Cambridge IGCSE · Physics 0625 · Notes

Mass and weight

Read online at **pastopic.com/cambridge/physics-0625/notes/mass-and-weight**

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Read first: **Motion**

What you need to know

By the end of this topic you should be able to:

1. **State what mass is:** a measure of the **quantity of matter** in an object (when the object is at rest compared with you). Mass is measured in kilograms (kg) and does not change when the object moves to another place.
2. **State what weight is:** the **gravitational force** on an object that has mass. Weight is a force, so it is measured in newtons (N).
3. **Define gravitational field strength** g as the **force per unit mass**, and recall and use $g = \frac{W}{m}$ (so $W = mg$). Know that g is the same thing as the **acceleration of free fall**: 9.8 N/kg near the Earth's surface is the same as 9.8 m/s².
4. **Know that weights, and so masses, can be compared using a balance.**
5. **Extended only:** describe weight as **the effect of a gravitational field on a mass**, and use this idea: the same mass has a different weight wherever the gravitational field is different (on the Moon, on another planet, far from the Earth).

Understand it

Mass: how much matter

Mass tells you how much "stuff" (matter) an object is made of. A 2 kg bag of rice contains twice as much matter as a 1 kg bag. Mass does not depend on where the object is: take the bag to the Moon, into orbit or to Mars and it still has a mass of 2 kg, because nothing has been added or taken away.

Heating, cooling, squashing or stretching an object doesn't change its mass either. When a metal block expands as it is heated, its volume goes up but its mass stays the same (so its density goes down).

Mass is a **scalar**: it has a size but no direction.

Weight: a force

The Earth pulls on every object that has mass. That pull is the object's **weight**. Because weight is a **force**, it:

- is measured in **newtons (N)**, never in kilograms;
- has a direction: **vertically downwards**, towards the centre of the Earth. This is true whatever the object is doing: a ball thrown sideways, an arrow flying horizontally or a plane climbing all have weight acting straight down;
- is a **vector**, drawn as an arrow pointing down from the middle of the object.

In everyday speech people say "I weigh 60 kilograms". In physics that is wrong: 60 kg is your **mass**, and your **weight** is about 590 N.

Extended only: a planet (or moon, or star) is surrounded by a **gravitational field**, a region where any mass feels a force. **Weight is the effect of a gravitational field on a mass.** No mass, no weight; no field, no weight. A stronger field gives the same mass a bigger weight.

Gravitational field strength

How hard the field pulls on each kilogram is the **gravitational field strength**, g:

$$g = \frac{W}{m} \qquad \text{(force per unit mass, in N/kg)}$$

Rearranged, this gives the equation you will use most:

$$W = mg \qquad \text{and} \qquad m = \frac{W}{g}.$$

Near the Earth's surface, $g = 9.8$ N/kg: every kilogram is pulled down with a force of 9.8 N. So

- a 1.0 kg bag of sugar weighs $1.0 \times 9.8 = 9.8$ N;
- a 60 kg student weighs $60 \times 9.8 = 588 \approx 590$ N;
- a 450 g phone weighs $0.450 \times 9.8 = 4.41 \approx 4.4$ N (change grams to kilograms first).

g **is also the acceleration of free fall.** The units N/kg and m/s² are the same thing. If you drop an object where there is no air resistance, its weight is the only force on it, and it speeds up by 9.8 m/s every second. A heavier object has a bigger pull on it, but it also has more mass to speed up, in exactly the same proportion: twice the mass means twice the weight. So every object falls with the same acceleration, g, whatever its mass. On the Moon, which has no air, a hammer and a feather dropped together land together.

(**Extended only:** with $F = ma$ from the Forces topic, $a = \frac{W}{m} = \frac{mg}{m} = g$.)

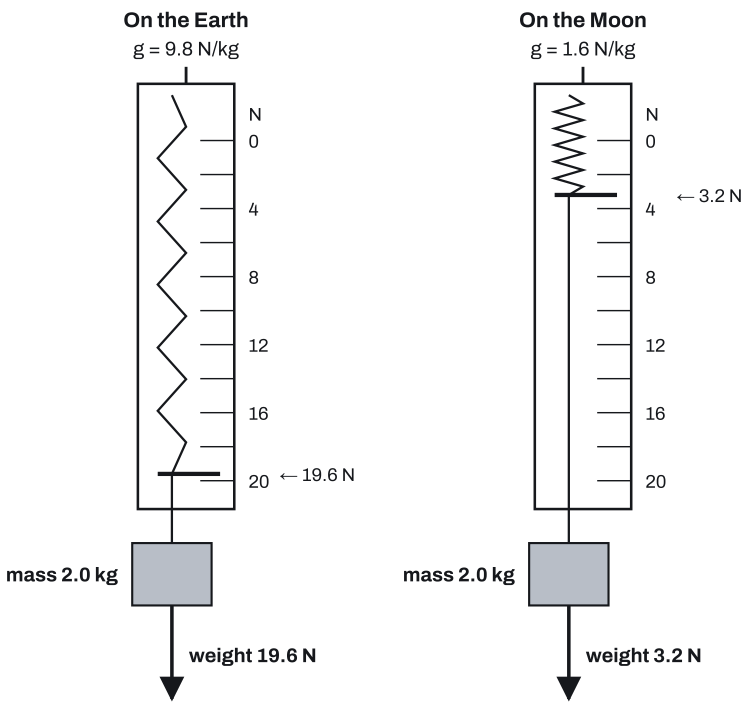
The same mass in different places

g is different in different places, so the **same mass has a different weight**:

Place	g (N/kg)	Mass of a 60 kg student	Weight of the student
Earth's surface	9.8	60 kg	$588 \approx 590$ N
Mars's surface	3.7	60 kg	$222 \approx 220$ N
Moon's surface	1.6	60 kg	96 N

The rule to remember: **mass stays the same; weight changes with g.** Where g is smaller, the weight is smaller; where g is bigger, the weight is bigger. On the Moon, g is about one sixth of the Earth's value, so everything weighs about one sixth as much.

g depends on the planet's **mass** and on **how far you are from its centre**: further away, the field is weaker. It has nothing to do with the air or atmospheric pressure. An astronaut in a space station about 400 km up still has a weight: g there is about 8.7 N/kg, not zero. Astronauts float because they and the station are falling round the Earth together, not because their weight has gone.



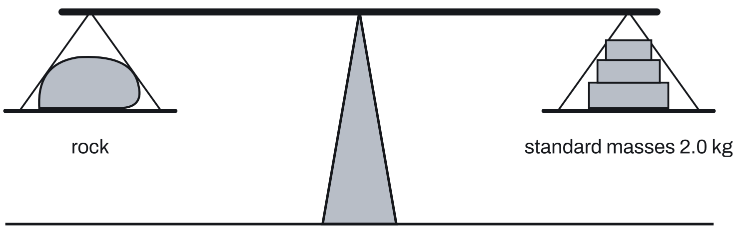
Same mass, 2.0 kg; weight W = mg changes with g.

Measuring and comparing: balances

A newton meter (spring balance) measures **weight**. The object's weight stretches a spring, and the stretch is read on a scale in newtons. Take it to the Moon and the same object stretches the spring less, so the reading is smaller, as in the diagram above. A spring balance marked in grams or kilograms is really measuring weight and then converting with Earth's g, so on the Moon it would give the wrong mass.

A beam balance (or any balance that compares two pans) **compares weights**. The beam is level when the weights on the two sides are equal. Both pans are in the same place, with the same g, so equal weights also mean **equal masses**. That is why a balance can compare masses as well as weights, and why a beam balance gives the same answer on the Moon as on the Earth: both weights become smaller by the same factor, and the beam still balances.

The beam is level: equal weights, so equal masses



On the Earth: 2.0 × 9.8 = 19.6 N on each side
On the Moon: 2.0 × 1.6 = 3.2 N on each side: it still balances

A balance **cannot** compare volumes or densities: two objects that balance have the same mass and the same weight, but they can have very different sizes.

Two readings that are the same on the same spring balance, in the same place, mean the two loads have the **same weight** (and so the same mass), even if they take up different volumes (rice and pasta, for example).

Weight inside bigger questions

Weight is the force you need in many other topics, so a 3 or 4 part question often starts with "calculate the weight". Whenever a question gives you a **mass** but the equation needs a **force**, change the mass to a weight with $W = mg$ first:

- pressure on the ground: $p = \frac{F}{A}$ with F = weight;
- work done lifting an object: force × distance with force = weight;
- moments: the weight of a beam or a child;
- a load on a spring or a tension in a rope holding something still: the force equals the weight.

Key facts and formulas

The 0625 papers have no formula sheet, so learn the equations. The value of g is printed on the front of the question paper.

Formula	Status
Gravitational field strength: $g = \frac{W}{m}$ (force per unit mass)	Learn it
Weight: $W = mg$; mass: $m = \frac{W}{g}$	Learn it
$g = 9.8$ N/kg $= 9.8$ m/s² near the Earth's surface (use this, not 10)	Given

Formula	Status
g is equal to the acceleration of free fall	Learn it
Units: mass in kg, weight in N, g in N/kg; $1000\ \mathrm{g} = 1\ \mathrm{kg}$	Learn it

	Mass	Weight
What it is	quantity of matter	gravitational force on a mass
Unit	kilogram (kg)	newton (N)
Scalar or vector	scalar	vector (a force), acts vertically down
Changes from place to place?	no	yes, with g
Measured with	balance	newton meter (spring balance)

How to do it

In the Paper 1 to 4 questions we have tagged for this topic (83 different questions, 2021–2025; 6 more appear on two papers), the types came up this often. 12 of the 83 questions mix two or three types, so the counts add up to more than 83.

Question type	Questions
Calculating weight, mass or g with $W = mg$	37
Definitions: mass, weight and g	34
Mass and weight in a different place	17
Balances and spring balances	8

1. Calculating weight, mass or g with W = mg (37 questions)

1. **Write the equation in symbols**: $W = mg$ (or $g = \dfrac{W}{m}$).
2. **Check the units.** Mass must be in **kg**: divide grams by 1000. Use $g = 9.8$ N/kg on the Earth unless the question gives another value.
3. **Rearrange if needed**: weight → mass means **divide** by g; mass → weight means **multiply**.
4. **Substitute and give the answer** to 2 or 3 significant figures, with **N** for a weight and **kg** for a mass.

For example, a 1.2 kg bag has weight $1.2 \times 9.8 = 11.76 \approx 12$ N, and a box that weighs 147 N has mass $147 \div 9.8 = 15$ kg.

Variations you will meet:

- **Another planet or moon.** Use that place's g: a 240 kg lander on Mars ($g = 3.7$ N/kg) weighs $240 \times 3.7 = 888 \approx 890$ N.

- **Weight on one planet, weight on another.** Find the mass first (it doesn't change), then multiply by the new g. An object weighing 24 N where $g = 8.0$ N/kg has mass $24 \div 8.0 = 3.0$ kg, so where $g = 3.0$ N/kg it weighs $3.0 \times 3.0 = 9.0$ N.
- **Find** g from a weight and a mass: $g = W \div m$. A 15.0 kg mass that weighs 132 N is somewhere with $g = 132 \div 15.0 = 8.8$ N/kg.
- **Masses in grams.** 450 g is 0.450 kg, so the weight is 4.4 N; using 450 gives 4410 N, which is absurd for a phone.
- **Weight given in newtons already.** If a question gives "a force of 0.75 N due to the load", that force **is** the weight: don't multiply by g again. To get the mass, divide: $0.75 \div 9.8 = 0.077$ kg.
- **A rope or thread holding a mass still.** The tension equals the weight, in newtons: a 15 kg load needs $15 \times 9.8 = 147$ N. An answer in kg is wrong.
- **Weight first, then another topic**: pressure, work, moments, springs. Work out the weight, then carry it into the next equation.

2. Definitions: mass, weight and g (34 questions)

1. **Match the word to its meaning**:
   - mass: the quantity of matter in an object; kg; a scalar; same everywhere;
   - weight: the gravitational force on an object with mass (**Extended:** the effect of a gravitational field on a mass); N; a force and a vector; acts downwards;
   - gravitational field strength: force per unit mass; N/kg; equal to the acceleration of free fall.
2. **Read every option or statement** and cross out the ones that swap mass and weight.

Variations you will meet:

- **"Which of these is a force?"** Weight (not mass, density or volume).
- **"Which unit is a unit of weight?"** A newton or kilonewton, never a kilogram.
- **"Which statements describe weight?"** It is the effect of a gravitational field on the object, and the pull between the object and the Earth. "The quantity of matter" describes mass, not weight.
- $W = mg$**: which quantities are forces?** Only W. m is a mass, and g is a force **per** kilogram.
- **"Which is equal to gravitational force?"** $g\times$ mass (that is, $W = mg$).
- **Recorded readings**: a balance gives a mass in kg or g; a force meter gives a weight in N. Check both unit and size: a 1 kg mass weighs about 10 N; a 20 kg mass cannot weigh 2 N.
- **Which statement about** g **is wrong?** g never changes the **mass** of an object.
- **Direction of weight**: straight down, even for an object moving sideways.
- **"Why do all objects fall with the same acceleration on the Moon?"** Because weight is **proportional to mass**, so the force per kilogram, g, is the same for every object.
- **"State the cause of the acceleration"** of a falling object: its weight (the gravitational force of the Earth on it).
- **Older papers (2021–2022)** describe mass as what **resists a change in motion**: with the same resultant force, the object with more mass accelerates less. This comes from $F = ma$ in the Forces topic.

3. Mass and weight in a different place (17 questions)

1. **Mass stays the same.** Always.
2. **Weight changes with g**: smaller g (the Moon, Mars, further from the Earth) means smaller weight; bigger g means bigger weight. The weight changes in proportion: half the g, half the weight.
3. If numbers are asked, find the mass, then $W = mg$ with the new g.

Variations you will meet:

- **Tables of four rows** giving mass and weight on the Earth and the Moon. Cross out every row where the mass changes, then check the weights. With "g on the Moon is one sixth of the Earth's", the Moon weight is the Earth weight $\div 6$.
- **Two objects with equal weights in different places.** An object weighing 10 N on the Earth has **less** mass than one weighing 10 N on Mars, because Mars's g is smaller, so it takes more mass to give the same weight.
- **The same spring stretched by the same amount on the Moon**: the spring needs the same **weight**, so the mass must be bigger by the same factor that g is smaller. If 2.0 kg stretches it by a certain amount on the Earth, it takes $2.0 \times 6 = 12$ kg on the Moon (g one sixth as big).
- **In orbit or further from the Earth**: g is smaller, so the weight is smaller but **not zero**, and the mass is the same.
- **A planet with twice the Earth's g**: the weight doubles; with the same horizontal push, the acceleration is unchanged, because acceleration depends on mass, which hasn't changed.
- **A rock brought back from the Moon**: its mass and its density are the same on both; only its weight differs.

4. Balances and spring balances (8 questions)

1. **Spring balance or newton meter**: measures **weight**. Its reading changes when g changes.
2. **Beam balance**: compares weights on its two pans, and so compares **masses**. Its result is the same on the Earth and the Moon.
3. **Same spring, same stretch, same place** means the same **weight** (and the same mass), whatever the volumes or densities.

Variations you will meet:

- **"Which methods compare two masses?"** A beam balance, or hanging each from the same spring and comparing the extensions. Comparing volumes (length × breadth × height) doesn't work for different materials, and every object falls with the same acceleration, so that tells you nothing.
- **Spring balance vs beam balance on the Moon**: the spring balance reads less on the Moon; the beam balance gives the same reading.
- **"What can a balance compare?"** Weight and mass only, not volume or density.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

A robot rover has a mass of 180 kg.

(a) Calculate the weight of the rover on the Earth. **[2]**

(b) The rover is sent to Mars, where the gravitational field strength is 3.7 N/kg. State its mass on Mars and calculate its weight on Mars. **[3]**

(a) $W = mg$ **M1** $= 180 \times 9.8 = 1764 \approx 1760$ N. **A1**

(b) Mass $= 180$ kg: the amount of matter hasn't changed. **B1**

$W = mg = 180 \times 3.7$ **M1** $= 666 \approx 670$ N. **A1**

Example 2

A bag of flour has a weight of 14.7 N on the Earth.

(a) Calculate the mass of the bag of flour. **[3]**

(b) Define *gravitational field strength*. **[1]**

(c) On a large planet the same bag has a weight of 36 N. Calculate the gravitational field strength on this planet. **[2]**

(a) $W = mg$, so $m = \frac{W}{g}$ **M1**

$m = \frac{14.7}{9.8}$ **M1** $= 1.5$ kg **A1**

(b) The (gravitational) force per unit mass. **B1**

(c) The mass is still 1.5 kg. $g = \frac{W}{m} = \frac{36}{1.5}$ **M1** $= 24$ N/kg. **A1**

Example 3

A student hangs a mass of 250 g from a newton meter on the Earth.

(a) Show that the reading on the newton meter is about 2.5 N. **[2]**

(b) The same mass and newton meter are taken to the Moon, where $g = 1.6$ N/kg. The mass is also placed on one pan of a beam balance, and standard masses are placed on the other pan until the beam is level.

(i) Calculate the reading on the newton meter on the Moon. **[2]**

(ii) State the total of the standard masses needed on the Moon, and explain your answer. **[2]**

(c) **Extended only.** On the Moon there is no air. Explain why a hammer and a feather, dropped together from the same height, hit the ground together. **[2]**

(a) $250\text{ g} = 0.250$ kg. $W = mg = 0.250 \times 9.8$ **M1** $= 2.45$ N, which is about 2.5 N. **A1**

(b)(i) $W = 0.250 \times 1.6$ **M1** $= 0.40$ N. **A1**

(b)(ii) 250 g. **B1** Both pans are in the same gravitational field, so the weights of both sides are reduced by the same factor and the beam balances when the masses are equal. **B1**

(c) The only force on each is its weight, and weight is proportional to mass (the weight is the effect of the gravitational field on the mass). **B1** So the force per unit mass, which is the acceleration, is the same for both: $g = 1.6$ m/s². **B1**

Common mistakes

- **Mixing up mass and weight.** Examiners report this every year: saying weight is "the quantity of matter", or giving a weight in kg. Mass is matter in kg; weight is a force in N.
- **Multiplying when you should divide.** Weight → mass is $W \div g$; writing $m = W \times g$ turns a 620 N boy into a 6000 kg one. Write $W = mg$ in symbols first, then rearrange.
- **Using $g = 10$.** The current papers say $g = 9.8$ N/kg on the front cover. Using 10 can cost the answer mark.
- **Not changing grams to kilograms.** 300 g is 0.300 kg: its weight is about 2.9 N, not 2900 N.
- **Using the mass where a force is needed.** In pressure, work done or moments, the force is the **weight**, not the mass. Candidates who put the mass straight into $p = F/A$ or work $= F \times d$ lose most of the marks.
- **Multiplying a force by g again.** If the question already gives a weight or "a force of ... N", it is already in newtons.
- **Thinking mass changes on the Moon**, or that weight is zero in orbit or when falling. Mass never changes; weight is smaller where g is smaller but it isn't zero near a planet.
- **Thinking g depends on the air** or on atmospheric pressure. It depends on the planet's mass and the distance from its centre.

- **Vague definitions.** "Gravity pulling things towards the centre of a planet" is not a definition of g: it needs **force per unit mass**.
- **Missing units.** A weight without "N" or with "kg" loses a mark when the answer line has no unit printed.

How to get the marks

- **Calculations** usually have a method mark for the equation or the substitution and an answer mark; the mark schemes give the method mark even when the answer is missing or wrong. Write $W = mg$ (or $m = W \div g$), then the numbers, then the answer. A correct method with a slip still earns something.
- **"Define" gravitational field strength**: "force per unit mass" or $g = \frac{W}{m}$ with the symbols explained. **"Define weight"**: "the gravitational force on an object (with mass)" or "the effect of a gravitational field on a mass".
- **"State"** questions need a short answer only, such as "stays the same" for the mass.
- **Significant figures.** Give 2 or 3 significant figures, and don't round the weight before you use it in the next part of the question.
- **Multiple choice.** Work the answer out before looking at the options. Wrong options are built from the usual slips: $m \times g$ instead of $m \div g$, grams not converted, $g = 10$, mass and weight swapped, or kg and N swapped.
- **Comparisons.** For "how do the mass and weight compare", give **both**: "the mass is the same; the weight is less (because g is smaller)".

Quick check

1. Which of these is a force: density, mass, volume, weight? Give its unit.
2. Calculate the weight on the Earth of a 300 g apple.
3. A crate weighs 490 N on the Earth. Calculate its mass, and its weight on the Moon, where $g = 1.6$ N/kg.
4. A rock is brought back from the Moon to the Earth. Which of its mass, weight and density are the same on the Earth as on the Moon?
5. **Extended only.** An object is taken from the Earth to a planet where $g = 15$ N/kg. State what happens to its mass and to its weight, and state its acceleration if it is dropped on that planet with no air resistance.

Answers

1. Weight. Its unit is the newton (N).
2. $300 \text{ g} = 0.300$ kg. $W = 0.300 \times 9.8 = 2.94 \approx 2.9$ N.
3. $m = 490 \div 9.8 = 50$ kg. On the Moon, $W = 50 \times 1.6 = 80$ N.
4. Its mass and its density are the same. Its weight is bigger on the Earth.
5. The mass stays the same. The weight increases, because g is bigger (15 N/kg compared with 9.8 N/kg); it is $15 \div 9.8 = 1.5$ times bigger. The acceleration of free fall equals g: 15 m/s².

Past questions to try

- **0625/41/O/N/25 Q2**: define g, then find a weight on Mars from a weight on the Earth (Extended).
- **0625/33/M/J/25 Q2**: mass from a weight, then the work done lifting it.
- **0625/11/M/J/22 Q4**: a spring balance and a beam balance on the Earth and on the Moon.
- **0625/11/M/J/23 Q5**: what equal spring balance readings tell you.