Unit 4: Making Things Move (8 Weeks)

Content Area: **STEM**
Course(s):
Time Period: **Full Year**
Length: **8 Weeks**
Status: **Published**

UNIT RATIONALE

This unit focuses on familiarizing students with basic engineering knowledge related to simple mechanical and electrical systems and the use of mathematical models to represent design ideas and to inform design decisions. Students begin by reverse engineering a mechanical device to identify simple machines and mechanisms that influence motion and contribute to the function of the device. Students identify different types of motion (rotary, oscillating, linear, and reciprocating) and investigate mechanisms that cause motion (including cams, gears, pulleys, chain and sprockets) and later use these mechanisms to create, transform, and control motion to solve a problem. Students practice CAD skills by developing assembly models of the mechanisms they investigate and simulating motion in the CAD environment. To support efficient CAD modeling, students will also learn to use mathematical functions to represent dimensional relationships in a 3D solid model. Students investigate forces that resist motion. First students study spring forces and develop a mathematical model to determine the relationship between spring displacement and force for a given spring. Students also learn about simple electrical circuits and how to transform electrical power to motion using a motor. Students design and install a circuit to run a hobby motor that powers their previously designed automaton. As part of the electrical circuit, students develop a mathematical model to inform the design of a simple potentiometer to control the speed of the motor. As an end of course project, students design and build a toy that includes an electro-mechanical system that will produce realistic motion of a figure(s) or object(s) resulting from the rotation of an axle powered by a motor with minimal frictional resistance. As part of the automaton design process, each student creates a CAD assembly model and creates a computer simulation of automata motion, CAD technical drawings, and a physical working model of their design.

ESSENTIAL QUESTIONS

1. What is a mechanical system? How can we effectively model mechanical systems?
2. How can we use mathematical models to model linear motion?
3. What is Hooke's Law? What are spring characteristics and how can they be modeled mathematically?
4. What is friction? How does an object's coefficient of friction affect it motion?
5. How can simple machines be used to transfer motion?
6. How can friction be reduced using a bushing?

7. What is a circuit and how can we use circuits to create motion?

8. What is a variable resistor?

STANDARDS

New Jersey Student Learning Standards: 21st Century

CRP.K-12.CRP1.1	Career-ready individuals understand the obligations and responsibilities of being a member of a community, and they demonstrate this understanding every day through their interactions with others. They are conscientious of the impacts of their decisions on others and the environment around them. They think about the near-term and long-term consequences of their actions and seek to act in ways that contribute to the betterment of their teams, families, community and workplace. They are reliable and consistent in going beyond the minimum expectation and in participating in activities that serve the greater good.
CRP.K-12.CRP2.1	Career-ready individuals readily access and use the knowledge and skills acquired through experience and education to be more productive. They make connections between abstract concepts with real-world applications, and they make correct insights about when it is appropriate to apply the use of an academic skill in a workplace situation.
CRP.K-12.CRP5.1	Career-ready individuals understand the interrelated nature of their actions and regularly make decisions that positively impact and/or mitigate negative impact on other people, organization, and the environment. They are aware of and utilize new technologies, understandings, procedures, materials, and regulations affecting the nature of their work as it relates to the impact on the social condition, the environment and the profitability of the organization.
CRP.K-12.CRP6.1	Career-ready individuals regularly think of ideas that solve problems in new and different ways, and they contribute those ideas in a useful and productive manner to improve their organization. They can consider unconventional ideas and suggestions as solutions to issues, tasks or problems, and they discern which ideas and suggestions will add greatest value. They seek new methods, practices, and ideas from a variety of sources and seek to apply those ideas to their own workplace. They take action on their ideas and understand how to bring innovation to an organization.
CRP.K-12.CRP7.1	Career-ready individuals are discerning in accepting and using new information to make decisions, change practices or inform strategies. They use reliable research process to search for new information. They evaluate the validity of sources when considering the use and adoption of external information or practices in their workplace situation.
CRP.K-12.CRP11.1	Career-ready individuals find and maximize the productive value of existing and new technology to accomplish workplace tasks and solve workplace problems. They are flexible and adaptive in acquiring new technology. They are proficient with ubiquitous technology applications. They understand the inherent risks-personal and organizational-of technology applications, and they take actions to prevent or mitigate these risks.
CRP.K-12.CRP12.1	Career-ready individuals positively contribute to every team, whether formal or informal. They apply an awareness of cultural difference to avoid barriers to productive and positive interaction. They find ways to increase the engagement and contribution of all team members. They plan and facilitate effective team meetings.

NEW JERSEY STUDENT LEARNING STANDARDS: CAREER READINESS, LIFE LITERACIES AND KEY SKILLS

TECH.9.4.12.CI.1	Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).
TECH.9.4.12.CI.2	Identify career pathways that highlight personal talents, skills, and abilities (e.g., 1.4.12prof.CR2b, 2.2.12.LF.8).
TECH.9.4.12.CI.3	Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

NEW JERSEY STUDENT LEARNING STANDARDS: COMPUTER SCIENCE AND DESIGN THINKING

CS.9-12.8.2.12.ED.2	Create scaled engineering drawings for a new product or system and make modification to increase optimization based on feedback.
CS.9-12.8.2.12.ED.5	Evaluate the effectiveness of a product or system based on factors that are related to its requirements, specifications, and constraints (e.g., safety, reliability, economic considerations, quality control, environmental concerns, manufacturability, maintenance and repair, ergonomics).

NEW JERSEY STUDENT LEARNING STANDARDS: Technology

New Jersey Core Curriculum - Grade 9 - Technology

8.2.12.C.4

Explain and identify interdependent systems and their functions.

8.2.12.C.5

Create scaled engineering drawings of products both manually and digitally with materials and measurements labeled.

8.2.12.D.3

Determine and use the appropriate resources (e.g., CNC (Computer Numerical Control) equipment, 3D printers, CAD software) in the design, development and creation of a technological product or system.

8.2.12.D.5

Explain how material processing impacts the quality of engineered and fabricated products.

TECH.8.2.12.C.4	Explain and identify interdependent systems and their functions.
TECH.8.2.12.C.5	Create scaled engineering drawings of products both manually and digitally with materials and measurements labeled.
TECH.8.2.12.D.3	Determine and use the appropriate resources (e.g., CNC (Computer Numerical Control) equipment, 3D printers, CAD software) in the design, development and creation of a technological product or system.
TECH.8.2.12.D.5	Explain how material processing impacts the quality of engineered and fabricated products.

PRE-ASSESSMENTS

Making movement using Vex IQ parts.

INSTRUCTIONAL PLAN

MODULE 1

Activity 4.1.1

Activity 4.1.1: Reverse Engineer a Mechanism: Students will reverse engineer a wind up toy with the purpose of understanding how motion is transferred through the system.

Student Learning Intentions (SLI) WALT: (We are learning to...)	- Define Cams and Identify Uses - Create a Motion Pathway
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Motion Pathway Display with accurate representation - Review of other wind up displays
Formative Assessment (drives instructional decisions)	- Engineering Notebook
Activities and Resources	
Suggested Modifications	**English Language Learners** **Adjusted Speech**: The teacher changes speech patterns to increase student comprehension. This could include facing the students, paraphrasing, clearly indicating the most important ideas, and speaking more slowly.

Visuals: The teacher uses graphics, pictures, visuals, and manipulatives. This helps ELL students better understand and comprehend the subjects at hand.

Front-Loading Vocabulary: The teacher front loads vocabulary. This means providing students with a list of important vocabulary words they will need to know for a book, lesson, etc. prior to the lesson being taught. Including pictures to go with the vocabulary words is also very beneficial for the students.

Students with Individualized Education Plans/504s
Chunking: The teacher presents information in a way that makes it easy for students to understand and remember. Chunking is based on the presumption that our working memory is easily overloaded by excessive detail. The best way to deliver information is to organize it into meaningful units. Because students with special needs get overloaded easily, chunking is an effective strategy to use with them.

Checking for Understanding: It is important to constantly chec for understanding, especially for students who have accommodations. Teachers want to make sure students understand the concepts being covered in a way that makes sense to them.

Extra time: The teacher provides students with special needs extra time to complete work or answer questions. It is important to give students enough time to process their thoughts.

Oral Reading: The teacher will read work orally to students. Class work such as tests and literature circles may need to be read aloud to the student.

Gifted & Talented Strategies
Extensions/Enrichments: Teachers will provide gifted and talented students with extension/enrichment projects. Students will be challenged to further their understanding, to apply acquired knowledge, and/or to produce something in reference to acquired knowledge.

Modify/Change Activities: Teachers will monitor and modify activities to accommodate those students who need to be challenged further. Additional reading, problem-solving, writing, or project work is necessary for those students who are ready to move on at a rate more accelerated than their peers. In this way G & T students are provided the same opportunity for support as special needs students.

Students at Risk of School Failure
Directions or Instructions: Make sure directions and/or instructions are given in limited numbers. Give directions/instructions verbally and in simple written format. Ask students to repeat the instructions or directions to ensure understanding occurs. Check back with the student to ensure he/she hasn't forgotten.

Peer Support: Peers can help build confidence in other student by assisting in peer learning. Many teachers use the 'ask 3 before me' approach. This is fine, however, a student at risk may have to have a specific student or two to ask. Set this up for the student so he/she knows who to ask for clarification before going to you.

Alternate or Modified Assignments: Always ask yourself, "How can I modify this assignment to ensure the students at risk are able to complete it?" Sometimes you'll simplify the task,

	reduce the length of the assignment or allow for a different mode of delivery. For instance, many students may hand something in the at-risk student may jot notes and give you the information verbally. Or, it just may be that you will need to assign an alternate assignment. **Increase One to One Time:** When other students are working, always touch base with your students at risk and find out if they're on track or needing some additional support. A few minutes here and there will go a long way to intervene as the need presents itself. **Contracts:** It helps to have a working contract between you and your students at risk. This helps prioritize the tasks that need to be done and ensure completion happens. Each day write down what needs to be completed, as the tasks are done, provide a checkmark or happy face. The goal of using contracts is to eventually have the student come to you for completion sign-offs **Hands On:** As much as possible, think in concrete terms and provide hands-on tasks. This means a child doing math may require a calculator or counters. The child may need to tape record comprehension activities instead of writing them. A child may have to listen to a story being read instead of reading it him/herself. **Tests/Assessments:** Tests can be done orally if need be. Break tests down in smaller increments by having a portion of the test in the morning, another portion after lunch and the final part the next day. **Seating:** Seat students near a helping peer or with quick access to the teacher. Those with hearing or sight issues need to be close to the instruction which often means near the front.

Activity 4.1.2

Activity 4.1.2: Cams Make the World Go Round: Students will use parametric modeling to design a CAD model of a cam. Students will consider the tolerance and allowance of the fit between the hole and the axle of the automata assembly.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Identify Types of Cams - Create a cam profile in OnShape - Use Parametric Constraints
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions

Success Criteria	- Properly Designed CAM in 3D
Formative Assessment (drives instructional decisions)	- 3D CAD file - Cam ID Sheet
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.1.3

Activity 4.1.3: Mechanisms of Motion: Students will build an assigned Mechanical System using Vex. Students will analyze the mechanical systems made by all groups, specifically looking at the necessary inputs and outputs of each system.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Building with VexIQ parts - Create mechanical motion
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly assembled and moving mechanical system
Formative Assessment (drives instructional decisions)	- Engineering Notebook Questions
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.1.4

Activity 4.1.4: Modeling Mechanical Motion: Students will build and analyze the motion of a pulley and different gear systems. They will model these systems on CAD and use the CAD animations features to analyze the motion of the pulley on the computer.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Copy Document files from Team Folder - Import and Export Parts - Animate Motion - Apply Gear Relations
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly constrained mechanical system with movement
Formative Assessment (drives instructional decisions)	- 3D CAD File
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.1.5

Activity 4.1.5: Cams in Motion: Students will model linear motion using graphs. Students will use motion graphs to compare the motion of different sized and different shaped cams.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Create and Interpret Linear Motion Graphs - Create Graphs in Google Sheets
Student Learning Strategies	Journaling Collaboration Cooperative Learning

	APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly recorded Data
Formative Assessment (drives instructional decisions)	- Google Sheet with Graph
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.1.6

Activity 4.1.6: Design a Cam: Students will design the cam or cams they wish to use in their automata, based on the type of motion that would fit with the story/theme of their automata. They will model the cam in CAD and create a physical model of the cam.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Identify and Create proper cam profiles for expected results data - Use Laser
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Prototype and Test Cam
Formative Assessment (drives instructional decisions)	- 3D CAD File
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.1.7

Activity 4.1.7: Simulating Cam Motion: Students will assemble a simple automata box with their cam in CAD.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Create tangential relationships in CAD
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly working Cam demo box in CAD
Formative Assessment (drives instructional decisions)	- CAD 3D File
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.1.8

Activity 4.1.8: Shoebox Automaton: Students will create a rough mock-up of an automata using the cams created in Activity 4.1.6. The cam should transfer motion from one axle to another. Students will test their design, make revisions and create a motion graph to describe the motion of the follower as it travels along the cam.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Demonstrate cam motion - Observe and Critique other designs
Student Learning Strategies	Journaling Collaboration Cooperative Learning

	APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Reflection analysis from students - Automata Box Prototype
Formative Assessment (drives instructional decisions)	- Engineering Notebook Data
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

MODULE 2

Activity 4.2.1

Activity 4.2.1: Force Springs Eternal: Students will conduct an experiment that will show the relationship between applied force and displacement of a spring. Students will create a mathematical model to show this relationship. Students will identify the slope of the model as the spring constant. Students will learn about Hooke's Law and examine Hooke's Law through the context of the experiment performed.
Students will research different types of springs to learn about classification, usage and storage of energy.
Students will design and conduct an experiment to test one of the characteristics of a spring. Students will analyze their data and present their experimental process to another team.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Define and Utilize Hooke's Law - Identify types of springs and their uses
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly filled out observation sheet with data

Formative Assessment (drives instructional decisions)	- Engineering Notebook
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.2.2

Activity 4.2.2: Friction is a Real Drag: Students will use an online simulation to analyze object particles when objects slide together to begin to understand the concept of friction. Students will learn about friction by watching a video. Students will be presented with different materials and will record the object's material, weight, normal force, frictional force and use the formula learned to calculate its coefficient of friction. Students will create a model to represent the coefficients of friction for each object.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Define and Identify different types of Friction and Stiction - Calculate Coefficient of Friction
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Coefficient of Friction Model for Object/Material
Formative Assessment (drives instructional decisions)	- Engineering Notebook
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.2.3

Activity 4.2.3: Fighting Friction: Students will analyze their Automata Box Kits to determine how friction will play a role in their final designs. They will brainstorm how to reduce friction using a bushing. They will 3D model their bushing concept.

Student Learning Intentions (SLI) WALT: (We are learning to...)	- Define and Identify types of Bushings - Design Bushing with specific material
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly designed Bushing with material assigned
Formative Assessment (drives instructional decisions)	- 3D CAD File
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.2.4

Activity 4.2.4: Friction: Design Friend of Foe: Students will design and build a cam and follower system that uses friction to translate rotational motion of the cam to rotational motion of the follower in another plane. Students will then design and build a pulley and belt system to efficiently transfer motion from one pulley to another. Lastly, students will design a mechanical system that uses friction in one part of the design and minimizes friction in another part of the design.

Student Learning Intentions (SLI) WALT: (We are learning to...)	- Analyze different forms of Friction and identify benefits and negatives in a mechanical system.
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems)

	Class Discussions
Success Criteria	- Properly rotating action within automata minimizing frictional forces
Formative Assessment (drives instructional decisions)	- Automata Prototype Redesign
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.2.5

Activity 4.2.5: Automata Design Challenge: Students will brainstorm ideas for their automata model, considering types of motion and the role springs and friction will play. Students will create a CAD model of their design and create technical drawings of the design. Students will construct and test their design. Students will peer review the designs of their classmates, providing effective feedback.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Identify relationship between Springs and Friction - Finalize Design Plans
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly designed 3D CAD file - Working Prototype of Automata
Formative Assessment (drives instructional decisions)	- Automata - Engineering Notebook - 3D CAD file
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

MODULE 3

Activity 4.3.1

Activity 4.3.1: Circuit Basics: Students will design and build a circuit to make a motor run using a battery, wires and a switch. Students will integrate their motor into their automata design to motorize the turning of your automaton's axle.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Define and Identify parts of a basic Circuit - Analyze and measure flow of electricity - Define and Identify parts of a motor - Define Battery - Identify difference between AC and DC Current
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Completed Circuit of Moving Motor
Formative Assessment (drives instructional decisions)	- Engineering Notebook - Properly labeled Circuit Diagram
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.3.2

Activity 4.3.2: Fun with Motors: Students will use a multimeter to create a variable resistor using nichrome wire and add this to their circuit. Students will create a mathematical model that estimates the cycles per second of the follower with respect to the setting of the variable resistor.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Define and Identify Resistor and Resistance - Analyze role of resistance in a circuit - Use a Multimeter - Identify relationship between flow of electricity and physical motion
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Proper readings from Multimeter - Properly assembled Circuit with Resistor
Formative Assessment (drives instructional decisions)	- Circuit Diagram - Model of Resistance
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

Activity 4.3.3

Activity 4.3.3: Automata Redesign: Students will automate their automata designs by incorporating what they know about circuits. Students will add to their CAD model of the design and update their technical drawings. Students will take a picture of their working automata and write a short story of their electromechanical system.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Set resistance to achieve proper rate of physical activity - Integrate a circuit to a mechanical system. - Using a switch to control a circuit
Student Learning Strategies	Journaling Collaboration Cooperative Learning

	APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly working electromechanical system
Formative Assessment (drives instructional decisions)	- Final Automata Design - Engineering Notebook
Activities and Resources	- See Above
Suggested Modifications	- See Activity 4.1.1

REFLECTIONS

INTERDISCIPLINARY CONNECTIONS: NEW JERSEY STUDENT LEARNING STANDARDS FOR ELA, SOCIAL STUDIES, SCIENCE AND/OR MATHEMATICS

CCSS.Math.Content.HSS-ID.A.1	Represent data with plots on the real number line (dot plots, histograms, and box plots).
CCSS.Math.Content.HSS-ID.A.2	Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.
CCSS.Math.Content.HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling.
CCSS.Math.Content.HSG-MG.A.1	Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).
CCSS.Math.Content.HSG-MG.A.2	Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).
SCI.HS-PS2	Motion and Stability: Forces and Interactions
SCI.HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
SCI.HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
SCI.HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
CCSS.ELA-Literacy.CCRA.W.9	Draw evidence from literary or informational texts to support analysis, reflection, and research.
CCSS.ELA-Literacy.CCRA.SL.2	Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
CCSS.ELA-Literacy.CCRA.SL.4	Present information, findings, and supporting evidence such that listeners can follow the

line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.