

Moments, levers and gears

4.5.4 · Forces · revision notes

A force can make an object turn about a pivot. You need to calculate moments with $M = F d$, use the balance of clockwise and anticlockwise moments, and explain how levers and gears transmit the turning effect of forces. This is in GCSE Physics only, not in Combined Science.

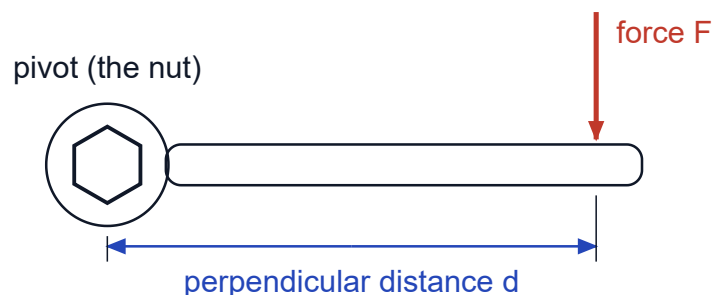
Key facts

- $M = F d$ (moment = force $\times$ perpendicular distance from the pivot)
- Units: M in $N\ m$, F in N , d in m
- Balanced: total clockwise moment = total anticlockwise moment
- Greater distance from the pivot means a smaller force is needed for the same moment
- Lever = force multiplier when the effort is further from the pivot than the load
- Small gear drives large gear: larger moment, slower rotation
- Large gear drives small gear: smaller moment, faster rotation
- Meshing gears turn in opposite directions

Notes

Moments

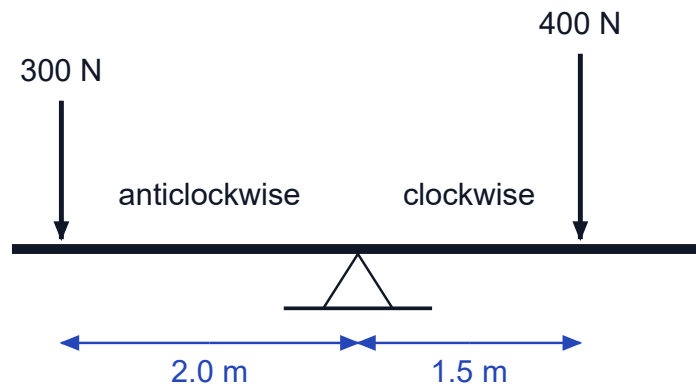
- A force, or a system of forces, can cause an object to rotate about a **pivot**.
- The turning effect of a force is called the **moment** of the force.
- moment of a force = force $\times$ distance: **$M = F d$**
- M in newton-metres ($N\ m$), F in newtons (N), d in metres (m).
- d is the **perpendicular distance** from the pivot to the **line of action** of the force. The moment is biggest when you push at right angles, far from the pivot.



Moment = $F \times d$, with d measured at right angles to the force.

Balanced objects

- If an object is balanced, the total clockwise moment about a pivot equals the total anticlockwise moment about that pivot.
- Example: a 300 N child sits 2.0 m from the pivot of a see-saw (moment 600 N m). A 400 N child balances it by sitting $600 \div 400 = 1.5$ m from the pivot on the other side.



Balanced: $300 \times 2.0 = 600$ N m anticlockwise equals $400 \times 1.5 = 600$ N m clockwise.

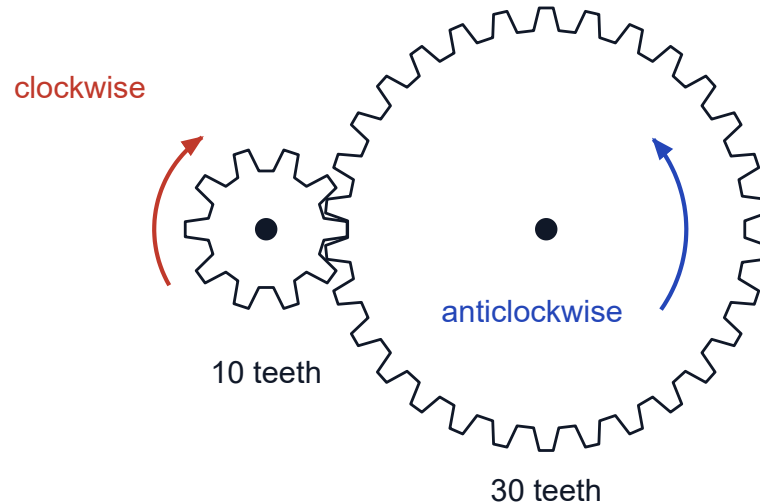
- If the moments are not balanced, the object turns in the direction of the larger total moment.

Levers

- A simple lever transmits the rotational effect of a force.
- The effort and the load each have a moment about the pivot. If the effort is further from the pivot than the load, a small effort can move a large load: the lever is a **force multiplier**.
- Examples: a crowbar, a wheelbarrow, a spanner, a bottle opener.

Gears

- Gears are wheels with teeth that interlock, so one gear turning makes the next one turn. Neighbouring gears turn in opposite directions.
- Where the teeth meet, the forces on the two gears are the same size. The bigger gear has a larger radius, so the moment on it is larger.



The small gear turns 3 times for each turn of the big gear. The big gear turns the other way, more slowly, with a bigger moment.

- Small gear driving a big gear: the big gear turns more slowly but with a bigger moment. This is how the first (lowest) gear in a car gives a large turning effect for pulling away.
- Big gear driving a small gear: the small gear turns faster but with a smaller moment.

How to answer each type of question

Calculate a moment

2 marks

Grade 4

1. Check the distance is the perpendicular distance from the pivot, in metres.
2. Write $M = F d$ and substitute.
3. Give the unit N m.

Example. A mechanic pushes at right angles on a spanner with a force of 45 N, 0.20 m from the centre of a nut.

Calculate the moment of the force about the nut.

Model answer. $M = 45 \times 0.20$ (1)

$M = 9.0 \text{ N m}$ (1)

Don't lose marks

- ✗ Using the length along a slanted bar instead of the perpendicular distance from the pivot to the line of action of the force.
- ✗ Using distances in cm when the answer should be in N m.

- ✗ Adding the clockwise and anticlockwise moments together instead of setting them equal.
- ✗ Forgetting that neighbouring gears turn in opposite directions.
- ✗ Saying gears 'create more energy'. They change the speed and the moment, but they do not give out more energy than is put in.

More tips

Memory tricks

- Moment = force $\times$ perpendicular distance to the pivot. Say 'perpendicular' every time.
- See-saw sense check: the heavier person must sit closer to the pivot.
- Gears: bigger driven gear = slower but bigger turning effect.
- Longer handle, less effort: that is why door handles are fixed far from the hinges.

Exam technique

- $M = F d$ must be recalled.
- In balance questions, write 'total clockwise moment = total anticlockwise moment' first, then substitute.
- In lever and gear 'explain' questions, use the word 'moment' and link the distance from the pivot to the size of force needed.

What each grade needs

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

Grade 3

Give examples of turning effects of forces

Opening a door, turning a spanner and a see-saw all involve forces that cause rotation.

Grade 4

Calculate a moment using $M = F d$

Moment (N m) = force (N) $\times$ perpendicular distance from the pivot (m).

Grade 5

Find a force or distance from a moment

$F = M \div d$ and $d = M \div F$.

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