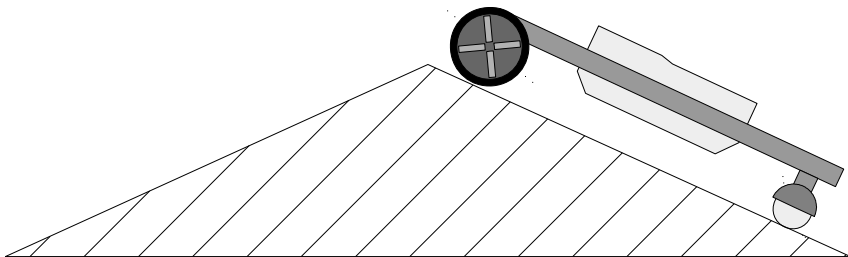




**MINDSTORMS**  
EV3

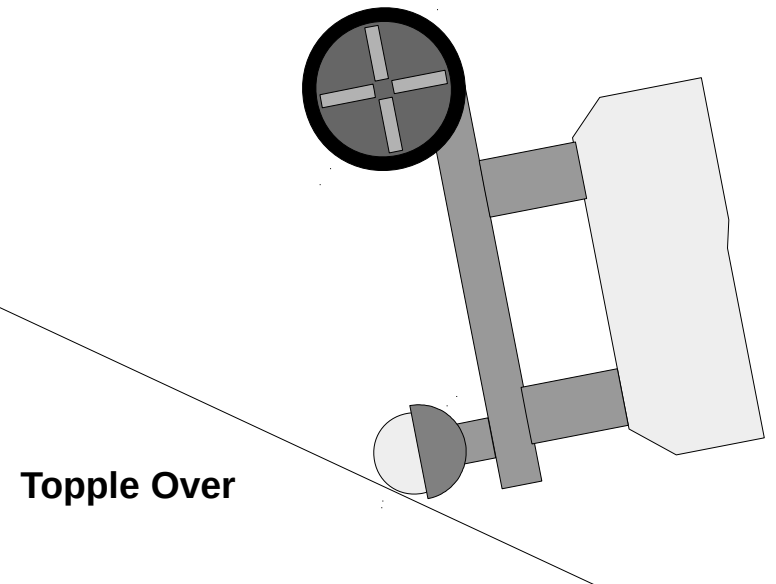
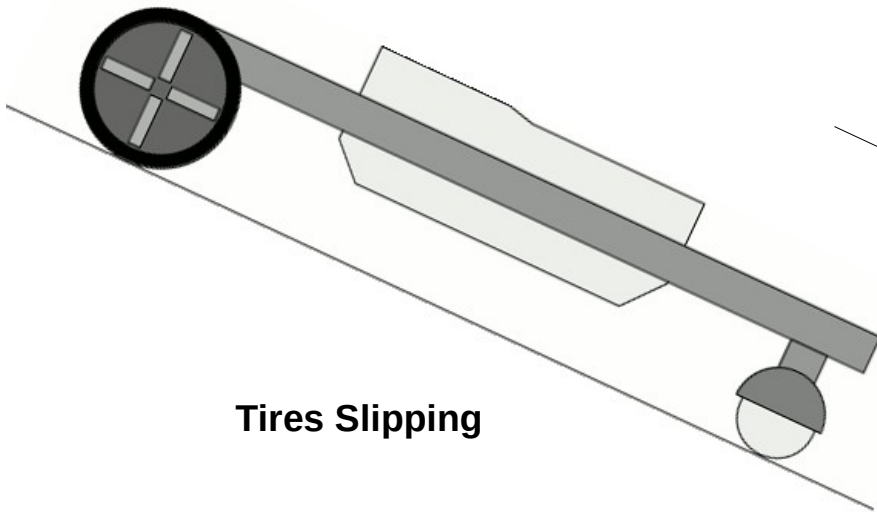
## Handling Inclines



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# Problem

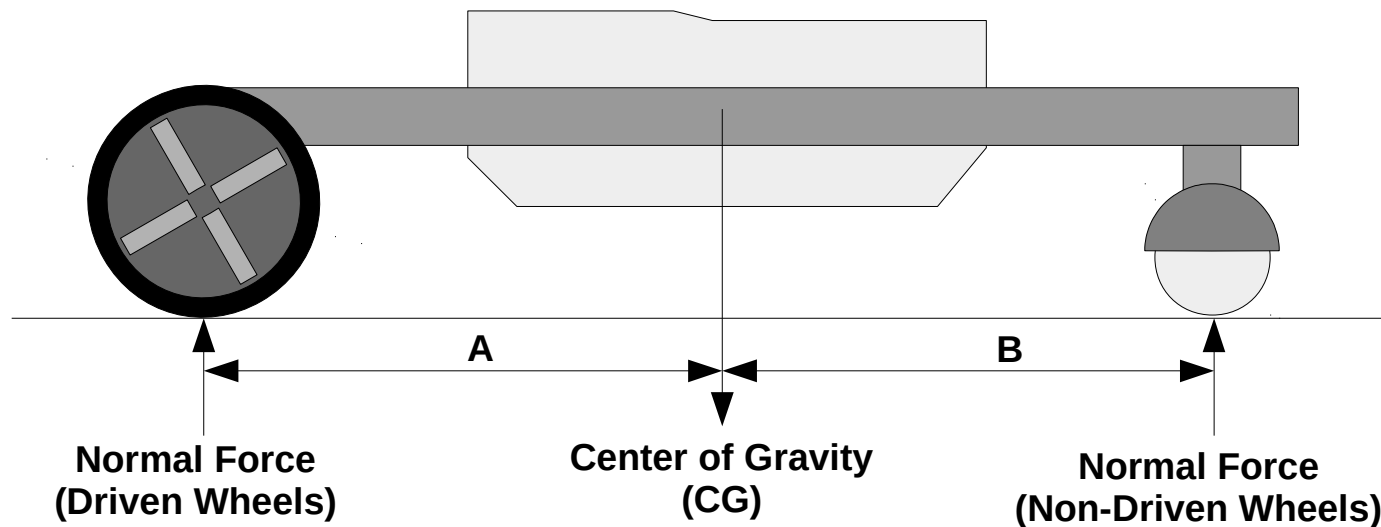
- Harder than it looks!
- Many robots will...
  - Loose traction
  - Topple over





# Flat Ground

- Example (A = B):
  - A = 10cm, B = 10cm, Weight = 1kg



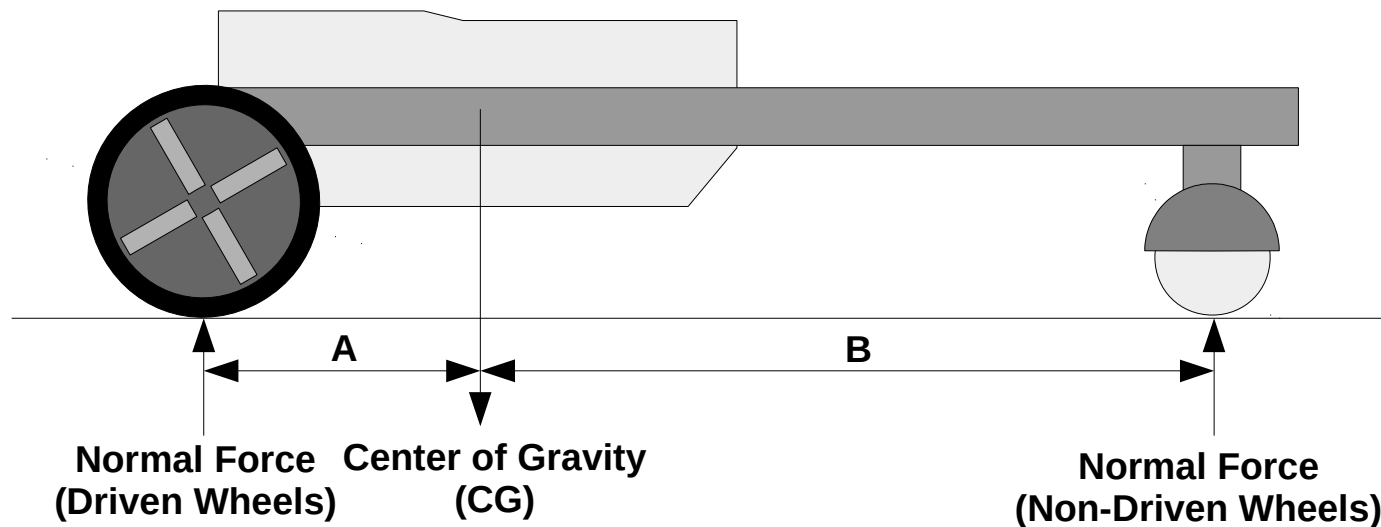
$$\text{Normal Force (Driven)} = \frac{1 \text{ kg} \times 10}{10 + 10} = 0.5 \text{ kg}$$

$$\text{Normal Force (Non-Driven)} = \frac{1 \text{ kg} \times 10}{10 + 10} = 0.5 \text{ kg}$$

- Equal forces on front and rear wheels

# Flat Ground

- Example ( $A < B$ ):
  - $A = 5\text{cm}$ ,  $B = 15\text{cm}$ , Weight =  $1\text{kg}$



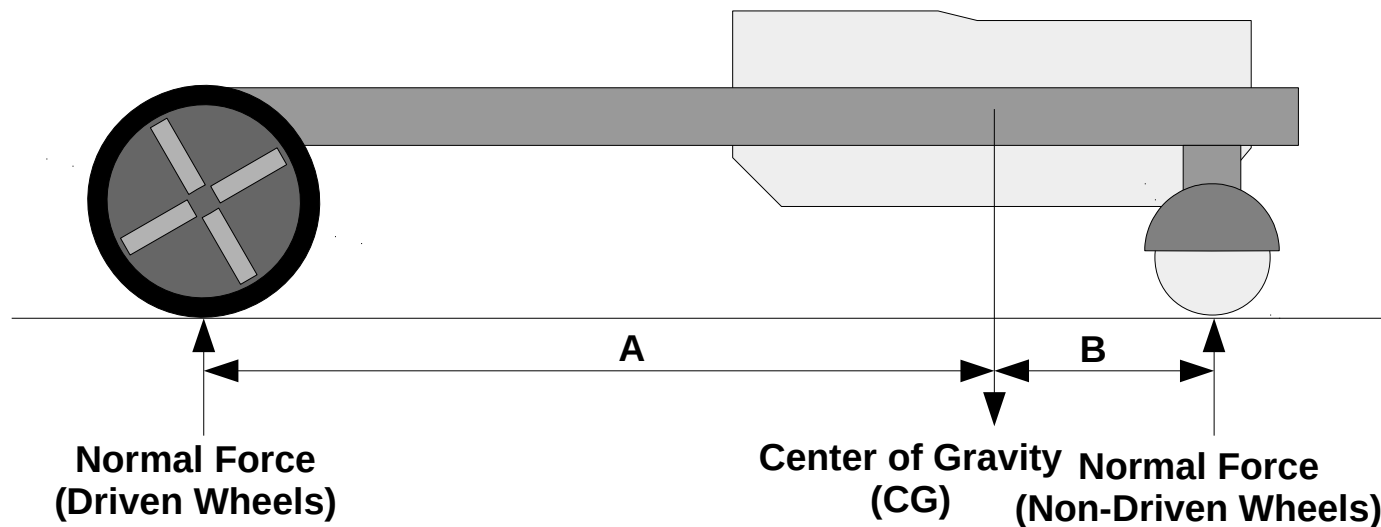
$$\text{Normal Force (Driven)} = \frac{1\text{ kg} \times 15}{5 + 15} = 0.75\text{ kg}$$

$$\text{Normal Force (Non-Driven)} = \frac{1\text{ kg} \times 5}{5 + 15} = 0.25\text{ kg}$$

- Greater force on front wheels (Good Traction)

# Flat Ground

- Example ( $A > B$ ):
  - $A = 15\text{cm}$ ,  $B = 5\text{cm}$ , Weight =  $1\text{kg}$



$$\text{Normal Force (Driven)} = \frac{1\text{ kg} \times 5}{5 + 15} = 0.25\text{ kg}$$

$$\text{Normal Force (Non-Driven)} = \frac{1\text{ kg} \times 15}{5 + 15} = 0.75\text{ kg}$$

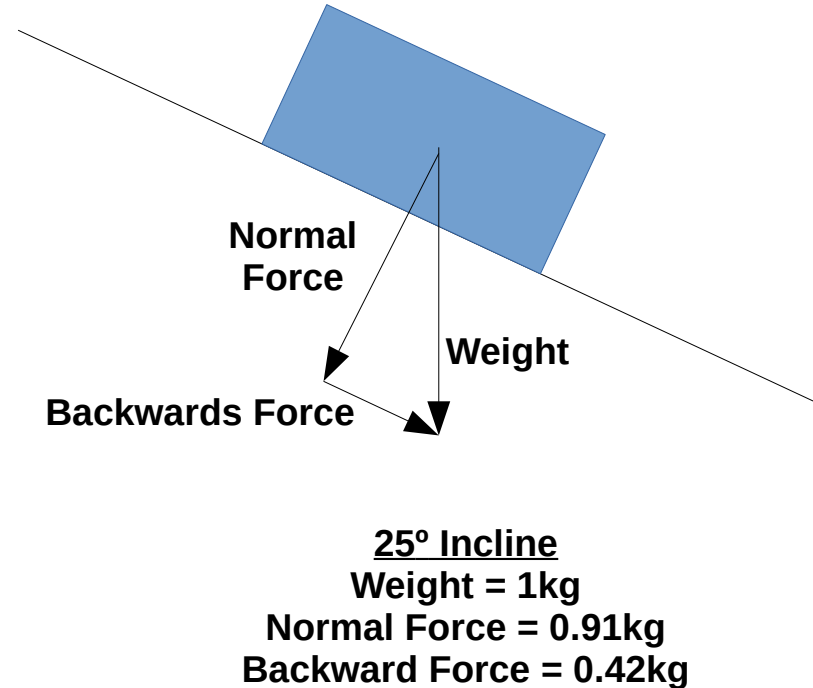
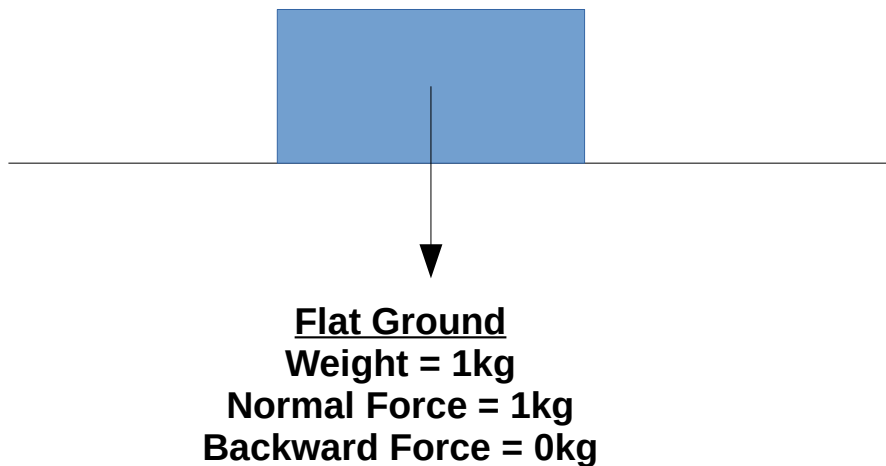
- Lesser force on front wheels (Poor Traction)

# Summary

- Keep your CG close to the driven wheels

# Incline

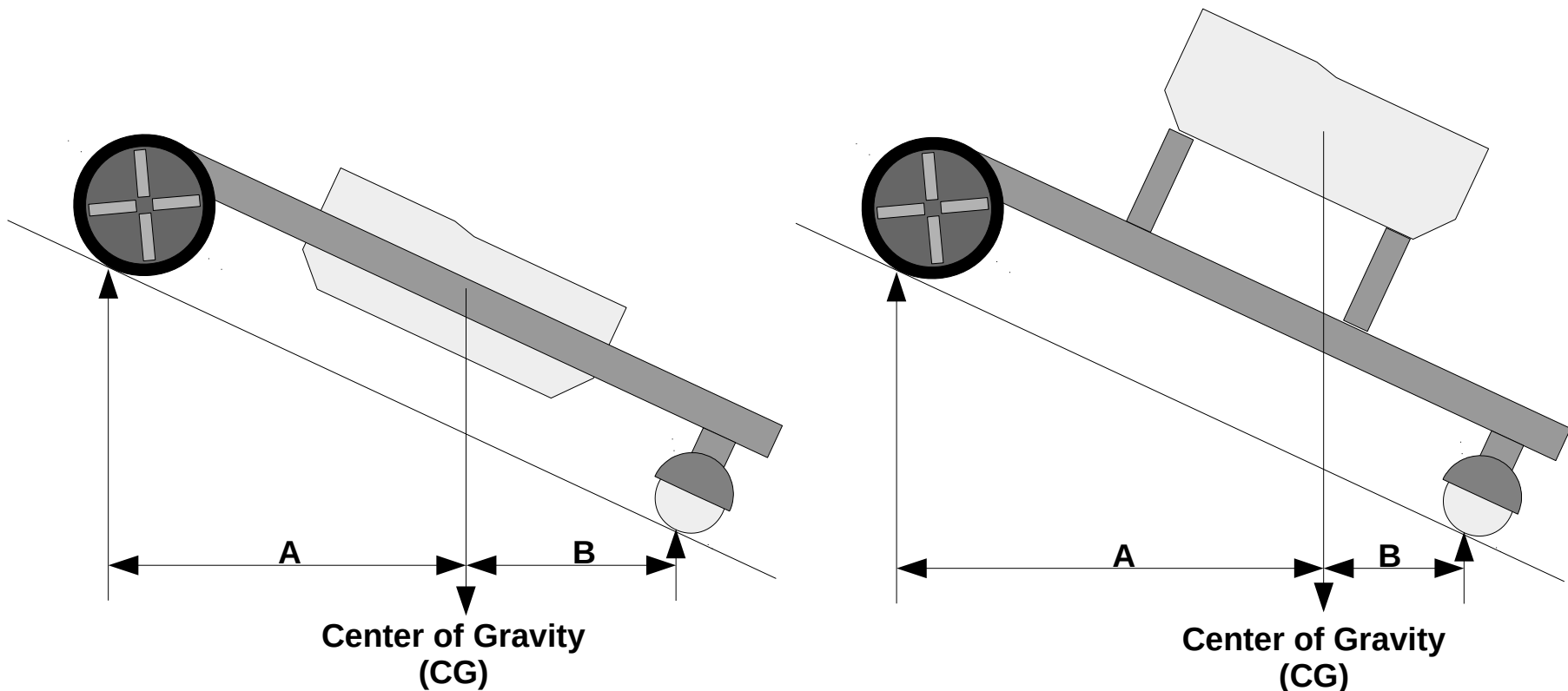
- Normal force reduces (Less traction)
- Gravity pulls robot backwards





# Incline

- Causes CG to move away from front wheels
- Effect is more significant if CG is high

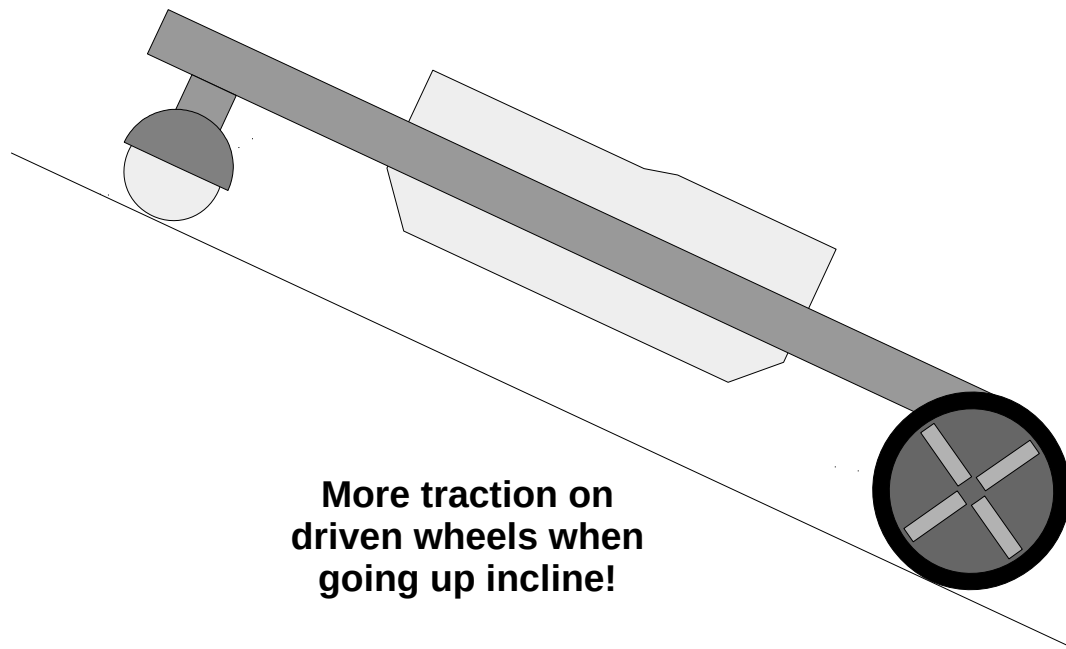


# Summary

- Keep your CG close to the driven wheels
- Keep your CG low

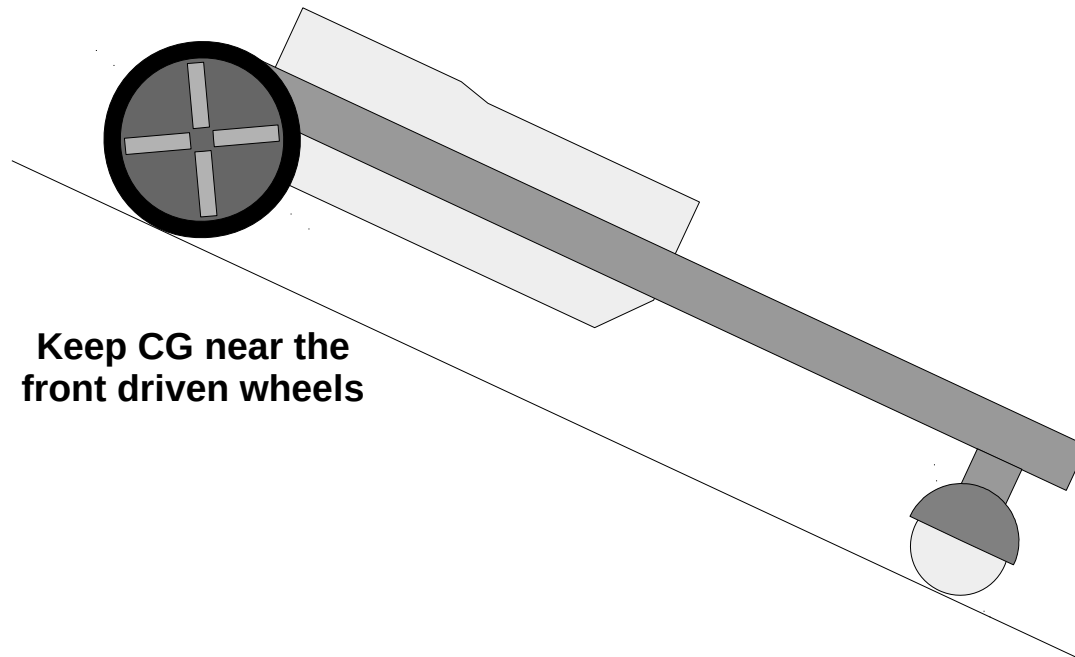
# Solutions

- Put the driven wheels at the back!
- Good for going UP an incline
- What happens when you're going down?



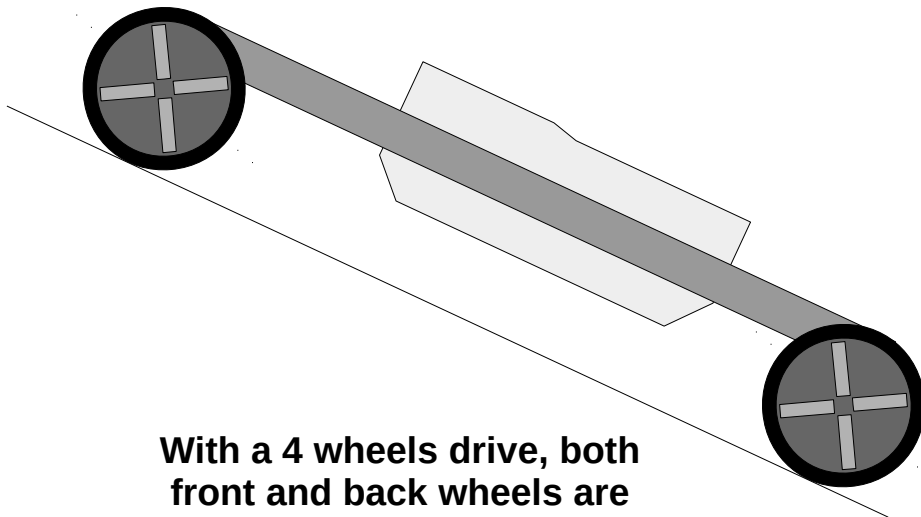
# Solutions

- Put the CG low and near the driven wheels
- Not too low or it won't clear the speed bumps

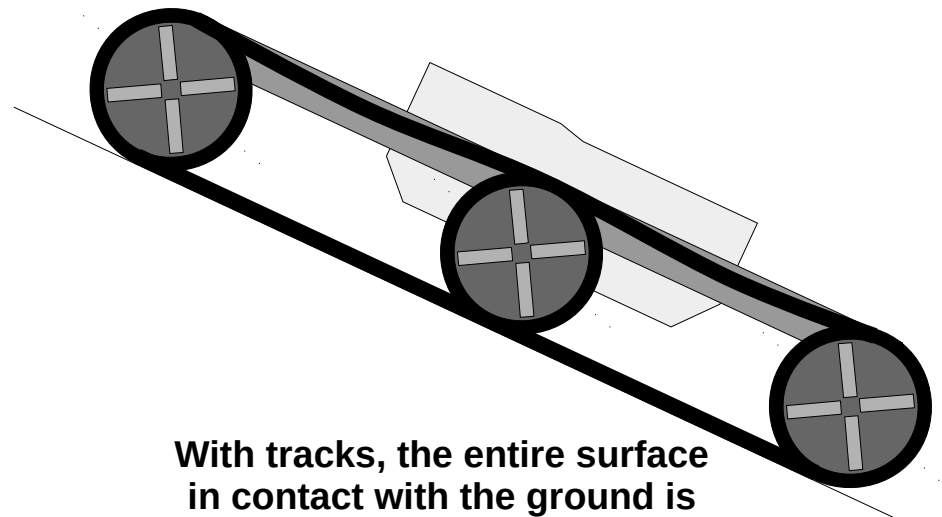


# Solutions

- Use tracks or 4 wheels drive
- Still need to keep CG low to prevent toppling over
- Tends to turn inaccurately



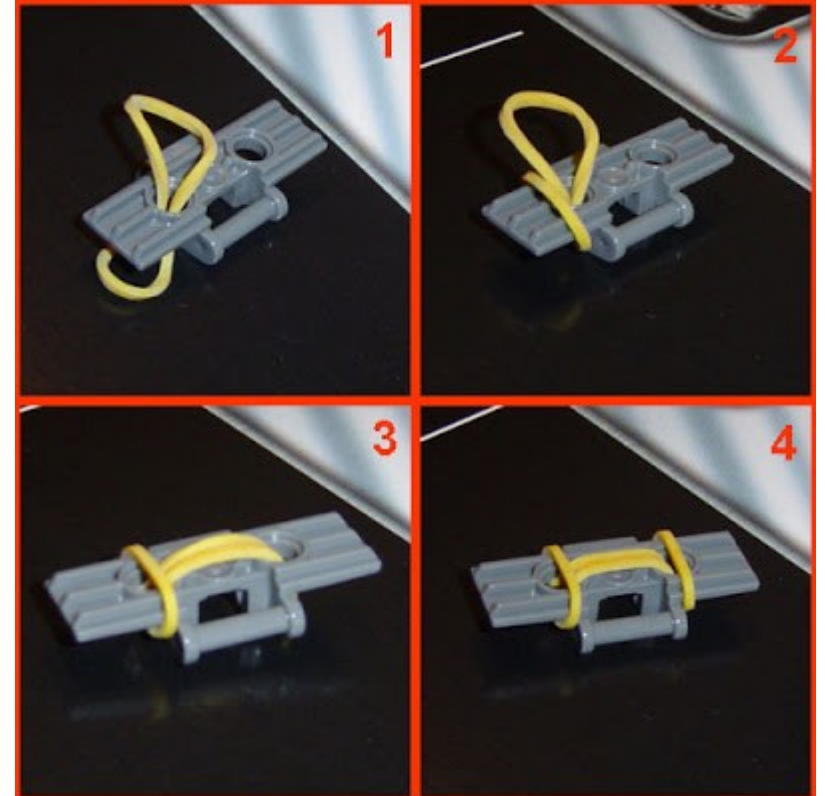
With a 4 wheels drive, both front and back wheels are driven



With tracks, the entire surface in contact with the ground is driven

# Tracks

- Tracks have poor grip
- Rubber inserts helps, but are NOT part of core set and needs to be purchased separately.
- Use rubber bands (small ones!) to improve grip cheaply



Rubber band idea and images credit of  
Fernando Correia of  
<http://www.technicbricks.com/>

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