HOLIDAY HOMEWORK 假期作业

AP Physics 1

Exercise sheets, topic by topic.

每个单元：练习卷。

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

Contents 目录

1 Describing motion and reading graphs – 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)		
Kinematics	运动学			
scalar	标量			
magnitude	大小			
vector	矢量			
Distance	距离			
Displacement	位移			
Speed	速率			
Velocity	速度			
Acceleration	加速度			
deceleration	减速			
gradient	斜率			

Recall

You met motion long before AP. Bring it with you:

- You measured **distance** with a ruler and **time** with a clock, and found **speed** from speed = distance ÷ time.

- You described a moving car, a falling ball, a running friend –how fast each one goes.
- At AP we look more carefully at **direction** (not just how fast, but which way) and at how motion **changes**.

Nothing on this sheet is harder than what you already know. It just lines up the ideas the AP 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 Distance and displacement

Kinematics 运动学 is the study of how things move. It uses two kinds of quantity.

A **scalar** 标量 has only size (its **magnitude** 大小): distance, speed, time, mass. A **vector** 矢量 has size **and** direction: displacement, velocity, acceleration.

Distance 距离 is the whole path length you travel –it only grows. **Displacement** 位移 is the straight line from start to finish, together with a direction.

Worked example. Walk 3 m east, then 1 m back west. The distance is $3 + 1 = 4$ m, but the displacement is only 2 m east –how far you ended from where you began.

■ 2 Speed and velocity

Speed 速率 tells you how fast, as a scalar. **Velocity** 速度 tells you how fast **and** which way, so it is a vector.

In one dimension, direction is just a **sign**. First choose which way is positive. Then a velocity of -5 m/s means 5 m/s in the negative direction –it does **not** mean ”slow.”

Worked example. A car covers 100 m in 5 s in the $+x$ direction, so its velocity is $\frac{100}{5} = +20$ m/s. A car going the other way at the same rate has velocity -20 m/s.

■ 3 Acceleration

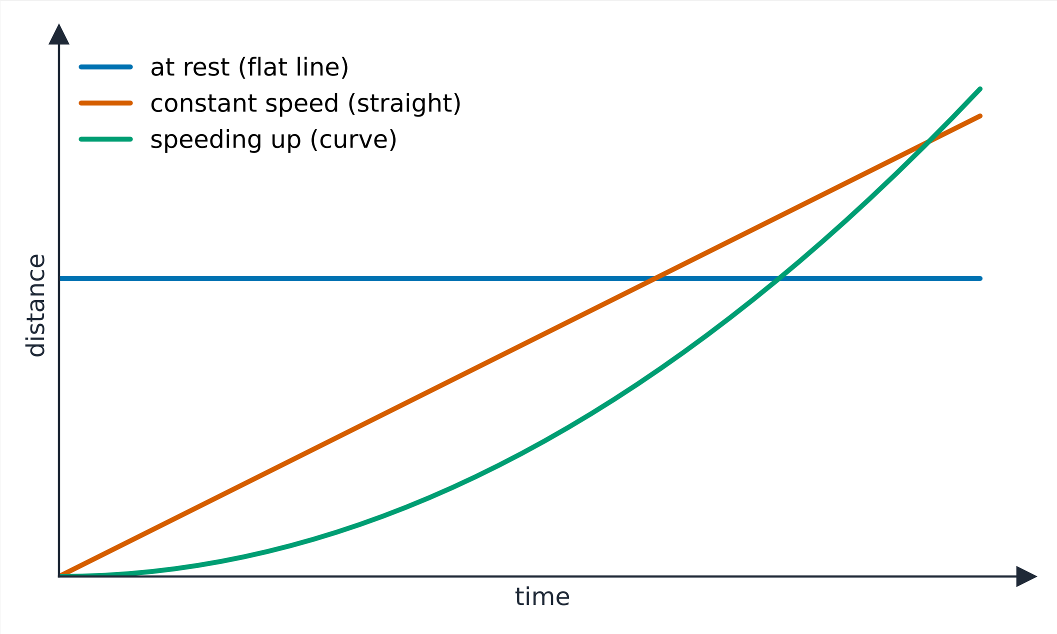
Acceleration 加速度 is how quickly velocity changes: $a = \frac{\Delta v}{\Delta t}$ (change in velocity ÷ time taken). Its unit is m/s^2.

An object speeds up when velocity and acceleration point the **same** way, and slows down (**deceleration** 减速) when they point **opposite** ways.

Worked example. A bike speeds up from 2 m/s to 8 m/s in 3 s: $a = \frac{8-2}{3} = 2$ m/s^2.

■ 4 Position–time graphs

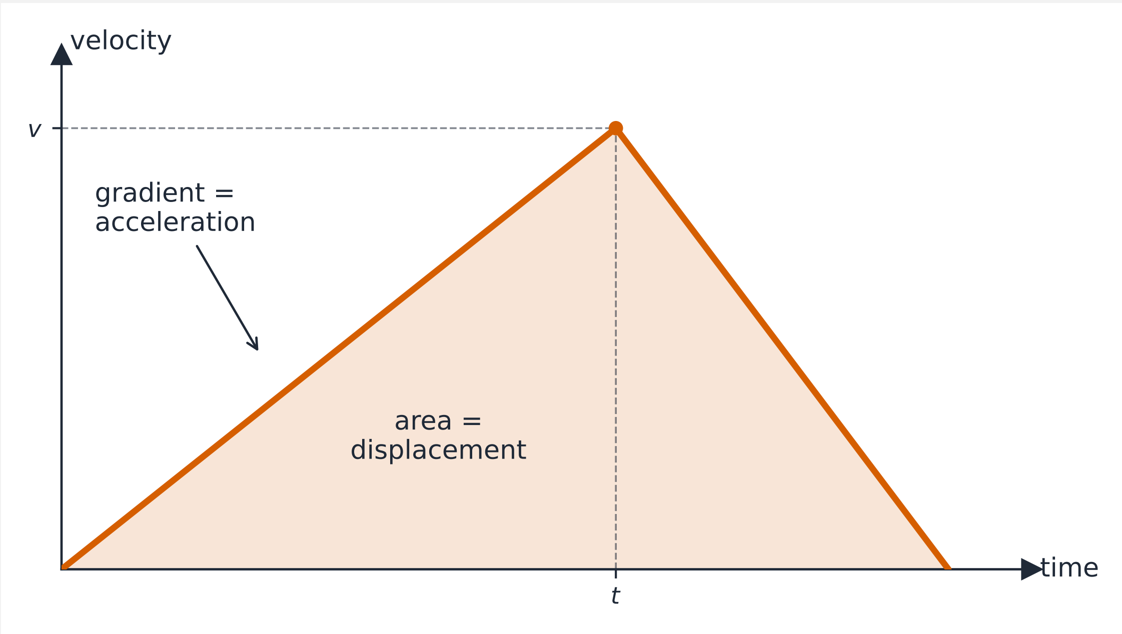
A graph shows motion at a glance. On a **position–time** graph, the **gradient** 斜率 (steepness) is the velocity.



- A flat line means the object is not moving.
- A straight slope means constant velocity (steeper = faster).
- A curve means the velocity is changing.

■ 5 Velocity–time graphs

On a **velocity–time** graph, two useful things are hidden in the shape:



- The gradient (slope) is the acceleration.
- The **area** under the line is the displacement.

Worked example. A car holds 6 m/s for 4 s. On the velocity–time graph this is a rectangle, so the displacement is $6 \times 4 = 24$ m.

> **Watch out:** a negative velocity does not mean slow –it means moving in the negative direction. Speed is the size of the velocity, so it is always positive.

Practice

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

2.1 A car travels 6 km north, then 2 km south. Find (a) the distance travelled, (b) the displacement. [2]

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

2.3 A runner covers 200 m in 25 s. Calculate the average speed. [1]

2.4 A velocity is written as -8 m/s. Explain what the minus sign tells you. [1]

2.5 A train speeds up from 5 m/s to 20 m/s in 6 s. Calculate its acceleration. [2]

2.6 A velocity–time graph shows a constant 12 m/s for 8 s. Find the displacement. [2]

2.7 On a position–time graph, describe the motion shown by (a) a flat horizontal line, (b) a straight upward slope. [2]

1 Equations of motion, free fall, and 2D motion – 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)		
air resistance	空气阻力			
acceleration due to gravity	重力加速度			
free fall	自由落体			
components	分量			
projectile	抛体			

Recall

In Part A you learned to describe motion and read graphs. Now bring two more tools:

- When velocity is constant, velocity = displacement ÷ time.
- When something speeds up steadily, you need equations that include **acceleration** – that is this sheet.
- From maths you know right-angled triangles (Pythagoras, sine, cosine). You will use them to split motion into two directions.

Take it slowly. Each idea has a worked example before the Practice.

New ideas

■ 1 The constant-acceleration equations

When acceleration is **constant** (steady), four equations link five quantities: start velocity v_0, final velocity v, acceleration a, time t, and displacement Δx.

$$v = v_0 + at, \qquad \Delta x = v_0 t + \tfrac{1}{2}at^2, \qquad v^2 = v_0^2 + 2a\,\Delta x, \qquad \Delta x = \tfrac{1}{2}(v_0 + v)t.$$

The trick: list what you know, then pick the equation that holds your three knowns plus the one you want, so only one unknown is left.

Worked example. A car starts from rest ($v_0 = 0$) and accelerates at 2.0 m/s^2 for 6.0 s. Final velocity: $v = v_0 + at = 0 + 2.0 \times 6.0 = 12$ m/s. Distance: $\Delta x = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 2.0 \times 6.0^2 = 36$ m.

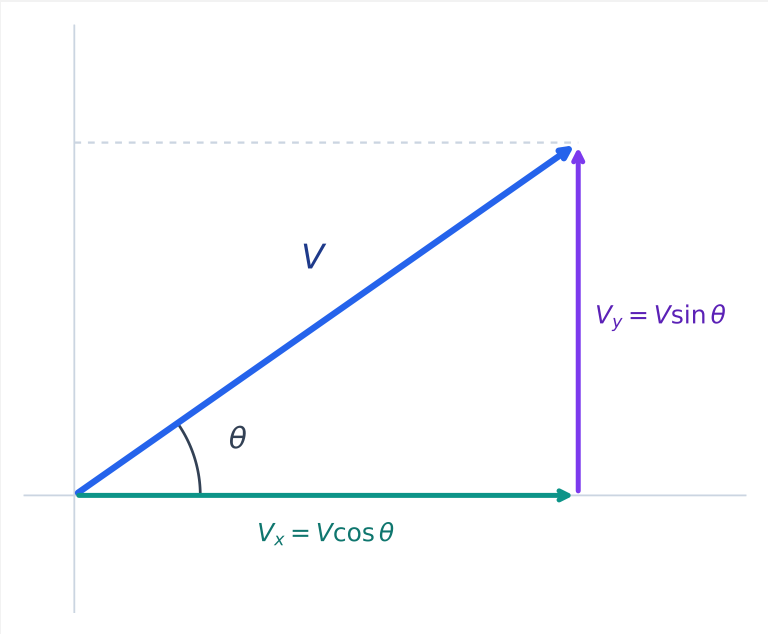
■ 2 Free fall

Near Earth, if we ignore **air resistance** 空气阻力, everything falls with the same **acceleration due to gravity** 重力加速度 $g = 9.8$ m/s^2, pointing down. This is **free fall** 自由落体.

Worked example. A stone is dropped ($v_0 = 0$) and falls for 2.0 s. Taking down as positive: speed $v = gt = 9.8 \times 2.0 = 20$ m/s, and distance $\Delta x = \frac{1}{2}gt^2 = \frac{1}{2} \times 9.8 \times 2.0^2 = 20$ m.

■ 3 Motion in two directions –components

A vector at an angle splits into two **components** 分量 at right angles: a horizontal part and a vertical part.



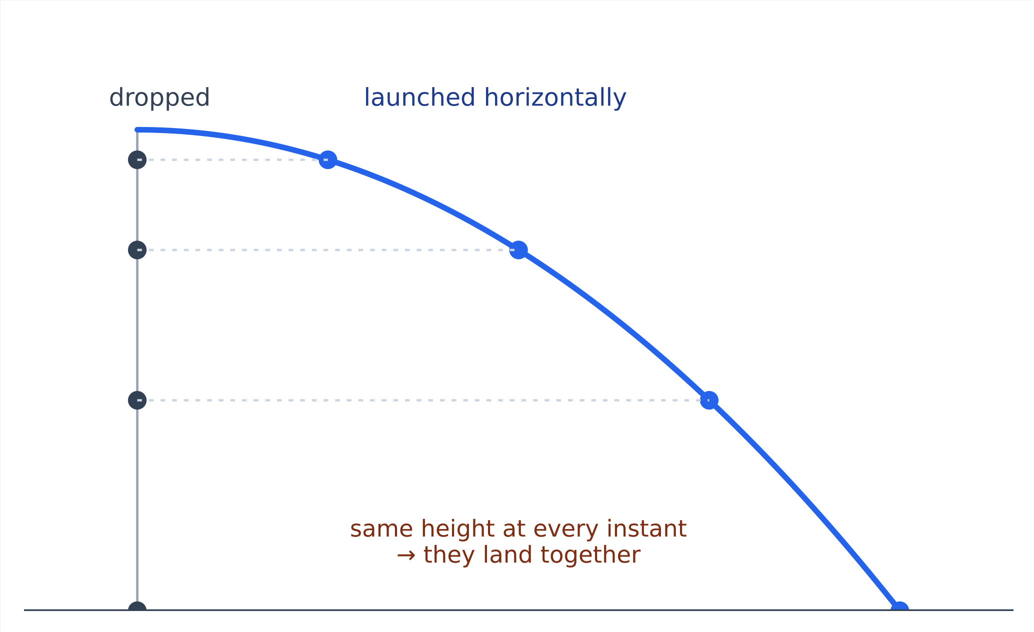
For a velocity v at angle θ above the horizontal:

$$v_x = v\cos\theta, \qquad v_y = v\sin\theta.$$

Worked example. A ball leaves at 10 m/s, 30° above the horizontal: $v_x = 10\cos 30° = 8.7$ m/s, and $v_y = 10\sin 30° = 5.0$ m/s.

■ 4 Projectile motion

A **projectile** 抛体 moves under gravity alone. The big idea: its horizontal and vertical motions are **independent** and share only the **time**.



- Horizontal: no acceleration, so the horizontal velocity stays constant.
- Vertical: acceleration g downward, exactly like free fall.

So a ball dropped and a ball thrown sideways from the same height reach the ground **at the same moment** –their vertical motions are identical.

Watch out: the two directions share only the time. Never mix a horizontal distance with a vertical velocity in one equation –solve each direction on its own, then join them through t.

Practice

Try these in order. The methods are all above.

2.1 A car accelerates from rest at 3.0 m/s^2 for 5.0 s. Find its final velocity. [2]

2.2 Using the same car, find the distance it travels in those 5.0 s. [2]

2.3 A ball is dropped from rest. Taking $g = 9.8\ \mathrm{m/s^2}$ and down as positive, find its speed after 1.5 s. [2]

2.4 A velocity of 12 m/s points 60° above the horizontal. Find its horizontal and vertical components. [2]

2.5 A stone is thrown horizontally from a cliff at the same moment another is dropped. Explain why they hit the ground at the same time. [2]

2.6 A motorbike slows from 20 m/s to 8 m/s while covering 42 m. Use $v^2 = v_0^2 + 2a\,\Delta x$ to find its acceleration. [3]

2 Forces and Newton's laws – 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			
free-body diagram	受力图			
Weight	重力			
Newton's first law	牛顿第一定律			
inertia	惯性			
net force	合力			
equilibrium	平衡			
Newton's second law	牛顿第二定律			
Newton's third law	牛顿第三定律			

Recall

You have met forces before. Bring these ideas with you:

- A **force** is a push or a pull, measured in newtons (N).
- Gravity pulls things down; a table pushes up; a rope pulls along its length.
- You know that a heavier object is harder to get moving. At AP we make this exact with **Newton's laws**.

Nothing here is harder than what you already know –we just line it up carefully and draw good diagrams.

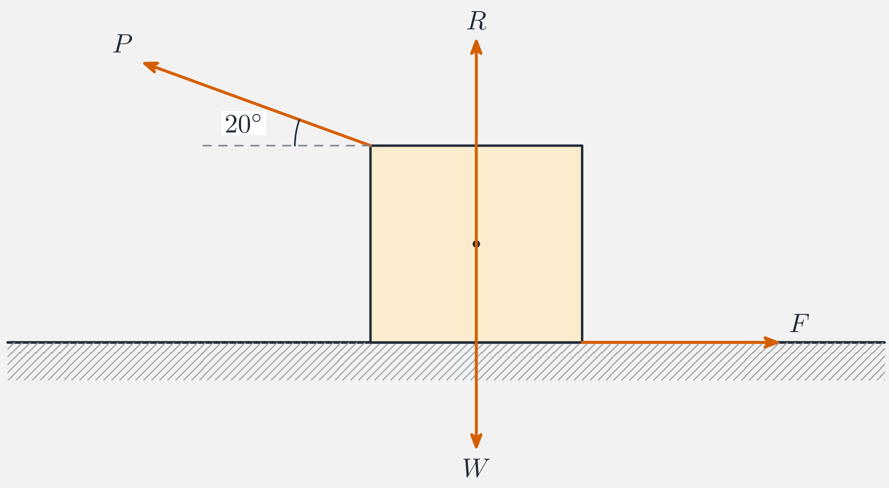
New ideas

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

■ 1 Force and the free-body diagram

A **force** 力 is a push or pull. It is a vector, so it has a size **and** a direction.

To solve any force problem, first draw a **free-body diagram** 受力图: show the object as a dot, then draw an arrow for **every** force acting **on** it –weight down, the surface's push, any rope or hand.



Two rules keep it honest: draw only forces acting **on** your object (not forces it pushes on other things), and draw only **real** forces (a rope, a surface, gravity) –never an "ma" arrow.

■ 2 Weight

Weight 重力 is the force of gravity on an object: $F_g = mg$, pointing down. Here m is the mass and $g = 9.8\ \mathrm{m/s^2}$ near Earth.

Worked example. A 2.0 kg bag has weight $F_g = mg = 2.0 \times 9.8 = 19.6$ N. On the Moon ($g = 1.6\ \mathrm{m/s^2}$) the same bag weighs only $2.0 \times 1.6 = 3.2$ N –but its **mass** is still 2.0 kg.

■ 3 Newton's first law

Newton's first law 牛顿第一定律 (the law of **inertia** 惯性): an object keeps a constant velocity unless a **net force** 合力 acts on it. So if the forces balance to zero, the object stays at rest or keeps moving at steady speed –it is in **equilibrium** 平衡.

Worked example. A car moves at a steady 25 m/s. Because the velocity is constant, the net force is zero –the engine's push exactly balances friction and air drag.

■ 4 Newton's second law

When the net force is **not** zero, the object accelerates: **Newton's second law** 牛顿第二定律 says

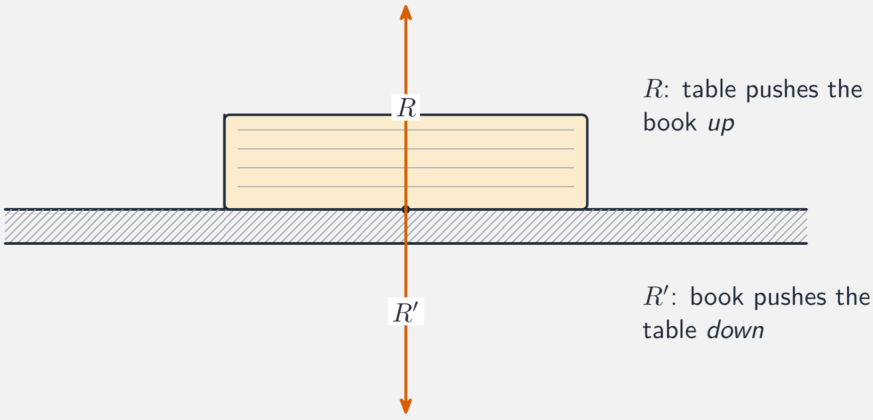
$$a = \frac{\sum F}{m}, \qquad \text{so} \qquad \sum F = ma.$$

The acceleration points the same way as the net force.

Worked example. A 4.0 kg box is pulled with 18 N while friction pulls back 6.0 N. The net force is $18 - 6.0 = 12$ N, so $a = \dfrac{12}{4.0} = 3.0\ \mathrm{m/s^2}$.

■ 5 Newton's third law

Newton's third law 牛顿第三定律: if A pushes on B, then B pushes back on A with an **equal and opposite** force.



The two forces act on **different** objects, so they never cancel.

Watch out: a book's weight and the table's push on the book are **not** a third-law pair –they act on the **same** object (the book). A third-law pair is always "A on B" with "B on A."

Practice

Try these in order. The methods are all above.

2.1 State the size and direction of the weight of a 3.0 kg book ($g = 9.8\ \text{m/s}^2$). [2]

2.2 A box rests on a table. Name the two forces on the box and state their directions. [2]

2.3 A 6.0 kg trolley is pushed with a net force of 18 N. Find its acceleration. [2]

2.4 A lift moves upward at a **constant** speed. What is the net force on it? Explain. [2]

2.5 A 2.0 kg ball is pulled by a 10 N force while a 4.0 N friction force opposes it. Find the acceleration. [2]

2.6 A student says ”the ground pushes up on my feet, and my feet push down on the ground –these cancel out, so I feel nothing.” State what is wrong with this reasoning. [2]

2 Friction, springs, and circular motion – 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)		
normal force	法向力			
Friction	摩擦力			
Static friction	静摩擦			
Kinetic friction	动摩擦			
coefficient of friction	摩擦系数			
Hooke's law	胡克定律			
spring constant	弹簧常数			
centripetal acceleration	向心加速度			
centripetal force	向心力			

Recall

In Part A you drew free-body diagrams and used $\sum F = ma$. Now meet three everyday forces that appear again and again:

- **Friction** slows sliding –you feel it when you drag a heavy box.
- A **spring** pulls back when you stretch it.
- Anything moving in a **circle** needs a force pulling it inward.

Each idea below has a worked example before the Practice.

New ideas

1 The normal force

When an object rests on a surface, the surface pushes back at right angles to it. This is the **normal force** 法向力 N. On a flat floor it balances the weight, so $N = mg$.

Worked example. A 5.0 kg box on a level floor has $N = mg = 5.0 \times 9.8 = 49$ N.

2 Friction

Friction 摩擦力 acts along a surface and opposes sliding. It comes in two kinds:

- **Static friction** 静摩擦 (before sliding) adjusts itself up to a maximum $f_s \le \mu_s N$ to stop motion starting.
- **Kinetic friction** 动摩擦 (while sliding) is $f_k = \mu_k N$.

Here μ is the **coefficient of friction** 摩擦系数 (a number for how rough the contact is).

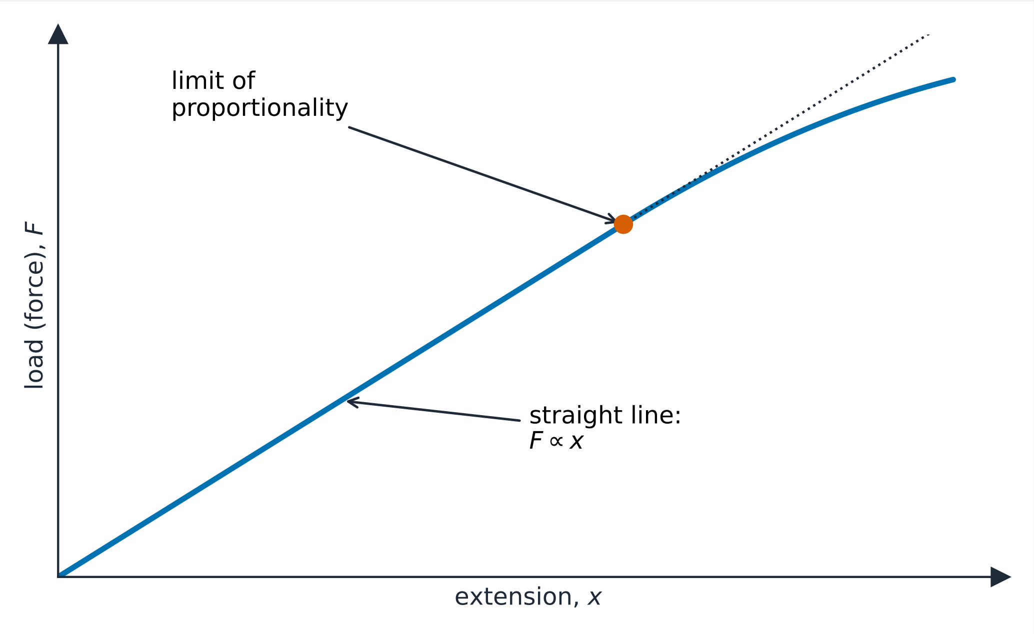
Worked example. A crate with $N = 49$ N and $\mu_s = 0.40$ needs a push above $f_{s,\max} = \mu_s N = 0.40 \times 49 = 19.6$ N to start moving. A 15 N push is too small, so it stays still.

3 Springs and Hooke's law

A spring pulls (or pushes) back toward its natural length. **Hooke's law** 胡克定律 says the force is proportional to the stretch x:

$$F_s = kx,$$

where k is the **spring constant** 弹簧常数 (its stiffness).

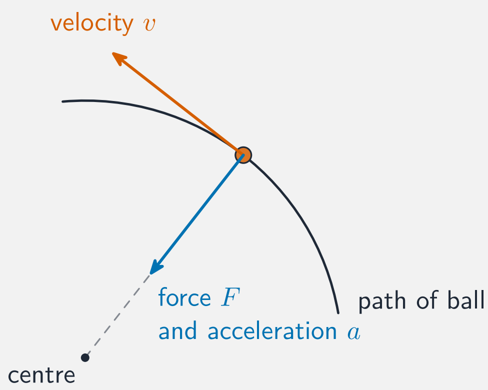


Worked example. A spring with $k = 200$ N/m holds a 0.50 kg mass at rest. The spring force balances the weight, $kx = mg$, so $x = \dfrac{mg}{k} = \dfrac{0.50 \times 9.8}{200} = 0.025 \text{ m} = 2.5 \text{ cm}.$

■ 4 Circular motion

An object moving in a circle at steady speed is still **accelerating**, because its direction keeps changing. This **centripetal acceleration** 向心加速度 points to the centre:

$$a_c = \frac{v^2}{r}.$$



It is caused by a real inward **centripetal force** 向心力 $F_c = \dfrac{mv^2}{r}$ –supplied by tension, gravity, or friction.

Watch out: there is no outward ”centrifugal” force pulling you out of the circle. The only force is the real one pulling you **inward**; you feel pushed out only because your body wants to keep going straight.

Practice

Try these in order. The methods are all above.

2.1 A 4.0 kg block sits on a flat floor. Find the normal force on it ($g = 9.8$ m/s^2). [2]

2.2 Using that block, the coefficient of static friction is $\mu_s = 0.30$. Find the largest static friction force before it slides. [2]

2.3 A spring stretches 0.040 m when a 12 N force pulls it. Find the spring constant k. [2]

2.4 Explain why an object going around a circle at constant speed is still accelerating. [2]

2.5 A 0.30 kg ball is whirled in a circle of radius 0.80 m at 4.0 m/s. Find the centripetal force needed. [3]

2.6 A student says a car turning a corner is pushed **outward** by a force. Correct this statement. [2]

3 Work, kinetic energy, and potential energy – 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			
joules	焦耳			
kinetic energy	动能			
Work	功			
work–energy theorem	动能定理			
Potential energy	势能			
Gravitational potential energy	重力势能			
Elastic potential energy	弹性势能			

Recall

You already know a lot about energy:

- Energy comes in forms –movement, height, heat, light –and can change from one form to another.
- You cannot make energy from nothing or destroy it; it is only moved around.
- You met the idea that a fast or heavy object carries more energy. At AP we make this exact with formulas.

Each idea below has a worked example. Then do the Practice.

New ideas

■ 1 Kinetic energy

Energy 能量 is the capacity to do work, measured in **joules** 焦耳 (J). A moving object has **kinetic energy** 动能:

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

It depends on the **square** of the speed, so doubling the speed makes the kinetic energy **four times** larger.

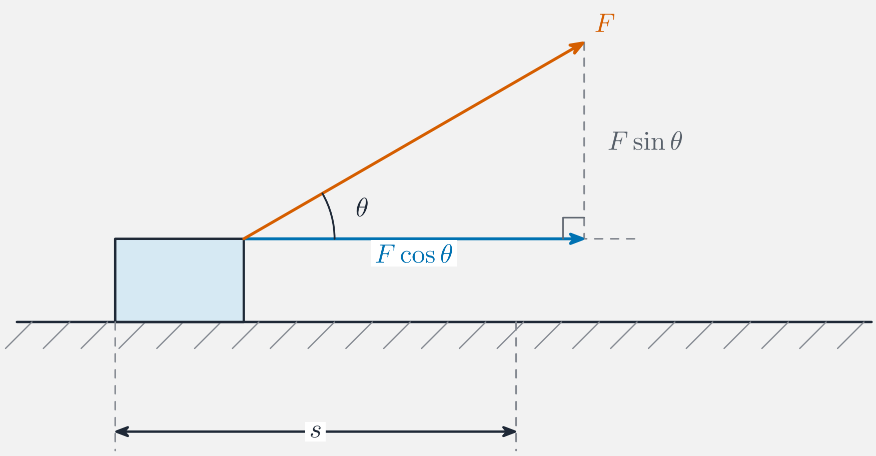
Worked example. A 1500 kg car at 20 m/s has $K = \frac{1}{2} \times 1500 \times 20^2 = 3.0 \times 10^5$ J. At 40 m/s it is four times as much.

■ 2 Work

Work 功 is energy transferred when a force pushes something through a distance:

$$W = Fd\cos\theta,$$

where θ is the angle between the force and the movement. Work is **positive** if the force helps the motion, **negative** if it opposes it, and **zero** if the force is at right angles to the motion.



Worked example. A 20 N force pushes a box 3.0 m in its own direction: $W = Fd = 20 \times 3.0 = 60$ J.

■ 3 The work–energy theorem

The net work done on an object equals the change in its kinetic energy –the **work–energy theorem** 动能定理:

$$W_{\text{net}} = \Delta K.$$

Worked example. If 60 J of net work is done on a resting 3.0 kg trolley, then $60 = \frac{1}{2} \times 3.0 \times v^2$, giving $v^2 = 40$ and $v = 6.3$ m/s.

■ 4 Potential energy

Potential energy 势能 is stored energy that depends on position:

- **Gravitational potential energy** 重力势能 (from height h): $U_g = mgh$.
- **Elastic potential energy** 弹性势能 (in a stretched spring): $U_s = \frac{1}{2}kx^2$.

Worked example. Lifting a 2.0 kg book 1.5 m stores $U_g = mgh = 2.0 \times 9.8 \times 1.5 = 29.4$ J.

Watch out: carrying a bag horizontally at steady height does **no** work on the bag – the lifting force is vertical but the movement is horizontal, so $\cos 90° = 0$.

Practice

Try these in order. The methods are all above.

2.1 Find the kinetic energy of a 0.50 kg ball moving at 6.0 m/s. [2]

2.2 A 40 N force pushes a crate 5.0 m in its own direction. Find the work done. [2]

2.3 State whether the work is positive, negative, or zero when (a) friction acts on a sliding box, (b) you carry a box horizontally at constant height. [2]

2.4 A 3.0 kg mass is lifted 2.0 m. Find the gain in gravitational potential energy ($g =$

9.8 m/s^2). [2]

2.5 A 2.0 kg trolley starts at rest. A net work of 36 J is done on it. Use the work–energy theorem to find its final speed. [3]

2.6 A car's speed triples. By what factor does its kinetic energy increase? [1]

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3 Conservation of 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)		
mechanical energy	机械能			
conserved	守恒			
thermal energy	热能			
Power	功率			
watts	瓦特			
efficiency	效率			

Recall

In Part A you met kinetic energy $K = \frac{1}{2}mv^2$ and potential energy $U = mgh$. Now put them together:

- Energy is never lost –it only changes form.
- A falling ball speeds up (gains K) as it drops (loses U).
- Doing the same job faster needs more **power** –that is the last idea on this sheet.

Each idea has a worked example before the Practice.

New ideas

■ 1 Mechanical energy

The **mechanical energy** 机械能 of an object is its kinetic plus potential energy:

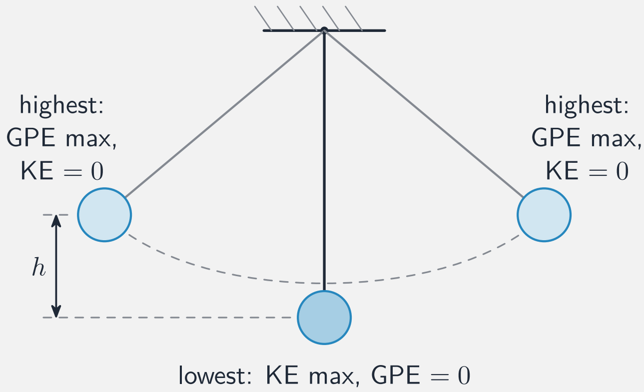
$$E = K + U.$$

■ 2 Conservation of energy

When only gravity and springs act (no friction), the mechanical energy is **conserved** 守恒–it stays the same:

$$K_1 + U_1 = K_2 + U_2.$$

So energy lost from one form appears in another.



Worked example. A ball is released from rest at the top of a smooth ramp 5.0 m high. All its potential energy becomes kinetic: $mgh = \frac{1}{2}mv^2$, so $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 5.0} = 9.9$ m/s. The mass cancels, so every object reaches the same speed.

■ 3 When friction acts

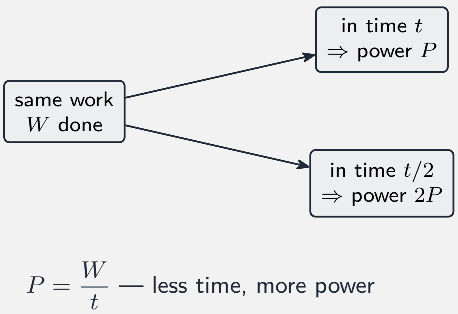
Friction turns mechanical energy into **thermal energy** 热能 (heat). Then energy is still conserved overall, but some has left the "useful" $K + U$ pool.

Worked example. If the ramp above loses 30 J to friction, you subtract it: $mgh - 30 = \frac{1}{2}mv^2$.

■ 4 Power

Power 功率 is the **rate** of transferring energy, measured in **watts** 瓦特 (W):

$$P = \frac{W}{\Delta t}, \qquad \text{and at steady speed} \qquad P = Fv.$$



Worked example. A motor lifts a 50 kg load at a steady 2.0 m/s. The force equals the weight, so $P = Fv = mgv = 50 \times 9.8 \times 2.0 = 980$ W.

■ **5 Efficiency**

Real machines waste some energy, so we quote **efficiency** 效率–useful output divided by total input:

$$\text{efficiency} = \frac{\text{useful output}}{\text{total input}}.$$

Worked example. A motor that draws 1400 W but delivers 980 W of useful lifting is $\frac{980}{1400} = 0.70 = 70\%$ efficient.

Watch out: at constant speed the net force is zero, but power is **not** zero –the motor still does work against gravity or friction. "Balanced forces" does not mean "no energy used."

Practice

Try these in order. The methods are all above.

2.1 A 0.20 kg ball is dropped from 1.8 m. Using energy conservation, find its speed just before it lands ($g = 9.8\ \text{m/s}^2$). [3]

2.2 State the energy change as a pendulum swings from its highest point down to its lowest point. [2]

2.3 A crane does 6000 J of work in 4.0 s. Find its power output. [2]

2.4 A machine takes in 500 W and delivers 300 W of useful power. Find its efficiency as a percentage. [2]

2.5 A ball rolls down a smooth slope 2.0 m high but 15 J is lost to friction. If the ball's mass is 1.0 kg, find its speed at the bottom. [3]

2.6 Explain why a car moving at constant speed still uses fuel (energy), even though the net force on it is zero. [2]

4 Momentum and impulse – 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)		
Linear momentum	动量	____________	____________	____________
impulse	冲量	____________	____________	____________

Recall

You already have a feel for momentum, even without the word:

- A heavy truck is harder to stop than a bicycle at the same speed.
- A fast ball hurts more than a slow one when you catch it.
- Catching a ball gently (moving your hands back) hurts less. This sheet explains why, exactly.

Each idea has a worked example before the Practice.

New ideas

■ 1 Momentum

Linear momentum 动量 is mass times velocity –a vector pointing the same way as the velocity:

$$p = mv.$$

It measures how hard something is to stop. Its unit is kg m/s.

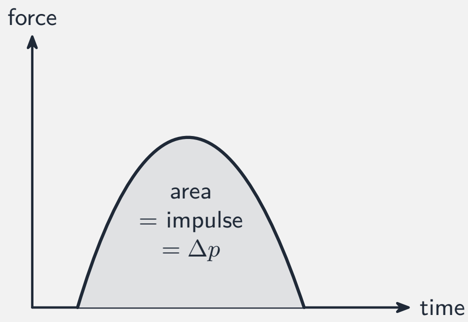
Worked example. A 0.40 kg ball moving at 5.0 m/s has momentum $p = mv = 0.40 \times 5.0 = 2.0$ kg m/s.

■ 2 Impulse

A force acting for a time changes the momentum. The **impulse** 冲量 is

$$J = F\,\Delta t,$$

and it equals the change in momentum: $J = \Delta p$. This is the **impulse–momentum theorem**.



Worked example. A 12 N force pushes a trolley for 3.0 s: impulse $= F\Delta t = 12 \times 3.0 =$ 36 kg m/s, so the momentum increases by 36 kg m/s.

■ 3 Why time matters

Because $F = \dfrac{\Delta p}{\Delta t}$, spreading the same momentum change over a **longer time** makes the force **smaller**. That is exactly how airbags, crash mats and bending your knees on landing protect you.

Worked example. A 0.15 kg ball hits a wall at 20 m/s and bounces back at 15 m/s; contact lasts 0.020 s. Taking the rebound direction as positive, $\Delta p = m(v - u) =$ $0.15(15 - (-20)) = 5.25$ kg m/s, so $F = \dfrac{\Delta p}{\Delta t} = \dfrac{5.25}{0.020} = 260$ N.

Watch out: when a ball **bounces back**, its velocity **reverses sign**, so the change in momentum is large. Forgetting the sign flip is the most common mistake here.

Practice

Try these in order. The methods are all above.

2.1 Find the momentum of a 2.0 kg ball moving at 6.0 m/s. [2]

2.2 A 5.0 N force acts on a cart for 4.0 s. Find the impulse. [2]

2.3 The cart in 2.2 started at rest with mass 2.0 kg. Find its final speed. [2]

2.4 Explain, using impulse, why bending your knees when landing from a jump reduces the force on your legs. [2]

2.5 A 0.20 kg ball moving at 8.0 m/s is caught and stopped in 0.50 s. Find the average force on it. [3]

2.6 A ball hits a wall at 10 m/s and rebounds at 10 m/s. Its mass is 0.25 kg. Find the size of the change in momentum. [2]

4 Conservation of momentum and collisions – 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)		
conserved	守恒			
perfectly inelastic collision	非弹性碰撞			
elastic collision	弹性碰撞			
recoils	反冲			

Recall

In Part A you met momentum $p = mv$ and impulse. Now the big payoff:

- When two things push on each other, their pushes are equal and opposite (Newton's third law).
- So in a crash or an explosion, the **total** momentum does not change.
- This one idea solves collisions that would be hard to do with forces.

Each idea has a worked example before the Practice.

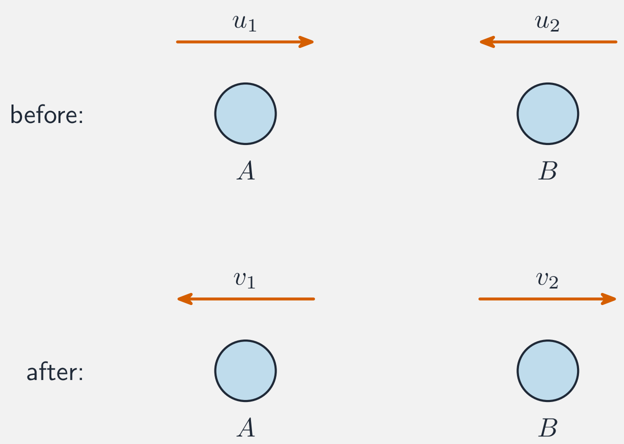
New ideas

■ 1 Conservation of momentum

If no outside force acts on a system, its total momentum is **conserved** 守恒–the total before equals the total after:

$$\sum p_{\text{before}} = \sum p_{\text{after}}.$$

The internal pushes come in equal-and-opposite pairs, so they cancel and cannot change the total.



■ 2 Collisions that stick

In a **perfectly inelastic collision** 非弹性碰撞 the objects **stick together** and move off with one shared velocity.

Worked example. A 1000 kg car at 20 m/s hits a stationary 1500 kg car and they lock together. Momentum is conserved:

$$1000 \times 20 = (1000 + 1500)\, v \;\Rightarrow\; v = \frac{20000}{2500} = 8.0 \text{ m/s}.$$

■ 3 Elastic and inelastic

Momentum is conserved in **every** collision, but kinetic energy is not:

- In an **elastic collision** 弹性碰撞, kinetic energy is also conserved (a clean bounce).
- In an **inelastic collision**, some kinetic energy becomes heat and deformation (a crash).

■ 4 Recoil

When one part of a still system is pushed one way, the rest **recoils** 反冲 the other way so the total momentum stays zero.

Worked example. A 60 kg skater at rest throws a 2.0 kg ball at 8.0 m/s. Starting from zero total momentum: $0 = (60)v + (2.0)(8.0)$, so $v = -\frac{16}{60} = -0.27$ m/s –she slides back at 0.27 m/s. This is how rockets work.

Watch out: momentum is a **vector**. Give one direction a + sign and the opposite a − sign before you add –two equal speeds in opposite directions add to **zero** momentum, not double.

Practice

Try these in order. The methods are all above.

2.1 A 2.0 kg trolley at 3.0 m/s hits a stationary 1.0 kg trolley and they stick together.

Find their common speed. [3]

2.2 State what is always conserved in a collision, and what is conserved only if the collision is elastic. [2]

2.3 A 50 kg student on frictionless ice throws a 1.0 kg ball at 6.0 m/s. Find the student's recoil speed. [3]

2.4 Two identical balls roll toward each other at the same speed and stick together. Explain why they stop. [2]

2.5 A 0.50 kg ball at 4.0 m/s collides head-on with a stationary 0.50 kg ball. After an **elastic** collision the first stops. State the second ball's speed and give your reason. [2]

5 Rotational motion and torque – 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)		
angular displacement	角位移			
radians	弧度			
angular velocity	角速度			
Torque	力矩			
moment arm	力臂			

Recall

You already know spinning things –wheels, gears, a spinning top:

- A wheel turns through an angle; you have measured angles in degrees.
- A point on the edge of a big wheel moves faster than one near the middle.
- You have used a **seesaw** and a spanner: pushing farther from the pivot turns things more easily.

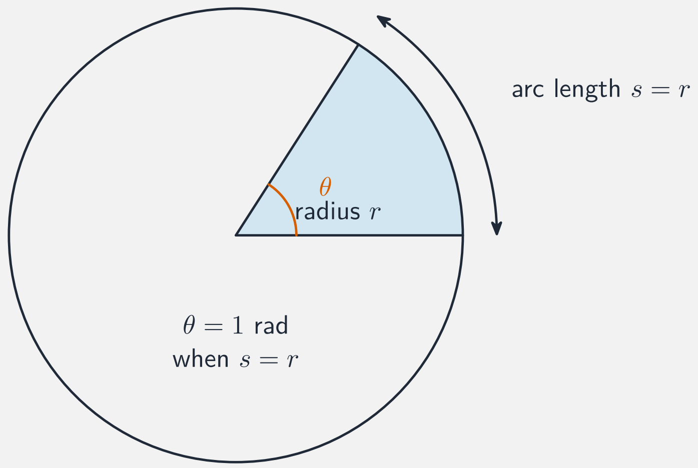
This sheet gives these ideas exact names and formulas. Each idea has a worked example.

New ideas

■ 1 Angular quantities

Rotation copies straight-line motion, with new names:

- **angular displacement** 角位移 θ –the angle turned, measured in **radians** 弧度 (one radian is the angle whose arc length equals the radius).
- **angular velocity** 角速度 $\omega = \dfrac{\Delta\theta}{\Delta t}$ –how fast it spins.



Worked example. A wheel turns 20 rad in 4.0 s, so $\omega = \dfrac{20}{4.0} = 5.0$ rad/s.

■ 2 Linking spin to straight-line speed

A point at distance r from the axis moves at speed

$$v = r\omega.$$

Points farther from the axis move faster.

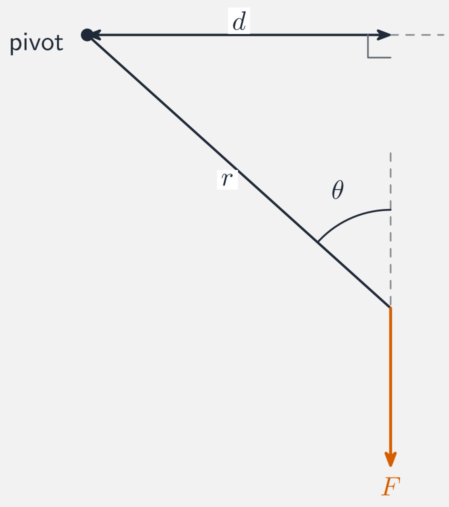
Worked example. A bicycle wheel of radius 0.35 m spins at 12 rad/s, so the rim (and the bike) moves at $v = r\omega = 0.35 \times 12 = 4.2$ m/s.

■ 3 Torque –the turning effect

Torque 力矩 (also called the moment) is how strongly a force turns something about a pivot:

$$\tau = F \times r_{\perp},$$

where $r_{\perp}$ is the **moment arm** 力臂–the perpendicular distance from the pivot to the line of the force.



Worked example. Pushing with 20 N at the end of a 0.30 m spanner, at right angles, gives $\tau = Fr = 20 \times 0.30 = 6.0$ N m.

Watch out: a force pointing straight **through** the pivot has zero moment arm, so it makes **no** torque. Push at a right angle, as far out as you can, for the biggest turning effect.

Practice

Try these in order. The methods are all above.

2.1 A wheel turns through 18 rad in 3.0 s. Find its angular velocity. [2]

2.2 A point on a rim of radius 0.20 m has the wheel spinning at 10 rad/s. Find the speed of the point. [2]

2.3 A force of 15 N is applied at right angles 0.40 m from a pivot. Find the torque. [2]

2.4 Explain why a door handle is placed far from the hinges, not near them. [2]

2.5 Two points sit on a spinning disc, one at the rim and one halfway to the centre. State which moves faster and why. [2]

2.6 A spanner is 0.25 m long. You push with 30 N at right angles to it. Find the torque, then state what happens to the torque if you push at the same force but only halfway along. [3]

5 Rotational inertia, balance, and torque = I alpha – 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)		
Rotational inertia	转动惯量			
rotational equilibrium	转动平衡			

Recall

In Part A you met torque –the turning effect of a force. Now use it two ways:

- to **balance** things (a seesaw, a shelf), which you have done before;
- to find how fast something starts to spin, the rotational copy of $F = ma$.

Each idea has a worked example before the Practice.

New ideas

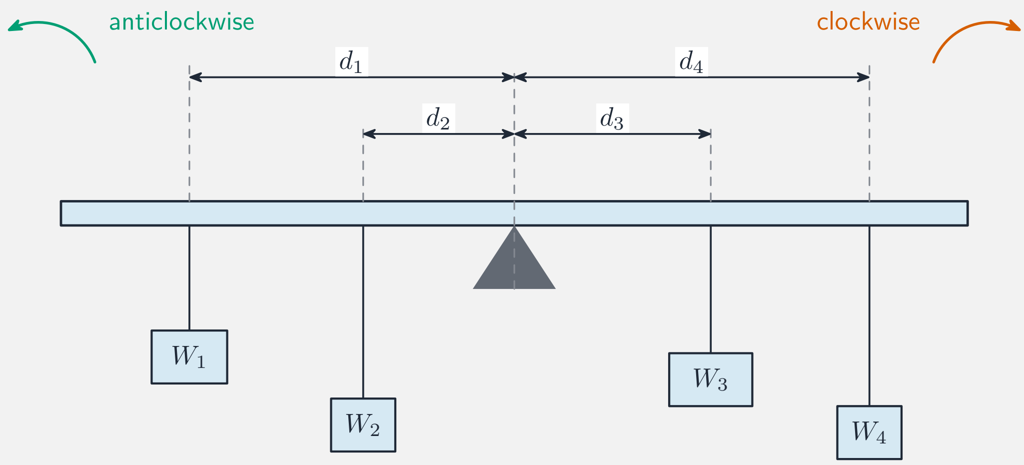
1 Rotational inertia

Rotational inertia 转动惯量 (symbol I) measures how hard it is to change something's spin –the rotational version of mass. It depends on the mass **and how far** that mass sits from the axis: mass spread farther out makes I larger.

This is why a spinning skater speeds up when she pulls her arms **in** –she brings her mass closer to the axis, making I smaller.

2 Rotational equilibrium

An object is in **rotational equilibrium** 转动平衡 when the total turning effect is zero –the clockwise torques balance the anticlockwise torques. Then it does not start to spin.



Worked example. A 30 kg child sits 2.0 m from the pivot of a seesaw. Where must a 40 kg child sit to balance it? Set the two torques equal (the g cancels):

$$30 \times 2.0 = 40 \times d \;\Rightarrow\; d = \frac{60}{40} = 1.5 \text{ m}.$$

The heavier child sits closer to the pivot.

■ 3 The rotational Newton's second law

Just as a net force gives linear acceleration, a **net torque** gives angular acceleration:

$$\sum \tau = I\alpha,$$

the exact twin of $\sum F = ma$ (with $\tau \leftrightarrow F$, $I \leftrightarrow m$, $\alpha \leftrightarrow a$).

Worked example. A net torque of 12 N m acts on a wheel with $I = 3.0$ kg m^2. Its angular acceleration is $\alpha = \frac{\tau}{I} = \frac{12}{3.0} = 4.0$ rad/s^2.

Watch out: the same mass can have different rotational inertia depending on where it sits –a ring is harder to spin than a solid disc of the same mass, because its mass is all at the edge.

Practice

Try these in order. The methods are all above.

2.1 State what two things the rotational inertia of an object depends on. [2]

2.2 A 20 kg child sits 1.5 m from a seesaw pivot. A 25 kg child sits on the other side.

How far from the pivot must the second child sit to balance? [3]

2.3 A net torque of 8.0 N m acts on a wheel of rotational inertia 2.0 kg m^2. Find the angular acceleration. [2]

2.4 Explain why a spinning ice skater speeds up when she pulls her arms in. [2]

2.5 A shelf is held by a bracket. State the condition on the torques for the shelf to stay balanced (not rotate). [1]

2.6 A wheel with $I = 5.0$ kg m^2 must reach $\alpha = 3.0$ rad/s^2. Find the net torque needed. [2]

6 Rotational energy and angular momentum – 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)		
rotational kinetic energy	转动动能			
Angular momentum	角动量			
conserved	守恒			

Recall

In the last topic you met angular velocity ω and rotational inertia I. Now spinning things get **energy** and **momentum**, just like moving things:

- A moving object has kinetic energy $\frac{1}{2}mv^2$ and momentum mv.
- A spinning object has rotational copies of both.
- A spinning skater who pulls her arms in speeds up –this sheet explains exactly why.

Each idea has a worked example before the Practice.

New ideas

1 Rotational kinetic energy

A spinning object stores **rotational kinetic energy** 转动动能:

$$K_{\text{rot}} = \tfrac{1}{2}I\omega^2,$$

the twin of $\frac{1}{2}mv^2$. A rolling ball has **both**: $\frac{1}{2}mv^2$ from moving plus $\frac{1}{2}I\omega^2$ from spinning.

Worked example. A wheel with $I = 2.0$ kg m^2 spins at $\omega = 3.0$ rad/s: $K_{\text{rot}} = \frac{1}{2} \times 2.0 \times 3.0^2 = 9.0$ J.

2 Work done by a torque

A torque turning through an angle does work: $W = \tau\,\Delta\theta$ (the twin of $W = Fd$).

Worked example. A motor gives a steady torque of 8.0 N m while a flywheel turns 10 rad: $W = \tau\,\Delta\theta = 8.0 \times 10 = 80$ J.

3 Angular momentum

Angular momentum 角动量 is the rotational version of momentum:

$$L = I\omega.$$

4 Conservation of angular momentum

If no outside torque acts, angular momentum is **conserved** 守恒:

$$I_1\omega_1 = I_2\omega_2.$$

So if I goes down, ω goes up to keep L the same.

Worked example. A skater spins at 2.0 rev/s with $I_1 = 4.0$ kg m^2. She pulls her arms in, dropping I to $I_2 = 1.6$ kg m^2: $\omega_2 = \dfrac{I_1}{I_2}\omega_1 = \dfrac{4.0}{1.6} \times 2.0 = 5.0$ rev/s.

Watch out: pulling the arms in raises **both** the spin rate and the kinetic energy –the extra energy comes from the work her muscles do pulling inward. Angular momentum stays the same; energy does not.

Practice

Try these in order. The methods are all above.

2.1 A flywheel with $I = 3.0$ kg m^2 spins at 4.0 rad/s. Find its rotational kinetic energy. [2]

2.2 A torque of 6.0 N m turns a wheel through 5.0 rad. Find the work done. [2]

2.3 Find the angular momentum of a disc with $I = 0.50$ kg m^2 spinning at 8.0 rad/s. [2]

2.4 A spinning student on a stool has $I_1 = 6.0$ kg m^2 at $\omega_1 = 1.0$ rad/s. He pulls weights in so $I_2 = 2.0$ kg m^2. Find his new angular velocity. [3]

2.5 State what stays the same and what changes when the student in 2.4 pulls the weights in. [2]

6 Rolling and orbiting satellites – 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)		
rolls without slipping	纯滚动			
satellite	卫星			

Recall

In Part A you met rotational energy and angular momentum. Two everyday examples bring them together:

- A wheel that **rolls** is moving and spinning at the same time.
- A **satellite** stays in orbit because gravity keeps pulling it toward the planet.

Each idea has a worked example before the Practice.

New ideas

■ 1 Rolling without slipping

When a wheel **rolls without slipping** 纯滚动, the point touching the ground is momentarily still, and the speed of the centre links to the spin:

$$v = r\omega.$$

Worked example. A wheel of radius 0.30 m rolls so its centre moves at 6.0 m/s. Its spin rate is $\omega = \frac{v}{r} = \frac{6.0}{0.30} = 20$ rad/s.

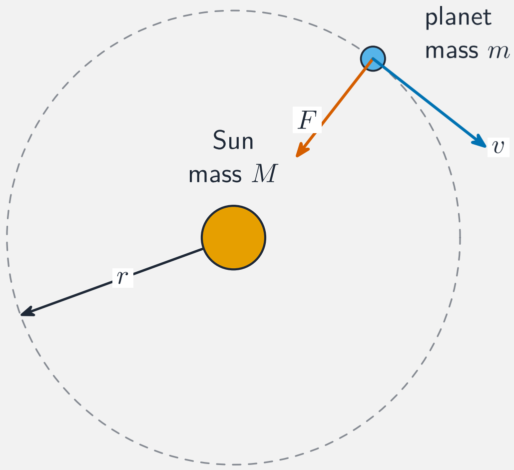
■ 2 Rolling shares the energy

A rolling object splits its kinetic energy between **moving** ($\frac{1}{2}mv^2$) and **spinning** ($\frac{1}{2}I\omega^2$). Because some energy goes into spin, a ball rolling down a ramp speeds up **more slowly** than a block that slides down without friction.

■ 3 Satellites and orbits

A **satellite** 卫星 in orbit is really in free fall: gravity provides exactly the **centripetal force** needed to bend its path into a circle. Setting gravity equal to the centripetal requirement gives the orbit speed

$$v = \sqrt{\frac{GM}{r}}.$$



Worked example. For a low orbit, $r = 6.4 \times 10^6$ m and $GM = 4.0 \times 10^{14}$ m^3/s^2: $v = \sqrt{\dfrac{4.0 \times 10^{14}}{6.4 \times 10^6}} \approx 7.9 \times 10^3$ m/s, about 7.9 km/s.

■ 4 Bigger orbit, slower speed

Because $v = \sqrt{GM/r}$, a satellite farther out (*larger* r) moves **slower**. The satellite's own mass cancels, so all satellites in the same orbit move at the same speed.

Watch out: a satellite is not "beyond gravity." Gravity is exactly what holds it in orbit –it is falling toward the planet all the time, but moving sideways fast enough to keep missing it.

Practice

Try these in order. The methods are all above.

2.1 A wheel of radius 0.25 m rolls without slipping; its centre moves at 5.0 m/s. Find its angular velocity. [2]

2.2 Explain why a ball rolling down a slope accelerates more slowly than a block sliding down the same frictionless slope. [2]

2.3 What force provides the centripetal force that keeps a satellite in orbit? [1]

2.4 Two satellites orbit the same planet, one close and one far. State which moves faster, and why. [2]

2.5 A wheel of radius 0.40 m spins at $\omega = 15$ rad/s while rolling. Find the speed of its centre. [2]

7 Simple harmonic motion, period, and frequency – 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)		
Simple harmonic motion	简谐运动			
oscillation	振动			
restoring force	回复力			
period	周期			
frequency	频率			

Recall

You have watched things swing and bounce back and forth:

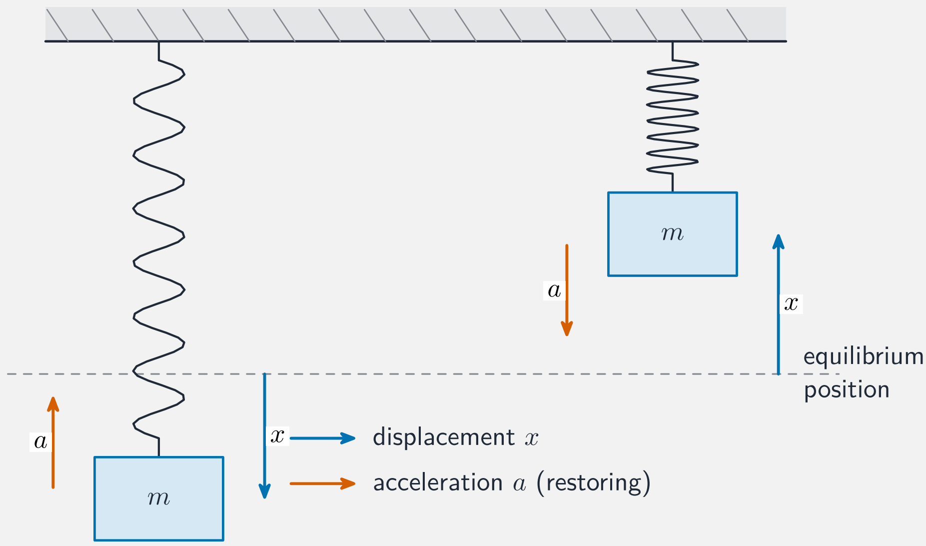
- A pendulum swings side to side; a mass on a spring bounces up and down.
- The motion repeats over and over, each cycle taking about the same time.
- A stiffer spring bounces faster; a longer pendulum swings slower.

This sheet gives the repeating motion a name –simple harmonic motion –and simple formulas. Each idea has a worked example.

New ideas

■ 1 Simple harmonic motion

Simple harmonic motion 简谐运动 (SHM) is a back-and-forth **oscillation** 振动 caused by a **restoring force** 回复力 that always pulls the object back toward the middle, and grows with the distance from the middle ($F = -kx$).



A mass on a spring, and a pendulum swinging through **small** angles, are the standard examples.

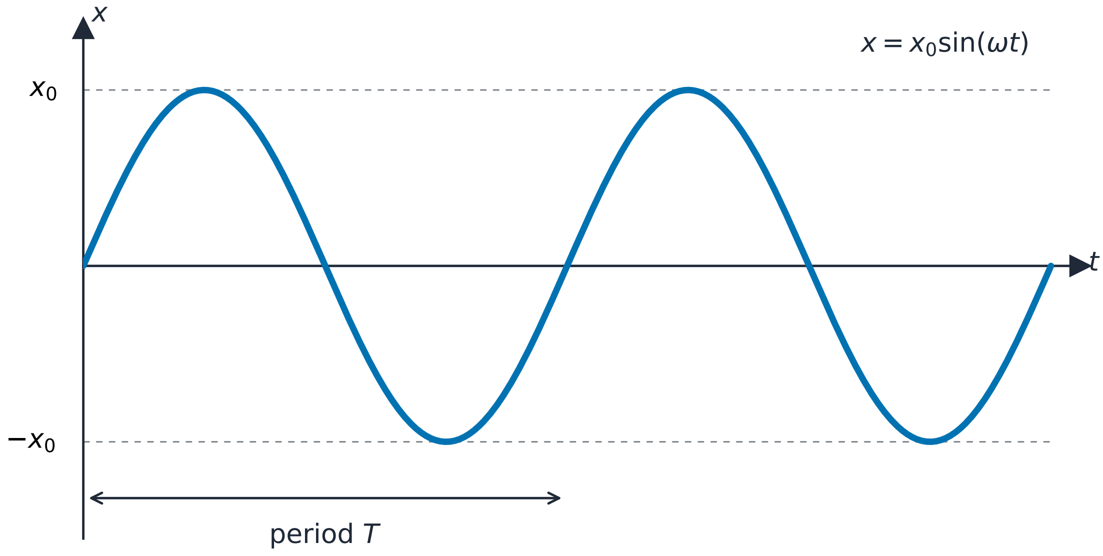
2 Period and frequency

- The **period** 周期 T is the time for one full cycle.
- The **frequency** 频率 $f = \dfrac{1}{T}$ is the number of cycles per second (in hertz, Hz).

3 The period formulas

For SHM the period depends only on the system, **not** on how big the swing is:

$$T_{\text{spring}} = 2\pi\sqrt{\frac{m}{k}}, \qquad T_{\text{pendulum}} = 2\pi\sqrt{\frac{L}{g}}.$$



Worked example. A 0.25 kg mass hangs on a spring of stiffness $k = 100$ N/m:

$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.25}{100}} = 0.31 \text{ s}, \qquad f = \frac{1}{T} = 3.2 \text{ Hz}.$$

Watch out: the period does **not** depend on the amplitude –a wide swing and a narrow swing take the same time. That is exactly what makes a pendulum a good clock.

Practice

Try these in order. The methods are all above.

2.1 A pendulum completes one full swing (there and back) in 2.0 s. State its period and find its frequency. [2]

2.2 Name the two conditions a force must meet to cause simple harmonic motion. [2]

2.3 A 0.40 kg mass sits on a spring of stiffness $k = 160$ N/m. Find the period of its oscillation. [3]

2.4 State what happens to a spring's period if the mass is increased. [1]

2.5 A pendulum has period 1.0 s. A student makes the swing wider (larger amplitude). State the effect on the period, and explain. [2]

7 The energy of oscillations – 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)		
equilibrium position	平衡位置			
amplitude	振幅			

Recall

In Part A you met simple harmonic motion and its period. Now follow the **energy** and **speed** through one cycle:

- At the far ends of a swing the object stops for an instant, then turns back.
- At the middle it is moving fastest.
- The energy keeps swapping between two forms while the total stays fixed.

Each idea has a worked example before the Practice.

New ideas

■ 1 Speed and acceleration through the cycle

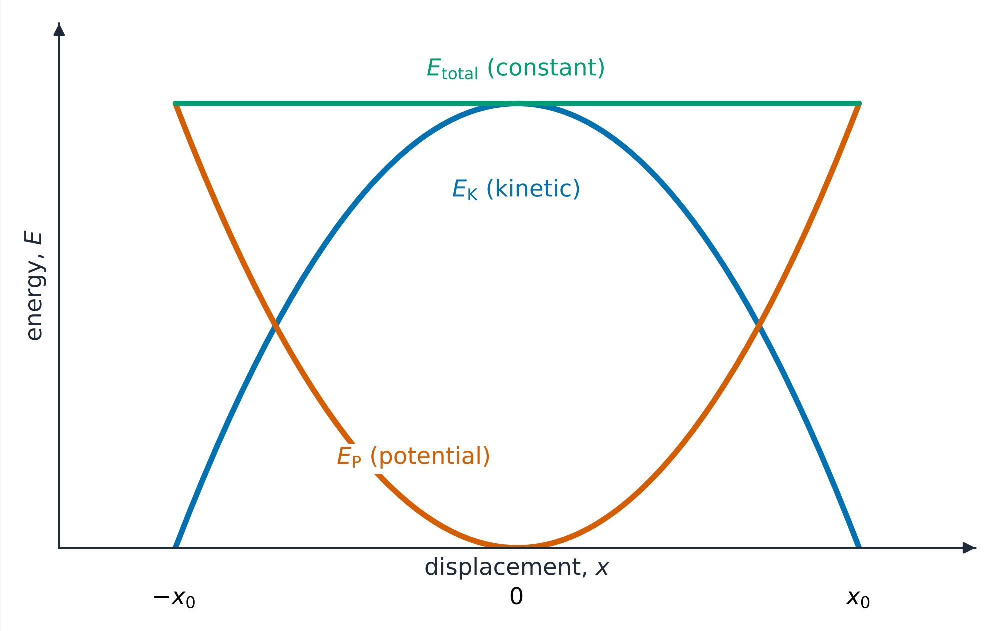
As the object oscillates about its **equilibrium position** 平衡位置 (the middle):

- At the **ends** (maximum displacement, called the **amplitude** 振幅 A): the speed is **zero** and the acceleration is largest.
- At the **middle** ($x = 0$): the acceleration is zero and the **speed is largest**.

■ 2 Energy swaps between two forms

The energy slides back and forth between kinetic and elastic potential, while the **total** stays constant (no friction):

$$E = \frac{1}{2}kA^2.$$



- At the ends: all **potential** (stretched spring, not moving).
- At the middle: all **kinetic** (moving fastest, spring relaxed).

Worked example. A 0.50 kg mass on a spring ($k = 200$ N/m) has amplitude $A = 0.10$ m. All the energy is kinetic at the middle, so $\frac{1}{2}kA^2 = \frac{1}{2}mv_{\max}^2$, giving $v_{\max} = A\sqrt{\dfrac{k}{m}} = 0.10 \times \sqrt{\dfrac{200}{0.50}} = 2.0$ m/s.

■ 3 Amplitude and energy

Because $E = \frac{1}{2}kA^2$, the energy depends on the **square** of the amplitude –double the amplitude and the energy becomes **four times** larger.

Watch out: the fastest point is the **middle**, not the ends. At the ends the object is momentarily at rest, even though the force on it is largest there.

Practice

Try these in order. The methods are all above.

2.1 State where in its swing an oscillating mass has (a) maximum speed, (b) zero speed. [2]

2.2 At which point of the motion is all the energy kinetic? [1]

2.3 A spring ($k = 300$ N/m) oscillates with amplitude $A = 0.20$ m. Find the total energy

$E = \frac{1}{2}kA^2$. [2]

2.4 A 0.20 kg mass on a spring ($k = 80$ N/m) has amplitude 0.15 m. Find its maximum speed. [3]

2.5 The amplitude of an oscillation is doubled. State the factor by which the total energy changes. [1]

2.6 Explain why the acceleration is largest at the ends of the swing, even though the speed there is zero. [2]

8 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)		
fluid	流体			
Density	密度			
Pressure	压强			
depth	深度			

Recall

You already know a lot about liquids and gases:

- Some things float on water and some sink.
- Deep water presses harder –your ears feel it at the bottom of a pool.
- Air and water can both flow. We call anything that flows a **fluid**.

This sheet turns these everyday facts into exact formulas. Each idea has a worked example.

New ideas

■ 1 Fluids and density

A **fluid** 流体 is a liquid or gas –its particles can move past each other, so it flows. **Density** 密度 is how much mass is packed into each unit of volume:

$$\rho = \frac{m}{V}.$$

Something less dense than the fluid around it floats; something denser sinks.

Worked example. A 2.0 kg block has volume 0.0025 m^3, so $\rho = \frac{m}{V} = \frac{2.0}{0.0025} = 800\ kg/m^3$ –less than water (1000), so it floats.

2 Pressure

Pressure 压强 is force spread over an area, measured in pascals (Pa):

$$P = \frac{F}{A}.$$

The same force on a smaller area gives a bigger pressure (why a sharp knife cuts).

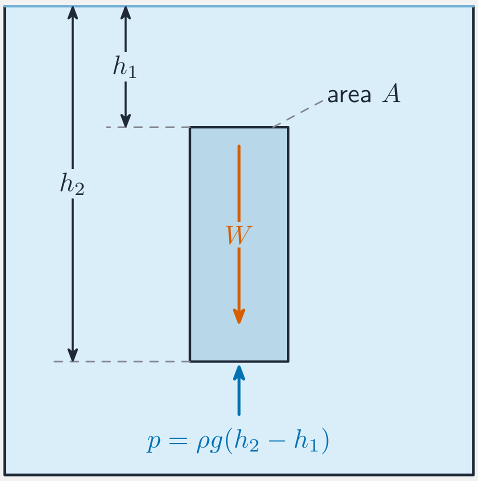
Worked example. A force of 50 N on an area of 0.010 m^2 gives $P = \frac{F}{A} = \frac{50}{0.010} = 5000$ Pa.

3 Pressure and depth

In a still fluid, pressure grows with **depth** 深度, because of the weight of fluid above:

$$P = P_0 + \rho g h,$$

where P_0 is the pressure at the surface and h is the depth.



Worked example. At 10 m deep in water ($\rho = 1000$ kg/m^3, $P_0 = 1.0 \times 10^5$ Pa): $P = P_0 + \rho g h = 1.0 \times 10^5 + 1000 \times 9.8 \times 10 = 1.98 \times 10^5$ Pa.

Watch out: the pressure at a depth depends only on the **depth**, not on the shape or width of the container. A thin tube and a wide lake have the same pressure at the same depth.

Practice

Try these in order. The methods are all above.

2.1 A 3.0 kg object has a volume of 0.0015 m^3. Find its density. [2]

2.2 A force of 80 N acts on an area of 0.020 m^2. Find the pressure. [2]

2.3 An object has density 1200 kg/m^3. State whether it floats or sinks in water (1000 kg/m^3), and why. [2]

2.4 Find the extra pressure ($\rho g h$) at a depth of 5.0 m in water ($\rho = 1000$ kg/m^3, $g = 9.8$ m/s^2). [2]

2.5 Explain why a diver feels the same pressure at a given depth whether in a narrow well or a wide sea. [2]

8 Buoyancy and flowing fluids – 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)		
buoyant force	浮力			
Archimedes' principle	阿基米德原理			
continuity	连续性			
Bernoulli's	伯努利			

Recall

In Part A you met density and pressure. Now two more fluid ideas you have already half-noticed:

- A ball pushed underwater pops back up –water pushes objects up.
- Squeeze a hose and the water shoots out faster.

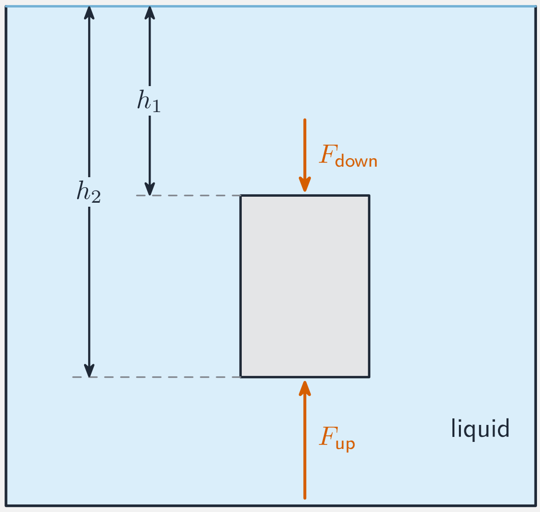
Each idea has a worked example before the Practice.

New ideas

■ 1 The buoyant force

A fluid pushes up on anything in it with a **buoyant force** 浮力 equal to the weight of the fluid the object pushes aside –**Archimedes' principle** 阿基米德原理:

$$F_b = \rho_{\text{fluid}}\, g\, V_{\text{displaced}}.$$



■ 2 Float or sink

Compare the buoyant force with the weight:

- floats when buoyancy balances weight,
- sinks when the weight wins.

Worked example. A block of density 600 kg/m^3 floats in water (1000 kg/m^3). The fraction below the surface is $\dfrac{\rho_{\text{object}}}{\rho_{\text{fluid}}} = \dfrac{600}{1000} = 0.60$ –so 60% sits underwater, the same reason most of an iceberg is hidden.

■ 3 Flowing fluids –continuity

When a fluid flows through a pipe, the same volume must pass every second. So where the pipe is **narrow**, the fluid must flow **faster** –this is **continuity** 连续性:

$$A_1 v_1 = A_2 v_2.$$

Worked example. Water flows at 2.0 m/s in a pipe of area 0.010 m^2, then reaches a narrow section of 0.0040 m^2: $v_2 = \dfrac{A_1 v_1}{A_2} = \dfrac{0.010 \times 2.0}{0.0040} = 5.0$ m/s.

■ 4 Fast flow, low pressure

Where a fluid flows faster, its pressure **drops** –**Bernoulli's** 伯努利 idea. This is why a fast stream of air over a wing lifts a plane, and why shower curtains get sucked inward.

Watch out: a floating object does not have "no weight" –its weight is exactly balanced by the buoyant force pushing up. The two forces are equal, not absent.

Practice

Try these in order. The methods are all above.

2.1 State the direction of the buoyant force on an object in water, and what it equals (in words). [2]

2.2 An object of density 800 kg/m^3 floats in water (1000 kg/m^3). Find the fraction that sits below the surface. [2]

2.3 Water flows at 3.0 m/s in a pipe of area 0.020 m^2. Find its speed where the pipe narrows to 0.0060 m^2. [3]

2.4 Explain why water speeds up when a pipe becomes narrower. [2]

2.5 A ball is held underwater and released. Explain, in terms of forces, why it rises. [2]