PHYSICS UNION MATHEMATICS

Physics I

Matter

Student Edition

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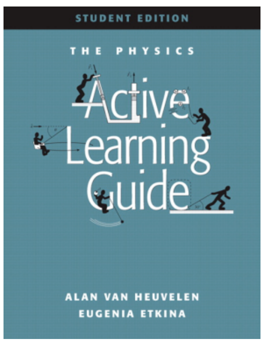
PUM Physics I
Matter



Many of the module activities were adapted from:

A. Van Heuvelen and E. Etkina, *Active Learning Guide*,
Addison Wesley, San Francisco, 2006.
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Lesson 1: Particles of Matter

1.1 Observe and Explain

Dip a piece of paper in rubbing alcohol (or rub the paper with alcohol) and place it on a table.

a) Observe what happens and describe it in your own words.

b) What do you need to **assume** about the makeup of alcohol to explain the *gradual* disappearance of alcohol from the paper?

1.2 Hypothesize

Think of possible **explanations** for the alcohol's *disappearanc*e. Suggest at least three different mechanisms. Fill in the table that follows.

Here's An Idea!

Coming up with explanations for this can be difficult but don't be afraid to use your imagination. There are no wrong ideas, only testable or non-testable ones!

For Example: *The alcohol is still there but we just can't see it (Testable Idea)*

Leprechauns came by, collected the alcohol, and left (Non-Testable Idea)

1.3 Test Your Idea

a) Think of an experiment you can perform to rule out each explanation.

b) Write a **prediction** for each testing experiment based on the corresponding explanation.

c) Perform the experiments. Some possible testing experiments can be found at: http://paer.rutgers.edu/pt3/experimentindex.php?topicid=7&cycleid=13

1.4 Explain

Based on the outcomes of the testing experiments what judgment can you make about each explanation? Revise your hypothesis for the disappearance of the alcohol.

1.5 Test Your Idea

You and your lab partners have a glass of pure alcohol, a container with colored alcohol, and a dropper. One of your lab partners says,

"*I think that the alcohol is made up of little tiny parts that are constantly in motion.*"

Your other partner disagrees. She says,

"No, I agree that the alcohol is made up of little tiny parts but they are definitely not moving!"

a) Based on your experience from the previous activities, which explanation do you agree with? Why?

b) How can you use the materials listed above to test these ideas?

c) Write your prediction for each of your partners' mechanisms.

d) Perform the experiments and record the outcomes.

e) What judgment can you make about each explanation?

Did You Know?

Scientists call these little parts that make up objects **particles**. Although we cannot see the particles, we can discuss their properties. Understanding their properties will help us better understand the nature of the object as a whole.

Homework

1.6 Represent and Reason

a) Create a picture that represents what the particles are doing in the alcohol experiment.

b) How do you think solids, liquids, and gases look at a particle level?

Lesson 2: The Motion of Particles

2.1 Observe and Explain

During lunch one of the custodians cleans up a spill using a cleaning solution. After a few seconds, your friend Diego begins complaining about the smell. Two minutes later, Hailey, who sits on the other side of the cafeteria, starts making comments about the smell as well. You don't smell anything for most of lunch but by the end of the period you notice it too.

a) Draw a picture of what happened in the cafeteria.

b) Why doesn't everyone smell the cleaner at the same time?

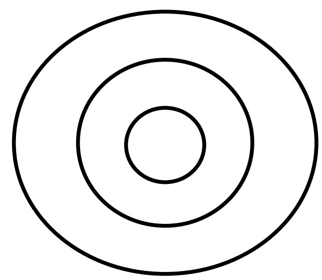
c) Did the smell spread out in a regular or predictable way? Explain.

d) Does your hypothesis for alcohol disappearing help you explain what happened in the lunchroom?

e) Revise your hypothesis for alcohol disappearing to incorporate the ideas from this observation.

2.2 Test Your Idea

As a class, stand in 3 (concentric) circles like in the picture. Your teacher will open a bottle of strong perfume in the center of the inner circle. You will raise your hands as soon as you detect the smell. **BE HONEST!!! This is very important!**



Use your ideas from the previous activities to predict how the smell will travel through the room.

a) Perform the experiment and describe what happened.

b) Compare the outcome to your prediction. Were there any surprises? Explain.

c) Use the ideas you developed in the previous activities, create a model for particle motion.

2.3 Explain

In 1827 Robert Brown, a Scottish botanist, used a microscope to observe pollen. To keep the pollen on the microscope glass he added a little water. To his surprise he saw the granules of pollen moving randomly. The biggest granules did not move at all and the smallest moved the most. At first Brown thought this only occurred because the pollen was alive but on testing his hypothesis, he found that ground up glass and powders (materials that definitely are not alive) behaved the same way. Use the hypothesis of moving particles and interactions between water and pollen granules to explain Brown's observations. What do you need to assume about the directions and magnitudes of the velocities?

2.4 Observe and Explain

Blow up a balloon and carefully observe how its shape changes during the process. Use the idea of moving particles to explain why it expands.

2.5 Test Your Idea

Jessie came up with a possible explanation for why balloons change shape when blowing them up and stay the same when you stop blowing:

"The balloon expands when you blow air into it because you're adding moving air particles to the inside which are hitting the wall of the balloon pushing it outward. The balloon stops expanding because the air particles inside and outside of the balloon are balancing each other out."

a) Describe an experiment that you can perform to test whether the particles of air outside of the balloon prevent it from expanding.

b) Use the hypothesis to predict the outcome of the experiment.

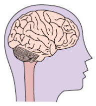
c) Perform the experiment and record the outcome.

Homework

2.6 Explain

When someone at your house is making cookies, why don't you smell them right away? Why doesn't everyone in the house smell them at the same time?

Lesson 3: Between the Particles

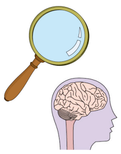


3.1 Reason

Your instructor has brought in the following measuring devices: ruler, stopwatch, graduated cylinder, beaker, triple-beam balance, and digital scale. Determine which measuring devices can be used to decide how much of a material you have. Do the devices measure the same quantities? Are there any devices that measure the same thing? Explain.

Did You Know?

Two physical quantities that can characterize the amount of a material are **volume** and **mass**. Volume is the amount of space the material or object takes up. Mass is the amount of matter that makes up the material or object.



3.2 Observe and Reason

Place a drop of food coloring in a glass of water.

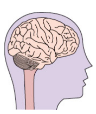
a) Draw a series of pictures showing the water and food coloring over time.

b) Below your pictures describe what happens.

c) Does our particle model completely explain what is going on in this process? Explain your answer.

3.3 Hypothesize

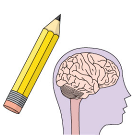
If the water is composed of particles, why can the food coloring move around so freely?



3.4 Reason

Consider a crowded room of people. How can you move through the room? What must be true for you to be able to pass through the crowd?

Use the crowd analogy to revise your hypothesis about the food coloring.



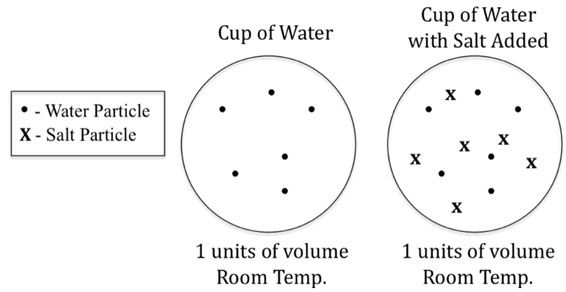
3.5 Represent and Reason

What is different about when you wave your hand through air from waving your hand through water? Can you wave your hand through a brick wall?

Make a Micro-View of air, water, and a brick wall.

Need Some Help?

If you had special glasses that enabled you to see the particles of an object, what would we see?



We can draw a simplified picture of an object called a **Micro-View**, which is based on our particle model. We can represent the particles with symbols like dots and x's, and empty space with no marks at all. We must always include a legend so that we know what the symbols represent.

We also need to include important labels to help us understand what the Micro-View represents (*Example: title, temperature, volume)*.

Remember! This representation is a snapshot of **one unit of space** at **one moment in time**.

a) What is similar in each of the situations?

b) What are all the differences about them?

c) Why might it be harder to wave your hand through water than through air?

3.6 Test Your Idea

Consider the experiment: You pour 10 ml of salt into 100 ml of water.

a) Using your hypothesis, form a prediction for what should happen to the volume of the mixture. Represent your prediction with a picture and explain.

b) Now perform the experiment and record the outcome. How did your prediction compare to the outcome? What judgment can you make about your hypothesis? Revise your hypothesis as needed.

c) Do you think that you can generalize this model for both gases and liquids? Think back to the perfume experiment.

3.7 Test Your Idea

a) Examine a test tube and explain whether it is empty or full.

b) Using your revised hypothesis, predict what will happen if you flip the test tube over (open side down) and push it slowly into the water. *Focus your prediction on what is happening on the inside of the test tube.*

c) Perform the experiment and record the outcome.

d) Why won't the test tube fill with water?

e) Draw a Micro-View picture for the particles inside the test tube before and after pushing the test tube into the water.

f) What is found in between the particles?

3.8 Observe and Explain

a) Fill a container with large rocks. Why might someone say the container is full? Do you agree or disagree?

b) What could you add to the container?

c) Share your ideas with your classmate and make a list of materials you can add to the container.

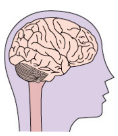
d) Add these materials to the container and discuss whether the bowl is full.

e) Is there anything else you can add? Explain.

Did You Know?

Particles move around in empty space, and that space can be filled with many kinds of particles. Empty space is not air - Air is made of different types of particles that take up space.

Homework



3.9 Reason

Imagine a basketball that is pumped it up until it feels full. (If you have this equipment, you may actually try to perform the steps.)

a) Make a Micro-View of the air in the ball.

b) Explain whether the ball is full? Can you add more air?

c) How would the ball differ if more air was added?

d) Imagine that more air is added to the ball. Make a new Micro-View for the ball.

e) How do the two Micro-Views compare? What is different, and what is similar?

Lesson 4: Exploring Mass

4.1 Observe and Explain

a) Examine a piece of paper before and after it is crumpled up. What is the same about the sheet before and after the process? What is different? How do you know?

b) What do you think we will notice if we measure the mass of the paper before and after a process and compare them? Explain why you believe this.

c) Perform the measurements with a new piece of paper and describe what you found. Does this support your hypothesis?

d) How does the volume of the paper change during the process? How does the mass change?

4.2 Testing Your Idea

Repeat the salt and water experiment from activity 3.6, however, this time you will measure the mass and volume of the water and salt before and after mixing.

a) Use your "crumpled paper" hypothesis to predict the total mass of the salt and water solution. Make a prediction about the volume of the solution.

b) Perform the measurements, combine the salt and water, and then measure the total mass and volume of the solution. What rule can you develop for mass? What rule can you develop for volume?

4.3 Observe and Explain

Does gas have any mass? To help us answer this question we can use an evacuation jar. On the right there is a picture of this special glass bottle. The top of this bottle has an adjustable valve so that air can be pumped out of the bottle. Inside of the bottle there is **a sealed** "hand-shaped" balloon that contains a very small amount of air.

a) What do you think will happen to the mass of the jar if we remove the air from the container? How did you come to this conclusion?

If you have these material you can perform the experiment. Otherwise, please watch the following video posted on the PUM website. Measure the mass of the rigid container when it has air in it and record this value. Remove the air from the jar using a one-way air pump. Once again, measure the mass of the container and record the value.

b) What did you notice about the mass of the bottle before and after the air is evacuated?

c) Does air have mass? How do you know?

4.4 Test Your Idea

Read the description of a possible testing experiment for your explanation. Make a prediction of the outcome of the experiment based on your explanation. Perform the testing experiment or watch the video of the experiment on the PUM website.

Explanation	**Describe an experiment to test this explanation.**	**Use the explanation to predict the outcome of the experiment.**	**Observe the experiment; record the outcome.**	**Based on the outcome of the experiment relative to the prediction, make a judgment about whether the experiment disproved the explanation or not.**
	You place a large empty plastic bag on a scale and record the mass. You then add air to the bag and mass the system again.	Prediction: What will happen to the reading on the scale? Assumption: What assumptions did you use when you made your prediction?		

Homework

4.5 Explain

a) Predict what will happen if you add 10 g of sand to 100 g of water. What could happen to the mass of them mixed together? What could happen to the volume?

Lesson 5: Exploring Volume and Capacity

5.1. Observe and Reason

Examine a book on the table.

b) What geometrical shape does it have?

c) What can you learn about this book using a ruler? Provide the answers in terns of physical quantities. What units do we use for those quantities?

d) What is the difference between the perimeter and the surface area? What is the difference between the area and the volume?

e) Explain how you found the volume of the book.

f) Can you use the same approach to determine the volume of a soda can (you cannot open it)?

g) Can you use the same approach to determine the volume of a water bottle (you cannot open it)? Explain your answer.

5.2 Observe and Explain

Fill a beaker full of water and drop a penny into the glass. Now try to reach in and take the penny out.

a) What happened when you stuck your hand in?

b) Why does this happen?

c) How can you use this idea to determine the volume of an object?

5.3 Design an Experiment

Come up with two different ways to find the volume of each of the following objects: ping pong ball, a metal block, soda can, and dice. You have a ruler, measuring tape, graduated cylinder, beaker, and water.

a) Think of what volume is. How is it different from length? How is it different from area? What units do we use to measure it?

b) Now think of how you will find the volume of each object. Is there more than one way to do it?

c) Make a plan for what data you will collect for each object. Think about how you will organize the data. A table might help.

Experiment 1:

Object	**Calculations**	**Volume____(units)**
Dice		
Ping pong ball		
Soda Can		
Metal Block		

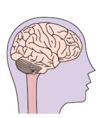
Experiment 2:

Object	**Calculations**	**Volume____(units)**
Dice		
Ping pong ball		
Soda Can		
Metal Block		

a) Perform the experiments and record the results in your table.

b) Make a graph of the capacity change vs. volume for each item. What will be your axes? What units will you use?

c) Compare the results of the experiments for each object. Are they the same? Explain how you came to this conclusion.



5.4 Reason

a) Revisit your previous response. Did you take into account the uncertainty in your measurement? If we do, are the two values the same?

b) Think of the units of measurement. Think of experimental uncertainties. How do you write the result of each measurement?

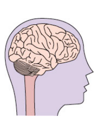
Remember!

Uncertainty is the margin within which you can possibly know the value of any physical quantity. Uncertainties depend on the instruments and the ways you conduct the experiment. ANY instrument has an uncertainty equal to half of the smallest division and must be considered when taking measurements.

5.5 Evaluate

Use the rubric below to evaluate your work.

Collect and Analyze Experimental Data					
Scientific Ability		**Missing**	**An attempt**	**Needs some improvement**	**Acceptable**
1	**Is able to identify sources of experimental uncertainty**	No attempt is made to identify experimental uncertainties.	An attempt is made to identify experimental uncertainties, but most are missing, described vaguely, or incorrect.	Most experimental uncertainties are correctly identified but the source of the biggest uncertainty is not specified.	All experimental uncertainties are correctly identified and the source of the biggest uncertainty is specified.
2	**Is able to evaluate specifically how identified experimental uncertainties may affect the data**	No attempt is made to evaluate experimental uncertainties.	An attempt is made to evaluate experimental uncertainties, but most are missing, described vaguely, or incorrect. Or only absolute uncertainties are mentioned. Or the final result does not take the uncertainty into the account.	The final result does take the identified uncertainties into account but is not correctly evaluated.	The experimental uncertainty of the final result is correctly evaluated; the final result is written within the margin of uncertainty.
3	**Is able to record and represent data in a meaningful way**	Data are either absent or incomprehensible.	Some important data are absent or incomprehensible.	All important data are present, but recorded in a way that requires some effort to comprehend.	All important data are present, organized, and recorded clearly.
4	**Is able to analyze data appropriately**	No attempt is made to analyze the data.	An attempt is made to analyze the data, but it is either seriously flawed or inappropriate.	The analysis is appropriate but it contains minor errors or omissions (units for example).	The analysis is appropriate, complete, and correct.



5.6 Reason

a) What do you notice about the two physical quantities?

Did You Know?

In the previous experiment you probably came up with the idea that you can place these objects in water and record the change in water level. We call this **capacity change** and it is the water displacement method for finding volume.

b) Why is it important to have several methods of finding volume?

5.7 Reason

a) Most TV shows are 0.5 hour or 30 minutes. How many minutes are in an hour? How many hours are in a minute?

b) Soda is typically sold in 2 Liter bottles or 0.53 gallons. How many liters are in a gallon? How many gallons are in a liter?

c) An iPod Touch weighs 115 grams or 0.115 kilograms. How grams are in a kilogram? How many kilograms are in a gram?

d) An Xbox 360 is 6617 cm^3 or 0.006617 m^3. How many centimeters are in a meter? How many meters are in a centimeter?

e) One serving of cough syrup is 5 mL or 5 cm^3. How many milliliters are in one centimeter cubed? How many centimeters cubed are in a millimeter?

5.8 Reason

A domino is a rectangular solid with a length of 2 cm, a width of 1½ cm and a height of ¼ cm.

a) Find its volume in meters cubed and centimeters cubed.

b) How much water would it displace?

A capped pen has a cylindrical shape, and displaces 4 ml of water when totally submerged. It has a radius of 0.5m.

c) How long is the pen?

A brand new battery has a length of 0.005 m and a radius of 0.5 cm.

d) Calculate its volume.

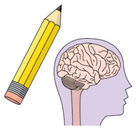
e) Do you think you could get a better measurement by measuring water displacement? Why do you think it is better in this case to measure using a ruler?

A sugar cube measures 1.2 cm on a side.

f) Find its volume.

g) Can you predict how much water the sugar cube would displace? Why or why not?

Lesson 6: Exploring Connections between Mass and Volume



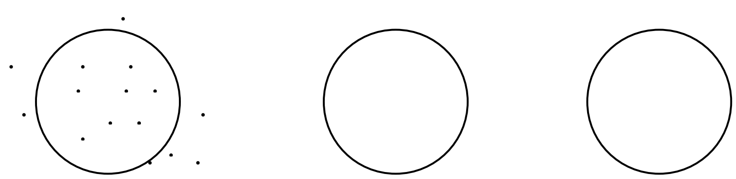
6.1 Represent and Reason

Revisit the experiment and video from Lesson 4. Remember that we measured the mass of the rigid container when it was evacuated, open to the air, and overfilled with air. Fill in the table below.

	Volume (cm^3)	**Mass (g)**
Evacuated	1000	
Open to air	1000	
Pumped up with air	1000	

a) What happened to the volume of air in the container as we filled it with air?

b) What happened to the mass of air in the container as we filled it with air?



c) Make at a Micro-View of the air in the container for each of the three mass measurements above. Include the air outside by representing it outside the circle. The "open to air" has been done. Complete the other two situations.

6.2 Explain

a) How do these three representations differ? What is the same about them?

b) What is in the evacuated bottle?

c) What is in between the particles of air when the bottle is pumped up?

d) How is the air inside the pumped up bottle different from the air that surrounds you? How is it similar?

e) What is in between the particles of the air that surrounds you?

f) What term can we use to describe the difference between each of the situations above?

Need Some Help?

In each of the three cases the volume stayed the same but the number of particles in that volume changed, thus causing the mass to change. More mass crowded into a smaller volume results in the material being more **dense**. Density is the property that describes how much mass is found in a particular volume.

6.3 Represent and Reason

You have two identical beakers. One has 90 ml of salt water, which has a mass of 100g. The other has 100 ml of tap water, which has a mass of 100 g.

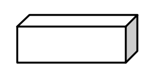
a) Make a Micro-View of both liquids.

b) Which is denser? How do you know?

6.4 Reason

You have a piece of aluminum that has a mass of 21.6 g. The aluminum block has a height of 1 cm, a width of 2 cm and a length of 4 cm.

a) Make a Micro-View of both pieces.



b) What is the volume of each block?

c) If the mass of all the particles in 8 cm^3 is 21.6 g, what is the mass of all the particles in each cubic centimeter of the aluminum?

d) What would the mass be for all the particles in a 10 cm^3 sheet of aluminum?

e) Can you write a mathematical relationship between mass and volume that doesn't change no matter how much or how little of the material you have?

f) Does the mass of all the particles in each cubic centimeter of the aluminum depend on the volume?

6.5 Reason

100 g of water fills a 100 ml cup.

a) Draw a Micro-View of the particles.

b) How massive is the water in a 20 ml cup?

c) Draw a Micro-View of the particles in the 20 ml cup.

d) What is the capacity of a cup that is filled with 45 g of water?

6.6 Describe

Take a lump of clay. Measure its mass and measure its volume. Describe how you measured its volume.

Homework

6.7 Reason

Sort the following quantities under the headings of mass, volume or length: 5 ml, 3.2 cm, 2.0 g, 5.6 in., 3.7 cm^3, 4.1 m^3, 4 feet, 25 cl, 2.0 L, 3.4 cubic feet, 6 gallons, 5 miles.

Mass	Volume	Length

6.8 Reason

10 cm^3 of silver has a mass of 193 g.

a) How massive is 1 cm^3 of silver?

b) How massive is 3 cm^3 of silver?

c) If a solid silver medal has a mass of 96.5 g, what is its volume?

6.9 Reason

A clay ball that occupies 314 cm^3 of space has a mass of 350 g. If you reform the clay so that it is a cylinder of height 1 cm, how big is its radius? How big is its mass?

Lesson 7: Representing Density and Exploring Fluids

7.1 Observe and Find a Pattern

a) In the front of the room we have several unknown liquids. What information can we collect from the liquids to help us understand them more?

b) Describe your procedures below.

c) Each group should take one liquid and perform at least ten different mass measurements at different volumes. Record your data in the table below. Remember to put the units of measurement at the top of each column.

Trial	Mass ( )	Volume ( )
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Sample Number: ____________________

d) Create a graph of your data and label the independent and dependent variables on the axis. Then draw a line of best fit for your data.

Need Some Help?

Since you decided how much volume to use, then measured the mass that makes the volume the **independent variable** and the mass the **dependent variable**. Therefore, mass should be placed on the vertical axis and the volume on the horizontal axis.

e) Please also record your data on the graph at the front of the room (if one is being kept). Add data to your graph from at least two additional groups.

f) Self-assess your graphic representation using the rubric below.

Rubric 3: Graphical representation

Missing	An attempt	Needs some improvement	Acceptable
No graph is present.	A graph is present but the axes are not labeled. There is no scale on the axes.	The graph is present and axes are labeled but the axes do not correspond to the independent and dependent variable or the scale is not accurate.	The graph has correctly labeled axes, independent variable is along the horizontal axis and the scale is accurate.

7.2 Reason

a) What do you think the meaning of the slope of the line is for each liquid? Come up with a name that you can use for the ratio as represented by the slope of the line.

b) For a given liquid, does the slope of the best-fit line remain constant? What does this mean for the liquid?

c) If the density of 30 ml of a liquid is 1.00 g/ml, what will the density be for 60 ml of the same liquid?

7.3 Explain

How would you modify the procedure you followed to reduce the scatter in your data?

Did You Know?

You probably notice some ***scatter*** in your data. This means that some of your data might not be very close to the best-fit line. In every experiment we expect to see scatter in the data. If there is a lot of scatter, we can conclude that either the measurements were not very precise or that a straight line is not the best function for describing the pattern we see.

7.4 Test Your Idea

a) How do water and oil differ in terms of density? How did you reach this conclusion?

b) Design an experiment to test this idea.

Here's an Idea!

To test this idea you can retrieve equal quantities of oil and water. Carefully pour oil into water and describe what you observe.

c) How is your observation related to the graph?

d) How can you use your graph to predict the outcome of similar experiments with different liquids? Explain.

Homework

7.5 Reason

You have a plastic cup full of water – about 200 ml.

a) What is its mass?

b) What will happen to the mass if you double the volume of water? How can you do it in real life?

c) What if you have 1/3 of the volume? How can you do it in real life?

d) You have 20 full glasses and 1 glass half full. What are the volume and the mass of water?

e) What is the density of the material inside the full cups? Inside a cup half full? What did you assume to be true when you answered the question?

7.6. Evaluate

In one of the episodes of "CSI" one of the detectives, Horatio, said: "oil is denser than water."

a) Do you agree or disagree?

b) Why do you think he said this?

c) How would you convince him of your opinion if you disagree?

d) How would you make others agree with Horatio if you agree with him?

7.7. Reason

Corn syrup has the density of about 1300 kg/m^3.

a) What does this mean?

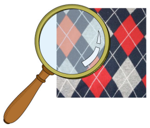
b) Represent this quantity graphically.

c) What will be the mass of a soda can filled with corn syrup? Explain how you came up with the answer.

7.8 Design an Experiment

How can you determine the density of regular coke? Diet coke? Describe two experiments for each density.

Lesson 8: Does It Float?



8.1 Observe and Find a Pattern

Using the simulation below, try to determine the relationship between the density of an object and whether or not it floats in a fluid. http://phet.colorado.edu/en/simulation/density

a) Begin by opening the simulation and conducting observational experiments with the blocks. Make sure to record a list of your observations. Use the "same mass," "same density," and "same volume" tabs to conduct your observations. Use these observations to develop a hypothesis about when an object floats and how it relates to density. Make sure this is VERY specific. **You should be able to determine whether an object floats given its mass and volume.**

8.2 Test your Idea

Design a test for your hypothesis using the custom or mystery tab. Make sure that you run at least 5 trials.

a) Make a prediction for each trial using your hypothesis. Include any calculations you performed.

b) Conduct the experiment you designed.

c) Write a short conclusion outlining whether or not your outcomes matched your prediction and what this means about your hypothesis. If necessary, revise your hypothesis and perform additional testing.

8.3 Design an Experiment

Once you have completed the density simulation you are going to extend your hypothesis using the buoyancy simulation: http://phet.colorado.edu/sims/density-and-buoyancy/buoyancy_en.html

a) Does your hypothesis work for all fluids? What do you think and why?

b) Conduct a series of observations using the Buoyancy Playground. You can change the fluids at the bottom and test Styrofoam, wood, ice, brick, and aluminum.

c) Construct another more sophisticated hypothesis that works for all fluids.

d) Design a test for your hypothesis by choosing a fluid and block density at random (you can make your own block by clicking the "My Block" button). You must have a minimum of 5 trials. Make sure you make a prediction for each trial.

e) Write a short conclusion outlining whether or not your outcomes matched your prediction and what this means about your hypothesis. If necessary, revise your hypothesis

8.4 Test your Idea

a) Use your knowledge of density to predict what will happen if you put the object into the oil and water mixture. Take the three objects at your station, make mass and volume measurements and put your data into the table below.

Object	Mass	Volume	Density	Prediction	Outcome of the experiment	Explanation
Wood						
Bouncy Ball						
Glass marble						

b) Perform each test and describe whether the prediction matched the outcome.

8.5 Communicate

Create a lab report to communicate your results. Write the report so a person who has not seen the experiments can repeat them and obtain the same results. Include pictures.

Lesson 9: Expanding Ideas of Particle Motion

9.1 Observe and Explain

Fill a transparent plastic cup with room temperature water and one with ice water. Put a drop of food coloring in each cup.

a) Describe what occurs to the dye.

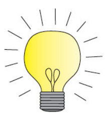
b) How does the behavior of the dye differ between the two cups?

9.2 Hypothesize

Propose a hypothesis to explain why the dye diffuses at different rates.

9.3 Test Your Idea

a) Design an experiment that tests your hypothesis above.



Here's An Idea?

You can test your idea by repeating the experiment above but using very hot water and room temperature water. What would you expect to happen?

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a) Write an **H-D statement** to help you predict the outcome of the experiment. Include a list with any assumptions you have made.

b) Perform the experiment and record the outcome. Explain whether the experimental evidence supports or disproves your hypothesis. (If your hypothesis was disproved, devise a new hypothesis and test again).

c) Use the rubric below to assess your experimental design and analysis. Describe how you could improve your experimentation next time.

Design, Testing, Analysis Rubric

Ability	**Absent**	**An attempt**	**Needs some improvement**	**Acceptable**
Is able to decide what is to be measured and variables	It is not clear what will be measured.	It is clear what will be measured (dependent variable) but independent variable is not identified.	It is clear what will be measured (dependent variable) but while independent variable is identified, choice is not explained.	It is clear what will be measured and independent and dependent variables are identified and the choice is explained.

Is able to identify and describe relevant experimental assumptions	No assumptions are identified or those identified are not relevant to the experiment.	Some assumptions are present as are the descriptions but they only slightly help with the interpretation of experimental results.	Most assumptions are identified and descriptions are present. These help with the interpretation of results but an important piece of info may be missing	All important assumptions are identified and described. These are expertly used to bring meaning to the experimental results.
Is able to make a reasonable judgment about the hypothesis	No judgment is made about the hypothesis.	A judgment is made but is not consistent with the outcome of the experiment.	A judgment is made and is consistent with the outcome of the experiment but assumptions are not considered.	A reasonable judgment is made and assumptions are taken into account.

9.4 Observe and Explain

a) Tovi is trying to open a jar of salsa and he cannot get the top off. He decides to run the top under hot water for several seconds and then he can easily open it. You've probably had experiences much like Tovi's but why does this occur? Why might it be more difficult to remove a cold lid from a jar than a warm lid?

b) Create a Micro-View picture of the lid when it's cold and when it's hot. Describe the difference(s) in the two situations.

c) How is this situation similar to the motion of particles of gases and liquids and how do you think it is different?

9.5 Test Your Idea

a) The image on the right is a ball and ring apparatus. The ball fits through the ring perfectly. Using what you know about particle motion, determine what you can do to the ball or ring so that the ball does **NOT** pass through the ring. Discuss what will happen to the particles in both the ball and the ring.

b) Does your prediction match the outcome?

9.6 Observe and Explain

A one-hole stopper is placed on a flask filled with air. A glass elbow tube is placed into the stopper and a small drop of colored water is placed in the glass tube. Record the position of the water droplet. Then hold the flask in you hands and gently rub the sides for several minutes. Record the new position of the water droplet.

a) Describe what occurred to the droplet and develop an explanation for why this occurred.

b) If you warmed up aluminum, do you think either the mass or the volume would change, or do you think it would stay the same? Explain.

c) What happens to the density of most materials when they are warmed? Explain.

Homework

m temp freezer

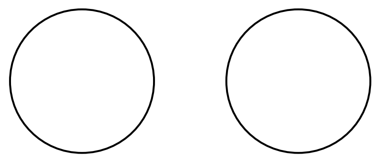
9.7 Test Your Idea

Take two empty plastic water bottles (approximately 0.5 L). Place one in the freezer overnight and leave the other out in the room temperature kitchen. Describe the difference in the two bottles. Explain why this occurs.

9.8 Explain

a) Do the particles of air in the water bottle experiment have more kinetic energy in hot air or in cold air? Explain.

b) Make a Micro-View of the air in the bottles from the previous experiment. Then add the Micro-View of the air outside the bottles



Lesson 10: Processes are Hot Topics!

10.1 Observe and Describe

Open the following: http://phet.colorado.edu/simulations/sims.php?sim=States_of_Matter
On the right-hand side of the simulation, click on the radio button for water. Observe water in each "phase" or "state" by clicking on the solid, liquid, and gas buttons.

a) What did you notice about water in each state?

b) Pay particular attention to the movement of the particles, how is it different in each state?

c) What can we say about the energy of the particles in one state of matter relative to another state? *(example: particles in a gas phase versus in a solid phase)*

10.2 Observe and Describe

Observe the following situations and describe what is happening over time.

a) An ice cube sitting on the counter.

b) A boiling beaker of water.

10.3 Hypothesize

Explain what you think happens to the motion of the particles in the material over time?

10.4 Test your Idea

Revisit the simulation from above and simulate the changes from activity 10.2 for water. *(Ice cube to liquid and liquid to vapor).*

a) What happened to the motion of the particles? How did your hypothesis match the outcome of your experiment?

b) What did you have to do in order to change the state of a material from solid to liquid or liquid to gas?

10.5 Explain

a) In order to change states did you have to *physically* add something to the material (put something inside) or did you have to *do something* (a process). Explain

b) When did the particles have the greatest kinetic energy? How did they get this energy?

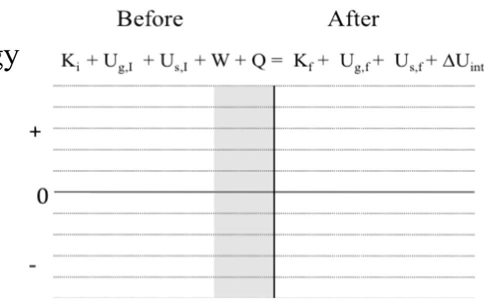
c) Remember from the PUM Energy Unit that a system gains energy when work is done on the system. We can represent this with a bar chart. Create a bar chart that illustrates the energy change in a system as a result of work being done.

d) How is the process of heating a system similar to doing work on a system? Where should we represent this on a bar chart?

e) Imagine that your system is one particle in a solid ice cube. Create an energy bar chart for an ice cube becoming water vapor.

Need Some Help?

Heating is a process, similar to work, that transfers energy from one object to another. Specifically, heating is responsible for transferring thermal energy between the environment and a system. Thermal energy can be expressed as the random kinetic energy of particles. Heating is represented on a bar chart using the variable "Q."



a) If +Q represents the process of heating a system (like the example above), how can we represent the opposite reaction (like water vapor becoming ice)? How would a bar chart look for this reaction?

b) If we consider all the water that makes up the ice cube as our system, we can't say that it's increased in kinetic energy when the ice cube becomes water vapor. What kind of energy would increase as a result of heating? In this situation, what instrument can we use to measure this increase in energy?

10.6 Reason

a) Elmar doesn't think of heating as a process. Instead, she believes that heat is a physical thing that is added or removed from a system. How could we design an experiment to test whether a *physical* thing called heat is added or removed from a system? *(Hint: What qualities do physical objects have?)*

b) Write up your experimental procedures and make a prediction of the outcome of the experiment using Elmar's hypothesis.

Need Some Help?

As you learned throughout this unit, objects have physical characteristics like mass, volume, and density. If "heat" is a physical thing, then it too should have these characteristics. That means that if we heat an object in a closed system, it should increase in mass just like when we added salt to water earlier in the unit.

c) Record the results of the experiment.

d) What does this mean for Elmar's hypothesis? Does the evidence support the concept of heat as an object or heating as a process? Explain.

10.7 Observe and Describe

a) To the best of your ability, describe how the energy is transferred through heating for each of the following examples:

- The top floor of a house gets hot despite the fact that the heater is on the bottom floor.
- A spoon is rested on the side of a metal pot sitting on the stove and it gets very hot.
- The pavement on the playground gets warm on a clear sunny day.

b) Examine the following simulations. How are they similar or different to the examples above?

- http://phet.colorado.edu/simulations/sims.php?sim=Friction
- http://phet.colorado.edu/simulations/sims.php?sim=Microwaves

c) Use the terms convection, conduction, and radiation to classify the different methods of heating discussed above.

Need Some Help?

Conduction is the method of heating through the exchange of energy between particles in a system with particles outside a system. It works best in solids.
Convection is the method of heating through the movement of the hot layers of gases or liquids upwards. When the bottom layer of gas or liquid is in contact with a hot object (flame), it warms up through conduction, becomes less dense and rises to the top. There it cools, become denser, and sinks back to the bottom. Convection occurs only from the bottom layers to the top layers, not sideways. If you warm up the top layers of a liquid, the bottom will stay cold.
Radiation is the method of heating without any contact between cold and hot systems. A hot object emits energy that travels through space. The cold object absorbs it. There is no preferred direction.

---

a) Give 3 additional examples of conduction, convection and radiation.

10.8 Observe and Explain

Place a glass full of cold lemonade in a bowl of hot water. After about 10 minutes, the lemonade in the glass will warm to a new higher temperature and the water in the bowl will cool to that same temperature.

a) Consider the lemonade in the glass as the system and explain this observed process using your knowledge of molecules and their motion. Then use the idea of work-heating-energy principle to explain what happened to the lemonade. Create a bar chart for this situation.

b) Repeat part a, only this time consider the water in the bowl as the system.

c) Use your knowledge of molecules and their motion to explain why when two liquids at two different temperatures mix together, the mixture will eventually reach some intermediate temperature.

Homework

10.9 Observe and Explain

Vigorously rub two pieces of paper together, pressing the fingers of each hand firmly on the paper as you rub it. Consider one piece of paper as the system. Why did the thermal energy of that paper increase? Why does the temperature decrease over time?

10.10 Observe and Explain

a) Explain why heating boards are always placed close to the floor.

b) If we pour hot tea in a paper cup, it feels hot but when we pour it in a Styrofoam cup, it does not feel that hot. Why?

c) Think of how a puffy winter jacket keeps you warm when it is cold outside. Explain.

d) You can hold your hand about 10 cm away on the side of a boiling pot of water. You do not feel any “hotness.” But if you try to hold it 10 cm exactly above the pot, it is burning hot there. Explain.

e) Explain why we need to insulate the house in the summer and in the winter.

f) Explain how you can warm your cold hands by holding them in warm water.

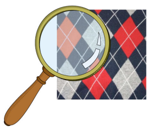
10.11 Observe and Explain

a) Find out what the term “liquid nitrogen” means. Describe how it is similar to water and how it is different.

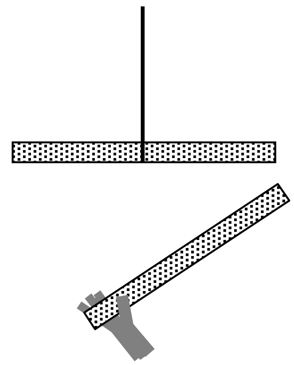
b) Find out what dry ice is. Describe how it is similar to regular ice and how it is different.

Lesson 11: Interaction Between Rubbed Objects

11.1 Observe and Find a Pattern



Suspend one foam insulation tube from a string, as shown in the illustration, and investigate how it interacts with other materials. If you don't have materials available, the experiment can be viewed by following the links below:



- http://paer.rutgers.edu/pt3/movies/OBS_CHANG_INTERC_1.mov
- http://paer.rutgers.edu/pt3/movies/OBS_CHANG_INTERC_2.mov
- http://paer.rutgers.edu/pt3/movies/OBS_CHANG_INTERC_3.mov

a) Bring the end of handheld tube (2) near the end of the suspended tube (1). Record the behavior of the suspended tube in the table that follows. After each observation, touch both tubes several times with your entire hand to "undo rubbing".

Object 1	**Object 2**	**Observed Behavior of Tube 1**
Unrubbed tube 1	Unrubbed tube 2	
Tube 1 rubbed with felt	Tube 2 rubbed with felt	
Tube 1 rubbed with felt	Felt used to rub the tubes	
Tube 1 rubbed with plastic wrap	Tube 2 rubbed with plastic wrap	
Tube 1 rubbed with plastic wrap	Plastic wrap used to rub the tube	
Tube 1 rubbed with plastic wrap	Tube 2 rubbed with felt	
Tube 1 rubbed with felt	Tube 2 rubbed with plastic wrap	

b) Identify patterns in these observations. Devise a possible explanation for the observed behavior.

c) Does the interaction seem to depend on how much rubbing you do? Does your explanation account for this observation?

11.2 Test Your Idea

Assemble two long pieces of nylon (stockings work fine) and a plastic grocery bag.

a) Design an experiment to test whether the patterns you found in activity 2.1 work for the interactions of nylon and the plastic bag. Describe the experimental design.

b) Predict the outcome of your experiment based on the pattern.

c) Perform the experiment and then describe the outcome.

d) Make a judgment about your pattern.

Did You Know?

The phenomena you investigated in this activity are called "electrical phenomena"; they were first observed when people noticed that objects made of amber attracted or repelled other rubbed objects, similar to the way the tubes interacted in your experiments. The Greek word for amber is "electron", thus the phenomena were called electric phenomena.

11.3 Hypothesize

In the first two activities you found a consistent pattern: Identical objects rubbed with a second material repel each other. The second material in turn attracts the objects it rubbed. And the strength of the interaction depends on how much the objects are rubbed. Think of a mechanism that might explain why rubbing objects makes them attract or repel each other.

Need Some Help?

Definition of mechanism: the structure or arrangement of parts of a system or a process working together to produce an observed effect.

Example: A pen was on the table and then disappeared. A possible mechanism explaining the disappearance would be that James took it.

11.4 Design an Experiment

You have two foam tubes (one of which can be suspended as in 2.1) and felt. Design an experiment to investigate what factors affect the magnitude of the electric force that the two foam tubes exert on each other.

Homework

11.5 Explain

Your clothing tends to cling together after going through the dryer. How might this occur in the dryer? Is your answer consistent with what you observed in class? Explain and represent your answer with a picture.

11.6 Explain

Experiment with materials that you have at home to establish which ones participate in electric interactions. Try to find the objects that attract each other and the objects that repel each other. Make a list below.

Lesson 12: Electric Charged Particles Inside Materials: Part I

12.1 Observe and Find a Pattern

Explore how two magnets interact. Place one magnet on a swivel (or suspend it horizontally from a string) and observe its interactions with another magnet. Record your observations.

12.2 Test an Idea

Your friend Josh says that electric interactions are the same as magnetic interactions because magnets also attract and repel each other. Consequently, he believes that when you rub objects, they become magnetized. Assemble a magnet on a swivel (or suspend it horizontally from a string), two foam tubes, felt, and plastic wrap.

a) Design an experiment to test Josh's hypothesis that rubbing causes materials to become magnetic.

b) Sketch the experimental set-up.

c) Predict the outcome of your experiment based on Josh's idea.

d) Perform the experiment and then describe the outcome.

e) Make a judgment about Josh's idea based on the outcome.

f) Use the rubrics below to help with your reasoning.

Scientific Ability	Missing	An attempt	Needs some improvement	Acceptable
Is able to distinguish between a hypothesis and a prediction	No prediction is made. The experiment is not treated as a testing experiment.	A prediction is made but it is identical to the hypothesis.	A prediction is made and is distinct from the hypothesis but does not describe the outcome of the designed experiment.	A prediction is made, is distinct from the hypothesis, and describes the outcome of the designed experiment.
Is able to make a reasonable prediction based on a hypothesis	No attempt to make a prediction is made.	A prediction is made that is distinct from the hypothesis but is not based on it.	A prediction is made that follows from the hypothesis but does not have if-and-then structure.	A prediction is made that is based on the hypothesis and has if-and-then structure.
Is able to make a reasonable judgment about the hypothesis	No judgment is made about the hypothesis.	A judgment is made but is not consistent with the outcome of the experiment.	A judgment is made and is consistent with the outcome of the experiment but assumptions are not taken into account.	A reasonable judgment is made and assumptions are taken into account.

Did You Know?

Electric charge: Electric charge is a physical quantity characterizing the property of objects that participate in electrostatic interactions.

12.3 Observe and Explain

a) Recall that a foam tube rubbed with felt and the piece of felt that was used to rub the tube attract each other. Describe the mechanism that you invented in lesson 11 that can explain the attraction between a foam tube rubbed with felt and the piece of felt that was used to rub the tube.

b) Hang an unrubbed foam tube (horizontally) and bring another tube rubbed with felt near it (without touching). Observe and record the observation. Next, use the same hanging tube but this time, bring a tube rubbed with plastic wrap close to it. Observe what happens and record your observation.

c) Devise a microscopic mechanism that will account for both observations.

d) This time instead of a foam tube, hang a metal bar. Repeat the experiment you did in part b) and record your observations. (Instead of hanging the rod you can put it on a swivel.)

e) Devise a microscopic mechanism that will account for both observations.

12.4 Observe and Explain

a) Observe the videotaped experiments and explain the outcomes using your new knowledge of the internal structure of materials:

- http://paer.rutgers.edu/PT3/experiment.php?topicid=10&exptid=189
- http://paer.rutgers.edu/PT3/experiment.php?topicid=10&exptid=190

b) Which material (the metal can or plastic bottle) allows the negative charges to move more freely throughout the material? How did you come to this conclusion?

12.5 Test Your Idea

a) Read the description of the experiment at the website below. Use the charge model you developed during the last two lessons to predict what will happen to the disc for each case.

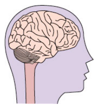
b) Now observe the experiment.

- http://paer.rutgers.edu/pt3/experiment.php?topicid=10&exptid=191

c) Why do you think nothing happened to the disk when the experiment was repeated with the plastic bottle?

d) Did your prediction match your outcome? What assumptions did you make? How can you alter your model to more accurately represent the charge distribution in a substance?

Homework



12.6 Reason

What can you say about the internal structure of objects such as foam tubes and the metal bar in terms of electrically charged particles?

12.7 Apply

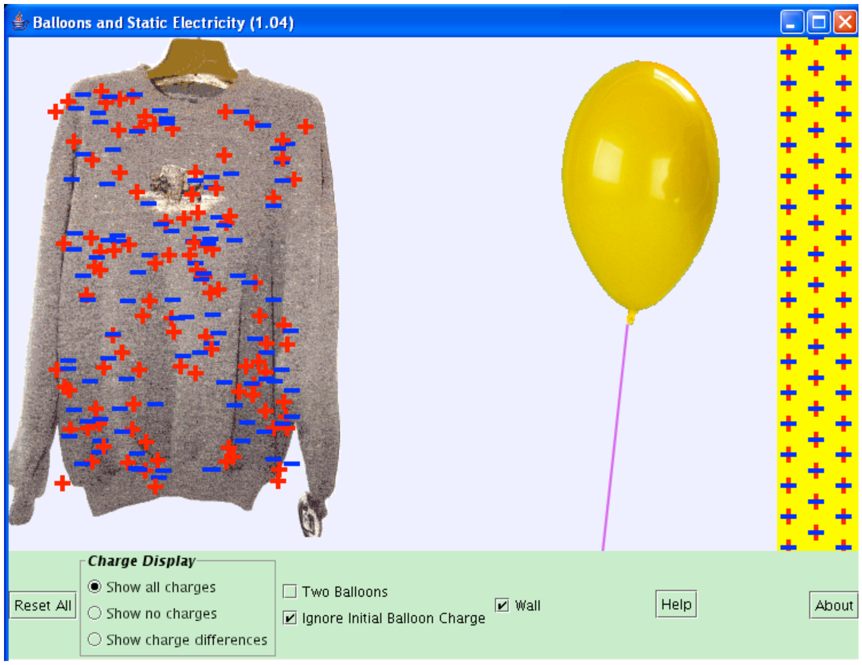
List everyday experiences that are consistent with these new observations.

Lesson 13: Electric Charged Particles Inside Materials: Part II

13.1 Observe and Explain

Go to the webpage below and download the simulation shown in the picture below.

http://phet.colorado.edu/simulations/sims.php?sim=Balloons_and_Static_Electricity



a) Click on the balloon and drag it towards the sweater. Rub the balloon on the sweater. Examine the charged particles. What happens? Which ones move? How does the amount of rubbing affect the number of charged particles that transfer? What is the overall charge of the balloon? What is the overall charge of the sweater? How do you know?

b) Drag the balloon to the space between the sweater and the wall. What happens to the balloon when it is released? What do you notice about the speed of the balloon, as it gets closer to the sweater? How do you explain it?

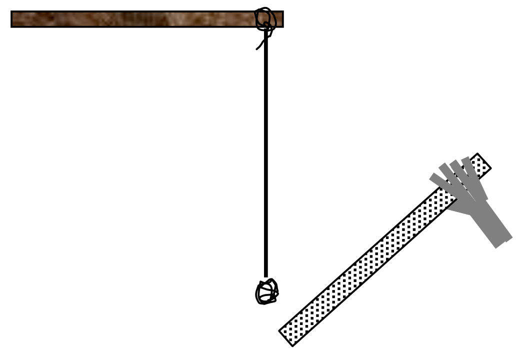
c) Drag the balloon close to the wall. What happens to the balloon when it is released? What happens to the charged particles in the wall? What is the charge of the balloon? What is the overall charge of the wall? What material is the wall comparable to from the previous lesson?

d) Click on the box for “Two Balloons”. Rub the balloons on the sweater, one at a time. Bring one balloon close to the other. What is the overall charge of each balloon? What happens when one balloon is released close to the second balloon?

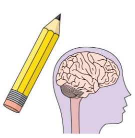
e) Evaluate the simulation. Is it consistent with the ideas developed earlier?

13.2 Test Your Idea

Hang a small piece of aluminum foil from a 30-cm-long piece of thread, which is tied at the top to a plastic or wooden rod (for example, a ruler). Use the ideas that you devised in previous lessons to predict what happens when you bring the end of a foam tube rubbed with fur near the piece of foil. Then repeat the procedure using a foam "peanut" (standard packing material) hanging from the thread.



	Predict what you will observe	**Explain your prediction**	**Do the experiment and write down your observations**	**Revise your explanations if necessary**
Aluminum foil suspended on string				
Packing peanut suspended on string				



13.3 Represent and Reason

Create a MicroView that describes the charged particles that make up the materials in the following situations.

a) Alicia says that her car seat is negatively charged. Make a MicroView of her car seat, and try to explain to Alicia how her car seat possibly got that way in terms of the particles that make it up.

Need Some Help?

We can modify the MicroView to describe charged particles. In place of the small dots, we'll use the convention invented by Benjamin Franklin.

For one type of charged particles we will use a "+" sign in place of the dot on the MicroView. When we use that symbol to describe the excess charge, we refer to the object as being **positively charged**. For the opposite type of charged particles we will use a "-" sign; we call the object **negatively charged** when there is an excess of the opposite type of charged particles.

b) Dan complains about his hair being negatively charged and unmanageable. Make a MicroView of Dan's hair, and try to explain to him how his hair may have gotten that way in terms of the particles that make it up.

13.4 Represent and Reason

After a foam tube and fur are rubbed together, the negatively charged foam tube is then rubbed on a conducting sphere. Draw a picture of the charged particles right before the two objects (tube and conducting sphere) touch, then one a few seconds after the charged particles have been transferred to the conducting sphere.

13.5 Test Your Idea

a) Design an experiment to test your idea: represented in the picture in 13.1 and the experiments in 13.2.

b) Make a prediction for the outcome of this experiment. Use diagrams to help you explain your prediction.

c) Conduct the experiment and record the outcome.

d) Modify your hypothesis if necessary.

13.6 Reason

Does it matter where you touch a conducting sphere or metal rod with a foam tube rubbed with felt? Explain.

13.7 Reason

Very careful physics experiments, with sensitive scales, show that when you charge an object by rubbing, whether it becomes positively or negatively charged, the mass of the object changes only a very tiny, tiny amount. This same result is found even when the rubbed object obtains a very strong charge. What do these experiments tell us about the charged particles that get transferred between objects during rubbing?

Did You Know?

Physics experiments and reasoning indicate that only the negative charged particles are able to move. Therefore, when an object is rubbed, negatively charged particles (electrons) can either be added to or removed from a material.

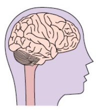
Homework

13.8 Observe and Represent

Rip up paper into confetti-sized pieces and place them on a table. Rub a foam tube (or PVC pipe or a plastic comb) vigorously and place it above the paper.

a) Observe what happens and record.

b) Sketch a picture of the experiment at the macroscopic level when the foam tube is far away, then another when it is brought near. Draw a force diagram representing the situation.



13.9 Represent and Reason

Two conducting spheres have an excess of negative charged particles and are placed very far apart from one another.

a) Draw a picture of the spheres when they are very far apart.

b) Draw a picture of the spheres when they are close together, but not touching.

c) Draw a picture of the spheres when they are moved far apart again.

Repeat for a positive and a negative charged sphere.

Did You Know?

Electric charge properties:

- Electric charge comes in two types – positive and negative; like-charged objects repel and unlike-charged objects attract. Historically, charge that accumulated on a glass rod rubbed with silk was called positive, electric charge accumulated on a resin rod rubbed with fur – negative.
- In neutral or uncharged objects, the amount of positive charge is equal to the amount of negative charge.
- Electric charge cannot be created or destroyed but only redistributed between objects.

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neutral

take away two negative charges

zero pairs and two unpaired positive charges

- (-2) = +2

Lesson 14: Quantifying Opposite Charges

14.1 Reason

What does it mean for a material to have a zero net charge?

Did You Know?

Integers help us to quantify opposites, and zero helps us to represent neutrality. Zero net charge means that all for every of the charged particles of one sign there is another particle of exactly the same in magnitude but oppositely charged..

When it comes to charge, neutral means balanced. All matter contains a very, very large number of charged particles, but they balance out each other's effect on the outside world. For every positively charged particle in a neutral object, there is a negatively charged one and the two together neutralize (or cancel) each other's effect on the outside world.

14.2 Represent and Reason

Zero pair blocks are blocks, such as Legos, that have two colors. Each side representing +1 and -1; together they have a total combined value of zero. Using the zero pair blocks, demonstrate how an object will lose or gain negative charge. Write a math statement to describe how the net charge of the material changes.

a) A neutral object gains 3 negative charges.

b) A neutral object loses 4 negative charges.

c) An object that has a +2 net charge gains negative charges and becomes neutral.

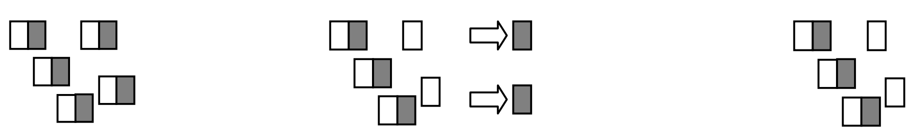
d) An object that has a +5 net charge gains 3 negative charges.

e) An object that has a -3 net charge is neutralized.

f) An object that has a -4 net charge loses 5 negative charges.

Need Some Help?

Write a math statement to describe how the net charge of the material changes when a neutral object loses 2 electrons (negatively charged particles):



14.3 Reason and Represent

You rub a plastic tube with felt and thereby transfer 10 negative charges from the tube to the felt.

a) Draw MicroViews that show the net charge on the tube and felt before and after rubbing them together.

b) Write a math statement that describes the charge transfer for the felt.

c) Write a math statement that describes the charge transfer for the tube.

d) Explain why the felt and the tube are attracted to each other after having been rubbed together even though they don't interact at all before they are rubbed together. This explanation should be based on your answers to b and c above. Make sure you use the terms *charged, neutral, transfer* and *net charge* correctly.

Homework

14.4 Represent and Reason

You rub a plastic tube with plastic wrap and thereby transfer 15 negative charges from the plastic wrap to the tube.

a) Draw sketches that show the net charge on the tube and plastic wrap before and after rubbing them together.

b) Write a math statement that describes the charge transfer for the plastic wrap.

c) Write a math statement that describes the charge transfer for the tube.

d) Explain why the plastic wrap and the tube are attracted to each other after having been rubbed together even though they don't interact at all before they are rubbed together. This explanation should be based on your answers to b and c above. Make sure you use the terms *charged, neutral, transfer* and *net charge* correctly.

Lesson 15: Putting It All Together

15.1 Hypothesize

Which charge makes up most of the mass of a particle? How did you reach this conclusion?

15.2 Test Your Idea

a) How could we test whether it is the negative charge (electron) or the positive charge (proton) that makes up most of the mass?

b) Create a list of procedures and then perform the experiment.

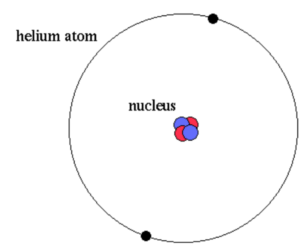
c) Describe any assumptions that you made.

Need Some Help?

When you charge an object, you are either adding or removing negatively charges. You can attempt to find the mass of the object before and after it has been charged. If electrons are responsible for most of the mass of the particle, we should see a noticeable difference once the object is charged.

d) Record the outcome of the experiment and evaluation your prediction.

15.3 Represent and Reason

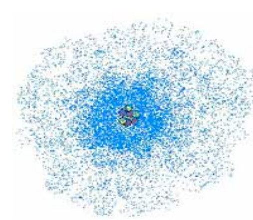


a) Examine the representation on the right. This is a Rutherford model of a particle or *atom.* Where would the electrons have to be located in the atom in order to be easily transferred?

b) Where would the positive charges or protons be found in the atom?

Did You Know?

Rutherford was an influential scientist that performed many experiment in order to develop an understanding of the structure of an atom. Since Rutherford's time scientists have developed more sophisticated models of atoms. The picture on the right represents our current understanding of an atom's structure. The blue dots represent the possible positions of electrons over time. The more dots, the more likely an electron occupies a certain position.



c) How are the two representations similar? How are they different?

15.4 Explain

a) On average, are atoms and molecules in a material found with a neutral, positive, or negative charge? What does that mean about the number of protons and electrons in an atom? Explain.

b) The tile on the right is an excerpt from the periodic table of elements. The "C" is the chemical symbol and stands for the element carbon. The bottom number represents the atomic mass of the atom while the top number is the atomic number and represents the number of protons in the atom. How many electrons would a neutral Carbon atom have?

6 **C** Carbon 12.0107

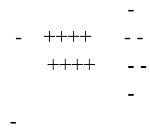
c) If atoms and molecules are neutral, why are they held together? In other words, if the atom or molecules in an object are neutral and aren't attracted to one another, why don't objects just fall apart?

15.5 Observe and Describe

To help us understand how materials are held together we need to perform a class demonstration. Eight students in the class need to huddle together in a tight circle. These students represent protons in the nucleus. Eight additional students will represent electrons. However, where will they stand? We saw in the electron cloud model of an atom that electrons have tendencies for certain positions but they can appear anywhere around the nucleus of the atom. To simulate this we will have each of the 8 students randomly choose whether they want to stand on the left or the right side of the "nucleus." We'll repeat this 10 times to represent how the electrons might change over time. Keep track of the choices for each of the students in the table below.

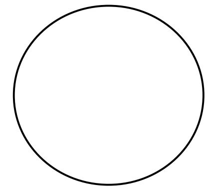
Trials	# of students on the left	# of students on the right
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

15.6 Represent and Reason



Represent each trial by drawing a MicroView of the charges.

Ex: 8 Protons, 2 electrons on the right, 6 on the left side.



a) If we consider the atom at one point in time, how does the charge on one side compare to the charge on the other side? What is the total charge of the atom over the course of several minutes?

b) What kind of charges would be attracted to the left side in the example above? What about the right side?

c) Determine the charge on either side of the atom for each of your ten trials.

d) Using the ideas you just constructed, why might one atom be attracted to its neighboring atom in an object?

e) If atoms and molecules are overall neutral, why are they held together? In other words, if the atom or molecules in an object are neutral and aren't attracted to one another, why don't objects just fall apart?

Did You Know?

The interaction between particles that you just constructed is called the Van der Waals force. This electrostatic interaction is responsible for holding one neutral particle to its neighboring neutral particle making up a larger object.

15.7 Observe and Explain

Revisit the simulation from the beginning of the lesson 13.1 and click on the tab at the top that says interaction potential.

a) Place one of the particles a short distance from the stationary particle. Describe what occurs. Now, place one of the particles at the very edge of the screen. Describe what occurs.

b) At what distances do Van der Waals forces act?

c) Why might the two particles start moving away from each other?

Homework

15.8 Reason

a) Write a story about a system that has negative heating occur.

b) Draw a picture of the initial and final states and identify your system.

c) Create an energy bar chart to represent the process.

d) Explain why particles in an object move, even in a solid.

Lesson 16: Summary and Review

16.1 Reason and Represent

Imagine you have a desk, an "empty" water bottle and a water bottle filled with water. If we had special glasses that allowed us to see the smallest pieces, what would we see? What would look the same inside the desk and the two bottles? What would look different? How can you represent your ideas with a picture?

16.2 Reason

You have two cylindrical blocks – one made of steel and the other one made of aluminum. You put them on the scale and the scale reads 100 g for both.

a) What can you determine about the cylinders using this information?

b) If you could draw those cylinders next to each other, what would they look like?

c) If you placed them in a graduated cylinder filled with water, what do you expect to happen?

16.3 Reason

You have a potato, water, and salt. You place a potato in water and it sinks. Then you add salt to the water and eventually the potato starts floating on top of water.

a) Explain why this happens.

b) Draw a MicroView of fresh water and salty water.

c) Describe an experiment that you can perform to determine the density of the potato.

d) Describe an experiment you can perform to determine the density of salty water.

16.4 Predict and Explain

You open a bottle of perfume in a classroom full of students.

a) Predict what you will observe.

b) Draw four successive MicroViews of what is happening inside the air in the room. Use different color pencils to represent different kinds of particles.

c) Explain what is between the air particles.

16.5 Predict and Explain

You have two identical cups with water. In one cup the temperature of water is 30^0 C, in the other one the temperature is 80^0 C. Predict what will happen if you place a tea bag in each cup. Explain your prediction.

16.6 Predict and Explain

You place a spoon in the second cup in the situation described in 16.5. Predict what will happen to the spoon. Explain your prediction.

16.7 Observe and Explain

a) On a hot day you probably noticed that the second floor in a two-story house is warmer. Explain.

b) A Styrofoam cup is sitting on a metal desk. You touch the desk and it feels cool. You touch the cup and it feels warm. When you use the surface thermometer to measure the temperature of the surface of the desk and the cup, they are the same, 20^{0}C. How can this be?

c) If you place your hand above a campfire, it feels much hotter than when you place it on the side. Explain.

d) How does a thermos work?

16.8. Reason

20 ml of salt is added to 100 ml of water. The result is 110 ml of salt water.

a) Draw a MicroView of the water before and after the salt is added.

b) Explain why you think there is not 120 ml of salt water.

c) Does the mass of the water and the mass of the salt add up to the mass of the salt water? Explain.

d) What is the density of salt water? Is it higher or lower than the density of fresh water?

e) Why can people float in the Dead Sea but they cannot float in a lake?

16.9 Reason

You have a plastic comb with a zero net electric charge. You rub the comb with a piece of felt that makes it negatively charged. Imagine that the total negative charge is equal to -17 units of charge.

a) Draw sketches that show the net charge on the comb and felt before and after rubbing them together.

b) Write a math statement that describes the charge-transferring process for the felt.

c) Write a math statement that describes the charge-transferring process for the comb.

d) Explain why the felt and the comb are attracted to each other after having been rubbed together even though they don't interact at all before they are rubbed together.

16.10 Reason

a) You have two cubes – one made of copper and the other one made of aluminum. The side of each cube is 4 cm. Make a list of quantities that you can determine about those cubes (at least 5 for each) and determine them.

b) Now you have bigger cubes – each has a side of 8 cm. Compare the same quantities characterizing these cubes with the quantities you determined for the cubes in a). How did each quantity change? Do you see a pattern?

c) Is there anything about the cubes that did not change? How can you test your answer?

16.11 Design an Experiment

Each group of students in your class will find a rock or a piece of wood. All groups will design experiments to determine the density of their objects. They need to decide what equipment they need, what data to collect and how to analyze the data. The groups will perform their experiments. How certain is each group in the value of the density that they obtained?

After everyone is done, you will decide how you can represent the data for different objects. Are there any patterns? Decide what you can conclude from the patterns.