RC Vehicle Gears

Challenge Problems and Resources

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1. RC VEHICLE GEARS

1.1. INTRODUCTION

Remote Controlled (RC) Vehicles are not just fun to play with, but can also be an exciting and useful tool for learning. This lesson explores the use of gears in RC Vehicles. Students will predict how different gears could affect the performance of a vehicle, then will be asked to create a new gear for an RC Vehicle. Finally, they will 3D print their gear, install the product, then observe and compare the results to their predictions.

1.2. MATERIALS

- 3D Modeling Software
  - Autodesk Fusion 360 or 3D modeling software of your preference.
- 3D Printer
  - If a 3D printer is not available, there are companies that will print your files for you.
- Assorted Tools
  - In order to disassemble and reassemble your RC Vehicle, you will need a variety of tools.
  - The tools needed will be based on the RC Vehicle, but will most likely require the following materials: small Phillips and flat head screwdrivers, a small socket set (Metric or English), Allen wrench set (Metric or English), lubricant spray and part storage container(s).
- Engineering Design Process Graphic
  - Resources: Image A.
- Open Space for RC Vehicle Testing
  - Gymnasium, cafeteria or outdoor space at least 50 feet long and free of obstacles.
- Productivity Software
  - Software capable of creating flowcharts as well as other various charts and graphs.
- RC Vehicle
  - Redcat Volcano EPX or RC Vehicle of your choice.
- RC Vehicle Logbook
  - Fillable Word Documents.
- Time Measuring Device
  - Stopwatch or other time/distance-measuring tool.

1.3. STANDARDS

This lesson aligns with the following Ohio Education Association Learning Standards:

Science: Physics

- P.M: Motion.
- P.E: Energy.

Technology: Design and Technology

- Topic 2: Identify a problem and use an engineering design process to solve the problem.
- Topic 4: Evaluate designs using functional, aesthetic and creative elements.

Engineering: Pre-Engineering: Design and Development

- Outcome 5.3. Computer-Aided Drafting and Modeling.
- Outcome 5.5. Production and Process Design.

Math: Geometry

- G.CO: Congruence.

Math: Algebra

- A.CED: Creating Equations, Create equations that describe numbers or relationships.

1.4. KEY TERMS

Quizlet Flashcards can be found at https://quizlet.com/413292675/flashcards

3D Model – Virtual representation of an object.

Frequency – Radio wave signal, in megahertz, broadcast by the transmitter.

Gear Ratio – The ratio of the angular speed of the initial or driving member of a gear train or equivalent mechanism to that of the final or driven member.

Motor – Motors can turn wheels, steer the vehicle, operate propellers, etc.

Power Source – Battery that supplies power to the vehicle.

Radio Wave – Electromagnetic wave propagated by an antenna.

RC – Radio Controlled.

Receiver – An antenna and circuit board inside the vehicle receives signals from the transmitter and activates motors inside the toy as commanded by the transmitter.

RPM – Revolutions per minute.

Transmitter – You hold the transmitter in your hands to control the vehicle and it sends radio waves to the receiver.

1.5. INSTRUCTIONAL PLAN

During this lesson students will be learning about gears in an RC Vehicle. Students will begin by observing how the gears affect the speed and power of the vehicle while conducting initial testing and collecting data. Next, they will disassemble an RC Vehicle, noting the tools and process needed to do so. Then, students will reassemble the vehicle with a new 3D printed gear. Finally, they will recollect data and compare the results.

1.5.1. LESSON OUTLINE

1. Introduction
2. Design Process
3. Research and Initial Data Collection
4. Project Requirements
5. Brainstorm, Evaluate and Select Solution
6. Prototyping
7. Data Collection
8. Data Comparison

1.5.2. LEARNING TARGETS

- I can implement the design process to solve a problem.
- I can create motion graphs utilizing data on position, velocity, acceleration and time.
- I can use collected data to create equations and solve problems.
- I can design and print a 3D model using appropriate modeling software.
- I can recognize figures with symmetry.

1.5.3. ESSENTIAL QUESTIONS

- What is the Design Process?
- How do gears in an RC Vehicle affect its performance?
- What types of graphs would be useful to compare different gears?
- What formula(s) would be useful to measure the effectiveness of a gear?

- What software(s) can be used to create 3D models?

1.5.4. DAILY INSTRUCTIONAL PROCESS

Day 1: Introduction

- Explain that over the next three to four weeks they will be using the Design Process to study an RC Vehicle with the goal of creating new parts to improve its performance.
- Give students an informal overview of the RC Vehicles and how they work.
- Demonstrate how to properly install the RC Vehicle's batteries, turn it on and drive it.
- Provide students an opportunity to drive the vehicles on their own.

Day 2: RC Vehicle Logbook

- Show students the Engineering Design Process Graphic (Resources: Image A) and explain that they will be using this process to learn about their RC Vehicle.
- Give students the RC Vehicle Logbook. Explain that they will be documenting their progress during the project and that this will be a major part of their grade so it is important that they take the time to fill it out completely.
- Begin to fill out the RC Vehicle Logbook by completing Section 1: Introduction.
- Review Section 2: Define the Problem.
    - This will be the general process they will go through to complete the project.

Days 3- 6: Background Research

- Review with students that for this project they are following the Engineering Design Process. There are a lot of similar processes to solve problems, so it might be informational to have students search online and compare this process to others.
- Explain that over the next four days they will be working on the Background Research Section of their logbooks. It is up to the instructor whether the students will work on their own or in small groups. However, if they work in groups, be sure that each student fills out their own logbooks.
- *Section 3: Background Research*
    - Day 3
        - Create a Flow Chart to describe how the RC Vehicle works.
        - Define Gear Ratio.
        - Define RPM.
    - Day 4
        - Calculate the vehicle speed by using the formula Speed = Distance / Time.

        - Set up this experiment be determining a Distance, then have students drive their vehicle over that distance, using a stopwatch or other timing device to determine the time to travel that distance.
        - Students should attempt multiple tests for the most accurate results.
    - Day 5
        - Disassemble the RC Vehicle.
        - Make sure the students have the correct tools needed.
        - They will need a place to store the disassembled vehicle.
        - It will be helpful to keep screws labeled for reassembly.
    - Day 6
        - Calculate the Gear Ratio for the RC Vehicle.
        - Find the RPMs for the RC Vehicle Motor.
        - Calculate the RPMs for the utilized gears.
        - Give an overall RC vehicle report.

Day 7: Project Requirements

- Explain to the students that they will be creating a new gear for the RC Vehicle.
- The gear will be 3D modeled using the 3D modeling software of your choice. It must fit into the RC Vehicle assembly and the RC Vehicle must be functional when assembled to earn full credit.
- In order to 3D model a gear for the vehicle, they first need to know how to use 3D modeling software. If students have 3D modeling experience, they may move on to brainstorming solutions. However, if they do not have experience, you can give a tutorial on software use or have the students research tutorials online covering gear creation with your desired software.
    - See the Resources Section of this lesson for software and tutorial ideas.
    - 3D modeling is important. Make sure students have an understanding of how to use the 3D modeling software. This could add up to a week to this project.

Day 8: Brainstorming, Idea Evaluation & Solution Selection

- Ask students to review their test results from the background research. In teams, have the students come up with ideas for how they can improve the RC Vehicle's performance.
- Have students present their brainstorming ideas to the class and compare their ideas.
- Review their brainstorming ideas, evaluate their ideas and come up with a final project solution that they will 3D model and prototype.
- Instruct students to record their thoughts in the RC Vehicle Logbook.

Day 9-12: Prototyping

- Explain to the class that they will have four days to model and simulate their prototypes.
- Remind them that they need to have accurate measurements and that the gears need to fit into the RC Vehicle and the RC Vehicle needs to run when the gear is installed.
- Students should also use their RC Vehicle Logbooks to note problems that occur during the project and how they solved their problems. It would be helpful to also note what they accomplish as well as what they are working on when they finish each day.

Day 13: Solution Testing

- Students will retest their vehicles with the new gears and record the results in their logs.
    - Calculate the Gear Ratio for the RC Vehicle.
    - Calculate the RPMs for the utilized gears.
    - Calculate the vehicle speed.
    - Give an overall RC vehicle report.

Day 14-15: Results Comparison

- Students need to compare the results from their initial test to their solution test results.
- They should type an explanation of their results in their logbook and also must use their choice of productivity software to create multiple charts or graphs to visually compare the results.

1.5.5. DIFFERENTIATION STRATEGIES

- Project Based Learning
    - This project could be set up as a Project Based Learning activity by introducing the RC Vehicles then challenging student teams to modify the vehicle to improve performance. If doing this, it is recommended that a teamwork grading component is added to the rubric.
- Team Based Project
    - Instead of working individually, students could work in teams or small groups to complete the project. If doing this, it is recommended that a teamwork grading component is added to the rubric.
- Prefabricated Components
    - If 3D printing is not an option, you can purchase alternative gears for your RC Vehicle, have students install them and then compare results.

1.6. GRADING RUBRIC

Student Name:							
Solution	**4**	**3**	**2**	**1**	**Multiplier**	**Points Earned**	**Points Possible**
Solution	*Gear(s) is 3D printed, is sized correctly, fits into RC vehicle properly, the vehicle is assembled and drives.*	*Gear(s) is 3D printed, is sized correctly, fits into RC vehicle properly, but the vehicle is not assembled.*	*Gear(s) is 3D printed, but does not fit into the RC vehicle.*	*Gear(s) is 3D modeled, but not printed.*	*4*		***16***
Written Explanation	*Detailed explanation for comparison citing the gear ratio, RPM and speeds as well as an overall vehicle report.*	*Detailed explanation for 2 of 4 sections, with simple explanation of other 2 of 4 sections.*	*Simple explanation for all 4 sections.*	*Simple explanation for all 2 of 4 sections.*	*3*		***12***
Gear Ratio Chart / Graph	*Chart/graph selected is used correctly, easily readable, includes headings that relay important information, accurately compare results.*	*Chart/graph hits 3 of 4 requirements.*	*Chart/graph hits 2 of 4 requirements.*	*Chart/graph hits 1 of 4 requirements.*	*1*		***4***
RPM Chart / Graph	*Chart/graph selected is used correctly, easily readable, includes headings that relay important information, and accurately compare results.*	*Chart/graph hits 3 of 4 requirements.*	*Chart/graph hits 2 of 4 requirements.*	*Chart/graph hits 1 of 4 requirements.*	*1*		***4***
Speed Chart / Graph	*Chart/graph selected is used correctly, easily readable, includes headings that relay important information, and accurately compare*	*Chart/graph hits 3 of 4 requirements.*	*Chart/graph hits 2 of 4 requirements.*	*Chart/graph hits 1 of 4 requirements.*	*1*		***4***

	results.						
Process	**4**	**3**	**2**	**1**			
Introduction	*Detailed paragraph is written.*	*Detailed sentence written or detailed bullet points are used.*	*Generic sentence written.*	*Single words written as response.*	*1*		***4***
Flowchart	*Flowchart has 7 or more steps.*	*Flowchart has 5-6 steps.*	*Flowchart has 3-4 steps.*	*Flowchart has 2 steps.*	*4*		***16***
Gear Ratio	*Gear Ratio is defined (1) with a source (1) RC Vehicle gear ratio is given (1) with explanation (1).*	*3 of 4 completed.*	*2 of 4 completed.*	*1 of 4 completed.*	*2*		***8***
RPM	*RPM is defined (1) with a source (1). RC Vehicle gear RPM is given (1) with explanation (1).*	*3 of 4 completed.*	*2 of 4 completed.*	*1 of 4 completed.*	*2*		***8***
Background Research	*RC Motor RPM found, RC speed found, handling and overall observations made.*	*3 of 4 completed.*	*2 of 4 completed.*	*1 of 4 completed.*	*1*		***4***
Brainstorming, Idea Evaluation and Solution	*5 of 5 sections completed.*	*4 of 5 sections completed.*	*3 of 5 sections completed.*	*2 of 5 sections completed.*	*1*		***4***
Prototype Notes	*Notes are taken for 75% of days worked.*	*Notes are taken for 50% of days worked.*	*Notes are taken for 25% of days worked.*	*At least 1 note is written.*	*1*		***4***
Prototype Images	*Top, front, side and Orthographic images are displayed.*	*3 of 4 images are displayed.*	*2 of 4 images are displayed.*	*1 of 4 images are displayed.*	*1*		***4***
Solution test	*4 of 4 sections completed.*	*3 of 4 sections completed.*	*2 of 4 sections completed.*	*1 of 4 sections completed.*	*1*		***4***
Reflection	*Detailed reflection citing, likes/dislikes of project and possible changes listed.*	*Reflection citing, likes/dislikes of project.*	*1 sentence, generically written.*	*Section listed.*	*1*		***4***

Deductions							
On Time	*1 day late (-5).*	*2 days late (-10).*	*3 days late (-15).*	*4 or more days late (-20).*			
Spelling/Grammar Mistakes	*3-4 mistakes (-2).*	*5-6 mistakes (-5).*	*7-8 mistakes (-8).*	*Contains more than 8 errors (-10).*			
Totals							**100**
Notes							

1.7. RC VEHICLE LOGBOOK

Directions

Use this logbook to document the progress during the RC Vehicle project.

Introduction	**Completion Date:**	
Give your initial thoughts on RC Vehicles.		

Define the Problem	**Completion Date:**	
Project Goals:	1. Understand how an RC Vehicle works. 2. Test the vehicle to determine performance. 3. Modify the RC Vehicle to improve performance. 4. Retest the vehicle and compare results.	

Background Research	**Completion Date:**	
How does the vehicle work? (*Create and insert flowchart)*		

RC Vehicle Assembly Notes (sketches, part list, or any helpful information when disassembling the vehicle)

Define Gear Ratio:
RC Gear Ratio:
Define RPM:
RC Motor RPM:
RC Gear RPM:
RC Vehicle Speed:
RC Vehicle Handling on Surface Observations:
Overall RC Vehicle Report:

Project Requirements	**Completion Date:**	
• 3D Printed Gear. • Gear fits into the vehicle. • Vehicle works when reassembled. • Gear Ratio is defined. • Gear RPM is defined. • Comparison Report.		

Brainstorming	**Completion Date:**	
What do you want to improve?		
How can gear ratio be changed?		
Other modification ideas?		

Idea Evaluation	**Completion Date:**	
Notes:		

Solution Idea	**Completion Date:**	
Describe the solution:		

Prototype	**Completion Date:**	
Prototyping Notes:		
Insert images of prototype:		

Solution Test	**Completion Date:**
Gear Ratio for the RC Vehicle:	
RPMs for the utilized gears:	
Calculate the vehicle speed:	
Give an overall RC vehicle report:	

Results Comparison	**Completion Date:**	
Written explanation of testing comparison:		

Gear Ratio Chart / Graph:
RPM Chart / Graph:
Vehicle Speed Chart / Graph:

Project Reflection	**Completion Date:**	
Written reflection citing process to complete the project, likes/dislikes of project and possible changes that could be made if this project were to be completed again.		

1.8. RESOURCES

1.8.1. WEBSITES

1. Beginner RC Car Guide – This blog gives information about the parts of an RC car: https://beginnerrccarsguide.com/category/knowledge-base/
2. Engineering Design Process – Detailed description of the Engineering Design Process: https://www.sciencebuddies.org/science-fair-projects/engineering-design-process/engineering-design-process-steps?from=Blog#theengineeringdesignprocess
3. Gears and Gear Ratios PowerPoint – This document helps explain what gears are and how they work. It can be used as a presentation to the class or as a resource: http://bowlesphysics.com/images/Robotics_-_Gears_and_Gear_Ratios.pdf
4. How RC Toys Work – This site explains how Radio Controlled Toys work: https://electronics.howstuffworks.com/rc-toy.htm
5. Ohio Learning Standards – This site provides multiple links to download and view the Ohio Educational Association Learning Standards: http://education.ohio.gov/Topics/Learning-in-Ohio/OLS-Graphic-Sections/Learning-Standards

6. Redcat Racing – Visit this site to purchase Redcat brand RC Vehicles:
   Please note, this is one option for RC Vehicles. Other brands and vehicles will work for this lesson.
   https://www.redcatracing.com/
7. Redcat Volcano Spur Gear Removal – This video shows how to remove and replace a spur gear in a Redcat Volcano RC Truck:
   https://www.youtube.com/watch?v=a3Tgo6a9XUU
8. Understanding Gears: Speed vs Torque – This is a short video with a student explaining how to set gears up for speed or torque:
   https://www.youtube.com/watch?v=UUfZnZ_0Cb8

1.8.2. IMAGES

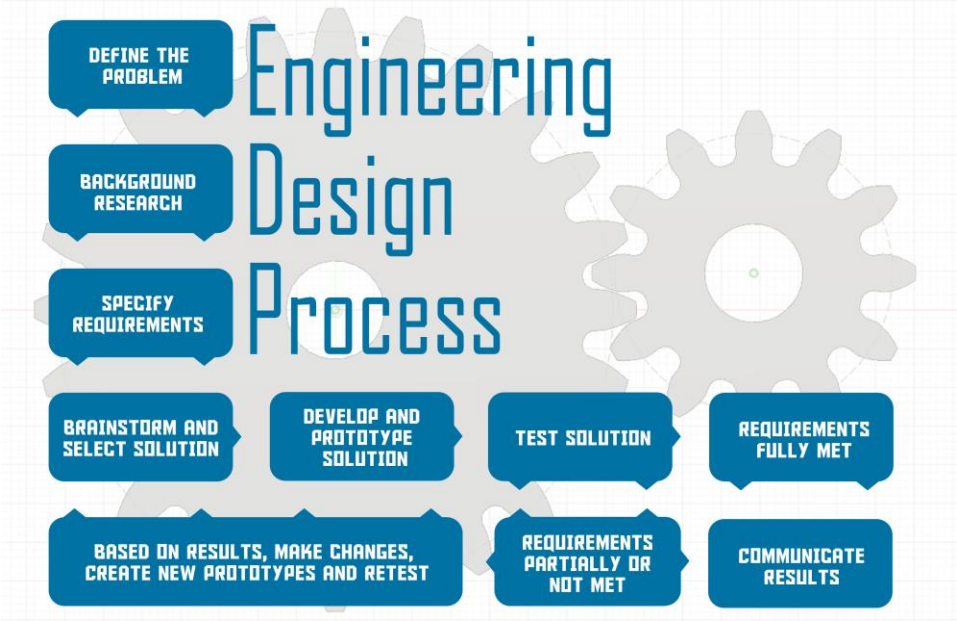

Image A: Engineering_Design_Process.jpg – Created by author using Adobe Photoshop and Autodesk Fusion 360

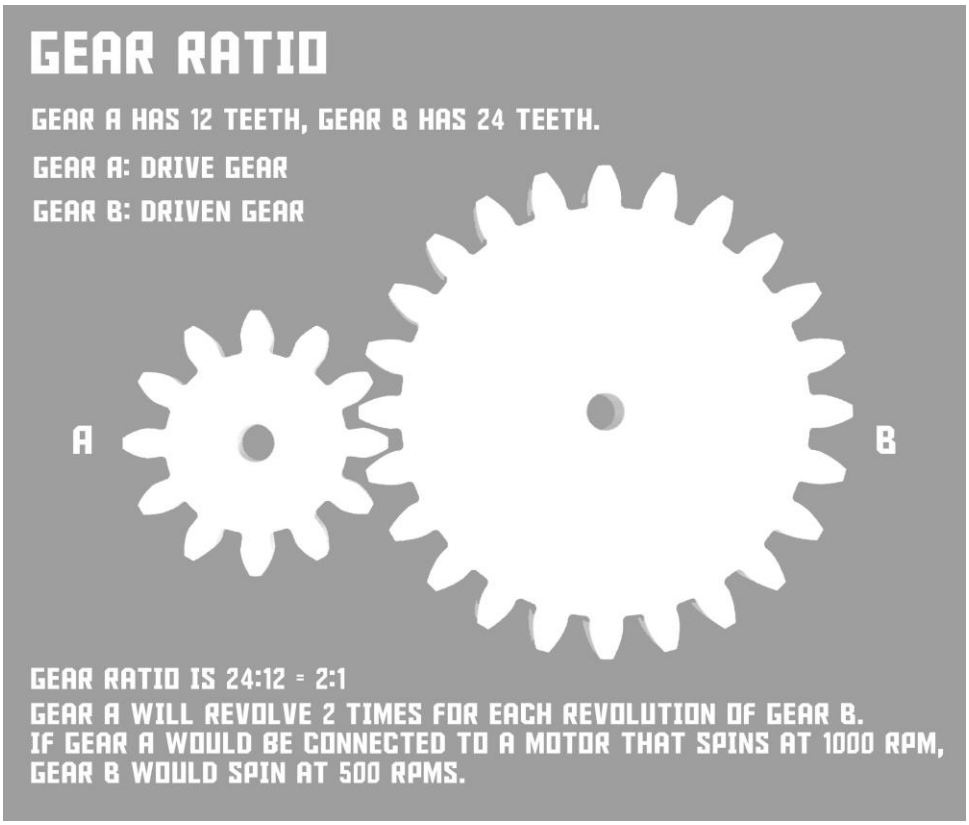

Image B: Gear_Ratio.jpg - Created by author using Adobe Photoshop and Autodesk Fusion 360