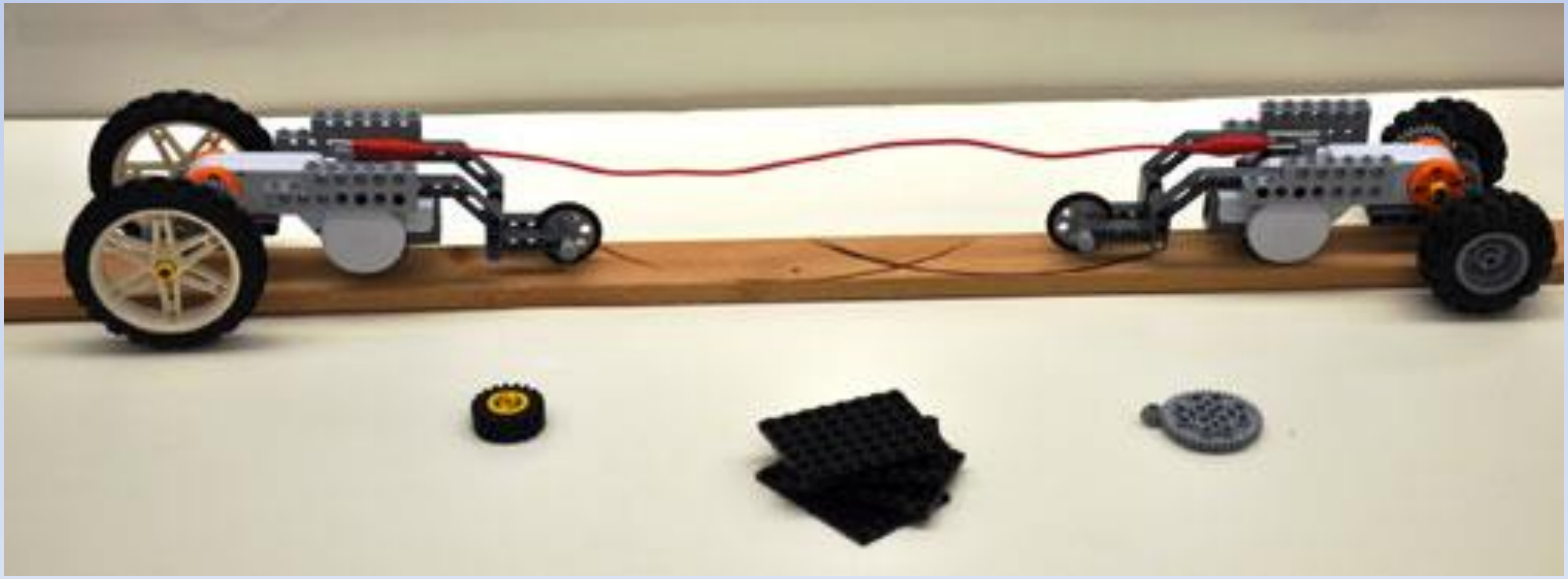
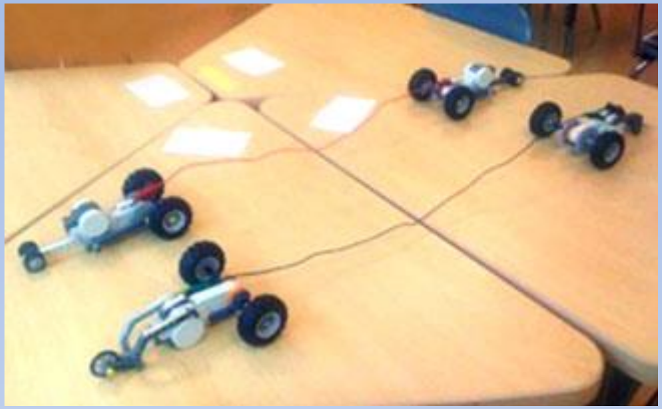
Tug of War Battle Bots



The Challenge

- To design a vehicle with maximum puling 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

force of friction

normal force

torque

applied force

weight

speed

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**

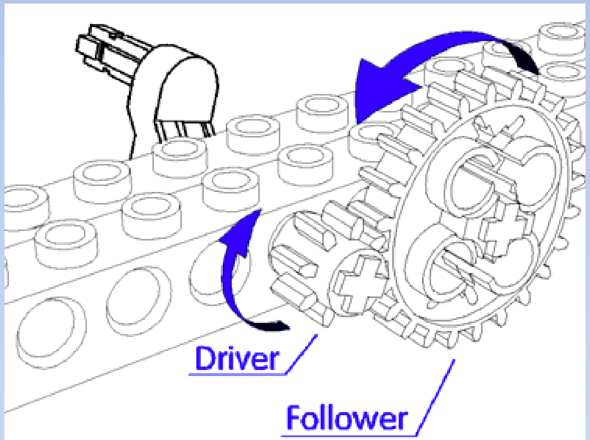
Concept of Gear Ratio

Gears are used for two basic purposes:

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

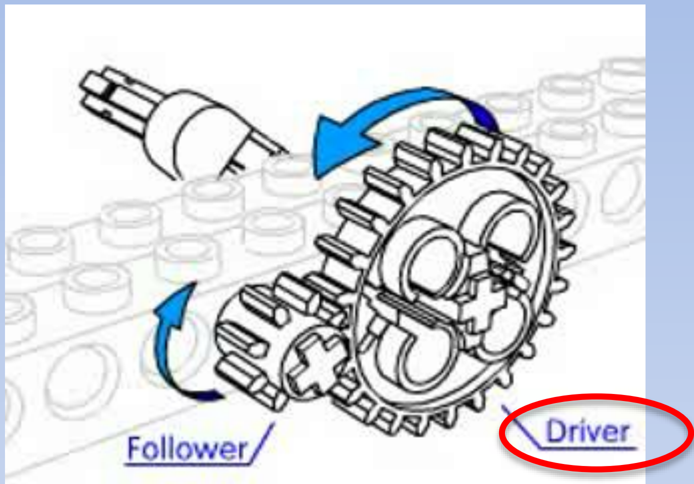
Concept of Gear Ratio

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



- 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

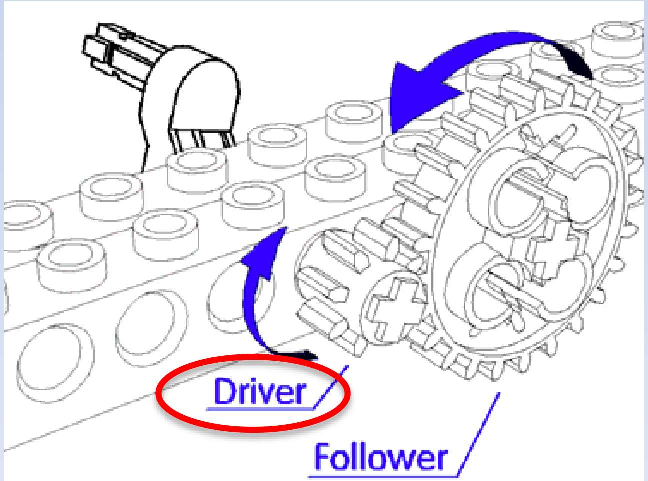


← Gearing up

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

Gearing down →

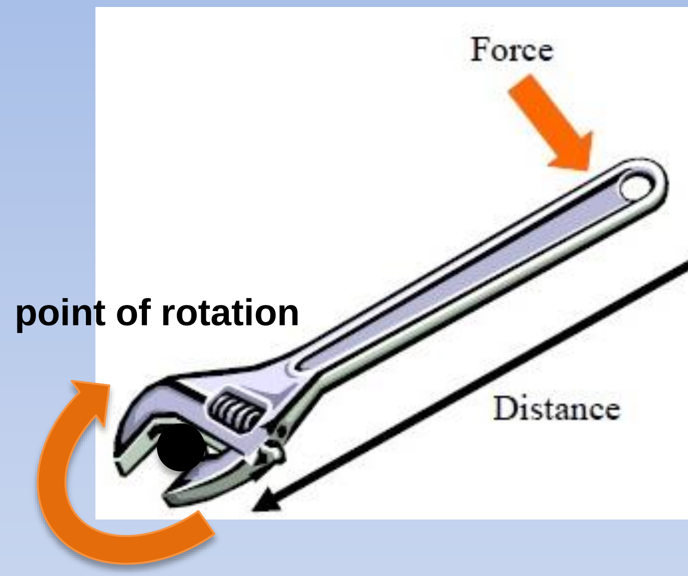
- Small gear drives LARGE gear
- The large gear turns slower
- speed ↘ torque ↗



Concept of Torque

- Torque is an applied force on a lever arm

$$T = r \times F$$



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

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

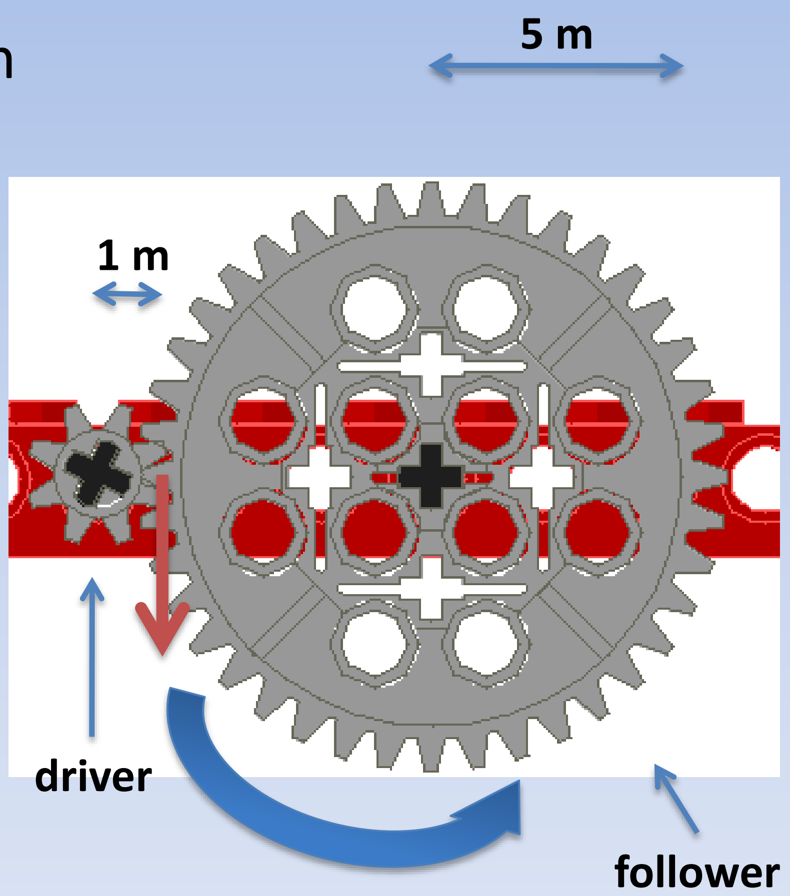
$$25N \cdot m = 1m \times F$$

$$F = 25N$$

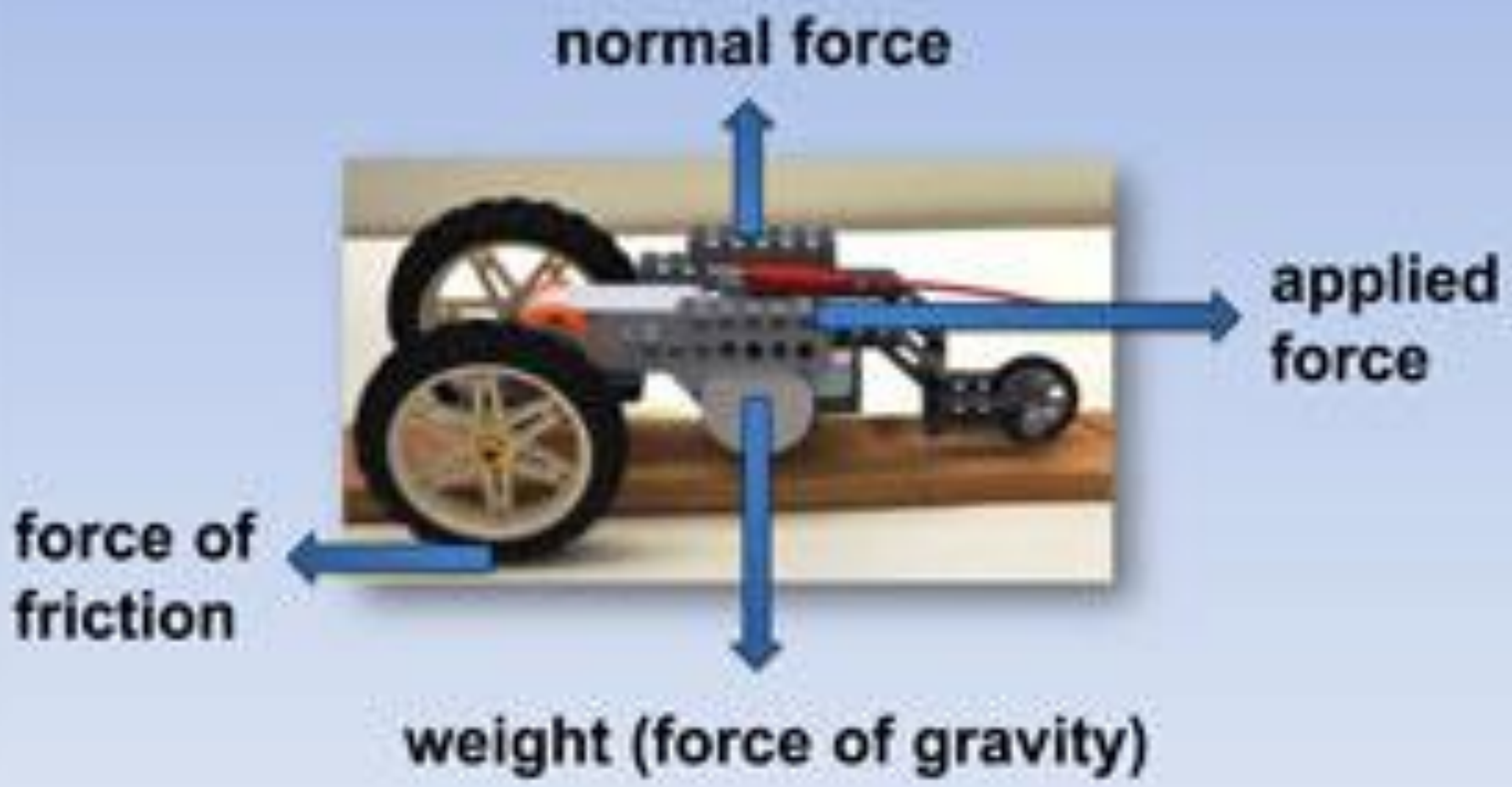
$$T = 5m \times 25N$$

$$T = 125N \cdot m$$

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

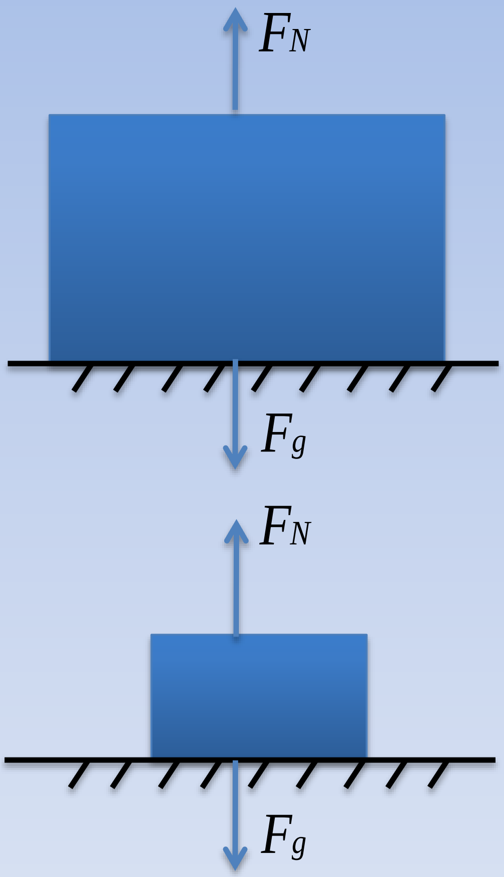


Concept of Force (and Motion)



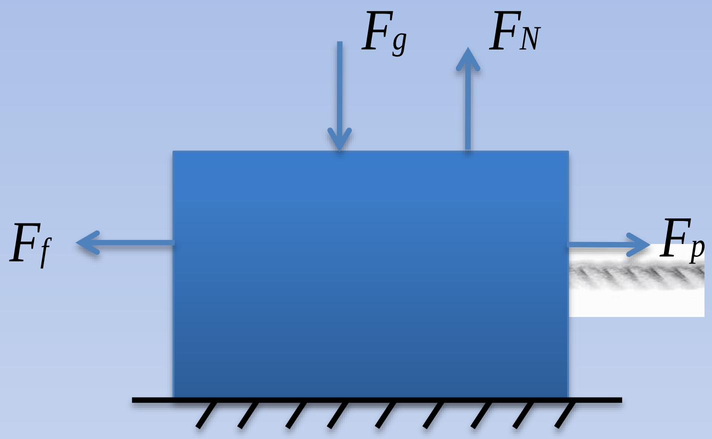
Concept of Weight and Normal Force

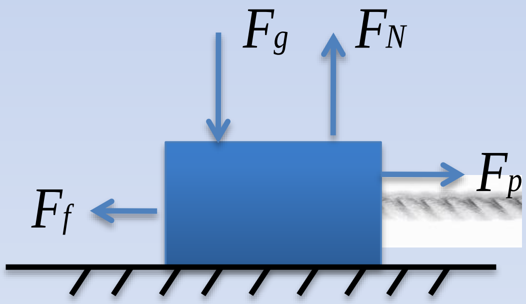
- The weight of an object is not the same as its mass
- The weight is defined as the force exerted by gravity
- For an object to stay on the ground, the force of gravity must be offset by an equal force pushing back—we call this force the normal force—the Earth is pushing back against gravity



Concept of Force of Friction

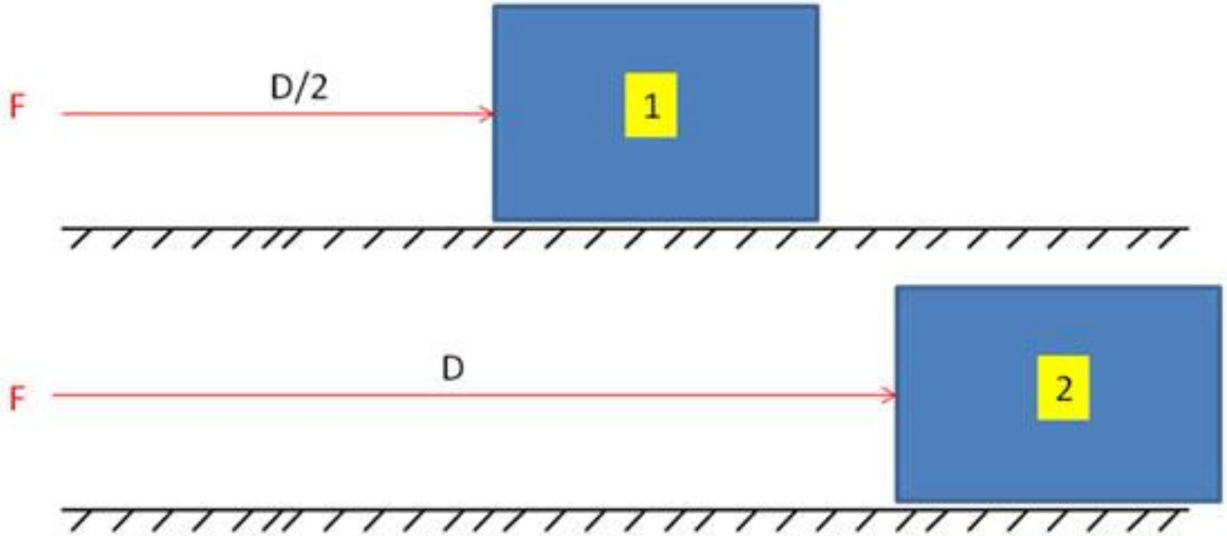
- Friction is the resistance encountered by two touching materials
- No contact = no friction
- Something with a lot of weight makes a lot of friction with the surface of the ground





$$F_f = F_N \times \mu$$

Concepts of Work and Power



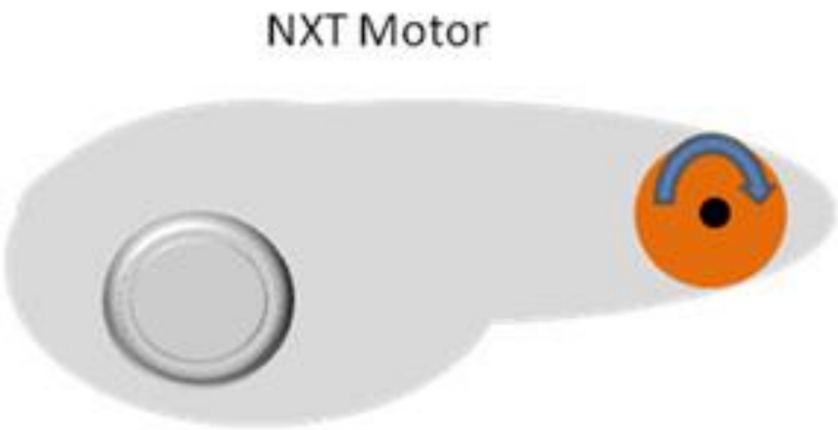
Work = Force x Distance
Power = Work/Time

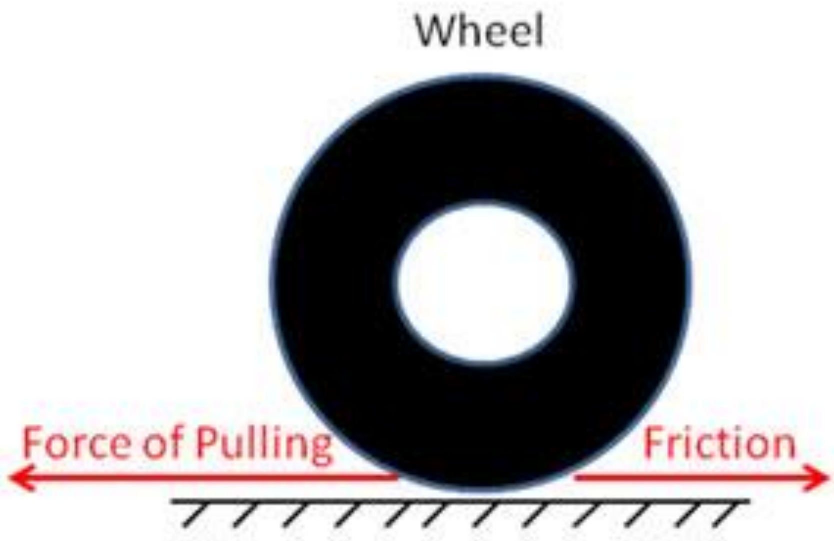
Question 1: If both objects move their respective distances with the same exerted force, which one required more work?

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





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