Moment and Torque

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Learning Outcome

I highly recommend you to finish this checklist to determine whether you've achieved the learning objectives.

- ☐ Define and apply the *moment*[1] of a force and the *torque of a couple*[2]
- ☐ State and apply the principle of moments
- ☐ Use the idea that, when there is no resultant force and no resultant torque, a system is in equilibrium.

[1] def:
[2] def:

Leadin

Sometimes there is no resultant force acting on the object while the object are still experiencing another type of motion - **Rotation**, what are the rationales behind it?

Figure 1: Torque sensor in the steering wheel

Moment of a force

The kinematics that has been studies before is actually *Translation*, there is also another branch in motional states - *Rotation*, which is the *turning effect* of forces. In IGCSE coursebook, a new physical quantity is introduced to quantify the turning effect. It's Moment (of force)

Definition 0.1 *Moment of a force is the product of the magnitude of the force and the perpendicular distance of the pivot*[3] *from the line of action of the force.*

[3] def:

If expressed in vector product, it is the cross product of the force and the vector from the pivot to the point of action of the force.

$$\text{moment} = \vec{F} \times \vec{d} = F \cdot d \cdot \sin\theta_{(F,d)} \tag{1}$$

Task

Determine the SI base unit of moment.

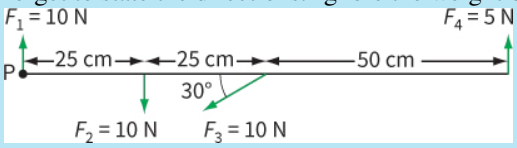
You might find that the base unit of moment is exactly the same as that of joule(J), but the two things are completely different, we do not have a special name for N m, this unit can not be changed into joule because of the **Vector** nature of moment[4]. Simply put, if the moment tend to turn object clockwise or anticlockwise. That would be the direction of moment[5]. And sometimes for convenience, we can define anticlockwise as postive.

[4] the direction of moment actually comes from the rule of cross product, if you want to dig more into it, search right hand rule or refer to my handout-vectors

[5] Not physically well defined

Task

Determine the moment of each force about point A, and don not forget to state the directions. Ignore the weight of the balance.



Principle of Moments

If multiple forces actig on the same object, the resultant moment can be calculated easily by the *principle of moments*, it states as following:

Definition 0.2 *For any object, the resultant moment about the one point equals to the sum of the anticlockwise moments provided by the forces acting on the object minus the sum of the clockwise moments about that same point.*

Task

Determine the resutlant moment of the forces acting on point A

what if the pivot now changed to point B, determine the resultant moment.

Torque of Couple

A *couple* consist of two forces with the following characteristic

- equal in magnitude
- parallel, but opposite in direction
- separated by a distance d

The turning effect or moment of a couple is known as its *torque*

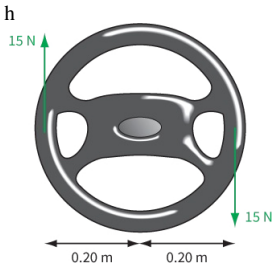


Figure 2: a couple of forces

Example

Calculate the torque of the couple in the steering wheel.

$$\begin{aligned} \text{torque} &= (15 \times 0.2) + (15 \times 0.2) \\ \text{or} &= 15 \times 0.4 \\ &= 6\,\text{N m} \end{aligned}$$

Because the forces form a couple must have same _____ and _____ direction, and usually, the pivot is right in the middle of their seperation[6], the torque is twice the moment of the single force. thus:

[6] actually the pivot could be somewhere else while the torque can still be the same

torque of a couple = one of the forces × perpendicular distance between the forces

And also, do not forget to specify the direction of the torque, clockwise or anticlockwise.

Condition for Static Equilibrium

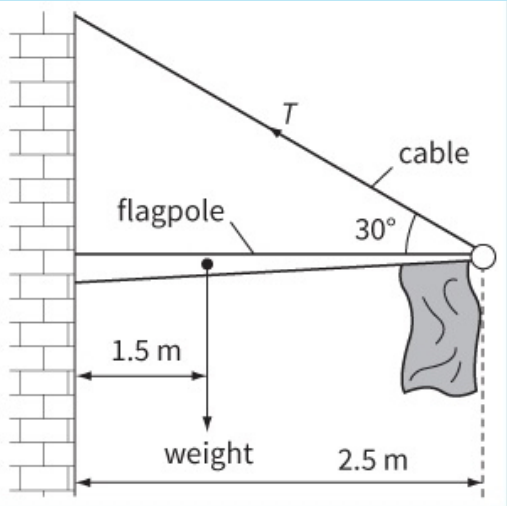
If we say a body is in static equilibrium, that means:

1. the object has no translation
2. the object has no rotation

considering the dynamics reasons behind motion, the conditions for object to be in static equilibrium are summarised below:

1. The resultant force acting on the object is zero.
2. The resultant moment(including torque) is zero.

Task



A flagpole of mass 25 kg is held in a horizontal position by a cable as shown. The centre of gravity of the flagpole is at a distance of 1.5 m from the fixed end.

(a). Write an equation to represent taking moments about the left-hand end of the flagpole. Use your equation to find the tension T in the cable.

(b). Determine the vertical component of the force at the left-hand end of the flagpole.