

Newton's Second Law

4.5.6.2.2 · Forces · revision notes

Newton's Second Law links resultant force, mass and acceleration: $F = m a$. You need to use it in calculations, estimate forces in everyday road transport, and describe the required practical on force, mass and acceleration.

Key facts

- $F = m a$ (resultant force = mass $\times$ acceleration)
- $a \propto F$ (at constant mass)
- Always use the **RESULTANT** force
- $\sim$ means 'approximately'; car mass ~ 1000 kg
- Units: F in N, m in kg, a in m/s^2
- $a \propto 1/m$ (at constant force)
- Acceleration is in the direction of the resultant force

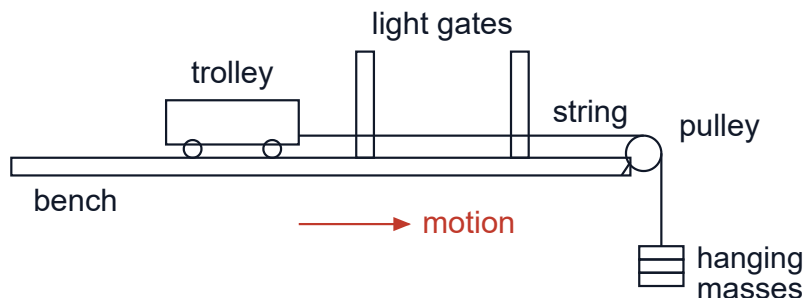
Notes

The law

- The acceleration of an object is **proportional** to the resultant force acting on it, and **inversely proportional** to its mass.
- resultant force = mass $\times$ acceleration: **$F = m a$**
- F in newtons (N), m in kilograms (kg), a in metres per second squared (m/s^2).
- The acceleration is in the same direction as the resultant force.
- Always use the **resultant** force. Example: thrust 5000 N forwards and drag 1400 N backwards give $F = 3600$ N.

Required practical: force, mass and acceleration

- A trolley on a bench is pulled by a string that passes over a pulley to a hanging mass. The weight of the hanging mass is the accelerating force.
- Measure the acceleration with light gates and a data logger, or by timing the trolley over marked distances.



The weight of the hanging masses accelerates the trolley; the light gates measure the acceleration.

- To vary the force at constant mass: move masses from the trolley to the hanger, so the total mass being accelerated stays the same.
- To vary the mass at constant force: add masses to the trolley and keep the hanging mass the same.
- Results: acceleration is proportional to force; acceleration decreases as mass increases.

How to answer each type of question

Calculate with $F = m a$

2 marks

Grade 4

1. Check the mass is in kg.
2. Write $F = m a$, or its rearranged form, and substitute.
3. Give the unit.

Example. A resultant force of 450 N acts on a motorbike and rider. Their total mass is 300 kg. Calculate their acceleration.

Model answer. $a = 450 \div 300$ (1)

$a = 1.5 \text{ m/s}^2$ (1)

Don't lose marks

- ✗ Using one of the forces instead of the resultant force.
- ✗ Using a weight in N as if it were a mass in kg. If a weight is given, use $m = W \div g$.
- ✗ Using a mass in grams: convert to kg first.
- ✗ In the practical, adding new masses to the hanger, which changes the total mass as well as the force.
- ✗ Saying acceleration is proportional to mass. It is inversely proportional.

More tips

Memory tricks

- Formula triangle: F on top, m and a underneath.
- Direction check: the acceleration always points the same way as the resultant force.
- In the practical, moving masses from the trolley to the hanger changes the force without changing the total mass, so it is a fair test.
- Rough values for estimates: car ~1000 kg, person ~70 kg.

Exam technique

- $F = ma$ must be recalled.
- In estimates, state the values you assumed (e.g. 'mass of car $\approx$ 1000 kg') and use ~ or 'about' in your answer.
- In practical questions, name the independent, dependent and control variables clearly.

What each grade needs

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

Grade 4

Calculate force using $F = ma$

For example, $1200 \text{ kg} \times 2.5 \text{ m/s}^2 = 3000 \text{ N}$.

Grade 5

Find mass or acceleration using $F = ma$

$a = F \div m$ and $m = F \div a$.

Grade 5

Describe how acceleration depends on force and mass

Acceleration is proportional to the resultant force and inversely proportional to the mass.

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