NGSS Lesson Planning Template

Grade/ Grade Band: 6th-8th	**Topic: Energy**	**Lesson #** 1 **in a series of** 4 **lessons**

Brief Lesson Description: During this unit, students will learn the effects of different types of forces on the motion of objects, through the study of the Newton's laws of motion. Newton's laws state: (1) an object at rest will stay at rest until an unbalanced force acts upon it. Every object moves in a straight line unless acted upon by a force. (2) The acceleration of an object is directly proportional to the net force exerted and inversely proportional to the object's mass. F=ma (3) For every action, there is an equal and opposite reaction.

Performance Expectation(s):

MS-PS3-1

Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]

MS-PS3-2

Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [*Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.*]

MS-PS3-5

Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] *[*Assessment Boundary: Assessment does not include calculations of energy.]

Specific Learning Outcomes:

Students will understand:

1. Concepts and forms of energy.
2. The relation between kinetic energy and object velocity.
3. The relation between the position of an object and its potential energy.
4. The transfer of energy from an object to another object.

Narrative / Background Information

Prior Student Knowledge:

1. The notion of the gravity.
2. The effect of forces on the motion of objects (Newton's law of motion).
3. Basic programming of the EV3.
4. Basic knowledge in building the EV3 and modifying its shape.

Science & Engineering Practices (SEPs)	**Disciplinary Core Ideas (DCIs)**	**Crosscutting Concepts (CCs)**

<u>MS-PS3-1</u> **Analyzing and Interpreting Data** Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Construct and interpret graphical displays of data to identify linear and nonlinear relationships.	<u>MS-PS3-1</u> **PS3.A: Definitions of Energy** Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	<u>MS-PS3-1</u> **Scale, Proportion, and Quantity** • Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
<u>MS-PS3-2</u> **Developing and Using Models** Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to describe unobservable mechanisms.	<u>MS-PS3-2</u> **PS3.A: Definitions of Energy** • A system of objects may also contain stored (potential) energy, depending on their relative positions. **PS3.C: Relationship Between Energy and Forces** • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	<u>MS-PS3-2</u> **Systems and System Models** • Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems.
<u>MS-PS3-5</u> **Engaging in Argument from Evidence** Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed worlds.	<u>MS-PS3-5</u> **PS3.B: Conservation of Energy and Energy Transfer** • When the motion energy of an object changes, there is inevitably some other change in energy at the same time.	<u>MS-PS3-5</u> **Energy and Matter** • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).

• Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.		

Possible Preconceptions/Misconceptions:

1. Energy is found/produced on/by living things.
2. Energy results only with movements.
3. Energy is a fuel.
4. Energy is recycled.
5. Energy and force are interchangeable terms.
6. An object at rest has no energy.
7. Energy is not conserved because we are using it.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

The teacher opens the class by asking students motivating questions related to the concept of energy of an object like:

- What are the forces acting on the EV3 in a standstill situation? (Aligned with **MS-PS3-1** since it partially addresses the DCI of this standard by asking about the fact that the kinetic energy is zero which proportional to the square of the linear velocity that is zero as well).

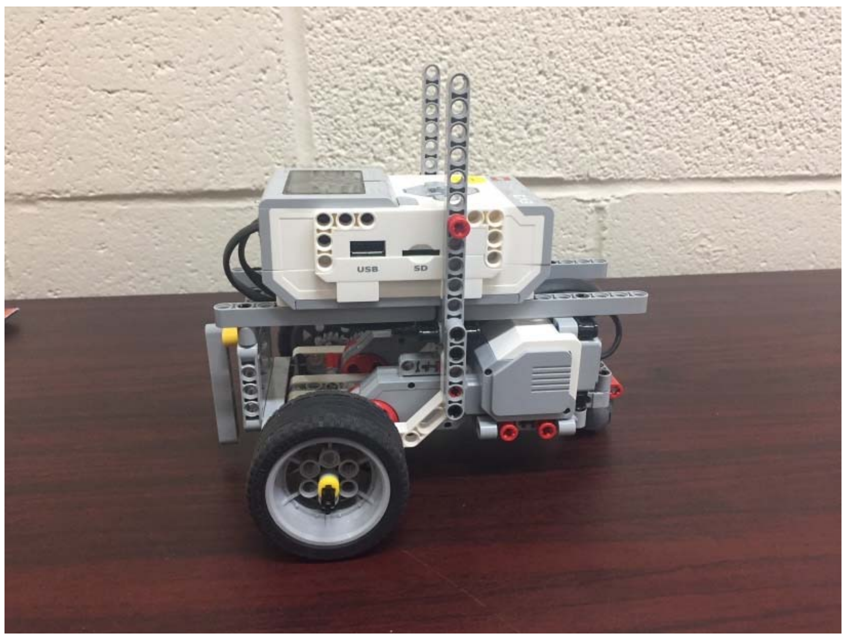

Figure 1 The EV3 is in a standstill situation.

- What are the forces affecting on the EV3 pushed by the hand? (Aligned with **MS-PS3-1** since it partially addresses the DCI of this standard by asking about the fact that the EV3 moves if a sufficient force applied to it and hence the EV3 would have a kinetic energy).

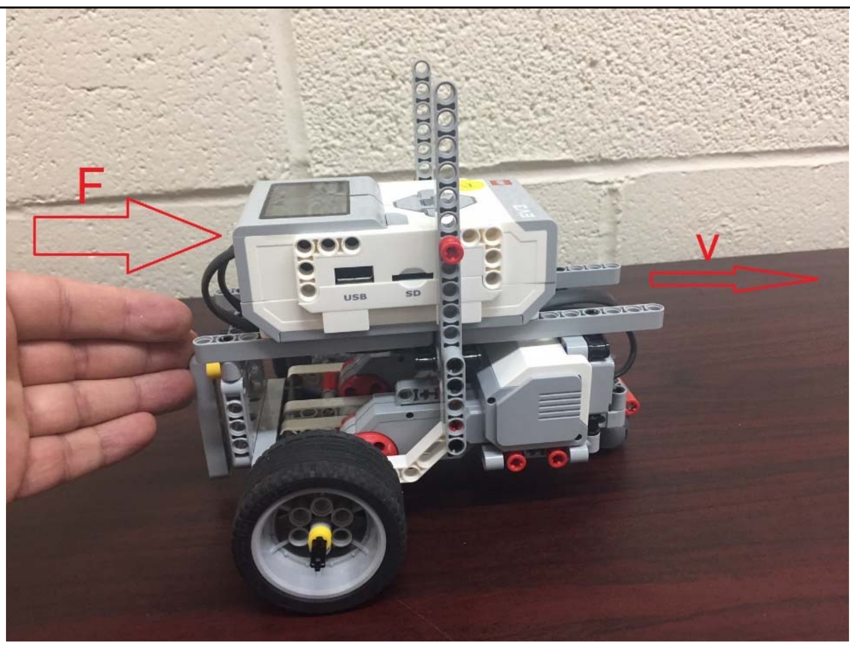

Figure 2 The EV3 is pushed by the hand.

- How much force should we apply to the EV3 in order to start moving? (Aligned with **MS-PS3-1** since it partially addresses the DCI of this standard by asking about the minimum value of the force required for the EV3 to move and acquire a kinetic energy).
- What is the relationship between the speed of the EV3 and the force applied on it? (Aligned with **MS-PS3-1** since it partially addresses the DCI of this standard by asking about the relation between the energy, force, mass and velocity).
- Suppose that we are given a ball placed on multiple heights of an inclined surface. Does the ball have the same energy as the height is changed? Why? (Aligned with **MS-PS3-2** since it partially addresses the DCI of this standard by considering the potential energy and the effect of the position on the value of the potential energy).

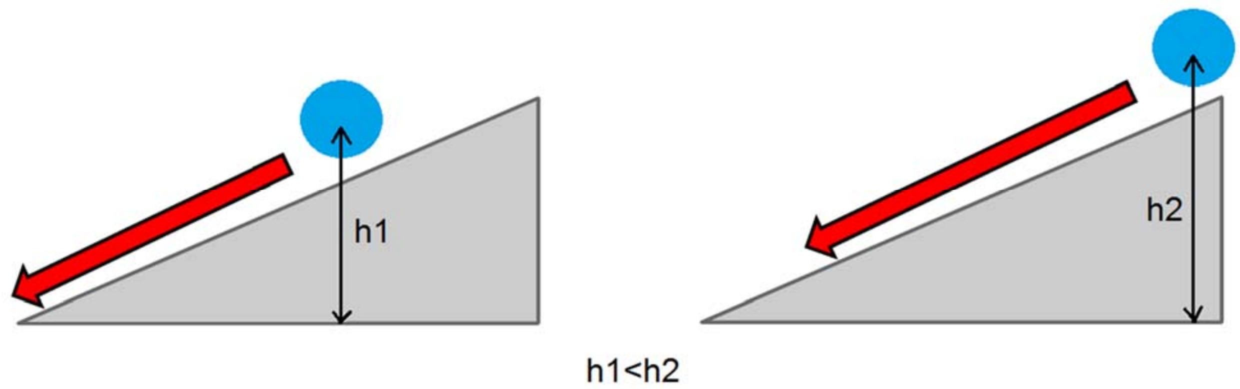

Figure 3 A ball released from multiple heights on an inclined surface.

- What happens if we put the EV3 at the buttom of the inclided surface with releasing the ball from hight h2? Why? (Aligned with **MS-PS3-2** since it partially addresses the DCI of this standard by considering the transfer of energy from the ball to the EV3 during their interaction/collision).

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Lesson Description:

In this unit, students will learn the concept of kinetic energy and its relationship with the mass and velocity of the object which meets the expectation of the **MS-PS3-1** NGSS standard. Then, students will assimilate the relationship between potential energy of a certain object and its relative position that meets the expectation of **MS-PS3-2** NGSS standard. Furthermore, students will discuss the mechanism of transferring the energy from a certain form into another one which meets the expectation of **MS-PS3-5** NGSS standard.

Materials Needed:

1. EV3 robot
2. Measuring tape
3. Balls of varying mass
4. Ramp
5. Ramp box base
6. Triple beam balance

Probing or Clarifying Questions:

The teacher divides the students into groups and gives an EV3 robot to each group.

- Starting from the standstill situation of the EV3 shown in Figure 1, students will discuss and discover the forces affecting on the EV3 and justify why it's not moving?
- The teacher moves between the groups, observes the students brainstorming, interact with their discussions.
- Possible questions that can be asked by the teacher are:
  - Why the EV3 is not moving?
  - Does it have an energy in any form?
  - How much is the energy? Why?
  - What is the friction and what is its effect on the EV3 motion?

- Then, the students move to the situation where the EV3 is pushed gently by one of the students of the group and observe the motion of the EV3 (as shown in Figure 2).
- The students will discuss the reason behind the EV3 movement and compare it with the kinetic energy of the standstill situation.
- The teacher will wander between the groups and ask the students question related to this activity. Possible question can be:
  - Why is the EV3 moving?
  - What is the minimum force required to move the EV3?
  - What is the relation between the applied force and the mass of the EV3?
  - What is the relation between the kinetic energy of the EV3 motion and the corresponding velocity?

*The above will meet the expectation of the **MS-PS3-1** NGSS standard since it addresses the CDIs of this standard and as detailed in the Engage part.*

EXPLAIN: Concepts Explained and Vocabulary Defined:

Activity 1:

- Students will move to the first activity and the teacher needs to get the EV3 prepared and assembled for this Activity.
- The students will release the ball on an inclined surface (See Figure 3).
- As the ball rolls over the surface, the students start brainstorming the reason of such motion.
- Students will discuss the motion of the ball from multiple heights of the surface and observe the relation between the energy of the ball motion and the height.
- Possible questions that can be asked by the teacher for this activity:
  - What is the reason of the ball motion along the surface when released?
  - What is the relation between the height of the ball and its potential energy before releasing it?
  - Will the kinetic energy of the motion of the ball increase with the increment of the height of the ball along the surface? Why?

The above will meet the expectations of the MS-PS3-2 and MS-PS3-5 NGSS standards since it addresses the CDIs of this standard and as detailed in the Engage part.

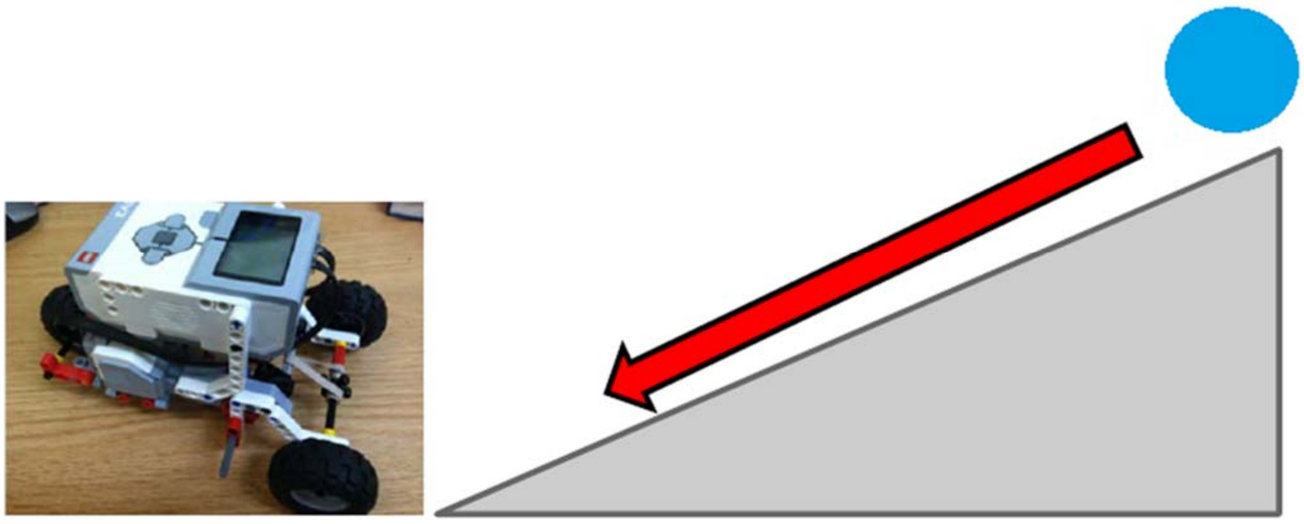

Figure 4 The ball is released from multiple heights and collides with the EV3 robot.

<u>Activity 2:</u>

- The teacher will hand a ramp, ramp box base, and a measurement tape for each group.
- The students will perform the following steps:
    1. Place robot at bottom center of ramp.
    2. Place the ball at a predetermined release point.
    3. Release a ball down ramp to collide with the robot at the bottom.
    4. Record the distance that the robot moved.
    5. Repeat this trial and record data on the worksheet
    6. Repeat steps 1-5 for other three distinct release points.
    7. Repeat steps 1-6 for other three distinct masses of the robot.
    Note: Other masses can be obtained by adding a lego block to the robot that increases its weight.

Table-1-Collision data table

Trial	Mass of Robot (g)	Distance Robot moved (cm)
1		
2		
3		
4		
5		
6		

Trial	Ball's Release Point (cm)	Distance Robot moved (cm)
1		
2		
3		
4		
5		
6		

- Possible questions that can be asked by the teacher are:
    - i. For each one of the readings, what are the forms of the energy and are there other forms **(CC of MS-PS3-5)**?
    - ii. Can you explain the trail of energy transfer between its forms, i.e. potential and kinetic energy for each one of the readings **(CDI of MS-PS3-5)**?
    - iii. According to the table above, what is the relationship between the distance moved by the robot and its mass **(SEP of MS-PS3-5)**?
    - iv. Why is the distance moved by the robot increases with the increment of the height of the ball **(PS 3.A of the CDI in MS-PS3-2)**?
    - v. What is the relation between the height and the velocity of the ball motion **(CDI of MS-PS3-1)**?
    - vi. Can you graph the curve relating the robot mass with its travelled distance **(SEP of MS-PS3-1)**?
    - vii. Can you graph the curve relating the ball release height with the travelled distance of the robot **(CC of MS-PS3-1)**?
    - viii. How much is the predicted EV3 travel distance if we multiply the release height by 5 **(SEP of MS-PS3-2)**?

The above will meet the CDI, CC, and SEP of the MS-PS3-1, MS-PS3-2 and MS-PS3-5 NGSS standards and as detailed below:

- ***MS-PS3-1**: The **CDI** of this standard is realized by observing the kinetic energy of the ball when it is released and the robot as it moves by considering the relationship between the velocity and kinetic energy of the considered objects. The **CC** of this standard is met by studying the proportional relation between the robot's travelled distance and the release height. The **SEP** of this standard is met by sketching the relation between the robot's mass with its travelled distance and the relation between the ball release heights with the travelled distance.*

- ***MS-PS3-2**: The **CDI** of this standard, namely PS 3.A, is realized by introducing the potential energy of the ball and showing that it is related to the height of the ball. While the other CDI, namely PS 3.C, is met by studying how the collision of the ball on the robot moves the robot as a consequence of the interaction of the force resulted by the ball with the robot causing it to move. The **CC** is met by considering the energy as an input to a system while the distance of the robot as the output of the system. Thus, studying the relationship between the distance and the energy of the activity above represents the CC of this NGSS standard. The **SEP** is realized by computing the predicted distance of the EV3 robot if we multiply the height by 5 which allows the possibility of students to predict the unseen phenomena from the table.*

- ***MS-PS3-5***: *The* ***CDI*** *of this standard is met by explaining the trail of energy conversion, the* ***SEP*** *is met by discussing the relationship between the distance and the mass from empirical data, and the CC is addressed by asking about the forms of energy.*

Vocabulary:
kinetic energy
potential energy
energy
distance
mass
acceleration
gravity
friction
force
Newton's Laws

ELABORATE: Applications and Extensions:

- The teacher will hand a ramp, ramp box base, and a measurement tape for each group.
- The students will perform the follow steps:

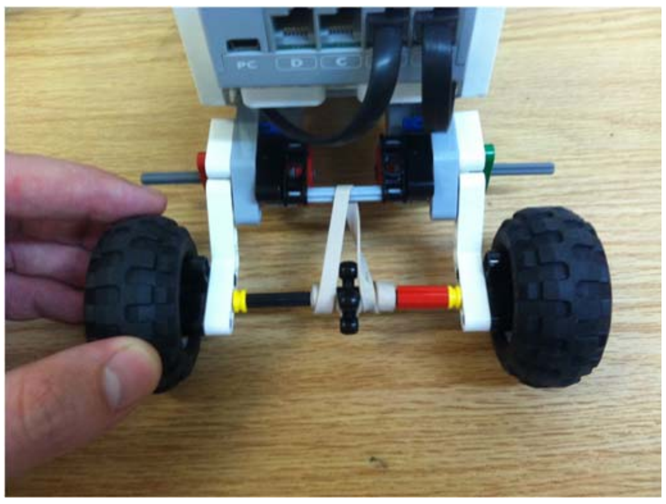

Figure 5 The EV3 robot attached with a rubber band.

1. Place the robot on the ground.
2. Attach the rubber band to its white flap and as shown in the Figure 5.
3. Pull it back a specific distance indicated on data table.
4. Prior to release, mark starting point of the robot.
5. Release the robot **(The CDI of MS PS3-2 PS 3.A is met since a potential energy is generated when the tire is rotated in the tire-rubber combination. The CDI of MS PS3-2 PS 3.C is addressed by investigating the energy transfer from the hand (kinetic) to the tire-rubber combination (potential) and then from the tire-rubber combination (potential) to the robot (kinetic). The CC of MS PS3-2 is met by developing a model that shows the energy flow. The CDI of MS PS3-5 is met by studying the energy conservation and its conversion from the potential to the kinetic and vice versa. The CC of MS PS3-5 is met by studying multiple forms of energy, i.e. kinetic and potential.)**.

6. As the robot moves, mark the endpoint and measure how far it moved from the starting point.
7. Repeat steps 1-6 for every value in data table.
8. The teacher can ask the following possible questions:

   i. What is the relation between the kinetic energy of motion and the velocity of the EV3? **(The CDI of MS-PS3-1 is met since it addresses the relation between the kinetic energy and the velocity of the EV3.)**
   ii. Does energy result only with movements? **The SEP of MS-PS3-5 is met by refuting the misconception that the energy results only from objects movement since we have shown that there is no movement in the case of potential energy.)**?
   iii. After performing this experiment 8 times (twice at 2,4,6,8 tire rotations), analyze the data and predict the outcome of a rotation not given. Students will graph the 8 trials and use that additional resources to make connections to assist in the development of their predictions. **(The CC of MS-PS3-1 is met since it addresses the proportional relation between the distance moved by the EV3 and number of tire rotations. It also meets the SEP of MS PS3-1 since data analysis and prediction are involved using basic statistical techniques of the given data.)**
   iv. Students will use the model of this system to label types of energy in a diagram on the worksheet. **(The CC of MS-PS3-2 is met by developing energy models and its flow.)**
   v. Students will explain and discuss how energy was transferred in this model. **(The CC of MS-PS3-5 is addressed by studying the energy forms, i.e. potential and kinetic energy. The CDI of MS-PS3-5 is met by investigating the conservation of the kinetic energy, from the hand, into potential energy. Moreover, the CDI of MS-PS3-5 is met with the change of energy from its kinetic form-hand motion-into potential form in the rubber-tire combination and from the potential energy of the rubber-tire combination to the kinetic energy in the EV3 robot.)**
   vi. Students can conduct additional experiments alternating the rubber band length and thickness. **(The SEP of MS-PS3-2 is addressed by predicting more abstract phenomena like the effect of length/thickness of the rubber band on the distance and describing the unobserved phenomena/mechanism behind the variation of the distance moved by the EV3 compared to the previous case.)**

Table-2-Rubber Band Robot Build Data Table.

Trial	Amount of full tire rotations	Distance Robot Traveled (cm)
1	2	
2	2	
3	4	
4	4	
5	6	
6	6	

7	8	
8	8	

EVALUATE:
Formative Monitoring (Questioning / Discussion):

1. What net force is required to accelerate a car at a rate of 2 m/s2 if the car has a mass of 3,000 kg?
F=__________
m=_________
a= __________

*Answering this question meets the **CC of MS-PS3-1** by addressing the proportionality between the force applied on a body and its acceleration (F=ma).*

2. In the Rubber Band activity, how and why changing the elasticity of the rubber band affect the distance that the robot travelling? ____
____
____

- *Answering this question meets the **CDI of MS-PS3-1** by addressing the proportionality between the kinetic energy and the speed of the robot when releasing the robot after rotating the wheel for multiple elasticity of the rubber band that affects the distance moved by the robot.*
- *It also meets the **CC of MS-PS3-1** by addressing the proportionality between the force applied by the rubber band on the robot shaft and its acceleration (F=ma).*
- *The **CDI of MS-PS3-2** is met by addressing the potential energy of the rubber band (**PS3.A**), the interaction between the rubber band and the robot shaft causing the energy to be transferred from the EV3 shaft (kinetic energy) to the rubber band (potential energy) and vice versa (**PS3.C**).*
- *Addressing the effect of the change of the rubber band elasticity will touch the concepts of energy conservation and energy transfer when the energy is transferred from the rubber band to the EV3 shaft and vice versa which meets the **CDI of MS-PS3-5**.*
- *The **CC of MS-PS3-5** is addressed by studying kinetic and potential energy forms.*
- *The **SEP of MS-PS3-5** is met by refuting the fact that the energy is having only one form.*

3. Describe the energy transferred when two objects of different masses collide.
____
____

- *The **CDI of MS-PS3-1** is met by addressing the proportionality between the kinetic energy with the mass of the object and square of its velocity.*
- *The **CC of MS-PS3-1** is met by addressing the proportional relation between the force of the impacted object and the acceleration of its motion.*
- *The **CDI of MS-PS3-2 (PS3.C)** is addressed when the objects collide by transferring the energy from and object to another.*

Elaborate Further / Reflect: Enrichment:

Explain how energy was transferred in the system you created?
____
____

____

Give examples from your daily life of the kinetic and potential energy forms.

____

____

____

Suppose that we are given a train that moves up on a mountain with multiple velocities until it arrives to the top of the mountain and then it descends to a valley. When does it have the largest value of its kinetic energy? Why? At what point will it possess the largest value of its potential energy? Why?

____

____

____

Materials Required for This Lesson/Activity			
Quantity	**Description**	**Potential Supplier (item #)**	**Estimated Price**
	Laptops		
	Lego Mindstorm kit		
	Ramp		
	Ruler/measurement tape		
	Rubber band		
	Scale		