetic energy of the projectile when it reaches its highest point?

A 0.50*E* **B** 0.71*E* **C** 0.87*E* **D** *E*

6 Deformation of solids – 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)		
deformation	形变			
extension	伸长量			
Hooke's law	胡克定律			
spring constant	劲度系数			
limit of proportionality	比例极限			
elastic	弹性			
plastic	塑性			
Stress	应力			
strain	应变			
Young modulus	杨氏模量			
elastic potential energy	弹性势能			

Recall

At IGCSE you stretched springs. Bring this with you:

- When you stretch or squash a solid you cause **deformation** 形变.
- The **extension** 伸长量 is how much longer a spring becomes when you pull it.
- You met **Hooke's law** 胡克定律: the extension is proportional to the force, up to a point.

At AS we write this exactly and extend it to any material with stress, strain and the Young modulus.

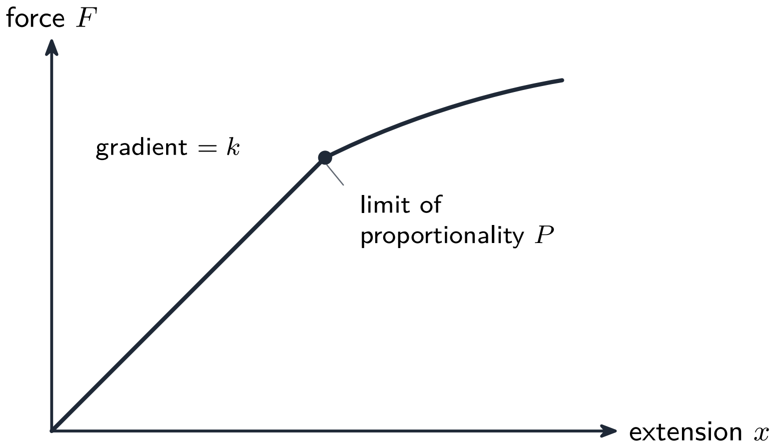
New ideas

1 Hooke's law

For a spring, force and extension are proportional:

$$F = kx,$$

where k is the **spring constant** 劲度系数 (in N m^{-1}) and x is the extension. This holds only up to the **limit of proportionality** 比例极限.



Below the **elastic** 弹性 limit a material springs back to its shape; beyond it the change is **plastic** 塑性 (permanent).

Worked example. A spring needs 6.0 N to stretch it 0.15 m: $k = \dfrac{F}{x} = \dfrac{6.0}{0.15} = 40$ N m^{-1}.

2 Stress, strain and the Young modulus

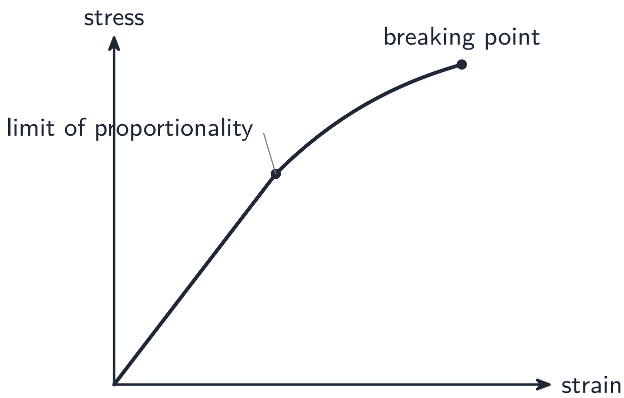
For a wire of cross-sectional area A and original length L stretched by x:

$$\text{stress } \sigma = \frac{F}{A}, \qquad \text{strain } \varepsilon = \frac{x}{L}.$$

Stress 应力 has units Pa; **strain** 应变 is just a ratio (no unit). Their ratio is the **Young modulus** 杨氏模量, a fixed number for each material:

$$E = \frac{\sigma}{\varepsilon}.$$

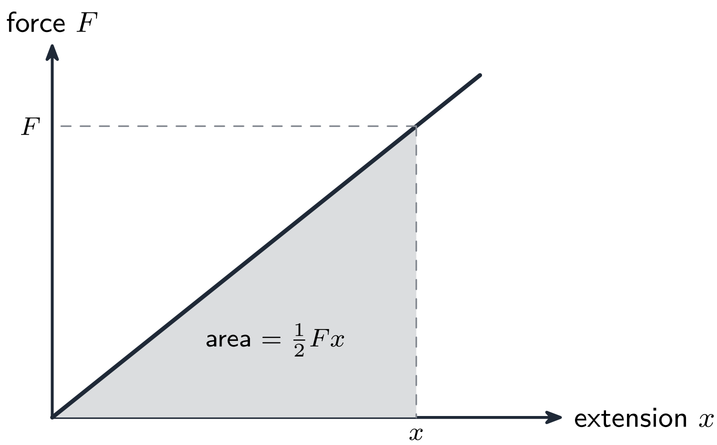
Worked example. A wire ($A = 5.0\times10^{-7}$ m^2, $L = 2.0$ m) stretches 1.0 mm under 50 N: $\sigma = \dfrac{50}{5.0 \times 10^{-7}} = 1.0 \times 10^8$ Pa, $\varepsilon = \dfrac{1.0 \times 10^{-3}}{2.0} = 5.0 \times 10^{-4}$, so $E = \dfrac{1.0 \times 10^8}{5.0 \times 10^{-4}} = 2.0 \times 10^{11}$ Pa.



Watch out: the Young modulus is a property of the *material*, not the wire — a thicker or longer wire of the same metal has the same E.

3 Elastic potential energy

The energy stored in a stretched spring is the area under its force–extension line — the **elastic potential energy** 弹性势能:



$$E = \tfrac{1}{2}Fx = \tfrac{1}{2}kx^2.$$

Practice

6.1 A spring has spring constant 25 N m^{-1}. Find the force needed to stretch it 0.20 m. [2]

6.2 Explain the difference between elastic and plastic behaviour. [2]

6.3 A wire of cross-sectional area 4.0×10^{-7} m^2 carries a load of 32 N. Find the stress. [2]

6.4 A 2.5 m wire stretches by 2.0 mm. Find the strain. [1]

6.5 Using the stress from 6.3 and strain from 6.4, find the Young modulus. [2]

6.6 Find the elastic potential energy stored in the spring of 6.1 when stretched 0.20 m. [2]

6.7 Challenge. Two wires are of the same material and thickness, but one is twice as long. Under the same pulling force, explain which one stretches more. [2]

23 Which expression gives the formula for the spring constant?

A Fx **B** $2Fx^2$ **C** $\dfrac{F}{x}$ **D** $\dfrac{F}{x^2}$

A-Level Physics: **s25 11**

23 A uniform metal wire of length L and diameter d has spring constant k.

What is the Young modulus of the metal?

A $\dfrac{\pi d^2}{4kL}$ **B** $\dfrac{\pi d^2}{kL}$ **C** $\dfrac{kL}{\pi d^2}$ **D** $\dfrac{4kL}{\pi d^2}$

A-Level Physics: **s25 13**

22 A wire of length L_0 is attached at one end to a fixed point. A tensile force is applied to the other end so that the wire extends and has a new length L_1.

What is the strain of the wire?

A $\left(\dfrac{L_1}{L_0}\right) - 1$ **B** $L_1 - L_0$ **C** $\left(\dfrac{L_1}{L_0}\right) + 1$ **D** $L_1 + L_0$

A-Level Physics: **s25 14**

17 What is the definition of strain?

A extension per unit cross-sectional area

B extension per unit original length

C force per unit cross-sectional area

D force per unit extension

6 Deformation of solids – 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)		
Series	串联			
Parallel	并联			
elastic limit	弹性极限			
pulley	滑轮			
diameter	直径			
micrometer	螺旋测微器			

Recall

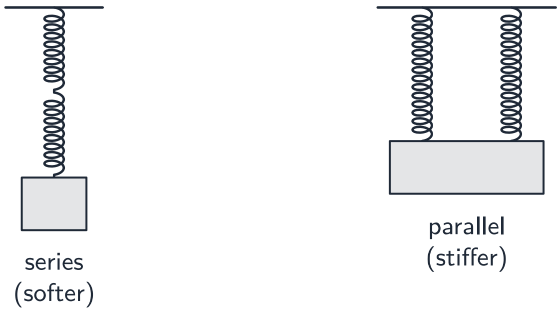
In **Part 1** you used Hooke's law ($F = kx$), stress, strain, the Young modulus, and the energy stored in a spring ($\frac{1}{2}kx^2$). Part 2 adds combining springs, what happens past the elastic limit, and the experiment to measure the Young modulus.

New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

■ 1 Springs in series and parallel

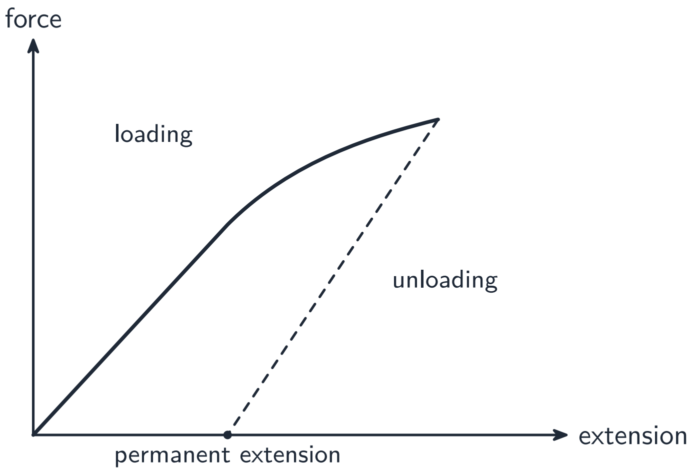
- **Series** 串联 (one below the other): the same load passes through both and the extensions add, so $\dfrac{1}{k_{\text{total}}} = \dfrac{1}{k_1} + \dfrac{1}{k_2}$ — a *softer* spring.
- **Parallel** 并联 (side by side): they share the load and stretch the same, so $k_{\text{total}} = k_1 + k_2$ — a *stiffer* spring.



Worked example. Two springs, each 20 N m^{-1}: in series $\frac{1}{k} = \frac{1}{20} + \frac{1}{20}$ so $k = 10$ N m^{-1}; in parallel $k = 20 + 20 = 40$ N m^{-1}.

■ 2 Beyond the elastic limit

Up to the limit of proportionality the force–extension line is straight. A little further the material is still **elastic** (springs back) until the **elastic limit** 弹性极限. Past that point it becomes **plastic** — when you remove the load it does **not** return to its first length; a permanent stretch is left.

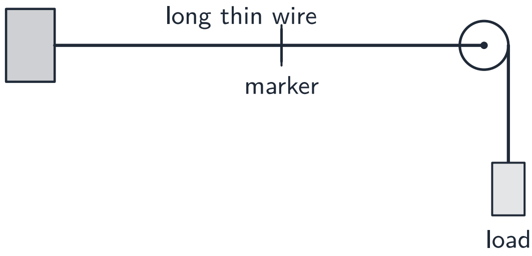


Worked example. Stretched a little, a wire springs back to its first length (elastic); pulled past its elastic limit and released, it stays — say — 2 mm longer, a permanent (plastic) stretch.

■ 3 Measuring the Young modulus

Use a long, thin wire fixed at one end and run over a **pulley** 滑轮:

1. measure the original length L_0 with a metre rule;
2. measure the **diameter** 直径 d at several places with a **micrometer** 螺旋测微器 and average it; then $A = \pi d^2/4$;
3. add loads one at a time and record the extension x;
4. plot F against x; the straight-line gradient is EA/L_0, so $E = \text{gradient} \times L_0/A$.



Worked example. If the F–x graph has gradient 9000 N m^{-1} for a wire of $L_0 = 2.0$ m and $A = 1.0 \times 10^{-7}$ m^2: $E = \text{gradient} \times \dfrac{L_0}{A} = 9000 \times \dfrac{2.0}{1.0 \times 10^{-7}} = 1.8 \times 10^{11}$ Pa.

Watch out: the area uses d^2, so a small error in the diameter has a *doubled* effect — measure d in several places and average.

Practice

6.1 Two springs each of spring constant 30 N m^{-1} are joined. Find the combined spring constant (a) in series, (b) in parallel. [2]

6.2 A wire is stretched past its elastic limit and the load is then removed. State what happens to its length. [1]

6.3 A wire of length 2.0 m and area 3.0×10^{-7} m^2 stretches 0.60 mm under a load of 18 N. Find the Young modulus ($E = FL_0/Ax$). [2]

6.4 State why a long, thin wire is chosen for the Young-modulus experiment. [1]

6.5 A wire has diameter 0.40 mm. Find its cross-sectional area ($A = \pi d^2/4$). [2]

6.6 Explain *why* an error in measuring the wire's diameter affects the Young-modulus result *twice* as much as the same percentage error in its length. [2]

23 Which phrase describes the strain at the elastic limit on a stress–strain graph?

A the maximum strain below which Hooke's law is obeyed

B the maximum strain below which the deformation is plastic

C the minimum strain above which Hooke's law is obeyed

D the minimum strain above which the deformation is plastic

A-Level Physics: **s25 14**

18 A spring of unstretched length 0.10 m is suspended vertically from a support.

A weight of 2.0 N is attached to the bottom of the spring and its length increases to 0.15 m.

An additional weight of 4.0 N is then added to the bottom of the spring.

The spring obeys Hooke's law.

How much extra elastic potential energy is stored in the spring due to the addition of the 4.0 N weight?

A 0.067 J **B** 0.13 J **C** 0.20 J **D** 0.40 J

A-Level Physics: **m25 12**

19 A wire is extended by a tensile force so that its deformation is elastic.

What is meant by elastic deformation?

A The extension of the wire is proportional to the tensile force.

B The extension of the wire is **not** proportional to the tensile force.

C When the tensile force is removed, the wire does **not** return to its original length.

D When the tensile force is removed, the wire returns to its original length.

7 Waves – 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			
amplitude	振幅			
wavelength	波长			
frequency	频率			
period	周期			
transverse wave	横波			
longitudinal wave	纵波			
progressive wave	行波			
electromagnetic spectrum	电磁波谱			
Polarisation	偏振			

Recall

At IGCSE you studied waves. Bring this with you:

- A **wave** 波 carries energy from place to place without moving matter along with it.
- You used wavelength and frequency, and the wave equation $v = f\lambda$.

At AS we define the wave quantities carefully and meet a new idea: polarisation.

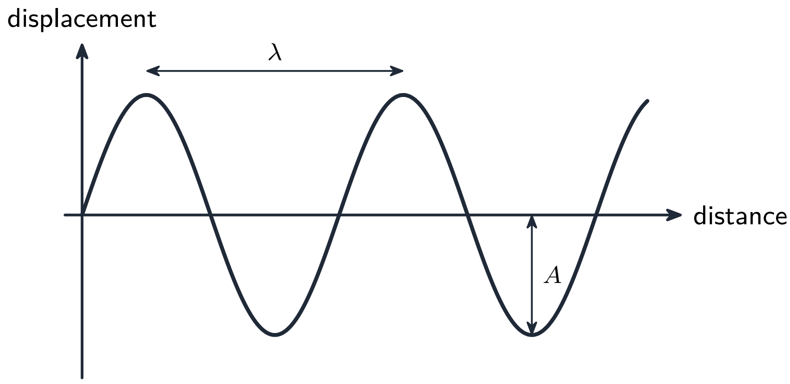
New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

1 Describing a wave

- **amplitude** 振幅: the largest distance a point moves from its rest position.
- **wavelength** 波长 λ: the length of one complete wave.
- **frequency** 频率 f: the number of waves passing each second, in hertz (Hz).
- **period** 周期 T: the time for one complete wave, with $T = \dfrac{1}{f}$.

These link through the wave equation $v = f\lambda$.

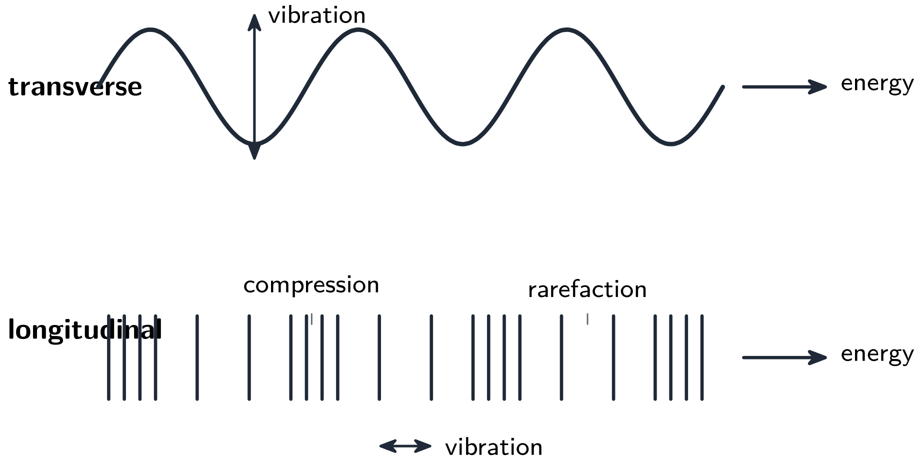


Worked example. A wave has $f = 50$ Hz and $\lambda = 6.0$ m: $v = f\lambda = 50 \times 6.0 = 300$ m s^{-1}, and $T = \dfrac{1}{50} = 0.020$ s.

Watch out: in $v = f\lambda$ keep the units matched — f in Hz and λ in metres give v in m s^{-1}.

2 Transverse and longitudinal waves

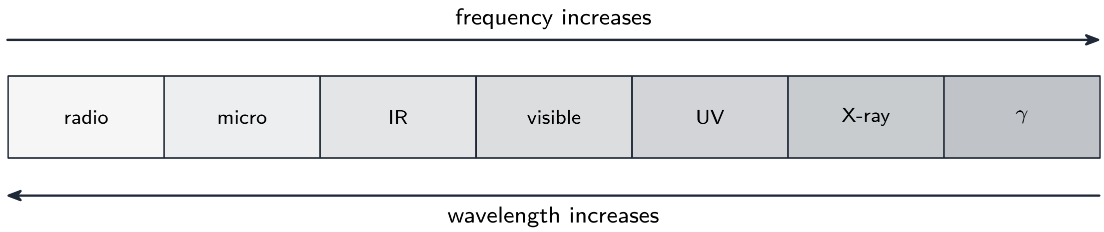
- In a **transverse wave** 横波 the points move at right angles to the wave's travel (light, water waves).
- In a **longitudinal wave** 纵波 the points move along the travel direction (sound).
- A **progressive wave** 行波 is one that travels and carries energy.



Worked example. Shaking a rope up and down sends a transverse wave (the rope moves across the travel); pushing a slinky back and forth sends a longitudinal wave (the coils move along the travel).

3 The electromagnetic spectrum and polarisation

All electromagnetic waves (radio, micro, infrared, visible, ultraviolet, X-rays, gamma) travel at 3.0×10^8 m s^{-1} in a vacuum; arranged by wavelength they form the **electromagnetic spectrum** 电磁波谱.



Only transverse waves can be polarised. **Polarisation** 偏振 makes all the oscillations lie in a single plane; a polarising filter lets through only that plane and blocks the rest.

Worked example. Two polarising filters at right angles block almost all light: the first passes one plane, and the second (crossed) blocks that plane.

Practice

7.1 A sound wave has frequency 200 Hz and wavelength 1.7 m. Find its speed. [2]

7.2 A wave has frequency 25 Hz. Find its period. [1]

7.3 Light travels at 3.0×10^8 m s^{-1}. Find the wavelength of light with frequency 5.0×10^{14} Hz. [2]

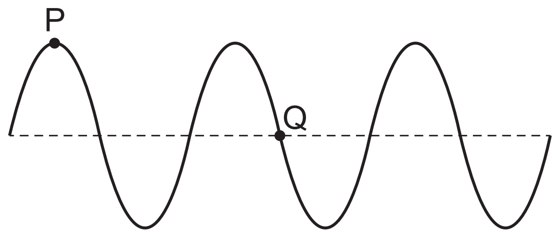
7.4 State whether each is transverse or longitudinal: (a) sound, (b) light. [2]

7.5 Light can be polarised but sound cannot. Explain why. [2]

7.6 All colours of light travel at the same speed in a vacuum but have different wavelengths. Explain how this fits the wave equation. [2]

7.7 Challenge. Two polarising filters are first lined up so light passes through. Describe and explain what happens to the brightness as the second filter is slowly rotated by 90°. [2]

25 What is the phase difference between points P and Q on the progressive wave shown in the diagram?



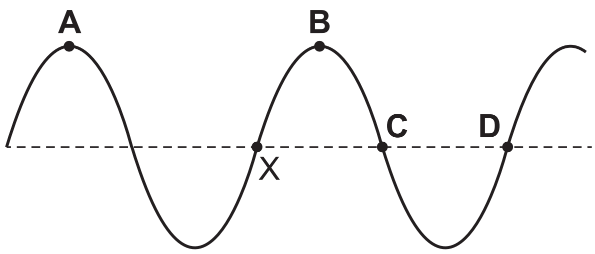
A 180° **B** 450° **C** 540° **D** 720°

A-Level Physics: **s25 11**

26 The diagram shows a progressive transverse wave on a stretched string at one instant in time.

One point on the string is labelled X.

Which point on the string is 270° out of phase with X?



A-Level Physics: **m25 12**

25 A progressive wave of frequency 300 Hz is travelling with a speed of $600\,m\,s^{-1}$.

What is the phase difference between two points on the wave that are a distance of 0.50 m apart?

A 45° **B** 90° **C** 180° **D** 360°

24 Which row is correct for sound waves?

	can travel in a vacuum	can be polarised	can diffract through a gap
A	no	no	yes
B	yes	no	no
C	no	yes	no
D	no	yes	yes

A-Level Physics: **s25 11**

25 Which statement about longitudinal and transverse wave motion for a progressive wave is correct?

A All transverse and longitudinal waves require a medium for propagation.

B All transverse waves travel at the same speed, but longitudinal waves can travel at different speeds.

C In both transverse waves and longitudinal waves, a particle with zero displacement has a maximum speed.

D In a longitudinal wave there is a net movement of particles in the direction of travel of the wave, but there is no net movement of particles in a transverse wave.

A-Level Physics: **s25 12**

28 Which statement compares the behaviour of transverse and longitudinal waves?

A Only longitudinal waves can be diffracted.

B Only longitudinal waves can travel in free space.

C Only transverse waves can be coherent.

D Only transverse waves can be polarised.

7 Waves – 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)		
intensity	强度			
point source	点源			
phase difference	相位差			
observer	观察者			
Doppler effect	多普勒效应			

Recall

In **Part 1** you used the wave quantities (amplitude, wavelength, frequency, period), the wave equation $v = f\lambda$, and transverse vs longitudinal waves. Part 2 adds how strong a wave is (intensity), how out-of-step two waves are (phase), and the Doppler effect.

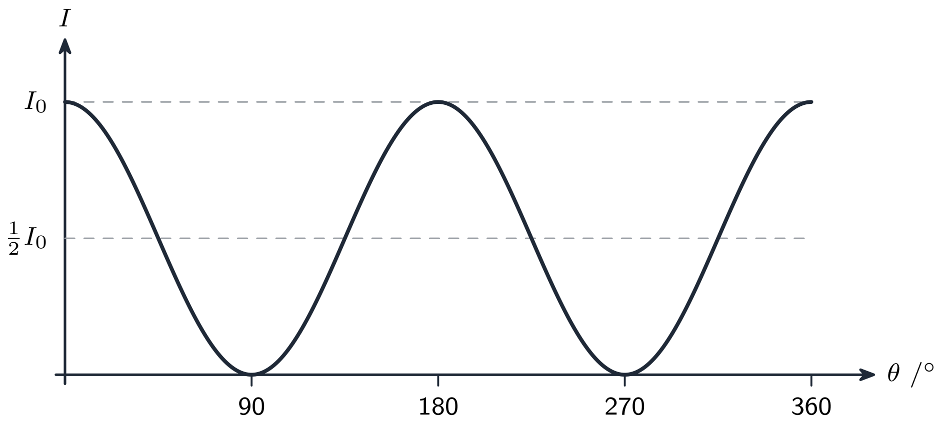
New ideas

■ 1 Intensity

The **intensity** 强度 of a wave is the power passing through unit area: $I = \dfrac{P}{A}$ (in W m^{-2}). It is proportional to the **square of the amplitude**: $I \propto A^2$.

A **point source** 点源 spreads its power over a sphere of area $4\pi r^2$, so

$$I = \frac{P}{4\pi r^2}, \qquad I \propto \frac{1}{r^2}.$$

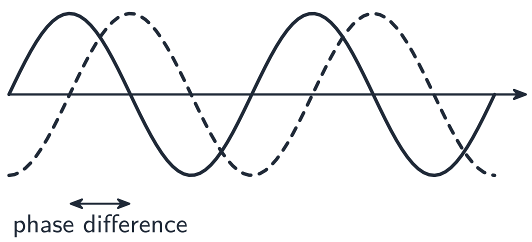


Worked example. A lamp emits 60 W equally in all directions. At 2.0 m: $I = \dfrac{60}{4\pi(2.0)^2} \approx 1.2\ \mathrm{W\ m^{-2}}$.

2 Phase difference

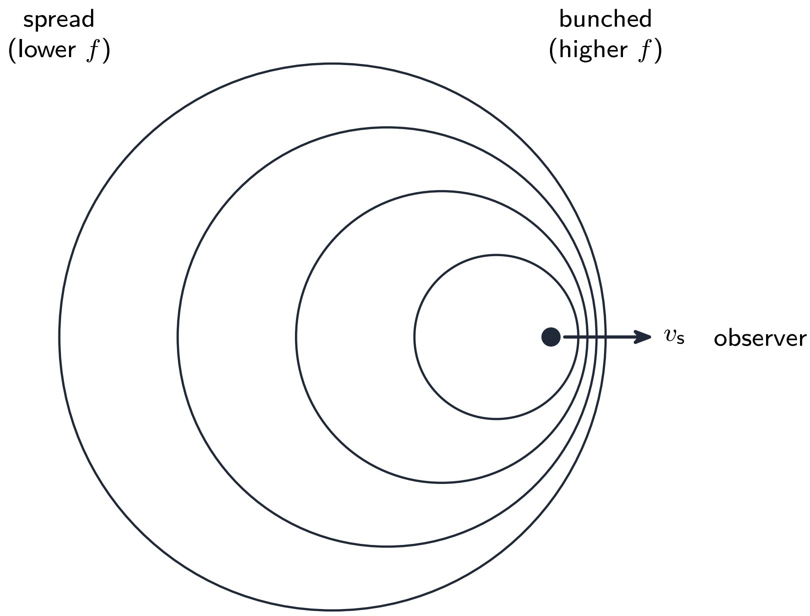
The **phase difference** 相位差 tells how far one oscillation leads or lags another, measured in radians (a full cycle is 2π) or degrees (a full cycle is 360°).

- two points one wavelength apart are *in phase* (phase difference 0);
- two points half a wavelength apart are *exactly out of phase* (phase difference π, or 180°).



3 The Doppler effect

When a sound **source** moves relative to a still **observer** 观察者, the heard frequency changes — the **Doppler effect** 多普勒效应. Moving **towards** → wavefronts squashed → higher frequency; moving **away** → lower.



$$f_o = \frac{v\,f_s}{v \pm v_s} \quad \text{(minus when approaching).}$$

Worked example. A 800 Hz horn moves at 30 m s^{-1} towards a still listener (v = 340 m s^{-1}): $f_o = \dfrac{340 \times 800}{340 - 30} \approx 877$ Hz.

Watch out: use *minus* in the bottom when the source moves *towards* the listener (pitch rises) and *plus* when it moves *away* (pitch falls).

Practice

7.1 A point source emits 100 W equally in all directions. Find the intensity 5.0 m away. [2]

7.2 The amplitude of a wave is doubled. State the factor by which its intensity changes. [1]

7.3 State the phase difference, in degrees, between two points half a wavelength apart on a wave. [1]

7.4 A car horn of frequency 500 Hz moves away from a still listener at 25 m s^{-1} ($v =$ 340 m s^{-1}). Find the heard frequency. [2]

7.5 The distance from a point source is doubled. State the factor by which the intensity changes. [1]

7.6 Explain *why* the pitch of an ambulance siren suddenly drops as it passes you. [2]

7.7 Challenge. Light from a distant star is measured with a *longer* wavelength than expected (a “red-shift”). Using the Doppler idea, state whether the star is moving towards or away from us, and why. [2]

27 A dolphin is swimming at a speed of $16.0\,\text{m}\,\text{s}^{-1}$ directly towards a stationary underwater microphone.

The dolphin emits a sound of frequency 122 kHz. The speed of sound in water is $1480\,\text{m}\,\text{s}^{-1}$.

What is the frequency of sound detected by the microphone?

A 1300 Hz **B** 1330 Hz **C** 121 kHz **D** 123 kHz

A-Level Physics: **w25 12**

27 A moving source emits sound of frequency 1200 Hz.

A stationary observer hears sound of frequency 960 Hz. The speed of the sound is $340\,\text{m}\,\text{s}^{-1}$.

What could be the velocity of the source?

A $68\,\text{m}\,\text{s}^{-1}$ directly away from the observer

B $68\,\text{m}\,\text{s}^{-1}$ directly towards the observer

C $85\,\text{m}\,\text{s}^{-1}$ directly away from the observer

D $85\,\text{m}\,\text{s}^{-1}$ directly towards the observer

A-Level Physics: **s25 14**

22 A vehicle is moving with a speed of $30.0\,\text{m}\,\text{s}^{-1}$ directly towards a stationary observer. The horn of the vehicle emits sound of frequency 440 Hz. The speed of sound in air is $340\,\text{m}\,\text{s}^{-1}$.

What is the frequency of the sound heard by the observer?

A 401 Hz **B** 404 Hz **C** 479 Hz **D** 483 Hz

25 Which statement about electromagnetic waves is correct?

A A wave of wavelength 5.0×10^{-6} m is invisible to the human eye.

B They can all travel at different speeds in free space.

C They **cannot** be polarised.

D They consist of vibrating atoms.

A-Level Physics: **s25 11**

27 Which wavelength of electromagnetic radiation in free space could be green light?

A 4.9×10^{-9} m **B** 6.6×10^{-9} m **C** 5.5×10^{-7} m **D** 8.6×10^{-7} m

A-Level Physics: **s25 13**

27 An electromagnetic wave travelling in free space is **not** visible to the human eye.

What is a possible wavelength of the wave?

A 4.5×10^{-10} km

B 6.2×10^{-7} m

C 5.4×10^{-6} cm

D 4.2×10^{-4} mm

A-Level Physics: **m25 12**

23 What is the approximate range of wavelengths in free space for infrared radiation?

A 100 nm to 400 nm

B 300 μm to 30 cm

C 400 nm to 700 nm

D 800 nm to 1000 μm

28 What may be observed with light waves but **not** with sound waves?

A diffraction

B interference

C polarisation

D reflection

A-Level Physics: **s25 11**

28 Which group contains only waves that can be polarised?

A infrared waves, radio waves, sound waves

B visible light waves, microwaves, radio waves

C visible light waves, radio waves, sound waves

D microwaves, visible light waves, sound waves

A-Level Physics: **s25 13**

25 Which phenomenon is only associated with transverse waves?

A diffraction

B interference

C polarisation

D reflection

A-Level Physics: **s25 14**

24 A horizontal beam of light is incident normally on a polarising filter. The incident light is vertically polarised and has an intensity of $24\,\mathrm{W\,m^{-2}}$. The direction of the transmission axis of the filter is at an angle of 30° to the vertical.

What is the intensity of the light in the transmitted beam?

A $18\,\mathrm{W\,m^{-2}}$ **B** $21\,\mathrm{W\,m^{-2}}$ **C** $28\,\mathrm{W\,m^{-2}}$ **D** $32\,\mathrm{W\,m^{-2}}$

8 Superposition – 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)		
superposition	叠加			
interference	干涉			
constructive interference	相长干涉			
destructive interference	相消干涉			
coherent	相干			
path difference	路程差			
stationary wave	驻波			
node	波节			
antinode	波腹			
diffraction	衍射			
diffraction grating	衍射光栅			

Recall

At IGCSE you saw waves reflect and overlap. Bring this with you:

- A wave has amplitude, wavelength and frequency.
- Two waves can be in the same place at the same time.

At AS we look at what happens when waves meet — this is superposition, the idea behind everything from noise-cancelling headphones to the colours in a soap bubble.

New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

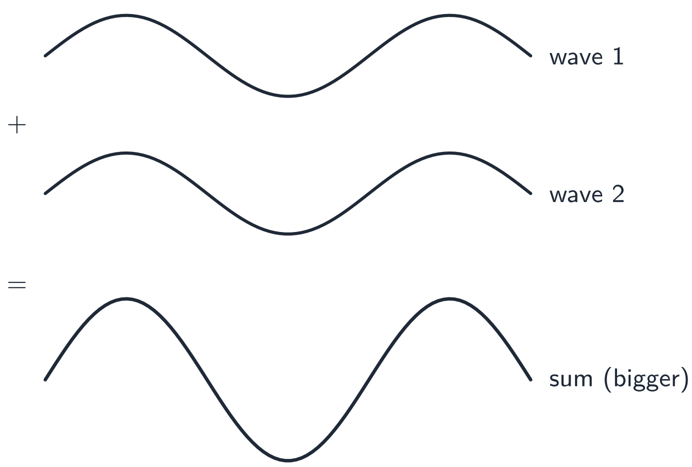
1 Superposition and interference

When two waves meet, their displacements add — this is **superposition 叠加**. The result is called **interference 干涉**:

- waves arriving in step → **constructive interference 相长干涉** (bigger amplitude);
- waves arriving exactly out of step → **destructive interference 相消干涉** (they cancel).

For two waves from **coherent 相干** sources (same frequency, steady phase), what decides the result is the **path difference 路程差** — the extra distance one wave travels:

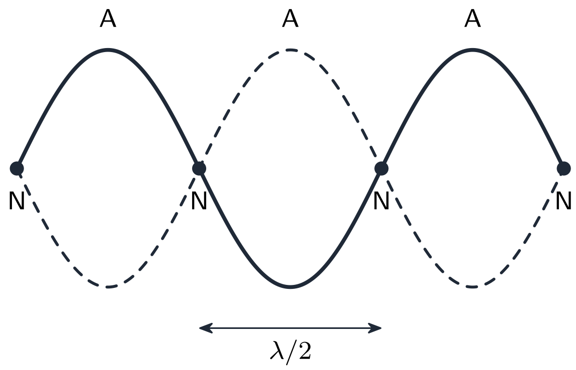
- a whole number of wavelengths $(0, \lambda, 2\lambda, \dots)$ → constructive;
- an odd number of half-wavelengths $(\frac{1}{2}\lambda, \frac{3}{2}\lambda, \dots)$ → destructive.



Worked example. Two waves of amplitude 2 mm arriving in step add to 4 mm (constructive); arriving exactly out of step they cancel to 0 (destructive).

■ 2 Stationary waves

A **stationary wave** 驻波 forms when two identical waves travel in opposite directions (for example a wave and its reflection). It does not move along.



It has **node** 波节 points (no movement) and **antinode** 波腹 points (largest movement) that stay in fixed places. Neighbouring nodes are half a wavelength apart.

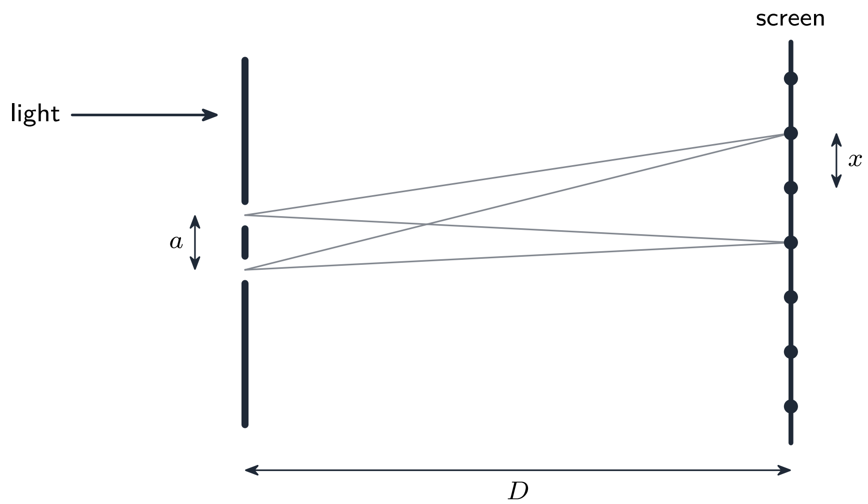
Worked example. If neighbouring nodes are 0.30 m apart, then $\frac{1}{2}\lambda = 0.30$ m, so $\lambda = 0.60$ m.

■ 3 Two-source interference

When light passes through two narrow slits it spreads out (**diffraction** 衍射) and the two beams interfere, making bright and dark bands on a screen. The bright-band spacing is

$$x = \frac{\lambda D}{a},$$

where a is the slit separation and D the distance to the screen.



Worked example. For $\lambda = 5.0 \times 10^{-7}$ m, $a = 0.40$ mm, $D = 1.5$ m: $x = \dfrac{\lambda D}{a} =$

$$\frac{(5.0 \times 10^{-7})(1.5)}{0.40 \times 10^{-3}} = 1.9 \times 10^{-3} \text{ m.}$$

A **diffraction grating** 衍射光栅 (many slits) gives sharp bright lines at angles where $d \sin\theta = n\lambda$.

Watch out: the sources must be **coherent** (same frequency, steady phase) for a steady pattern — two ordinary bulbs will not interfere visibly.

Practice

8.1 Two waves meet exactly in step. Each has amplitude 3 mm. State the type of interference and the resulting amplitude. [2]

8.2 Two coherent waves meet with a path difference of 1.5λ. State whether the interference is constructive or destructive, and why. [2]

8.3 On a stationary wave, neighbouring nodes are 0.40 m apart. Find the wavelength. [1]

8.4 Light of wavelength 6.0×10^{-7} m passes through slits 0.50 mm apart onto a screen 2.0 m away. Find the bright-fringe spacing $x = \dfrac{\lambda D}{a}$. [3]

8.5 Explain *why* the two slits must be lit by one single source (or a laser), not by two separate lamps. [2]

8.6 Challenge. In the two-slit experiment, state and explain what happens to the fringe spacing if the slits are moved *closer together*. [2]

29 A wire is fixed at both ends and is vibrated by a source of frequency f. A stationary wave is formed on the wire with a total of two antinodes.

The frequency of the source is increased to $3f$ and a new stationary wave is formed.

What is the total number of antinodes on the new wave?

A 4 **B** 5 **C** 6 **D** 9

A-Level Physics: **s25 11**

31 A hollow tube is closed at one end and open at the other.

A stationary sound wave of the lowest possible frequency, 820 Hz, is produced in the tube.

The speed of sound in air is $330\,\mathrm{m\,s^{-1}}$.

What is the length of the tube?

A 10 cm **B** 20 cm **C** 40 cm **D** 160 cm

A-Level Physics: **s25 12**

30 Two waves meet.

What is **not** a necessary condition for the waves to produce a stationary wave?

A They must be of the same type.

B They must have the same period.

C They must have the same wavelength.

D They must travel in the same direction.

28 A light wave passes through a single slit and a diffraction pattern forms.

What happens to the frequency and the speed of the wave when it is diffracted?

	frequency	speed
A	decreases	increases
B	increases	decreases
C	no change	decreases
D	no change	no change

A-Level Physics: **w25 13**

24 Which row is correct for sound waves?

	can travel in a vacuum	can be polarised	can diffract through a gap
A	no	no	yes
B	yes	no	no
C	no	yes	no
D	no	yes	yes

A-Level Physics: **w25 14**

26 For a progressive transverse wave, what describes the term diffraction?

A the change in observed frequency of a wave due to a movement of the wave source

B the spreading of a wave as it passes through a gap or around an obstacle

C when oscillations of a wave are confined to one plane

D the resultant displacement of two waves is equal to the sum of the displacements of the individual waves when the waves meet

8 Superposition – 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)		
Intensity	强度			
fundamental	基频			
resonance tube	共鸣管			
normal	法线			
slit spacing	缝间距			
order	级次			

Recall

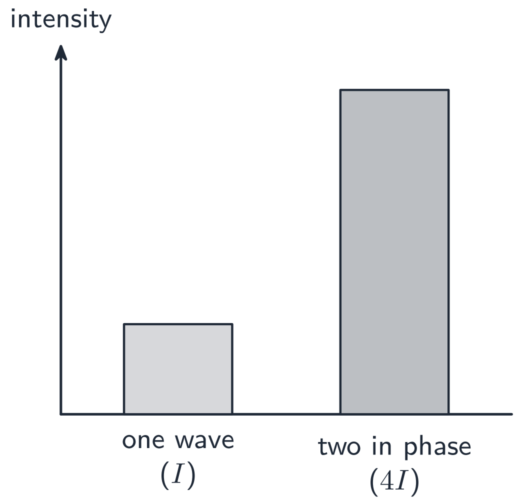
In **Part 1** you used superposition, constructive and destructive interference, path difference, stationary waves (nodes and antinodes), and the double-slit fringe spacing $x = \lambda D/a$. Part 2 adds intensity in interference, stationary waves in strings and pipes, and the diffraction grating.

New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

■ 1 Intensity in interference

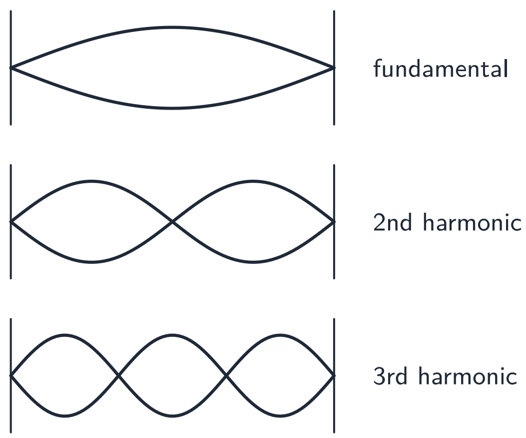
Intensity 强度 goes as the square of the amplitude, $I \propto A^2$. So when two equal waves meet **in phase**, the amplitude is $2A$ and the intensity is $(2A)^2 = 4A^2$ — **four times** the intensity of one wave alone (not twice).



Worked example. If one wave alone gives an intensity of 5 W m^{-2}, two equal waves in phase give $4 \times 5 = 20$ W m^{-2}.

■ 2 Stationary waves in strings and pipes

- A string fixed at both ends vibrates with a node at each end. The **fundamental** 基频 (lowest note) is a single loop, so $L = \frac{1}{2}\lambda$.
- A **resonance tube** 共鸣管 closed at one end has a node at the closed end and an antinode at the open end, so its fundamental has $L = \frac{1}{4}\lambda$. A tube open at both ends has $L = \frac{1}{2}\lambda$.



Worked example. A guitar string 0.65 m long sounds its fundamental, so $L = \frac{1}{2}\lambda$ and $\lambda = 1.3$ m.

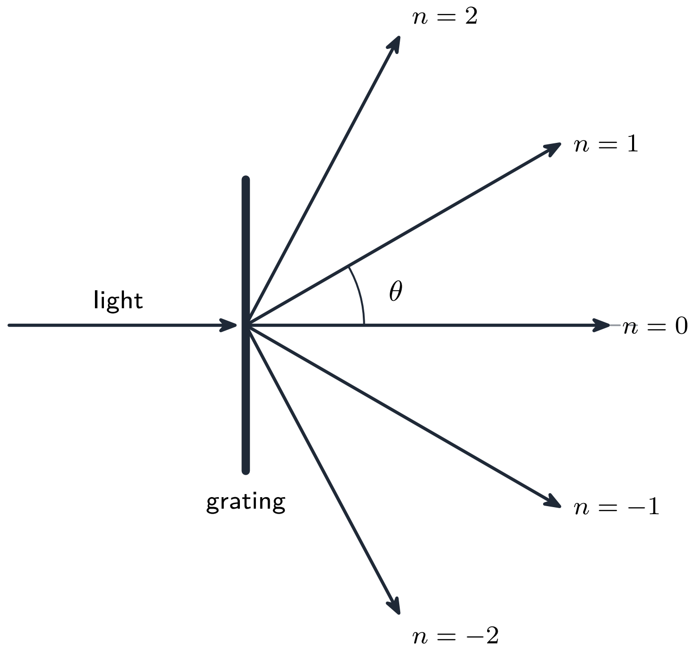
Watch out: a closed pipe fits only a *quarter* wavelength in its fundamental ($L = \frac{1}{4}\lambda$), but a string or open pipe fits a *half* ($L = \frac{1}{2}\lambda$) — check which one you have.

■ 3 The diffraction grating

A diffraction grating has many equally spaced slits. Bright maxima appear at angle θ from the **normal** 法线 where

$$d \sin\theta = n\lambda,$$

with d the **slit spacing** 缝间距 and n the **order** 级次 $(0, 1, 2, \ldots)$. More slits make the maxima much sharper than a double slit.



Worked example. A grating with 500 lines per mm ($d = 2.0 \times 10^{-6}$ m) with light of 600 nm: $\sin\theta = \dfrac{n\lambda}{d} = \dfrac{600 \times 10^{-9}}{2.0 \times 10^{-6}} = 0.30$, so $\theta \approx 17°$ for $n = 1$.

Practice

8.1 Two waves of equal amplitude meet exactly in phase. State the factor by which the intensity is greater than that of one wave alone. [1]

8.2 A string fixed at both ends vibrates in its fundamental mode with the loop 0.60 m long. Find the wavelength. [1]

8.3 A tube closed at one end has its fundamental when its length is 0.25 m. Find the wavelength of the sound. [2]

8.4 A grating with 300 lines per mm is lit normally by light of wavelength 500 nm. Find the angle of the first-order ($n = 1$) maximum. [3]

8.5 A grating has 400 lines per mm. Find the slit spacing d in metres. [1]

8.6 Explain *why* two equal waves meeting in phase give *four* times the intensity of one, not twice. [2]

8.7 Challenge. A grating gives a first-order maximum where $\sin\theta_1 = 0.30$. Find the angle of the second-order ($n = 2$) maximum for the same light. [2]

31 Light of a single wavelength is incident normally on a double slit. Interference fringes are observed on a screen.

The distance from the double slit to the screen is 0.60 m and the fringe separation is 1.8 mm.

The distance from the double slit to the screen increases by 0.90 m.

What is the new fringe separation?

A 1.2 mm **B** 2.7 mm **C** 4.5 mm **D** 5.4 mm

A-Level Physics: **s25 13**

31 Light of a single frequency from two coherent sources interferes to produce a pattern of bright and dark fringes on a screen.

Which change results in a larger fringe separation?

A increasing the distance between the sources and the screen

B increasing the distance between the two sources

C increasing the frequency of the light

D increasing the intensity of the light

A-Level Physics: **m25 12**

27 Light waves are emitted from two sources.

What is a necessary condition for observable interference fringes to be produced?

A The waves must be polarised.

B The waves must **not** be polarised.

C The waves must be coherent.

D The waves must have equal amplitudes.

30 Green laser light passes through a diffraction grating and forms an interference pattern.

The diffraction grating contains 400 lines per mm.

The wavelength of the laser light is 550 nm.

What is the highest order diffraction maximum produced by the grating?

A 4 **B** 5 **C** 8 **D** 9

A-Level Physics: **w25 14**

30 A parallel beam of red light of wavelength 700 nm is incident normally on a diffraction grating that has 400 lines per millimetre.

What is the total number of intensity maxima from the grating?

A 6 **B** 7 **C** 8 **D** 9

A-Level Physics: **s25 11**

30 Light of wavelength 680 nm is incident normally on a diffraction grating with 450 lines mm^{-1}.

What is the angle of diffraction of the second-order maximum in the diffraction pattern that is produced?

A 1.8° **B** 3.5° **C** 18° **D** 38°

A-Level Physics: **m25 12**

29 Light of wavelength 567 nm is incident normally on a diffraction grating. The grating has 400 lines per mm. A number of diffraction maxima are observed on the far side of the grating.

What is the angle between the second-order maximum and the third-order maximum?

A 13.1° **B** 13.9° **C** 15.9° **D** 27.0°

9 Electricity – 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)		
charge	电荷			
Electric current	电流			
Potential difference	电势差			
power	功率			
Resistance	电阻			
Ohm's law	欧姆定律			
resistivity	电阻率			

Recall

At IGCSE you built circuits. Bring this with you:

- Current is the flow of electricity; you used $V = IR$.
- You compared series and parallel circuits.

At AS we define current and voltage from **charge** 电荷 and energy, and add resistivity.

New ideas

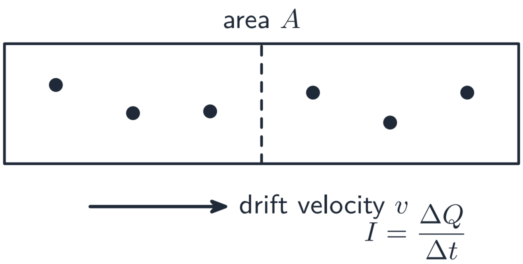
1 Current is the flow of charge

Electric current 电流 is the rate at which charge flows:

$$I = \frac{Q}{t},$$

where Q is charge in coulombs (C), t is time, and I is in amperes (A).

Worked example. If 60 C of charge flows in 20 s: $I = \frac{60}{20} = 3.0$ A.



2 Potential difference and power

Potential difference 电势差 (voltage) is the energy given to each unit of charge: $V = \frac{W}{Q}$.

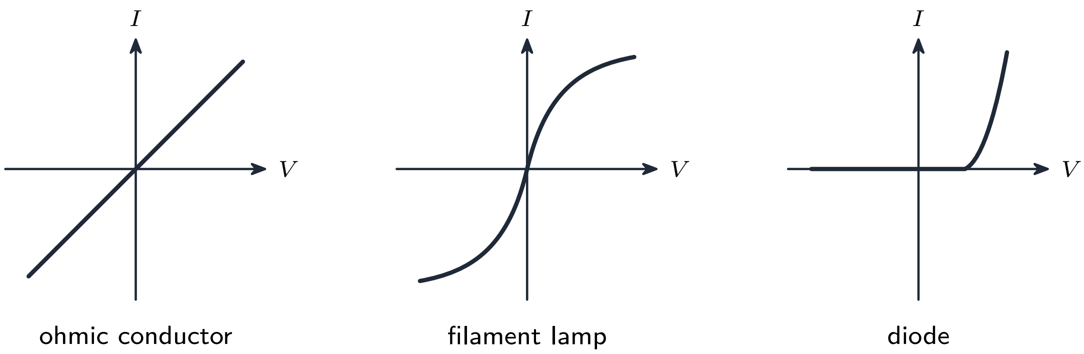
Electrical **power** 功率 is

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

Worked example. A bulb at 12 V carrying 2.0 A: $P = VI = 12 \times 2.0 = 24$ W.

3 Resistance and resistivity

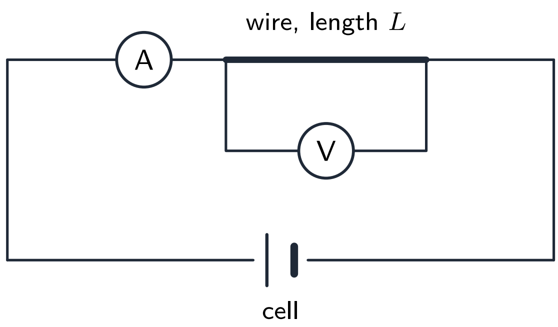
Resistance 电阻 is $R = \frac{V}{I}$. **Ohm's law** 欧姆定律 says that for a metal at constant temperature the current is proportional to the voltage.



A wire's resistance depends on the material through its **resistivity** 电阻率 ρ:

$$R = \frac{\rho L}{A},$$

where L is length and A is cross-sectional area.



Worked example. A 2.0 m copper wire of area 1.0×10^{-6} m^2 ($\rho = 1.7 \times 10^{-8}\ \Omega\,\text{m}$):
$R = \dfrac{\rho L}{A} = \dfrac{(1.7 \times 10^{-8})(2.0)}{1.0 \times 10^{-6}} = 3.4 \times 10^{-2}\ \Omega.$

Watch out: resistivity ρ is a property of the *material* (fixed for copper); resistance R also depends on the wire's length and thickness.

Practice

9.1 A charge of 45 C flows through a lamp in 15 s. Find the current. [2]

9.2 A resistor has 6.0 V across it and a current of 0.50 A. Find its resistance. [2]

9.3 A heater works at 230 V and draws 4.0 A. Find its power. [2]

9.4 A 5.0 Ω resistor carries a current of 2.0 A. Find the power dissipated using $P = I^2R$.[2]

9.5 A wire has resistivity $1.7 \times 10^{-8}\ \Omega\,\mathrm{m}$, length 2.0 m and area $5.0 \times 10^{-7}\ \mathrm{m}^2$. Find its resistance. [2]

9.6 Two wires are of the same material and length, but one is twice as thick. Explain which has the lower resistance. [2]

9.7 Challenge. A wire is stretched to twice its length; its volume stays the same, so its cross-sectional area halves. State the factor by which its resistance changes. [2]

32 What is a possible charge on a particle?

A 6.40×10^{-20} C

B 4.00×10^{-19} C

C 1.12×10^{-18} C

D 9.11×10^{-18} C

A-Level Physics: **w25 14**

35 A wire carries a current of 5.6 A.

What is the number of conduction electrons that pass a point on the wire in a time of 20 s?

A 1.8×10^{18} **B** 2.2×10^{19} **C** 3.5×10^{19} **D** 7.0×10^{20}

A-Level Physics: **s25 12**

34 A resistor of resistance 200 Ω is connected to a supply that has a p.d. of 4.00 V.

How many electrons enter the resistor in 4.00 s?

A 3.13×10^{16} **B** 1.25×10^{17} **C** 5.00×10^{17} **D** 1.25×10^{21}

A-Level Physics: **s25 14**

29 The resistance of a lamp is 10 Ω and the potential difference across it is 6.0 V.

How many electrons pass through the lamp in a time of 24 hours?

A 5.2×10^{4} **B** 9.0×10^{19} **C** 5.4×10^{21} **D** 3.2×10^{23}

A-Level Physics: **m25 12**

33 A metal electrical conductor has a resistance of 5.6 kΩ. A potential difference (p.d.) of 9.0 V is applied across its ends.

How many electrons pass a point in the conductor in one minute?

A 6.0×10^{20} **B** 1.0×10^{19} **C** 6.0×10^{17} **D** 1.0×10^{16}

9 Electricity – 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)		
charge carriers	载流子			
elementary charge	基本电荷			
drift velocity	漂移速度			
filament lamp	灯丝灯泡			
diode	二极管			
thermistor	热敏电阻			
light-dependent resistor	光敏电阻			

Recall

In **Part 1** you used $I = Q/t$, $V = W/Q$, electrical power, resistance, Ohm's law and resistivity. Part 2 looks at what actually flows (charge carriers, drift velocity), how real components behave, and components that sense their surroundings.

New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

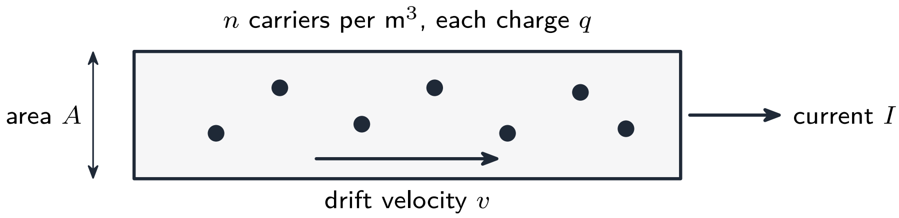
■ 1 Charge and drift velocity

A current is a flow of **charge carriers** 载流子 (electrons in a metal). Charge comes in whole numbers of the **elementary charge** 基本电荷 $e = 1.6 \times 10^{-19}$ C: since $Q = It$, the number of electrons is $N = Q/e$.

The carriers drift slowly at a **drift velocity** 漂移速度 v, linked to the current by

$$I = nAvq,$$

where n is the number of carriers per m^3 and A is the area.

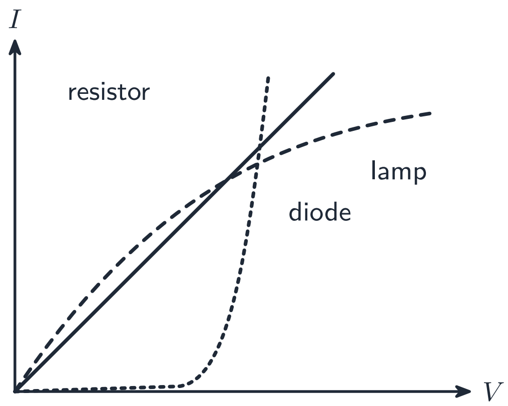


Worked example. A copper wire ($A = 1.0 \times 10^{-6}$ m^2, $n = 8.5 \times 10^{28}$ m^{-3}) carries 5.0 A: $v = \dfrac{I}{nAq} = \dfrac{5.0}{(8.5 \times 10^{28})(1.0 \times 10^{-6})(1.6 \times 10^{-19})} \approx 3.7 \times 10^{-4}$ m s^{-1} — under a millimetre per second.

Watch out: the drift velocity is tiny, yet a lamp lights instantly — because the electric *field* travels through the wire near light-speed and pushes every electron at once.

■ 2 Real components

- A **filament lamp** 灯丝灯泡: as more current heats the filament, its resistance **rises**, so its I–V graph bends over (gets flatter).
- a **diode** 二极管: lets current flow one way only — almost none in reverse, and little until about 0.7 V forwards, then it rises sharply.

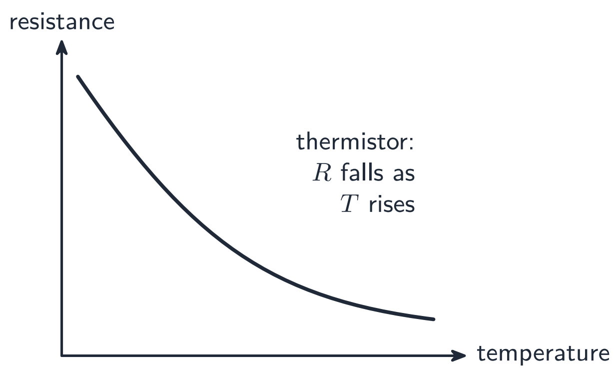


Worked example. Reading a diode's I–V graph: below about 0.7 V forwards almost no current flows; above it the current rises steeply; in reverse the current stays near zero.

■ **3 Sensing components**

- a **thermistor** 热敏电阻: its resistance **falls** as the temperature rises.
- a **light-dependent resistor** 光敏电阻 (LDR): its resistance **falls** as the light gets brighter.

Both are used in sensing circuits (a thermostat, a light-controlled lamp).



Worked example. On a cold night a thermistor's resistance is high; as a heater warms it, the resistance falls — a circuit can sense that change and switch the heater off.

Practice

9.1 A current of 2.0 A flows for 30 s. Find (a) the charge that passes, (b) the number of electrons ($e = 1.6 \times 10^{-19}$ C). [3]

9.2 A wire of area 2.0×10^{-6} m^2 carries 8.0 A, with $n = 8.5 \times 10^{28}$ m^{-3} and $q = 1.6 \times 10^{-19}$ C. Find the drift velocity. [2]

9.3 State what happens to the resistance of a filament lamp as the current through it increases, and why. [2]

9.4 State the key property of a diode in a circuit. [1]

9.5 State how the resistance of (a) a thermistor changes as it gets hotter, (b) an LDR changes as the light gets brighter. [2]

9.6 Using $I = nAvq$, explain *why* a thicker wire carrying the same current has a smaller drift velocity. [2]

9.7 Challenge. Explain why an LDR is a good component for a circuit that switches a light on automatically when it gets dark. [2]

31 There is a potential difference V across a resistor of resistance R. The current in the resistor is I.

Which equation gives the power P dissipated by the resistor?

A $P = V^2 I$ **B** $P = \dfrac{V^2}{I}$ **C** $P = V^2 R$ **D** $P = \dfrac{V^2}{R}$

A-Level Physics: **w25 12**

32 The current in a resistor of constant resistance is 8.0 mA. The power dissipated by the resistor is P.

The current in the resistor is increased to 12.0 mA.

What is the new power dissipated by the resistor?

A $0.44P$ **B** $0.67P$ **C** $1.5P$ **D** $2.3P$

A-Level Physics: **s25 14**

30 What is equivalent to one volt?

A one coulomb per second

B one joule per coulomb

C one joule per second

D one joule second per coulomb squared

32 Which expression gives the definition of resistance?

A current divided by potential difference

B current multiplied by potential difference

C potential difference divided by current

D resistivity multiplied by length

A-Level Physics: **s25 14**

31 The resistance of some electrical components may change with changing conditions.

Which component's resistance increases?

A a filament lamp as the potential difference (p.d.) across it increases

B a light-dependent resistor (LDR) as the intensity of the light incident on it increases

C a metallic conductor at constant temperature as the current through it increases

D a thermistor as its temperature increases

A-Level Physics: **m25 12**

31 A copper wire is 6.4 m long and has a resistance of $0.92\,\Omega$.

The resistivity of copper is $1.8 \times 10^{-8}\,\Omega\,\text{m}$.

What is the diameter of the wire?

A $5.7 \times 10^{-5}\,\text{m}$ **B** $1.0 \times 10^{-4}\,\text{m}$ **C** $4.0 \times 10^{-4}\,\text{m}$ **D** $7.1 \times 10^{-4}\,\text{m}$

10 D.C. circuits – 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)		
series	串联			
parallel	并联			
electromotive force	电动势			
internal resistance	内阻			
Kirchhoff's first law	基尔霍夫第一定律			
junction	节点			
Kirchhoff's second law	基尔霍夫第二定律			
potential divider	分压器			

Recall

At IGCSE you built and measured circuits. Bring this with you:

- You used $V = IR$ and added resistors in **series** 串联 and **parallel** 并联.
- Current is the same all the way round a single loop.

At AS we treat real cells, two circuit laws, and a useful circuit called the potential divider.

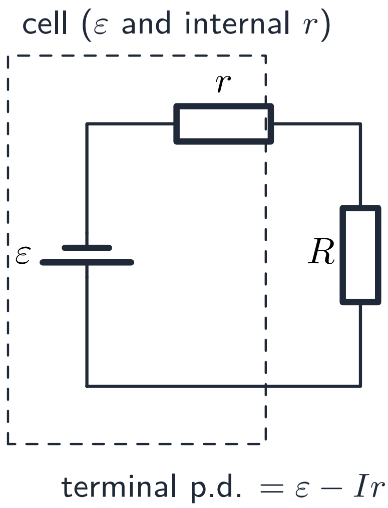
New ideas

1 E.m.f. and internal resistance

The **electromotive force** 电动势 ε of a cell is the energy it gives each unit of charge. A real cell also has some **internal resistance** 内阻 r, so when a current I flows the voltage you can use across the terminals is less:

$$V = \varepsilon - Ir.$$

Worked example. A cell with $\varepsilon = 12$ V and $r = 0.50\ \Omega$ supplies 2.0 A: $V = 12 - (2.0)(0.50) = 11$ V.

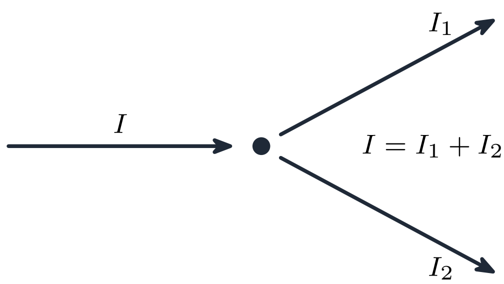


Watch out: the terminal voltage V is always *less* than the e.m.f. ε once current flows, because some energy is lost across the internal resistance r.

2 Kirchhoff's two laws

- **Kirchhoff's first law** 基尔霍夫第一定律 (charge is conserved): the total current into a **junction** 节点 equals the total current out.
- **Kirchhoff's second law** 基尔霍夫第二定律 (energy is conserved): around any loop, the sum of the e.m.f.s equals the sum of the voltage drops.

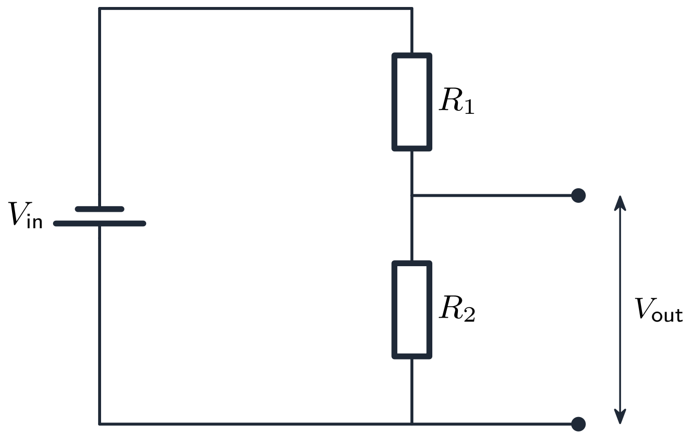
Worked example. 5.0 A flows into a junction and splits into two wires; one carries 2.0 A, so the other carries $5.0 - 2.0 = 3.0$ A.



3 The potential divider

Two resistors in series share the supply voltage in proportion to their resistance. This is a **potential divider** 分压器. The voltage across R_2 is

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



Worked example. $R_1 = 4.0\ \text{k}\Omega$, $R_2 = 2.0\ \text{k}\Omega$, $V_{\text{in}} = 9.0$ V: $V_{\text{out}} = \dfrac{2.0}{6.0} \times 9.0 = 3.0$ V.

Practice

10.1 A cell of e.m.f. 1.5 V and internal resistance 0.40 Ω supplies 0.50 A. Find the terminal voltage. [2]

10.2 At a junction, 3.0 A and 1.5 A flow in along two wires. Find the current flowing out along the third wire. [1]

10.3 Around a loop, a 9.0 V cell drives current through two resistors. One has 5.0 V across it. Use Kirchhoff's second law to find the voltage across the other. [2]

10.4 A potential divider has $R_1 = 3.0\ \text{k}\Omega$ and $R_2 = 1.0\ \text{k}\Omega$ across a 12 V supply. Find the output voltage across R_2. [3]

10.5 In that potential divider, explain what happens to the output voltage across R_2 if R_2 is *increased.* [2]

10.6 Challenge. A potential divider uses a thermistor as R_1 and a fixed resistor as R_2. Explain what happens to the output voltage across R_2 as the temperature rises. [2]

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*.

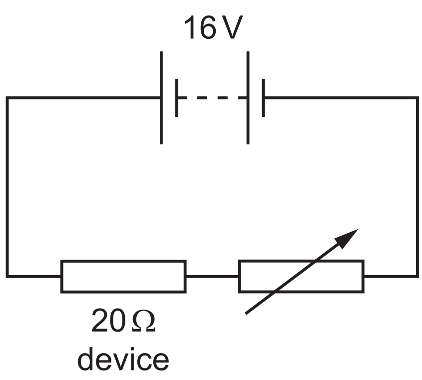
B The energy dissipated within the cell is *EQ*.

C The external resistance is *EQ*.

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

A-Level Physics: **s25 13**

37 An electrical device of fixed resistance 20 Ω is connected in series with a variable resistor and a battery of e.m.f. 16 V and negligible internal resistance.



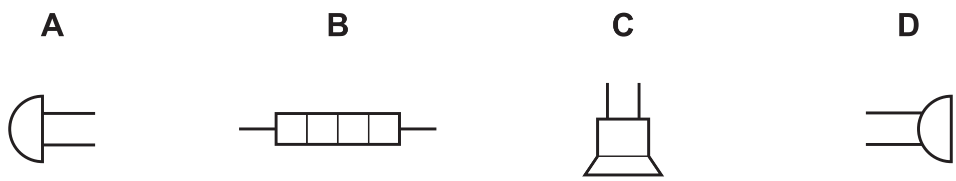
The power dissipated in the electrical device is 4.0 W.

What is the resistance of the variable resistor?

A 16 Ω **B** 36 Ω **C** 44 Ω **D** 64 Ω

A-Level Physics: **m25 12**

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



10 D.C. circuits – 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)		
Series	串联			
Parallel	并联			
sensor	传感器			
thermistor	热敏电阻			
light-dependent resistor	光敏电阻			
terminal p.d.	端电压			

Recall

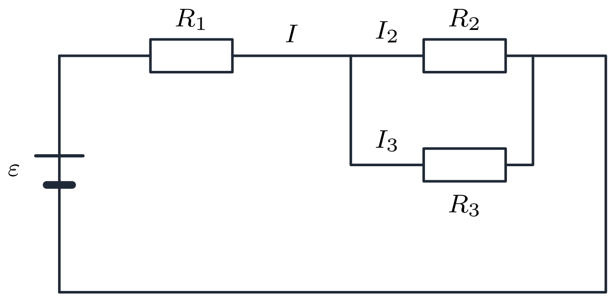
In **Part 1** you used e.m.f. and internal resistance ($V = \varepsilon - Ir$), Kirchhoff's two laws, and the potential divider. Part 2 adds combining resistors, using a divider to sense temperature or light, and measuring a cell's e.m.f. and internal resistance.

New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

■ 1 Combining resistors

- **Series** 串联 (same current): $R = R_1 + R_2 + \dots$ — always bigger.
- **Parallel** 并联 (same p.d.): $\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dots$ — always *smaller* than any single resistor (two equal $R \to R/2$).



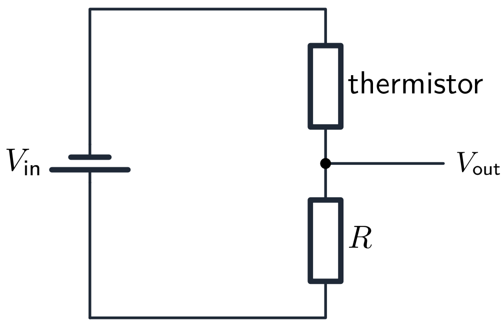
Worked example. A 4.0 Ω and a 12 Ω resistor in parallel: $\dfrac{1}{R} = \dfrac{1}{4.0} + \dfrac{1}{12} = \dfrac{3+1}{12} = \dfrac{1}{3}$, so $R = 3.0\ \Omega$.

■ 2 Sensor circuits

Put a **sensor** 传感器 in a potential divider instead of a fixed resistor:

- a **thermistor** 热敏电阻 — its resistance falls as the temperature rises;
- a **light-dependent resistor** 光敏电阻 (LDR) — its resistance falls as the light gets brighter.

The divider's output voltage then changes with temperature or light, and can switch a heater or lamp on and off.

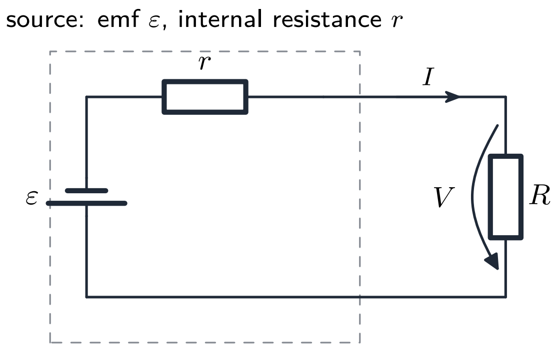


Worked example. In a thermistor-plus-fixed-resistor divider, a cold room gives the thermistor a high resistance; as it warms, that resistance falls and the output voltage shifts — enough to switch a fan on.

■ 3 Measuring e.m.f. and internal resistance

Connect a cell to a variable resistor and record the **terminal p.d.** 端电压 V and current I as you change it. Plotting V against I gives the line $V = \varepsilon - Ir$:

- the y-intercept (at $I = 0$) is the e.m.f. ε;
- the gradient is $-r$ (the internal resistance).



Worked example. A V–I line cuts the axis at $V = 1.5$ V (so $\varepsilon = 1.5$ V) with a gradient of -0.50 V A^{-1} (so $r = 0.50\ \Omega$).

Watch out: resistors in parallel always give a total *smaller* than the smallest one — each extra path gives the current another way to flow.

Practice

10.1 Find the combined resistance of a 3.0 Ω and a 6.0 Ω resistor in **series**. [1]

10.2 Find the combined resistance of a 6.0 Ω and a 3.0 Ω resistor in **parallel**. [2]

10.3 State how the resistance of a thermistor changes as it gets warmer. [1]

10.4 When the terminal p.d. V is plotted against the current I for a cell, state what (a) the y-intercept and (b) the gradient represent. [2]

10.5 A cell of e.m.f. 1.5 V and internal resistance 0.50 Ω supplies a current of 0.60 A.

Find the terminal p.d. [2]

10.6 Explain *why* adding a second resistor in parallel *lowers* the total resistance, even though you have added more resistor. [2]

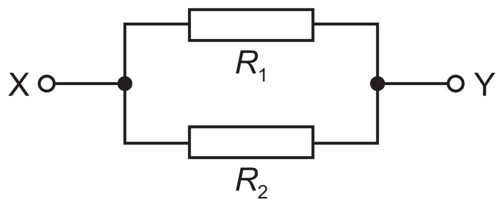
10.7 Challenge. You have three identical 6.0 Ω resistors. State the largest and the smallest total resistance you can make using all three. [2]

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

A-Level Physics: **s25 11**

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** $\dfrac{R_1}{R_2}$

A-Level Physics: **s25 14**

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?

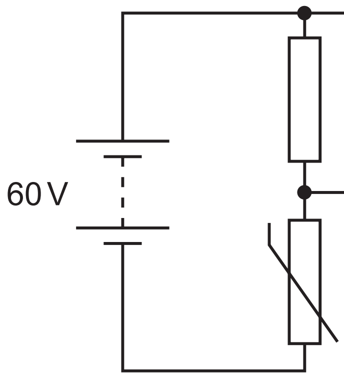
A This is Kirchhoff's first law, which results from the conservation of charge.

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 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

11 Particle physics – 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)		
nucleus	原子核			
proton	质子			
neutron	中子			
nucleon	核子			
proton number	质子数			
nucleon number	核子数			
isotope	同位素			
radioactive	放射性			
radiation	辐射			
quark	夸克			

Recall

At IGCSE you met the atom. Bring this with you:

- An atom has a tiny central **nucleus** 原子核 with electrons around it.
- The nucleus holds **proton** 质子 (positive) and **neutron** 中子 (no charge) particles.

At AS we count these particles exactly and look at what protons and neutrons are made of.

New ideas

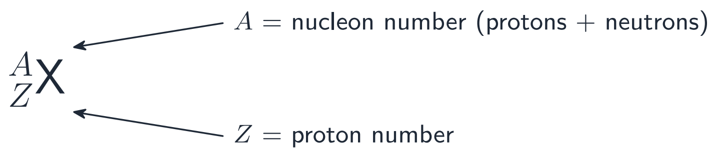
Read these first. Each idea has a short worked example. Then do the Practice.

1 Counting the nucleus

A proton and a neutron are both **nucleon** 核子 particles. We label a nucleus ${}^{A}_{Z}\mathrm{X}$:

- the **proton number** 质子数 Z = number of protons (it decides which element it is);
- the **nucleon number** 核子数 A = total protons + neutrons, so neutrons = $A - Z$.

Atoms of one element with different neutron numbers are **isotope** 同位素 forms of it (same Z, different A).

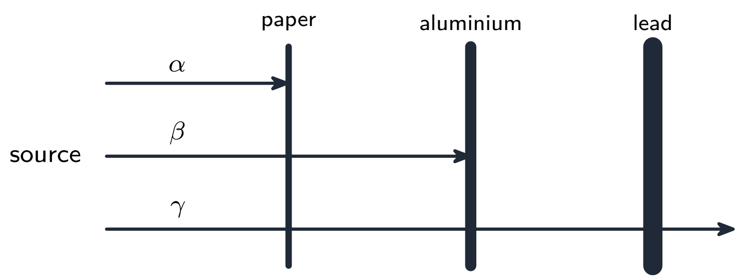


Worked example. Carbon-14 is ${}^{14}_{6}\mathrm{C}$: $Z = 6$ protons, and $A - Z = 14 - 6 = 8$ neutrons.

Watch out: the proton number Z decides the *element*. Change only the neutron number and you get an *isotope* of the same element — not a new element.

2 Radioactivity

Some nuclei are unstable and **radioactive** 放射性: they give out **radiation** 辐射 to become more stable. There are three kinds — alpha (α), beta (β) and gamma (γ). Alpha is stopped by paper, beta by thin metal, and gamma is the most penetrating.



Worked example. To identify a source: if paper stops it, it is alpha; if it passes paper but a few mm of aluminium stops it, it is beta; if even thick lead only reduces it, it is gamma.

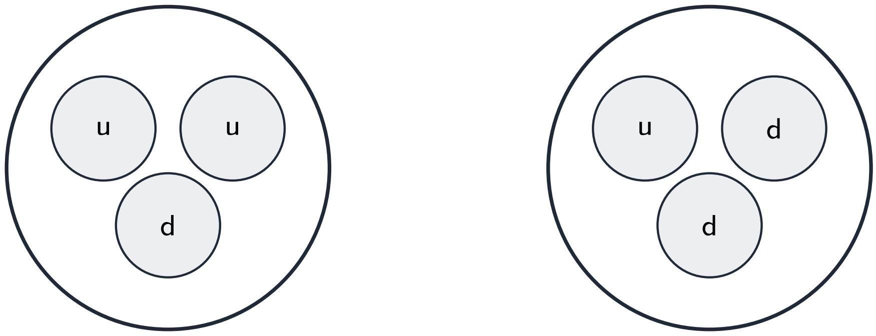
3 Inside protons and neutrons

Protons and neutrons are not the smallest particles — each is built from three **quark** 夸克 particles (the ”up” quark u with charge $+\frac{2}{3}$, and the ”down” quark d with charge $-\frac{1}{3}$):

- proton = $u\,u\,d$,

- neutron $= u\,d\,d$.

proton (charge $+1$) **neutron (charge 0)**



$+\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=+1$ $+\frac{2}{3}-\frac{1}{3}-\frac{1}{3}=0$

Worked example. Adding the quark charges in a proton: $+\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=+1$ — the proton's charge. For a neutron: $+\frac{2}{3}-\frac{1}{3}-\frac{1}{3}=0$.

Practice

11.1 A nucleus is written $^{23}_{11}\text{Na}$. State (a) the number of protons, (b) the number of neutrons. [2]

11.2 Explain what is meant by two isotopes of an element. [2]

11.3 State the quark content of (a) a proton, (b) a neutron. [2]

11.4 Put alpha, beta and gamma radiation in order, from least to most penetrating. [1]

11.5 Explain *why* an alpha source is fairly safe outside the body but dangerous if swallowed. [2]

11.6 Challenge. Using the quark charges $u = +\frac{2}{3}$ and $d = -\frac{1}{3}$, show that a proton (uud) has charge $+1$ and a neutron (udd) has charge 0. [2]

38 The diagram shows a sequence of radioactive decays involving three α-particles and a β^- particle.

$$^{237}_{93}Np \xrightarrow{\alpha} Q \xrightarrow{\beta^-} R \xrightarrow{\alpha} S \xrightarrow{\alpha} T$$

What is nuclide T?

A $^{225}_{88}Ra$ **B** $^{231}_{88}Ra$ **C** $^{225}_{90}Th$ **D** $^{229}_{90}Th$

A-Level Physics: **w25 14**

38 What is the correct equation for β^+ decay?

A neutron $\rightarrow$ proton + electron + electron antineutrino

B neutron $\rightarrow$ proton + electron + electron neutrino

C proton $\rightarrow$ neutron + positron + electron antineutrino

D proton $\rightarrow$ neutron + positron + electron neutrino

39 A nucleus of polonium, $^{214}_{84}Po$, decays by emitting an α-particle to become a nucleus of lead.

The nucleus of lead is also unstable and decays by emitting a β^- particle to form a nucleus of bismuth which then decays by emitting a β^- particle to produce a nucleus X.

What is the number of neutrons in nucleus X?

A 126 **B** 128 **C** 130 **D** 210

A-Level Physics: **s25 14**

37 A uranium atom with a charge of +2*e* has a nucleon number of 235 and a proton number of 92.

e is the elementary charge.

What is the total number of protons, neutrons and electrons in this charged atom?

A 235 **B** 325 **C** 327 **D** 329

11 Particle physics – 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)		
deflection	偏转			
antiparticle	反粒子			
positron	正电子			
neutrino	中微子			
hadron	强子			
baryon	重子			
meson	介子			
lepton	轻子			

Recall

In **Part 1** you used the nuclear model (a tiny nucleus of protons and neutrons, with electrons around), proton and nucleon number, isotopes, the three radiations (α, β, γ) and quarks (proton = uud, neutron = udd). Part 2 adds the experiment that found the nucleus, writing decay equations, and the family of particles.

New ideas

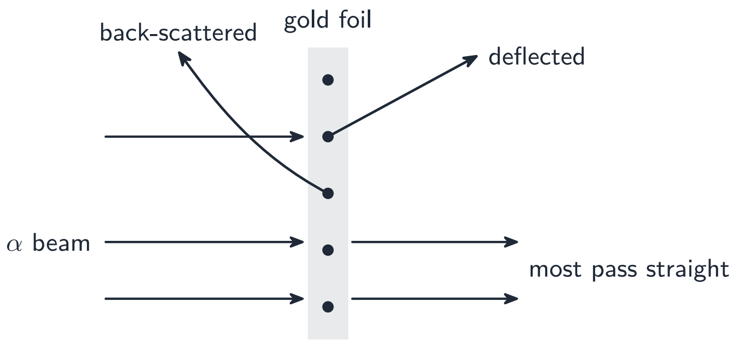
Read these first. Each idea has a short worked example. Then do the Practice.

1 The α-scattering experiment

α-particles were fired at a thin gold foil. What was seen, and what it showed:

- **most passed straight through** $\rightarrow$ the atom is mostly empty space;
- a **few were deflected** through large angles (a strong **deflection** 偏转) $\rightarrow$ there is a tiny, dense, positively charged nucleus at the centre.

The nucleus ($\sim 10^{-15}$ m) is about 10^5 times smaller than the atom ($\sim 10^{-10}$ m).



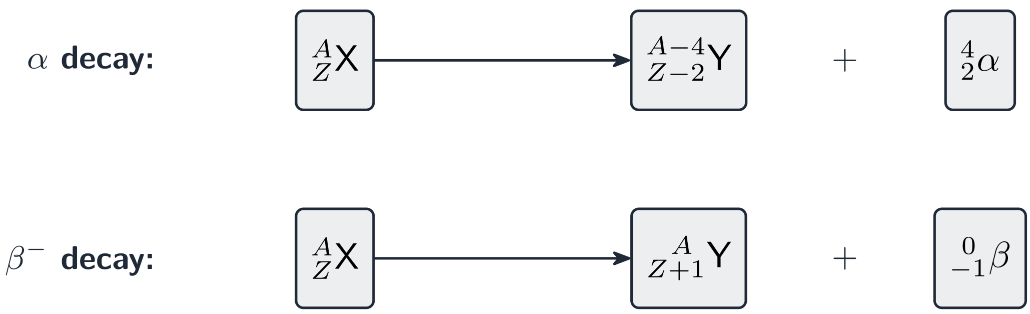
Worked example. Of thousands of α-particles, nearly all pass straight through (the atom is mostly empty), and only about 1 in 8000 bounces back — showing the nucleus is tiny but very dense and charged.

2 Writing decay equations

Two things are conserved: the **nucleon number** A (top) and the **charge / proton number** Z (bottom). So:

- α-decay: A drops by 4, Z drops by 2 — ${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A-4}_{Z-2}\mathrm{Y} + {}^{4}_{2}\alpha$.
- β^--decay: A stays, Z rises by 1 — ${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+1}\mathrm{Y} + {}^{0}_{-1}\beta$.

Worked example. ${}^{238}_{92}\mathrm{U}$ decays by α to ${}^{234}_{90}\mathrm{Th}$; ${}^{14}_{6}\mathrm{C}$ decays by β^- to ${}^{14}_{7}\mathrm{N}$.



Watch out: in a decay equation the numbers must balance on *both* sides — the top numbers (A) total the same, and so do the bottom numbers (Z).

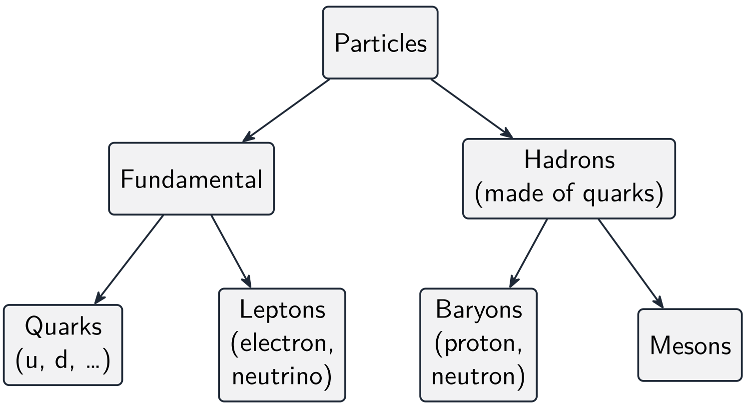
■ 3 Antiparticles and the particle families

Every particle has an **antiparticle** 反粒子 with the same mass but opposite charge; the **positron** 正电子 is the electron's antiparticle. β-decay also gives out a tiny **neutrino** 中微子 (or antineutrino).

Particles built from quarks are **hadron** 强子 particles:

- a **baryon** 重子 is three quarks — the proton and neutron are baryons;
- a **meson** 介子 is one quark + one antiquark.

A **lepton** 轻子 (the electron, the neutrino) is **not** made of quarks. The truly *fundamental* particles are the **quarks** and **leptons**; protons and neutrons are not fundamental.



Worked example. A proton is *uud* — three quarks, so a baryon (a hadron). An electron contains no quarks, so it is a lepton, and fundamental.

Practice

11.1 In the α-scattering experiment, state what we learn from (a) most α-particles passing straight through, (b) a few deflecting through large angles. [2]

11.2 Radium-226, $^{226}_{88}\text{Ra}$, decays by α-emission. Write the nucleon and proton numbers of the daughter nuclide. [2]

11.3 Strontium-90, $^{90}_{38}\text{Sr}$, decays by β^--emission. Write the nucleon and proton numbers of the daughter nuclide. [2]

11.4 State what a positron is, and its charge. [2]

11.5 State whether each is fundamental: (a) a proton, (b) an electron. [2]

11.6 Explain *how* the α-scattering result showed the nucleus is *positively* charged, not just small and dense. [2]

11.7 Challenge. Complete the α-decay ${}^{210}_{84}\mathrm{Po} \rightarrow {}^{?}_{?}\mathrm{Pb} + \alpha$: give the nucleon number and proton number of the lead nucleus. [2]

38 An up quark in a hadron changes to a down quark.

The elementary charge is e.

What is the magnitude of the change in the charge of the hadron?

A $\frac{1}{3}e$ **B** $\frac{2}{3}e$ **C** e **D** zero

A-Level Physics: **s25 11**

40 A hadron consists of antiquarks that are all identical.

What is a possible value, in terms of the elementary charge e, for the charge on the hadron?

A $0e$ **B** $+1e$ **C** $+2e$ **D** $+3e$

A-Level Physics: **s25 14**

40 How many flavours (types) of antiquark are there?

A 3 **B** 4 **C** 5 **D** 6

A-Level Physics: **m25 12**

37 What is a general description of a baryon?

A It consists of three quarks that **must** all be the same flavour.

B It consists of three quarks that do **not** need to be the same flavour.

C It consists of two quarks that **must** both be the same flavour.

D It consists of two quarks that do **not** need to be the same flavour.

40 What is the charge, in terms of the elementary charge e, on a charm quark?

A $-\frac{2}{3}e$ **B** $-\frac{1}{3}e$ **C** $+\frac{1}{3}e$ **D** $+\frac{2}{3}e$