IGCSE PHYSICS • EXERCISE SHEET

1.5 Forces

Name: ______________ Class: __________ Date: ____________ **Total: 41 marks**

KEY WORDS forces 力 • equilibrium 平衡 • resultant force 合力 • limit of proportionality 比例极限 • stability 稳定性 • resultant force 合力 • moments 力矩 • friction 摩擦力 • limit of proportionality 比例极限 • principle of moments 力矩原理

Objective

Build the skills to answer exam questions on **forces 力**: **Hooke's law 胡克定律** and the load–extension graph, **resultant force 合力** and $F = ma$, **solid friction 固体摩擦**, **moments 力矩** and **equilibrium 平衡**, and the **centre of gravity 重心**.

You must be able to:

- describe the load–extension experiment, sketch the graph and use $k = \dfrac{F}{x}$
- find the resultant of forces on a straight line and use $F = ma$
- describe solid friction and drag, and explain motion in a circle
- use the principle of moments, and state the two conditions for equilibrium
- state what the centre of gravity is, find it for a lamina, and explain stability

1 Worked examples

Forces change shape, speed or direction

A force can change an object's **shape 形状**, its speed, or its direction. **Solid friction 固体摩擦** is the force between two surfaces that touch: it acts against the motion, tries to stop it, and heats the surfaces. Drag is friction in a liquid or a gas (air resistance).

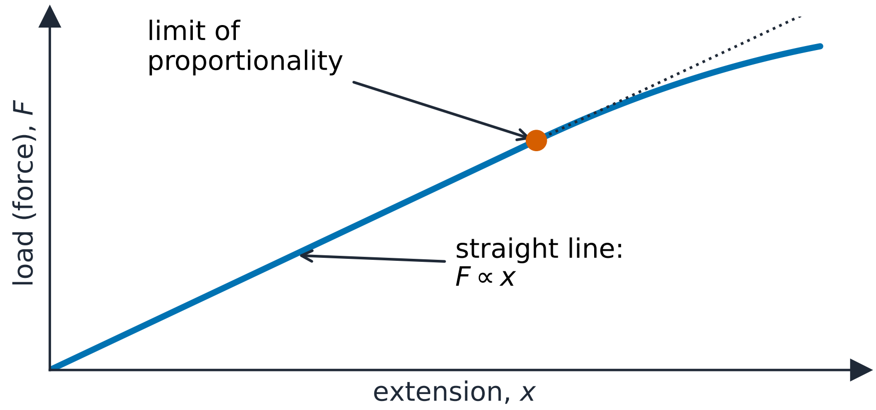
A resultant force at right angles to the motion changes only the direction, so the object moves in a circle at a steady speed. A bigger force is needed for a faster speed or a smaller radius, and for a bigger mass.

Hooke's law and the load–extension experiment

Hang the spring from a clamp with a ruler beside it. Read the position of the bottom of the spring with no load: that is the original length. Add loads one at a time and record the new length each time; the **extension 伸长量** is the new length minus the original length. Plot load (y) against extension (x).

The graph is a straight line through the origin up to the **limit of proportionality 比例极限**, then it curves away. The **spring constant 弹簧常数** is the force per unit extension:

$$k = \frac{F}{x}$$



Load is proportional to extension up to the limit of proportionality; the gradient of the straight part is k

Worked example 1. A spring stretches 4.0 cm under a load of 20 N. Then $k = \frac{20}{4.0} = 5.0$ N/cm.

■ Resultant force and $F = ma$

Add forces on a straight line with signs: one direction positive, the other negative. If the resultant is zero, the object stays at rest or keeps moving in a straight line at constant speed. If it is not zero, the object accelerates in the direction of the resultant:

$$F = ma$$

Worked example 2. A car of mass 1200 kg has a driving force of 3000 N and friction of 600 N.

1. Resultant: $3000 - 600 = 2400$ N.
2. $a = \frac{F}{m} = \frac{2400}{1200} = 2.0$ m/s^2.

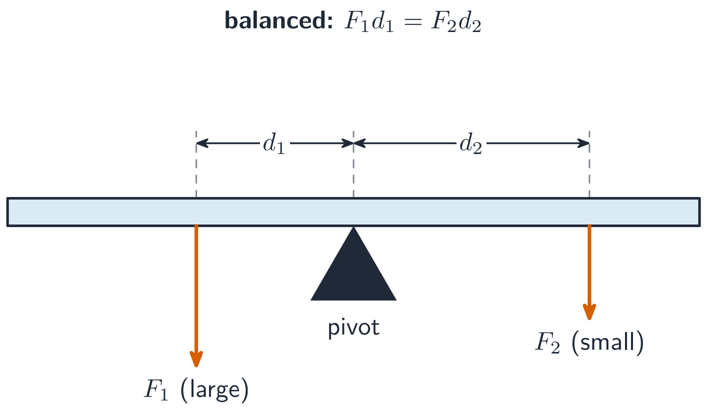
If the question asks why the engine must produce more force than $F = ma$ suggests, the answer is friction and air resistance: some of the driving force is used against them.

■ Moments and equilibrium

The **moment** 力矩 of a force is its turning effect about a **pivot** 支点:

$$\text{moment} = \text{force} \times \text{perpendicular distance from the pivot}$$

Principle of moments: for a balanced object, total clockwise moment = total anticlockwise moment. An object is in equilibrium when there is **no resultant force and no resultant moment**.



Balanced: clockwise moment equals anticlockwise moment

Worked example 3. A 30 N weight sits 0.20 m left of a pivot. How far right must a 20 N weight sit?

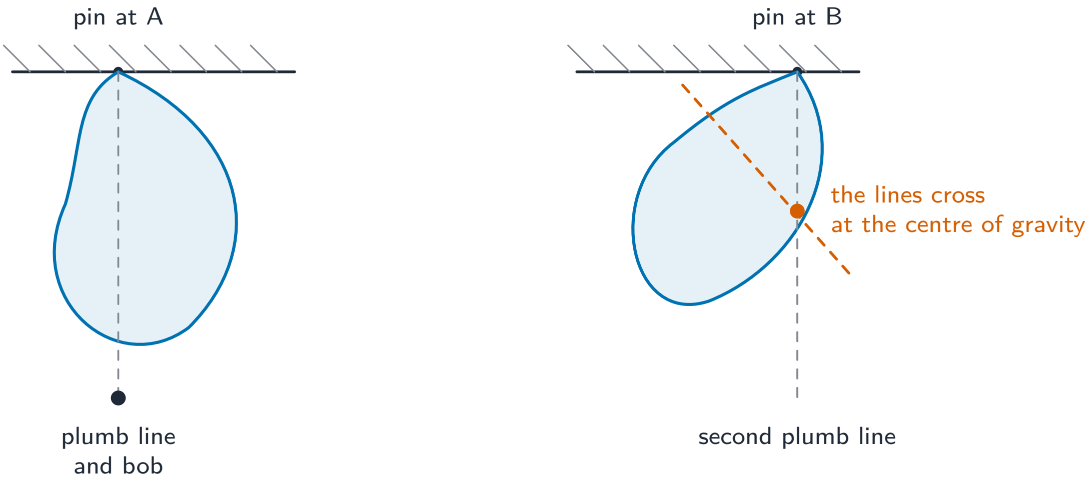
$30 \times 0.20 = 20 \times d$, so $d = \dfrac{6.0}{20} = 0.30$ m.

The experiment. Balance a metre rule at its centre. Hang a known weight each side and move them until it balances again. Measure both distances. Force × distance on the left equals force × distance on the right within the measurement errors, so a balanced object has no resultant moment.

■ Centre of gravity and stability

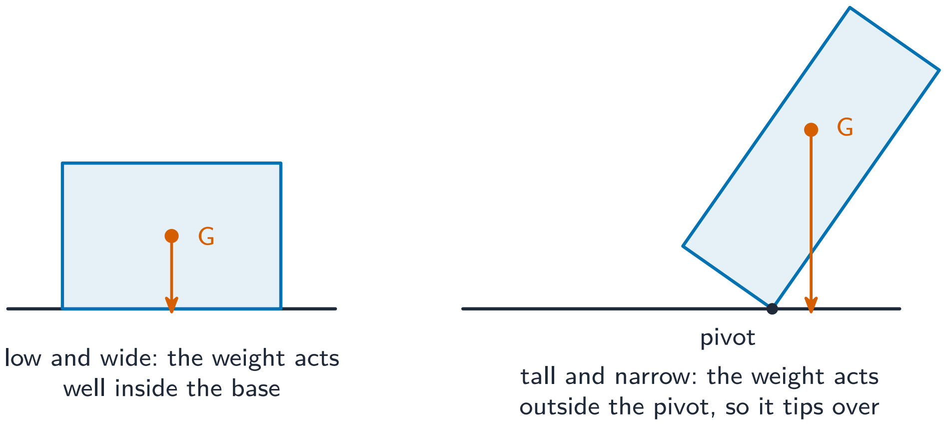
The **centre of gravity** is the single point where all the weight of an object seems to act.

Finding it for a lamina 薄片 (a flat shape): hang the shape from a pin at a point near its edge and let it settle. Hang a plumb line from the same pin and draw the vertical line on the shape. Repeat from a second point. The centre of gravity is where the two lines cross. (A third line is a useful check.)



The two vertical lines cross at the centre of gravity

Stability 稳定性 depends on where the centre of gravity is and how wide the base is. A low centre of gravity and a wide base make an object stable. It tips over once a vertical line down from the centre of gravity falls outside the base.



While the weight acts inside the base the object settles back; once it acts outside the pivot corner the object tips over

2 Practice

2.1 A spring stretches 4.0 cm under a 20 N load. Find the spring constant in N/cm. [2]

2.2 State the principle of moments. [1]

2.3 Describe what is meant by solid friction, and state one effect it has besides slowing an object down. [2]

2.4 State the two conditions for an object to be in equilibrium. [2]

2.5 A spring of original length 12.0 cm stretches to 15.5 cm under a load of 7.0 N. Calculate its spring constant in N/cm. (Hint: use the extension, not the whole length.) [3]

2.6 State what is meant by the centre of gravity of an object. [1]

2.7 A ball on the end of a string is whirled in a horizontal circle at a steady speed. State the direction of the resultant force on the ball, and state what the force changes. [2]

3 Exam-style questions

3.1 A car is travelling along a straight road at a constant speed. Which statement about the forces on the car is correct? [1]

A	B
C	D

A The driving force is larger than the total resistive force.
B The driving force is equal to the total resistive force.
C There is no driving force and no resistive force.
D The driving force is smaller than the total resistive force.

3.2 Two objects, X and Y, have the same mass and the same height. X has a wide base and Y has a narrow base. Which is more stable, and why? [1]

A	B
C	D

A X, because its centre of gravity is further from the ground.
B X, because the weight stays inside its base for a bigger tilt.
C Y, because it is narrower and lighter at the top.
D They are equally stable, because they have the same mass.

3.3 A train has a total mass of 520 000 kg. It accelerates uniformly along a straight, level track.

(a) Define acceleration. [1]

(b) The train speeds up from 15 m/s to 28 m/s with an acceleration of 1.1 m/s^2. Calculate the time this takes. [2]

(c) Calculate the resultant force needed to produce this acceleration. [2]

(d) The force produced by the train's motors is larger than the value in (c). Explain why. [1]

(e) The driver then applies the brakes and the train slows down. State how the direction of the resultant force compares with the direction of motion. [1]

3.4 A uniform beam of weight 12 N and length 1.2 m rests on a pivot at its centre. A 40 N weight hangs 0.30 m to the left of the pivot.

(a) Explain why the weight of the beam itself has no turning effect about this pivot. [1]

(b) A weight W is hung 0.50 m to the right of the pivot so that the beam balances. Calculate W. [3]

(c) The 40 N weight is now moved to 0.45 m from the pivot. State and explain what happens to the beam. [2]

(d) Describe an experiment that shows there is no resultant moment on a balanced beam. [3]

3.5 A student investigates how a spring stretches.

(a) Describe how she should carry out the experiment, including the measurements she takes. [3]

(b) Sketch the load–extension graph she obtains, continuing the line beyond the limit of proportionality. Label the limit of proportionality on your sketch. [3]

(c) Her spring stretches 2.5 cm for a load of 10 N, within the straight part of the graph. Calculate the extension for a load of 6.0 N. [3]

(d) Explain why her method for the load of 60 N gives an extension larger than the calculation predicts. [1]