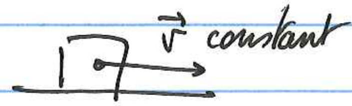
PHYS 107 - Week 08 - Wednesday

* Static equilibrium : constant velocity (dynamic equilibrium)
or special case : zero velocity (static equilibrium)

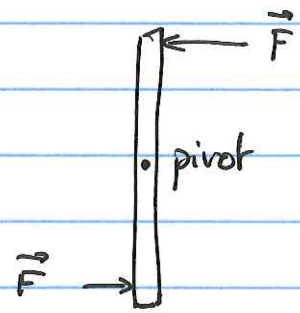


dynamic equilibrium — static equilibrium

→ no acceleration → net force is zero, $\vec{F}_{net} = \vec{0}$

But, does $\vec{F}_{net} = 0$ automatically also mean equilibrium?

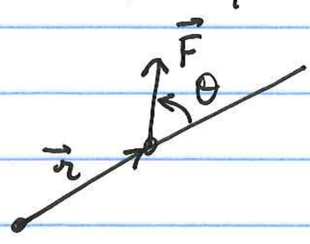
Consider



→ $\vec{F}_{net} = 0$, $\vec{a} = 0$
but the object will start to rotate → not in equilibrium!

It matters <u>where</u> the force applies!

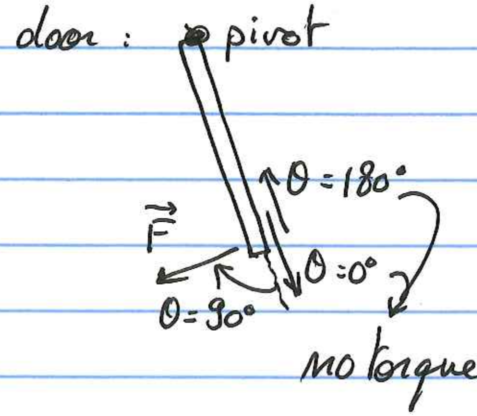
* Torque of a force {about / around} a pivot point



$\tau = r F \sin\theta$ (units: N·m)
r = distance from the pivot to where the force is applied
θ = angle between $\vec{r}$ and $\vec{F}$

* Dependence on angle θ:

$\theta = 90° \rightarrow \tau$ is maximal
$\theta = 0°$ or $180° \rightarrow \tau$ is minimal



τ is technically a vector quantity
→ sign is important
+ for CCW
− for CW

* Theorem for zero torque

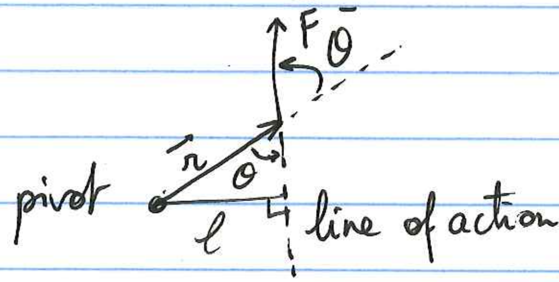
If $\tau_{net} = 0$ around one point of a rigid object,
then $\tau_{net} = 0$ around any point of the rigid object.

↳ you can pick the most convenient pivot point,
just like choosing coordinate system origin.

* Condition for equilibrium:

If $\vec{F}_{net} = 0$ and $\tau_{net} = 0$
then $\vec{a} = 0$ and no rotation, and the object
will be in equilibrium

* Other geometric interpretations of the definition of torque



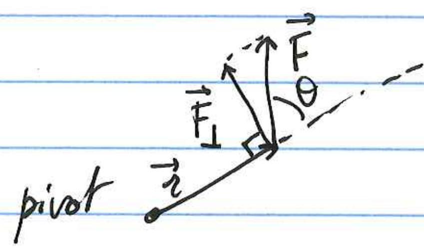
l = distance of pivot point to the line of action

$l = r \sin\theta$

$\downarrow$

$\tau = F \cdot l = F r \sin\theta$

= product of force and distance from pivot point to line of action



$F_\perp$ = component of the force perpendicular to the line from pivot point to where F is applied $= F \sin\theta$

$\longrightarrow \tau = F_\perp r = F r \sin\theta$

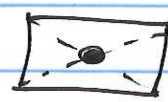
= product of perpendicular component of the force with distance to pivot point.

Q Equilibrium 1, ~~a~~ b – c

* Where do forces apply exactly?

Weight / gravity of extended object is an extended force: applies to all "atoms". But which point moves with acceleration $\vec{a} = \frac{\vec{F}_{net}}{m}$?

$$\vec{r}_{CM} = \frac{\vec{r}_1 m_1 + \vec{r}_2 m_2 + \cdots}{m_1 + m_2 + \cdots}$$

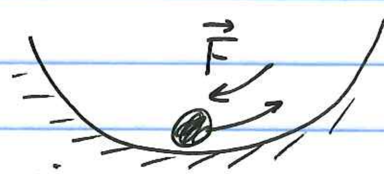
→ center of mass : 

 (CM can be outside object)

Demo: throwing hammer with LED

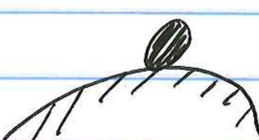
* Stability of equilibrium :

Stable equilibrium :



small changes in position from the equilibrium will result in a restoring force that brings the system back to the equilibrium

Unstable equilibrium :



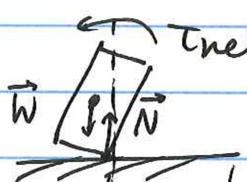
small changes result in force removing from equilibrium

Neutral equilibrium : small displacement have no effect

* Conditions for stability under gravity

if CM is over the area of contact → stable

$\tau_{net} = 0$
<u>stable</u>



restoring to equilibrium

$\tau_{net} = 0$
unstable

small displacement will result in τ_{net} that brings object further away from equilibrium

Lower CM → need larger angle before stability is lost → more stable

Larger area of support → more stable

* Problems with equilibruim

1) $\vec{F}_{net} = 0$ and $\tau_{net} = 0$
2) determine unknown force using these equations

Q Equilibruim 3 a-b