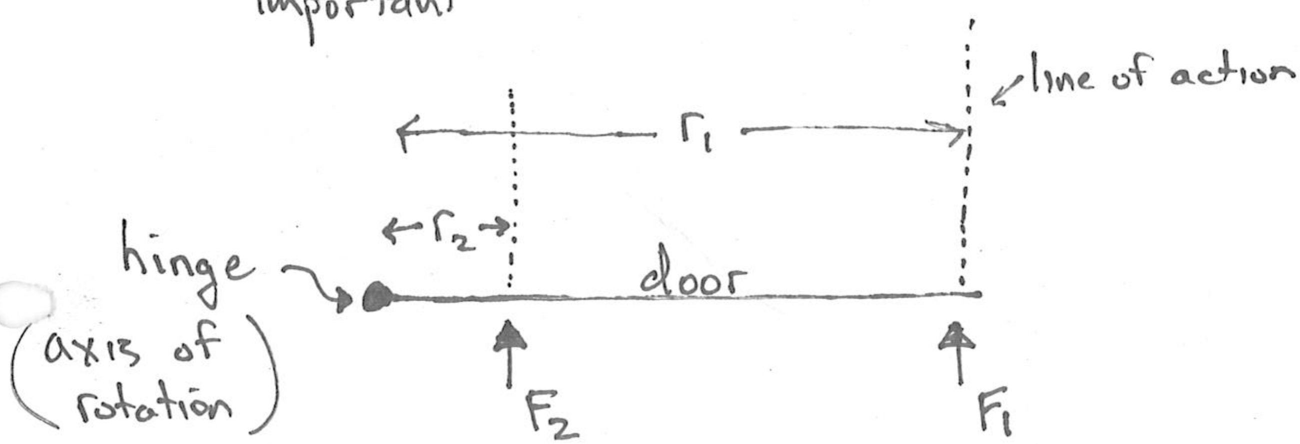
Rotational Equilibrium

Torque

To make an object start rotating about an axis requires a force. But the direction of this force and where it is applied, are also important



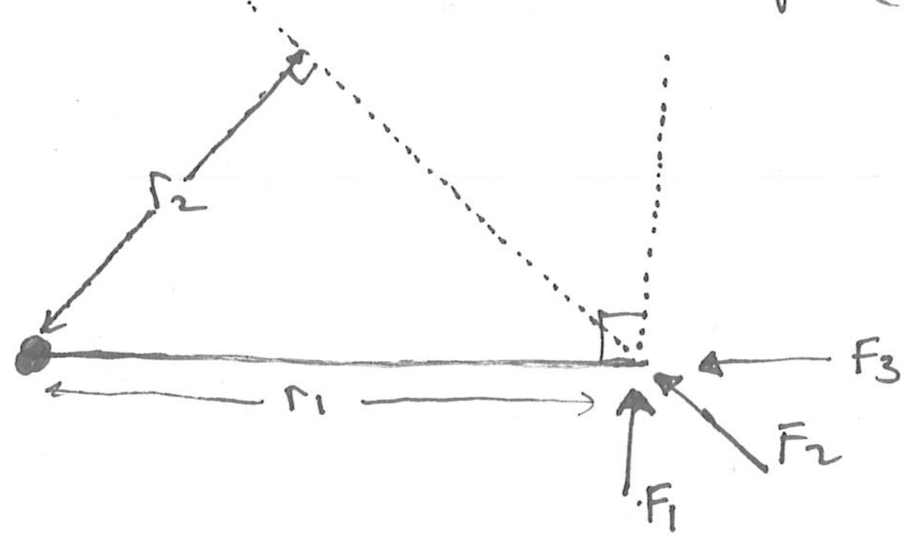
r = lever arm → which is the perpendicular distance to the axis of rotation from the line of action of the force.

Applying a force at F_1 opens the door → the greater the force the faster the door opens. Applying the same force at F_2 and the door is slower to open → the effect of the force is less (torque)

So the angular acceleration (aa) of the door is proportional to; 1) the magnitude of the force

2) the perpendicular ($\perp$) distance from the axis of rotation to the line which the force acts

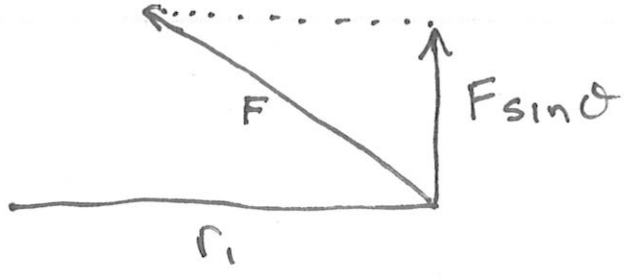
so $aa \propto r_\perp F$ = torque (τ)



Applying a Force at F_1 produces more torque then at F_2 because $r_1 > r_2$

Applying a force at F_3 results in no torque (or aa) because the force is in the same direction as the lever arm (ie there is no $\perp$ component of the force)

The force at F_2 can be broken down into a y-component that is ⊥ to the lever arm



$$\tau = r F_{\perp}$$

Since $F \sin\theta$ is ⊥ to the lever arm

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

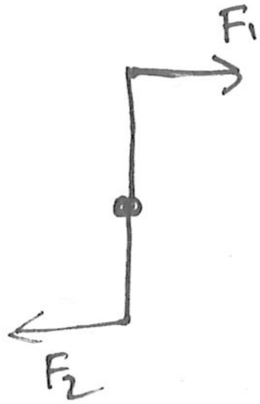
The unit for torque is the N·m – the <u>same</u> unit as energy but energy is scaler and torque is a vector so oddly they may share the same unit they <u>are not</u> the same → Do not use the Joule ($1 J = 1 N \cdot m$) to express torque

$W = Fd$ F is in same direction as d

$\tau = F_{\perp} r$ F is ⊥ to r

The direction of torque is either clockwise or counter-clockwise (around the point of rotation)

When more than one torque acts on a body, the acceleration is found to be proportional to the net torque

1) 

When all torques acting on a object tend to rotate in the same direction

$$\tau_{net} = \tau_1 + \tau_2$$

2) 

When torques tend to rotate in opposite directions then

$$\tau_{net} = \tau_1 - \tau_2$$

(pick either clockwise or counter-clockwise to be the positive direction)

In (1) the vector sum of the forces $= 0$ but this object will still move (rotate)

In (2) Net force will make this object accelerate $(F = ma)$