Edexcel GCSE Physics

Your notes

Moments

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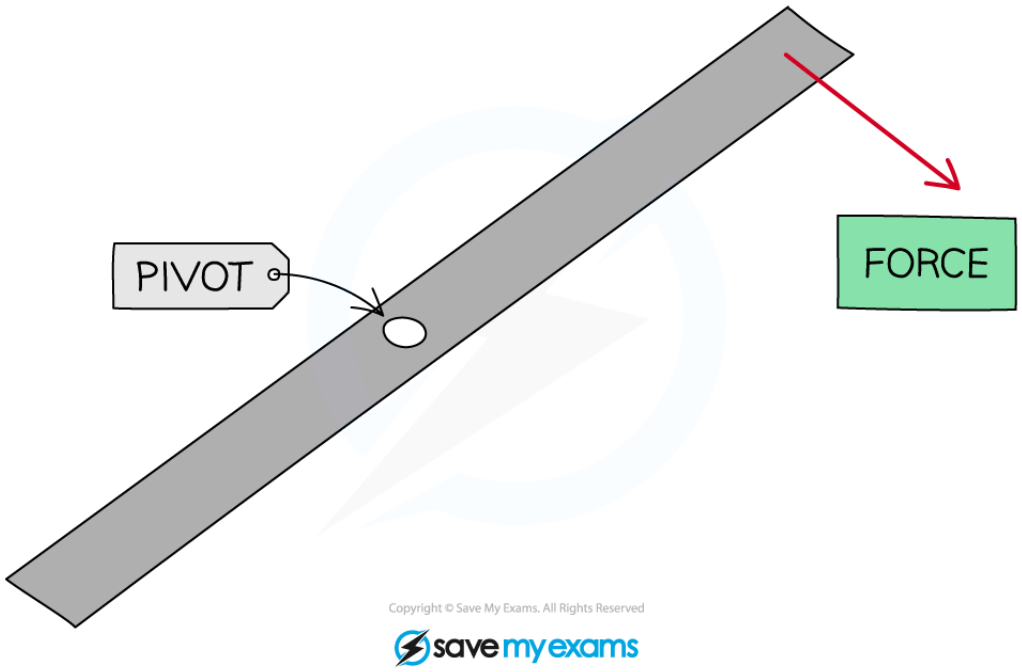
Moments

Your notes

Forces & Rotation

- As well as causing objects to speed up, slow down, change direction and deform, forces can also cause objects to **rotate**
  - A **system** of forces can also do this
- An example of a rotation caused by a force is on one side of a pivot (a fixed point that the object can rotate around)
  - This rotation can be **clockwise** or **anticlockwise**



The force will cause the object to rotate clockwise about the pivot

- More examples of rotation caused by a force are:
  - A child on a see-saw
  - Turning the handle of a spanner
  - A door opening and closing

- If two forces act on an object **without** passing through the same point, then the object can still rotate
  - If the forces are equal and opposite, this is known as a **couple**

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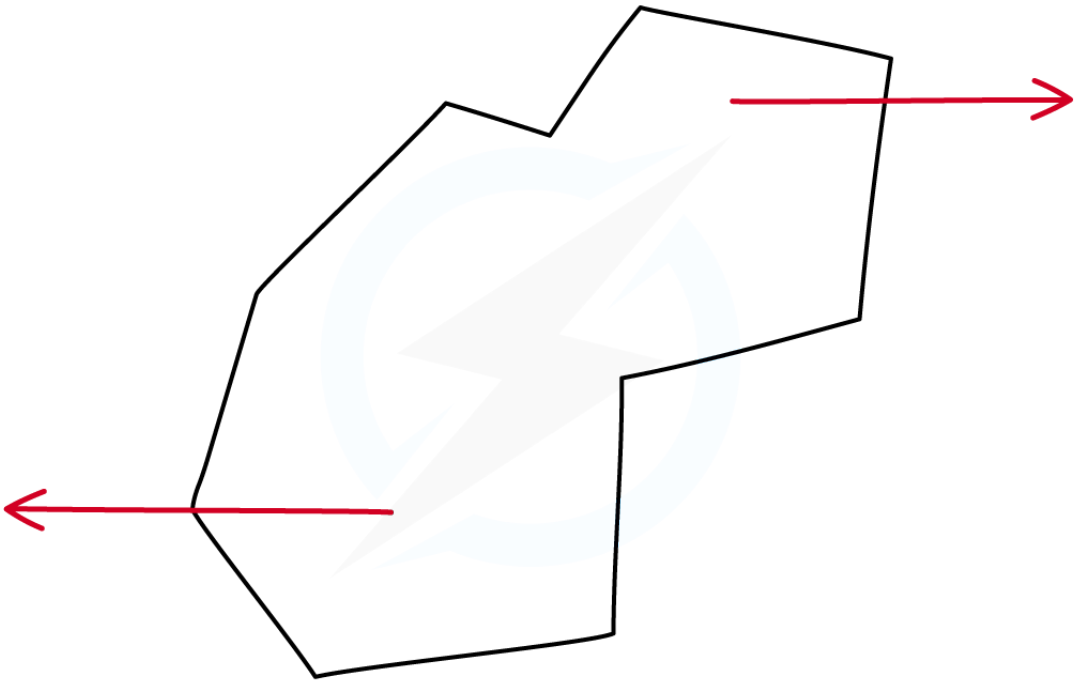

The above forces are balanced, but will still cause the object to rotate clockwise as they don't act through a common point

The Moment of a Force

- A **moment** is defined as:

  The turning effect of a force about a pivot

- The size of a moment is defined by the equation:

$$M = F \times d$$

- Where:
  - M = moment in newton metres (Nm)

- F = force in newtons (N)
- d = perpendicular distance of the force to the pivot in metres (m)

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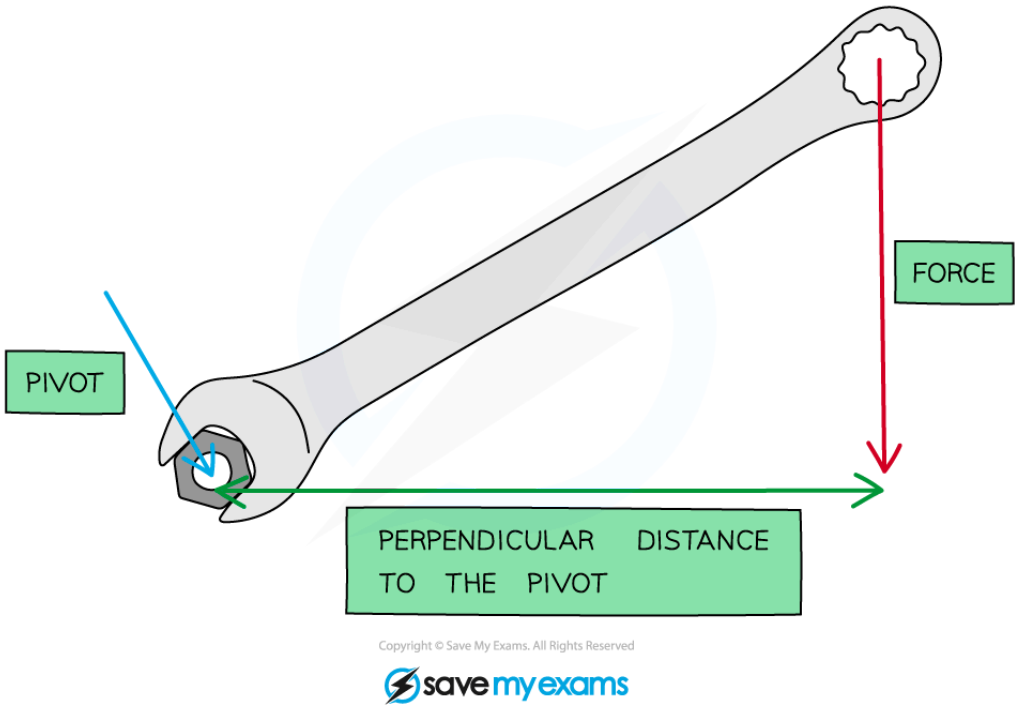

The moment depends on the force and perpendicular distance to the pivot

- This is why, for example, the door handle is placed on the opposite side to the hinge
  - This means for a given force, the perpendicular distance from the pivot (the hinge) is larger
  - This creates a larger **moment** (turning effect) to make it easier to open the door
- Opening a door with a handle close to the **pivot** would be much harder, and would require a lot more **force**

Examiner Tips and Tricks

The units of a moment is Newton metres (N m), but can also be Newton centimetres (N cm) ie. where the distance is measured in cm instead If the exam question doesn't ask for a specific unit, always convert the distance into **metres**

The Principle of Moments

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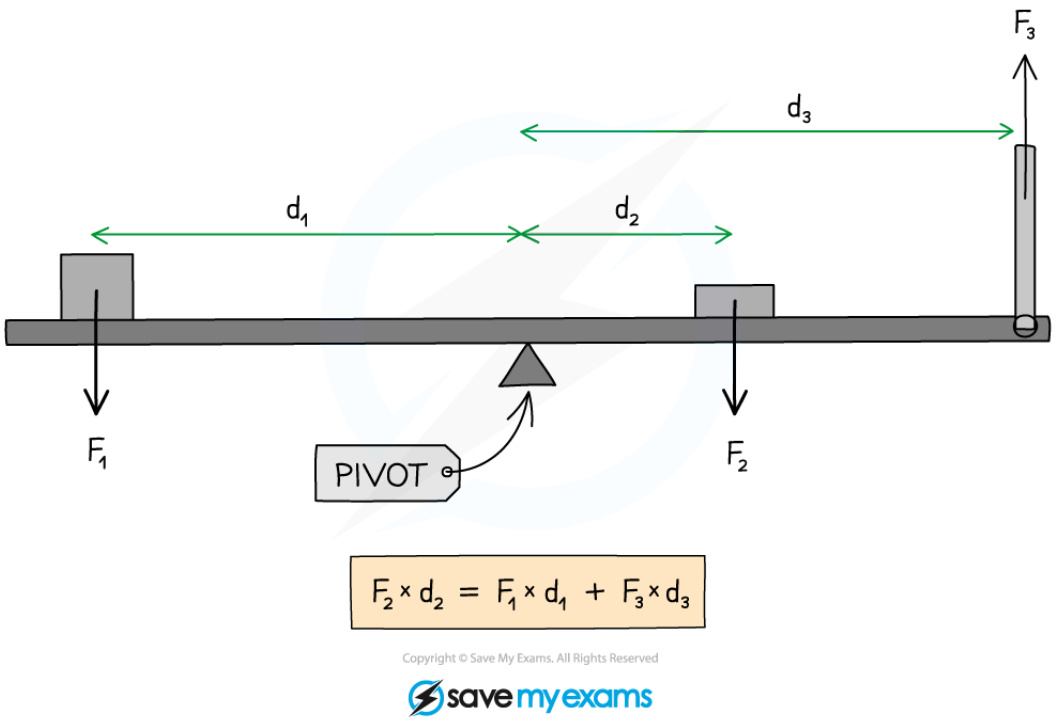
The Principle of Moments

- The principle of moments states that:

  If an object is balanced, the total clockwise moment about a pivot equals the total anticlockwise moment about that pivot

- Remember that the moment = **force × distance from a pivot**
- The forces should be **perpendicular** to the distance from the pivot
  - For example, on a horizontal beam, the forces which will cause a moment are those directed upwards or downwards



Moments on a balanced beam

- In the above diagram:
  - Force F_2 is supplying a clockwise moment;

- Forces F_1 and F_3 are supplying anticlockwise moments

- Due to the principle of moments, if the beam is balanced

Total clockwise moments = Total anticlockwise moments

- Hence:

$$F_2 \times d_2 = (F_1 \times d_1) + (F_3 \times d_3)$$

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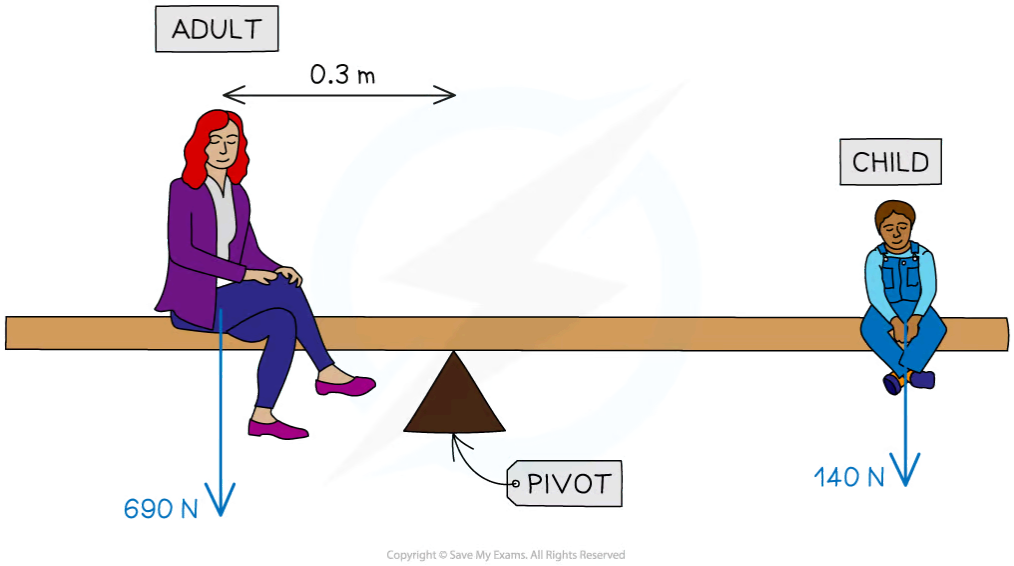
Worked Example

A parent and child are at opposite ends of a playground see-saw. The parent weighs 690 N and the child weighs 140 N. The adult sits 0.3 m from the pivot. Calculate the distance the child must sit from the pivot for the see-saw to be balanced.



Answer:

Step 1: List the know quantities

- Clockwise force (child), $F_{child} = 140$ N
- Anticlockwise force (adult), $F_{adult} = 690$ N
- Distance of adult from the pivot, $d_{adult} = 0.3$ m

Step 2: Write down the relevant equation

Moment = force × distance from pivot

- For the see-saw to balance, the principle of moments states that

Total clockwise moments = Total anticlockwise moments

Step 3: Calculate the total clockwise moments

- The clockwise moment is from the child

$$\text{Moment}_{child} = F_{child} \times d_{child} = 140 \times d_{child}$$

Step 4: Calculate the total anticlockwise moments

- The anticlockwise moment is from the adult

$$\text{Moment}_{adult} = F_{adult} \times d_{adult} = 690 \times 0.3 = 207 \text{ Nm}$$

Step 5: Substitute into the principle of moments equation

$$140 \times d_{child} = 207$$

Step 6: Rearrange for the distance of the child from the pivot

$$d_{child} = 207 \div 140 = 1.48 \text{ m}$$

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Examiner Tips and Tricks

Make sure that all the distances are in the same units and you're considering the correct forces as **clockwise** or **anticlockwise**, as seen in the diagram below

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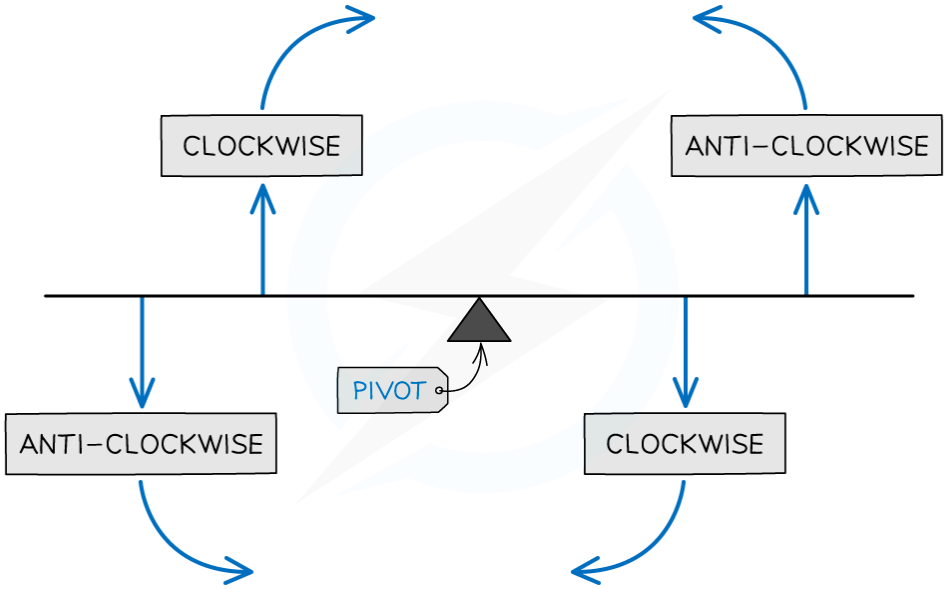
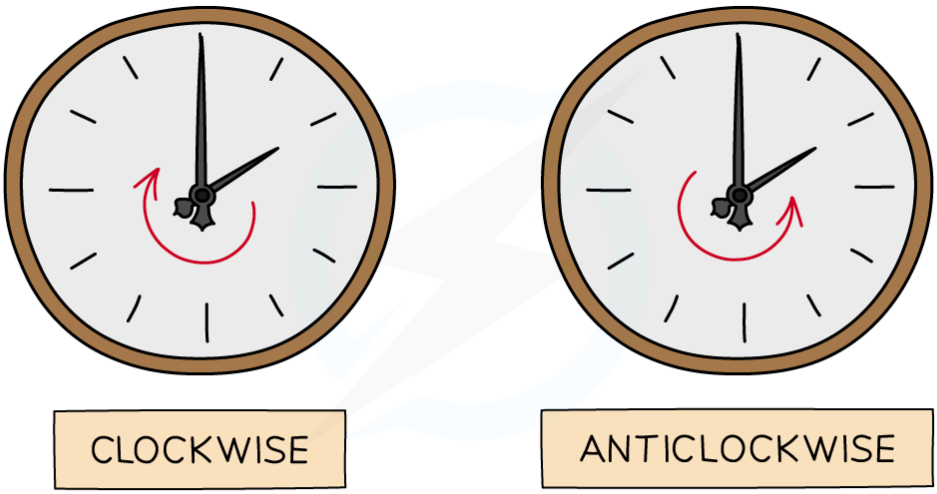


Clockwise is defined as the direction the hands of a clock move (and anticlockwise as the opposite)



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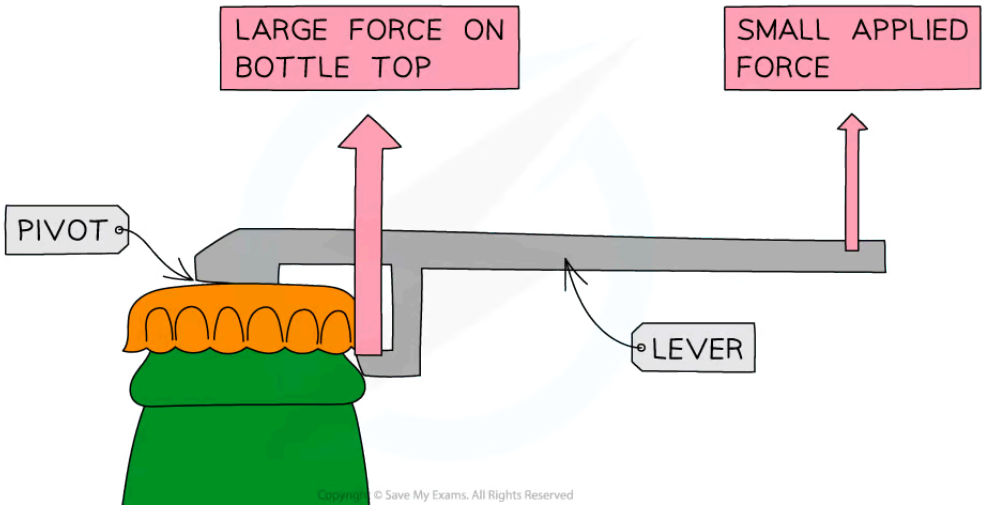
Levers & Gears

- Both simple lever and gear systems can be used to transmit and amplify the rotational effects of forces
  - This can be achieved using the concept of moments

Levers

- Levers **increase** the size of a **force** acting on an object to make the object turn more easily
- The force applied to a lever must act **further** from the pivot than the force has to overcome
- To make a lever work better:
  - Increase the **size** of the force applied
  - Increase the **distance** of the force from the pivot
- An example of a lever is a bottle opener

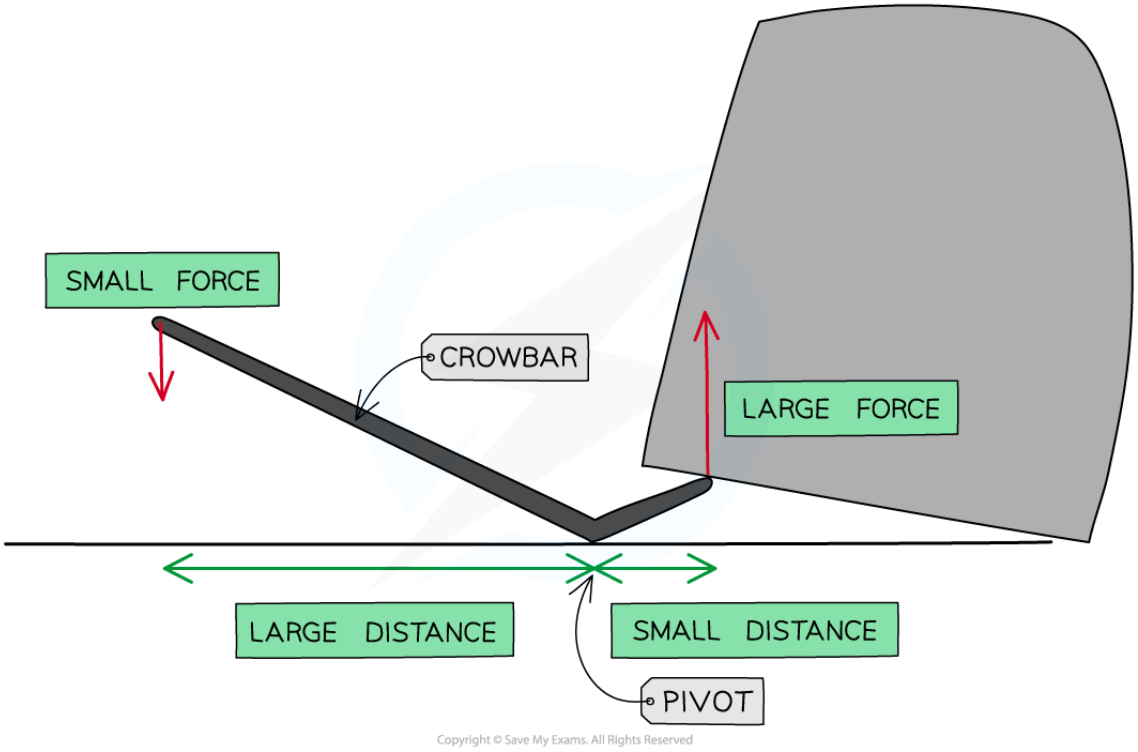


Using a bottle opener to create a large force upwards on the bottle top

- A bottle opener uses a lever to **amplify** the small force upwards applied by the person to create a large force upwards on the bottle top to remove it
  - The line of action of the small force is much further from the pivot than the large force that is needed at the edge of the cap to remove it

- The bottle opener (lever) makes use of moments to act as a force multiplier

- A crowbar is also a type of lever used to exert a large force to a narrow opening. This helps lift heavy objects
  - The small force downwards applied by a person is far away from the pivot
  - This creates a large force upwards on the heavy object, making it easier to lift



A small force applied at a large distance from a pivot can create a large moment

Gears

- Gears, similar to levers, multiply the effect of a turning force using moments
- They consist of wheels with toothed edges that rotate on an axle or shaft, which acts as the **pivot**
  - The teeth of one gear fit into the teeth of another gear
  - This lets one gear turn the other, meaning one axle or shaft can be used to turn another shaft
- As one gear turns, the other must also turn
  - Where the gears meet, the teeth will then move in the **same** direction (e.g. downwards)

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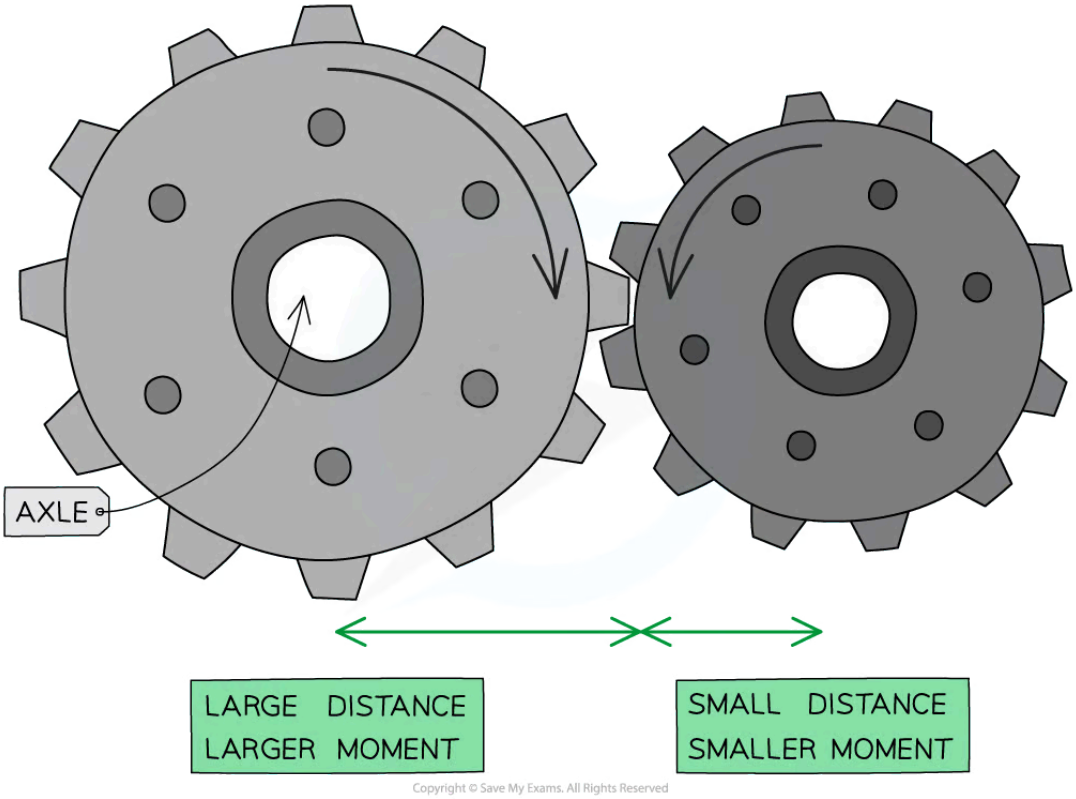
- One of the gears will then move clockwise, and the other anticlockwise (in opposite directions)

- Although the force will be the same on both gears, the **moment** will not be. This depends on the size of the gear, which changes the distance of the teeth to the pivot (axle)
  - If a larger gear is driven by a smaller gear, the large gear will rotate slower than the smaller gear but will have a greater moment. For example, a low gear on a bike or car
  - If a smaller gear is driven by a larger gear, the smaller gear will rotate quicker than the larger gear but will have a smaller moment. For example, a high gear on a bike or cart
- This is because the turning force on the larger gear wheel acts further from its pivot than the turning force of the smaller gear wheel acting on its own pivot



Two gears will rotate in opposite directions. A larger gear will have a larger moment

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