Forces and interactions

Grade/ Grade Band: 6-8th grade	Topic:Forces and interactions	Lesson # 3 in a series of 4 lessons

Brief Lesson Description:
In this lesson students learn about balanced and unbalanced forces acting on an object. Unbalanced forces causing a change in the motion of an object. While, balanced forces do not cause a change in its motion. Balanced forces are equal in magnitude, but opposite in direction. Students will learn how to identify balanced and unbalanced forces through Lego robot based activities. They also learn how the mass of the object affecting its motion (F=ma).

Performance Expectation(s):
MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
[Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]

Specific Learning Outcomes:
1. Learn about the different types of forces acting on an object.
2. The effect of forces acting on the motion of an object.
3. Understanding of Newton's first law of motion.
4. Understanding of Newton's second law of motion.

Narrative / Background Information

Prior Student Knowledge:
- Students will have prior knowledge of basic building and programming of the robot.
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Science & Engineering Practices (SEPs)	Disciplinary Core Ideas (DCIs)	Crosscutting Concepts (CCs)
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions. ● Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering,	**PS2.A: Forces and Motion** ● The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. ● All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen	**Stability and Change** ● Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

how measurements will be recorded, and how many data are needed to support a claim. - **Connections to Nature of Science** **Scientific Knowledge is Based on Empirical Evidence** · Science knowledge is based upon logical and conceptual connections between evidence and explanations.	reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.	

Possible Preconceptions/Misconceptions:

- No force acting on an object at rest. (Truth: Net force acting on the object is zero)
- When an object moves, the forces are acting only in the direction of its motion. (Truth: Net force is acting on the direction of motion).

LESSON PLAN – 5-E Model

ENGAGE:

Teacher shows the students a few cases where we see balanced and unbalanced forces

Example: Tug of war

Case 1: *A horse won against 18 men*

Unbalanced or balanced force ?

Fig 1: Horse vs men tug of war

PC: https://gifrific.com/horse-wins-tug-of-war-against-people/

(Youtube link: https://www.youtube.com/watch?v=-srzT2olJ2Q)

Case2: Rope is not moving!!

Unbalanced or balanced force?

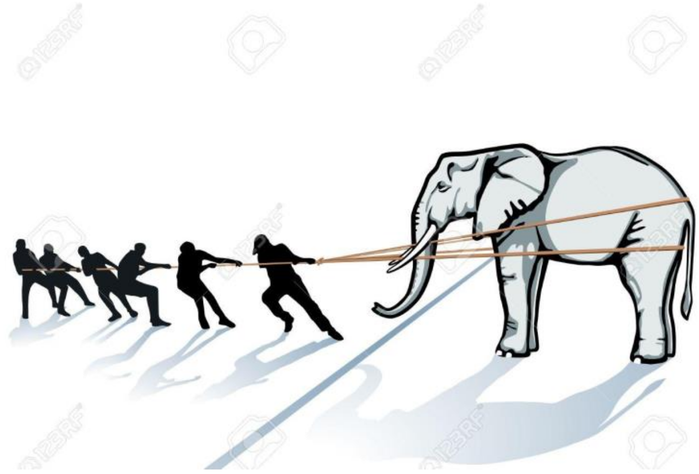

Fig 2: Elephant vs human tug-of war

*PC: https://www.123rf.co*m.

Alignment with the NGSS standard:

This is covering the Science and Engineering practice (SEP) of MS- PS2-2.

Planning and Carrying Out Investigations:

"careful observation and description often lead to identification of features that need to be explained or questions that need to be explored."

EXPLORE:

Lego tug of war

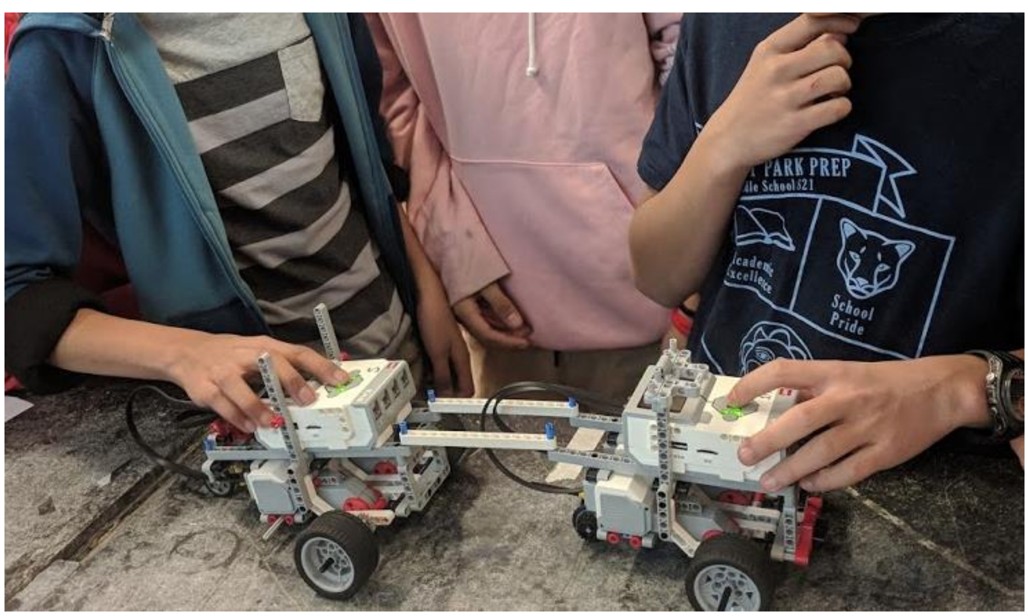

Fig 3: Robot tug-of -war

Now, students are divided into two teams and do the below tug- of- war activities as instructed by the teacher. Students will observe which robot win the game in each of the competition. The each activity will do for 3-5 seconds. They can discuss the different factors which helped the robot to win?

Activity 1: Both the robots A & B having same specifications

- Same power level (50)

- Same construction(Gear ratio 1:1, pivot castor wheels)

Activity 2: First team (robot A) modifying the robot specification.

- ***Power level is increased to 80.***
- Same construction(Gear ratio 1:1, pivot castor wheels)

Activity 3: Second team (robot B) modifying the robot specification.

- Same power level (50) for both teams
- ***Modify the brick position to adjust its center of gravity or adding more weight on their robot.***

x

Sample activity sheet

	Robot A			Robot B		
	Initial position	Final position	Distance travelled	Initial position	Final position	Distance travelled
Trial 1						
Trial 2						
Trial 3						
	Average distance travelled(units)			Average distance travelled (units)		

Discussion with students:

After each of this activity, there would be a discussion with to students to know their observations and predictions.

- Which robot won the game in each of the activity?

- What are the reasons do you think that helped the robot to win the game or lose the game?

Alignment with the NGSS standard:
These activities and post activity discussion addresses the SEP of the NGSS standard MS-PS2-2. Students observe and describe their theories about the factors which helped robots to win the game.
"Planning and Carrying Out Investigations:
Scientists and engineers investigate and observe the world with essentially two goals:

1. Careful observation and description often lead to identification of features that need to be explained or questions that need to be explored.
2. The second goal requires investigations to test explanatory models of the world and their predictions and whether the inferences suggested by these models are supported by data."

EXPLAIN:
How can one predict an object's continued motion, changes in motion, or stability?

The force acting on an object is not only depends on that force,but also depends on all the forces acting on the body.

Concepts to discuss:

1. **Explain the different forces acting on the robots?**

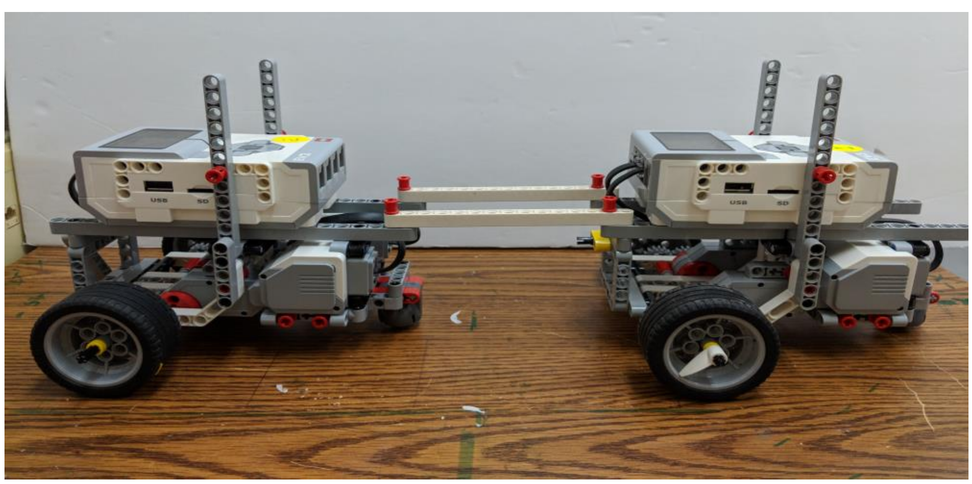

Fig 4: Tug-of -war between robots

- ❑ Gravitational force
- ❑ Normal force
- ❑ Frictional force
- ❑ Pulling force
- ❑ Pushing force

2. **What causes to change the state of an object? Discuss Newton's first law of motion?**

"An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force"

Does force always change the state of an object?

Balanced Forces:

Forces that are equal in size but opposite in direction are called **balanced forces**. Balanced forces do not cause a change in motion. When balanced forces act on an object at rest, the object will not move and is in an *equilibrium* state.

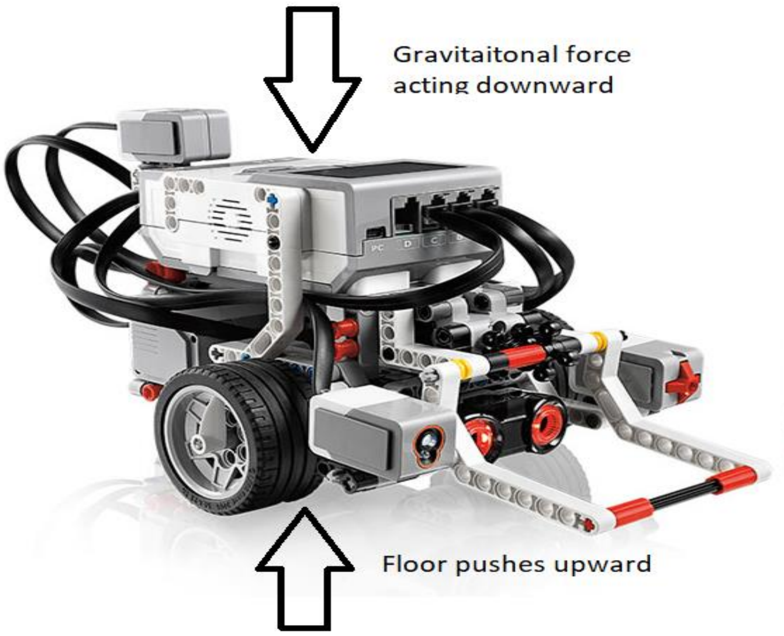

Fig 5: balanced force acting on the robot

- Does normal force always equal to the gravitational force ? What if the contact surface is not horizontal, or there are other vertical forces present?

Unbalanced forces:

Unbalanced forces are not equal in magnitude and opposite in direction. They cause a change in the state of robot. Assume, robot A pulls harder than robot B. Then forces would no longer be equal and robot A will move to the robot B’s side.

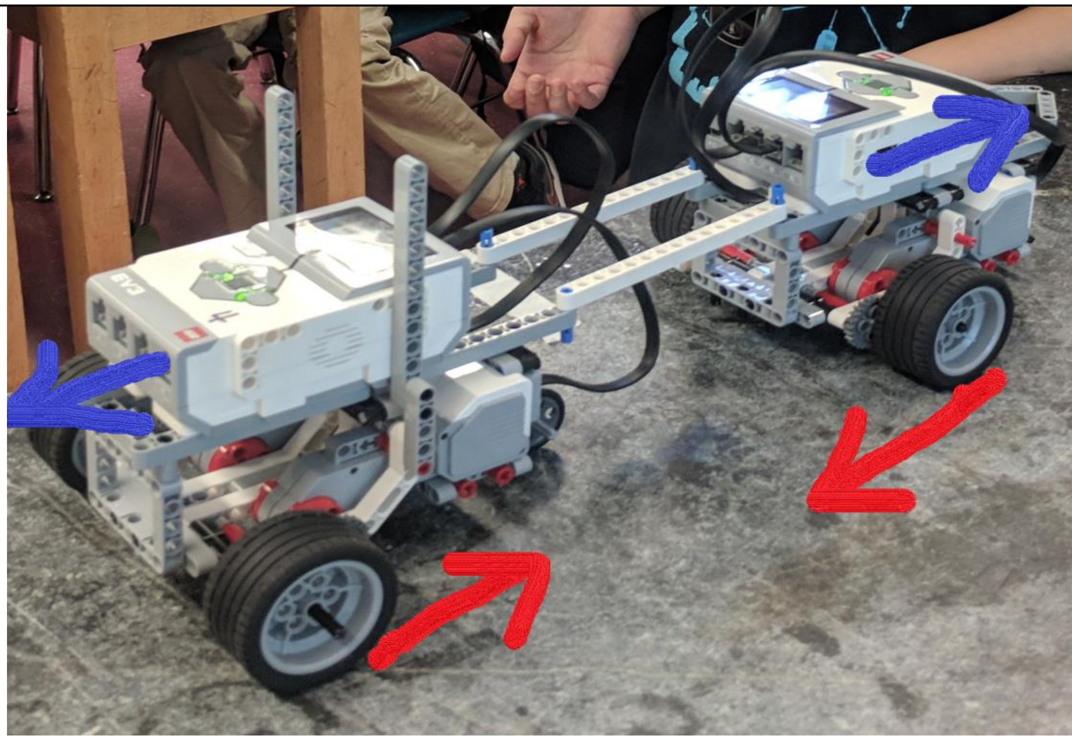

Fig 6: Unbalanced force acting on the robot

- What are the blue and red colored forces indicated in the above figure?

3. How the magnitude and direction of net force affecting the motion of the robot?

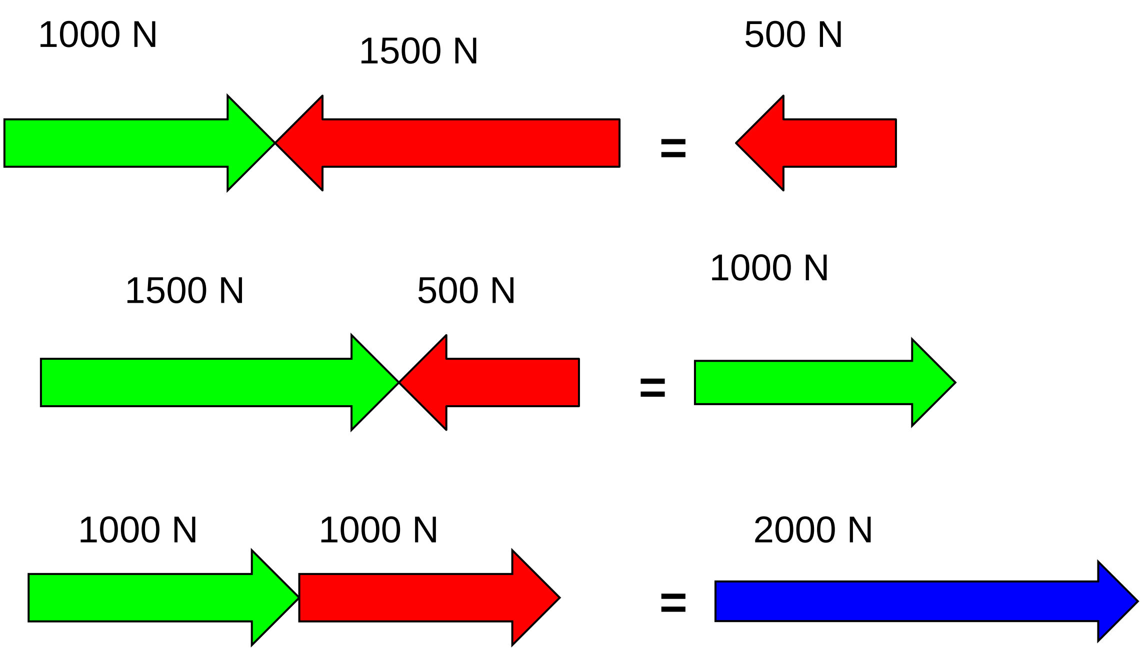

Fig 7 : Net force acting on an object

4. How the wheel type affects the friction on the robot?

Small wheel   Ball castor wheel

Fig 8 : Different types of rear wheels

- Which one causes less friction on the ground? Why?

5. Based on your observation, what is the effect of adding mass on net force on an object.

Fig 8 :Tug-of -war between robots of unequal masses

- Which robot do you think would win tug-of-war? Why?

Vocabulary:
Mass
Weight
Center of mass
Balanced force
Unbalanced force
Net force
Friction
EV3 Power level
Torque
Equilibrium
Newton’s laws
Speed
Velocity
Acceleration
Deceleration
Independent variable
Dependent variable
Acceleration

Unit of force(Newton)
Castor wheel
Inertia

Alignment with NGSS standard:

- The explanation will meet the **DCI (PS2.A)** of the standard PS2.2, since it is addressing the cause of the motion of an object is determined by the forces acting on it and the mass of the object. (q1- q5)
- Also, it is aligned with the **CCs of MS-PS2-2(Stability and Change)**
  - Explains the concept of stability and change. “Stability denotes a condition in which some aspects of a system are unchanging, at least at the scale of observation”. When balanced force alone acting on the robot, it is in a static equilibrium state. (q2)
  - How change occurs in nature? Unbalanced forces acting on a body changes its equilibrium state. “Any system has a range of conditions under which it can operate in a stable fashion, as well as conditions under which it cannot function”.(q2,q4,q5)
- **Addresses SEP of MS-PS2-2**: Changing the design and its investigation?
  “ investigations to test explanatory models of the world and their predictions and whether the inferences suggested by these models are supported by data. (q.4 & q.5)

ELABORATE: Applications and Extensions

A. **Newton’s first law of motion (Law of inertia):**
   a. What is inertia? What does Newton’s first law have to do with inertia?
      Inertia is the tendency of a body at rest to remain at rest or of a body in motion to stay in motion in a straight line unless acted on by an external force.
   b. Why do passengers fallback if a train or bus suddenly starts?
   c. Why do we fall forward when brakes are suddenly applied on a moving vehicle?

To do:

1. Ask the student to put a block over the robot and run the robot suddenly. Observe what happens to the block over the brick. Explain..
2. Run a robot with a block over it and stop the robot suddenly after 5 seconds. Observe what happens to the block over the brick. Explain.

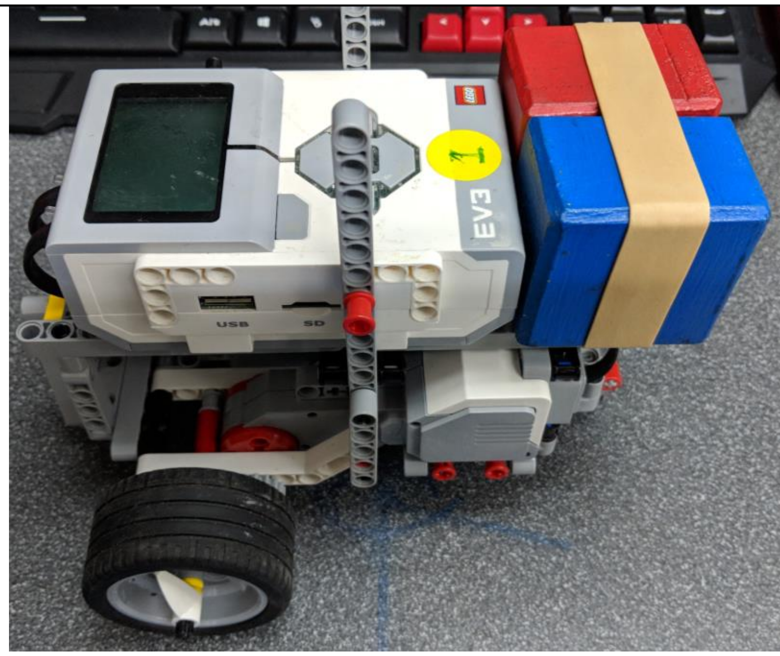

Fig 9 : Robot carrying a weight

B. Newton's second law of motion

Force = mass X acceleration

Acceleration of an object dependents on two variables,

- Acceleration of the object is directly proportional to the net force which is acting on the object.
- Acceleration of the object is inversely proportional to the mass of the object.

To do:

1. Move your robot without any load and observe its speed and distance travelled after 10 seconds.
2. Put a ball/block just in front of the robot and observe the same.
3. Increase the weight of the block/ball and observe the change in robot's speed (acceleration) and distance travelled after 10 seconds.

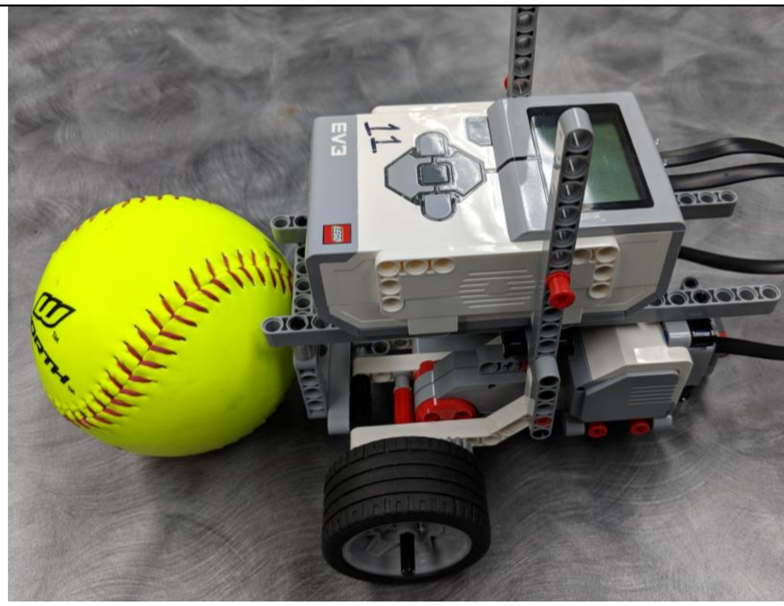

Fig 10: Robot pushing a ball.

Alignment with NGSS standard:
SEP of MS-PS2-2: Identifies the dependent and independent variables .(Force and mass are independent variables, acceleration is a dependent variable.)
DCI of MS-PS2-2: Explained the concepts of Newton's first and 2nd laws of motions.

EVALUATE:
Tug-of-war competition:
Now it's time for the students to demonstrate their understanding of the lesson.
Using the concepts learned from this unit,

- ❏ What would be the best design for your robot to win the the tug-of war?
- ❏ How do you generate more net force for your robot to win the tug-of-war? Explain.

Summative Assessment (Quiz / Project / Report):

1. What are the different forces acting on the robots in a tug-of -war game? Draw the forces acting on it..
2. How much force is required for your robot to move a block of a 10 kg mass at an acceleration of 2 m/s^2? (Answer: F = 10 kg * 2 m/s^2= 20 N)
3. Given a force of 50 N and an acceleration of 10 m/s^2, what is the object's mass?

   (Answer: m = 50 N/ 10 m/s^2 = 5 kg)

Elaborate Further / Reflect: Enrichment:
Ask students to find some real life examples of Newton's laws of motion. Explain how it is applied.

Examples:

- Old fashioned weighing scale.
- Seesaw.
- Why does a cricketer lower his hand while catching cricket ball?

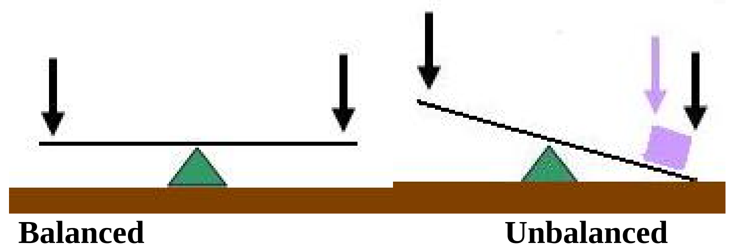

Fig 11: Seesaw

Materials Required for This Lesson/Activity			
Quantity	**Description**	**Potential Supplier (item #)**	**Estimated Price**
2 No.	Lego EV3 robot (base model)		
	Wooden blocks		
	Ball with different weights		
	Measurement tape		
	Computer with EV3 software		