Learning Cycle Five

Ready, Set, GO!

5

Introduction

THROUGHOUT THIS LEARNING UNIT, you have learned how to calculate distance, construct structural suspension systems, and create carriage systems. This learning cycle will allow you to explore some basic concepts related to propulsion. Propulsion is the act of moving an object and maintaining its motion. Propulsion is an integral part of transportation devices. After you complete this learning cycle, you will be ready to devote your full attention to solving the *Primary Challenge.*

Objectives

After completing this learning cycle, you will be able to:

1. Design gear systems to increase and decrease the torque of an electric motor.
2. Evaluate the relationship between speed, torque, and direction of power.

What is torque?

Exploration 1

Torque is the force needed to cause an object like a door or wheel to rotate. A good example of torque is when you use a wrench to tighten lug nuts. When you apply force to the handle, this creates torque on the lug nut and turns it. Your instructor will assign you to teams to collect torque-related data. Follow the steps below to complete the assignment.

1. Obtain the necessary materials from your instructor to construct a torque bar from PVC pipe like the one in Figure 1.

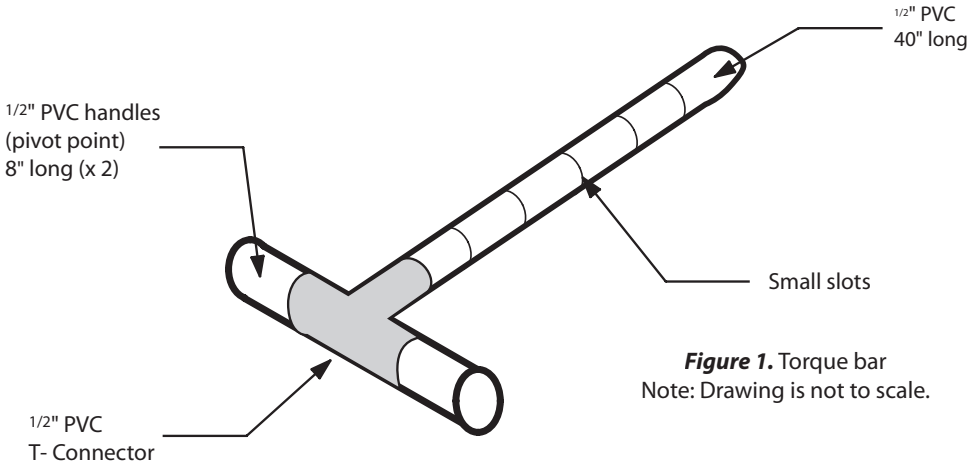


Figure 1. Torque bar
Note: Drawing is not to scale.

Safety

Glue joints using PVC glue. Be sure to use the glue in a ventilated area.

2. Mark 4″ increments along the 1 meter pipe. Using a file, cut small notches in the pipe to prevent the hanging weight from slipping on the pipe when testing.

3. Create a 2.5 pound weight to hang on the long arm of the torque bar. This can be constructed from a variety of things such as a can filled with sand, a jug of water, or a stack of metal washers. Verify that your weight equals 2.5 pounds before collecting any data.

4. Each team member should take a turn at holding the torque bar directly in front of them using the handles while a member of their team places the weight at each marked location (hold handles with palms down). After a short period of time, the weight should be moved up the long arm to each of the marks. How far away can you place the weight before the torque is too great to hold up the torque bar?

Safety

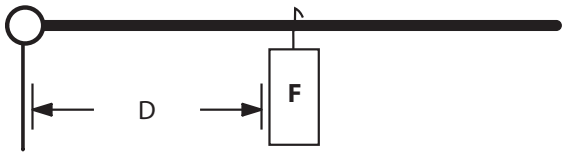
Be careful not to drop the weight on your toes!

Inventor's Logbook

Logbook 5.1

Table 1. *Torque bar trials*

Trial	Distance (in)	Force (lb)	Torque (lb/in)
1	0 cm	2.5	



Torque = Force x Distance

Figure 2. Measuring torque
Note: Drawing is not to scale.

5. Use Table 1 on the previous page to record your data as you move the weight up the torque bar. Use the illustration in Figure 2 and the formula for torque to determine the torque applied to the handle at each increment. Record this data in the column labeled "Torque."

6. Graph the data from Table 1 in the space provided when you have completed your calculations.

Inventor's Logbook

Logbook 5.2

Reflection

Write the answers to the following questions in the Inventor's Logbook space provided and prepare to discuss them as a class.

Inventor's Logbook

Logbook 5.3

1. Why did the torque bar become too hard to hold as the weight moved away from the pivot point?

_____

_____

_____

2. What was the highest torque you could hold?

_____

_____

_____

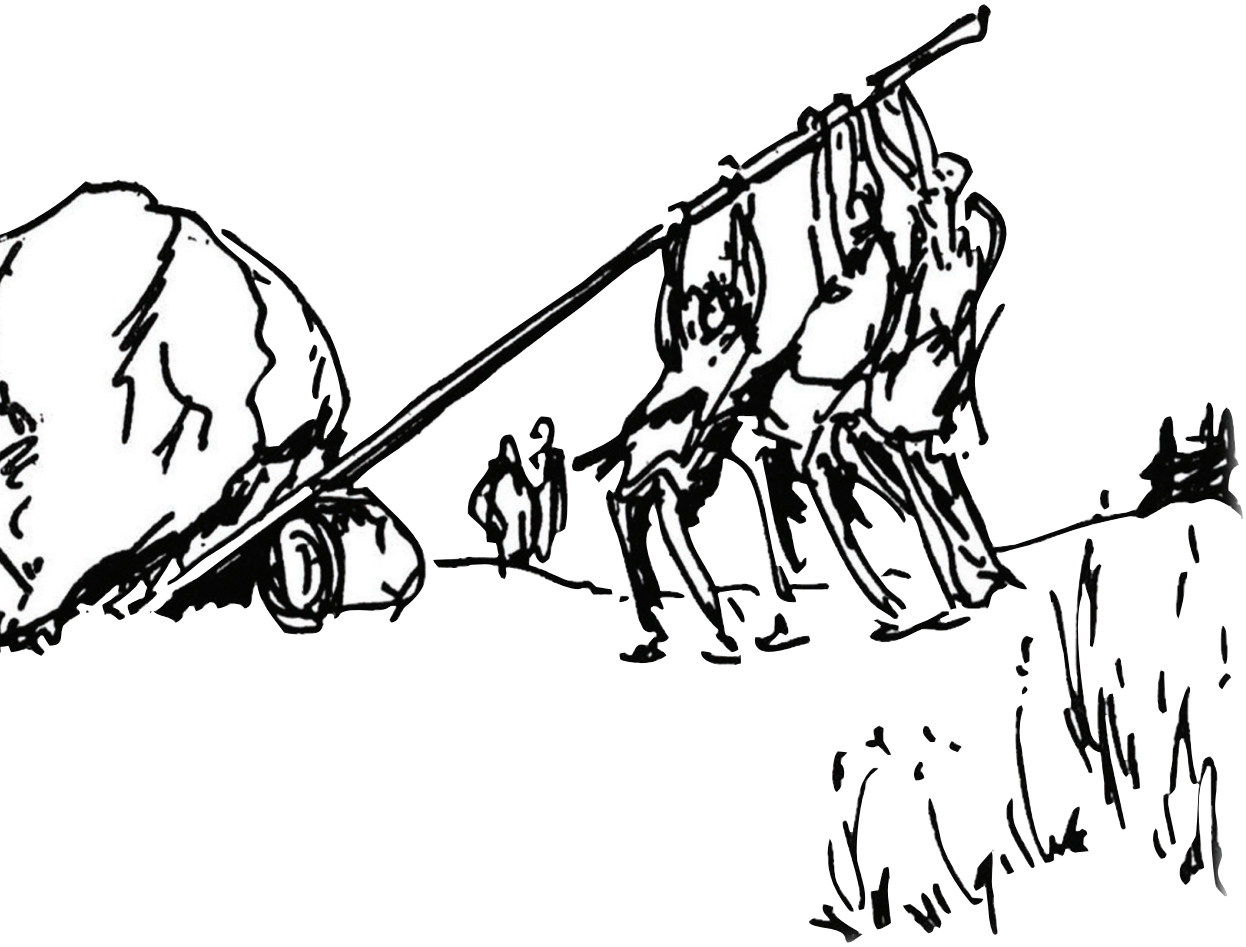
3. What would the torque be at the 90 cm point of the torque bar?

_____

_____

_____

4. What would the torque be at 2 meters if you could extend the torque bar?



Exploration II

In the previous *Exploration*, you were able to feel the force (torque) of a 1,000-gram weight being transmitted from a lever arm to the pivot point (axle). You were also able to calculate the variance as the weight moved further from your hands. The torque applied to the teeth of a gear works in much the same way as the lever arm on the torque bar.

Torque can be transmitted from the axle of a driver gear (the gear on the shaft of the motor or power source), through the force on the gear's teeth, to the axle of a driven gear. Gears are used in many mechanical devices to transmit and control torque. Two or more gear wheels that mesh are called a gear train. The following activity will show you how torque can be increased and decreased using a series of gears. Follow the directions on the following pages.

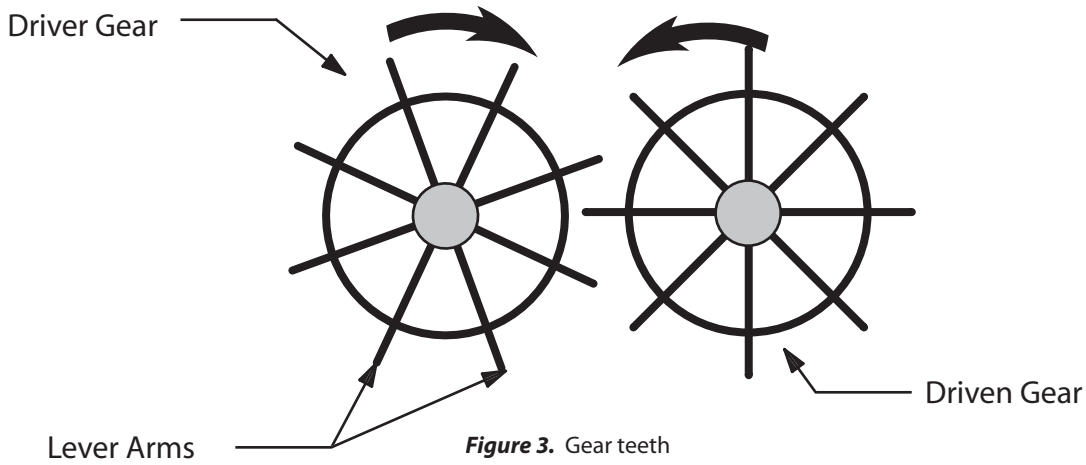


Figure 3. Gear teeth
Note: Drawing is not to scale

1. Create the gear train illustrated in Figure 3 using two gears of the same size and the gear box plates provided in your gear box kit.

$$\text{Gear Ratio} = \frac{\text{Turns of Driven Gear}}{\text{Turns of Driver Gear}} = \frac{\text{Teeth of Driven Gear}}{\text{Teeth of Driver Gear}}$$

Figure 4. Formula for calculating gear ratio

2. Use the formula found in Figure 4 to calculate the gear ratio for this setup. Mark a spot on the gear as a reference point and turn the driver gear one full revolution. Count the number of times the driven gear turns. Record this information in the Inventor's Logbook space provided.

Inventor's Logbook

Logbook 5.4

3. Use one grey gear, one red gear, and gear box plates to set up a similar configuration. Sketch this configuration in the Inventor's Logbook space provided. Calculate the gear ratio and record the ratio in the Inventor's Logbook space provided. Turn the driver gear one full revolution and count the number of times that the driven gear turns. Record this information below.

Inventor's Logbook

Logbook 5.5

The example in Figure 5 has three gears meshed together. Each place where the gears mesh defines a gear ratio. One gear has 10 teeth, one has 50 teeth and one has 30 teeth. This gear train ratio can be calculated in a variety of ways. For example, the formula in Figure 4 can be used to calculate the gear ratio by following these steps:

a. Write a gear ratio fraction that represents each pair of meshing gears

A:B = $\frac{50}{10}$ B:C = $\frac{30}{50}$

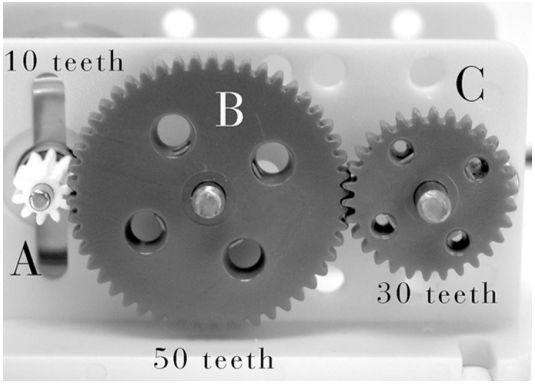


Figure 5. 3-gear configuration

b. If possible, simplify the fractions A:B = $\frac{5}{1}$ B:C = $\frac{3}{5}$

c. Multiply the numerators and denominators $\frac{5}{1}$ x $\frac{3}{5}$

d. Write the product $\frac{15}{5}$

e. If possible, simplify the gear ratio = 3 to 1

4. Add a third gear to the configuration in Step 3 to create a gear train. Sketch this configuration in the Inventor's Logbook space provided below. Calculate the gear ratio for each place that the gears mesh. Multiply the ratios to calculate the total gear ratio, like the example provided, and record your answer below.

   Turn the driver gear one full revolution and count the number of times that the last driven gear turns. Record all of this information in the Inventor's Logbook space provided.

Inventor's Logbook

Logbook 5.6

5. Take turns among your team members creating different configurations using at least five gears (make sure that each team member creates at least three different configurations). Have your team members:

    a. Predict the final direction that the last driven gear in the gear chain will rotate and then check to determine accuracy.

    b. Calculate the total gear ratio for your configuration.

    c. Test predictions by having someone turn the driver gear while observing the last driven gear in the gear chain. How many times did the last driven gear turn for each revolution of the driver gear?

    d. Place your predictions, calculations, and results in the Inventor's Logbook space provided below.

Inventor's Logbook

Logbook 5.7

Reflection

Find the answers to the following questions and write them in the Inventor's Logbook spaces provided. Be prepared to discuss your answers with the class.

1. What is the relationship between the torque bar and the teeth on a gear?

_____

_____

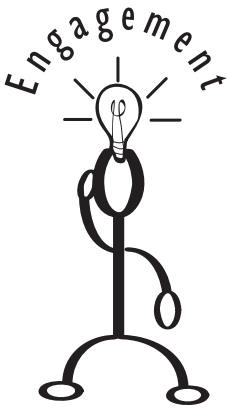
_____

Inventor's Logbook

Logbook 5.8

2. How would you configure a gear train to have the driven gear go as fast as possible? Sketch your answer below.

3. How would you configure a gear train to produce the most torque on the driven gear? Sketch your answer below.



What is the relationship between torque, speed, and distance?

Engagement

Gear trains are used in many machines to control the power of the engine or motor. In this activity, your instructor will assign you to a team that, together, will apply the concepts you explored to create a vehicle that pulls with the greatest possible force.

Design Challenge

Using materials supplied by your instructor, design and construct a vehicle that pulls with the greatest possible force.

Criteria/Constraints

1. Your vehicle must be able to connect to a spring scale at the height indicated by your instructor to measure the force.
2. Your team can only use the gear kit supplied by your instructor. Additional gears, motors, or batteries are not permitted.
3. You may use materials you find to create the structure for your vehicle.

Expansion

Select one of the following *Expansion* activities to engage in and follow the directions.

1. Set up an experiment to measure the torque produced by a bicycle in various "gears."
2. Prepare a presentation about torque and gear chains suitable for a middle school technology, mathematics, or science class and volunteer to make a presentation in one of those classes.
3. Find a discarded device that contains gears and take it apart. Using reverse engineering, find out why gears were used in the device and what the gear ratios were for each gear train.

Career Connections

Precision Instrument Repairer
Aerospace Engineer
Machinist

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

Within your *Primary Challenge* teams, reflect back to the requirements for the *Primary Challenge* and identify what you now know and what you still need to know to design a solution to the challenge. Begin to identify plausible solutions for moving your vehicle. Sketch several ideas in the space provided and share them with your team members.

Inventor's Logbook

Logbook 5.9

Ready, Set, Go!

Name: Date:

Element	Criteria				Points
	4	3	2	1	
Engagement Design work for	Exceptional design work to increase vehicle torque.	Above average design work to increase vehicle torque.	Average amount of design work to increase vehicle torque.	Limited design work on vehicle.	
Documentation	Exceptional documentation of design; more than 10 logbook entries/sketches.	Above Average documentation of design; 7-9 logbook entries/ sketches.	Average documentation of design; 4-6 logbook entries/ sketches.	Below average documentation of design; 1-3 logbook entries/ sketches.	
Design	Exceptional creativity and innovation in design.	Above average creativity and innovation in design.	Average creativity and innovation in design.	Below average creativity and innovation in design.	
Exploration Torque	Fully identifies and comprehends the concept of torque.	Identifies and comprehends most of the concept of torque.	Identifies and comprehends some of the concept of torque.	Does not identify or comprehend the concept of torque.	
Gear Ratio	Fully identifies and comprehends gear ratios.	Identifies and comprehends most gear ratios.	Identifies and comprehends some gear ratios.	Does not identify or comprehend gear ratios.	
				Total Points	