

Combining forces and drawing force diagrams

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: A resultant force is the single force that has the same effect as all the forces acting on an object. Forces in the same direction add, opposite forces subtract, and perpendicular forces combine by Pythagoras. A zero resultant means balanced forces, so the object stays at rest or keeps a constant velocity.

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What is a force and how is it measured?

A force is a push or a pull that one object exerts on another. It can change the speed of an object, change its direction or change its shape. Because it has a direction as well as a size, a force is a vector. Forces are measured in newtons (N) with a newton meter.

Definition

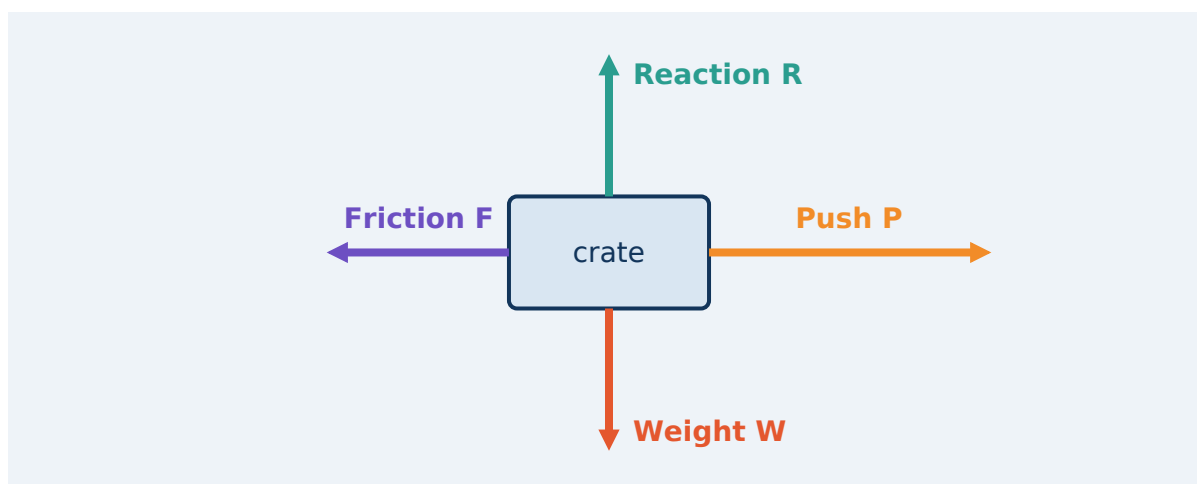
The **resultant force** is the single force that has the same effect on an object as all the forces acting on it together. When the resultant is zero, the forces are **balanced**.

Force	What causes it	Direction
Weight (W)	gravity pulling on mass	down, towards the centre of the Earth
Normal reaction (R)	a surface pushing back	at right angles to the surface
Friction (F)	rough surfaces in contact	opposite to the sliding
Drag (air or water resistance)	moving through a fluid	opposite to the motion
Tension (T)	a stretched rope or string	along the rope, pulling inwards
Upthrust	a fluid pushing up on an object	up
Driving force or thrust	engine, muscles, propeller	in the direction of motion

Weight depends on the mass and the gravitational field strength: $\mathbf{W = m g}$, where $g = 9.8$ N/kg on Earth. A 60 kg person weighs $60 \times 9.8 = 588$ N.

How do you draw a free-body diagram?

A free-body diagram shows one object on its own with an arrow for every force acting on it. Draw each arrow from the centre or edge of the object, point it in the direction of the force, make its length proportional to the size of the force, and label it with the name and size. Show only forces acting on that object.



The crate is pushed right, friction acts left, and weight and the reaction of the floor act vertically.

Common mistake

Do not draw forces that the object exerts on something else, and do not add a force for “motion”. A moving object needs a resultant force only to change its speed or direction, not to keep going.

How do you find the resultant of forces along a line?

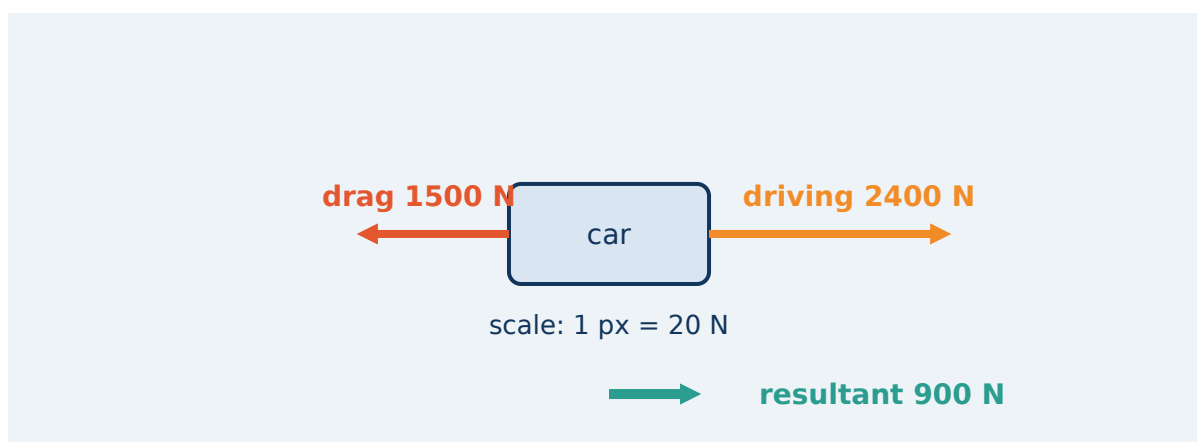
Key law

Forces in the **same direction add**. Forces in **opposite directions subtract**, and the resultant points the way of the larger force.

Worked example 1

The engine of Bilal's car in Lahore gives a driving force of 2400 N. Drag and friction together are 1500 N. Find the resultant force.

$R = 2400 - 1500 = \mathbf{900 \text{ N forward}}$. The car speeds up.



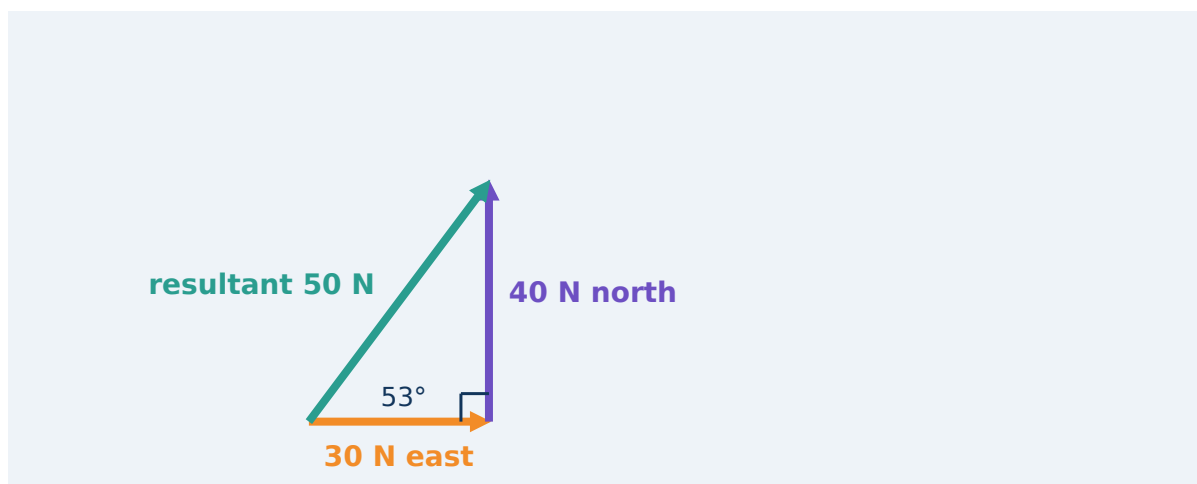
Unequal forces give a non-zero resultant in the direction of the larger one.

What does a balanced or unbalanced resultant do?

If the resultant force is zero, the object keeps doing what it was doing: it stays at rest or moves at constant velocity. This state is called **equilibrium**. If the resultant is not zero, the velocity changes in the direction of the resultant, so the object speeds up, slows down or turns. A hot-air balloon hovering at a fixed height has an upthrust equal to its weight and drag together, so its resultant is zero.

How do you add forces at right angles?

When two forces act at 90° to each other, draw them tip to tail. The resultant is the third side of a right-angled triangle, so use Pythagoras to find its size and tangent to find its direction.



Tip-to-tail drawing: the resultant goes from the start of the first force to the end of the second.

Worked example 2

Two ropes pull a boat: 30 N to the east and 40 N to the north. Find the resultant.

$R^2 = 30^2 + 40^2 = 900 + 1600 = 2500$, so $R = \mathbf{50\text{ N}}$. The angle north of east is $\tan^{-1}(40 \div 30) = \mathbf{53^\circ}$.

Worked example 3

A 500 kg balloon floats at constant height. Calculate the upthrust, ignoring drag.

$W = m g = 500 \times 9.8 = 4900\text{ N}$. The resultant is zero, so the upthrust equals the weight: **4900 N upwards**.

Lina's tip

Sketch the object as a dot or box first, then ask “what pulls, what pushes, what holds it up?” in that order. Count the arrows against the table of forces so none is missed.

Key points to remember

- Force is a vector measured in newtons (N); weight $W = m g$, with $g = 9.8\text{ N/kg}$.
- Same direction: add forces; opposite directions: subtract.

- Zero resultant means equilibrium: rest or constant velocity.
- Perpendicular forces: $R = \sqrt{F_1^2 + F_2^2}$, direction from $\tan \theta$.
- A free-body diagram has one labelled arrow per force on one object.

Combining forces and drawing force diagrams: frequently asked questions

What is a resultant force?

A resultant force is the single force that has the same effect as all the forces acting on an object together. You find it by adding forces in the same direction and subtracting forces in opposite directions.

What is a free-body diagram?

It is a drawing of one object with an arrow for each force acting on it. The arrows show direction, their lengths show relative size, and each one is labelled with its name and value.

What happens when forces are balanced?

When the resultant is zero, the object stays at rest or moves at a constant velocity in a straight line. Balanced forces do not make the object stop.

How do you find the resultant of two forces at right angles?

Draw them tip to tail and use Pythagoras: $R = \sqrt{F_1^2 + F_2^2}$. The direction comes from $\tan \theta = \text{opposite} \div \text{adjacent}$.

How do you calculate weight?

Multiply the mass in kilograms by the gravitational field strength: $W = m g$. On Earth g is 9.8 N/kg, so a 2.0 kg object weighs 19.6 N.