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.

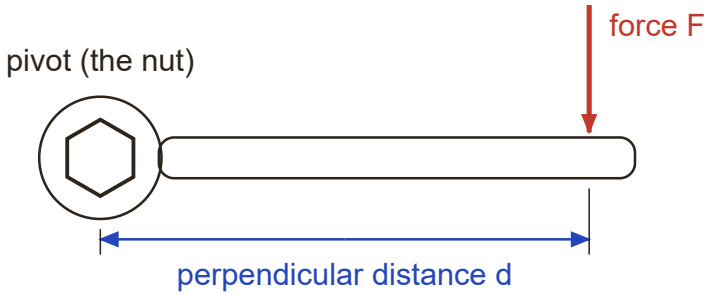
Key facts

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

Notes

Moments

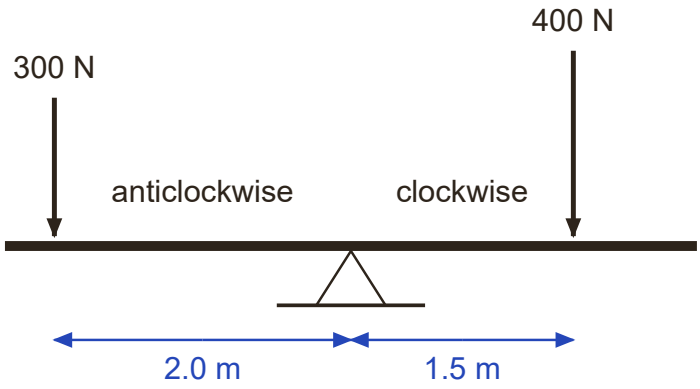
- A force, or a system of forces, can cause an object to rotate about a **pivot**.
- The turning effect of a force is called the **moment** of the force.
- moment of a force = force × distance: **M = F d**
- M in newton-metres (N m), F in newtons (N), d in metres (m).
- d is the **perpendicular distance** 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 × 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 ÷ 400 = 1.5 m from the pivot on the other side.



Balanced: 300 × 2.0 = 600 N m anticlockwise equals 400 × 1.5 = 600 N m clockwise.

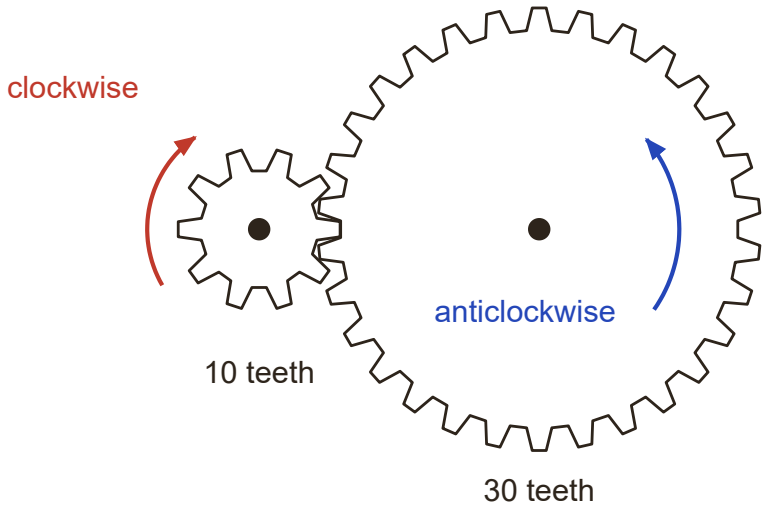
- If the moments are not balanced, the object turns in the direction of the larger total moment.

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 × 0.20 (1)

M = 9.0 N m (1)

Calculate using balanced moments

3 marks | Grade 5

1. Work out the moment of each known force about the pivot.
2. Write total clockwise moment = total anticlockwise moment.
3. Solve for the unknown force or distance.

Example. A uniform plank is balanced at its centre on a pivot. A 12 N weight is placed 0.30 m to the left of the pivot.
Calculate the distance to the right of the pivot at which an 8.0 N weight must be placed to balance the plank.

Model answer.

anticlockwise moment = 12 × 0.30 = 3.6 N m (1)

3.6 = 8.0 × d (1)

d = 0.45 m (1)

Explain how a lever works

2 to 3 marks | Grade 7

1. Quote moment = force × distance.
2. Compare the distances from the pivot.
3. Conclude that a smaller force gives the same moment.

Example. Explain why it is easier to undo a tight nut with a long spanner than with a short spanner.

Model answer.

The moment of a force = force × perpendicular distance from the pivot (1).

With the long spanner the force can act further from the nut (the pivot) (1)

so a smaller force is needed to produce the moment needed to turn the nut (1).

Explain how gears transmit rotation

2 to 3 marks | Grade 5

1. State the direction of rotation of the driven gear.
2. Compare the speeds using the numbers of teeth.
3. Compare the moments using the sizes of the gears.

Example. A small gear with 10 teeth drives a large gear with 30 teeth.
Describe and explain how the rotation of the large gear compares with that of the small gear.

Model answer.

The large gear turns in the opposite direction (1).

It turns more slowly: once for every three turns of the small gear (1).

The moment on the large gear is bigger, because the force from the teeth acts at a greater distance from its axle (1).

Moments with several forces

3 to 4 marks | Grade 8

1. Decide which forces give clockwise and which give anticlockwise moments.
2. Add up each total separately.
3. Set the totals equal and solve.

Example. A see-saw is pivoted at its centre. Child A (weight 350 N) sits 1.6 m to the left of the pivot. Child B (weight 250 N) sits 1.2 m to the right of the pivot.
Calculate where child C (weight 200 N) must sit to balance the see-saw.

Model answer.

anticlockwise moment = 350 × 1.6 = 560 N m	(1)
clockwise moment from B = 250 × 1.2 = 300 N m	(1)
child C must provide 560 − 300 = 260 N m, so 200 × d = 260	(1)
d = 1.3 m to the right of the pivot	(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 × 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 is on the equations sheet: use the perpendicular distance from the pivot, in metres, and give the moment in N m.
- 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) × perpendicular distance from the pivot (m).

Grade 5

Find a force or distance from a moment

F = M ÷ d and d = M ÷ F.

Grade 5

Apply balanced moments to a balanced object

For a balanced object, total clockwise moment = total anticlockwise moment about the pivot.

Grade 5

Explain how gears change speed and moment

A small gear driving a larger gear makes it turn more slowly but with a larger moment.

Grade 7

Explain how levers act as force multipliers

A small effort far from the pivot gives the same moment as a large load close to the pivot.

Grade 8

Solve moment problems with several forces

Add up all the clockwise moments and all the anticlockwise moments, then set the totals equal.

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