

PocketLab Voyager/Wonder Gears: An Experiment on Gear Ratios and Angular Velocity

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Introduction

Gears date back many centuries and are extremely useful since they can change the direction imposed by a source of power, as well as torque and speed. This lesson describes an experimental study of the relationship between *gear ratio* and *angular velocity* by using PocketLab Voyager and [Wonder Gears](#). Wonder Gears is listed for ages 3+, with this lesson heavily emphasizing the “+” part of the description—since this lesson is perfect for junior high students aged 12 through 14. ***This is one of the many advantages of PocketLab as it allows studying science principles quantitatively with toys initially designed strictly for creative play by very young children.***

The Experiment Setup

Figure 1 shows how “Wonder Gears” is used in this lesson to set up a simple gear train with three gears. Construction take a couple of minutes and requires no tools. The pink gear is the *drive* gear—as it is connected to the motor. The green *intermediate* gear is a so-called “idler” gear, and the blue gear is a *driven* gear—the gear to which the load would be attached. The number of teeth (or cogs) on each of the gears is indicated and can also be determined by simply counting the teeth. Students will notice that the green gear rotates more slowly than the pink drive gear. Similarly, they will see that the blue gear rotates more quickly than the green gear. These observations can be encapsulated by defining ***gear ratio*** = T_2/T_1 as the ratio of the number of teeth T_1 in the first gear to the number of teeth T_2 on the second gear. For the pink and green gears this ratio is $14/6 \approx 2.33$. For the green and blue gears, this ratio is $10/14 \approx 0.71$. Students can then determine the angular velocity ω in degrees/second for each gear by using PocketLab Voyager’s angular velocity sensor. They can then show that the angular velocity is *inversely proportional* to the number of teeth—the larger the number of teeth, the smaller the angular velocity, and vice versa:

$$\frac{\omega_1}{\omega_2} = \frac{T_2}{T_1}.$$

Finally, students can show that the *overall gear ratio* of a gear train equals the ***product*** of the *intermediate gear ratios*. Put another way, idler gears don’t affect the overall gear ratio of the gear train.



Figure 1

Analyzing PocketLab Voyager's Angular Velocity Data

Voyager can be attached to the gears using Scotch® Removable Mounting Squares. Data was collected at 10 points/second, although higher rates would be great. A 40-second video accompanies this lesson showing the entire data collection process. Figure 2 shows a screen capture of data collected from the PocketLab app on an iPhone. Note that Voyager has been attached with the orange side up, *i.e.*, positive z-axis up. Data from the drive, intermediate, and driven gears have been labeled for clarity.

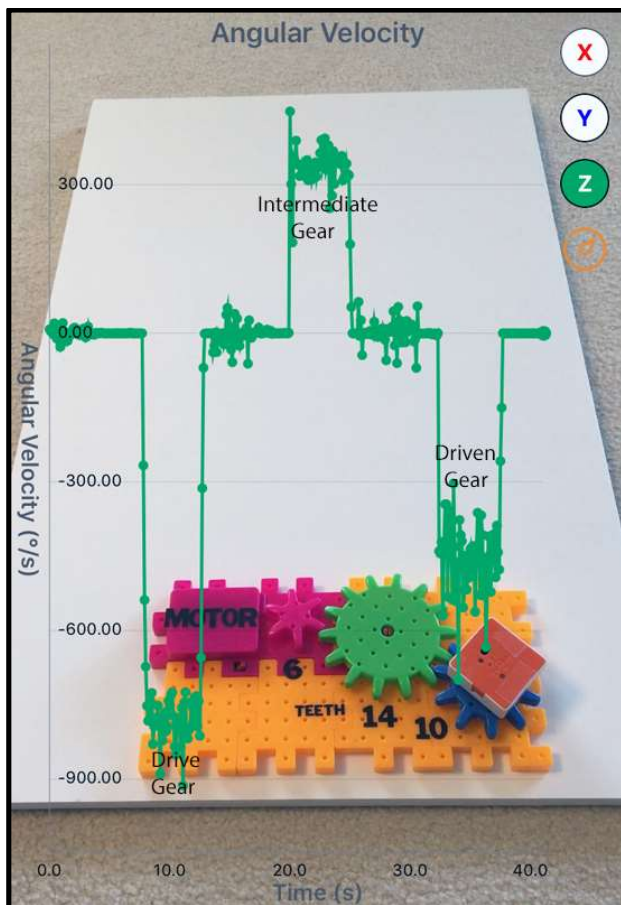


Figure 2

There is clearly a lot of variation in the angular velocity for any given gear. It therefore becomes necessary for students to determine the average angular velocity for each of the gears. There are at least three ways that this can be done:

1. Eyeball the average, based upon clustering of the data points near a visual central value. This could be done directly from the graph produced by the PocketLab app while viewing the results on the iPhone. This is quick but not as accurate as techniques 2 and 3 below.
2. Import the PocketLab app's csv file into a spreadsheet and have the spreadsheet compute average angular velocity for each of the gears.
3. When PocketLab's CloudLab is released, use its built-in capability to highlight data ranges and automatically compute a variety of statistics including average. See Figure 3 for screen prints of this feature for the drive gear.

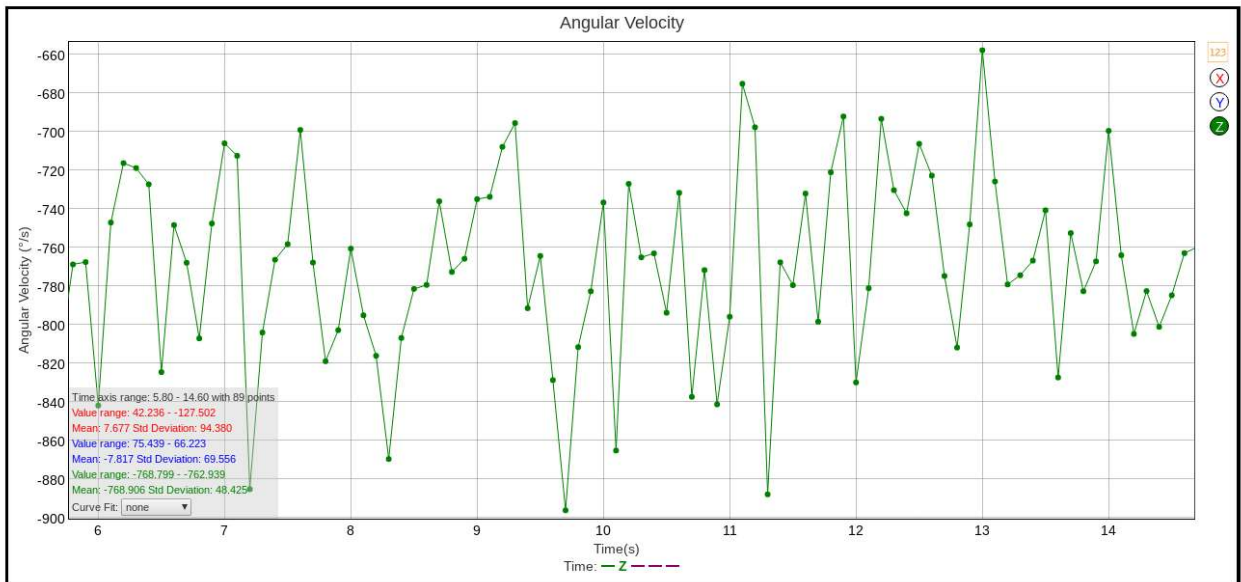
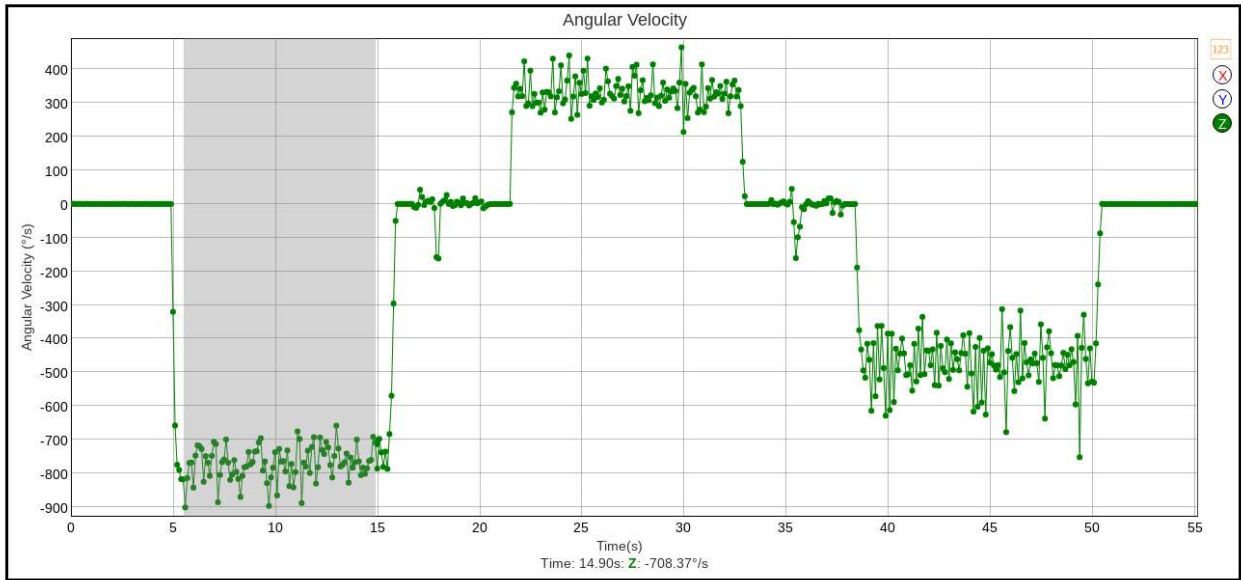


Figure 3

Questions for Students

1. Is the drive gear rotating clockwise or counterclockwise based upon information in Figure 2?
2. Explain why the angular velocity alternates negative/positive when moving from the drive gear to the intermediate gear, and finally to the driven gear in the gear train.

Gear Train Investigation Data Table

		1 → Drive Gear	2 → Intermediate Gear			3 → Driven Gear	R is Gear Ratio				
T_1	T_2	T_3	ω_1 (%/s)	ω_2 (%/s)	ω_3 (%/s)	$R_{21} = T_2/T_1$	ω_1/ω_2	$R_{32} = T_3/T_2$	ω_2/ω_3	$R_{21} \bullet R_{32}$	ω_1/ω_3
Data from Counting Gear Teeth			Data from Pocketlab			Are these equal?		Are these equal?		Are these equal?	

Conclusions:

Example Data: Gear Train Investigation Data Table

		1 → Drive Gear	2 → Intermediate Gear	3 → Driven Gear	R is Gear Ratio						
T_1	T_2	T_3	ω_1 (°/s)	ω_2 (°/s)	ω_3 (°/s)	$R_{21} = \frac{T_2}{T_1}$	ω_1/ω_2	$R_{32} = \frac{T_3}{T_2}$	ω_2/ω_3	$R_{21} \bullet R_{32}$	ω_1/ω_3
6	14	10	769	331	475	2.33	2.32	0.71	0.70	1.65	1.62
Data from Counting Gear Teeth			Data from Pocketlab			Are these equal?		Are these equal?		Are these equal?	

Conclusions:

- The data columns that are supposed to be equal are very close to being equal.*
- Gear ratio is inversely proportional to the ratio of angular velocities.*
- The overall gear ratio is the product of the intermediate gear ratios.*