Chapter 8:Torque

Lecture 1

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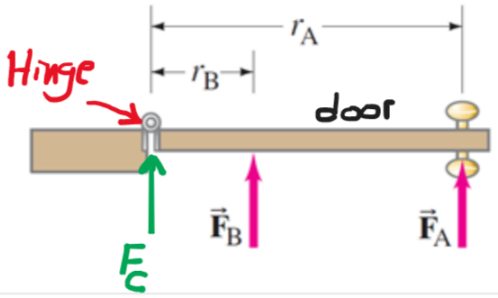
8-4] Torque :

Ability to cause rotation about an axis.



When you apply a force far from the rotation axis (F_A) it is easy to open the door.

rotational motion.

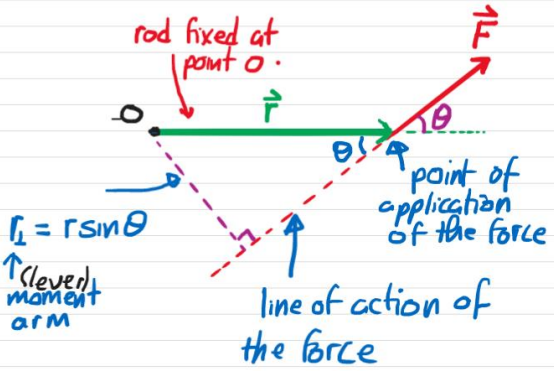
Applying a force close to the rotation axis it is difficult to open the door.

Note: the rotation axis passes through the hing and is perpendicular to the plane of the page.

Can you open the door by applying force $\vec{F}_2$ at the rotation axis? NO.

O: point of rotation (rotation axis is perpendicular to the page and passes through point 'O'.)

θ: smaller angle between $\vec{r}$ and $\vec{F}$ when both vectors originate from the same point.



$\tau = rF\sin\theta$

$\vec{r}$: a vector that extends from point "O" to the point of application of the force.

$r_\perp$: moment arm which is the perpendicular distance from point 'O' to the line of action of the force.

Clearly, $\vec{F}$ causes the rod to rotate about point 'O' in a counterclock wise direction. The ability of $\vec{F}$ to cause rotation is called Torque (τ).

Defining torque:

$$\tau = r F \sin\theta \quad (m \cdot N)$$

$\tau = 0$ if

i) $\theta = 0$

ii) $\theta = 180°$

In both cases the line of action of the force passes through the rotation point.

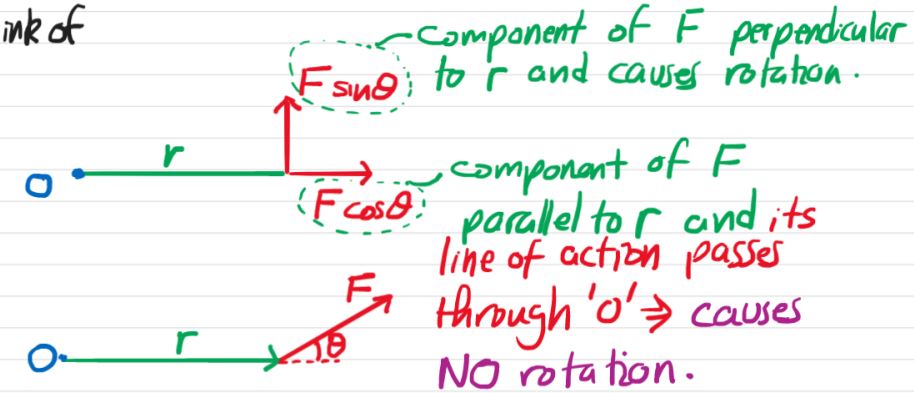
iii) $r = 0$

As in (i) and (ii) this means F or its line of action pass through the rotation point.

Note Two ways to think of torque.

① $\tau = r(F\sin\theta)$

Resolve F into components but don't resolve r

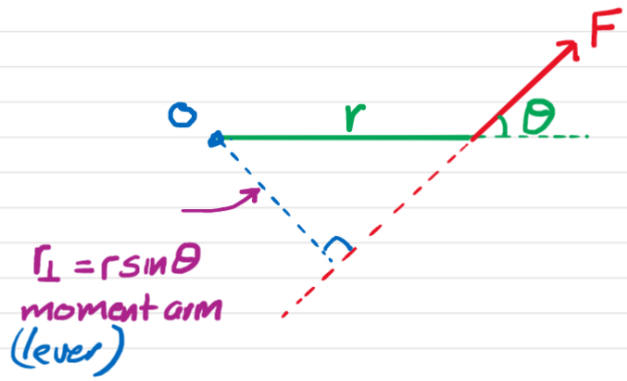


② $\tau = (r\sin\theta)F$

$= r_\perp F$

↑ moment arm. (lever arm)

Resolve r but dont resolve F.



BOTH WAYS GIVE THE SAME ANSWER.

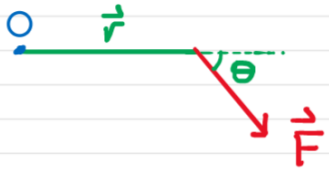
Convention for the sign of torque.

Counterclockwise rotation ⇒ positive torque

F causes the rod to rotate in counterclockwise

Colockwise rotation ⇒ negative torque.

F causes the rod to rotate in clockwise direction.



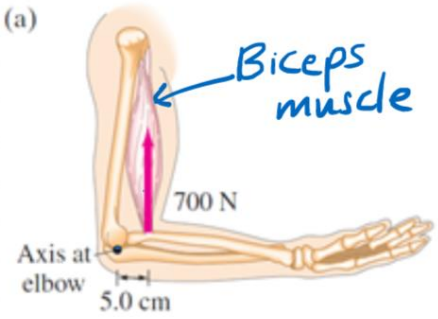
Torque is involved in so many of our body activities, for example:

- raising and lowering your forearm.
- raising and lowering your arm.
- nodding your head forward and backward.
- moving your lower jaw while speaking.
- motion of your fingers

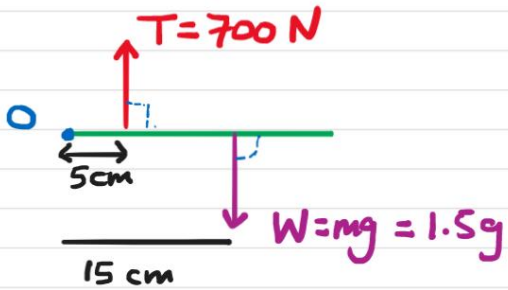
etc....

Example

Biceps torque. The biceps muscle exerts a vertical force on the lower arm, bent as shown in the figure, calculate thetorque about the axis of rotation through the elbow joint, assuming the muscle is attached 5.0 cm from the elbow as shown. Also find the torque of the weight of the lower arm (forearm)



Torque of the Biceps musk



+↻ O) torque about 'O' counterclockwise as positive

$\tau = r F \sin 90^\circ$

$\tau_T = (0.05)(700)(1)$

$= 35$ N.m (positive since T causes the forearm to rotate about the elbow in a counterclockwise direction.

+↺ O) $\tau_{mg} = -mg(0.15)\sin 90^\circ$

$= -(1.5 \times 10)(0.15)$

$= -2.25$ N.m

↑ since mg rotates the arm in the clockwise direction.

$W = Fd$

$\vec{\tau} = \vec{r} \times \vec{F}$ ↑ vector , $W = \vec{F} \cdot \vec{d}$ ↑ scalar

Find the net torque about point 'O'.

$\tau_{net} = \tau_T + \tau_{mg} = 35 + (-2.25) = 32.75$ N.m .

72%

∴ Forearm rotates counterclockwise.

$\tau = rF\sin\theta$

for fixed r and F when do we have τ_{max}? when $\sin\theta = 1$

$\Rightarrow \theta = 90^\circ$