PocketLab Voyager/LEGO®: Gears, Gear Ratio, and Motor RPM

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Introduction

This lesson combines LEGO®'s capability for building powered machines having gears with PocketLab Voyager's ability to make detailed measurements of the resulting motion. This lesson uses parts from LEGO®'s Simple & Powered Machines Set (URL link** at the end of this document). Students will construct a powered car with two interlocked gears—the input *drive* gear on the motor and the output *driven* gear on the rear wheel axle. By using Voyager's range finder to determine the translational speed of the car, students will calculate the gear ratio and compare this ratio to that determined from the ratio of the number of teeth on the gears. Using the car's translational speed along with measurement of wheel diameter, students will determine the angular velocity of the wheels as well as the RPM of the motor. Finally, students will replace the wheels with a set of wheels having a larger diameter, *predict* the translational speed of the car with the larger wheels, and then *compare their prediction* with Voyager range finder measurements of speed.

Student Instructions

1. Construct the LEGO® powered car shown to the left of Figure 1 and having detailed instructions at the URL at the end of this document. A *slightly* modified optional version constructed by the author is shown to the right in Figure 1. Taller blue supports were used so that Voyager could be attached to the rear of the car with rubber bands. The IR sensor on the orange side of Voyager faces a wall (see Figure 2) from which the powered car is initially started. The 8t (tooth) gear on the motor and the 24t gear on the axle are seen to be interlocked. **Begin this lesson by using the *smaller* set of four wheels**.

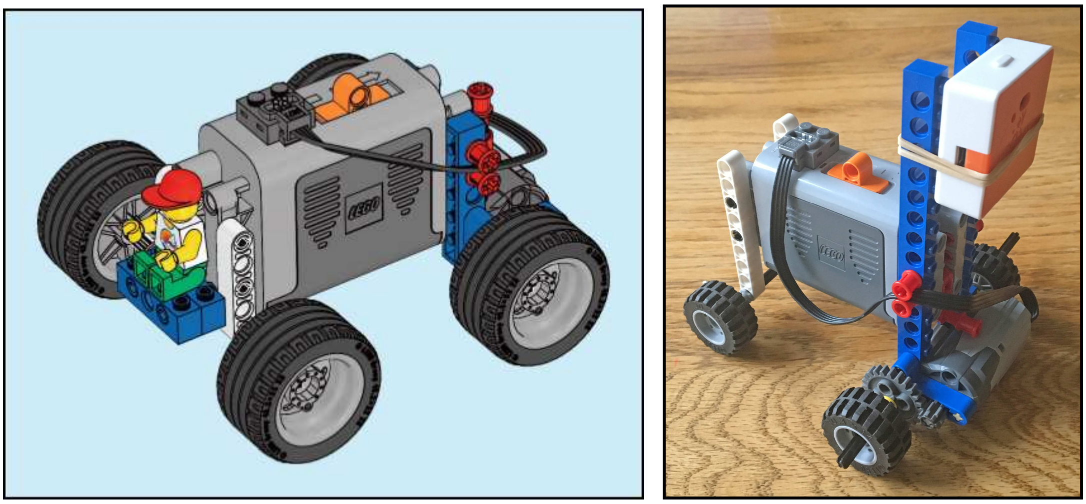

Figure 1

2. With the 8t gear on the motor and the 24t gear on the wheel axle, use Voyager's range finder to calculate the translational speed of the car. You can obtain the translational speed in either of two ways: (1) from the slope of the position versus time graph, or (2) by averaging the velocity values in the velocity versus time graph. (At the time of publishing this lesson, the velocity versus time graph feature had not yet been released by PocketLab.)

3. Calculate the gear ratio. This is the number of teeth in the driven gear divided by the number of teeth in the drive gear.

4. Replace the two gears in the car with a pair of 16t gears and again obtain the translational speed of the car using Voyager's range finder. What is the gear ratio now?

5. Find the ratio of the translation speed from step 2 to the translation speed from step 4. How does this ratio compare to the gear ratio that you found in step 3?

6. Determine the radius of the wheels. Use the equation $v = \omega r$, where v is the translation speed *from step 4*, ω is the angular velocity, and r is the radius, to determine the angular velocity in radians/second. Note that with a gear ratio of 1:1, this is also the angular velocity of the motor's shaft!

7. Convert the angular velocity from step 6 to degrees/second. (Recall that π radians = 180°.)

8. Using your answer to step 7, compute the motor's RPM (rotations per minute).

9. Change back to the 8t drive gear and 24t driven gear, and replace the smaller wheels with the set of larger wheels. Predict the translational velocity of the larger wheels using the equation $v = \omega r.$ (Be careful in calculating the value of ω that you use in this equation!)

10. Now use Voyager's range finder to determine the actual translation velocity of the car. Compare this to your prediction from step 9. (The author found that the two values agreed with one another to within 3 %.)

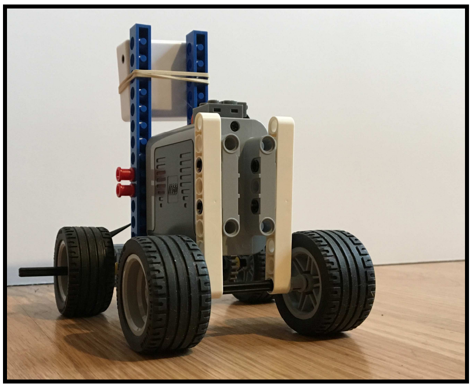

Figure 2

* https://le-www-live-s.legocdn.com/sc/media/files/building-instructions/mm/9686-power-car-e73a11a06a7970be5e6c03cbfc84d6cf.pdf

** https://education.lego.com/en-us/products/simple-powered-machines-set/9686