To Pull or Not To Pull...

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Focus on Inquiry

Throughout this activity student will formulate and test multiple hypothesis concerning contact forces during tug of war. Students will use evidence and observations from their tests to propose explanations and communicate results.

Lesson Content Overview

Students will participate in a tug of war game while exploring contact forces. After experiencing an unfair, unbalanced game, students will be given the chance to create and test a fair team. The experimentation will culminate in a class tug of war championship and discussion of contact forces. Students will extend their discussion with a magnet video connecting contact forces and forces acting at a distance.

Duration	Setting	Grouping	PTI Inquiry Subskills
140 minutes	Classroom	Whole Class/Groups	

Lesson Components	Estimated Time	Inquiry Subskills Used	Technology Used	Level of Student Engagement	Brief Description
Engage	45 min	1.1,1.3	none	3	Unbalanced tug of war (teacher chosen teams)
Explore	45 min	1.3,2.1	Internet, computers or handheld devices	3	Students will create hypotheses of their ideal tug-of-war groups and test their groups in a variety of ways. Class will have a competition of the best choice from each group.
Explain	20 min.	5.2,5.3, 7.2	none	2	Students will discuss and explain the results of the tug-of-war tournament.
Expand/ Elaborate	20 min	5.2, 5.7	none	3	Students sort several pictures exhibiting contact forces and forces acting at a distance and describe those forces.
Evaluate	10 min	7.3	Internet, projector, laptop	1	Students will take a short multiple choice assessment demonstrating their learning on forces

Level of Student Engagement

1	Low	Listen to lecture, observe the teacher, individual reading, teacher demonstration, teacher-centered instruction
2	Moderate	Raise questions, lecture with discussion, record data, make predictions, technology interaction with assistance
3	High	Hands-on activity or inquiry; critique others, draw conclusions, make connections, problem-solve, student-centered

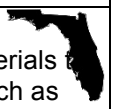
Next Generation Science Standards – Inquiry

NGSS Practice 1: Asking Questions and Defining Problems
NGSS Practice 2:Developing and Using Models
NGSS Practice 3: Planning and Carrying Out Investigations
NGSS Practice 4: Analyzing and Interpreting Data
NGSS Practice 6: Constructing explanations
NGSS Practice 7: Engaging in arguments from evidence
NGSS Practice 8: Obtaining, Evaluating and Communicating Information

Next Generation Science Standards – Content

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.

Florida Science Standards – Nature of Science



SC.8.N.1.1 Define a problem from the eighth grade curriculum using appropriate reference materials to support scientific understanding; plan and carry out scientific investigations of various types, such as systematic observations or experiments; identify variables; collect and organize data; interpret data in charts, tables, and graphics; analyze information; make predictions; and defend conclusions.
SC.8.N.1.3 Use phrases such as "results support" or "fail to support" in science, understanding that science does not offer conclusive "proof" of a knowledge claim.
SC.8.N.1.4 Explain how hypotheses are valuable if they lead to further investigations, even if they turn out not to be supported by the data.
SC.8.N.1.2 Design and conduct a study using repeated trials and replication.

Florida Science Standards – Content

SC.6.P.13.1 Investigate and describe types of forces, including contact forces and forces acting at a distance, such as electrical, magnetic, and gravitational.

Materials and Advance Preparation

Materials List

Class set:

- "Tug-of-war" rope. Rope/jump rope.
- Enlarged Classroom Competition Bracket (Optional)

Student materials:

- Blackline Master #1 - Student Bell work Sheet (1 per student)
- Blackline Master #2 – Hypothesis and Planning Sheet (1 per table of students)
- Blackline Master #3 – Contact vs. Forces Acting at a Distance (1 per student)
- Student devices or class computers

Blackline Masters

1. Blackline Master #1 -- Student Bell-work worksheet
2. Blackline Master #2 – Team Planning Worksheet
3. Blackline Master #3 – Contact Forces vs. Forces Acting at a Distance Worksheet
4. Blackline Master #4 -- Lesson Assessment
5. Blackline Master #5 – Forces Graphic Organizer
6. Blackline Master #6 – Net Force Activity (Optional)

Advance Preparation

1. Secure a large outside area for students to play tug of war.
2. Secure a "tug-of-war" rope or rope that will be large enough for students to pull.
3. Print "Student Bell-work" Worksheet and cut into strips (3 per page, one per student needed)
4. Print "Team Planning" worksheet (one per small group of students)
5. Print "Contact Forces vs. Forces Acting at a Distance" worksheet (one per student)
6. Print "Lesson Assessment" worksheet (one per student)
7. Access http://freebracketgenerator.com/, create and print an appropriate competition bracket for the number of teams to be used. May be drawn on larger paper or enlarged so that it can be posted during the final competition.

Lesson Information

Learning Objectives

1. The student will be able to describe the relationship among distance, mass and gravitational force between any two objects.

2. The student will be able to identify and/or describe examples of contact forces and forces acting at a distance..

Prior Knowledge Needed by the Students

- SC.5.P.10.3: Investigate and explain that an electrically-charged object can attract an uncharged object and can either attract or repel another charged object without any contact between the objects.
- SC.5.P.13.1: Identify familiar forces that cause objects to move, such as pushes or pulls, including gravity acting on falling objects.

Background Information

A force is a push or a pull upon an object resulting from the object's *interaction* with another object. There are two categories of forces: contact forces and forces acting at a distance. Contact forces occur when two objects are in physical contact whereas forces acting at a distance occur between object typically not in contact.

Contact forces include:

- Friction (friction force is the force exerted by a surface as an object moves across it or makes an effort to move across opposite direction of its motion.)
- Tension (The tension force is the force that is transmitted through a string, rope, cable or wire when it is pulled tight by forces acting from opposite ends)
- Normal (The normal force is the support force exerted upon an object that is in contact with another stable object.)
- Resistance (resistance is a special type of frictional force opposing the motion of objects as they travel through a fluid.)
- Applied (An applied force is a force that is applied to an object by a person or another object.)
- Spring (The spring force is the force exerted by a compressed or stretched spring upon any object that is attached to it.)

Forces acting at a distance include:

- Gravitational (The force of gravity is the force with which an object attracts another object towards itself.) Note: weight is the result of the force of gravity
- Magnetic (Magnetic force is the attraction or repulsion that arises between electrically charged particles because of their motion.)
- Electrical (Electrical force is the attractive or repulsive interaction between any two charged objects.)

Many forces can act upon one object at a time and thus determine the Net Force upon an object. If the Net Force is zero then there is no change to the motion of an object. If the Net force is not zero then the forces are considered to be unbalanced and the object may change direction or speed.

Lesson Procedure

Engage

1. Students will complete the bell work "How many ways can you move a rope?"
2. After bell work, students will go outside for a "tug-of-war". At this point the teacher will choose teams, purposefully making the teams uneven. (For example: All girls vs. All boys, Shorter students vs. Taller students, one student vs. The rest of the class...)
3. Allow students to try several times, with the expectation that the weaker team will lose each time.
4. Ask students if the teacher created a fair tug of war game. Most classes will answer with a resounding "NO". Do not go into a discussion as to why the game was unfair at this point. Challenge students to show you their understanding of tug of war by creating a fair, winning team in the next activity.

Explore

1. Teacher will place students into teams of 5 or more students. (ex. split class in half and then divided into subgroups by table or create lab groups .)
2. Give each table a team planning sheet to complete. (**Blackline Master 2**)
3. Have students follow these Team Building Instructions:
    a. Create 3 test teams, each containing 4 members from their larger team.
    b. Each student in the larger group must be included on at least one team.
4. Students will describe their rationale for choosing the team members and for the order that the students will stand in along the rope. This will serve as their hypothesis.
5. After planning their three teams, each group will test the effectiveness of each team. Testing can be done by any combination of:
    a. using the pHet Interactive Simulation: Forces and Motion: Basics (https://phet.colorado.edu/en/simulation/legacy/forces-and-motion-basics)
    b. having remaining members of the team pull against each of their test teams.
    c. Other testing opportunities available in the classroom at teacher discretion
6. Once students have tested, they will complete the remaining reflection questions on their planning sheet and select the one team they believe will best represent their group. .
7. Teacher will take students back outside for a bracket style tug of war championship. Teacher may choose to use the bracket forms [Blackline master 4]

Explain

Lead a class discussion about the outcomes of the team planning and class competition. Some questions you might ask students include:

- Did your hypothesis work as you planned? Why or why not? (Sample answer: Yes, we thought the team with bigger people would be stronger than the team with smaller people. No, our group did not work, maybe they were matched differently.)
- What caused the movement in the rope? (Sample answer: people pulling on the rope)
- What factor(s) did you use when creating your team? (Sample answer: we chose people who were the tallest, we chose people who weighed the most, we chose people who were the strongest.)
- What would happen if our winning team had switched the order of their teammates along the rope? (Student responses will vary based on which team won but teacher could reenact the final team match up via the pHet simulation)
- Based on the students in this class, who do we think would have made the ultimate tug of war team? (Student responses will vary based on classroom composition)
- Now that we have used the terms push and pull, what other vocabulary terms can we use instead?(Sample answer: What about gravity, or magnetic fields)
- Now that we are looking at the term of gravity, how would this effect our tug of war teams? (Sample answer: students may mention that if gravity were greater it would be harder to pull but that if gravity were less then the game may have been easier)
- We looked at the term weight, how can we describe the difference between weight and mass? (Sample answer: One is how much you weigh and mass is what you are made up of.)
- How would the over mass of the teams effect how they did? (Sample answer: The group with more people were able to pull harder on the rope than the other team.)
- When we talk about pulling harder on the ropes how can we explain this in our vocabulary terms? (Sample answer: The group with the more mass was able to pull with more force allowing them to win.)

Expand

1. Teacher will pose a second situation as follows: "We have seen how forces work when we are holding onto a rope but can forces also work when object are not touching?" Students may have various responses based on their previous knowledge.
2. Have students watch the following video on the maglev train.
   Video: How Maglev Trains Work (This video explains the non-contact forces along with magnetic forces.) https://www.youtube.com/watch?v=iaEIPV0FWJ0
   ***Preview; this video has commercial at the beginning, the video length is 1:54 min.

3. After the video you can prompt the students to identify what would be a distance force. They should be using prior knowledge and what they have learned
4. Have students complete the "Contact Forces vs. Forces at a Distance" Worksheet [Blackline Master 3] Teacher may choose to guide students through one or two questions to model the expectation of describing the forces that are shown in the picture.

Evaluate

FORMAL EVALUTION

5 question, multiple choice assessment is provided [Blackline Master 4]

INFORMAL or OPTIONAL EVALUTIONS

Teacher may informally evaluate using the provided worksheets and at any other point during the lesson as necessary.

WRAP UP.

Teacher may use the assessment to wrap up the lesson.

Supplementary Resources

Teachers

Song on Forces: https://www.youtube.com/watch?v=lNX7A7PK9pc

Forces Graphic Organizer [Blackline Master 5]

Net Force Activity [Blackline Master 6]

CITATION OF SOURCES.

The Physics Classroom http://www.physicsclassroom.com/Class/newtlaws/U2L2b.cfm#grav

Encyclopedia Britannica https://www.britannica.com/science/magnetic-force

Picture 1: https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0ahUKEwjVz4CN5oLPAhVL5iYKHV8TBr4QjRwIBw&url=https%3A%2F%2Fen.wikipedia.org%2Fwiki%2FCurling&bvm=bv.132479545,bs.2,d.eWE&psig=AFQjCNHUsPZ7VbJELEB4jGmNI5zFWq0ZWw&ust=1473528089252064

Picture 2: https://upload.wikimedia.org/wikipedia/commons/thumb/e/e2/VFPt_cylindrical_magnets_attracting.svg/320px-VFPt_cylindrical_magnets_attracting.svg.png

Picture 3: https://pixabay.com/static/uploads/photo/2013/02/15/02/22/skydivers-81778_960_720.jpg

Picture 4: http://quietstateofmind.net/wp-content/uploads/2013/05/sisyphus-drawing.jpg

Picture 5: https://upload.wikimedia.org/wikipedia/commons/f/f3/Magnetosphere_rendition.jpg

Picture 6: http://i.kinja-img.com/gawker-media/image/upload/s--BU2Vu666--/18mjrc4fg2pmtjpg.jpg

Picture 7: https://upload.wikimedia.org/wikipedia/commons/4/4b/STS115_Atlantis_undock_ISS.jpg

Picture 8: https://upload.wikimedia.org/wikipedia/commons/0/0e/Fotbaov%C3%BD_hr%C3%A1%C4%8D.jpg

__✓__ Yes, I cited all materials and resources used in the lesson.

Your name

Lesson author signature

Forces Bellwork

Name: ______________________________

Date: __________________ **Period:** _______

How many ways can you make a rope move?

_______________________________________ _______________________________________

_______________________________________ _______________________________________

_______________________________________ _______________________________________

_______________________________________ _______________________________________

Forces Bellwork

Name: ______________________________

Date: __________________ **Period:** _______

How many ways can you make a rope move?

_______________________________________ _______________________________________

_______________________________________ _______________________________________

_______________________________________ _______________________________________

_______________________________________ _______________________________________

Forces Bellwork

Name: ______________________________

Date: __________________ **Period:** _______

How many ways can you make a rope move?

_______________________________________ _______________________________________

_______________________________________ _______________________________________

_______________________________________ _______________________________________

_______________________________________ _______________________________________

Blackline Master 2

Forces: Team Planning Sheet

All Group Member Names: _____

_____

_____

Answer the following questions as you prepare for the class tug of war tournament.

1. What made the tug of war game unfair?

2. How would you have changed the game so that it was fair?

3. What makes a "good" tug of war team?

Given your assigned teammates, create three potential tug of war team combinations for our class competition. Answer all associated questions for each team. Teams may be made of no more than 4 students and you must include each member of your team in at least one of the combinations. After creating your possible team combinations, test your hypotheses from your

Team Combination 1:

A. Which order will these students line up in? Why?

B. Why do you think this team would be able to win?

C. Which processes did you use to test this combination?

Team 1:

_____

_____

_____

_____

Team Combination 2:

A. Which order will these students line up in? Why?

B. Why do you think this team would be able to win?

C. Which processes did you use to test this combination?

Team 2:

_____

_____

_____

_____

Team Combination 3:

A. Which order will these students line up in? Why?

B. Why do you think this team would be able to win?

C. Which processes did you use to test this combination?

Team 3:

_____

_____

_____

_____

Of your three Team Combinations, which do you this is most likely to win the class competition? Explain how your tests of this hypothesis showed that this team is the best of your 3.

Team _____ will be the best team because _____

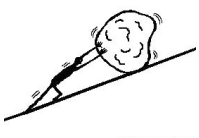
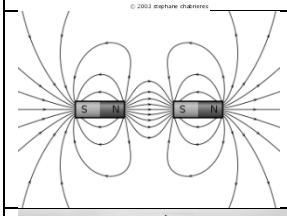
_____

_____

Blackline Master 3

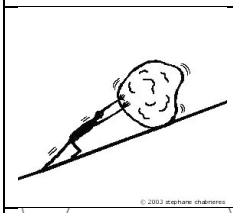
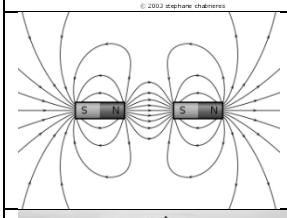
Contact vs. Non-contact forces

Based upon the pictures below identify if they are a contact or non-contact force, and explain your reasoning.

Picture	Force	Reasoning
		
		
		
		
		
		
		

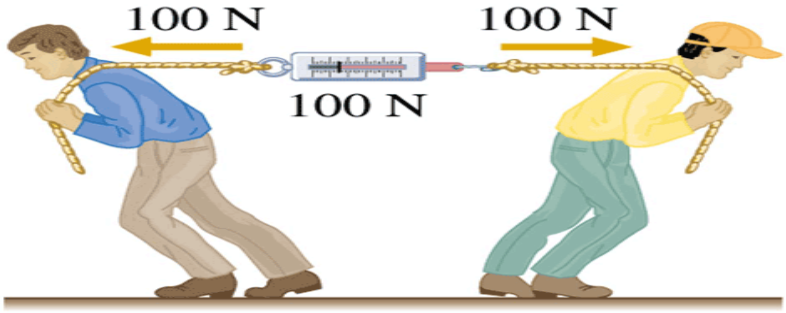
Contact vs. Non-contact forces ANSWER KEY (student answers can vary slightly)

Based upon the pictures below identify if they are a contact or non-contact force, and explain your reasoning.

Picture	Force	Reasoning
	Contact	The person is in direct contact with the rock and applying force to it.
	Non-contact	The Magnets are showing their magnetic fields and how they interact without direct contact of the objects.
	Non-contact	The sky divers are in free fall, gravity is a non-contact force that accelerates them to the ground.
	Contact	The curler is in contact with the stone applying force allowing it to move across the ice.
	Contact	The soccer player hits the ball, creating a contact force that moves the ball.
	Contact & Non-contact	Contact- the chess pieces are held in place through direct contact (magnets) Non-contact- the astronaut is in a zero gravity
	Non-contact	The space shuttle is kept in orbit through gravitational forces.

Blackline Master 4

1. Four pairs of objects have the masses as described below, along with the distances between them…Which pair of objects would have the greatest gravitational force between them? (SC.912.P12.4)
   a. Mass of 1Kg and 1Kg, 2 meters apart
   b. Mass of 1Kg and 2Kg, 1 meters apart
   c. Mass of 1 Kg and 1 Kg, ½ meters apart
   d. Mass of 2 Kg and 1Kg, ½ meter apart



2. According to the picture above what is the net force?
   a. 100 Newtons to the left
   b. 100 Newtons to the right
   c. 100 Newtons pushing upward
   d. 0 Newtons

3. How does the gravitational force change as two objects move farther apart? (SC.912.P.12.4)
   A.) It increases
   B.) It decreases
   C.) It remains constant
   D.) It is zero

4. Which of the following would cause the gravitational force between object A and object B to increase? (SC.912.P.12.4)
   A.) Increase the mass of object A
   B.) Increase the distance between them
   C.) Decrease the mass of object A
   D.) Decrease the mass of both objects

5. What is the gravitational force exerted on an object called? (SC.912.P.12.4)
   A.) Centripetal force
   B.) Friction
   C.) Momentum
   D.) Weight

1. Which of the following is an example of a contact force?

A. ball falling from the roof of a building to the ground
B. A maglev train running along the track
C. An Olympic swimmer doing the backstroke.
D. Hair being attracted to a sweater just out of the dryer

Two factors affecting the magnitude of the force of gravity between two objects are:

a. Mass and distance
b. Mass and matter
c. Distance and weight
d. Weight and mass

1. The teacher instructs her students to return the books closest to them back to the shelf. Neither Jennifer nor Brianna wants to take the book back to the shelf. Being in the exact middle, they begin to push the book back and forth to force it on the other's side.

Who will lose the book battle and what will be the resultant net force moving the book toward their direction?

a. Brianna and 2 N
b. Brianna and 38 N
c. Jennifer and 2 N
d. Jennifer and 38 N

Gretchen, Juan, and Kenisha are discussing the Normal force. Gretchen states that the normal force is the force exerted by a surface as an object moves across it opposite direction of its motion. Juan states that the normal force is a force of the center of the Earth pulling objects towards itself. Kenisha states that the normal force is the support force exerted upon an object that is in contact with another stable object. Which student is correct? SC 6 P 13.1 (L2)

A. Gretchen
B. Juan
C. Kenisha
D. None of them are correct

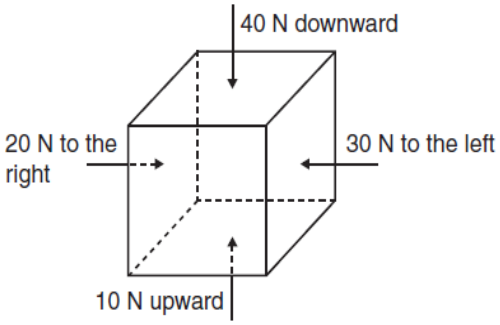
What is the statement is true of contact force and forces acting at a distance?

a. Contact forces involve objects that touch while forces acting at a distance do not require objects to be touching
b. Forces acting at a distance involve objects that touch while contact forces do not require touch.
c. Contact forces involve objects that are moving while forces acting at a distance involve objects that are stationary.
d. Forces acting at a distance are balanced while contact forces are unbalanced.

1. On Earth, a brick has a mass of 8 kg and a weight of 4 lbs. What predictions could we make about the mass and weight of the brick on the Moon, where there is less gravity?

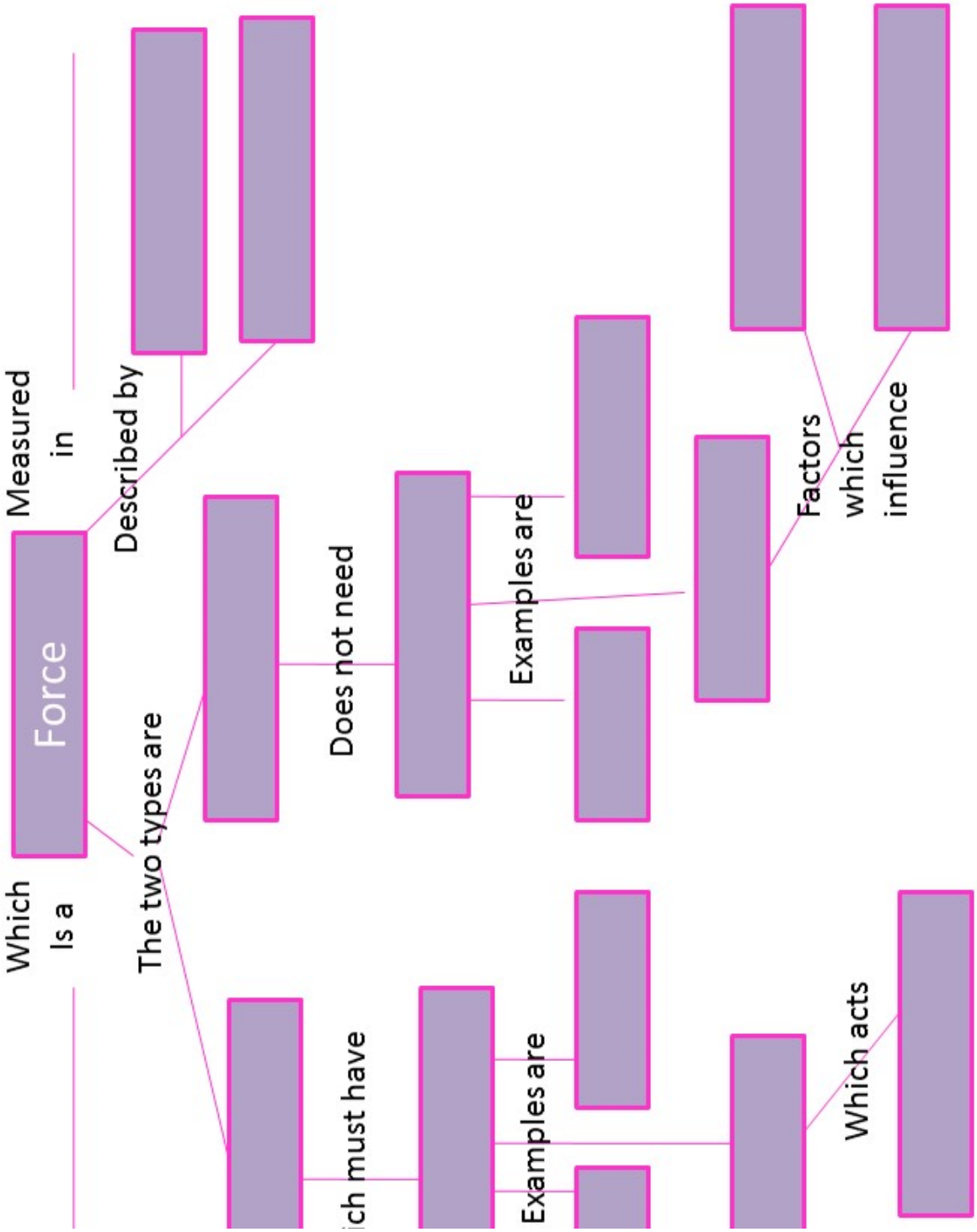
   a. The mass of the brick would be less than 8 kg on the Moon.
   b. The weight of the brick could be less than 4lbs on the Moon.
   c. The mass of the brick would be greater than 8 kg on the Moon.
   d. The weight of the brick could be greater than 4lbs on the Moon.

8. SC 6 P.13.1 (L2) **Four forces are acting on a box, as shown here:**



This box will increase in speed
a. downward and to the right
b. downward and to the left
c. upward and to the right
d. upward and to the left

Blackline Master 5



Blackline Master 6

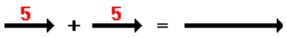
Net Force: What is it and how to calculate it

The definition of **Net Force** is the sum of all forces that act upon an object. When we talk about all the forces we also have to say what a vector is. A **vector** is a quantity that has *direction and magnitude*. For example a block is pushed 2m to the right.
Let's do one together!

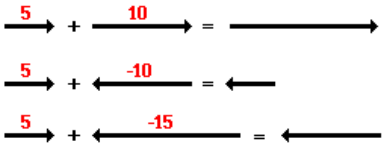
A Newton is a SI unit of force. If we have 5N pushing to the left and 5N pushing to the right, this is how we will write the equation:

5N + -5N = 0

Force is a vector and two forces of equal magnitude and opposite direction will cancel each other out.



On the arrows write in your answer



In the following examples draw a diagram to help you solve the problems.

1) Ned is pulling his wagon with 5N to the right, the wind is pushing against him to the left with the force of 2N. What is the overall net force?
2) Maggie is walking her dog, the dog is pulling her to the left with the force of 10N, she got she pants caught on a fence and is pulling her 3N to the right. What is the overall net force?
3) Mike and Ike are moving their couch. Mike is pushing to the right with the force of 4N, Ike is pulling with the force of 6N. What is the overall net force?
4) Twins Gabby and Abby are fighting over their desk, Abby is pushing with a force of 5N and Gabby is also pushing on the desk with 5N. What would the overall force be?

Based on what you have learned create your own word problem that shows the net force between two objects.

_____

_____

_____

Net Force: What is it and how to calculate it Answer Key

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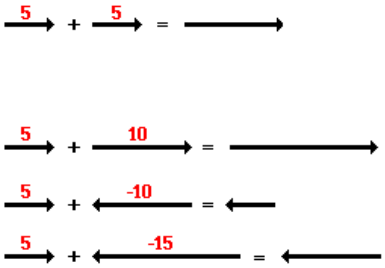

On the arrows write in your answer
5+5= 10N
5+10= 15N
5+ -10= -5N
5+ -15= -10N

In the following examples draw a diagram to help you solve the problems.

1) Ned is pulling his wagon with 5N to the right, the wind is pushing against him to the left with the force of 2N. What is the overall net force? 5→ + -2 ← =3N
2) Maggie is walking her dog, the dog is pulling her to the left with the force of 10N, she got she pants caught on a fence and is pulling her 3N to the right. What is the overall net force? ← -10 + 3N → =-7N
3) Mike and Ike are moving their couch. Mike is pushing to the right with the force of 4N, Ike is pulling with the force of 6N. What is the overall net force? 4N → + 6N → = 10N
4) Twins Gabby and Abby are fighting over their desk, Abby is pushing with a force of 5N and Gabby is also pushing on the desk with 5N. What would the overall force be? 5N → + -5N ← = 0N

Based on what you have learned create your own word problem that shows the net force between two objects.
Student answers will vary: double check to make sure that they are using the correct directional vectors, and that their net forces are valid.