# Ratios and Calculating Mechanical Advantage

## Project 4 of 4

The following lesson is part of a series that should be explored in a sequential manner. Students will need the full exploration each concept in order to move from one phase of Levers, Arms and Fulcrum Points to the next. It is more than just play at this level. The purpose of these exercises is to take the concept of play into the field of science. It may not be easy, but it's certainly will be fun!

## Overview

This plan introduces skills of collaboration, problem solving, new understanding of mechanical advantage

**Level:** Advanced
**Age Group:** 3-5

**Time: 40 minutes**

**Main Goal: Collaboration, problem solving, new understanding of mechanical advantage**

## Guiding and supporting play:

- Observe, observe, observe!
- Allow children to explore their own Rigamajig play ideas. There is no set formula for "right" or "wrong" outcomes.
- Children may produce a variety of Rigamajig ideas to meet the basic objectives of the lesson plan. No two creations or play sessions are alike. Be comfortable with letting children's play evolve.
- There are no mistakes, let them explore and problem solve.
- Resist the urge to "fix" things for children and to show or tell children how to do things. Observe, and pay attention to children's ideas and actions. Support play in ways that focus children on their own ideas. Ask about what students are planning to do, what they are making, and what they can change to make their Rigamajig work better?
- Discover insights into children's creative thinking, and foster creativity!

## Materials needed:

- Rigamajig Basic Builder Kit
- Simple Machines Add-on Kit

## Getting started:

- (INSERT ANIMATION OF Unequal Gears Demo)

Set up two gears of unequal size on a vertical plane. It's best to start with the smallest 6 toothed gear and largest 18 toothed gear. Ask the students to count the number of rotations the small gear makes in the time it takes the large gear to complete a single rotation.

- (INSERT IMAGE OF Different size gears on a vertical plane)
- Get students to start thinking about ratios by asking, "What could explain the number of rotations?" "Do you think the number of rotations has anything to do with the number of teeth?"
- Note for Teacher:
    - **Definition of Gear Ratio:** The ratio between the rates at which the last and first gears rotate.
    - **Example:** If the small gear makes 3 revolutions when driven by a larger gear that makes 1, we would say that the gear ratio is 3:1 If the small gear were driving the larger gear, it would be 1:3
    - Explain that this ratio can also be determined by the number of teeth. 18 teeth driving 6 teeth is 18/6 = 3/1 = 3:1
- Note for Teacher:
    - The gear ratio not only determines the number of revolutions, it also determines the output of force or the mechanical advantage!
    - **Definition of Mechanical Advantage:** The ratio of the force produced by a machine to the force applied to it.
    - In addition to counting the number of teeth on a gear or revolutions, another way to determine the mechanical advantage is to compare the length of lever arms.
- (INSERT IMAGE OF measuring the gear)
- Measure the distance between the center of a gear and the middle of a tooth, halfway between to tooth's tip and base. This is approximately the radius of the gear's pitch circle and can be

used as the length of the gear's lever arm. Comparing this measurement between gears can give you the gear ratio and mechanical advantage of one gear driving another.

- **Hint:** It may be easier to measure from the edge of the hole in the center to the tip of the tooth. On these gears this should give approximately the same measurement.
- The same principle applies to levers! A plank with one end extending 4ft. past the fulcrum point and the other end extending 2 ft. would yield a mechanical advantage of 4/2 or 2:1 if the long end was pushed down to lift a weight on the short end.
- For Reference:
    - **Definition of Pitch Circle:** An imaginary circle that forms a single point of contact with a similar circle of another meshing gear. See illustration below. The pitch circle diameter of the gears in the Simple Machines Add-On Kit are as follows:
        - 6 tooth: 4in.
        - 9 tooth: 6in.
        - 12 tooth: 8in.
        - 15 tooth: 10in.
        - 18 tooth: 12in.
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## While play is underway:

Observe with an interested and supportive attitude and, as needed, encourage problem solving thinking, creativity, collaboration, discussion, and questions

Extension Challenge:

- A good math extension would be to have students calculate the gear ratio of all the possible pairings of gears in the Simple Machines Add-On kit. Some of the gears can be meshed together using the standard 8" hole spacing on the Basic Builder Kit planks. With these, the students can count the number of rotations as one gear drives another.
- There are also pairings of gears that will not mesh with an 8" hole spacing. For these pairings, students can use other information such as the number of teeth or the length of the gear's lever arm to determine gear ratios and mechanical advantage.

- **HINT**: Keep in mind that some gears will make partial rotations and students will have to work with fractions to figure the ratios out! Answers can be double checked by finding the same solution in a different way.

Expansion of Gear Ratio Lesson: Gear trains

- Connecting more than two gears together
    - Calculate total gear ratio of the entire gear train. Can very fast or very slow rotations be achieved?
    - *play and experimentation needed. How big of a gear train can be created with the provided parts?

## Vocabulary

Post some of the following words on a White Board, SmartBoard, sheet of chart paper or have the students make their vocabulary lists or posters of the key words. Encourage children's use of these words as they design and build. Encourage children to label the physical components of their creations.

- Gear Ratio
- Lever Arm
- Force
- Distance
- Planes
- Vertical
- Fulcrum
- Balance
- Horizontal
- Gears
- Ratios
- Goal

- Design
- Solve Problem
- Evaluate
- Teamwork

## What to look for:

- Watch for children's collaborations in their thinking and construction. Offer encouraging words about working together to build something.
- Pay particular attention to how children go about their construction process. Do they seem to have a specific goal? Or, do they seem more focused on learning about the properties of the materials and different things they can do with them?
- Pay attention to the language. What do their words reveal about their knowledge of objects, physical processes, design, and/or social collaboration?
- When children indicate they accomplished something, give them a chance to demonstrate their construction and how it works, and share with other children.

## What if the children "stall"?

- Sit with the group and ask them to discuss their ideas for what to build. Can they agree on something?
- Reinforce that any kind of construction is OK, it's whatever they want to do!
- Pick up a few pieces and put them together for children to see. Don't be afraid to model taking a risk, exploring, or changing an initial idea.

## Wrapping up & reflecting:

- What are you (were you) most curious about?
- What made for good collaboration?
- Tell us about a problem you encountered and your group's solution.
- Create drawings and descriptions or photographs and descriptions of work, including step by step as preferred
- Share and present work, include discuss about how and why construction decisions were made

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With the help our Captain of Play and Learing Ngina Johnson, we've put together a few project plans to get you started.