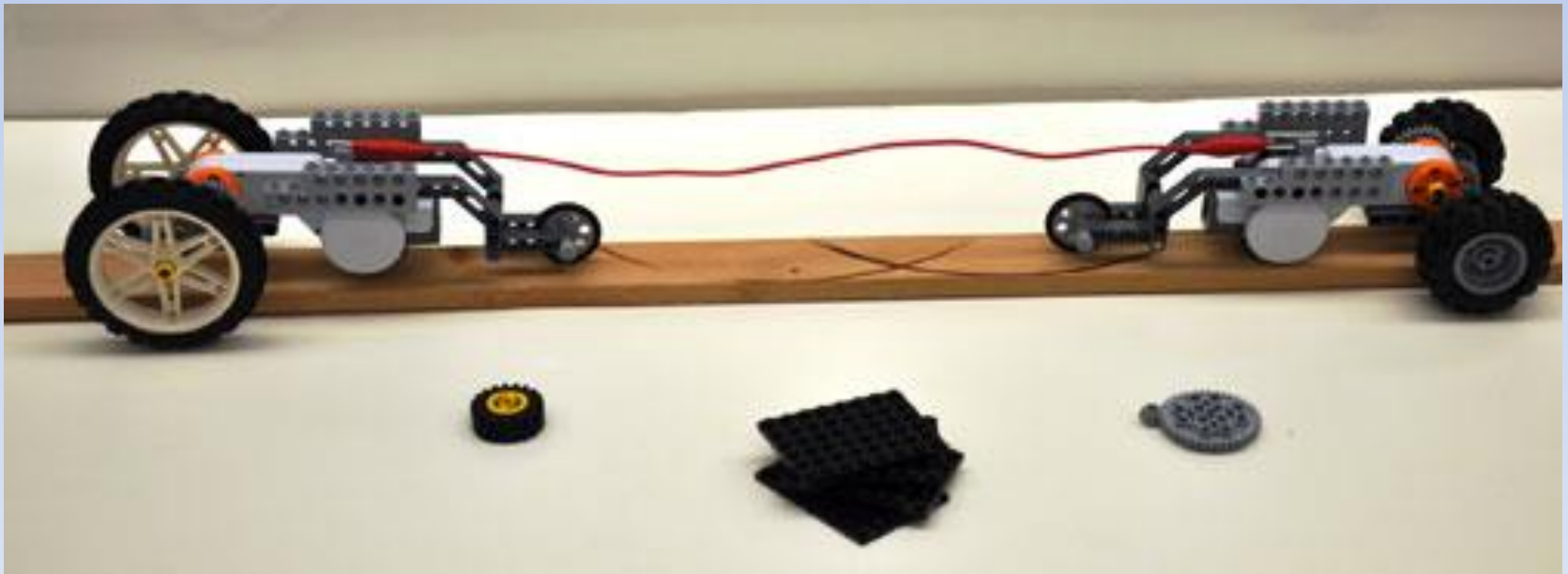


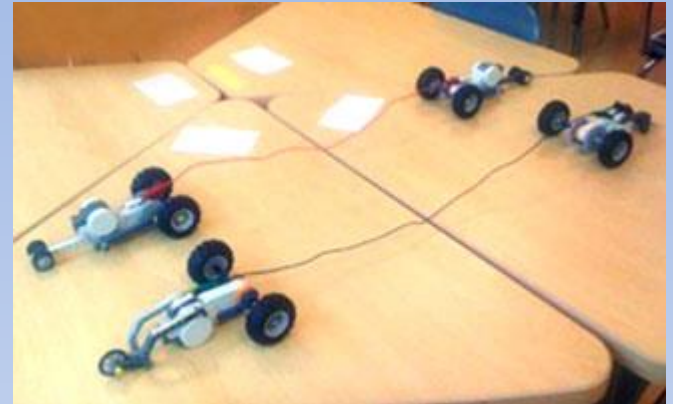


Tug of War Battle Bots



The Challenge

- To **design** a vehicle with maximum pulling power, in order to pull an opponent's robot over the middle line.
- To understand the concepts of **friction**, **torque** and **gear ratio** while playing games.



Battle Bots: The Tug of War Game

- Each team is given an identical robot to modify
- **Modifications:** amount of power provided to motor, robot weight, gear ratio, wheel size
- Each team receives the same amount of points to spend on modifications; every modification costs some points



- After design modifications, tug of war begins
- **Winner:** The robot that wins the game and costs the least

Lego Mechanisms

gears — motors — physics concepts



gear ratio

speed

**force of
friction**

weight

**normal
force**

torque

**applied
force**

Concept of Gear Ratio

2004 Dodge Viper SRT-10



Siromer 204 Tractor



- Sports cars **go FAST** (**have speed**), but **cannot pull** any weight

- Big trucks and tractors **can PULL** heavy loads (**have power**), but **cannot go fast**

Concept of Gear Ratio



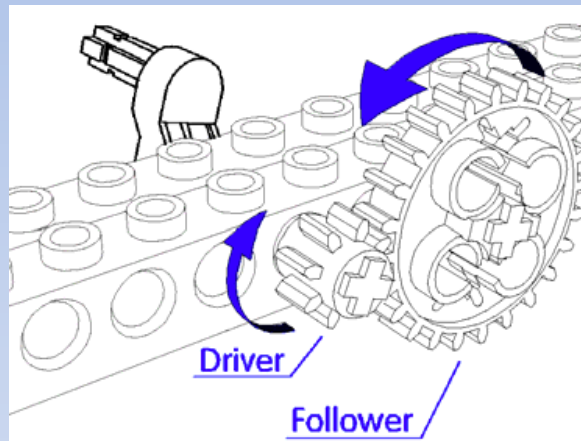
Gears are used for two basic purposes:

- To increase or decrease **rotation speed**
- To increase or decrease **torque**



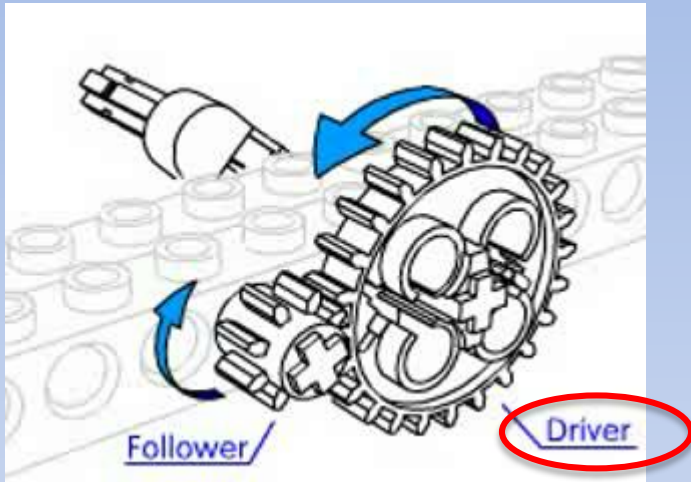
Concept of Gear Ratio

$$\text{Gear ratio} = \frac{\text{\# of teeth on Follower gear}}{\text{\# of teeth on Driver gear}} = \frac{\text{diameter of Follower gear}}{\text{diameter of Driver gear}}$$





- The smaller gear has 13 teeth; the larger gear has 21 teeth
- Therefore, the gear ratio is 21/13 or 1.62/1 or 1.62.1
- In other words, it takes 1.62 revolutions of the smaller wheel to make the larger wheel turn one revolution



Concept of Gear Ratio

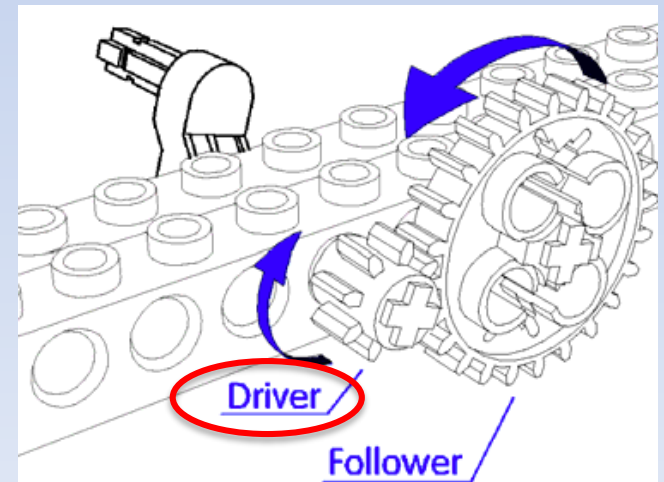


← Gearing up

- LARGE gear drives small gear
- The small gear turns faster
- speed  torque 

Gearing down →

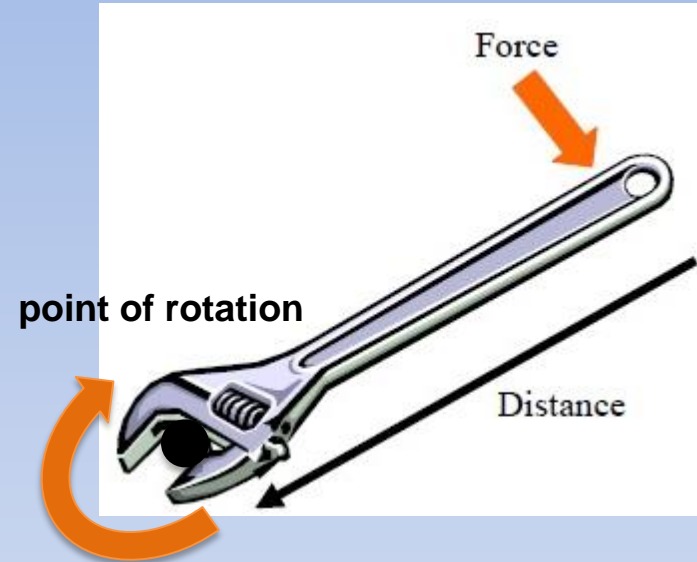
- Small gear drives LARGE gear
- The large gear turns slower
- speed  torque 



Concept of Torque

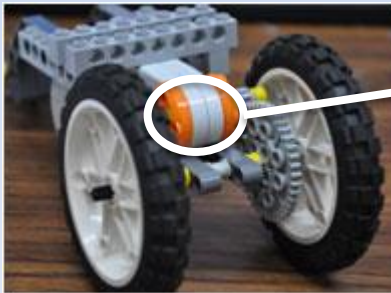
- Torque is an applied force on a lever arm

$$\mathbf{T} = \mathbf{r} \times \mathbf{F}$$



Where is the torque on your robot?

- The motor on your robot uses a set amount of torque to turn the wheels. The driver gear uses torque to turn the follower gear.



Torque Discussed

- Constant torque from the motor (driver gear), for example 25 N-m
- Force exerted at the point of contact between gears is 25 N
- Torque about center of follower gear is 125 N-m

$$\mathbf{T} = \mathbf{r} \times \mathbf{F}$$

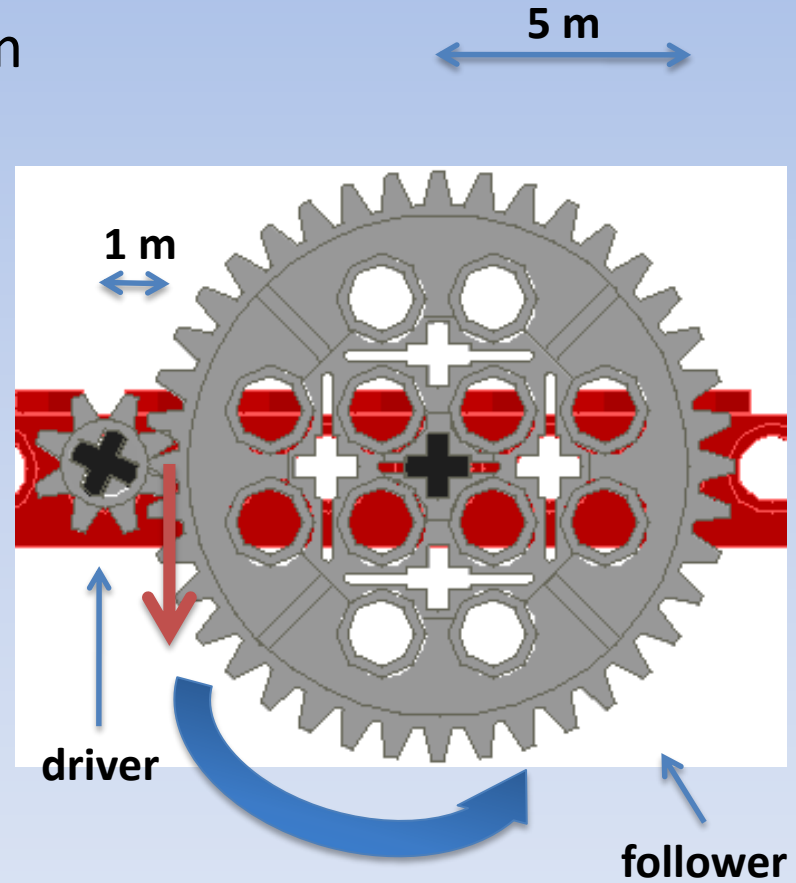
$$25N \cdot m = 1m \times F$$

$$F = 25N$$

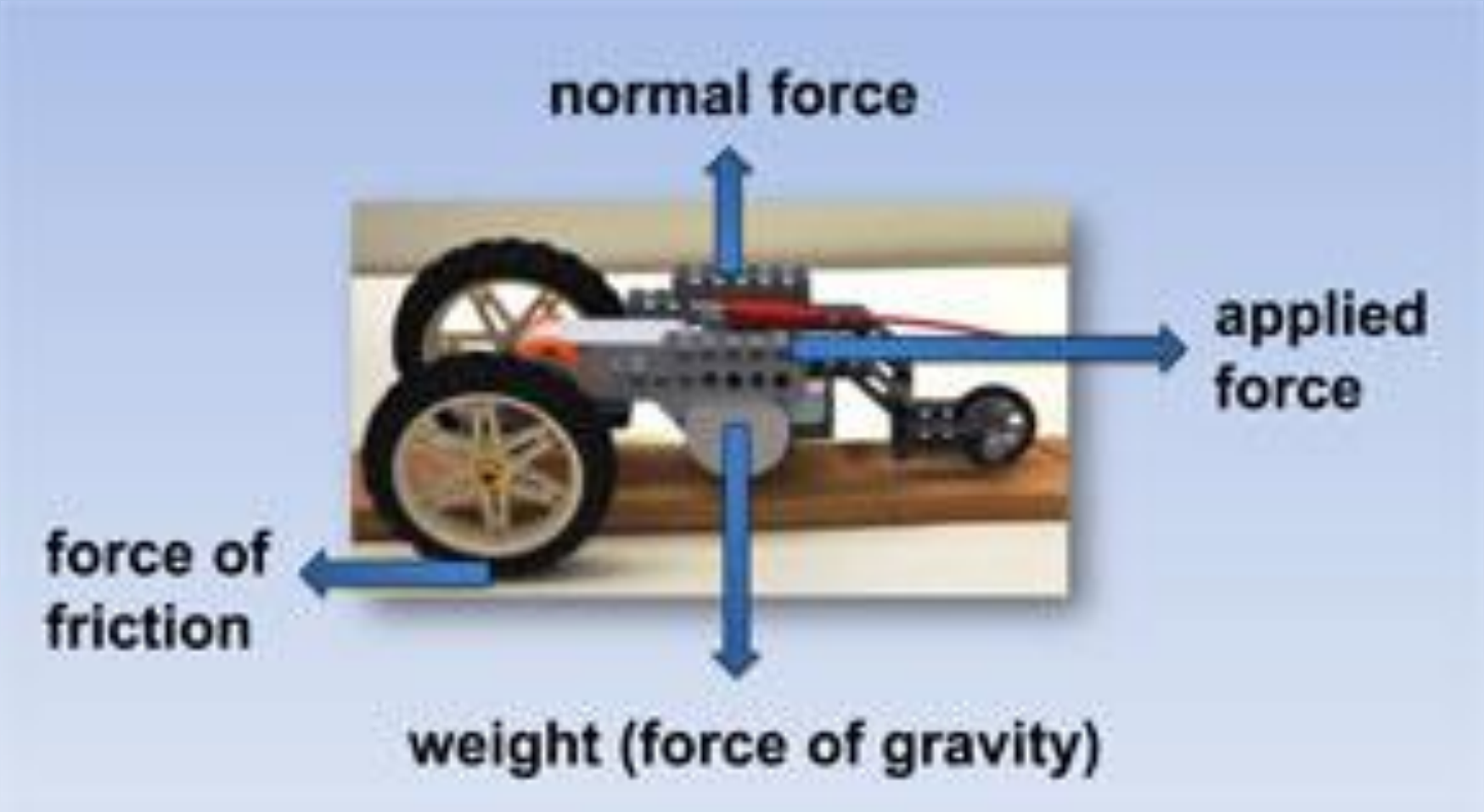
$$T = 5m \times 25N$$

$$T = 125N \cdot m$$

$$T_{out} = G.R. \times T_{driver}$$

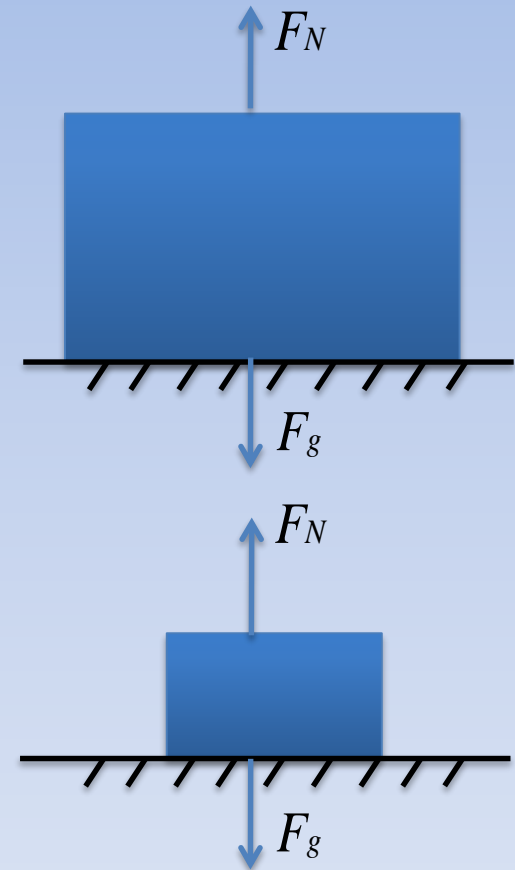


Concept of Force (and Motion)



Concept of Weight and Normal Force

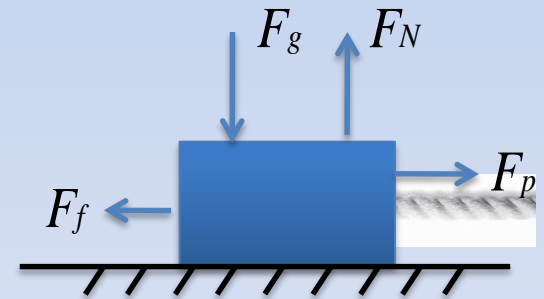
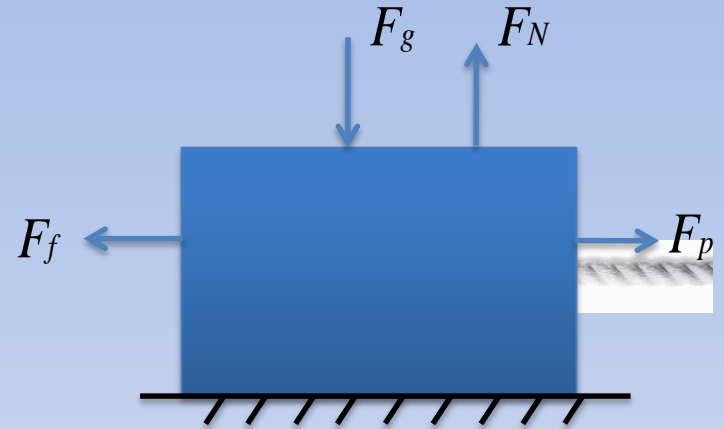
- The weight of an object is not the same as its mass
- The weight is defined as the force exerted by gravity
- For an object to stay on the ground, the force of gravity must be offset by an equal force pushing back—we call this force the **normal force**—the Earth is pushing back against gravity



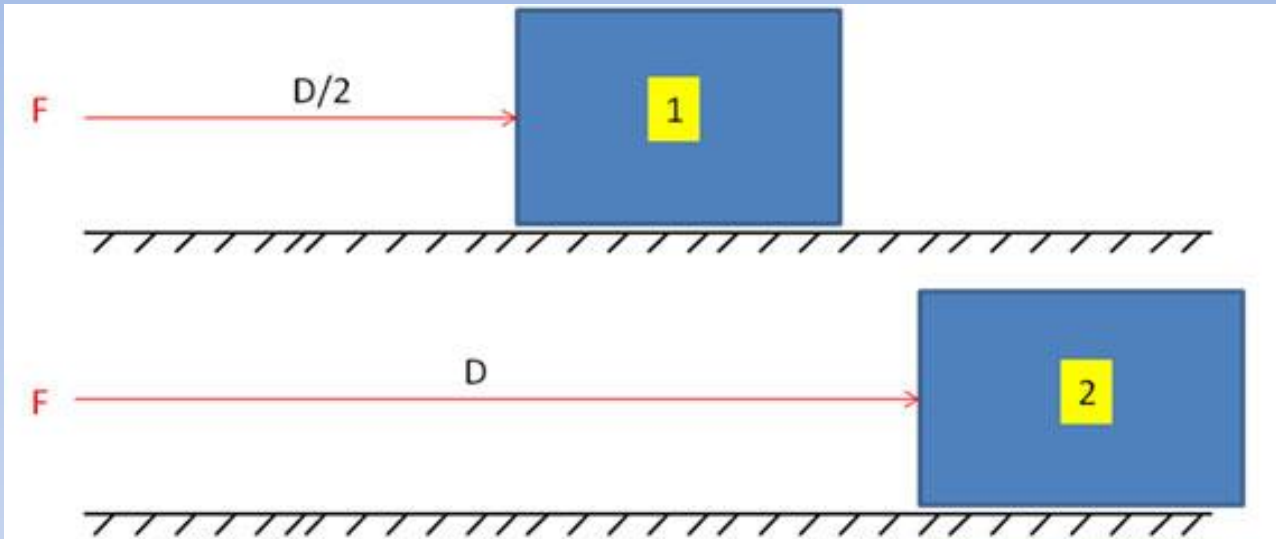
Concept of Force of Friction

- Friction is the resistance encountered by two touching materials
- No contact = no friction
- Something with a lot of weight makes a lot of friction with the surface of the ground

$$F_f = F_N \times \mu$$



Concepts of Work and Power



Work = Force x Distance
Power = Work/Time

Question 1: If both objects move their respective distances with the same exerted force, which one required more work?

Question 2: If both objects moved in the same amount of time as well, which one required more power?

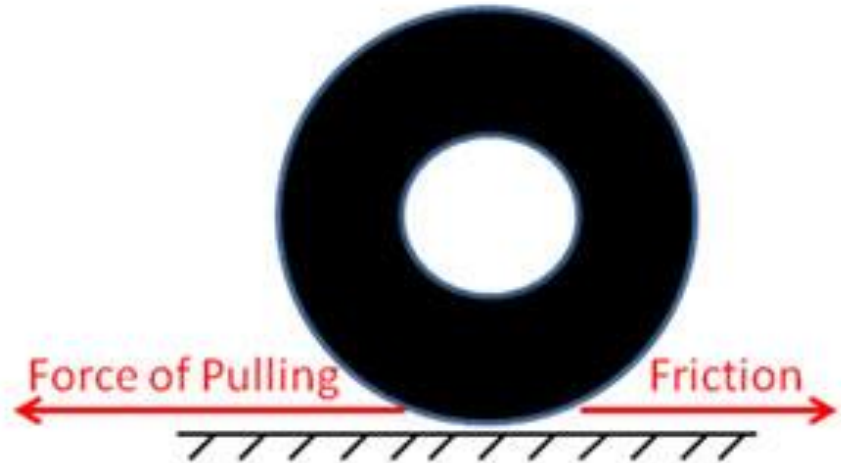
Question 3: If object 2 moved its respective distance in twice the time it took for object 1 to move its respective distance, which object required more power?

Concepts of Work and Power

EV3 Motor



Wheel



For Motors:

Power = Torque x Angular Velocity

When we program the motor, we are providing a value of the percentage of full power it can use.

The wheel diagram shows how torque is applied to the wheel and what forces it encounters.

The Game Rules

- At the start:
 - Each team receives 50 points
 - All robot vehicles come with: **large wheels, 1:1 gear ratio, no added weight, 75 power**
- Point allocation for robot modifications:

Points	Modification
10	Gear ratio change
5	Smaller wheels
2	More motor power
1	One sheet of weight