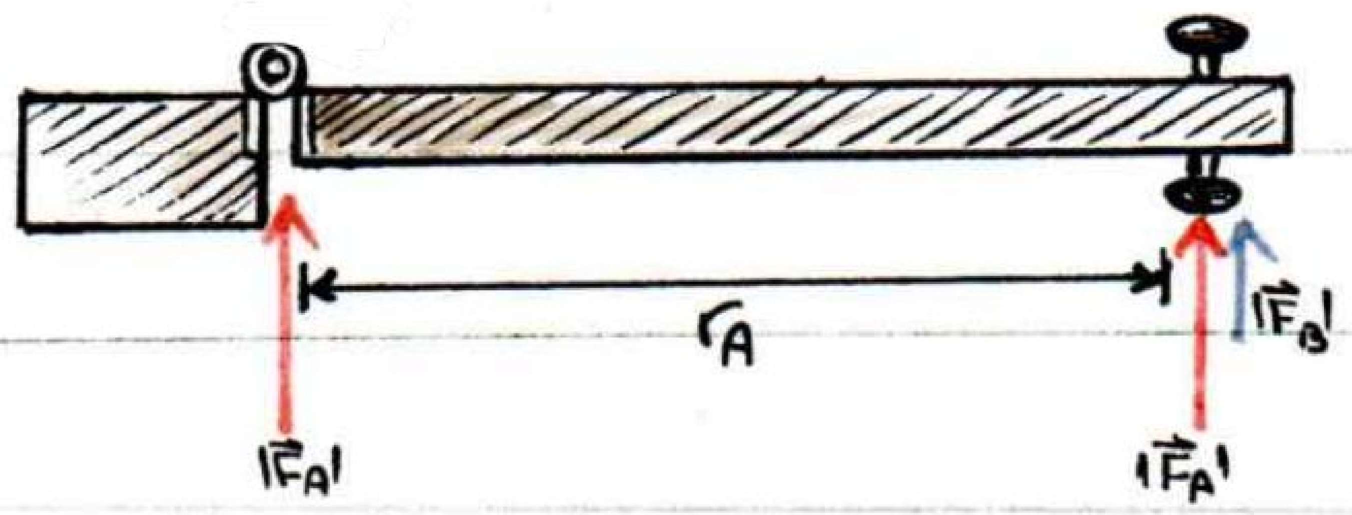
8-4 Torque:

* To make an object start rotating about an axis clearly requires a **Force**, but its direction and where it is applied are important.
e.g. In this overhead view of the door, if you apply a force $\vec{F}_A$:-
a) Perpendicular to the door on the handle
- the greater $|\vec{F}_A|$ the more quickly it opens.

b) Perpendicular to the door on the hinge
- the door Will NOT open.



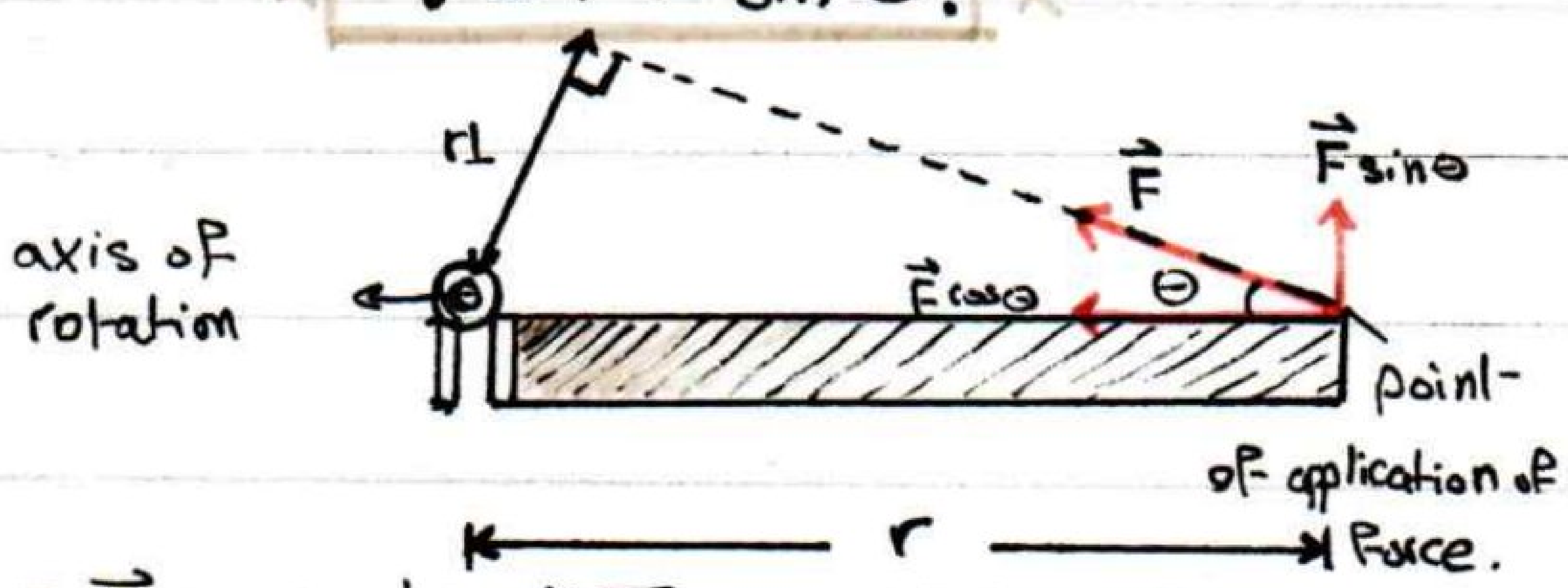
* You can see that even if $|\vec{F}_A|$ is the same and $\theta = 90^\circ$ (here) but the distances are different, the ability to cause rotation will differ too.

* If you repeat this experiment without changing the distance and θ remains 90° too, but decrease $|\vec{F}_A|$ to the half $\rightarrow |\vec{F}_B|$ you will see that the ability to cause rotation differs too. (The angular $\vec{a}$ will be half of the first experiment).

* We call the ability to cause rotation about an axis: the **torque**, or we can say it is the moment of the force about the axis.

* Moment arm (lever arm): the perpendicular distance from the axis of rotation to the line along which the force acts. ($r\perp$).
(that is the distance which is perpendicular both to the axis of rotation and to an imaginary line drawn along the diretion of the force.) → because we must take into account the effect of forces acting at an angle.
So if a force applied at an θ, torque will be less. In general, we can write this formula:

$$\boxed{\tau = r F \sin\theta.}$$



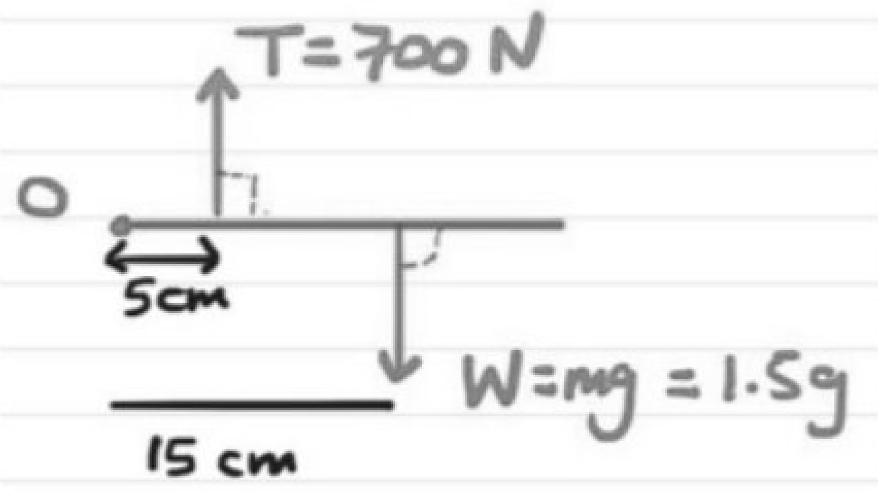
* $\vec{F}\cos\theta$ does NOT cause rotation because its line of action passes through the axis of rotation, but $\vec{F}\sin\theta$ causes rotation. or
$\left[\sin\theta = \frac{r_\perp}{r} \rightarrow r_\perp = r\sin\theta\right]$ *

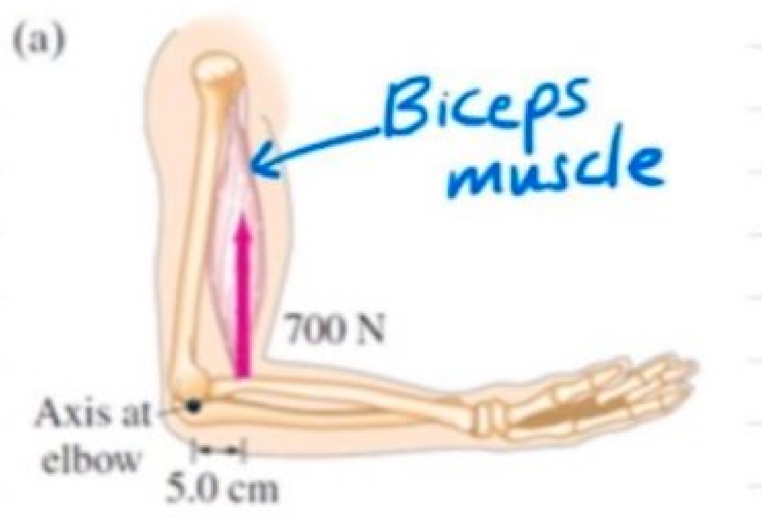
* (+) torque → Counterclockwise rotation.
(−) torque → clockwise rotation.

* Torque is measured in units of (m.N) in SI units.

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)





$\overset{+}{\circlearrowleft}$ torque about 'O' counterclockwise as positive

$$\tau_T = r\overset{F}{T}\sin 90^\circ$$
$$= (0.05)(700)(1)$$

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

$\overset{+}{\circlearrowleft}$ $\tau_{mg} = -\overset{F}{mg}(0.15)\sin 90^\circ$
$= -(1.5\times10)(0.15)$
$= -2.25$ 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 .

∴ Forearm rotates counterclockwise .

$\tau = rF\sin\theta$

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

$\Rightarrow \theta = 90^\circ$