Moments, Levers and Gears Notes

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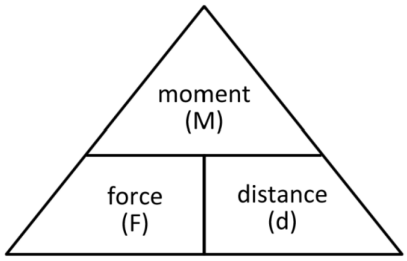
Moments, levers and gears is a lovely topic 😊 with some lovely straight forward calculations. But, what is a moment?

A moment: a turning force about a pivot. "About" means that the force turns around the pivot.
A moment is calculated using the following equation:



Moment = force × distance

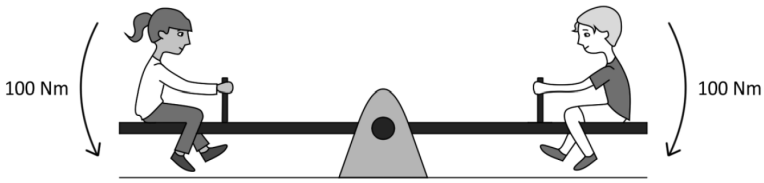
M = F × d

The unit of moments is Newton-metres written as Nm.

M = moment (Nm)	**F** = Force (N)	**D** = perpendicular distance from the pivot (m).

The principle of moments: states that the clockwise moment is equal to the anti-clockwise moment in a balanced system. This means that **if** the moment turning left is the same size as the moment turning right then the system will be perfectly balanced and won't move. Check out the diagram below to see what I mean.

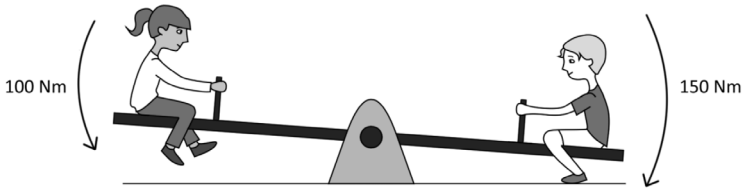
Just to remind you that a system in physics is an object or group of objects that you are dealing with.



As you can see the system (in this case the seesaw and children) is balanced.
This is because the clockwise moment and anticlockwise moment are equal to each other.

As the system is balanced and there is no resultant moment so no movement.
In a question you could see the phrase "**the system is in equilibrium**" this is just another way of saying that the system is perfectly **balanced** so the moments are equal and opposite.

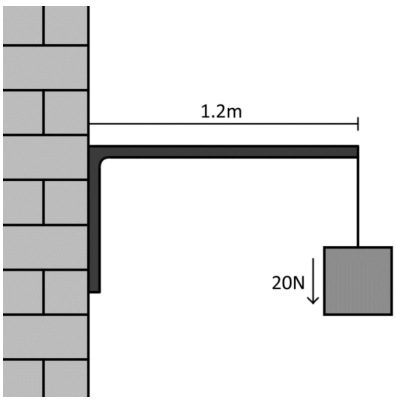
If one of the moments is larger than the other then there will be a resultant moment. So there will be movement.



As you can see the system here is unbalanced.
This is because the clockwise moment is greater than the anticlockwise moment. Therefore there is a resultant force.

Let's look at some example questions and calculations involving moments.

Example 1: The figure below shows a lamp hanging from a metal bracket that is secured to a wall. The lamp is 1.2 m from the wall and has a weight of 20 N. Calculate the moment of the lamp.

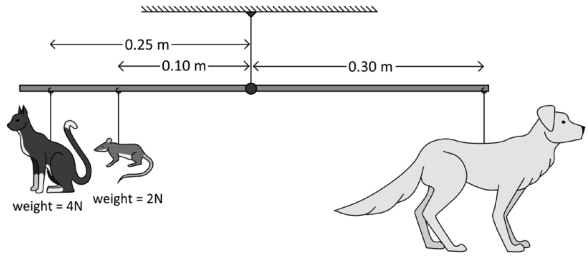


Moment = force × distance

Moment = 20 N × 1.2 m

Moment = 24 Nm

Example 2: The figure below shows three card animals hanging from a child's toy. The child's toy hangs from a supporting arm and a string is attached to the centre of the toy. The system is balanced.
Use the principle of moments to determine the weight of the dog.



Step 1: find the moment of each card and add them together to get the total anticlockwise moment.

Moment of cat	Moment of mouse
Moment = weight × distance	Moment = weight × distance
Moment = 4 N × 0.25 m	Moment = 2 N × 0.10 m
Moment = 1 Nm	Moment = 0.2 Nm

Total anticlockwise moment = 1 Nm + 0.2 Nm

Total anticlockwise moment = 1.2 Nm

Note: As the system is balanced the anticlockwise moment is equal to the clockwise moment. We now know the moment of the dog card. All we need to do now is find its weight 😊

Step 2: Calculate the weight of the dog card.

Weight = moment ÷ distance

Weight = 1.2 Nm ÷ 0.30 m

Weight = **4 N**

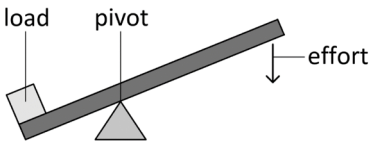
That's it 😊 Moments are lovely 😊

Just make sure you learn the equation and are comfortable rearranging it.

Levers

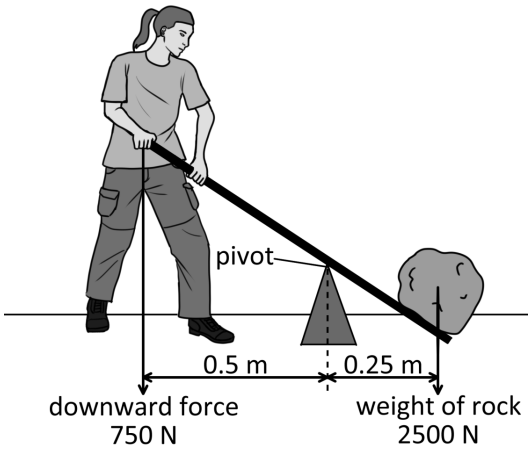
What is a lever? A lever is anything that can cause a moment when a force is applied to it. The most common levers are simple levers such as a stick or metal bar. A simple lever needs to have three things in order to work.

1. **An effort** – this is the force that we apply to the lever to try to move an object.
2. **A pivot** – this is the point around which the lever will turn to move the object.
3. **A load** – this is the force that the lever is trying to move.



Questions involving levers work in the same way as moment problems and the same equation is used to solve both. Check out the example of a typical exam style question below. Levers are force multipliers 😊

Example 3: Show via calculations that the person cannot lift the stone with the force that they are applying.



Moment of person = force × distance

Moment of person = 750 N × 0.5 m

Moment of person = 375 Nm

Moment of the stone = force × distance

Moment of the stone = 2500 N × 0.25 m

Moment of the stone = 625 Nm

The person **is not able to move the stone** as they have a **moment that is less than the stone**.

Gears

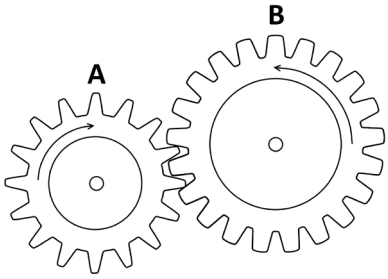
What is a gear? A gear is a tool that allows a turning effect to be transmitted.

What's quite cool about gears is that they act as force multipliers 😊 If a small gear drives (turns) a larger gear, the larger gear will turn slower, but it will produce a greater moment (turning effect).

But, how does it create a greater moment? This is pretty cool! Where the teeth of the two gears meet, they push against each other. According to Newton's Third Law, the force acting on the teeth is exactly the same for both gears.

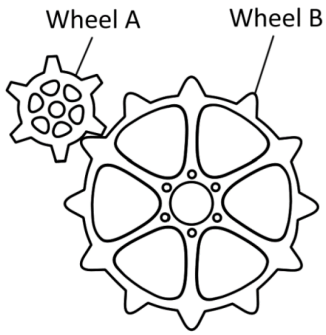
But, the larger gear has a much larger radius. This means the force is acting at a greater distance from the pivot. Remember that **moment** = **Force** × **distance**, having the same force but a bigger distance creates a much bigger moment! 😊 I hope that helps!

The figure below shows two typical gears.



As gear A turns it causes gear B to turn. Where the gears meet, the teeth of each gear both move in the same direction. In the diagram, the teeth of both gears move to the right. This means that the gears will rotate in opposite directions. The force acting on the teeth will be the same for both gears, but their moments are different as the distances from the pivot is different for each gear. Let's look at a couple of typical exam style questions 😊

Example 4: Wheel A is turned clockwise. Which statement explains how these gears transmit forces?



A Wheel B has a bigger rotational effect and turns more quickly than wheel A.

B Wheel B has a bigger rotational effect and turns more slowly than wheel A.

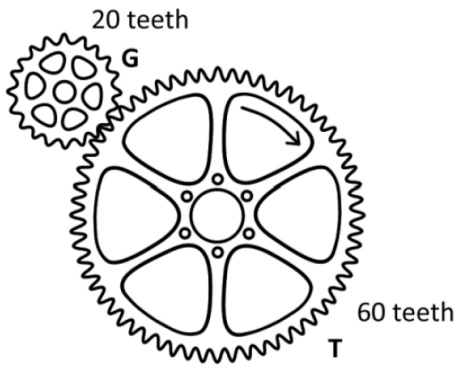
C Wheel B has a smaller rotational effect and turns more quickly than wheel A.

D Wheel B has a smaller rotational effect and turns more slowly than wheel A

Yes the correct answer is **B** 😊

Example 5: the figure below shows part of the gear system of a child's toy. Gear wheel T rotates clockwise at a rate of 1.0 complete rotation per minute.

Calculate the rotation rate of gear wheel G in complete rotations in **one** hour.



These questions can look a bit scary but gears are just circles 😊
The same maths that comes into circles can be used here. But we haven't been given a radius or diameter so that's a good clue that we don't need to use these in this question. This is a **ratio problem** 😊

Ratio of G : T = 20 : 60 This simplifies to 1 : 3

This means that **G** does 3 rotations for each rotation of **T**.
If **T** does 1 rotation a min then **G** does 3.

3 × 60 mins = **180** rotations in one hour.