UTCRS High School STEM Curriculum

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Objectives

By the end of the curriculum lessons, the student will be able to:

1. Understand the relationship between force, mass, and acceleration with regard to MagLev systems.
2. Understand the benefits of MagLev trains as a viable transportation alternative.
3. Use the engineering design process to design, test, and evaluate a MagLev train system.
4. Think critically and find solutions to transportation engineering problems.
5. Work collaboratively in small groups.
6. Design the fastest and safest MagLev train possible.
7. Use problem-solving skills to read and interpret diagrams to build a robot.
8. Use problem-solving skills to create, run, and test programs created to control a robot.
9. Recognize and interpret transportation related traffic signs and signals.
10. Recognize and interpret railway safety signs and signals.
11. Plan a route through an obstacle course that is efficient and obeys all traffic and railroad safety signs and signals.
12. Use the color sensor and the touch sensor to build a robot that can follow a line and complete specific activities.
13. Apply principles of logic and critical thinking to find the most effective and efficient way to navigate a maze design.
14. Use variables in the context of programming to determine the state of an object, such as "true" or "false".
15. Understand and utilize the loop constructs in programming.
16. Complete the creation of a robot design arm and truck in the final challenge.

Texas Essential Knowledge and Skills (TEKS) and National Standards

TEKS Science 9-12

§112.38. Integrated Physics
(2) Scientific processes. The student uses scientific methods during laboratory and field investigations. The student is expected to:
   (A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;
   (B) plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting equipment and technology;

(C) collect data and make measurements with precision;

(D) organize, analyze, evaluate, make inferences, and predict trends from data; and

(E) communicate valid conclusions.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem-solving to make informed decisions. The student is expected to:

    (A) evaluate the impact of research on scientific thought, society, and the environment; and

    (B) describe connections between physics and chemistry and future careers.

(4) Science concepts. The student knows concepts of force and motion evident in everyday life. The student is expected to:

    (A) describe and calculate an object's motion in terms of position, displacement, speed, and acceleration;

    (B) measure and graph distance and speed as a function of time using moving objects;

    (C) investigate how an object's motion changes only when a net force is applied, including activities and equipment such as toy cars, vehicle restraints, sports activities, and classroom objects;

    (D) assess the relationship between force, mass, and acceleration, noting the relationship is independent of the nature of the force, using equipment such as dynamic carts, moving toys, vehicles, and falling objects;

    (E) apply the concept of conservation of momentum using action and reaction forces such as students on skateboards; and

    (F) describe the gravitational attraction between objects of different masses at different distances.

(5) Science concepts. The student recognizes multiple forms of energy and knows the impact of energy transfer and energy conservation in everyday life. The student is expected to:

    (A) recognize and demonstrate that objects and substances in motion have kinetic energy such as vibration of atoms, water flowing down a stream moving pebbles, and bowling balls knocking down pins;

    (B) demonstrate common forms of potential energy, including gravitational, elastic, and chemical, such as a ball on an inclined plane, springs, and batteries; and

    (C) demonstrate that moving electric charges produce magnetic forces and moving magnets produce electric forces.

TEKS Math 9-12

Algebra I

(1) Foundations for functions. The student understands that a function represents a dependence of one quantity on another and can be described in a variety of ways. The student is expected to:

    (A) describe independent and dependent quantities in functional relationships;

    (B) gather and record data and use data sets to determine functional relationships between quantities;

    (C) describe functional relationships for given problem situations and write equations or inequalities to answer questions arising from the situations;

    (D) represent relationships among quantities using concrete models, tables, graphs, diagrams, verbal descriptions, equations, and inequalities; and

    (E) interpret and make decisions, predictions, and critical judgments from functional relationships.

(3) Foundations for functions. The student understands how algebra can be used to express generalizations and recognizes and uses the power of symbols to represent situations. The student is expected to:

    (A) use symbols to represent unknowns and variables; and

    (B) look for patterns and represent generalizations algebraically.

(4) Foundations for functions. The student understands the importance of the skills required to manipulate symbols in order to solve problems and uses the necessary algebraic skills required to simplify algebraic expressions and solve equations and inequalities in problem situations. The student is expected to:

    (A) find specific function values, simplify polynomial expressions, transform and solve equations, and factor as necessary in problem situations.

International Technology and Engineering Educators Association (ITEEA) Standards

Grades 9-12

<u>Standard 2.</u> Students will develop an understanding of the core concepts of technology.

- System thinking applies logic and creativity with appropriate compromises in complex real-life problems.

- Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.
- The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.
- Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.
- Quality control is a planned process to ensure that a product, service, or system meets established criteria.

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

- Technological progress promotes the advancement of science and mathematics.

<u>Standard 8.</u> Students will develop an understanding of the attributes of design.

- The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.
- Design problems are seldom presented in a clearly defined form.
- The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
- Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

<u>Standard 12.</u> Students will develop the abilities to use and maintain technological products and systems.

- Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision**.**
- Operate systems so that they function in the way they were designed.

Engineering Design

NGSS (Next Generation Science Standards) suggest that all students should be able to do the following by the time they leave high school:

(A) Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success, and constraints or limits.

(B) Designing solutions to engineering problems begins with generating a number of different possible solutions, and then evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.

(C) Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.

National Science Education Standards

Content Standard (A): generate and interpret graphs and charts describing different types of motion, including the use of real-time technology such as Vernier motion detectors or photogates

Content Standard (B): describe and analyze motion in one dimension using equations with the concepts of distance, displacement, speed, average velocity, instantaneous velocity, and acceleration

Content Standard (D): calculate the effect of forces on objects, including the law of inertia, the relationship between force and acceleration, and the nature of force pairs between objects

Content Standard (E): research and describe the historical development of the concepts of gravitational and electromagnetic forces

Content Standard (F): describe and calculate how the magnitude of the gravitational force between two objects depends on their masses and the distance between their centers

Content Standard (G): identify examples of electric and magnetic forces in everyday life

Content Standard (H): investigate and describe the relationship between electric and magnetic fields in applications such as generators, motors, and transformers

Content Standard (I): investigate examples of kinetic and potential energy and their transformations

Day 1 - Magnetic Levitation Train Systems

Activity #1

Estimated time needed: 15 minutes

Title: Icebreaker - Chalkboard Sentences

Lesson Overview: Students will work cooperatively to create a sentence describing their prior knowledge of railway safety. This activity will create team unity and pride as they will be competing against other teams to compose a sentence without talking to each other and writing only one word at a time. Sample sentence might look as follows: All buses stop at railroad crossings.

Objective:
1. To access prior knowledge of students pertaining to railway safety.

Materials Needed: (per class)
- Dry-erase markers and white board or
- Paper and regular markers

Lesson Flow:
1. For this exercise, ask the participants to work in teams. Within their teams, students are to discuss and formulate a sentence pertaining to what they already know about railway safety. Each team member adds a word to the sentence. The facilitator begins by explaining that participants will be competing to see which team is the first to complete a group sentence.
2. Next, ask group members to divide into two teams. If the group contains an uneven number, one participant may compete twice. Line up team members ten feet away from the board. After giving the first person in each team's line a dry-erase marker, the facilitator explains the following rules:
   - Each member is to add one word to his/her team's sentence.
   - The first person in each line is to come forward and write the first word of their team's sentence, go back and pass on the marker to the next team member, and return to the end of the line.
   - No preplanning of sentences is allowed.
   - Each player may participate only once.
   - The winner is the team that is the first to build a full sentence using words contributed by all of its group members.

Activity #2

Estimated Time: 30 minutes

Title: Designing a MagLev - Incline and Speed

Lesson Overview: Students will measure the speed of a MagLev train system using Vernier probes, and investigate changes in speed associated with three different ramp angles (heights).

Objectives:

1. Use engineering principles to design a simple MagLev train system using simple magnets.
2. Determine if the angle of the ramp (height of ramp) affects the speed of the MagLev train.
3. Calculate potential and kinetic energies of the train at different angles (heights).
4. Use appropriate technologies, i.e. – Vernier probes.

Materials Needed: (per group)

- MagLev Train Educational Kit
- Speed and Incline Data Table available in *Appendix A.1*.
- Protractor
- Complete ramp setup
- Vernier probes (if available)
- Stopwatch
- Spring scale _or_ electronic balance
- 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.
2. Have students configure a variety of positioning possibilities for their magnets on the MagLev train system rails.
3. Have students construct four different inclines: 0, 20, 40, and 60 degrees. Using five washers (each washer represents a "passenger"), measure the distance traveled by the train and the elapsed time, record both in the data table of *Appendix A.1*.
4. Using the Vernier probes, determine the force, mass, and acceleration of the train at each ramp angle/incline. The mass can also be determined using a spring scale or electronic balance.
5. Students are to record the kinetic energy (KE) and potential energy (PE) of their individual MagLev train using the formulas provided.

Adaptation/Extensions:

➢ Use distance and time data to graph the average velocity of the train. Printable graph paper is available in *Appendix A.2*.

➢ Use the Vernier probes to find the relationship between the ramp angle and velocity.

Additional Resources:

➢ How to use Vernier Probes:

- Photogate:
  http://www2.vernier.com/manuals/Logger_Pro_Introduction_to_the_Vernier_Photogate.pdf

- Motion Detector: http://www.vernier.com/manuals/md-btd/

- Dual-Range Force Sensor: http://www.vernier.com/manuals/dfs-bta/

➢ Formulas:

Potential Energy (PE) = mass • acceleration due to gravity • height = m·g·h

Kinetic Energy (KE) = 0.5 • m • v^2

where *m* = mass of the object, *h* = height of the object, *g* = gravitational field strength (9.81 m/s^2 on Earth) - sometimes referred to as the acceleration of gravity, and *v* = speed of the object.

➢ Videos:

- Show students the "World's Fastest Trains-MagLev" video related to real-world impact of activity (Note that the title of this video mistakenly states that the MagLev train's top speed is 3500 km/h, this value should be about 360 km/h):
  https://www.youtube.com/watch?v=aIwbrZ4knpg

- Talk to students about the difference between the German MagLev design and the Japanese MagLev design

  - German MagLev design Video:
    https://www.youtube.com/watch?v=hUATDtZble0

  - Japanese MagLev design Video:
    https://www.youtube.com/watch?v=SUBUTo82EQw#rpctoken=287669679&_methods=setNotificationWidgetSize%2CsetNotificationWidgetHeight%2CsetNotificationText%2ChideNotificationWidget%2CopenSharebox%2ConError%2C_ready%2C_close%2C_open%2C_resizeMe%2C_renderstart&id=I1_1446659761580&parent=https%3A%2F%2Fwww.y

Activity #3

Estimated Time: 30 minutes

Title: Mass, Force, and Acceleration

Lesson Overview: Students will use the MagLev train system to investigate the relationship between force, mass, and acceleration by changing the load or the number of passengers (represented here by "washers").

Objectives:

1. Determine how the mass added to the MagLev train affects the force needed to accelerate the train.
2. Calculate the acceleration of the train by measuring force and mass with Vernier probes.

Materials Needed: (per group)

- Constructed MagLev train kits
- Stopwatch (may be replaced with Vernier Photogate)
- Ramps/inclines
- Protractor
- Mass, Force, and Acceleration Data Table Worksheet available in *Appendix A.3*
- Electronic balance _or_ spring scale
- Journal (per student)

Lesson Flow:

1. Review what was learned in Activity #2 regarding speed and inertia.
2. Discuss speed, acceleration, and deceleration. Use examples like a car speeding up and slowing down, etc.
3. Using your findings from Activity #2, have student groups decide on the most efficient incline angle.
4. Have students add one washer to their car. Measure the distance traveled and time elapsed. Use the Vernier probe to measure acceleration and mass. Record all data in the Mass, Force, and Acceleration Data Table provided in *Appendix A.3*. Calculate the force or measure with Vernier probe.
5. Repeat step 4, adding one washer at a time and recording data in the chart provided.
6. Calculate the *Figure of Merit (FOM)* for each trial.

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

where *P* = number of washers, *X* = distance traveled in [cm], *N* = number of magnets, and *T* = elapsed time in seconds. Explain to students how the *FOM* is used to determine the

best design taking mass, distance, time, and number of passengers into account. The higher the FOM, the better the design is judged.

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?*

Additional Resources:

➢ Videos that use drawing illustrations

- Potential and Kinetic Energy
  https://www.youtube.com/watch?v=BSWl_Zj-CZs
  https://www.youtube.com/watch?v=iYEWIuQBVyg

Activity #4

Estimated Time: 45-60 minutes
Title: Does the Number of Magnets Used Affect the Acceleration?
Lesson Overview: Students will continue to investigate force, mass, and acceleration by changing the number of magnets on their railcar.
Objectives:
1. Determine the relationship between the number of magnets and the acceleration of the MagLev train.
2. Calculate acceleration by measuring force and mass, while changing the number of magnets on the train.

Materials Needed: (per group)
- Constructed MagLev train kits
- Stopwatch
- Ramps/inclines
- Protractor
- Worksheet
- Vernier probes
- Journal (per student)

Lesson Flow:
1. Repeat the same steps in Activity #3, except have the students vary the number of magnets used on the train. Be sure they record all data in the data table provided in *Appendix A.3*.
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 distance traveled as the number of magnets decreases?*
   c. *What happens to the acceleration as the number of magnets increases?*
   d. *What happens to the acceleration as the number of magnets decreases?*
   e. *What happens to the mass of the car as the number of magnets increases?*
   f. *What happens to the mass of the car as the number of magnets decreases?*

Activity #5

Estimated Time: 30-45 min

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. Students need to create a more creative/effective PTC which doesn't stop the train abruptly (i.e., crash).

Objectives:

1. Determine the best MagLev train design that will stop the train at the end of the ramp without crashing or obstructing the train track in any way.
2. Define and investigate effective PTC techniques.
3. Evaluate various engineering MagLev train designs.

Materials Needed: (per group)

- Constructed MagLev train kits
- Stopwatch
- Ramps/inclines
- Protractor
- Extra track
- Miscellaneous materials: magnets, rubber bands, paper clips, etc., that students can utilize to create an effective PTC mechanism
- Journal (per student)

Lesson Flow:

1. Review the concepts of magnetic forces (opposite poles attract, like poles repel) and north and south poles.
2. Show a simulation that explains PTC: 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: Another train has stalled at the intersection. Your challenge is to use the materials at your desk to create a PTC mechanism that will stop your train before a collision occurs.
   a. Have students brainstorm their ideas verbally first, and record them in their journals.
   b. 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 possible! Encourage students to explore more than one solution.

Days 2 & 3 - Robotics Programming

Activity #1

Estimated Time: 45-60 min

Title: Assemble the Basic Robot Design

Lesson Overview: Students will be building and programming a LEGO® MINDSTORM® EV3 robot. Students will follow the basic instructions for building and programming their own robot.

Objectives:

1. Learn to work in groups, modeling teams of engineers.
2. Learn and assume different roles in teams, lead engineer and assistant engineers.

Materials Needed: (per group)

- LEGO® MINDSTORM® EV3 completed robot (one to show as example)
- LEGO® MINDSTORM® EV3 Educational Kit
- Laptop
- MINDSTORM® Software installed on the laptop
- Electric tape
- Journal (per student)

Lesson Flow:

1. Inform students that they are going to be learning more about transportation engineering by working with robots. Tell them that they will be building and programming their own robot.
2. Show students a completed basic robot and pass it around to all of the teams.
3. Have students briefly look at the directions for building the Basic Robot in the LEGO® MINDSTORM® EV3 manual (pg. 7-38), included in the kit.
4. Instruct students to begin building their robot. Students need to role play working as a team of engineers; during each round of three steps, there will be one "lead engineer" and the rest of the team will be "assistant engineers". The function of the lead engineer is to construct the robot. The assistant engineers are to look for parts and help the lead engineer. Emphasize that there are approximately 600 pieces in each robot kit and they must take care not to lose or misplace any of the parts.

Activity #2

Estimated Time: 10-15 min

Title: Overview of Programming Basics

Lesson Overview: Students will become familiar with writing basic programming commands for their robot.

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- LEGO® MINDSTORM® EV3 constructed robot from Activity #1
- Laptop
- MINDSTORM® Software installed on the laptop
- Overhead Projector and display screen to view programming software
- Journal (per student)

Lesson Flow:

1. Using the "Straight Move" program in the software manual, review the following basic commands with the students.
   NOTE: Start command (green arrow) – Make sure that the students understand that all programs must use this as their first block!
2. Review the "Move STEERING Block", explaining each command – rotations on/off, steering, power, # of rotations, and break/coast at end. A printable guide to the Basics of the "Move STERRING Block" is available in *Appendix A.5*.
   a. Wait for block: used extensively with sensors and other programming basics.
   b. Sensors: Color, Gyro, Ultrasonic, and Touch.

Activity #3

Estimated Time: 15 min

Title: Program Your Robot

Lesson Overview: Students will build their robot using diagrams from the handbook. In addition, they will create, test, and run programs to control a robot.

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- LEGO® MINDSTORM® EV3 Educational Kit
- Laptop
- LEGO® MINDSTORM® Software installed on the laptop
- Projector to view programming software
- Journal (per student)

Lesson Flow:

1. Before students begin programming, connect each robot to a computer using the cable provided. Press the button in the middle of the block to turn it on.
2. Students are going to program simple commands to control a robot.
   a. Program the robot to move in a straight line for one meter.
   b. Once students have accomplished this task, students should now program their robot to move forward for one meter, wait one second, and then move in a straight line backwards for two meters.
3. To see an example of the LEGO® MINDSTORM® EV3 Software, you can go to the LEGO® MINDSTORM® Website. Select Robot Educator → Basics → Straight Move.
4. Have students test their program after every block to make sure it works correctly.

Activity #4

Estimated Time: 45 min

Title: Build and Program the Line Follower

Lesson Overview: Students will create, test, and run programs designed for a robot to follow a line.

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- LEGO® MINDSTORM® EV3 constructed robot
- Laptop
- LEGO® MINDSTORM® Software installed on the laptop
- Projector to view programming software
- Journal (per student)

Lesson Flow:

1. Quickly review railway safety signs with students. Explain how to use the color sensor to command their robot to obey safety signs and signals.
2. If necessary, show students the "Line Follow and Smooth Follow" programming tutorials on YouTube (i.e., https://www.youtube.com/watch?v=ODAGVeeDagk).
3. The "Line Follower" Program is available in *Appendix A.6*.
4. Introduce students to their next activity: Program robot to follow a line along a curved path while responding to different colors (safety signs) on the test path.

Activity #5

Estimated Time: 35-45 min

Title: Color Sensor Programming

Lesson Overview: Students will create, test, and run programs to command a robot to respond to a change in signal color.

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- LEGO® MINDSTORM® EV3 constructed robot
- Laptop
- MINDSTORM®s Software installed on the laptop
- Projector to show programming software
- Journal (per student)

Lesson Flow:

1. The "Color Sensor" Program is available in *Appendix A.7*.
2. Before students begin programming, connect each robot to a computer using the cable provided. Press the button in the middle of the block to turn it on.
3. Have students follow the "Color Sensor" programming steps to program their robot to recognize and respond to colors with a command.
4. Have students test their program after every block to make sure it works correctly.

Activity #6

Estimated Time: 30-45 min

Title: Build and Program a Forklift Robot Design

Lesson Overview: Students will build a forklift using the LEGO® manual. They will program the forklift to lift a box and drop it off at a designated drop-off area.

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- LEGO® MINDSTORM® EV3 constructed robot
- Laptop
- LEGO® MINDSTORM® Software installed on the laptop
- Projector to view programming software
- Journal (per student)

Lesson Flow:

1. Begin by explaining to students that they will be designing and programming a Forklift Robot to move objects.
2. Show students which objects they must move from location A to location B.
3. *Appendix A.8* has two images of possible forklift robot designs. Have students construct their forklift using the manual (pages 54-68) as a guide.
4. Before students begin programming, connect each robot to a computer using the cable provided. Press the button in the middle of the block to turn it on.
5. Have students follow the "Forklift Robot Design" programming steps to program their robot to recognize and respond to a variety of sensors that may be used in conjunction with the forklift . This program is completely open-ended. Encourage students to use their creativity and imagination.
6. Create a point A to point B route. Have students test their program after every block to make sure it works correctly.

Discussion Activity: Energy, Work, and Power

1. Ask students what they think about when they hear the word "energy."
   a. *How do you use energy in your life?*
   b. *Name a few things that we do that use energy. What happens when we don't have enough energy?*
2. Explain to students the difference between our everyday definition for energy, and the scientific definition.
   > **Energy**: *Energy is the capacity of a physical system to perform work. Energy exists in several forms such as heat, kinetic, potential, mechanical energy, light, electrical energy, or other forms.*
3. Introduce students to the terms *force*, *work*, *energy*, and *power*. Give some everyday examples of each term.
4. Explain the formulas for computing force, work, and power to students.

<p align="center">*Force = mass × acceleration*</p>

   a. Acceleration due to gravity [9.81 m/s^2]
   b. Energy is the ability to do work, and is measured in Joules [J].
   c. Work is force acting over a distance to move an object, and is measured in [N·m or J].

<p align="center">*Work = Force × distance traveled*</p>

   d. Power is how fast work can be done or the rate at which work is done, and is measured in Watts [W].

$$Power = \frac{Work}{time}$$

5. Tell students to place different objects in the box that they built as part of the Forklift Robot. It does not matter what is placed in the box as long as the objects are small enough to fit inside. Use a scale to determine the weight of the box with the objects inside.
6. Students should program the Forklift to lift the box with the objects off the ground and take the box with the items from point A to point B. Measure the total distance the box (with the objects inside) travels while on the forklift.
7. Have students record the time it took to lift the object by setting the duration of the motion block (in seconds).

8. Have students compute the mass of the box with the objects, the distance it was lifted off the ground, and the time it took to lift the box off the ground. Compute the force, work, and power needed to move the box.

9. Using the following equations, guide students to calculate the force, work, and the power needed to move the box and items:

$$Force = mass \times acceleration$$

$$Work = Force \times distance\ traveled$$

$$Power = Work\ /\ time$$

Additional Resources:

➢ How to use Vernier Probes

- Photogate Video: https://www.youtube.com/watch?v=AzDjp3ifDek
- Motion Detector Booklet: http://www2.vernier.com/booklets/md.pdf
- Dual-Range Force Sensor Booklet: http://www2.vernier.com/booklets/dfs-bta.pdf

Day 4 - Transportation Design Challenge!

Activity #1

Estimated Time: No time limit (up to teacher)
Title: Build and Program a Forklift Robot Design
Lesson Overview: Students will work through a realistic scenario challenge to learn the practical applications of the force, mass, and acceleration concepts in the transportation industry.
Objectives: Students will apply engineering design principles to a real-life scenario. In addition, students will apply principles of Newtonian physics to a real-life scenario.
Materials Needed: (per group)

- Small scale
- Forklift box (made from Lego pieces, about 10 cm^3)
- Robot with Forklift program
- Five small objects that fit in the forklift box
- Black masking tape or vinyl electrical tape to delineate the challenge course
- Prize for winning team: to be determined by the teacher
- Journal (per student)

Lesson Flow:

1. Introduce students to the challenge at hand, letting them know this challenge will be judged. A winning team will be selected.
2. Introduce the challenge:

   A North Atlantic Rail freight train derailed near Edinburg, TX spilling an unknown number of barrels carrying hazardous chemicals. Your team has been hired by XXX Corporation to be the first responders to the site of this accident. Your team of engineers must create and program your LEGO® MINDSTORM® EV3 robot to:

   a. clean up the hazardous materials that have been spilled;
   b. remove the derailed train railcars from the accident site;
   c. check the rail tracks for any damage and ensure that they are safe to use; and
   d. pick-up the remaining materials/debris from the accident site.

3. Explain to students that they will be judged on:

   a. Design, efficiency, and reliability of each LEGO® MINDSTORM® EV3 constructed.
   b. Their PowerPoint Presentation on the design process they followed.

4. Additional Guidelines: Students can use the MagLev train kit and accessories to simulate the derailment of the North Atlantic Rail freight train described above. Students will be

judged on their creativity and imagination in simulating the events leading to this accident.

5. Students will need to design and construct two LEGO® MINDSTORM® EV3 robots.
   a. Each model needs to be created from a different core set, and must implement a lifting mechanism to transport the crane to the accident site.
   b. The color sensor on the transportation vehicle must abide by the following traffic signals:

TRAFFIC SIGNAL COLOR	ACTION
RED	STOP
YELLOW	SLOW DOWN
GREEN	GO

   c. *Appendix A.10* provides some colored rectangles that might be used.

Day 5 - Final Design Challenge and Competition

Activity #1

Estimated Time: No time limit (up to teacher)
Title: Final Design Challenge and Competition
Lesson Overview: Students will participate in hands-on investigative activities that will allow them to apply their understanding of robotics and Newtonian Physics to create a positive train control (PTC) mechanism. Students need to devise a more creative/effective PTC which doesn't stop the train abruptly (i.e., crash).
Objectives:
1. Define and investigate effective PTC techniques.
2. Determine the best PTC design that will stop the train at the end of the ramp without crashing or obstructing the rail track in any way.
3. Evaluate various engineering train designs.

Materials Needed: (per group)
- Constructed EV3 Robot
- Stopwatch
- Ramps/inclines
- Protractor
- Miscellaneous materials (magnets, rubber bands, paper clips, etc.) for students to utilize in creating an effective PTC mechanism
- Journal (per student)

Lesson Flow:
1. Explain to students the following hypothetical scenario:

   A North Atlantic Rail Train that routinely travels through your region just derailed spilling some hazardous chemicals. Your team has been hired by XXX Corporation to be the lead first-responder group of engineers to this accident. Your team of engineers must create and program your LEGO® MINDSTORM® EV3 robot to:
   a. clean up the hazardous materials that have been spilled; and
   b. remove the derailed train railcars from the accident site.
2. Explain and make sure that the students know they will be judged on:
   a. their ability to remove all hazardous chemicals from the accident site;
   b. their ability to remove the derailed train from the accident site; and
   c. the amount of time it takes to accomplish tasks "a" and "b".

Appendices

Appendix A. Worksheets and Guides

Appendix A.1 Speed and Incline Data Table

Angle	# of Washers P	Distance Traveled X [cm]	Elapsed Time T [sec]	Mass m [kg]	Acceleration a [m/s²]	Force F = m·a [N or kg·m/s²]	Potential Energy PE [J or kg·m²/s²]	Kinetic Energy KE [J or kg·m²/s²]
0°	5							
10°	5							
20°	5							
30°	5							
40°	5							
60°	5							

Appendix A.2 Graph Paper

Appendix A.3 Mass, Force, and Acceleration Data Table

# of Washers	Distance Traveled	# of Magnets	Elapsed Time	FOM	Mass	Acceleration	Force
P	X [cm]	N	T [sec]	$\dfrac{P \cdot X}{N \cdot T}$	m [kg]	a [m/s^2]	$F = m \cdot a$ [N or kg·m/s^2]
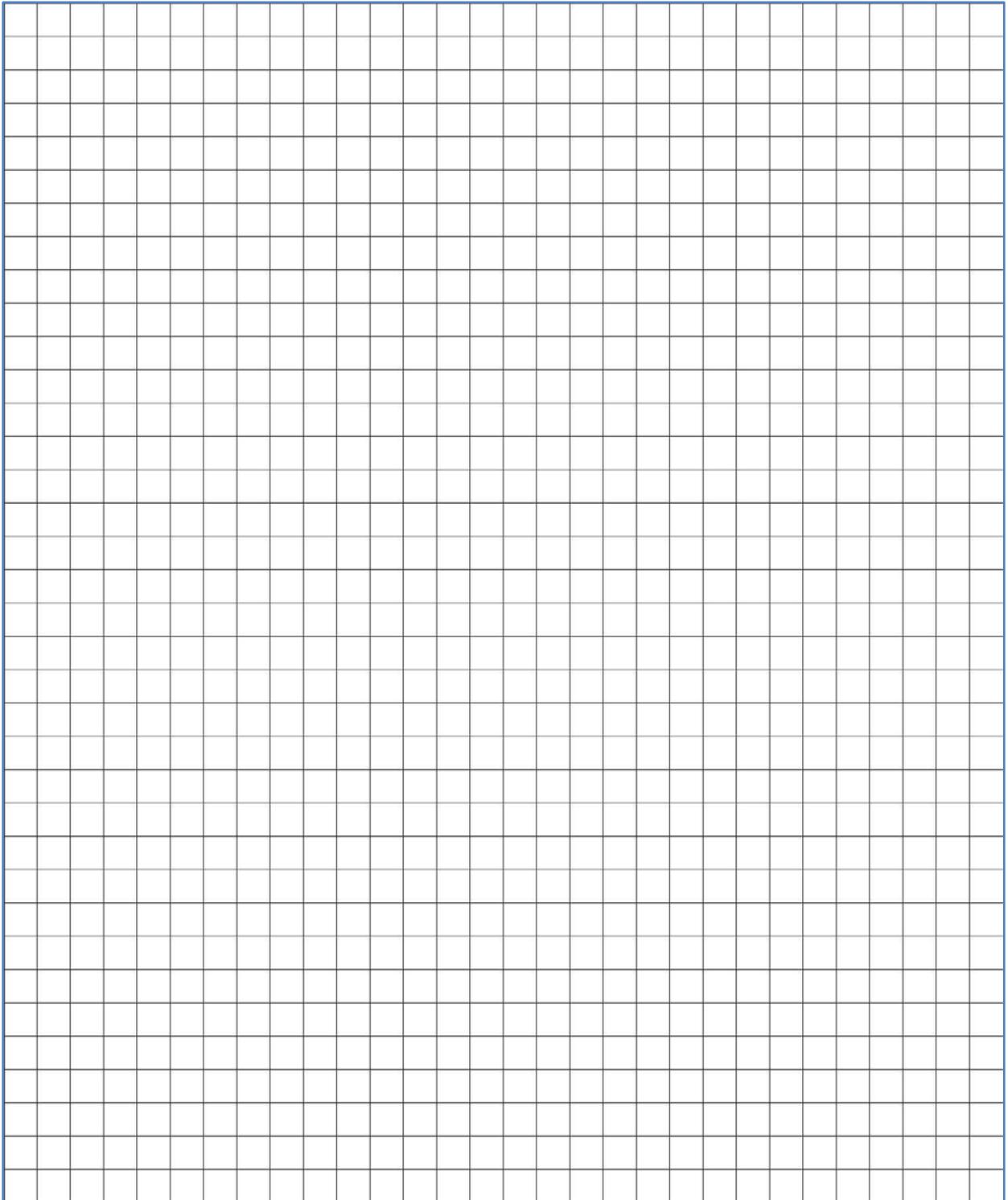
Appendix A.4 Magnet and Acceleration Data Table

Trial	# of Washers P	Distance Traveled X [cm]	# of Magnets N	Elapsed Time T [sec]	FOM $\dfrac{P \cdot X}{N \cdot T}$	Mass m [kg]	Acceleration a [m/s²]	Force F = m·a [N or kg·m/s²]
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 A.5 Basics of the Move STEERING Block
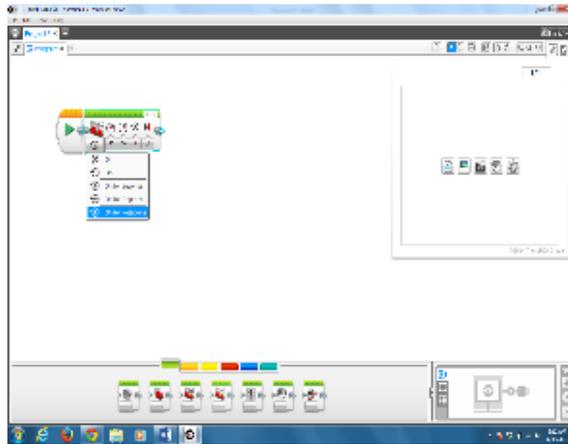
All programs must start with the **Start command**. It is the green arrow.

The **Move STEERING Block** is used to make the robot drive forward, backward, turn, or stop. It also adjusts the steering to make your robot go straight, drive in arcs, make tight turns or spin turns.
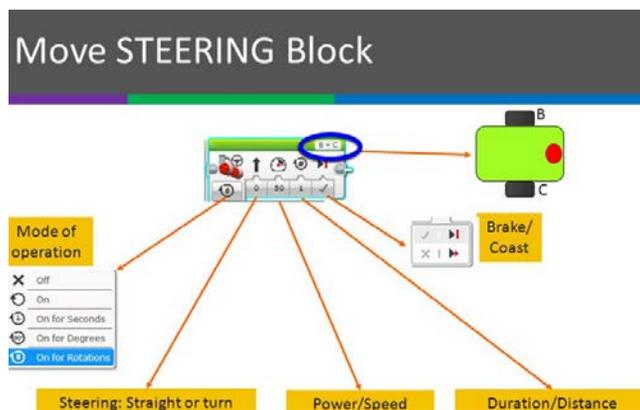
The first button on the **Move STEERING Block** determines its main function; motors off, on, on for so many seconds, so many degrees of rotation, or on for so many rotations. The number of seconds, rotations, and degrees are specified on the third button. The buttons are explained in Table 1 below.

Table 1. Move STEERING Block button explanations.

|	
The second and third buttons specify the amount of power from the first and second motor, respectively. Default power is 50 percent. The motors are specified in the box on the upper right hand and explained below.	
The fourth button is the place to specify the numb of seconds, rotations, or degrees that the motors should execute.	
The function of the fifth button is to specify what happens after the task is performed; should the motor stop after the task, or should it let the built momentum follow its course. For most tasks, the brake function is recommended.	
The top right box is the place to specify which motors will be used by this block.	
This is the steering block. It is operated exactly the same as the move tank block with the exception of the steering button. This button specifies the direction of the turn, and how wide or tight the turn should be.	
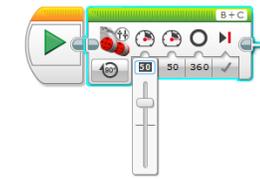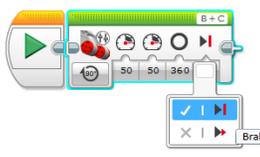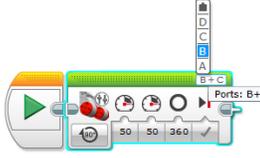
There are a wide variety of blocks available in the development environment to program LEGO® MINDSTORM® EV3 robots. They can be categorized as Action Blocks (Green), Flow Blocks (Orange), Sensor Blocks (Yellow), Data Operation Blocks (Red), and Advanced Blocks (Blue). The following images show the five types of programming blocks available.

ACTION BLOCKS (Green)
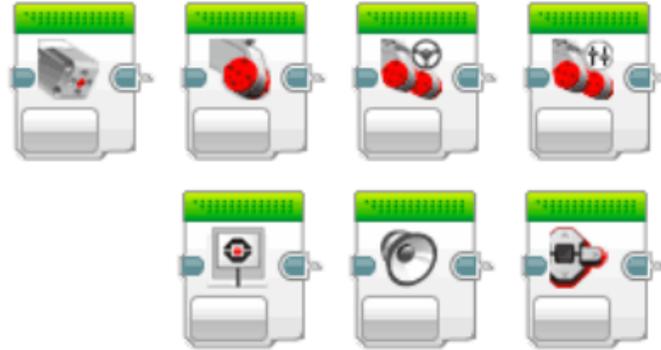
The action blocks control the actions of the program. They control motor rotations and also image, sound and the light on the EV3 P-brick.

FLOW BLOCKS (Orange)
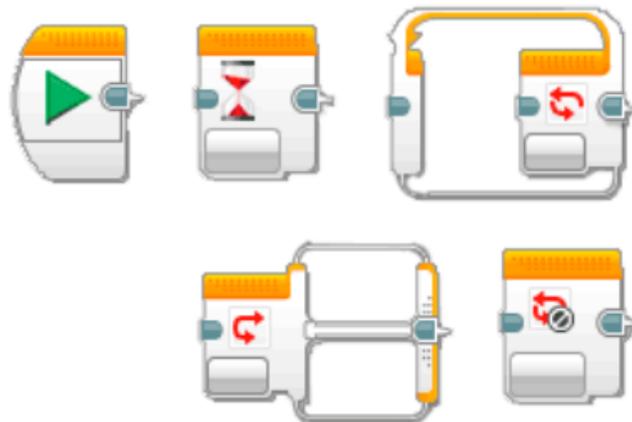
The Flow blocks control the flow of the program. All programs you create will start with the start block.

SENSOR BLOCKS (Yellow)
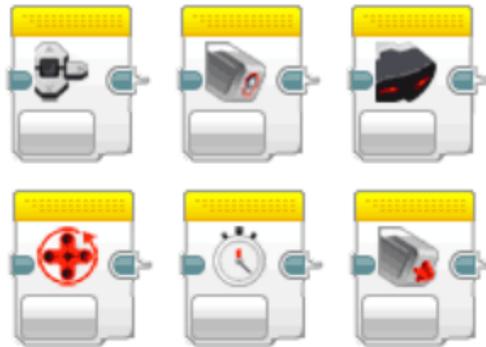
The Sensor blocks allows your program to read the inputs from the Color sensor, IR sensor, Touch sensor and much more.

DATA OPERATION BLOCKS (Red)
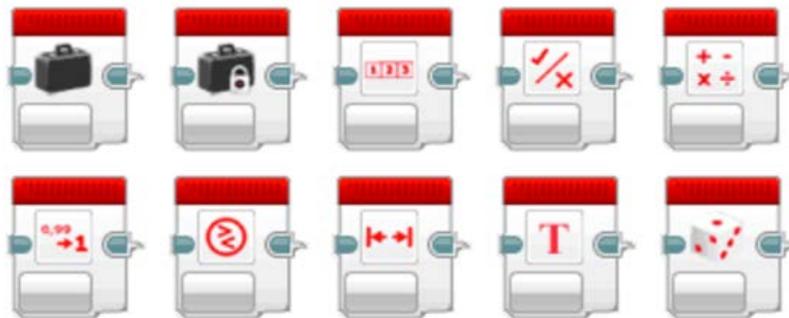
The data operation blocks let you write and read variables, compare values and much more. Please note: the red data blocks are only available in the programming software for PC/Mac and NOT in the EV3 Programmer App.

ADVANCED BLOCKS (Dark blue)
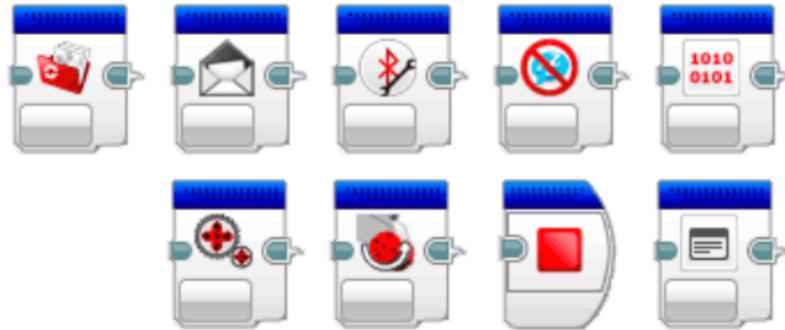
The advanced blocks let you manage files, Bluetooth connections and much more. Please note: the blue advanced blocks are only available in the programming software for PC/Mac and NOT in the EV3 Programmer

Appendix A.6 Line Follower Program

Notes: In this program, everything is inside a loop. The color sensor is set to measure reflected light intensity; the math blocks are set to advanced; the upper variable blocks are set to write numeric (default); the lower variable blocks are set to read numeric; and the move tank block is set to on. On the formula spaces, the formula is (a-b)*c.

Appendix A.7 Color Sensor Program

Notes: The program is inside a loop. A switch block is dragged in and set to measure color with the color sensor. Then, the wanted actions are dragged to each color. At the top, the no color tab is selected as default, and the default action is selected. In this case, we set it to move both motors at 50% power.

Appendix A.8 Sample Forklift Designs
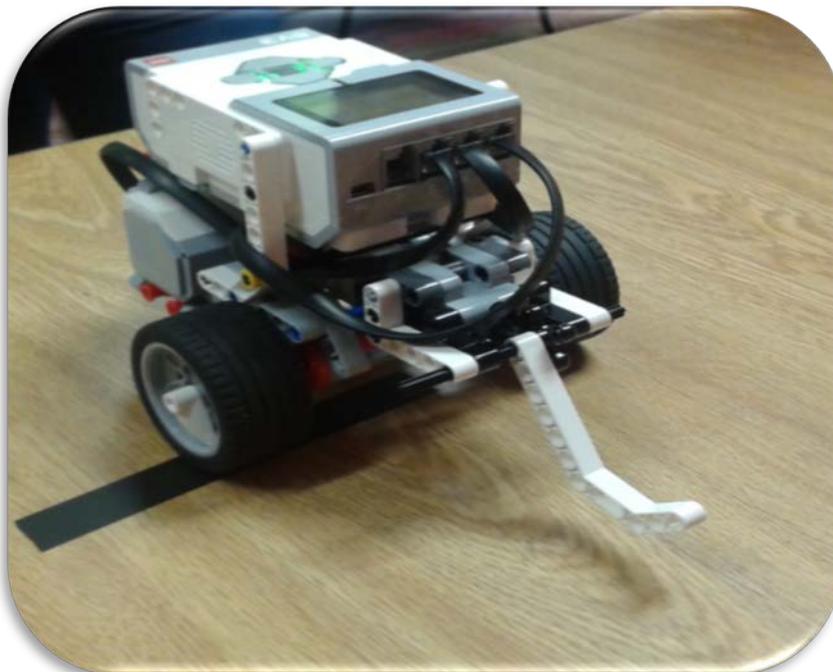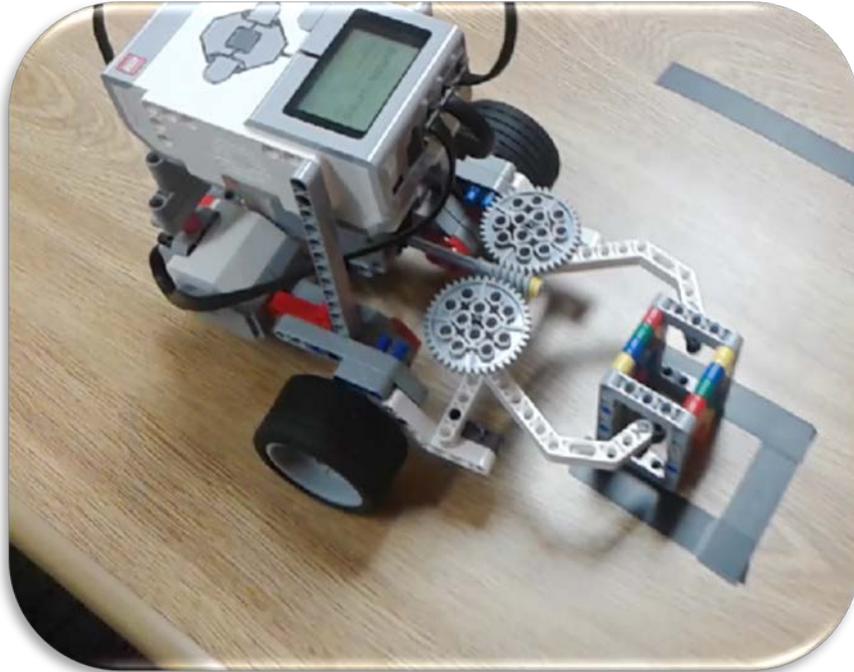
Appendix A.9 Basic Forklift Program

Notes: This program is completely open-ended. Any number of sensors can be used in conjunction with the forklifting action. This small and simple program illustrates the use of the medium motor block as the means to drive the lifting and lowering mechanism. This example also shows a claw mechanism driven by a worm or screw gear.
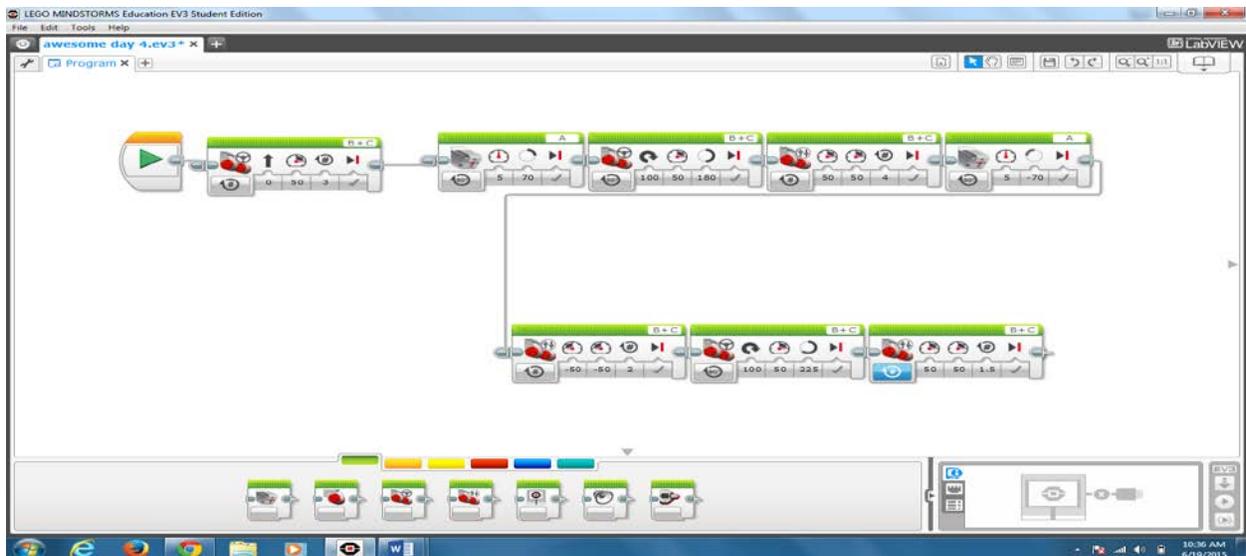
Appendix A.10 Colored Rectangles
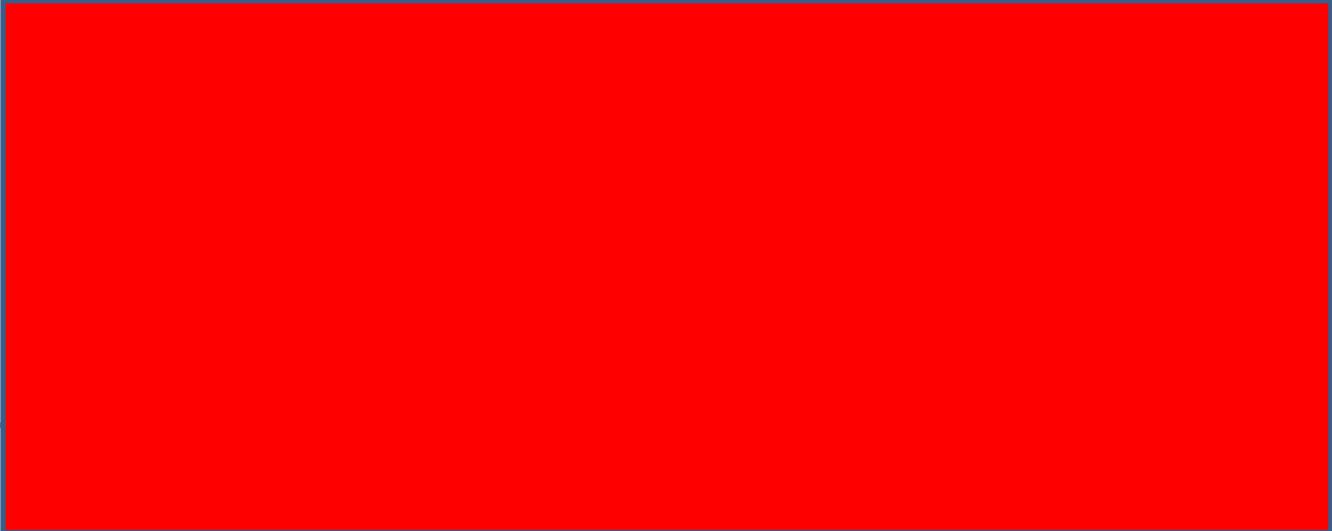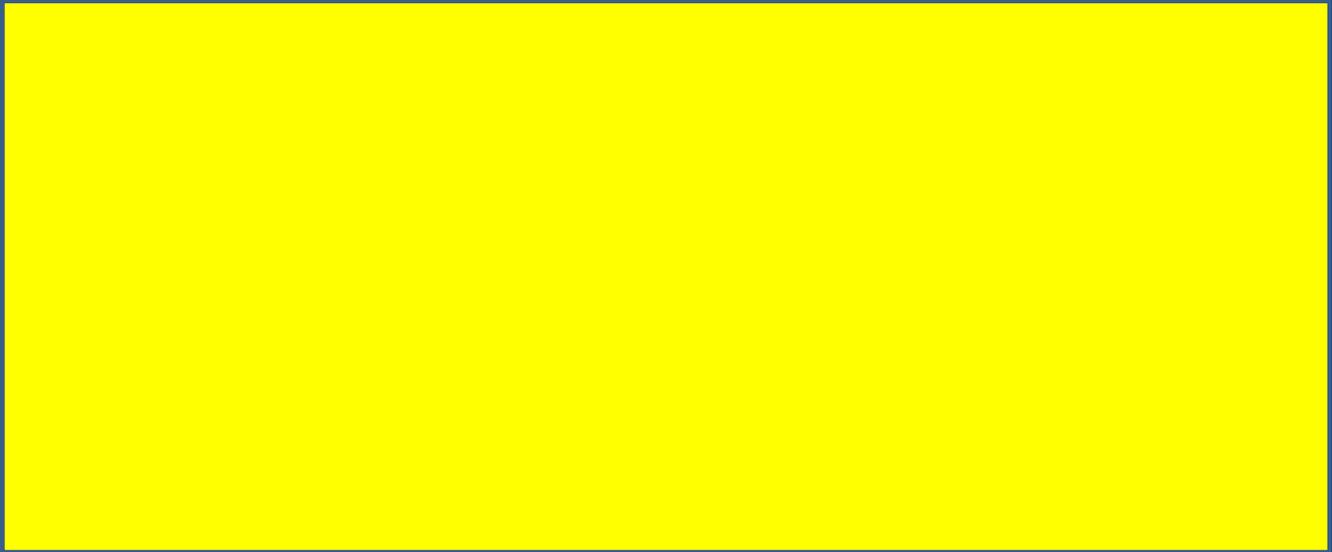
Appendix B. Video and Resource List

Day 1
Activity #1
Engage video: https://www.youtube.com/watch?v=cXgB3lIvPHI

Activity #2
Photogate:
http://www2.vernier.com/manuals/Logger_Pro_Introduction_to_the_Vernier_Photogate.pdf
Motion Detector: http://www.vernier.com/manuals/md-btd/
Dual-Range Force Sensor: http://www.vernier.com/manuals/dfs-bta/
World's Fastest Trains - MagLev Video: https://www.youtube.com/watch?v=aIwbrZ4knpg
German MagLev design Video: https://www.youtube.com/watch?v=hUATDtZble0
Japanese MagLev design Video:
https://www.youtube.com/watch?v=SUBUTo82EQw#rpctoken=287669679&_methods=setNotification WidgetSize%2CsetNotificationWidgetHeight%2CsetNotificationText%2ChideNotificationWidget%2CopenSharebox%2ConError%2C_ready%2C_close%2C_open%2C_resizeMe%2C_renderstart&id=I1_1446659761580&parent=https%3A%2F%2Fwww.y

Activity #3
Watch: Potential and Kinetic Energy Videos
https://www.youtube.com/watch?v=BSWl_Zj-CZs
https://www.youtube.com/watch?v=iYEWIuQBVyg

Day 2
LEGO® MINDSTORM® EV3 Programming Basics
https://www.youtube.com/watch?v=CeCM_Z46Ys4
Using Touch Sensor - LEGO MINDSTORM® EV3 Tutorial
https://www.youtube.com/watch?v=YWOThIuvU4U

Day 3
Traffic Signs and their meanings
https://www.youtube.com/watch?v=41dPJ322pK0

Using Color Sensor - EV3 Programming 1.9: How to follow a straight line smoothly

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

Using Color Sensor- EV3 Programming 1.3: How to detect color (Using Color Sensor)

https://www.youtube.com/watch?v=xjOQ_LZRzw8

Day 4

Newton's Laws

1st Law:

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

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

Day 5

This video can be used any day.

http://www.lego.com/en-us/mindstorms/videos