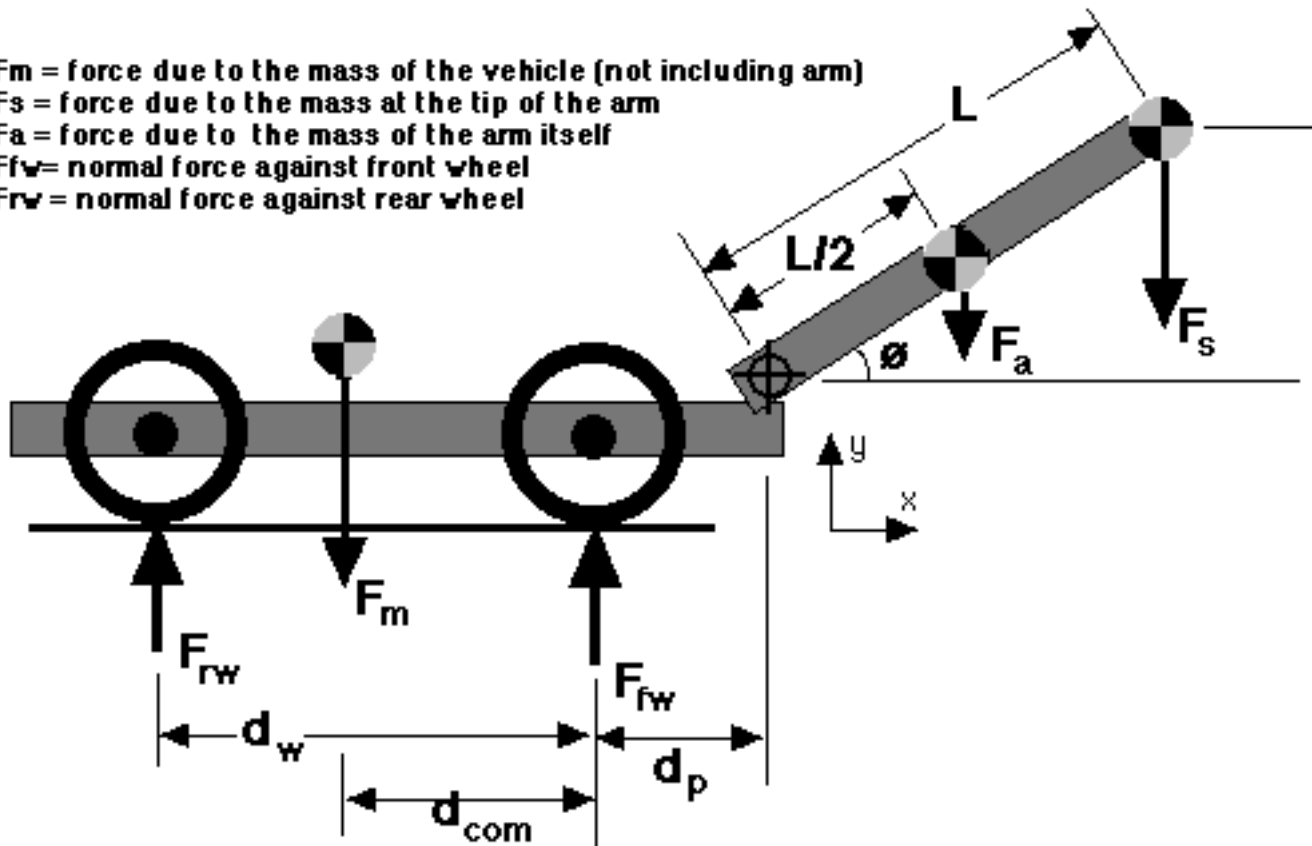


Balance

Balancing a Machine with an Arm

F_m = force due to the mass of the vehicle (not including arm)
 F_s = force due to the mass at the tip of the arm
 F_a = force due to the mass of the arm itself
 F_{fw} = normal force against front wheel
 F_{rw} = normal force against rear wheel



d_{com} = distance from com to front wheel
 d_p = distance from pivot point to front wheel
 d_w = wheel base
 L = length of arm

$$\sum F_y = 0: F_{rw} + F_{fw} - F_a - F_S - F_m = 0$$

$$\sum M_{fw} = 0: F_{rw}d_w - F_m d_{com} + F_a \left(\frac{L}{2} \cos \theta + d_p \right) + F_S (L \cos \theta + d_p) = 0$$

$$\rightarrow F_{rw} = \frac{F_m d_{com} - F_a \left(\frac{L}{2} \cos \theta + d_p \right) - F_S (L \cos \theta + d_p)}{d_w}$$

$$\rightarrow F_{fw} = \frac{F_m (d_w - d_{com}) + F_a \left(d_w + d_p + \frac{L}{2} \cos \theta \right) + F_S (d_w + d_p + L \cos \theta)}{d_w}$$

Tipping of the machine occurs at the maximum load $F_S = F_{S,max}$ when $F_{rw} = 0$:

$$F_{rw} = 0: \frac{F_m d_{com} - F_a \left(\frac{L}{2} \cos \theta + d_p \right) - F_{S,max} (L \cos \theta + d_p)}{d_w} = 0$$

$$\rightarrow F_{S,max} = \frac{F_m d_{com} - F_a \left(\frac{L}{2} \cos \theta + d_p \right)}{L \cos \theta + d_p}$$

What can be done to maximize the load at which the machine starts to tip?

- Increase the weight and hence the gravitational force of the machine
 - Moving the center of gravity away from the front wheels
 - shortening the length of the arm
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