UNIVERSITY TRANSPORTATION CENTER FOR RAILWAY SAFETY

UTCRS Elementary STEM Curriculum

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Objectives

By the end of the summer camp, students will be able to:

1. Explain that magnets have north and south poles.
2. Understand forces between two magnetic objects.
3. Understand that a force is a push or pull between two objects.
4. Understand inertia and how external forces change the motion of an object with regard to their MagLev Train system.
5. Explore different forces including gravity, friction, magnetism, and electromagnetism.
6. Understand electromagnetic properties and their role in MagLev trains.
7. Understand the role of superconductivity and how it can improve the efficiency of magnets.
8. Understand the relationship between force, mass, and acceleration with regard to their MagLev Train system.
9. Understand the benefits of MagLev trains as a real-life viable transportation alternative.
10. Use the engineering design process to design, test, and evaluate a MagLev system.
11. Think critically and find solutions to transportation engineering problems.
12. Work collaboratively in small groups.
13. Complete a challenge of designing the fastest and safest MagLev Train.

Texas Essential Knowledge and Skills (TEKS) and National Standards

TEKS Science 3-5

(2) Scientific investigation and reasoning. The student uses scientific inquiry methods during laboratory and outdoor investigations. The student is expected to:

- (A) plan and implement descriptive investigations, including asking and answering questions, making inferences, and selecting and using equipment or technology needed, to solve a specific problem in the natural world;
- (B) collect data by observing and measuring using the metric system and recognize differences between observed and measured data;
- (C) construct maps, graphic organizers, simple tables, charts, and bar graphs using tools and current technology to organize, examine, and evaluate measured data;
- (D) analyze and interpret patterns in data to construct reasonable explanations based on evidence from investigations;

(E) demonstrate that repeated investigations may increase the reliability of results; and
(F) communicate valid conclusions supported by data in writing, by drawing pictures, and through verbal discussion.

(6) Force, motion, and energy. The student knows that forces cause change and that energy exists in many forms. The student is expected to:
(A) explore interactions between magnets and various materials;
(B) observe and describe the location of an object in relation to another such as above, below, behind, in front of, and beside; and
(C) observe and describe the ways that objects can move such as in a straight line, zigzag, up and down, back and forth, round and round, and fast and slow.

TEKS Math 3-5

(8) Data analysis. The student applies mathematical process standards to solve problems by collecting, organizing, displaying, and interpreting data. The student is expected to:
(A) collect, sort, and organize data in up to three categories using models/representations such as tally marks or T-charts;

International Technology and Engineering Educators Association (ITEEA) Standards

Grades 3-5

Standard 2. Students will develop an understanding of the core concepts of technology.

- A subsystem is a system that operates as a part of another system.
- When parts of a system are missing, it may not work as planned.
- Resources are the things needed to get a job done, such as tools and machines, materials, information, energy, people, capital, and time.
- Tools are used to design, make, use, and assess technology.
- Materials have many different properties.
- Tools and machines extend human capabilities, such as holding, lifting, carrying, fastening, separating, and computing.
- Requirements are the limits to designing or making a product or system.

Standard 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

- Technologies are often combined.

- Various relationships exist between technology and other fields of study.

Standard 8. Students will develop an understanding of the attributes of design.

- The design process is a purposeful method of planning practical solutions to problems.
- Requirements for a design include such factors as the desired elements and features of a product or system or the limits that are placed on the design.

Standard 12. Students will develop the abilities to use and maintain technological products and systems.

- Recognize and use everyday symbols.
- Follow step-by-step directions to assemble a product.
- Select and safely use tools, products, and systems for specific tasks.
- Use computers to access and organize information.
- Use common symbols, such as numbers and words, to communicate key ideas.

National Science Education Standards

Content Standard A:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B:

- Properties of objects and materials
- Forces and motion
- Electricity and magnetism
- Transfer of energy

Content Standard E:

- Abilities of technological design
- Understanding about science and technology

Content Standard F:

- Science and technology in local challenges
- Science and technology in society

Day 1 - Overview of Transportation and Speed

Activity #1

Estimated Time Needed: 15 minutes
Title: Transportation Engineering Scavenger Hunt
Lesson Overview: Students will learn to identify different types of transportation modes and their proper names.
Materials Needed: (per group)

- 25 pictures and names of transportation modes (trains, cars, airplanes, ships…)

Objectives:

1. Investigate different types of transportation
2. Determine how to group various types of transportation

Lesson Flow:

1. After forming groups of 4-5 students, give each student group a set of modes of transportation pictures and names. Have each group match the picture with the name.
2. Instruct students to brainstorm about different ways to group these types of transportation modes. For example: fastest to slowest, land/air/water, number of wheels, etc.

Activity #2

Estimated Time Needed: 15 minutes
Title: Transportation in the Community
Lesson Overview: Students will compare different transportation systems that are necessary for citizens in the Rio Grande Valley. Part of this activity will involve the concepts of speed and velocity, including how to measure speed.
Objectives:

1. Investigate the force between two surfaces.
2. Determine the effect of friction on the speed of the train.

Materials Needed: (per group)

- Toy cars
- Wood ramp
- Plastic ramp
- Sandpaper surfaced ramp

- Stopwatch
- Meter sticks
- Journal (per student)

Lesson Flow:

1. Engage: Ask students to come up with as many different types of transportation modes as possible.
    a. Accept any reasonable answer. Record all reasonable responses on the board or display on an overhead projector and screen. Possible list: airplane, train, automobile, bicycle, bus, boat…
    b. Ask students: *What are the advantages and disadvantages of each?* Guide them to the topic of speed.
2. Rank your list from fastest to slowest speed. *How could you determine the speed of each on your list?*
3. Ask students: *What do you need to know to determine speed?*
    a. Use guided questions to help students understand they need to know distance and time.
    b. Record all reasonable responses on the board or display on an overhead projector and screen.
4. Design and carry out an experiment to determine on which surface your "car" will move the fastest. Specifically, have students work in groups to address:
    a. *How will you determine how fast the car is moving on each surface?*
    b. *How will you make your car move initially?* Some students will want to push it, others may think of creating an incline. Help students understand that some ways are better than others. For example, if they choose to push the car then *how will they know if they are pushing it with the same force each time*? Thus, an incline might work better because you can more accurately control the height.
    c. *How many trials will you perform (for each surface)?*
5. Post the following on the board for students to answer in their journals. Circulate among groups and use guided questions to help them answer these questions.
    a. *Which surface created the greatest speed for your car?*
    b. *Why do you believe this surface worked the best?*
    c. *Why did you do more than one trial? Why is this important?*

Activity #3

Estimated Time Needed: 35 minutes

Title: Creative Inventions

Lesson Overview: Provide students with the opportunity to use creative thinking, problem solving skills and engage them with real-life situations. Students may work individually or with a partner to design a new invention or idea to solve the problem of people driving around lowered gates at a railroad crossing.

Objectives:

1. Complete the engineering design process with a team of students.
2. Investigate railway crossings to evaluate the problem that the city is facing.
3. Design a solution to the problem of drivers ignoring crossing gates.

Materials Needed: (per student)

- Provide student groups with a "Creative Inventions Handout" available in *Appendix A.1* or can be downloaded from http://oli.org/images/page/creativehandout.pdf

Lesson Flow:

1. Begin with a discussion: *Have you ever seen anyone disobey a stop sign? Why do we have stop signs? What are some consequences that could occur if someone disobeys a stop sign?*
2. After discussion, introduce students to the topic by mentioning: *Today we are going to look at some warning signs that need our attention when we see them or serious consequences could occur.*
3. Discuss the railroad safety background information while displaying warning devices on an overhead projector and screen. Explain to students there is a problem in a community surrounding a railroad crossing. This particular crossing has flashing lights and gates that lower when a train is approaching. However, the problem is that drivers keep driving around the lowered gates and the locomotive engineers are reporting high incidents of "near misses."
4. Tell students it is their job to design and create a device or an idea that will stop this from happening before someone gets hurt. Give students the invention handout; you can have students work in pairs or alone.
5. Have students share their ideas and inventions, explaining why their device would work and any problems they may encounter if they were able to carry out their plan.

Activity #4

Estimated Time Needed: 45 minutes
Title: Exploring with Magnets (Compass Building): *Which End is Up?*
Lesson Overview: Students will learn that magnets have a north and south pole, which attract or repel. Students will construct a compass by placing a magnetized nail on a piece of cork floating on water, one end will point toward the Earth's North Magnetic Pole (North Pole) and the other end will point toward the Earth's South Magnetic Pole (South Pole). The end pointing toward the North Pole is called the north end of the compass and the end pointing toward the South Pole is called the south end of a compass. If the north end (N) of a bar magnet is held close to a compass, the south end (S) of the compass will be attracted to it. The same thing happens when the south end of a bar magnet is held close to the north end of a compass.
Objectives:

1. Determine that magnets have poles.
2. Recognize that opposite poles attract and poles that are alike repel.

Materials Needed: (per pair of students)

- 2 Bar magnets
- Nail
- Masking tape (~ 1" piece)
- Cork
- Shallow dish with water
- Journal (per student)

Lesson Flow:
Before you begin, perform this demonstration for the class:

a. Tie a piece of string around the middle of a bar magnet.
b. Let the magnet hang in mid-air, and then spin it quickly.
c. After the magnet stops turning, ask the class which way the ends are pointing.
d. Ask the students whether or not the ends will always point the same way.
e. Explain to the students that they will get to explore with magnets and figure out which end is up!

1. Have students repeat what you did in the demonstration and determine if the ends will always point the same way. Have students record their observations in their journal. After all groups have come up with an answer, discuss the findings with the class. Ask: *Why does the end always point the same way?* Use guided questions to get them to understand that one end of the magnet is the north pole and one end is the south pole.

2. Allow students to explore with the two bar magnets. Ask the following guided questions: *What happens when two north poles are placed end to end? What happens when two south poles are placed end to end? What happens when the north pole is placed end to end with a south pole?* Lead students to understand that there is a magnetic force between the two bar magnets. Explain to them that a force is a push or pull (in this case attract or repel) between two objects. **This is the basis of magnetic levitation!**
3. Students will now make their own compass (don't tell them they are doing this!). They will need this compass for the next activity. Give each group the following directions:
   a. Rub the nail from left to right several times (up to 200×) with a permanent magnet.
   b. Tape the magnetized nail to the cork.
   c. Put the cork in a shallow dish of water and let it float.
   d. With the dish in their hand, turn in all directions and see what the needle does.
   e. If necessary, help students figure out which end points toward the North Pole. Using chart paper or the board, mark each wall of the classroom as N, S, E and W.
4. Mark the north pole of their magnet with an "N" and south pole with an "S".
5. Use guided questions to make sure they understand that all magnets have a north and a south pole, and that opposite poles attract (pull towards each other), while like poles repel (push away from each other). Make sure students know that the force is BETWEEN two objects, not within a single object. Help students understand they have just made their own compass.
6. Have students explore polarities with their "compass" and the bar magnet. Use guided questions like: *What happens when they bring the north pole (N) of their magnet close to the "compass?" What happens when they pull the magnet away? What happens when they bring the south pole (S) end of a magnet close to the "compass"?* Have students record their observations and explanations in their journal. Make sure their explanations follow the scientific explanation model:
   a. A claim (for example, the north and south poles of a magnet will always pull towards each other).
   b. Evidence to support the claim (for example, the blue end of one magnet always pulls toward the red end of another magnet).
   c. Connecting the evidence to scientific concepts (for example, the definition of magnetic force).

Extension:

1. Move all of the magnets away from one bar magnet. Put the compass at the end of the magnet marked "N". Then repeat for the end marked "S".

2. Use the compass in the same way to determine the location of the north and south poles.

Activity #5

Estimated Time Needed: 15 minutes
Title: Engineering Design Process
Lesson Overview: Introduce students to the engineering design process. This is an activity that can be an extension of one of the previous lessons (cars and ramps, magnets). For example, give students an engineering challenge to design a better compass, or use the worksheet found in *Appendix A.2* as an assessment or as a way to help students understand that the creative inventions lesson was based on engineering design principles.

Day 2 - The Physics of Transportation, "Newton's 1st Law Engage"

Activity #1

Estimated Time Needed: 30 minutes

Title: Speed, Inertia, and the Transport of Hazardous Materials

Lesson Overview: Students will investigate the importance of trains coming to a stop and how this relates to the concept of inertia. Students will participate in hands-on activities that will allow them to understand that a train or a car changes its acceleration but the people in the train or car do not.

Objectives:

1. Investigate Newton's First Law of Inertia.
2. Recognize that an object in motion stays in motion OR that an object at rest will remain at rest, UNLESS an outside force acts upon the object.
3. Explain the purpose of seat belts in cars.

Materials Needed: (per group)

- Stopwatch
- Toy transportation modes: cars, trains, boats, trucks or similar object (varied sizes and masses)
- Objects that can be placed in the toy cars (i.e., pennies)
- Ramps/inclines
- Block or similar object to create a collision with the car/train
- Journal (per student)

Lesson Flow:

1. Pose the following questions to students:
   a. *What happens when a small car comes to a stop?*
   b. *How is this different from a large car?*
   c. *What happens to the people sitting in a car or train when the car/train comes to a sudden stop?*

   Facilitate a discussion around their answers. Write all answers on the board or display on an overhead projector and screen. Do not correct any misunderstandings at this point. Rather, focus on what students are thinking about the topic.
2. Provide students with the following materials: toy transportation modes (trains, cars, trucks…) of different sizes and masses, ramps, objects to place in the cars and trains, stopwatch.

3. Ask students the following questions to help them make a prediction about what will happen when a car or train moves along different ramps with different inclines.
    a. *Which car or train will have the greater speed?*
    b. *Which car or train will take the longest to come to a stop?*
    c. *What happens to the objects in the car or train when it comes to a sudden stop? Why is this an important consideration when railways are transporting hazardous materials?*
4. Have students record their observations and responses to the questions in their journal.
5. Show students a simulation or video of a train coming to a sudden stop.
6. Facilitate a discussion around their answers, especially around any misconceptions. Help students connect this to speed and inertia. Explanation: When a person is in a car with their seatbelt on, and the car accelerates or speeds up then the person and the car are moving together with the same motion or speed. If the car comes to a sudden stop, then the person wearing the seatbelt stops with the car (to an extent because sometimes at greater speeds we move forward slightly). However, if a person is not wearing a seatbelt, they would propel forward as the car suddenly stops. This is an example of Newton's first law of motion: an object will remain in motion unless acted on by an external force. In the case of a passenger without a seatbelt, the external force is the stopping object (e.g., a brick wall) acting on the car, but not the person. The car stops because of the external force while the person remains in motion because the external force is acting only on the car.

Activity #2

Estimated Time Needed: 30 minutes

Title: How Far Will a Car Travel?

Lesson Overview: Students will work with their team to design an investigation that will allow them to determine if the height of the ramp (angle of incline) will affect the speed of an object. Students should recognize that it is the height of the ramp that is changing while no other variables change.

Objective:

1. Design an experiment that will depict how height may be manipulated so that a toy car can travel a predetermined distance using a ramp.

Materials Needed: (per group)

- Toy car

- Ramp
- Meter stick
- Books
- Journal (per student)

Lesson Flow / Procedure:

Step 1: Build a ramp using books and a flat surface

Step 2: Place a meter stick at the end of the ramp

Step 3: Place car at the top of the ramp

Step 4: Manipulate the height of the ramp so that the car rolls an average distance of 34 cm, 52 cm, and 82 cm after three trials

Step 5: Record the different heights of the ramp and the corresponding results for each height trial

Activity #3

Estimated Time Needed: 60 minutes

Title: Electromagnet Activities

Lesson Overview: Students will make a simple electromagnet by wrapping a wire around a nail and attaching the ends of the wire to a battery to create an electric circuit. As electrical current flows through the coiled wire, a magnetic field is produced and the nail is magnetized. This lesson will help students understand the concept of electromagnetism as a lead into how MagLev trains use electromagnetic properties to operate in real-life applications.

Objectives:

1. Create an electromagnet.
2. Explain the relationship between magnets and electricity.

Materials Needed: (per group)

- Steel nail
- Several small paper clips
- Flexible insulated wire
- Scissors
- Rubber band
- D cell battery
- Journal (per student)

Lesson Flow:

1. Ask the following questions to the class:
    a. *Is a nail a magnet?*
    b. *Do you think it can be made into one?*
    c. *Why or why not?*

    Have students write responses to these questions in their journals.
2. Facilitate a discussion around their answers. Do not correct any misunderstandings at this point. The goal is to learn more about what students are thinking in regards to the topic.
3. Provide each group of students with the materials.
4. Explain the task to students: They will be wrapping a wire around a nail; the ends of the wire will be connected to a battery.
5. Have students make a prediction about what will happen for each of the following:
    a. The bare nail touches the paper clips
    b. The nail with wire wrapped around it touches the paper clips
    c. The nail with wire wrapped around it, and both ends of the wire touching the battery, touches the paper clips
6. Have students touch the bare nail to paper clips and record their observations in their journal. (The paper clips will not be attracted to the nail.)
7. Have them wrap a piece of wire tightly around the nail in coils (there should be about 25 turns), leaving six inches of wire free at both ends. Strip about one inch of insulation from both ends of the wire. Have them touch the wrapped nail to the paper clips and record their observations. (The paper clips will not be attracted to the nail.)
8. Have them wrap a rubber band around a battery the long way. Slide one end of the wire under the rubber band so it touches one terminal to the battery. Slide the other end of the wire under the rubber band so it touches the other end. Have them touch the nail to the paper clips and record their observations. (The paper clips will be attracted to the nail.)
9. Have students test what happens when they add more coils to the wire. Let them discover that more coils increase the strength of the magnetic field.

Extension:

Challenge: Use your electromagnet to move a small object. The small object can be a toy car or something similar. In addition to the electromagnet, each group will need a small object to move and small magnets.

Activity #4

Estimated Time Needed: 75 minutes

Title: Build a MagLev Train System

Note: There may not be enough time to complete this activity on this day, in this case, have students complete the construction during Activity #1 of day 3.

Lesson Overview: Discuss the advantages and disadvantages of MagLev trains, recall from yesterday's discussion. Explain to students that they will construct their MagLev trains today. The passengers are washers (provided in the kit).

Objectives:

1. Students will understand the engineering design process.
2. Be sure to reinforce to students that they have been and are using the engineering design process. You can use the image in *Appendix A.3* to facilitate a class discussion.

Materials Needed: (per group)

- MagLev Train Kit
- Double-sided masking tape
- Compass (from previous activity)
- Blocks (to create inclines)
- Journal (per student)

Lesson Flow:

Before you begin, show a video on Bullet Train (Note that the title of this video mistakenly states that these trains can go up to 3500 km/h, but the correct number is about 360 km/h): https://www.youtube.com/watch?v=aIwbrZ4knpg

1. MagLev track construction:
   a. Place each wood base on a flat surface.
   b. Slide the plexiglass side rails into each side slotted groove.
   c. Lay one of the magnetic strips so that it is flush against the plexiglass side rail (it does not matter which side is up). Use your compass to determine which end is north and which end is south and mark each end as north "N" or south "S". Use the double-sided tape to secure the strip.
   d. Use your compass to determine the N and S ends of the second magnetic strip. Lay this magnetic strip so that it is flush against the other plexiglass side rail, making sure to place it in the same orientation as the first magnetic strip. Use the double-sided tape to secure the strip.

e. Repeat for the second four foot track. Lay them end to end, and use the 8' support to create a straight track that can be inclined.

2. MagLev railcar construction:
   a. Have each student group decide on their car design. It may be necessary for an adult to do the actual cutting of the foam blocks as carts. Give them the following guidelines:
      i. Don't change the width
      ii. Length must be less than 16"
      iii. *How many "passengers" do you want your car to hold?* (The more passengers, the better the efficiency, and the more the return on investment…)
      iv. *How many magnets will you use?*
      v. Applying magnets: Students need to remember that opposite poles attract and like poles repel when placing the magnets on the bottom of the car.
3. Have students use the engineering design process to improve their train. The goal is to design the fastest and safest train. Allow some flexibility, but make sure the students change only one variable (# of passengers, # of magnets, etc.) at a time.

Wrap Up & Clean Up

Estimated Time Needed: 15 minutes

Discuss (as they relate to MagLev train design)**:**

1) Newton's Laws of Motion
2) Engineering Design Process
3) Name your train! This will be helpful for upcoming activities. Before the end of the day, each group should have a cool name for their train. Be sure to label the train using masking tape (**not permanently!**).

Day 3 - The Physics of Transportation, "Newton's 2nd Law"

Activity #1

Estimated Time Needed: 60 minutes

Title: MagLev Train Construction

Lesson Overview: Have students test their engineering design. First, make sure each group's car levitates properly. Students may need to adjust the position of the magnets, and may need to check for polarity. Second, have the students attempt to use electromagnets as a force to get their train to move.

Objectives:

1. Design and build a model of a MagLev train.

Materials Needed: (per group)

- MagLev Train Kits constructed during previous activities

Lesson Flow:

1. Discuss how MagLev trains can operate using electromagnets. You can show students the video of the train that operates using a giant electromagnet. (You may have shown this video on day two.) https://www.youtube.com/watch?v=aIwbrZ4knpg
2. Have students use their electromagnet as a force to change the motion of the rail car. Focus on how to create a stronger electromagnet using inquiry based questions (let the students figure out that more turns/coils will result in a stronger electromagnet). This is meant to be open-ended inquiry with two objectives; namely: (1) make sure each student group can get their train to be functional, and (2) try to use an electromagnet to get their train to move.

Activity #2

Estimated Time Needed: 30 minutes

Title: Incline and Speed

Lesson Overview: Students will investigate how the incline of the ramp affects the speed of their train.

Objectives:

1. Determine the effect that the height of the ramp will have on the speed of the train.

Materials Needed: (per group)

- Constructed MagLev Train Kits

- Stopwatch
- Ramps/inclines
- Protractor
- Worksheet (*Appendix A.4*: Speed and Incline Data Table)
- Journal (per student)

Lesson Flow:

1. Allow some flexibility in this lesson, but make sure students understand to change only one element of their design at a time (height, magnets, etc.)
2. Construct four different inclines: 10°, 20°, 30°, and 40° and use five washers only (these represent five "passengers"). Record in the data table the distance traveled and the elapsed time.

Activity #3

Estimated Time Needed: 30 minutes

Title: How Does Mass Affect Force and Acceleration?

Lesson Overview: Students will explore the relationship between force, mass, and acceleration with respect to transportation. Students will use the MagLev trains to investigate the relationship between force, mass, and acceleration by changing the load carried by the train car (number of passengers).

Objectives:

1. Investigate Newton's Law of Force and Acceleration.
2. Recognize the force required to accelerate an object if influenced by the mass of the object.

Materials Needed: (per group)

- Constructed MagLev Train Kits
- Stopwatch
- Ramps/inclines
- Protractor
- Worksheet (*Appendix A.5*: Mass, Force, and Acceleration Data Table)
- Journal (per student)

Lesson Flow:

1. Review what was learned from days 2 and 3 regarding speed and inertia.
2. Discuss speed, acceleration, and deceleration. Use examples (trains or cars speeding up, slowing down, etc.)

3. Using their findings from the day's Activity #1 (MagLev Construction), student groups should decide on the best incline.
4. Have students add one washer (representing one "passenger") to their train car. Measure the distance traveled and time elapsed. Record data in the provided data chart (provide Mass, Force, and Acceleration Data Table worksheet).
5. Continue to repeat step 3, adding one washer at a time.
6. Calculate the Figure of Merit (FOM) for each trial.

   Explain that the FOM is used to determine the best design as it takes mass, distance, time, and the number of passengers into account. The higher the FOM, the better the design!

$$\mathbf{FOM} = \frac{\boldsymbol{P \cdot X}}{\boldsymbol{N \cdot T}}$$

   Where ***P = # of washers***, ***X = distance traveled*** in cm, ***N = # of magnets***, and ***T = elapsed time*** in seconds.

7. Facilitate student understanding of the relationship between force, mass, and acceleration with some questions. For example:
   a. *What happens to the distance traveled as the mass increases?*
   b. *What happens to the elapsed time when the mass increases?*
   c. *What happens to the acceleration as the mass increases?*

Activity #4

Estimated Time Needed: 15 minutes
Title: How Does Magnetic Force Affect Mass and Acceleration?
Lesson Overview: Students will continue to investigate force, mass, and acceleration by changing the number of magnets on their train car.
Objectives:

1. Determine the effect that the number of magnets on the train has on the force, mass, and acceleration of a train.

Materials Needed: (per group)

- Constructed MagLev Train Kits
- Stopwatch
- Ramps/inclines

- Protractor
- Worksheet (*Appendix A.5*: Mass, Force, and Acceleration Data Table)
- Journal (per student)

Lesson Flow:

1. Repeat the same steps in Activity #2 (Incline and Speed), except have students vary the number of magnets used. Be sure they record all data in the table provided and in their journal.
2. Facilitate student understanding of the relationship between force, mass, and acceleration with some questions. For example:
   a. What happens to the distance traveled as the number of magnets increases?
   b. What happens to the acceleration as the number of magnets increases?
   c. What happens to the mass of the train car as the number of magnets increases?

Discussion (Isaac Newton is credited with laws of force and motion):

(1) One of Newton's laws states that an object at rest remains at rest unless another force acts on it. Ask the following questions:
   a. *What other forces caused the train car on your railway to start moving?*
   b. *How do external forces affect an object that is not moving?*

(2) Another one of Newton's laws describes how mass and acceleration change force. Use the following questions to guide the discussion:
   a. *What is acceleration?*
   b. *What happens to the acceleration of an object (your train car on the railway) when the mass increases (more washers or "passengers" are added)?*
   c. *What happens to the force produced when mass increases? Decreases? Acceleration decreases? Increases?*

Day 4 - The Physics of Transportation, "Collisions"

Activity #1

Estimated Time Needed: 85 minutes

Title: Railway Safety

Lesson Overview: Students will learn about railway safety issues, including collisions at intersections. They will come up with ways to improve railway safety of MagLev trains (e.g., at highway-railway-grade-crossings or trains being able to stop effectively.)

Objectives:

1. Determine the outcome of a collision between two train cars of same mass and between train cars with different masses.
2. Determine the time required for a train to stop depending on the mass of a train car.

Materials Needed: (per group)

- Constructed MagLev Train Kits
- Stopwatch
- Ramps/inclines
- Protractor
- Extra track
- Worksheet (*Appendix A.7*: Magnet and Acceleration Table)
- Journal (per student)

Lesson Flow:

1. Have students create an intersection in their railway using extra track.
2. Students will investigate what happens during a collision between the two MagLev train cars:
   a. Two train cars of the same mass
   b. Two train cars with one of the train car having a greater mass
3. Students will need to determine what happens when a stationary object is placed at a railway crossing, specifically how the mass of the train affects the time before collision. In this activity, students will use wind as an external force (no incline) to initiate movement of their car. Their car will have 10 passengers. Students need to determine:
   a. *How much time elapses before the collision?*
   b. *How much time elapses if the number of passengers is decreased to 5?*
   c. *How much time elapses if the number of passengers is increased to 20?*
4. Have students brainstorm ways to prevent a collision.

Activity #2

Estimated Time Needed: 85 minutes
Title: Railway Safety - Positive Train Control (PTC)
Lesson Overview: Students will participate in hands-on investigative activities that will allow them to apply their understanding of magnetic forces to create a positive train control (PTC) mechanism.
Objective:

1. Define positive train control (PTC) mechanism.
2. Recognize the importance of safety.

Materials Needed: (per group)

- Constructed MagLev Train Kits
- Stopwatch
- Ramps/inclines
- Protractor
- Extra track
- Extra material to construct mechanism: paper clips, tape, etc.
- Journal (per student)

Lesson Flow:

1. Review the concepts of north and south poles, and magnetic forces (opposite poles attract, like poles repel).
2. Show students a video of a simulation that explains positive train control (PTC): https://www.youtube.com/watch?v=33y3E7mqZYM
3. Explain that each group will use their extra track to create an intersection.
4. Give students a challenge:
    a. Another train has stalled at the intersection. Their challenge is to use the materials at their desk to create a positive train control (PTC) mechanism that will stop their train before a collision occurs.
    b. Have students brainstorm their ideas verbally, and record them in their journals.
    c. One possible solution is to position the extra bar magnets in the tracks just before the intersection, aligning the polarity so that the magnets on the bottom of the train are opposite to the bar magnet (the magnets will attract and stop). Other solutions are also possible. Have students explore other possible solutions.

Wrap Up & Clean Up

Time Needed: 15 Minutes

Discuss:

1. Have students explain one thing they learned about railway safety today.
2. Play video – Newton's Laws (https://www.youtube.com/watch?v=mn34mnnDnKU).
3. Relate collisions to Newton's 1^{st}, 2^{nd}, and 3^{rd} laws.

Day 5 - MagLev Train Design Challenge!

Challenge - Design

Estimated Time: 2 hours
Title: You're the Engineer!
Lesson Overview: This is a roleplay challenge in which students apply all engineering design and STEM concepts they have learned to design a MagLev train system. At the end of the day, student's MagLev designs will be judged for speed and safety in a competition. First, second, and third place designs will be selected.
Lesson Flow: Explain to students this is a roleplay challenge ending in a competition.
Challenge: You have been hired by a transportation firm to design a magnetically levitating (MagLev) train system. The new system will provide commuters with fast, economical, and safe transportation to and from work. As a member of the design team, your responsibility is to design and construct a MagLev Train model that will travel the length of the track provided in class, as quickly and safely as possible.
You will be judged on:

- Speed of train (faster is better)
- Safety of train (no passengers can fall out of the train)
- Cost (more passengers means more income $$ to railway company)
- Students should consider the following variables: weight, shape, distribution of the load, track resistance, guidance, height of levitation, number of magnets.
    - ***Note:*** *If possible, allow students to change the shape of their car (adult assistance may be needed to cut a new car).*

Challenge - Showcase/Competition

Estimated Time: 45 min.
Title: You're the Engineer!
Objective:

1. Students apply all STEM concepts learned throughout the activities toward the most efficient and safe MagLev design possible.

Lesson Flow:

1. Competition Overview:
    a. Student groups will discuss how to demonstrate their MagLev Train designs.

   b. Students present their design to judges.

2. Judges will determine the 1st place winner that will advance to an overall competition (if there is an overall competition). Otherwise, judges will determine 1st, 2nd, and 3rd place winners.

Wrap Up & Clean Up

Time Needed: 30 minutes

(1) Clean up and count all MagLev Train Kit parts. Make sure all kits are complete and organized.
(2) Announce the winning team.

Appendices

Appendix A. Worksheets and Diagrams

Appendix A.1 Creative Inventions Handout

Look Listen & Live Operation Lifesaver®

Name ____________________

DIRECTIONS – Follow the steps below and help your community design a railroad crossing device that will save lives.

Step One:

The Problem: People in your community are driving around lowered gates at a railroad crossing. The locomotive engineers are reporting many "near misses" with vehicles to your local police department. You have been asked to try and solve this problem for your community with a unique idea or a new invention. Good Luck!

Step Two:

The Cause: What causes this problem? What are the future possibilities of this problem?

Step Three:

Brainstorm: List as many ideas as you can possible think of for solving this problem. Don't let anything stand in your way during this step. Think of the unique and even the impossible–you never know where it may lead you.

Step Four:

Think: Look at your brainstorming list. Rank your ideas from best to average. Try combining some of your ideas to come up with new ones.

Step Five:

Design: Put your ideas down on paper. Draw the invention with different parts labeled, or write your new idea out in paragraph form.

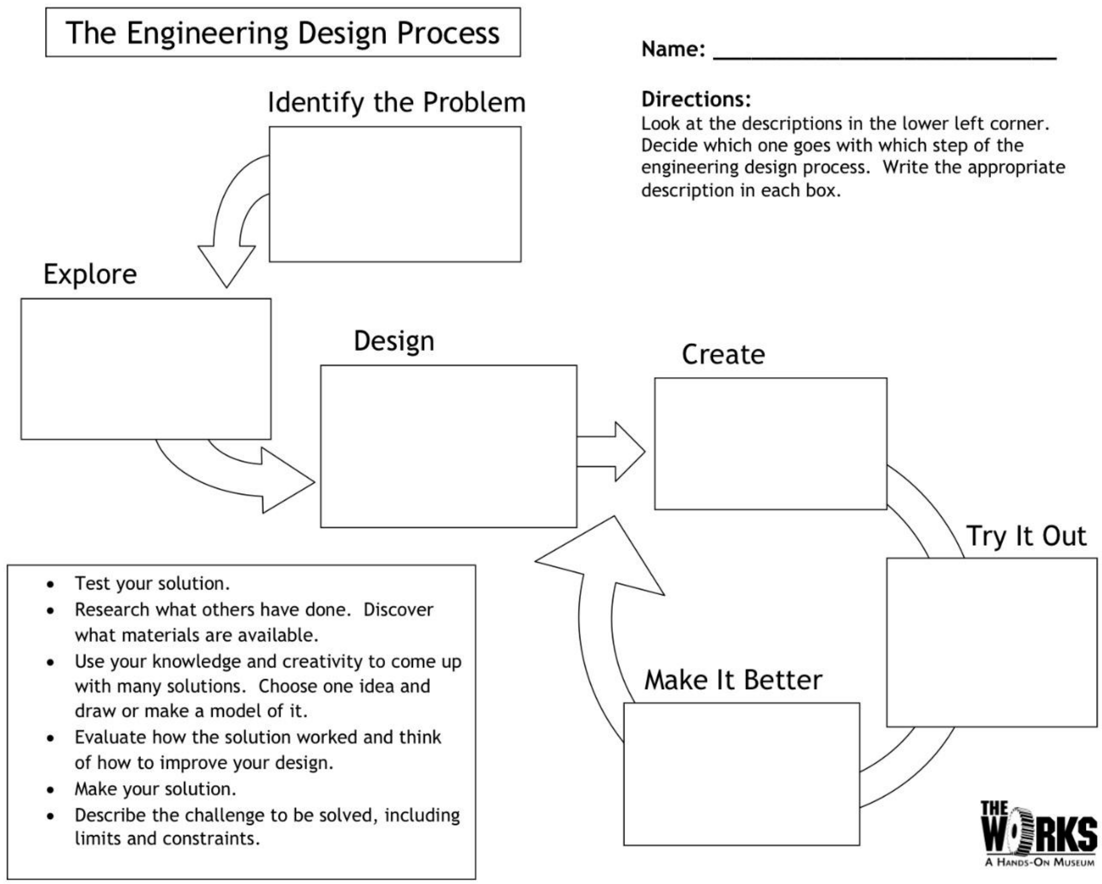
Step Six:

Analyze: Will your invention really work? Is it practical? Is it too large? Will it be too expensive?

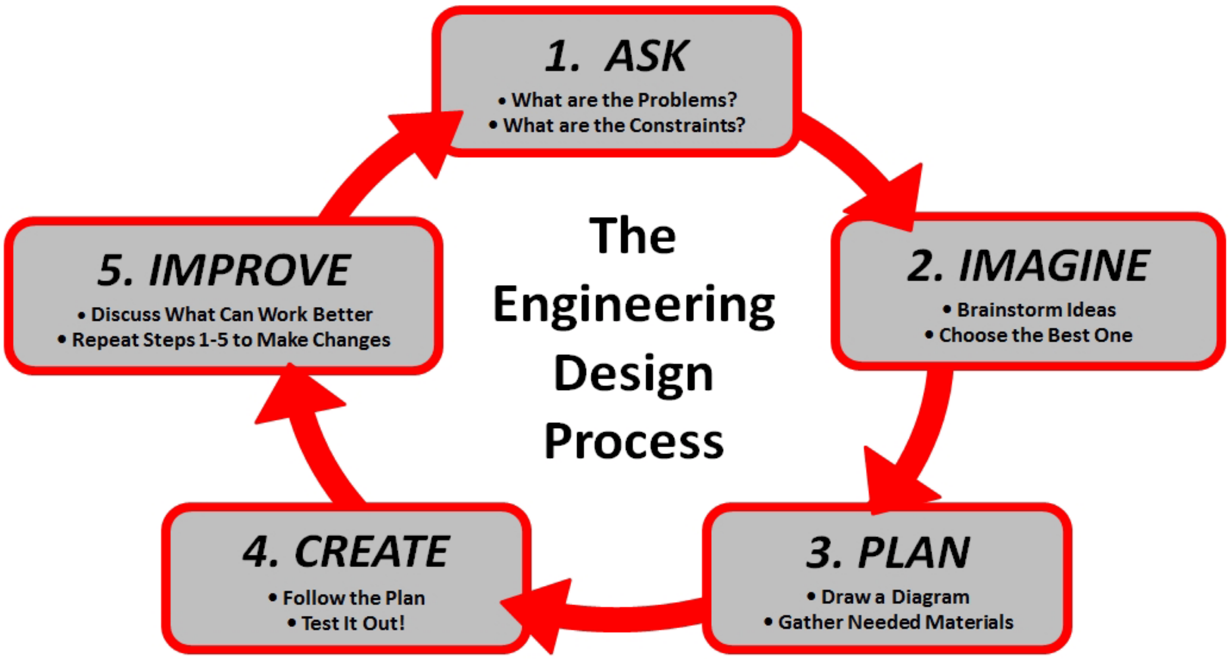
Step Seven:

Share: Share your invention or new idea with your classmates. Look for unusual combinations among your class members to design a class solution.

Appendix A.2 The Engineering Design Process



Appendix A.3 The Engineering Design Process (Alternate Representation)



Appendix A.4 Speed and Incline Data Table

Angle	# of Washers	Distance Traveled	Elapsed Time	Mass	Acceleration	Force	Potential Energy	Kinetic Energy
	P	*X* [cm]	*T* [sec]	*m* [kg]	*a* [m/s^2]	*F = m·a* [N or $kg \cdot m/s^2$]	*PE* [J or $kg \cdot m^2/s^2$]	*KE* [J or $kg \cdot m^2/s^2$]
0°	5							
10°	5							
20°	5							
30°	5							
40°	5							
60°	5							

Appendix A.5 Mass, Force, and Acceleration Data Table

# of Washers	Distance Traveled	# of Magnets	Elapsed Time	FOM	Mass	Acceleration	Force
P	X [cm]	N	T [sec]	$\frac{P \cdot X}{N \cdot T}$	m [kg]	a [m/s^2]	$F = m \cdot a$ [N or kg·m/s^2]

Appendix A.6 Graph Paper

Appendix A.7 Magnet and Acceleration Data Table

Trial	# of Washers	Distance Traveled	# of Magnets	Elapsed Time	FOM	Mass	Acceleration	Force
	P	*X* [cm]	*N*	*T* [sec]	$\frac{P \cdot X}{N \cdot T}$	*m* [kg]	*a* [m/s^2]	*F = m·a* [N or kg·m/s^2]
1	0		4					
2	5		4					
3	10		4					
4	15		4					
5	20		4					
6	25		4					
7	30		4					
8	35		4					
9	40		4					
10	45		4					
11	50		4					
12	75		4					
13	100		4					
14								
15								
16								
17								
18								
19								
20								

Appendix B. Video and Resource List

Day 1

Activity #3: Creative Inventions Handout: http://oli.org/images/page/creativehandout.pdf

Day 2

Introduction: https://www.youtube.com/watch?v=aIwbrZ4knpg

Day 3

Activity #1: Discussion - Giant Electromagnet: https://www.youtube.com/watch?v=aIwbrZ4knpg

Day 4

Activity# 2: Video on Positive Train Control (PTC)

https://www.youtube.com/watch?v=33y3E7mqZYM

Wrap Up & Clean Up: Newton's Laws

https://www.youtube.com/watch?v=mn34mnnDnKU

Appendix C. Extra Resources on Newton's Laws

Newton's 1st Law -

https://www.youtube.com/watch?v=lbHt5mg_33w

Newton's 2nd Law -

https://www.youtube.com/watch?v=qu_P4lbmV_I (NFL)

https://www.youtube.com/watch?v=iwP4heWDhvw

https://www.youtube.com/watch?v=nJTKiS444BQ