SPH4U Unit 1 Dynamics

Chapter 2 Dynamics Lesson Package

Schoolwork	Useful Links/ Videos/ Handouts	Homework
Chapter 2 Videos		
	Animations 1. Newton's Laws **Websites:** 1. Newton's Laws 2. Standard Newton's Laws Problems **Videos** 1. Forces, Newton, FBDs 2. Pulley Systems	
2.1 Forces and Free-Body Diagram		
1. Lesson 2.1 Presentation 2. Lesson 2.1 Lesson Package	**Videos:** 1. 2.1 Forces and free-body diagrams (Lesson) 2. Is Normal Force always equal to the Force of Gravity? 3. Normal Force Physics Problems	1. 2.1 Check Your Understanding 2. 2.1 Check Your Knowledge 3. Textbook pg 68 # 1, 3 4. Textbook pg. 69 #1-9
2.2 Newton's Laws of Motion		
1. Lesson 2.2 Lesson Package	**Videos:** 1. 2.2 Newton's laws of motion (Lesson)	1. 2.2 Check Your Understanding 2. 2.2 Check Your Knowledge 3. Textbook pg. 76 #1-8 4. TIPERs pg. 107 CT41; pg. 108 QRT42; pg. 112 RT48, RT49; pg. 113 RT50; pg. 117 WWT55
2.3 Applying Newton's Laws of Motion		
1. Lesson 2.3 Lesson Package	**Videos:** 1. 2.3 Applying Newton's laws of motion (Lesson)	1. 2.3 Check Your Understanding 2. Textbook pg 79# 1, 2; 3. Textbook pg 81 and 82 #1, 4-6 4. Textbook pg. 83 #1-6 5. TIPERs pg. 121 CT62; pg. 122 QRT 63; pg. 124 RT67; pg. 126 WWT69

2.4 Forces of Friction		
1. Lesson 2.4 Lesson Package	**Videos:** 1. 2.4 Forces of Friction (Lesson)	1. 2.4 Check Your Understanding 2. Textbook pg 89 # 5, 6 3. Textbook pg. 90 #1-8 4. TIPERs pg. 128 CT73; pg. 133 SCT83; pg. 137 QRT90
Chapter 2 Review		
1. Chapter 2 Self- Quiz pg. 99 (attempt all) 2. Chapter 2 Review pg. 100 #1-74 3. Dynamics Communication Questions (lesson package)		1. Chapter 2 Self- Quiz pg. 99 (attempt all) 2. Chapter 2 Review pg. 100 #1-74 3. Dynamics Communication Questions (Lesson package) 4. **Chapter 2 Quiz** 5. TIPERs

Lesson 2.1 Forces and Free-Body Diagrams

Lesson Goal: Describe common forces that you encounter every day and use a FBD to show all forces acting on the object

Success Criteria: At the end of this lesson, I will be able to:

- ✓ Describe a force as an interaction between two objects or systems and identify both objects or systems for any force.
- ✓ Categorize forces as long-range or contact forces
- ✓ Draw and use free-body diagrams in problems to analyze situations involving multiple forces exerted on an object
- ✓ Distinguish between static friction, kinetic friction, and air resistance
- ✓ Determine net force in 2-D

Grade 11 Forces - Review

Recall: **A free-body diagram (FBD)** is a simple drawing of an object that shows all forces acting on the object. FBDs can help you visualize the forces, determine the components, and calculate the net force.

Videos:

[Is the Normal Force always equal to the Force of Gravity?]

[Normal Force Physics Problems]

Term	**Notation**	**Definition**
_____ dynamics		1. A simple line drawing that shows all the forces acting on an object
_____ newton (N)		2. A force exerted by objects that can be stretched. It is a pulling force from a rope or string on an object and it always points toward the rope or string
_____ system diagram		3. The sum of all forces acting on an object. Also called resultant or total force.
_____ free-body diagram (FBD)		4. Force of attraction between all objects due to mass
_____ applied force		5. A force that opposes the sliding of two surface across one another. Friction always acts opposite to the motion or attempted motion
_____ static friction		6. The study of the causes of motion
_____ tension		7. A perpendicular force exerted by a surface on an object in contact with the surface. The normal force points always away from the surface
_____ normal force		8. A simple sketch of all objects involved in a situation
_____ air resistance		9. A force that results when one object makes contact with another and pushes or pulls on it

____ friction		10. A force that requires one object to be in contact with another
____ contact force		11. The SI unit of force. Symbol is N; $1N= 1kg*m/s^2$
____ force of gravity		12. A force that does not require one object to be in contact with another. These forces are also known as action-at-a-distance
____ net force		13. A force exerted on a moving object by a surface in the direction of motion opposite to the motion
____ non- contact force		14. The friction between objects and the air around them
____ kinetic friction		15. A force of friction that resists attempted motion between two surfaces in contact

Example 1: Applying a Horizontal Force

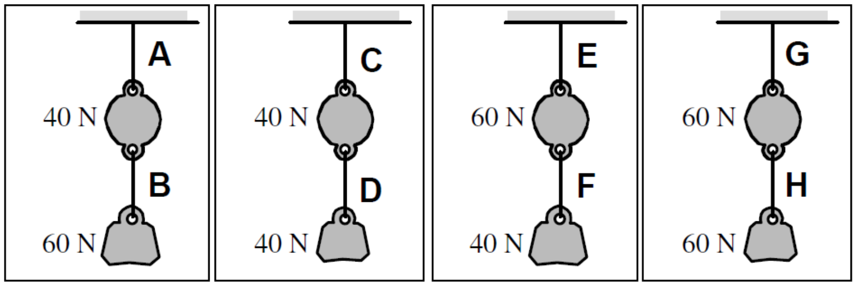
You are pushing with a horizontal force to the right against a large printer on a table. The printer remains stationary. Draw a system diagram and an FBD of the forces acting on the printer.

Example 2: Applying a Non-horizontal Force

A rope pulls a skier up a hill to the right at a constant velocity. Draw a system diagram and an FBD of the forces acting on the skier.

TIPERs pg. 93 B3-17 HANGING WEIGHTS—ROPE TENSION

Two weights are hung by ropes from the ceiling as shown. All of these systems are at rest.



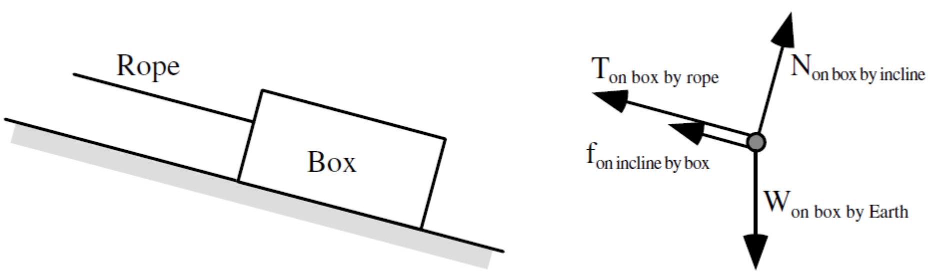
Rank the tensions in the ropes.

								OR		
1 Greatest	2	3	4	5	6	7	8 Least		All the same	Cannot determine

Explain your reasoning.

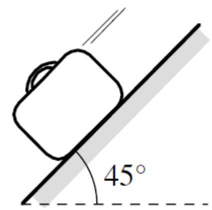
TIPERs pg. 109 B3-WWT43: BOX ON INCLINE—FORCES

A heavy box is sitting at rest on an incline. There is friction between the box and the incline, and a rope is pulling on the box in a direction up and to the left, parallel to the incline. A physics student draws the free-body diagram below.



What, if anything, is wrong with this student's free-body diagram? If something is wrong, explain the error and how to correct it. If this free-body diagram is correct, explain why.

TIPERs pg 110 B3-CRT45: Suitcase Sliding Down Ramp at Constant Speed—Forces on Suitcase



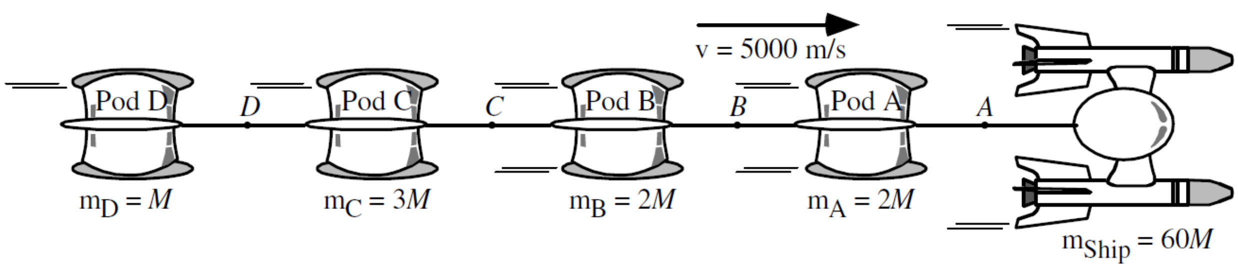
A suitcase is moving at a constant speed as it slides down a ramp angled at 45° to the horizontal. Draw a free-body diagram below, labelling and defining all the forces on the suitcase.

Rank the magnitudes of these forces on the suitcase.

Explain your ranking.

TIPERs (pg. 87 B3-RT05): MOVING SPACESHIP WITH FOUR CARGO PODS—TENSION IN RODS

A spaceship and four cargo pods are connected together by rods, and they are all moving at a constant velocity of 5000 m/s. All masses are given in the diagram in terms of *M,* the mass of an empty pod.



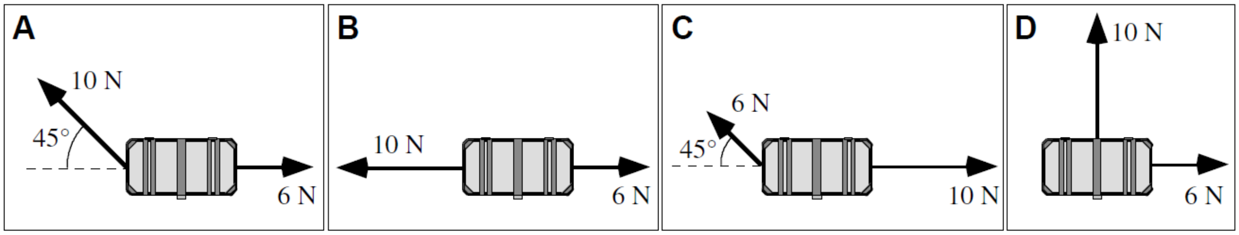
Rank the tension at the labeled points in the rods.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

TIPERs B3-RT10: TWO-DIMENSIONAL FORCES ON A TREASURE CHEST—FINAL SPEED

Identical treasure chests (shown from above) each have two forces acting on them. All chests start at rest.



Rank the speed of the treasure chest after 2 seconds.

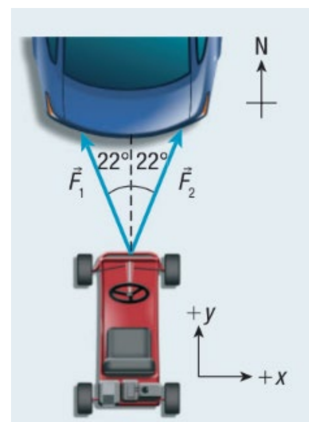
				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Example 3: Net Force above the Horizontal

A baseball player lightly bunts a baseball with an average force of 14 N at 29° above the horizontal (figure below). The force of gravity on the baseball is 1.4 N. Calculate the net force on the ball at the moment of contact, assuming that air resistance is negligible.

Example 4: Total Force of Friction on a Towed Object



A go-cart is being towed north by a car along a road with a net force of zero. The go-cart is attached to the car by two ropes. The tension in the ropes is the same, 31 N. The ropes make 22° angles to the direction of motion, one on the west side and the other on the east. Determine the force of friction on the go-cart.

Note: The figure below shows a top view of the go-cart. The figure does not show the normal force and gravity because they are perpendicular to the page and cancel each other.

Activity: Free-Body Diagrams and Acceleration task (15 min)

Lesson Reflection

State one thing you learn in this lesson:

*

State one thing you found challenging:

*

Check Your Understanding - Lesson 2.1

1. Force is measured in ________________, a unit named after ____________________ in honour of his work in this field.

2. What does one newton represent?

3. What do FBDs represent?

4. What do the arrows on a FBD represent?

5. Is the acceleration due to gravity constant?

6. Are all forces applied in one direction?

7. Why is kinetic friction lower than static friction?

8. Explain how to choose the directions to resolve forces into perpendicular components.

9. What is the best choice of directions to resolve forces into perpendicular components for a crate sliding down a ramp?

10. How would this differ if the crate were being dragged up the ramp with a rope that was at an angle to the ramp?

11. Would you classify air resistance and wind as contact or non-contact forces?

12. Is a normal force simply a reaction force to gravity?

2.2 Newton's Laws of Motion

Lesson Goal: Use the three Newton's Laws to explain the motion of many types of objects experiencing and exerting different types of forces.

Success Criteria: At the end of this lesson, I will be able to:

- ✓ Use Newton's second law to predict the motion of an object subject to forces exerted by other objects in a variety of physical situations.
- ✓ Use a free-body diagram and Newton's second law to construct a mathematical representation relating the acceleration of an object to its mass, and to solve that equation for an unknown quantity.
- ✓ Recognize the distinctions among mass, weight, and inertia.
- ✓ Construct explanations of physical situations involving the interaction of objects using Newton's third law and the representation of action–reaction pairs of forces.

What are Newton's Laws?

- Newton's laws of motion are three separate statements that explain how and why objects move or stay at rest.
- Newton's laws also describe the forces that objects exert on each other.

- You can use these three laws to explain the motion of many types of objects experiencing and exerting different types of forces.

Inertia and Mass

Inertia is a measure of an object's resistance to change in velocity. Inertia is the property of matter that causes an object to resist any changes in motion. This means that an object at rest will stay at rest unless a net force acts on it. In addition, if an object is in motion, it will maintain a constant velocity unless a net force acts on it. The concept of inertia is closely related to Newton's first law.

Some objects have more inertia than others. In fact, objects that have more mass have more inertia. The degree to which an object resists a change in motion depends on the magnitude of the object's mass. **Mass** is a measure of the amount of matter in an object. The SI unit for mass is the kilogram (kg).

Newton's First Law of Motion

If the external net force on an object is zero, the object will remain at rest or continue to move at a constant velocity.

Important implications of Newton's first law are the following:

• A net force is not required for an object to maintain a constant velocity.

• A net force is required to change the velocity of an object in magnitude, direction, or both.

• External forces are required to change the motion of an object. Internal forces have no effect on an object's motion.

Newton's Second Law of Motion

If the net external force on an object is not zero, the object will accelerate in the direction of the net force. The magnitude of the acceleration is directly proportional to the magnitude of the net force and inversely proportional to the object's mass.

Mathematically, Newton's second law is written as: $\Sigma\vec{F} = m\vec{a}$

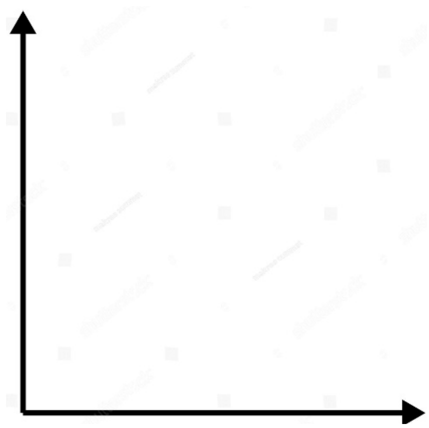
Newton's second law indicates that the acceleration of an object is always in the same direction as the net force acting on the object (since m is always a positive number).

However, since acceleration and velocity might be in different directions, velocity and net force need not be in the same direction.

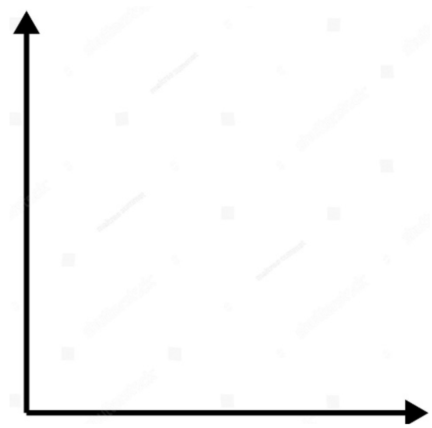
For example, you can be moving forward in a car while applying the brakes. You and the car are still moving forward, but you are accelerating backward.

$\vec{F}_{net}$ vs $\vec{a}$ graph; $\vec{F}_{net}$ vs m graph; $\vec{a}$ vs m graph

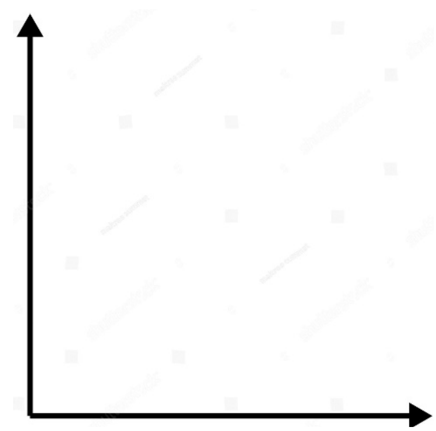
$\vec{F}_{net}$ vs $\vec{a}$ (m=const.)



$\vec{F}_{net}$ vs m ($\vec{a}$=const.)



$\vec{a}$ vs m ($\vec{F}_{net}$=const.)



THE NEWTON

You can write the newton in terms of the SI units for mass (kilograms) and acceleration (metres per second squared):

$$\Sigma\vec{F} = m\vec{a}$$

$$N = kg{\cdot}m/s^2$$

The value of the newton as a unit of force is therefore

$$1\ N = 1\ kg{\cdot}m/s^2$$

The force of 1N would give a mass of one kilogram an acceleration of one meter per second per second.

Newton's Third Law of Motion

For every action force, there exists a simultaneous reaction force that is equal in magnitude but opposite in direction.

- Newton's first two laws of motion deal with a single object and the forces acting on it.

- Newton's third law of motion deals with the forces that two objects exert on each other.

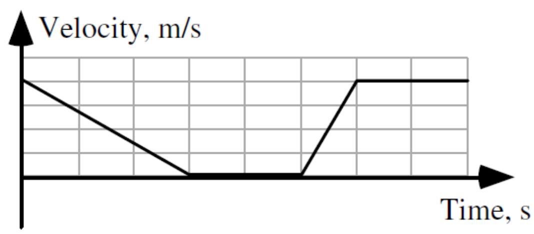
- Newton's third law is also known as the action–reaction principle.

- These two equal and **opposite forces must always act on different objects.**

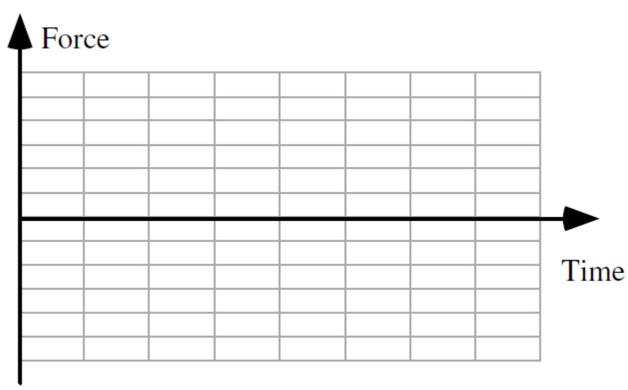
For example, if you push east on a wall, the wall exerts a simultaneous force west on you, causing you to move away from the wall.

TIPERs pg. 104 B3-CRT37: VELOCITY-TIME GRAPH—FORCE-TIME GRAPH

Shown is the velocity versus time graph for an object that is moving in one dimension under the (perhaps intermittent) action of a single horizontal force.



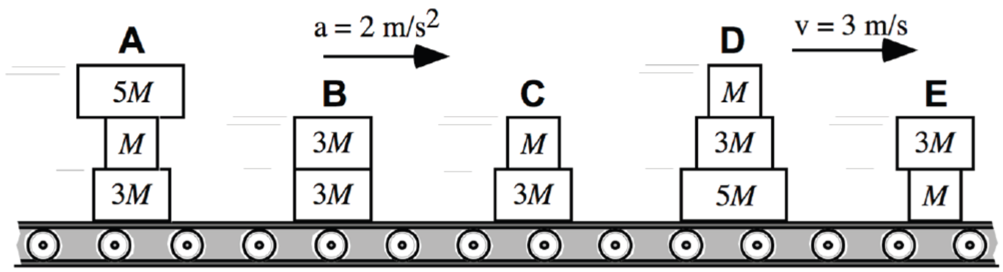
On the axes below, draw the horizontal force acting on this object as a function of time.



Explain your reasoning.

TIPERs pg. 104 B3-RT38: Stacked Blocks Speeding up on a Conveyor Belt—Net Force

Various stacks of blocks are travelling along a conveyor belt. At the instant shown, all blocks have the same velocity of 3 m/s to the right and the same acceleration of 2 m/s2, also to the right. The blocks do not slip. All masses are given in the diagram in terms of *M,* the mass of the smallest block.



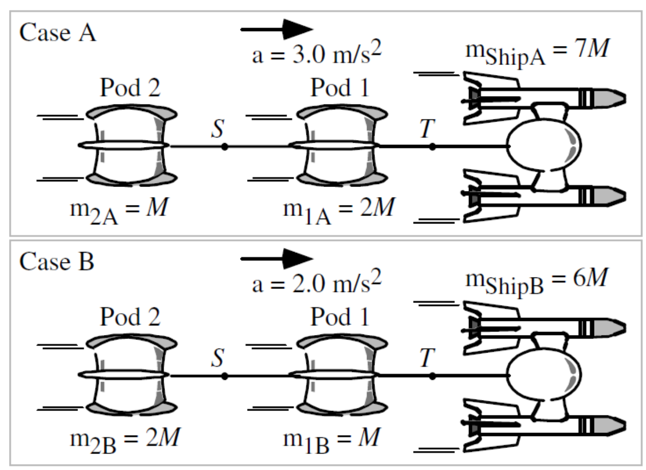
Rank the magnitude of the net force on each stack of blocks.

					OR			
1 Greatest	2	3	4	5 Least		All the same	All zero	Cannot determine

Explain your reasoning.

TIPERs pg. 105 B3-CT39: SPACESHIPS PULLING TWO CARGO PODS—TENSION IN TOW RODS

In both cases, a spaceship is pulling two cargo pods, one empty and one full. At the instant shown, the speed of the pods and spaceships is 300 m/s, but they have different accelerations as shown. All masses are given in terms of *M,* the mass of an empty pod.



(a) Will the tension at point *S* in the tow rod be (i) *greater* in Case A, (ii) *greater* in Case B, or (iii) *the same* in both cases? _____

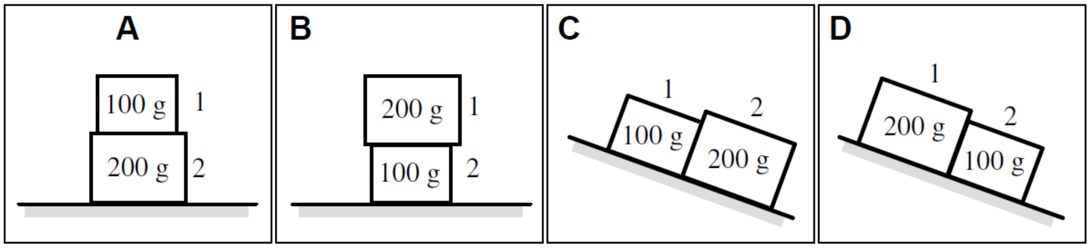
Explain your reasoning.

(b) Will the tension at point *T* in the tow rod be (i) *greater* in Case A, (ii) *greater* in Case B, or (iii) *the same* in both cases? _____

Explain your reasoning.

TIPERs pg 111 **B3-RT46: Two Blocks at Rest—Force Difference**

In each case shown, there are two blocks with different masses that are at rest and in contact with each other. One of the blocks given in each arrangement is labelled 1, and the other is labelled **2**. The mass of each block is given in the figures.



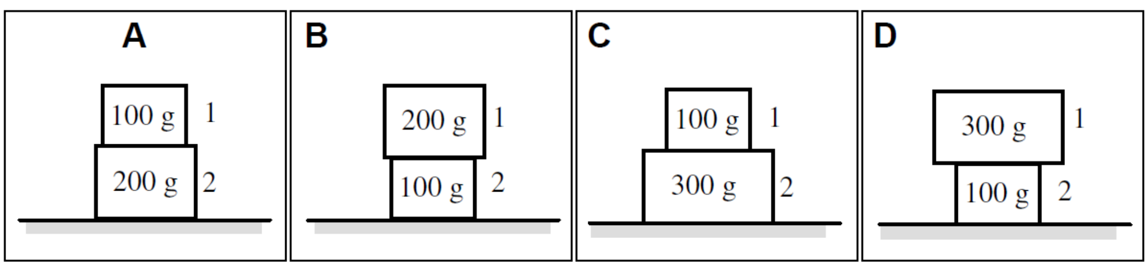
Rank the difference between the strengths (magnitudes) of the force 1 exerts on 2 and the force 2 exerts on 1.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

TIPERs pg 111 **B3-RT47: TWO STACKED BLOCKS AT REST—FORCE ON THE TOP BLOCK BY BOTTOM BLOCK**

Two wooden blocks with different masses are at rest, stacked on a table. The top block is labelled 1, and the bottom block is labelled **2**.



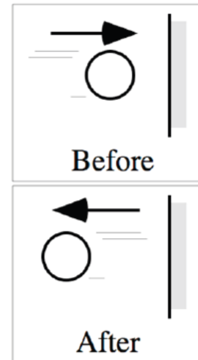
Rank the magnitude of the force that the bottom block (2) exerts on the top block (1).

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

TIPERs pg. 117 B3-WWT56: Ball Hitting a Wall—Forces

A student observes a rubber ball hitting a wall and rebounding. She states:



"In this situation, the wall exerts a larger force on the ball than the ball exerts on the wall, because the ball undergoes an acceleration, but the wall doesn't move. That is, the ball goes from an initial speed to zero and then from zero to the rebound speed, but the wall does not accelerate since it is stationary the whole time."

What, if anything, is wrong with this contention? If something is wrong, identify it, and explain how to correct it. If this contention is correct, explain why.

Example 1: Calculating Acceleration and Direction

Two tugboats are pulling a $4.2*10^3$ kg barge into a harbour. The first tugboat exerts a constant force of $1.8*10^3$ N [E 37° N]. The second tugboat exerts a constant force of $1.3*10^3$ N [E 12° S]. Draw a system diagram and then calculate the acceleration of the barge. Assume there is no friction acting on the barge.

Example 2: Calculating Acceleration Due to Newton's Third Law

The person on roller blades in the figure below is pushing on a refrigerator that sits on a cart on a level floor. Assume no force of friction exists on either the person or the refrigerator. The person has a mass of 60.0 kg, and the refrigerator has a mass of $1.2*10^2$ kg. The force exerted by the person on the refrigerator is $1.8*10^2$ N [forward]. Calculate the refrigerator's acceleration and the person's acceleration.

Conceptual Questions: Does the action-reaction pair cancel each other out? Explain.

Weight and the Normal Force

Conceptual Understanding: Is $\vec{F}$n always equal and opposite to $\vec{F}$g?

Lesson Reflection

State one thing you learn in this lesson:

*

State one thing you found challenging:

*

Check Your Knowledge – Lesson 2.2 Definitions

Term	Notation	Definition
____ inertia		1. If the external net force on an object is zero, the object will remain at rest or continue to move at a constant velocity
____ mass		2. The gravitational force exerted by Earth on an object
____ Newton's First Law of Motion		3. If the net external force on an object is not zero, the object will accelerate in the direction of the net force. The magnitude of the acceleration is directly proportional to the magnitude of the net force and inversely proportional to the object's mass.
____ Newton's Second Law of Motion		4. For every action force, there exists a simultaneous reaction force that is equal in magnitude but opposite in direction.
____ Newton's Third Law of Motion		5. A measure of an object's resistance to change in velocity
____ weight		6. A measure of the amount of matter in an object

Check Your Understanding – Lesson 2.2

1. Why do you move forward when the driver of a car you are riding in presses the brakes?

2. Students may wonder why objects move at all if, according to Newton's third law, for every action force, there is a simultaneous reaction force that is equal in magnitude and opposite in direction. Does this not mean that the action force and reaction force add to give zero, and so objects just would not move?

3. If you push against a solid wall, what are the action and reaction forces and what do each of these forces do?

4. What would happen to the reading on the scale if the person were standing on the scale in an elevator that has just started to accelerate upward? What laws are you using in your explanation?

5. Is the normal force the reaction force to gravity? Support your answer with an example and diagram.

2.3 Applying Newton's Laws of Motion

Lesson Goal: Apply Newton's laws to objects subjected to various forces in 2-D

Success Criteria: At the end of this lesson, I will be able to:

- ✓ Determine when an object is in equilibrium i.e. when the net force on it is zero
- ✓ For objects experiencing forces in 2D, break the motion into perpendicular components, which can be analysed independently
- ✓ Determine the net force using the components
- ✓ Use Newton's second law to determine the acceleration

When the net force on an object is zero, that object is said to be in **equilibrium**. An object with no net force acting on it will not accelerate. So, an object in equilibrium will remain at rest or remain moving at a constant velocity until a force acts on it.

Mathematically, an object is in equilibrium when $\Sigma\vec{F}$ = 0, or, when you break the forces down into their components, both $\Sigma F_x = 0$ and $\Sigma F_y = 0$.

When solving problems involving objects in equilibrium, you can set the positive x-axis in any direction, but you should draw the FBD first and then pick the most convenient direction. **"Convenient" direction means the direction that will give you the fewest components.**

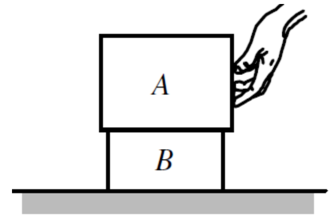
Accelerating Objects

If an object is not in equilibrium, then it is accelerating in some direction. You can use Newton's second law, $\Sigma\vec{F} = m\vec{a}$, to determine the acceleration from the net force on the object, $\Sigma\vec{F}$.

When solving problems that involve accelerating objects, **set the positive x-axis in the direction of the net force (acceleration)**. This will ensure that the net force has no additional y-component, which will simplify the solution.

If you do not know the direction of the net force, then just set the positive x-axis in the direction that is the most convenient to solve the problem.

TIPERs pg 125 B3-QRT68: Stacked Blocks—Normal Forces



A student pushes two blocks, A and B, across a desk at a constant speed. The force exerted on block A by the student is directed horizontally to the left. The mass of block A is greater than the mass of block B.

(a) The magnitude of the normal force exerted on block A by block B

(i) is *greater than* the magnitude of the normal force exerted on block B by block A.

(ii) is *less than* the magnitude of the normal force exerted on block B by block A.

(iii) is *equal to* the magnitude of the normal force exerted on block B by block A.

(iv) *cannot be compared* to the magnitude of the normal force exerted on block B by block A based on the information given.

Explain your reasoning.

(b) The magnitude of the normal force exerted on block A by block B

(i) is *greater than* the magnitude of the weight of block A.

(ii) is *less than* the magnitude of the weight of block A.

(iii) is *equal to* the magnitude of the weight of block A.

(iv) *cannot be compared* to the magnitude of the weight of block A based on the information given.

Explain your reasoning.

(c) The magnitude of the normal force exerted on block B by block A

(i) is *greater than* the magnitude of the weight of block B.

(ii) is *less than* the magnitude of the weight of block B.

(iii) is *equal to* the magnitude of the weight of block B.

(iv) *cannot be compared* to the magnitude of the weight of block B based on the information given.

Explain your reasoning.

(d) The magnitude of the normal force exerted on block B by block A

(i) is *greater than* the magnitude of the normal force exerted on block B by the desk.

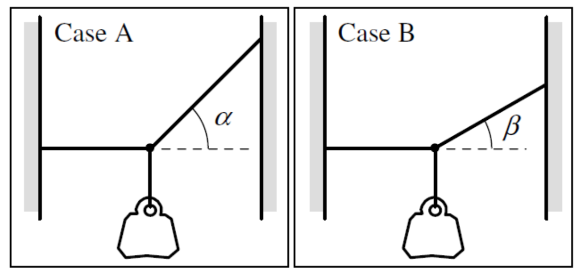
(ii) is *less than* the magnitude of the normal force exerted on block B by the desk.

(iii) is *equal to* the magnitude of the normal force exerted on block B by the desk.

(iv) *cannot be compared* to the magnitude of the normal force exerted on block B by the desk based on the information given.

Explain your reasoning.

TIPERs pg. 130 B3-SCT78: Hanging Mass—Tension in Three Strings



A hanging mass is suspended midway between two walls. The string attached to the left wall is horizontal, while the string attached to the right wall makes an angle with the horizontal, as shown. This angle (▯) in Case A is larger than the angle (▯) in Case B. Four students make the following claims about the tensions in the strings:

Abbie: "I think the tensions in any string in Case A is going to be the same as the equivalent string in Case B. The weight is the same, and the weight is still going to be divided up among the three ropes."

Bobby: "I think the tensions in the horizontal and vertical strings are the same, because they are exactly the same in both cases. But in Case B the diagonal rope is shorter, so the tension is more concentrated there."

Che: "The diagonal string still has to hold the weight up by itself, because the horizontal string can't lift anything. So the diagonal string still has the same tension. But in Case B it's pulling harder against the horizontal string because of the angle, so the tension in the horizontal string has to go up."

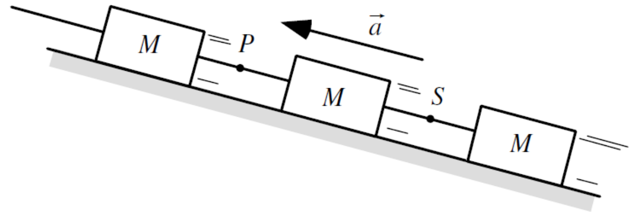
Damian: "But the diagonal string is fighting harder against the weight in Case A—it is pointing more nearly opposite the weight. So it has to have a greater tension in Case A. And since the tension in the diagonal string is greater, and the tension in the vertical string is the same, the tension in the horizontal string must be less in Case A. The tensions still have to balance out so that they are the same in both cases."

With which, if any, of these students do you agree?

Abbie __ Bobby __ Che __ *Damian* __ None of them

Explain your reasoning.

TIPERs pg. 131 B3-WWT80: Blocks on a Smooth Incline—Tension



Three identical blocks are tied together with ropes and pulled up a smooth (frictionless) incline. The blocks accelerate up the incline. A student who is asked to compare the tension in the rope at point *P* to the tension at point *S* states:

"Each rope is pulling one block. All three blocks are accelerating at the same rate and they are identical. I think the tensions at points P and S will be the same."

What, if anything, is wrong with this contention? If something is wrong, identify it and explain how to correct it. If this contention is correct, explain why.

Example 1: Calculating Tension and the Normal Force

A sled has a mass of 14 kg and is on a hill that is inclined 25° to the horizontal. The hill is very icy (negligible friction), and the sled is held at rest by a rope attached to a post. The rope is parallel to the hill.

a) Draw a system diagram.

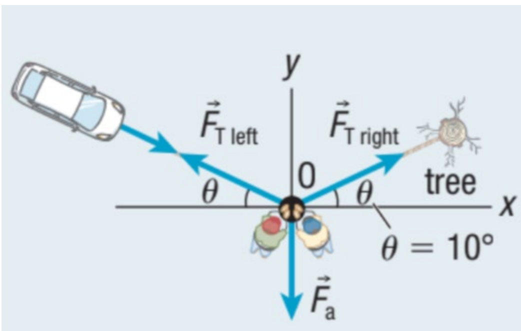
b) Draw the FBD.

c) Calculate the magnitude of the tension in the rope.

d) Calculate the magnitude of the normal force acting on the sled.

Example 2: Force Applied at an Angle

Your car is stuck in the mud, and you ask a friend to help you pull it free using a rope. You tie one end of the rope to your car and then pull on the other end with a force of 10^3 N. Unfortunately, the car does not move. Your friend then suggests that you make a knot in the middle of the rope, tie the other end of the rope to a tree, and then pull on the knot. Although you are skeptical that your friend's idea will help, you try it anyway. You make a knot in the middle of the rope. You leave one end of the rope attached to the car and tie the other end to a tree at an angle α=10°. Then you and your friend pull on the knot in the direction indicated by $\vec{F}_a$ in the figure below.



You discover that when a 10^3 N force is applied to the knot in the middle of the rope in the direction shown in figure below, you are just able to free the car at a slow constant velocity. Why does this work? Start by drawing the FBD with the forces acting on the knot at point O.

Example 3: Velocity due to Acceleration

A sled is at the top of a hill, which makes an angle of 18° with the horizontal. The height of the hill is 25 m. Assume that no friction acts on the sled.

a) Draw a system diagram.

b) Draw the FBD for the sled.

c) Calculate the speed of the sled as it reaches the bottom of the hill.

Example 4: Acceleration and Tension

A crate with a mass of 32.5 kg sits on a frictionless surface and is connected to a second crate by a string that passes over a pulley. The second crate has a mass of 40.0 kg. The pulley is frictionless and has no mass. The string also has no mass.

a) Draw a system diagram.

b) Draw the FBD for the crates.

c) Determine the acceleration of the system of crates and the magnitude of the tension in the string.

Lesson Reflection

State one thing you learn in this lesson:

*

State one thing you found challenging:

*

Check Your Understanding – Lesson 2.3

1. Students might suggest that in **Example 4**, if the mass of the object on the table is larger than the mass of the object hanging over the edge, the system will not move. Is the student correct? Justify your answer.

2. Refer to the system diagram in **Example 4.**

a) If the mass on the table were twice the mass of the object hanging, what would the acceleration of the system be?

b) How would this answer change if the two masses are interchanged so that the larger mass is hanging?

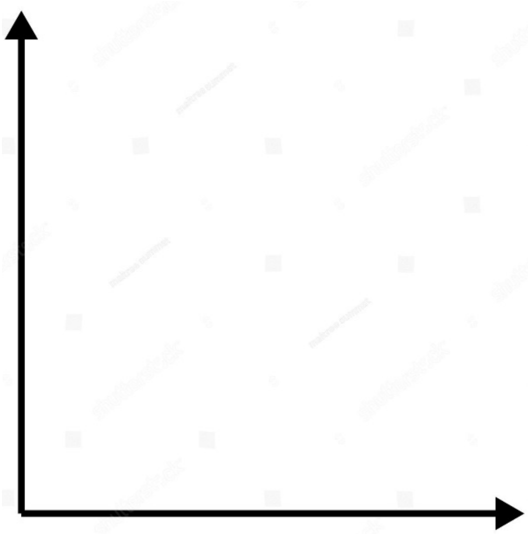
2.4 Forces of Friction

Lesson Goal: Understand the forces of friction and how they affect the motion of an object

Success Criteria: At the end of this lesson, I will be able to:

- ✓ Distinguish between static friction and kinetic friction
- ✓ Relate the coefficient of static friction and kinetic friction to the forces of friction
- ✓ Determine the magnitude of the static friction force and find the magnitude and direction of the maximum static friction force exerted on an object by a surface.
- ✓ Find the magnitude and direction of the force of kinetic friction exerted on an object by a surface.
- ✓ Construct free-body diagrams to solve for properties of the motion of an object when the forces on an object include static or kinetic friction.

$|\vec{F}_{\mathrm{f}}|$ vs $|\vec{F}_{\mathrm{a}}|$ *graph*



Conclusion:

Note: Different types of kinetic friction apply to different situations. If an object is scraping or sliding across a surface, we call it ***sliding friction***. If the object is round and it rolls across a surface, it is called ***rolling friction***. Fluid friction or air resistance (also known as ***drag***) is involved when a boat goes through water or a plane moves through the air.

We will deal with sliding friction for most of the problems. However, we will use the generic term "kinetic friction" under most circumstances.

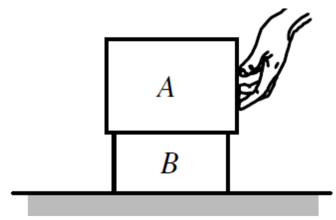
TIPERs pg. 132 B3-WBT82: Newton's Second Law Equation—Physical Situation

The equation below results from the application of Newton's Laws to an object:

$$27 \text{ N} - (\mu)(14 \text{ kg})(9.8 \text{ m/s}^2) = 0$$

Draw a physical situation that would result in this equation and explain how your drawing is consistent with the equation.

TIPERs pg. 137 B3 – 90 MOVING STACKED BLOCKS—FRICTION FORCES



A student pushes two blocks across a desk at a constant speed. The force exerted on block A by the student is directed horizontally to the left. The mass of block A is greater than the mass of block B.

(a) The magnitude of the friction force exerted on block A by block B

(i) is *greater than* the magnitude of the friction force exerted on block B by block A.

(ii) is *less than* the magnitude of the friction force exerted on block B by block A.

(iii) is *equal to* the magnitude of the friction force exerted on block B by block A.

(iv) cannot be compared to the magnitude of the friction force exerted on block B by block A based on the information given.

Explain your reasoning.

(b) The magnitude of the friction force exerted on block B by the desk

(i) is *greater than* the magnitude of the friction force exerted on block B by block A.

(ii) is *less than* the magnitude of the friction force exerted on block B by block A.

(iii) is *equal to* the magnitude of the friction force exerted on block B by block A.

(iv) cannot be compared to the magnitude of the friction force exerted on block B by block A based on the information given.

Explain your reasoning.

(c) The magnitude of the friction force exerted on block A by block B

(i) is *greater than* the magnitude of the force exerted on block A by the hand.

(ii) is *less than* the magnitude of the force exerted on block A by the hand.

(iii) is *equal to* the magnitude of the force exerted on block A by the hand.

(iv) cannot be compared to the magnitude of the force exerted on block A by the hand based on the information given.

Explain your reasoning.

TIPERs B3-91: STACKED BLOCKS SLOWING DOWN—FRICTION FORCES

A student pushes two blocks across a desk. At the instant shown, the blocks are ***slowing down**.* The force exerted on block A by the student is directed horizontally to the left. The mass of block A is greater than the mass of block B*.*

(a) The magnitude of the friction force exerted on block A by block B

(i) is *greater than* the magnitude of the friction force exerted on block B by block A*.*

(ii) is *less than* the magnitude of the friction force exerted on block B by block A.

(iii) is *equal to* the magnitude of the friction force exerted on block B by block A.

(iv) cannot be compared to the magnitude of the friction force exerted on block B by block A based on the information given.

Explain your reasoning.

(b) The magnitude of the friction force exerted on block B by the desk

(i) is *greater than* the magnitude of the friction force exerted on block B by block A*.*

(ii) is *less than* the magnitude of the friction force exerted on block B by block A.

(iii) is *equal to* the magnitude of the friction force exerted on block B by block A.

(iv) cannot be compared to the magnitude of the friction force exerted on block B by block A based on the information given.

Explain your reasoning.

(c) The magnitude of the friction force exerted on block A by block B

(i) is *greater than* the magnitude of the force exerted on block A by the hand.

(ii) is *less than* the magnitude of the force exerted on block A by the hand.

(iii) is *equal to* the magnitude of the force exerted on block A by the hand.

(iv) cannot be compared to the magnitude of the force exerted on block A by the hand based on the information given.

Explain your reasoning.

Example 1: Comparing Pushing and Pulling

A worker must move a crate that can be either pushed or pulled. The worker can exert a force of $3.6 * 10^2$ N. The crate has a mass of 45 kg. The worker can push or pull the crate at an angle of 25°, and the coefficient of kinetic friction between the floor and the crate is 0.36. The worker wants to move the crate as quickly as possible, but he does not know whether it is better to push or pull.

a) Draw a system diagram.

b) Calculate the acceleration when pushing the crate.

c) Calculate the acceleration when pulling the crate.

d) Evaluate your answers to (a) and (b). Does it matter whether the worker pushes or pulls the crate? Explain your answer.

Example 2: Overcoming Static Friction

A crate is placed on an inclined board. One end of the board is hinged so that the angle θ is adjustable. The coefficient of static friction between the crate and the board is 0.30.

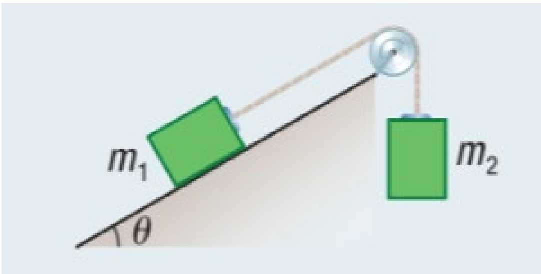
a) Draw a system diagram.

b) Draw the FBD.

c) Determine the angle at which the crate just begins to slip.

Example 3: Calculating Mass in Friction Problems

The figure below shows two blocks joined with a rope that runs over a pulley. The mass of m_2 is 5.0 kg, and the incline is 35°. The coefficient of static friction between m_1 and the inclined plane is 0.25. Determine the largest mass for m_1 such that both blocks remain at rest.



Lesson Reflection

State one thing you learn in this lesson:

*

State one thing you found challenging:

*

Check Your Understanding – Lesson 2.4

1. a) Explain why pushing backward with your foot can cause you to accelerate forward.

b) If a runner pushing backward on the sidewalk propels the runner forward, what happens when a rotating tire on a car moves?

2. Describe a situation in space where Newton's laws can help motion. How do astronauts move about the exterior of a space station as they do repairs, and how can they return to the space station if they become detached or untethered from the station?

Chapter 2 – Dynamics: Communication Questions

1. A student stretches a string horizontally between two retort stands such that the tension in the string is 1000 N. What is the maximum mass that the student can hang from the centre point of the string while still keeping the string perfectly horizontal? Explain your answer.

2. A helicopter drops a cable which is attached to a load. The cable is partially reeled in, and the helicopter flies east. Air resistance causes the load to swing backwards such that it makes an angle of 20.0° with the vertical. Draw a FBD of the situation.

3. Newton's First Law of Motion says that no net force is needed for a moving object to continue moving in a straight line at a constant speed. In real life, you may have noticed that something like a moving soccer ball will eventually come to a stop, even if no one exerts a force on it. How would you explain this discrepancy to a friend who has not studied physics?

4. A student who has not studied physics claims that there is little danger from a large object if it is moving at a slow speed. For example, if a truck is moving at only one or two m/s, there is no danger if it hits you, since your body will only need to supply a small force to stop the truck. Reflect on what you have learning about forces and motion, and comment on this hypothesis.

5. A car is parked on a hill that makes an angle of 18.0° with the horizontal. The parking brake is set, and the car remains in the parking spot. Use a FBD to help you explain why the car does not roll down the hill.

6. A window washer on a tall building is hanging from a cable that makes an angle of 85.0° with the horizontal. She believes that if she braces her feet against the wall on either side of the window the tension in the cable exceed her weight. Is she correct? Explain your answer.

7. A sprinter accelerates by pushing against the ground. Use a FBD to help you explain why the force is not perpendicular to the ground, and why it should not have too great a component parallel to the ground.

8. Amy is pulling a crate across the floor at a constant speed. Randall is pulling on an identical crate, and pulls almost hard enough to start it moving. Amy claims that she is pulling harder, since her crate is moving. Is she correct? Explain how you know.

9. Alfredo is pulling on a sled with a force of 75.0 N at an angle of 35.0°. The coefficient of friction between the sled and the snow is 0.332. Maribor is pulling on a similar sled with a force of 75.0 N directly along the horizontal. How do the forces of friction compare in the two cases? Explain your answer.

10. Kathryn ties a light rope to a tree, and pulls with a force of 150 N. The rope almost breaks. She unties the rope from the tree, and gives the end to her friend Piet, who also pulls with a force of 150 N. Will the rope break when Kathryn and Piet both pull? Explain your answer.

11. How are linear actuators used in different working environments to benefit workers?

12. Give at least three examples of specific tasks that can be performed by a linear actuator.

13. Sun Lee says, "Newton's First Law of Motion must be wrong. When I shoot a hockey puck across the ice, it will eventually come to a stop, even if it doesn't hit anything." Is Sun Lee correct? Explain your answer.

14. A ship with a mass of 20 000 tonnes is approaching a dock at 0.010 m/s. Zack is in a small boat between the ship and the dock. Zack claims that there is no danger. The ship is moving very slowly, and it will stop when it wedges Zack's small boat between itself and the dock. Is Zack correct? Explain your answer.

15. Anita finds herself in a boat in the middle of a pond with no motor or paddle. However, she does have a large number of softballs piled in the bottom of the boat. How can she use the softballs to reach the shore?