Forces
The Nature of Forces

CONCEPT EXPLORATION

In the last unit, we investigated how to describe the motion of an object. In this unit we will examine how to **change** the motion (velocity) of an object.

Consider the volleyball player illustrated on the right. The volleyball moves as a projectile as it falls toward the floor. The player strikes the ball, changing its motion.

Engagement Questions

1. In what way is the motion of the volleyball changed?

2. What did the player actually do to the ball in order to change its motion?

A balloon puck is a disc that has a balloon attached to it. If you inflate the balloon and attach it to the puck, the air escapes through a tiny hole in the base of the puck. As the air escapes, the puck is lifted slightly above the surface of the table.

3. What affect will this have on the motion of the puck?

The Challenge

You will be investigating the different ways that you can change the motion of a balloon puck by pushing it.

Your Ideas about the Challenge

An inflated balloon puck is moving at constant speed in a straight line across a table top,

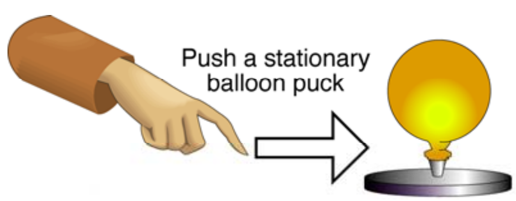
4. Describe at least two ways that you can push the moving balloon puck and change its motion.

At each lab station you will find the following:
one balloon puck

The Investigation

a. Inflate the balloon puck and set it down on the table top so that it doesn't move.
b. Give a small horizontal push to the side of the disc of the balloon puck.
c. After allowing the puck to move a short distance, stop it and then reinflate it. Set it down on the counter, once again, so that it doesn't move.
d. Give the puck a somewhat larger push in the same direction as you did before.

5. Did the balloon puck accelerate when you pushed on it? How do you know? What did the balloon puck do that would be considered acceleration?



6. When did the acceleration take place? Did it accelerate before, during, or after your push?

The Investigation (continued)

a. Inflate the balloon puck and set it down on the table top so that it **moves** with a small speed.
b. Give a small horizontal push to the side of the disc of the balloon puck in the same direction that it is moving.
c. After allowing the puck to move a short distance, stop it and then reinflate it. Set it down on the counter, once again, so that it moves with a small speed.
d. Try to push on the balloon puck in such a way that it will stop moving.

7. Did the balloon puck accelerate when you pushed on it in the direction of motion? How do you know? What did the balloon puck do that would be considered acceleration?

8. When did the acceleration take place? Did it accelerate before, during, or after your push?

9. In what direction did you have to push on the balloon puck in order to get it to stop? Was it in the same direction of motion, the opposite direction of motion, or in some other direction?

10. Did the balloon puck accelerate when you pushed on it in order to get it to stop? How do you know? What did the balloon puck do that would be considered acceleration?

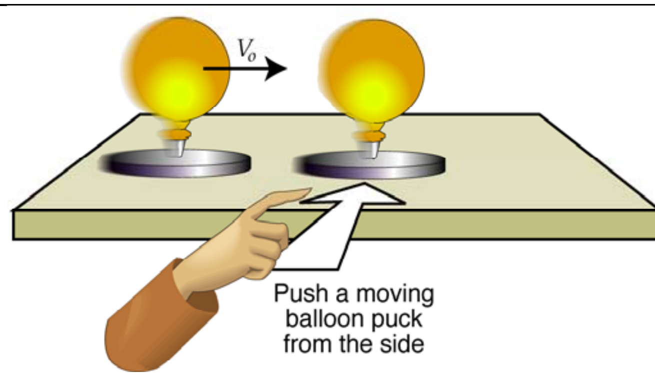
11. When did the acceleration take place? Did it accelerate before, during, or after your push?

The Investigation (continued)

a. Inflate the balloon puck and set it down on the table top so that it **moves** with a small speed.
b. Give a small horizontal push to the side of the disc of the balloon puck **perpendicular** to the direction that it is moving. Try not to either speed the puck up or slow it down.

12. Did the balloon puck accelerate when you pushed on it in a direction that was perpendicular to the direction of its initial motion? How do you know? What did the balloon puck do that would be considered acceleration?

13. When did the acceleration take place? Did it accelerate before, during, or after your push?



14. Evaluate the following student statements about the investigation you performed. Identify ideas that are consistent with your observations and others that are not consistent with your observations.

Student A
"The only time when the balloon puck accelerated was when it either speeded up or slowed down. When I pushed it on the side, perpendicular to its motion, it didn't change its speed."

Student B
"It accelerated when I pushed on it perpendicularly, because it changed direction. Remember, that acceleration is a change in velocity and velocity includes both speed and direction of motion."

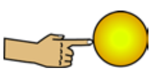
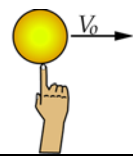
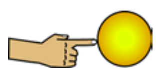
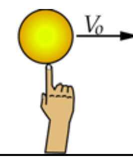
Check your work with your teacher

When you pushed on the balloon puck you were exerting a force on the balloon puck. We will define a **force** as being either a push or a pull. In order to change the motion of an object, or accelerate an object, something has to exert a force on the object.

15. Can you think of a situation where an object is accelerated and there are no forces acting on the object? If so, describe the situation.

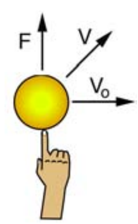
16. Are forces vector quantities? Explain how you know.

The illustrations below represent a top down view of the balloons in the situations you investigated.

17. Draw the vector that represents the force that you exerted on the balloon puck in each situation.		**18. Draw the vector that represents the final velocity of the puck, after the push, in each situation.**	
puck initially at rest	puck with initial velocity	puck initially at rest	puck with initial velocity
			

19. How did the direction for the applied force and the acceleration of the puck compare in each situation? Were they in the same direction, opposite direction, or some unrelated direction?

When you pushed perpendicular to the initial direction of motion of the puck you probably noticed that the balloon moved off in a direction that was in between the direction of your applied force and the initial velocity that it had. The direction that the puck moved, after the push, is indicated by the final velocity (**v**) shown in the diagram to the right.



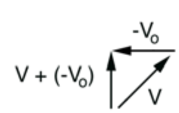
Remember that acceleration is a change in velocity and a change in velocity is equal to the final velocity minus the initial velocity ($\Delta v = v - v_0$). Both final and initial velocities are vector quantities. When you subtract a vector quantity you actually add a negative vector. Therefore $v - v_0 = v + (-v_0)$.

20. If the initial velocity (v_0) is directed towards the right ($\xrightarrow{V_0}$), what would $-v_0$ look like?

When you add vectors together, graphically, you need to arrange them head to tail.

21. Show how you could rearrange the vectors, shown below, so that you are adding them together appropriately.

The change in velocity (Δv) is the direction indicated by the vector labeled $v + (-v_0)$ shown in the diagram to the right.



22. How does the direction of the change in velocity (Δv) compare to the direction of the applied force? Are they in the same direction?

Forces
The Nature of Forces

CONCEPT DEVELOPMENT

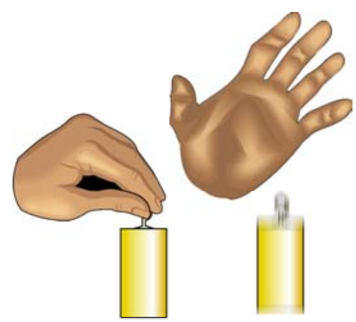
In the last investigation, we observed how forces affected the motion of an object. When a force acts on an object like a balloon puck in a low friction state, it is possible to change its velocity with a small force. Some of the forces we observed resulted in either a change in speed or a change in the direction of motion.

In this part of the lesson, we will include the force of gravity, and forces applied by supporting surfaces. We will investigate how groups of forces acting on an object can be resolved. We will also define specific rules for drawing force or “free-body” diagrams.

Engagement Questions

1. If you drop an object and allow it to fall, what kind of motion will it experience?

You drop an object.



2. If it is accelerating, what must be acting on the object?

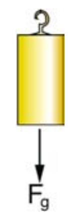
3. What force(s) must be acting on the object as it falls?

The Challenge
You will draw what is known as a free-body diagram to graphically represent forces acting on an object.

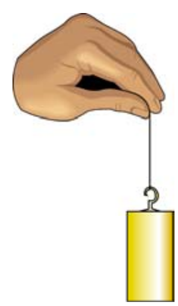
Your Ideas about the Challenge
4. When an object is falling, how many forces are acting on it?

The first step in problem solving is to draw a diagram that represents the problem in question.

You will be introduced to a powerful technique that can be used to help you solve problems that involve forces. This technique isn’t just useful, it is essential in some very complex situations in order to understand what is important to solving the problem.

A. When you draw a free-body diagram you start by drawing the object that you are interested in. In this case, we are interested in the motion of the falling body.	
B. The next step is to draw a vector that emanates outwards from the body in the direction that the force acts. We will ignore air resistance at first.	
C. The force in this situation is the force of gravity, which we will label F_g. If their wasn't any air resistance or you were told that air resistance was negligible, this would be your completed free body diagram. It is important to note that you **do not** include in your diagram any forces that act upon other objects. You only include the forces that act upon the object you are interested in.	
D. If air resistance was a factor to be considered in this particular problem we could add another vector to represent the force of air resistance acting in the opposite direction of motion of the falling body. We will label this F_a. Notice that the vector that represents the force of air resistance (F_a) is drawn shorter in length than the vector that represents the force of gravity (F_g). **5. Why do you think that the air resistance vector was drawn shorter than the force of gravity vector?**	

The next situation that we will consider will involve a mass being held at rest as it hangs from the end of a string.
In order to correctly draw the free body diagram for this situation you will need to review the steps outlined above for the object falling under the influence of gravity.



6. Draw the free- body diagram that represents the forces acting on the hanging mass seen in the diagram above.

Check your work with your teacher

A free body diagram for an object that is at rest on a horizontal surface, is similar to the one that you just drew for the hanging mass.

For example, consider a briefcase laying on a table top.

7. How many forces act on the briefcase that is lying on the table top? What are these forces?

The free-body diagram that represents the briefcase lying on the table top should appear as you see to the right.

The force of gravity is always directed downwards towards the center of the earth.

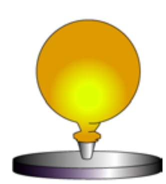
The force that the table exerts on the briefcase belongs to a special group of contact forces known as “normal” forces. Whenever you touch a surface, the surface exerts a contact force back on you that is a normal force.

8. What is a normal line in mathematics?

9. Describe, draw, and label at least 2 normal forces that are acting on the man relaxing in the easy chair shown to the right.

For now on, whenever we consider a contact force that belongs to the group of forces known as normal forces we will label them F_n.

We will now return to the situation in which you were pushing a balloon puck around. When the balloon puck was at rest it had two forces acting on it, the force of gravity and the table top pushing back on it.
Actually this was more complicated since the balloon was forcing air out through the bottom of the puck. The puck was actually supported by a cushion of air. We will simplify this scenario and consider the upwards-normal force supporting the puck to have been the normal force of the table top.

10. Appropriately draw and label all of the forces that are acting on the balloon puck shown to the right at the moment that you were pushing on the puck in the direction that it was moving. Disregard any frictional forces or air resistance.	

Check your work with your teacher

Force
The Nature of Forces

CONCEPT REFINEMENT

Review

We have examined some of the basic properties of forces in the last investigations. The simplest definition for a force is that it is a **push or a pull**.

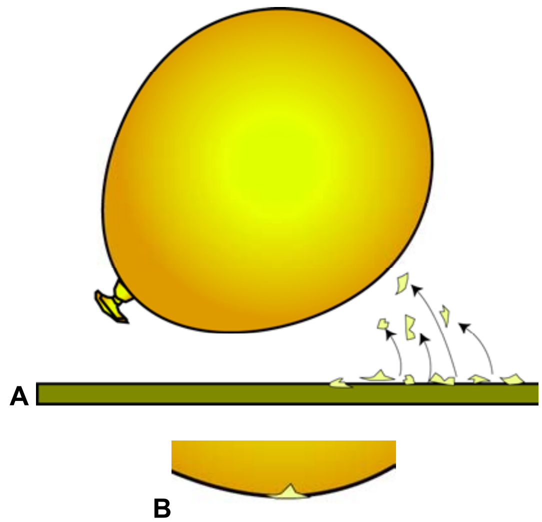
We have observed that a force **can result in a change in motion** for an object. Forces can change the speed of an object, or the direction that an object is moving, or both. If the motion of an object changes (acceleration) then there had to be a force acting on the body in the direction of the acceleration.

We also practiced identifying the forces acting on an object by drawing **free-body diagrams**. Free-body diagrams help us predict the motion of an object, or explain why the object moves as it does.

Scenario Analysis

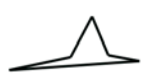
The following section contains sample situations involving forces. You will answer questions about the situations using your experiences with forces.

I. Jaina rubs an inflated balloon against her hair. She then holds the balloon above some bits of paper resting on a table as the diagram **A** to the right illustrates. The paper bits "leap" off of the table toward the balloon. One of the bits of paper sticks to the balloon as diagram **B** illustrates.



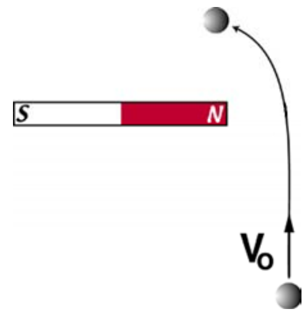
1. What had to have acted on the bits of paper to cause them to move as seen in diagram A?

2. Draw and label all of the forces acting on the tiny bit of paper, shown in the diagram below, that is sticking to the underside of the balloon.



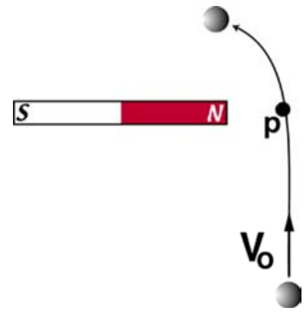
Check your work with your teacher.

II. Conrad rolls a steel ball bearing near a magnet. The ball bearing is deflected as the diagram, shown to the right, illustrates. The speed of the ball bearing **does not** change.



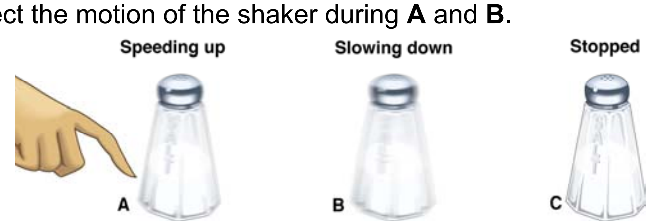
3. Other than the downward force of gravity and the upward force of the surface the ball was rolling on, was a force applied to the ball bearing? How do you know?

4. What is the direction of the force applied by the magnet on the ball bearing at point p? Draw this force in the diagram to the right. Label it the magnetic force.



Check your work with your teacher.

III. Isabella slides the salt shaker across the table to her sister. While she is pushing the salt shaker it is speeding up. As soon as she stops pushing the shaker it starts slowing to a stop. The shaker then comes to rest in front of her sister. Friction forces affect the motion of the shaker during **A** and **B**.

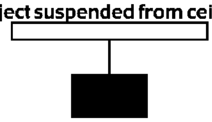
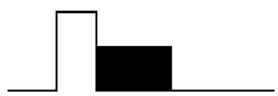
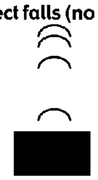
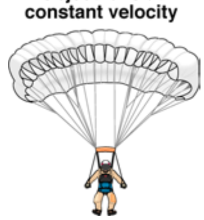


5. Complete each of the three free-body diagrams shown below.

Salt Shaker Motion	Speeding up  A	Slowing down  B	Stopped  C
Free Body Diagram			

Check your work with your teacher.

6. Draw the free-body diagram that represents each of the situations illustrated below.

Illustration	Free-body diagram
Object slides at a constant speed without friction 	
Object suspended from ceiling 	
Object lies motionless 	
Object falls (no air resistance) 	
Object falls at constant velocity 	
Object is pulled upward at a constant speed