Bike Lab Worksheet

In Class

Your Name: (first and last) ______________________

Your Lab Teammates: (first and last names) ______________________ ______________________ ______________________

Your Pod: (circle)

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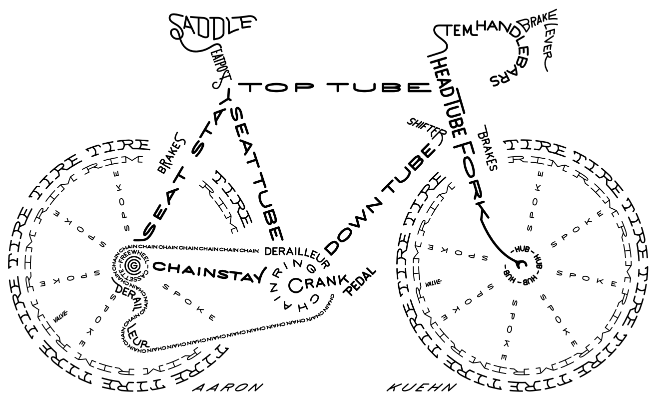
Part 1: Bicycle Overview

Draw a line from the Bicycle Part to its location on the Bicycle.

- Rear Derailleur ◎
- Cassette ◎
- Spoke ◎
- Rear Wheel Rim ◎
- Rear Wheel Tire ◎
- Tire Stem Valve ◎

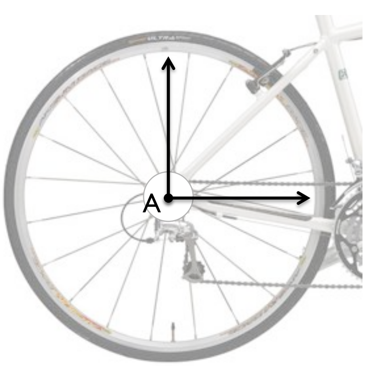


- ◎ Chainring
- ◎ Chain
- ◎ Crank
- ◎ Pedal
- ◎ Chainstay
- ◎ Front Derailleur

Part 2: Free Body Diagram:

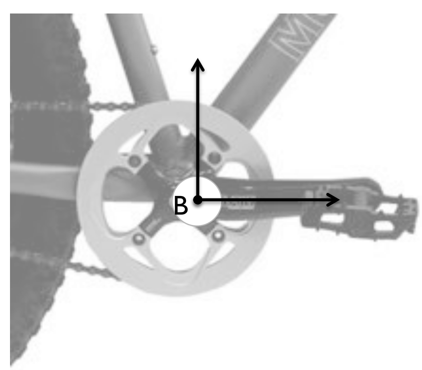
Label and Draw forces over each picture below that illustrates the drive train forces.

Cassette – Rear Wheel



Label: F_{AX} and F_{AY}
Draw: F_{chain} and $F_{friction}$

Chainring – Front Wheel



Label: F_{BX} and F_{BY}
Draw: F_{chain} and F_{foot}

Part 3: Measuring Your Bicycle

Place your bicycle on a table or on the ground (seat and handle bars down, wheels up) and fill out the chart below:

Manufacturer	**# Gear Teeth**			
	Cassette – Rear Wheel		**Chainring – Front Wheel**	
Brand	largest gear		largest gear	
	smallest gear		smallest gear	
Rear Wheel Radius *(axle to outer tire edge)* mm				
Crank Length *(center of drive shaft to pedal pivot)* mm				

Grader Space 1 2

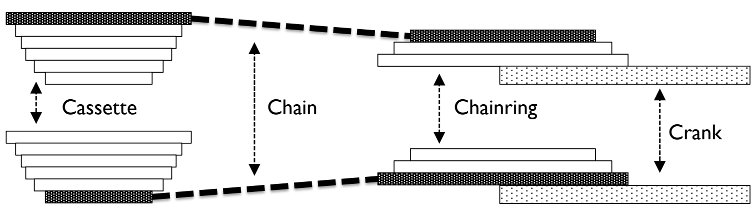
Bike Lab Worksheet

In Class

Part 4: Calculating Speed Ratio

The speed ratio describes the relationship between the crank gears and the cassette gears connected by the chain. It defines the number of rotations of the rear wheel for each rotation of the crank.

"Low Gear": Smallest Chainring, Largest Cassette (Top View)



"High Gear": Largest Chainring, Smallest Cassette

Speed Ratio • Eqn. (1)

$$Speed\ Ratio = \frac{\omega_{out}}{\omega_{in}} = \left(\frac{N_{chainring}}{N_{cassette}}\right)$$

Mechanical Advantage • Eqn. (2)

$$M.A. = \frac{F_{out}}{F_{in}} = \left(\frac{L_{crank}}{R_{wheel}}\right)\left(\frac{N_{cassette}}{N_{chainring}}\right)$$

With your bicycle still turned over so it rests on the seat and handle bars, set your bicycle to "low gear" (smallest chainring, largest cassette gear). Turn the crank exactly 5 full rotations and count the number of rotations of the rear wheel. Record your answer to the nearest 1/10th rotation in the chart below on the "low gear" line. Next, hold the wood block against the wheel to create light resistance as you turn the crank; note your observations in column (2) below.

Next, set your bicycle to "high gear" (largest chainring, smallest cassette gear). SLOWLY turn the crank 5 full rotations and count the number of rotations of the rear wheel by watching the tire stem valve. Record your answer to the nearest 1/10th rotation below using the "high gear" line. Again, hold the wood block against the wheel to create light resistance while you turn the crank; note your observations in column (2) of the table.

	Observation		**Measurement & Calculation**				
Gear State	(1) Observed # of Rear Wheel Rotations (5 crank turns)	(2) Difficulty to resist rotation (hard/easy)	(3) Chainring (# teeth) *From Part 3*	(4) Cassette Gear (# teeth) *From Part 3*	(5) Speed Ratio (Eqn. 1)	(6) Calculated # of Rear Wheel Rotations (5 crank turns)	(7) % Difference: [(1) – (6)]/[(1)]
Low Gear							
High Gear							

Now, calculate the Speed Ratio (item 5 above) by using the number of teeth in the chainring (3) and cassette gear (4) for each gear state and using Equation (1) from Part 4. From this, calculate the number of wheel rotations for 5 crank turns (item 6 above), and compare your observed wheel rotations to your calculated wheel rotations (7).

Speed ratio can also be used to calculate distance traveled. Calculate how far the bicycle would travel with 5 crank turns in low gear and 5 crank turns in high gear. Remember, the circumference of a wheel is $2\pi \times wheel\ radius$.

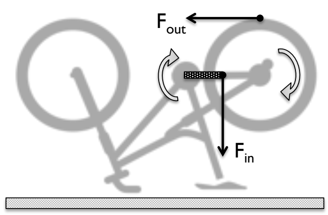
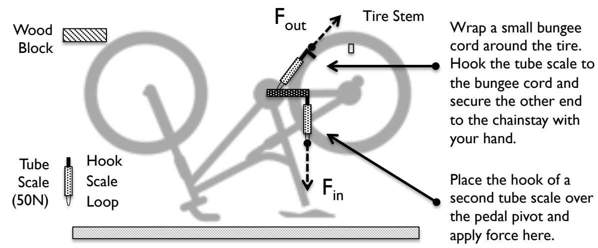
Hint: Calculate the distance traveled for one wheel turn and multiply it by the number of wheel turns for each gear state. ($\pi = 3.14159$)

	Distance Traveled 5 crank turns
Low Gear	meters
High Gear	meters

Bike Lab Worksheet

In Class

Part 5: Calculating Mechanical Advantage

Summary of Forces	Instructions	Lab Set-Up
	Place the bicycle on a table upside down.	

Mechanical advantage (MA) is a measure of force amplification. On a bicycle, force is imparted on the pedal by the rider (F_{in}) and reduced because the crank length is only about ½ the radius of the rear wheel. The gears amplify force (F_{out}) based on the ratio of cassette gear to the chainring. The combination of the crank length, wheel radius, cassette gear and chainring define the mechanical advantage (MA).

Set your bicycle to "low gear" (smallest chainring, largest cassette gear) and set the crank to a horizontal position as shown above. Attach a force gauge (tube scale) to the pedal pivot post with the hook to measure "force" input. Use a second force gauge and wrap the strap around the chainstay to secure the gauge, while placing the hook over a spoke as near to the rim as possible. Tare both gauges and apply 40 newtons of force (F_{in}) on the pedal; In the chart below record F_{in} as well as the force (F_{out}) on the gauge attached to the rim [(1) and (2)].

Next, set your bicycle to "high gear" (largest chainring, smallest cassette gear) and repeat the experiment. Record the force (F_{out}) on the gauge attached to the rim in the chart below. Now, from Part 3 transfer the number of teeth in the chainring (4) and cassette gear (5) for each gear state. Record the crank length from Part 3. Calculate the mechanical advantage (8) of your bike in low gear and high gear using Equation (2). Find the difference (9) between your observed value and calculated value.

	Measured		**Calculated**						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Gear State	Pedal Force (F_{in}) (N)	Wheel Force (F_{out}) (N)	Observed MA (F_{out})/ (F_{in}) (2)/(1)	Chainring (# teeth) *From Part 3*	Cassette Gear (# teeth) *From Part 3*	Crank Length (mm)	Wheel Radius (mm)	Calculated MA Eqn (2)	% Difference in MA: [(3)-(8)]/[(3)]
Low Gear									
High Gear									

Part 6: Summary - Let's pull it all together …

Which gear state has a higher Speed Ratio? In other words, which yields more wheel rotation for each turn of the crank?	Low Gear	High Gear
Which gear state has a higher MA? In other words, which applies more friction at the wheel for the same input?	Low Gear	High Gear
Which gear state is good for going uphill?	Low Gear	High Gear
Which gear state is good for going fast on flat roads?	Low Gear	High Gear
Can a gear state have both higher MA and more rear wheel rotation than all the others?	Yes	No
Why/Why Not?		
What might explain differences in the calculated and measured values of MA and Speed Ratio?		

Bike Lab Worksheet

In Class

Part 7: Empathy Notes and a Persona *(discuss in Teams, write individual notes)*

Empathy notes are the designer's way of "getting inside" the motivations of the design customer. This provides input to the development of an empathy map. Empathy maps are not a rigorous, research-based process, but it can quickly get a group to focus on the most important element: the customer.

Product designers often create "personas" to help them think about design. A persona is a description of a person for whom the design is intended. Personas are often displayed in the form of an empathy map that helps summarize learning, compare and contrast different potential design targets and ultimately focus design decisions.

Record your empathy notes below, describing what you have learned about potential customers of B-cycle – the Tourist, the Shopper and the Commuter. Some data can be found in the case study and some information is your opinion about what might be important to a particular type of B-cycle customer. Work in a group and discuss your thoughts – it is not necessary that you all agree.

Empathy Notes

Persona:	**Tourist**	**Shopper**	**Commuter**
What problem is each persona trying to solve?			
Pains – what PAIN are each persona trying to avoid?			
Gains – what GAIN are each persona trying to achieve?			