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| **TEXAS CTE LESSON PLAN**  [www.txcte.org](http://www.txcte.org) | |
| **Lesson Identification and TEKS Addressed** | |
| **Career Cluster** | Science, Technology, Engineering, & Mathematics |
| **Course Name** | Robotics I |
| **Lesson/Unit Title** | Intro to Robotics I - Part 3 - Propulsion |
| **TEKS Student Expectations** | **130.408. (c) Knowledge and Skills**  (6) The student develops the ability to use and maintain technological products, processes, and systems.  (A) The student is expected to demonstrate the use of computers to manipulate a robotic or automated system and associated subsystems.  (B) The student is expected to maintain systems to ensure safe and proper function and precision operation.  (7) The student develops an understanding of engineering principles and fundamental physics.  (A) The student is expected to demonstrate knowledge of Newton's Laws as applied to robotics such as rotational dynamics, torque, weight, friction, and traction factors required for the operation of robotic systems.  (B) The student is expected to demonstrate knowledge of motors, gears, gear ratios, and gear trains used in the robotic systems. |
| **Basic Direct Teach Lesson**  (Includes Special Education Modifications/Accommodations and  one English Language Proficiency Standards (ELPS) Strategy) | |
| **Instructional Objectives** | The students will be able to:   * Describe the purpose and use of gears in a robotic application. * Apply mathematical formulas to calculate how a gear train affects either speed or torque. * Identify the components of a DC motor. * Describe the relationship between current, speed, and torque in a DC motor. * Explain the theory of operation of a DC motor. * Apply mathematical formulas to calculate speed, current, torque, and efficiency for a DC motor in a robotic application. * Recognize the relationship between values in a mathematical formula and their graphical representation for variables like speed, current, and torque. |
| **Rationale** | The primary purpose of this module is to demonstrate the importance of math to robotics and technology. |
| **Duration of Lesson** | Teacher’s Discretion |
| **Word Wall/Key Vocabulary**  *(ELPS c1a,c,f; c2b; c3a,b,d; c4c; c5b) PDAS II(5)* | * Rotational Dynamics * Torque * Weight * Friction * Traction * DC Motor * Angular Velocity * Propulsion |
| **Materials/Specialized Equipment Needed** | Instructional Aids:   * Introduction to Robotics Part 3: Propulsion System Quiz answer key * Pictures of various DC motors and robots from website links   Materials Needed:   * Paper, pen/pencil * Introduction to Robotics Part 3: Propulsion System Quiz   Equipment Needed:   * Computer with internet access * DC motor used for demonstration |
| **Anticipatory Set**  (May include pre-assessment for prior knowledge) | **SAY:** Before you can design and build a robot on your own, there are many things you must know for the robot to perform effectively and efficiently.  **ASK:** Does anyone know what the requirements are for building a robot?  **SAY:** You need to follow the design process. It must perform the performance objectives given. You need to know why things like DC motors and specific gear ratios are used. SHOW: A DC motor.  **SAY:** This is the most common type of motor for a student robot. We must understand how this works and how we can design things like a gear train to make it work most efficiently.  **SAY:** One of the ways we learn how a DC motor works is by looking at the mathematics behindits operation. This is an example of how something real – making this DC motor work – requires an understanding of math. |
| **Direct Instruction \*** | 1. Propulsion System Basics    1. Students have learned the fundamentals of building structurally sound robots in Introduction to Robotics Parts 1: Overview; and Part 2: Structural System.    2. The main components of the propulsion system are motors, wheels, and gears.   TEACHER NOTE: In this lesson, students are expected to learn about DC motor and gears, but the primary purpose of this module is to demonstrate the importance of math to robotics and technology.   1. Gears    1. Provide a cursory overview of gears and their application.    2. Search internet for additional information on gears for more detail. There are many great tutorials, videos, and animations.    3. The key concept is that gears are used to either increase speed of rotation of the wheels or apply additional torque to the load. Gears trade one for the other.    4. There is an optimal gear ratio that will maximize both robot speed and motor efficiency. This gear ratio needs to be calculated for a specific application.   TEACHER NOTE: Show a gear video tutorial from the internet.   1. Motors    1. A motor always gets its mechanical energy from the interaction of 2 magnetic fields.    2. These example motor specs are for a real DC motor and are used for the worked examples in this lesson.    3. The load on a motor in a robot is the robot weight. The force required to make a robot move is delivered by the motors through the wheels.    4. The wheels act like a lever arm with a distance equal to the radius of the wheel. Bigger wheels place a larger torque load on the motor.   TEACHER NOTE: There are a variety of different types of motors; each of which works differently and would have different characteristic curves. We chose the permanent magnet DC motor because it is the most common type found in student-built robots.   1. Angular Velocity    1. The concept of angular velocity may be new to some students.    2. There are two categories of units, American and International (System International, or SI). International units are also sometimes called metric units.    3. Students need to be able to make calculations in both sets of units and so need to be able to convert back and forth.    4. The units of angular velocity are like work (force times distance) but a motor only does work when it rotates through an angle.   TEACHER NOTE: Practice some conversions before moving on. There will be questions like this on the quiz. Teachers may want to make up some conversion practice examples to supplement.   1. DC Motor Parts    1. Pictures are provided to clarify the descriptions.    2. There are some hidden parts, like the springs used to hold the brushes against the commutator.    3. Like a wheel, the direction of rotation of the top of the rotor is opposite of the direction of the bottom of the rotor. The direction of movement through the external magnetic field affects the direction of the resultant force.    4. For the forces in a motor to allow continuous rotation, the polarities must be consistent. For example, the polarity of the rotor field near the stators N pole always must be positive, the polarity of the voltage in the rotor field near the stators S pole must always be negative.    5. If the commutator did not reverse the polarity, the same polarity (say, positive) would follow the rotor field from the N pole to the S pole, the resultant force would also reverse, and the motor would not be able to rotate for a full turn.   TEACHER NOTE: Students may have trouble understanding why the commutator must switch the polarity of the voltage to the rotor field, You may want to search the internet for good quality cutaway diagrams of brushed DC motors   1. Generator Action in a Motor    1. A motor is supposed to produce mechanical energy out.    2. However, as the motor spins the motion of conductors in a magnetic field generates a voltage.    3. Generator action in a motor produces CEMF    4. This CEMF opposed the supply voltage.    5. The effect is for low current at high speed (which you get with low or no load on the motor) and higher current at lower speeds.    6. As the external load applied slows the motor down, the motor draws more current.   TEACHER NOTE: This will be another tricky thing for students to understand.   1. Motor Characteristic Curves    1. These are visual representations of the relationships between torque (load on the motor), current, and speed.    2. These relationships are also expressed mathematically.    3. Note the mathematical symbols for the various quantities. 2. Motor Characteristic Formulas    1. There is only one formula showing the relationship between speed and torque. The other formulas shown are algebraic manipulations solving for different variables.    2. The relationship between speed and current involves CEMF. In fact, CEMF is directly proportional to speed, which makes current inversely proportional to speed and CEMF.    3. The two formulas mentioned here will be the main formulas used in our calculations.    4. These are great mathematical formulas to use because they require a step by step process to solve and they are not simple and direct like Ohms Law.    5. The formulas shown are mostly for information only, although students will need to use the velocity and power formulas later.   TEACHER NOTE: We primarily use the formula for motor speed.   1. Example Problems    1. These equations are necessary to calculate exactly where robot motors will be operating with an actual robot.    2. Students may not be as interested in efficiency but they should be interested in being able to determine how to make their robot go as fast as possible.    3. The examples given are from a real motor used often in student robotics.    4. The questions asked involve multiple steps to solve, and there is a sequence needed for the steps.    5. The motor constant Key is often determined experimentally because it can differ slightly from motor to motor even of the same type.    6. Example motors 2 and 3 are also real motors used in the BEST robotic contest, but the answers need to be calculated by the students so the solutions are not provided here.    7. Actual motor load torque used in real robots should be less than half stall torque to minimize current and to allow robots to pick up objects without overloading the motors.   TEACHER NOTE: These are real world problems a student would have to solve when working with real robots. If you can, have students experiment with different gear ratios to demonstrate the reality of the formulas to applications  *Individualized Education Plan (IEP) for all special education students must be followed. Examples of accommodations may include, but are not limited to:*  None |
| **Guided Practice \*** | Under the teacher’s guidance, have students calculate speed, current, efficiency, and optimal gear ratio using example motor 2.  *Individualized Education Plan (IEP) for all special education students must be followed. Examples of accommodations may include, but are not limited to:*  None |
| **Independent Practice/Laboratory Experience/Differentiated Activities \*** | Have students calculate speed, current, efficiency, and optimal gear ratio using example motor 3.  *Individualized Education Plan (IEP) for all special education students must be followed. Examples of accommodations may include, but are not limited to:*  None |
| **Lesson Closure** | Question: How would you demonstrate that these calculations apply to real motors in real robots?  Answer: We could build some practice robots and test them. |
| **Summative/End of Lesson Assessment \*** | Introduction to Robotics Part 3: Propulsion System Quiz and sample problems  *Individualized Education Plan (IEP) for all special education students must be followed. Examples of accommodations may include, but are not limited to:*  None |
| **References/Resources/**  **Teacher Preparation** | Website from the MIT Mechanical Engineering department: <http://lancet.mit.edu/motors/motors3.html> |
| **Additional Required Components** | |
| **English Language Proficiency Standards (ELPS) Strategies** |  |
| **College and Career Readiness Connection[[1]](#footnote-1)** |  |
| **Recommended Strategies** | |
| **Reading Strategies** |  |
| **Quotes** |  |
| **Multimedia/Visual Strategy**  **Presentation Slides + One Additional Technology Connection** |  |
| **Graphic Organizers/Handout** |  |
| **Writing Strategies**  **Journal Entries + 1 Additional Writing Strategy** |  |
| **Communication**  **90 Second Speech Topics** |  |
| **Other Essential Lesson Components** | |
| **Enrichment Activity**  (e.g., homework assignment) | * Have students create the motor characteristic curves shown on by themselves from the motor specs given for example motors 2 and 3. * Have students look up specs for other hobby/robot motors and work calculations and create curves. * Have students build gear trains that optimize motor efficiency and robot speed. * Have students perform time and distance experiments that show the relationship between gear ratio and maximum robot speed. |
| **Family/Community Connection** |  |
| **CTSO connection(s)** | SkillsUSA, TSA |
| **Service Learning Projects** |  |
| **Lesson Notes** |  |

1. Visit the Texas College and Career Readiness Standards at <http://www.thecb.state.tx.us/collegereadiness/CRS.pdf>, Texas Higher Education Coordinating Board (THECB), 2009. [↑](#footnote-ref-1)