Resultant forces

4.5.1.4 · Forces · revision notes

The resultant force is the single force that has the same effect as all the forces acting on an object together. You need to find the resultant of forces along a line, draw free body diagrams, and (Higher) use scale drawings to add two forces at an angle or to resolve one force into two components at right angles.

Key facts

- Resultant force = single force with the same effect as all the forces together
- Balanced forces: resultant = 0 N, so the object is at rest or moves at constant velocity
- Grade 7+ only Scale drawing: draw the forces tip-to-tail; the resultant goes from the start to the finish
- Grade 8+ only Equilibrium: force arrows drawn tip-to-tail make a closed triangle
- Same direction: add; opposite directions: subtract
- Free body diagram: all the forces acting ON one object, labelled arrows drawn to scale
- Grade 8+ only A force can be resolved into two perpendicular components that have the same effect

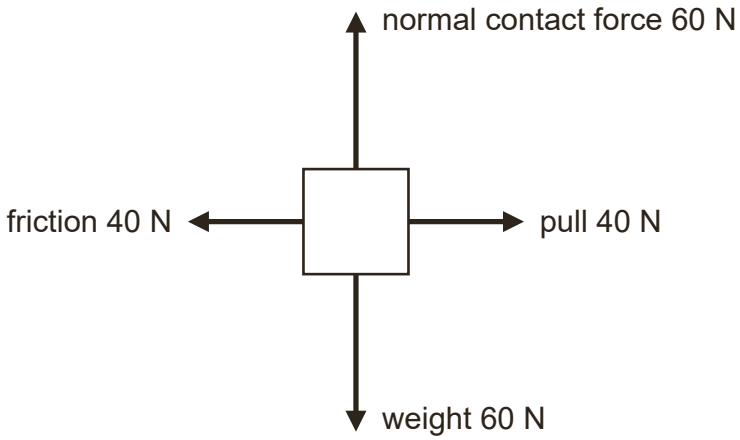
Notes

Forces along a line

- The forces acting on an object can be replaced by a single **resultant force** that has the same effect as all of them together.
- Forces in the same direction: add them. Forces in opposite directions: subtract, and the resultant acts in the direction of the larger force.
- Example: 700 N forwards and 250 N backwards give a resultant force of 450 N forwards.
- If the resultant force is zero, the forces are **balanced**. The object is either stationary or moving at a constant velocity.

Free body diagrams Grade 6+ only

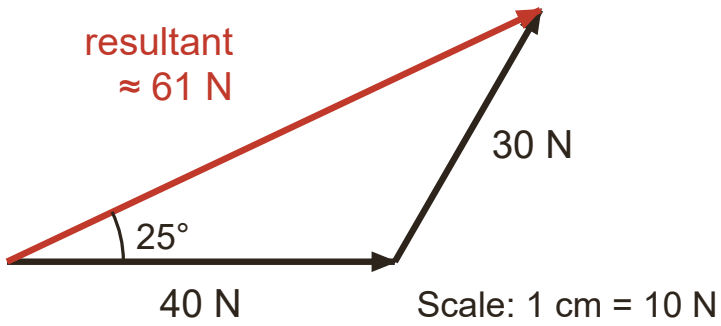
- A free body diagram shows one object (often as a box or dot) with every force acting **on it** drawn as an arrow.
- Each arrow starts at the object, points in the direction of the force and is labelled with its name and size.
- Example: the free body diagram for a box pulled along a level floor at a steady speed. The two arrows in each pair are equal in length, so the resultant force is zero.



- Longer arrows mean bigger forces. Balanced forces are shown by equal-length arrows in opposite directions.
- Only include forces that act on the object, not forces that the object exerts on other things.

Adding two forces at an angle Grade 7+ only

- Choose a scale, e.g. 1 cm = 10 N, that makes the drawing as large as possible.
- Draw the first force to scale. From its tip, draw the second force to scale in its direction (tip-to-tail).
- The resultant is the arrow from the tail of the first force to the tip of the second. Measure its length for the magnitude and its angle with a protractor for the direction.

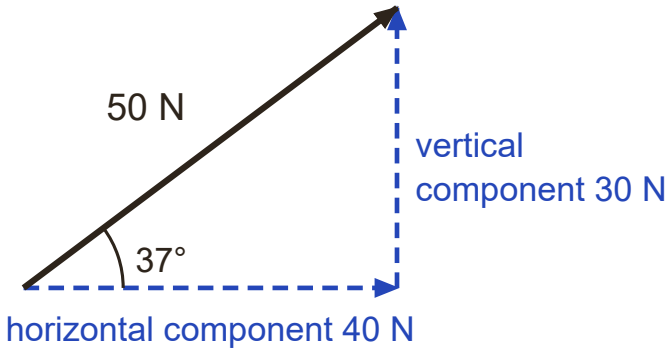


Tip-to-tail: the resultant (red) is about 6.1 cm long, so about 61 N, at 25° to the 40 N force.

- An object is in **equilibrium** when the force arrows drawn tip-to-tail make a closed shape: the resultant is zero.

Resolving a force Grade 8+ only

- A single force can be **resolved** into two components acting at right angles to each other. Together, the two components have the same effect as the single force.
- Draw the force to scale, then draw horizontal and vertical lines to make a right-angled triangle with the force as the longest side. Measure the other two sides.



The force is the longest side; the two components are the other sides of the right-angled triangle.

- Example: a 50 N pull at 37° above the horizontal has a horizontal component of about 40 N and a vertical component of about 30 N.

How to answer each type of question

Calculate the resultant of forces along a line 2 marks **Grade 4**

1. Add up all the forces acting in each direction.
2. Subtract the smaller total from the larger.
3. Give the size and the direction of the resultant.

Example. A cyclist has a driving force of 180 N forwards. Air resistance of 60 N and friction of 25 N both act backwards.
Calculate the resultant force on the cyclist and give its direction.

Model answer.

backward forces = 60 + 25 = 85 N; resultant = 180 − 85 (1)
= 95 N forwards (1)

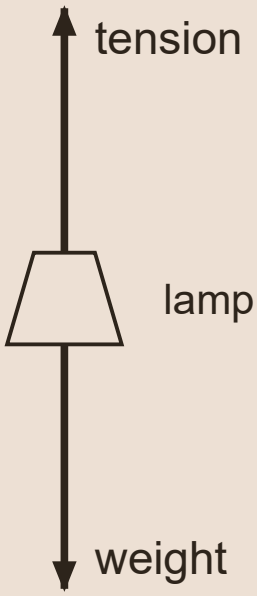
Draw a free body diagram and explain the motion

2 to 3 marks | **Grade 6**

1. Draw one arrow for each force acting on the object, starting on the object.
2. Label each arrow and make the lengths show the relative sizes.
3. Use the resultant force to explain the motion.

Example. A lamp hangs at rest from a ceiling on a cable.
Describe the free body diagram for the lamp and explain why the lamp stays at rest.

Model answer.



An arrow downwards from the lamp labelled weight (1).

An arrow upwards labelled tension, the same length as the weight arrow (1).

The forces are equal and opposite, so the resultant force is zero and the lamp stays at rest (1).

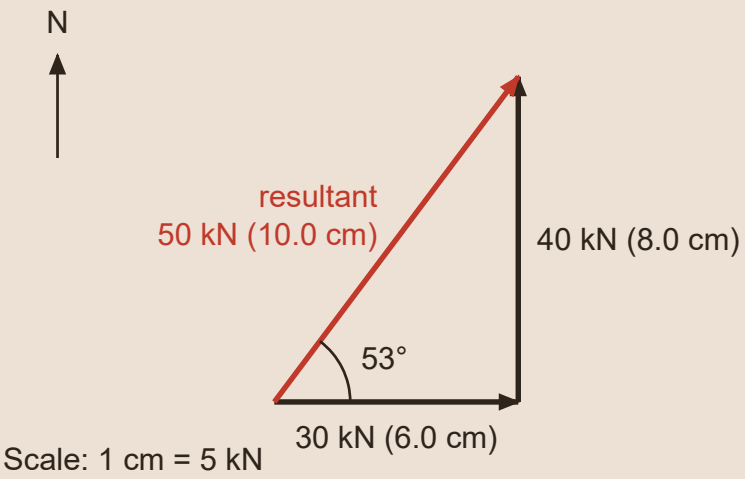
Scale drawing: resultant of two forces at an angle

3 to 4 marks | **Grade 7**

1. Choose and state a scale.
2. Draw the forces tip-to-tail, accurately, with a ruler and protractor.
3. Draw the resultant from start to finish.
4. Measure its length and angle, and convert the length using the scale.

Example. Two tugs pull a ship. Tug A pulls with a force of 30 kN due east. Tug B pulls with a force of 40 kN due north.
Use a scale drawing to determine the size and direction of the resultant force on the ship.

Model answer.



Suitable scale, e.g. 1 cm = 5 kN, with 6.0 cm east then 8.0 cm north drawn tip-to-tail (1)

Resultant drawn from the start to the finish (1)

Length 10.0 cm, so the resultant = 50 kN (1)

Direction about 53° north of east (1)

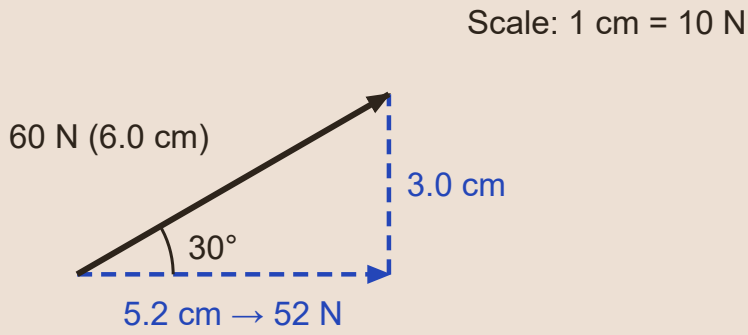
Scale drawing: resolve a force into components

2 to 3 marks | **Grade 8**

1. Draw the force to scale at the given angle.
2. Complete the right-angled triangle with horizontal and vertical sides.
3. Measure the side you need and convert it with the scale.

Example. A child pulls a sledge with a force of 60 N along a rope at 30° above the horizontal. Use a scale drawing to determine the horizontal component of the force.

Model answer.



Force drawn to scale at 30° to the horizontal, e.g. 6.0 cm with 1 cm = 10 N	(1)
Right-angled triangle completed with horizontal and vertical sides	(1)
Horizontal side about 5.2 cm, so the horizontal component ≈ 52 N	(1)

Don’t lose marks

- Giving a resultant force without a direction. A force is a vector.
- Adding forces that act in opposite directions instead of subtracting them.
- Thinking a moving object must have a resultant force on it. At constant velocity the resultant force is zero.
- Drawing both forces from the same point and joining their tips. That line is not the resultant: with both forces drawn from one point, the resultant is the diagonal of the parallelogram they make.
- Making scale drawings too small, which makes the measured values inaccurate.
- Including forces that the object exerts on something else in a free body diagram.

More tips

Memory tricks

- Tip-to-tail: draw the arrows like a line of elephants, nose to tail. The resultant runs from the very first tail to the very last tip.
- For two forces at right angles, check your drawing with Pythagoras: 30 kN and 40 kN give 50 kN (a 3-4-5 triangle).
- Balanced does not mean stopped. A zero resultant means no change in velocity: still, or steady speed in a straight line.
- Along a line, the resultant always acts in the direction of the bigger force.

Exam technique

- Always give the size and the direction of a resultant force.
- In scale drawings, write your scale on the diagram and give the angle from a stated direction (e.g. '53° north of east').
- Examiners allow a small tolerance on measured values, so use a sharp pencil, a ruler and a protractor.
- Link the resultant to the motion: zero resultant means constant velocity or at rest; a non-zero resultant means acceleration in its direction.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Define resultant force**
A single force that has the same effect as all the original forces acting together.

Grade 4 — **Find the resultant of forces along a line**
Add forces acting in the same direction; subtract forces acting in opposite directions.

Grade 5 — **Recognise balanced forces (zero resultant)**
If the resultant force is zero, the object stays at rest or keeps moving at a steady velocity.

Grade 6 — **Draw and use free body diagrams**
Show every force acting on one object as a labelled arrow drawn from the object.

Grade 7 — **Find a resultant using a scale drawing**
Draw the two forces tip-to-tail to scale; the resultant is the arrow from the start of the first to the end of the second.

Grade 8 — **Resolve a force into two perpendicular components**
Draw the force to scale and complete a right-angled triangle to measure its horizontal and vertical components.

Grade 8 — **Use vector diagrams for equilibrium**
If three forces are in equilibrium, their arrows drawn tip-to-tail form a closed triangle.

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