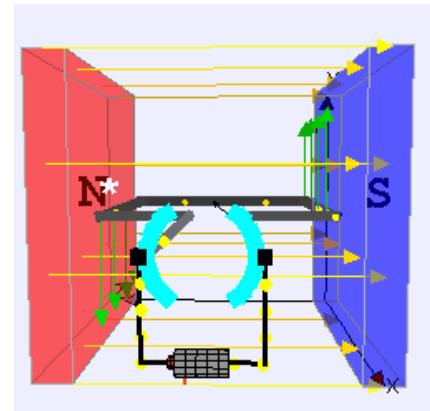


CISC 1003 – EXPLORING ROBOTICS

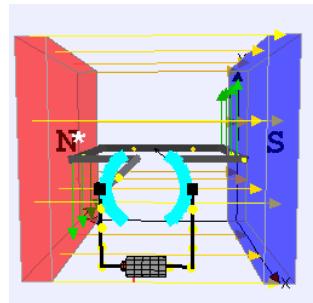
GEARS

Motors



- Compared with all other types of actuators, ***direct current (DC) motors*** are simple, inexpensive, easy to use, and easy to find.
- Motors have a copper wire wound in a way that creates magnetic fields
 - These “push” the rotor inside of the motor around in a circle.

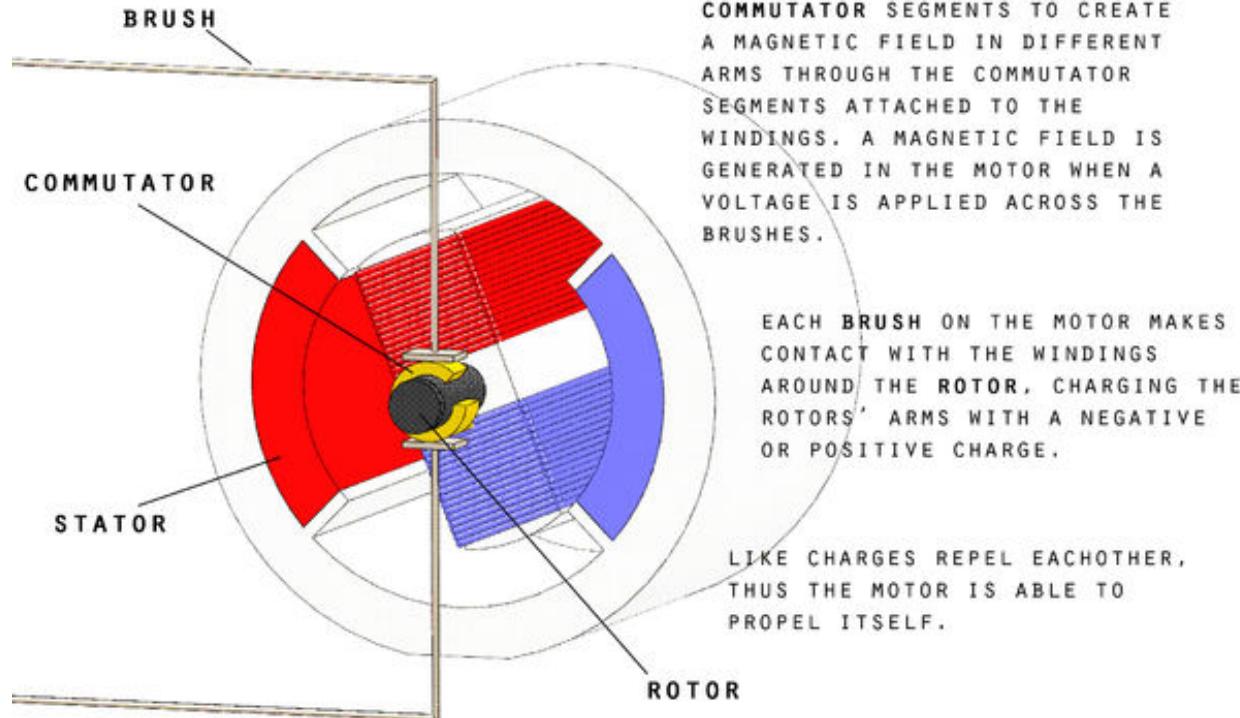
Motors



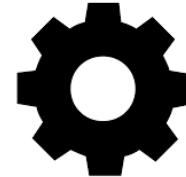
- To make a motor run, you need to provide it with electrical power in the right voltage range.
 - Low voltage, slower movement.
 - Higher voltage, faster movement
 - but more wear on the motor and can burn out if run fast for too long.
 - Like a lightbulb on a battery. More voltage means a brighter light.

Motors

ELECTRIC MOTORS



Gears



- Gears are wheels with teeth. Gears mesh together and make things turn.
- Gears are used to transfer motion or power from one moving part to another.

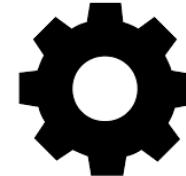
Gearing of motors



- Combining different ***gears*** is used to change the **speed** of motors.

<http://www.jsumo.com/steel-gear-bundle-08-module-6421-reduction>

Gears



- Both the input gear (driven gear) and the output gear each have a set number of teeth
- The ratio between these two gears can be used to find the speed of the output gear
 - if the input speed to the driven gear is known.

Gears



Academy Artworks

- **Output Speed = (Input gear / Output gear) * Input Speed**

Gears - example



Academy Artworks

- A motor is attached to a 10 tooth spur gear
 - Gear spins at 100 rpm (rotations per minute)
 - Gear has a torque of 1 joule
- 20 tooth gear attached to the 10 tooth gear
- What are the output speed?

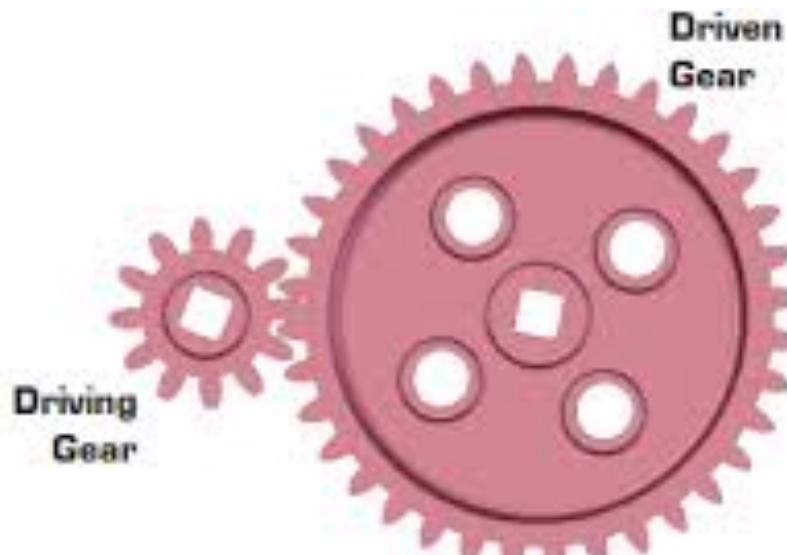
Gears - example



Academy Artworks

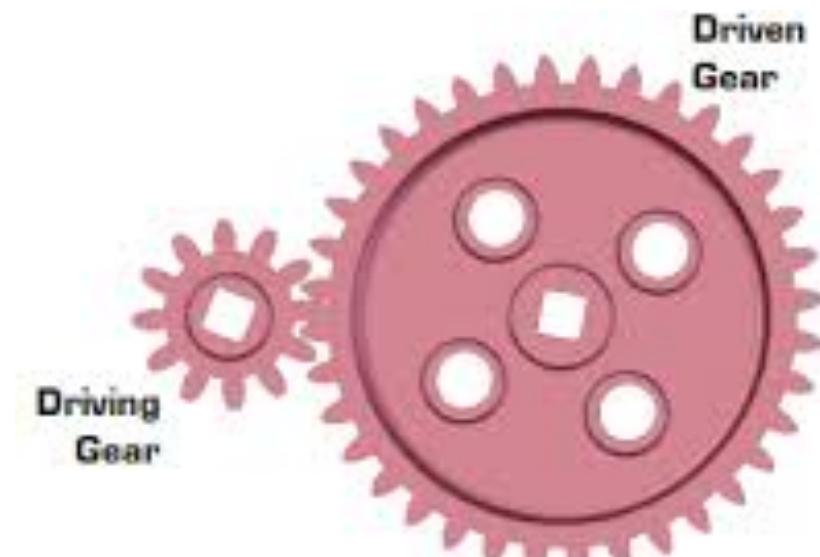
- A motor is attached to a 10 tooth spur gear
 - Gear spins at 100 rpm (rotations per minute)
 - Gear has a torque of 1 joule
- 20 tooth gear attached to the 10 tooth gear
- What are the output speed and torque?
 - Output speed = $(10 / 20) * 100 = 50 \text{ rpm}$

Combining Gears



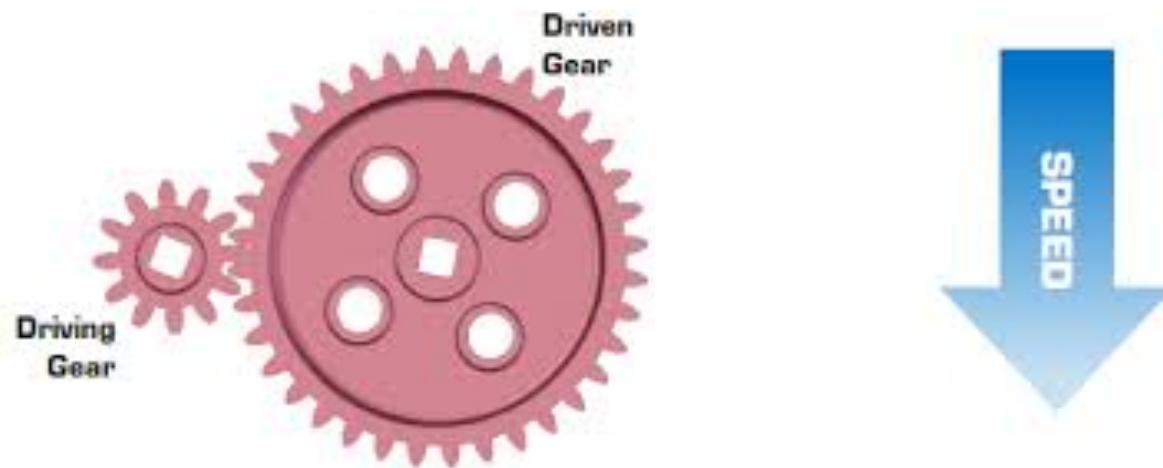
Combining Gears

- What happens to the speed?

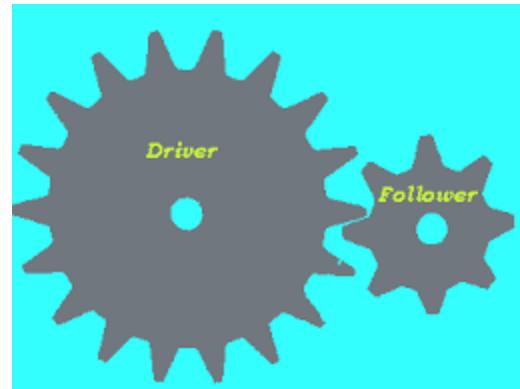


Combining Gears

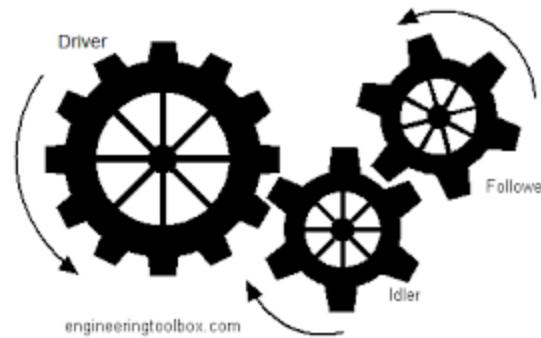
- What happens to the speed?



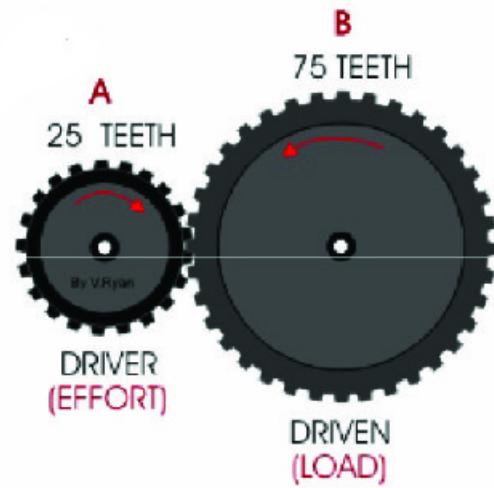
Gear System



- Compound Gears



Gear Ratio



$$\frac{\text{Driven}}{\text{Driving}} = \frac{75}{25} = \frac{3}{1} \rightarrow 3:1$$

Gears – The Purpose



Gears are generally used for one of four different reasons:

- To reverse the direction of rotation
- To increase or decrease the speed of rotation
- To move rotational motion to a different axis
- To keep the rotation of two axis synchronized

Questions?



GEARS – SPEED AND TORQUE

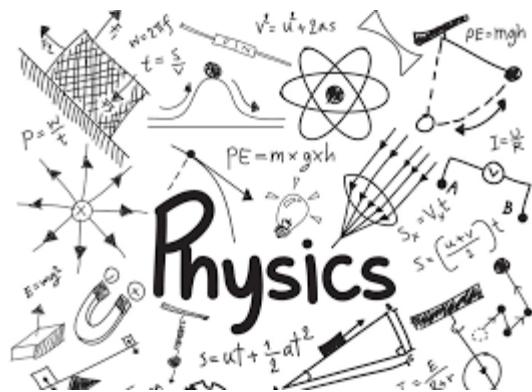
Gearing of motors



- Combining different **gears** is used to change the speed and **torque** (turning force) of motors.

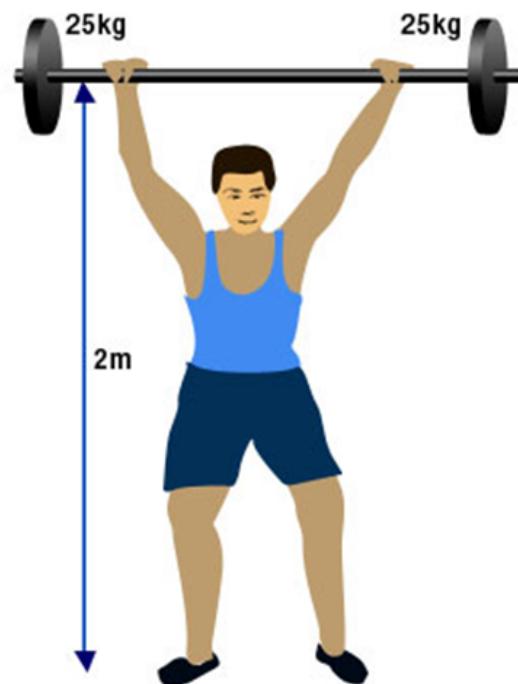
<http://www.jsumo.com/steel-gear-bundle-08-module-6421-reduction>

SOME PHYSICS



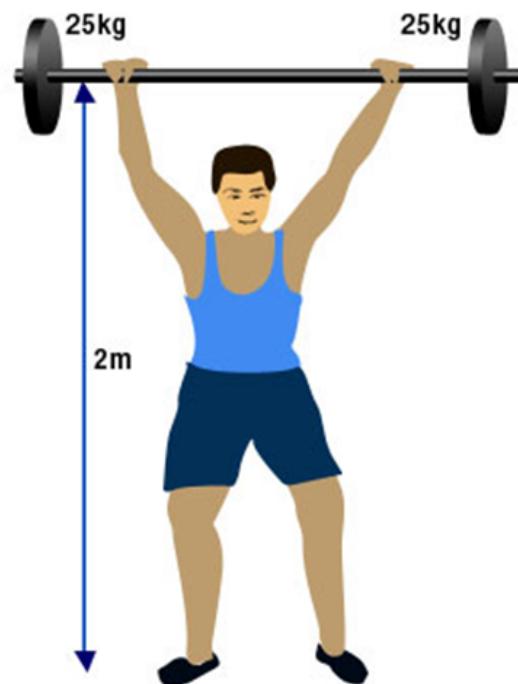
Work, Force and Distance

- Energy is the ability to do work
- Measured in Joules
- Work: The action of a *force* to cause *displacement* of an object
 - $\text{Work(J)} = \text{Force (N)} \times \text{distance (m)}$
 - 1 joule = 1 Newton * 1 meter



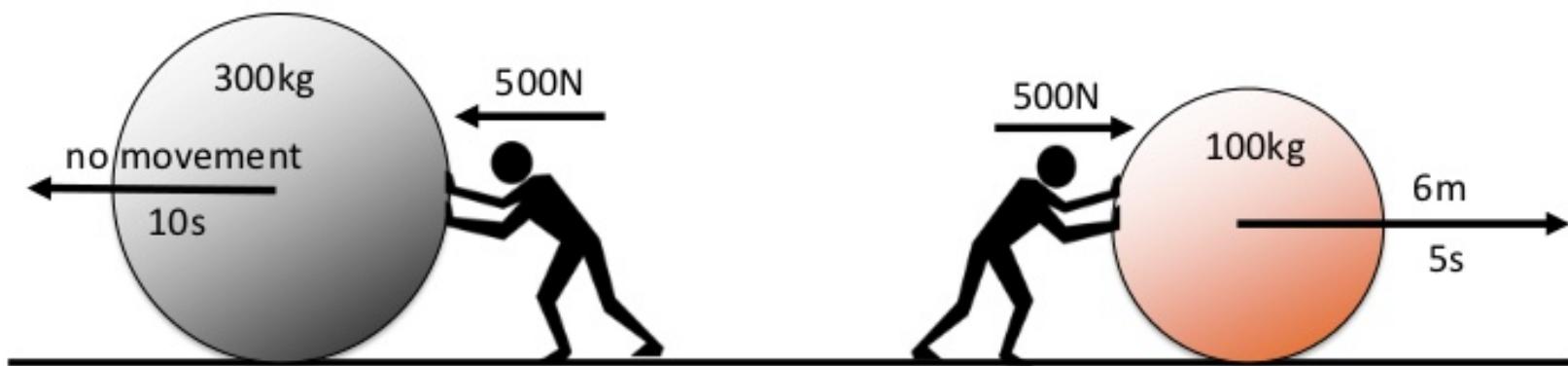
Work, Force and Distance

- Here, in this figure, we can say that, the work done upon the weight against gravity is
- $(\text{Mass} \times \text{acceleration due to gravity}) \times \text{Displacement}$
- $= (25 \times 2 \times 9.8) \times 2 = 980 \text{ J}$



Work, Force and Distance

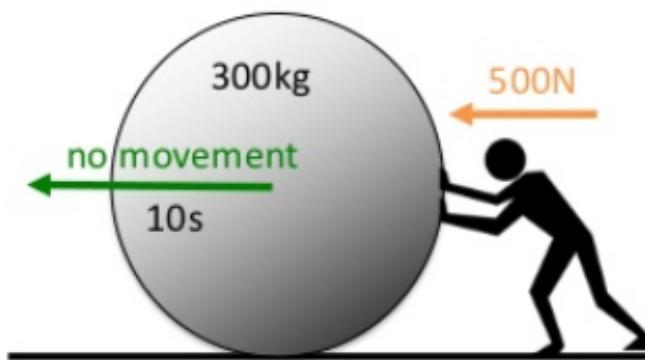
- Who has done the most work?
 - Work = Force x Distance



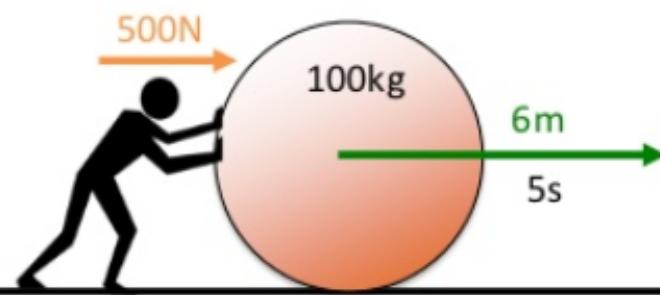
Work, Force and Distance

- Who has done the most work?
 - Work = Force x Distance

$$\begin{aligned}\text{Work} &= 500\text{N} \times \underline{0\text{m}} \\ &= 0\text{J}\end{aligned}$$



$$\begin{aligned}\text{Work} &= 500\text{N} \times \underline{6\text{m}} \\ &= 3000\text{J} \quad (3\text{kJ})\end{aligned}$$



Torque

- Torque is a measure of the force that can cause an object to rotate about an axis.
- TORQUE measures ROTATIONAL FORCE
- $TORQUE = FORCE \times DISTANCE$
 $= FORCE \times Radius$
 - RADIUS of the rotational circumference.

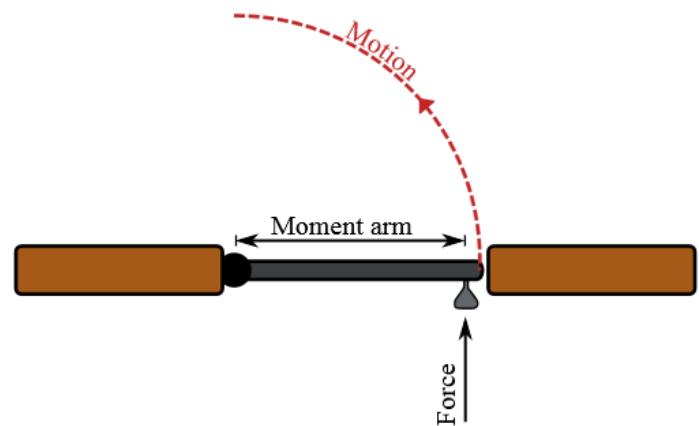
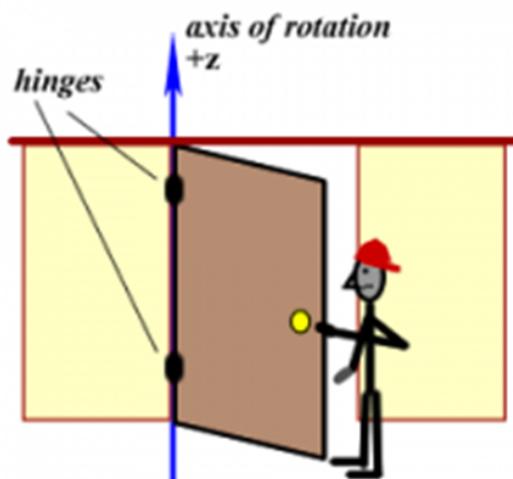


Figure 1: Opening a door with maximum torque.

Torque

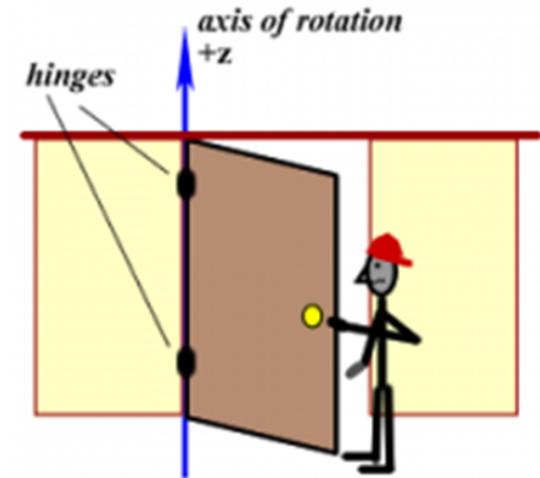
- Example: opening a door:
 - Torque is the angular force that the person exerts



Torque

- What if your door knob was closer to the hinge?
 - But you used the same force to open it?
 - It would be much harder to open
 - Torque is smaller
 - $TORQUE = FORCE \times DISTANCE = FORCE \times Radius$

•



Torque

- Torque
- Torque and horsepower

Gearing of motors



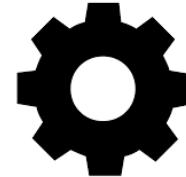
- Combining different *gears* is used to change the speed and torque (turning force) of motors.
- Work, as defined in physics, is the product of force and distance.
 - $\text{Work} = \text{force} \times \text{distance}$
 - Distance moved in the direction of the force
- Gears rotate around their axis in a certain velocity
 - Rotational Velocity is specified in Rotations Per Minute.

Gearing of Motors



- **Torque** provided by motor is typically constant
- For a wheel on the ground, **torque** needed to turn wheel equals to overcome friction
 - $Torque = F_f * Radius$
- For a larger wheel, smaller rotational force will be provided by same engine
 - Harder to turn larger wheels
 - Think of a truck vs. car, who has the bigger engine?

Gears



- Both the input gear (driven gear) and the output gear each have a set number of teeth
- The ratio between these two gears can be used to find the torque and speed of the output gear
 - if the input torque/speed to the driven gear is known.

Gears



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- **Output Speed** = (*Input gear / Output gear*) * *Input Speed*
- **Output Torque** = (*Output gear / Input gear*) * *Input Torque*

Gears - example



Academy Artworks

- A motor is attached to a 10 tooth spur gear
 - Gear spins at 100 rpm (rotations per minute)
 - Gear has a torque of 1 joule
- 20 tooth gear attached to the 10 tooth gear
- What are the output speed and torque?

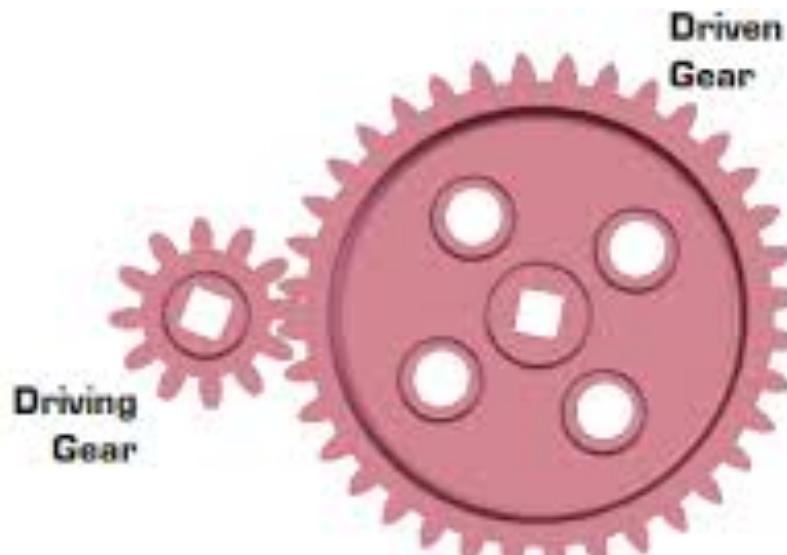
Gears - example



Academy Artworks

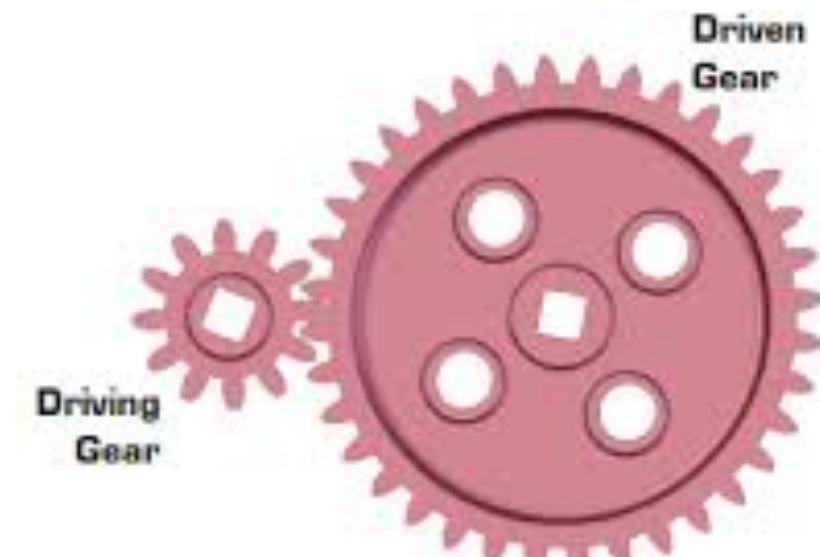
- A motor is attached to a 10 tooth spur gear
 - Gear spins at 100 rpm (rotations per minute)
 - Gear has a torque of 1 joule
- 20 tooth gear attached to the 10 tooth gear
- What are the output speed and torque?
 - Output speed = $(10 / 20) * 100 = 50 \text{ rpm}$
 - Output torque = $(20 / 10) * 1 = 2 \text{ joules}$

Combining Gears



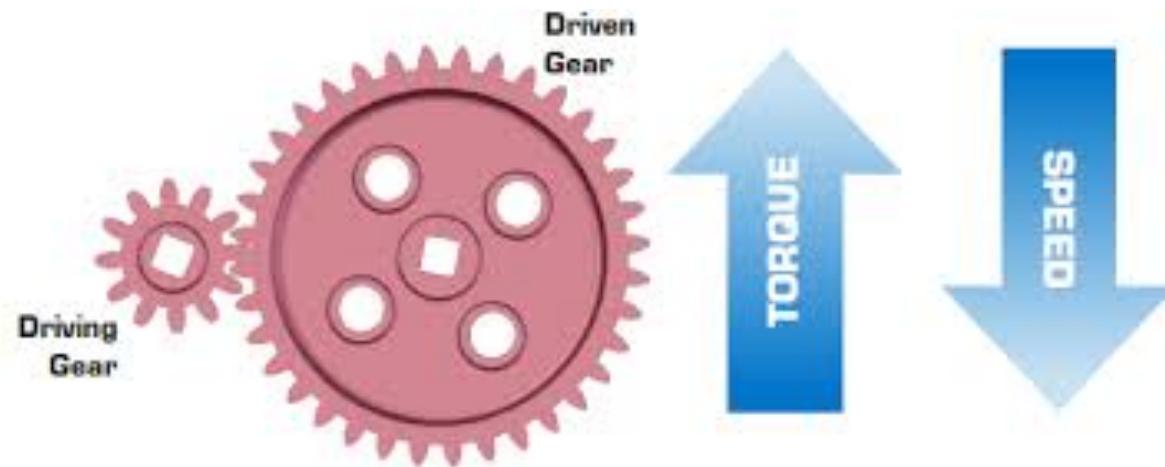
Combining Gears

- What happens to the speed?
- What happens to the torque?



Combining Gears

- What happens to the speed?
- What happens to the torque?

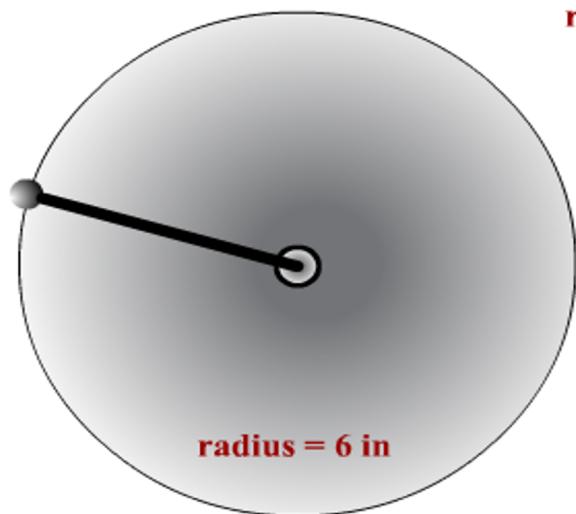




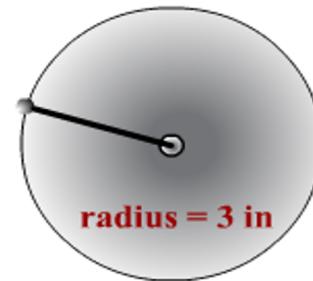
VELOCITY

Rotational and Linear Velocity

- Both wheels touch the ground and rotate at 120rpm
- Which wheel will travel further?
 - Larger wheel will travel further!
 - Can we calculate its linear velocity?



rpm = 120/min



radius = 3 in



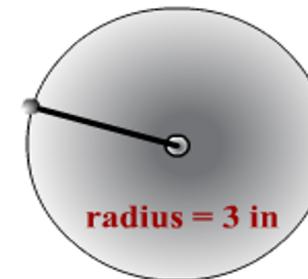
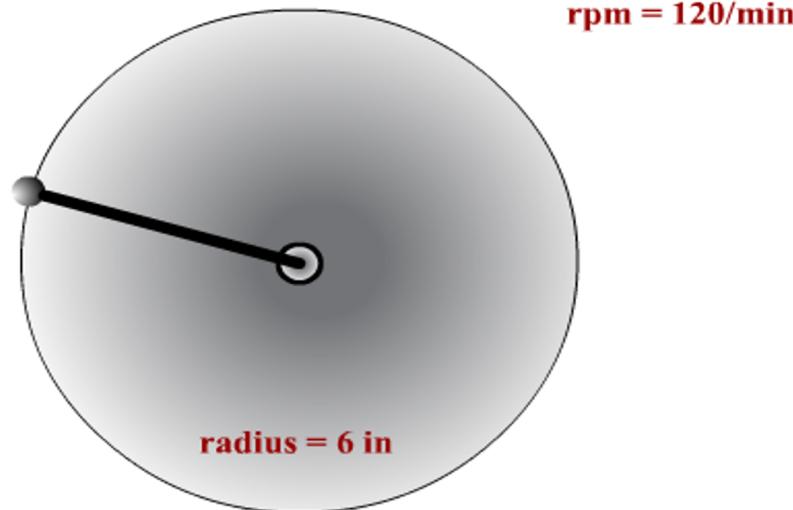
Rotational and Linear Velocity

- Rotational Velocity (RV) to Linear Velocity (LV) conversion:
 - Find the Circumference (C) of the circles:
$$C = 2 \times \pi \times r \text{ inches } (\text{ where } r \text{ is the radius})$$
 - Where $r = \text{radius}$
 - $\text{Linear Velocity} = C \times \text{Rotational Velocity}$



RV to LV conversion:

- Find the Circumference (C) of the circles:
 - $C = 2 \times \pi \times r$ inches (where r is the radius)
- Larger circle: $C_1 = 2 \times \pi \times 6 = 37.70 \text{ inches}$
- Smaller circle: $C_2 = 2 \times \pi \times 3 = 18.85 \text{ inches}$





RV to LV conversion:

- *Linear Velocity = C x Rotational Velocity*
(120 rpm speed of both circles)

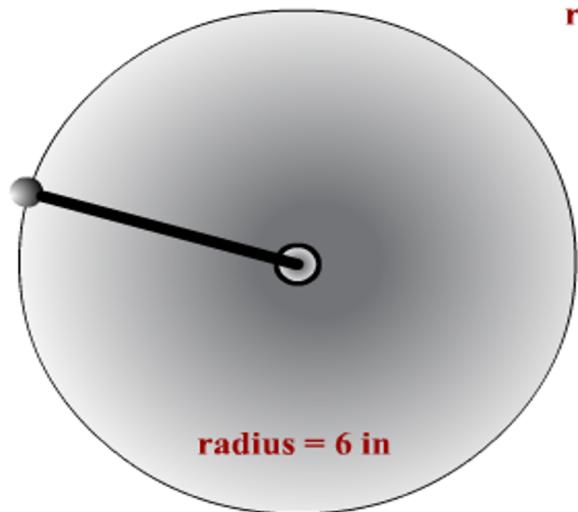
Larger wheel:

- $V_l = 37.70 * 120 = 4524 \text{ inches/min}$
- Smaller wheel:
 - $V_2 = 18.85 * 120 = 2262 \text{ inches/min}$

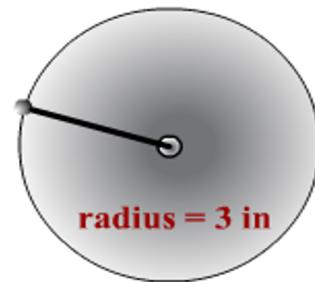
Rotational and Linear Velocity

- Note:

- Rotational Velocity is specified in Rotations Per Minute.
- Linear Velocity is usually specified in Feet Per Minute



rpm = 120/min



Lab time!

- Let's work with our virtual robots!

