How can containers keep stuff from warming up or cooling down?

OpenSciEd

MIDDLE SCHOOL SCIENCE

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Cup Design

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Cup Design

The development of this material was supported by the Bill & Melinda Gates Foundation, Carnegie Corporation of New York, Charles and Lynn Schusterman Family Foundation, and William and Flora Hewlett Foundation.

This unit was adapted from *Energy: How can we design a device to warm something up?*, originally co-developed by San Francisco Unified School District and SCALE at Stanford University 2017–2018. Used with permission. *Energy: How can we design a device to warm something up?* was developed with funding from Lucas Education Research, part of the George Lucas Education Foundation.

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Student Procedures

Lesson 1: Why does the temperature of the liquid in some cup systems change more than in others?

Staying cool

Turn and talk

1. Discuss these questions:

- Why does the drink in the regular cup warm up?
- How could the fancy cup keep the drink from warming up?

Test the 2 cups

In your notebook

2. Write this claim at the top of a new page in your science notebook.

Claim: The fancy cup works better than the regular cup.

3. Below the claim, write down ideas about how you could test the claim and the evidence you want to collect to prove or disprove the claim.

4. Be prepared to share your thinking with a elbow partner first, then with the whole class.

Cold Cup Test

With your class

5. Discuss this question with your class:
    - What do we need to do to make this a fair test between the 2 cups?

6. Draw a data table in your science notebook following your teacher's instructions. It will look something like this:

Temperature change (°C)

Time	1 min	__ min	__ min	__ min	Temp change
Regular cup					
Fancy cup					

7. Record the temperature measurements of the 2 cups after 1 minute.

8. Write the title "Cold Cup Test" at the top of your page.

9. While you wait for the second measurement, identify what is similar and different about the 2 cups and what this makes you wonder.

10. When instructed by your teacher, make visual observations of the outside of the cups and note what you can see and feel with each cup.

Systems we are trying to explain

Turn and talk

11. Think about what parts we should include if we want to make a model of the cup systems.

    - What are the parts of each cup system?
    - What does each part do in the system?
    - How do the parts work together to keep a drink cold?

In your notebook

12. Draw systems models for the regular cup and fancy cup.
    - Your models should explain how the drink in the regular cup warms up and how the fancy cup could keep the drink colder for longer.
    - Use symbols, color, and words to help you communicate.

13. Remember to continue recording temperature data when directed by your teacher.

Initial conclusions and home learning

With your class

14. Discuss this question:
    - What conclusions can we draw from the temperature data?

15. When you are at home, look for systems that keep something inside them the same temperature (either hot or cold). Make sure to look for systems that do not use electricity to do their job.

Navigation

In your notebook

16. Turn to your science notebook page with the *Cold Cup Test*.

17. Look back at the claim and your class data.

    Claim: The fancy cup works better than the regular cup.

18. What conclusions did we come to in the last class? Write those conclusions below your data table in your science notebook.

19. Be prepared to share those conclusions with a partner and then with your class.

Select a norm for the day

Turn and talk

20. Discuss these questions with your partner:
    - What community norm do you want to focus on during our work today?
    - Why did you choose this norm?

Models help us explain how and why

The goal of this discussion is to figure out areas of agreement and disagreement in our initial models. We also want to think about what is causing the drink to warm up inside both systems and to warm up more in the regular cup.

With your class

21. Bring your science notebook and a chair with you to a Scientists Circle.

22. Discuss this question:
    - ***Why*** does one cup system keep water cold for longer than the other cup system?

23. First share your cup system models with a partner. Take turns listening to each other and asking questions of each other's models.

24. Share your models with your class. Our discussion is guided by these questions:
    - What do we all seem to agree on?
    - What do we disagree on?
    - What are some new ideas that we may want to consider?

Related phenomena

The purpose of this activity is to share what you found out about similar systems and objects that can keep something inside them cold or hot.

With your class

25. Discuss the following questions:
    - What kinds of systems and objects maintain the temperature of the stuff inside without using electricity?
    - How do these things work?
    - Is it the same or different depending on if cold or hot stuff is inside?

26. Revisit our consensus model:
    - Are there any new things we need to track in our models?
    - Do you think our ideas in our class model for the fancy cup might apply to some of these other systems and objects too?

Exit Ticket

On your own

27. Find a new page in your science notebook and title the page "Related System Model".
28. Pick 1 object or system from the Related Phenomena poster and draw a model to explain how *you think* the item works to keep something inside it cold or hot.
    - Step 1: Diagram the important parts of the system: inside, outside, and any important structural features.
    - Step 2: Use the model to answer these questions:
        - How does the thing inside warm up or cool down?
        - How do the parts of the system work together to keep this from happening?
    - Step 3: Use colors, symbols, and words to help you.

Silent Gallery Walk

On your own

29. Quietly walk around the room and look at others' models for related phenomena. Look for *similarities* and *differences* in these things:
    - what causes things to warm up or cool down
    - structures of the systems that stop this from happening

What questions do you have now?

On your own

30. Take a minute to review
    - your models for the regular cup and fancy cup,
    - your model for the related phenomenon, and
    - what you noticed and wondered in the gallery walk.

With your partner

31. Brainstorm with your partner how to turn your ideas into why and how questions to explain the cups and the related phenomena.

32. Then, write your questions:
    - Write 1 question per note card.
    - Use big, bold, and clearly readable handwriting.
    - Put your initials in pencil on the back of each note card.

Driving Question Board (DQB)

With your class

33. How to build a Driving Question Board:

> a. The first student reads his or her question aloud to the class, then posts it on the DQB near the part of the model the question most relates to.
> b. Students should raise their hand if any of their questions relates to the question that was just read aloud.
> c. The first student selects the next student whose hand is raised.
> d. The second student reads his or her question, says why or how it relates, and posts it near the question it most relates to on the DQB.
> e. The student selects the next student to share a related question or a new question.
> f. We will continue until everyone has at least 1 question on the DQB.

Ideas for investigations

With your class

34. What kind of investigations could we do and/or what additional sources of data might we need to figure out the answers to our questions?
    - Talk with a partner first, then be prepared to share your ideas with the class.

Lesson 2: What cup features seem most important for keeping a drink cold?

Reviewing our data and ideas

Turn and talk

1. Discuss the questions:
   - Which features seemed to matter most?
   - What do you think we'll see if we test these features?

Setting up a fair test

Turn and talk

2. You will modify 1 of the cups, either the regular cup or fancy cup. You will only be able to modify 1 thing about the cup. Think about what you would want to change. Discuss these questions:
   - What different parts of the system do we want to test?
   - What should be kept the same across all our tests?
   - How often should we record temperature, and for how long?

In your notebook

3. Find a new page in your science notebook and title it "Testing Cup Features".
4. Write the conditions your class agreed should be the same for all the tests.
5. Draw a data table following your teacher's instructions. The data table will likely look similar to this:

Time (minutes)	Temperature (°C)
0 (starting temp)	
3	
6	
9	
12	
15	

Plan cup investigation in small groups

With your group

6. Below your data table, write your planned modification to the cup.
   - Decide which is your control cup--the regular cup or fancy cup.
   - Decide which cup feature you will test (modify).
   - Make a plan to test your cup and write it down.

Carry out the cup investigation

With your group

7. Set up your investigation. Follow your investigation plan.
8. Remember, everyone starts/ends together. Record the starting temperature in your data table.

In your notebook

9. While you wait to record the next temperature, draw and label a diagram in your notebook. Draw your diagram on the page opposite your data table and investigation plan.
    - Draw the original cup you are comparing to (regular cup or fancy cup).
    - Use a different color to show what you changed and to show how or why this change will affect your results.
10. Record the temperature in your data table every few minutes.
11. Give your group's data to your teacher before you leave class.

Analyze class data

With your group

12. Review your own data first. Then discuss the following questions:
    - What conclusions can you draw from your data?
    - Do you think that your group's test was reliable? How do you know?
13. Review your class data table. Brainstorm different ways you can organize and sort the data. Decide on 1-2 ways you can sort the data.

With your class

14. Share 1-2 ways you can sort the data.
15. As your class sorts the data, identify patterns about different features that were tested. Can you tell if any of these features are related to temperature change?

In your notebook

16. Find a new page in your notebook and title it "Data Analysis: Cup Investigations". Record what patterns you notice when your class sorts the data. Think about the following questions:
    - How does the data look different now?
    - What patterns do we notice?
    - Are there any parts of the system without a clear pattern?
    - What does this make us think?

With your group

17. Continue to sort the data to identify more patterns.
18. Record the patterns you notice in your notebook.
19. Be prepared to share your patterns with the class.

Progress Tracker: What have you figured out?

In your notebook

20. Turn to the pages in your notebook reserved for your Progress Tracker.
21. Write "Progress Tracker" at the top of the page.
22. Draw a T-chart down the page. Write "Question" on the left side and "What I've figured out" on the right side.

Question	What I've figured out

23. Write the lesson question in the left column: "What cup features seem most important for keeping a drink cold?"
24. Write/draw what you figured out in the right column.

Order the cups by performance

With your class

25. Discuss what cup features seem most important for keeping a drink cold.
    - Which cup features are we more certain about?
    - Which cup features are we less certain about?
26. Place the cups in order from best to worst performers.
27. Do you think the cups that work well to keep things cold would also work well to keep things hot?

Lesson 3: How are the cup features that keep things cold the same or different for keeping things hot?

Navigation

Turn and talk

1. Discuss these questions:
   - Why did we order the cups in this way?
   - Do you think this order would stay the same if we added hot water in the cups instead?

Designing a test with hot water

Turn and talk

2. You decide to add hot water to the cups. Discuss these questions:
   - What things do we need to think about to ensure that we are conducting a fair test?
   - Why is it important to conduct a fair test?

Plan the Hot Water Test

In your notebook

3. Find a new page in your science notebook and title it "Hot Water Test".
4. Write down what your class agreed should be the same.
5. Draw a data table following your teacher's instructions. The data table will likely look similar to this:

Time (minutes)	Temperature (°C)
0 (starting temp)	
3	
6	
9	
12	
15	

Conduct the Hot Water Test

With your group

6. Set up your investigation following your class's agreed-upon plan.
7. Remember, everyone starts and ends together. Record the starting temperature in your data table.
8. Record the temperature in your data table every few minutes.
9. After 15 minutes, calculate your overall temperature change and record it on the class data table.

Analyze class data

With your group

10. Look at the class data for the tests with cold and hot water.
    - What patterns do you notice in the data?
    - How did our findings compare to the test with cold water?
    - What additional questions do you have?

11. Write your answers to these questions on the page opposite your data table.

Best and worst performers

In your notebook

12. Pick out a cup that performed well for both cold and hot water. Pick out a cup that did not perform well.
13. Draw a model to explain why one cup works better at keeping liquids hot *and* cold compared to the other cup. Draw this model near your hot water data analysis or on a new page.
    - Use colors, symbols, and words to explain how one cup works better than the other cup.

With your group

15. Share your best-performing versus worst-performing cup models.
16. Add ✓ to the parts of your model that have evidence to support your ideas.
17. Add ? to the parts of your model where you need more evidence or more information.

Progress Tracker: What have you figured out?

In your notebook

18. Turn to the pages in your notebook reserved for your Progress Tracker.
19. Draw a line under your last entry.
20. Write the lesson question in the left column: "How are the cup features that keep things cold the same or different for keeping things hot?"
21. Write what you figured out in the right column. You can use pictures and words.

Plan an investigation to test the lid

With your class

22. On your *Investigation Plan* handout, label the cup feature your class will investigate.
23. Brainstorm the investigation question together.
24. Record your class's agreed-upon investigation question.

With your class

25. Decide the independent variable for the investigation. This is the variable you plan to change in your investigation.
26. Decide the dependent variable. This is what you will measure.
27. Decide all the variables that you want to keep constant, or the same, in your investigation.
28. Imagine you will test a cup of hot water with a lid and without a lid. Write a list of procedures to follow to conduct a fair test.

Agree on how to test the lid

With your class

29. After your class discusses variables, make edits to your investigation plan using a different colored pencil or ink to show the changes.
30. Then write the new set of procedures your class agreed upon in the right-hand column of your handout under *Procedures*.

Lesson 4: How does a lid affect what happens to the liquid in the cup?

Set up predictive models during the investigation

In your notebook

1. On the top of the next page of your science notebook, add this title: “My models showing what I predict is going to happen to the hot water in both systems and why:” Below that label, use half of the page to draw two predictive models during the lab:
   - (A) Cup with a lid
   - (B) Cup without a lid
2. Review where you will post your group’s data for the entire class to reference.
3. Review the safety guidelines for the lab with your class.

Carry out Cup Lid Lab 1

With your group

4. Refer to the procedures you created for this lab in the last lesson. Carry out your investigation with your group.
5. Put a check mark next to each step of your procedures as it is completed.

Pooling our results

With your class

6. Pool all of the results into a class data table. Your class data table will look like this

Group	Temperature change (°C) in cups with no lids	Temperature change (°C) in cups with lids
1		
2		
3		
....		

Discussing averages

With your class

7. Discuss the questions below, first with a partner and then with the whole class:
   - Have you learned how to calculate the average (or the mean) of a set of numerical data in math class this year?
     - If yes: Why might it be easier to compare the average temperature change from systems with lids to the average from systems without lids, rather than try to compare all of the data at once?
     - If no: How have you heard the word *average* used outside of math class?
8. Review how to calculate a mean as a class.

In your notebook

9. Calculate the mean temperature changes for both conditions.

Arguing from evidence

With your class

10. Read through the claims listed below on your own. Then pick the one(s) that apply to our class data. Be ready to share why you didn't select the other choice(s) with the whole class.
    A. A cup with a lid causes a hot liquid in the cup to drop in temperature ***more than*** in a cup without a lid.
    B. A cup with a lid causes a hot liquid in the cup to drop in temperature ***less than*** in a cup without a lid.
    C. A cup with a lid causes ***no difference*** in the amount a hot liquid drops in temperature compared to a cup without a lid.

Navigation

With your group

11. Turn and talk with a partner about these questions:
    - Do you think anything was getting into or out of either of our 2 cup systems as the liquid in them was cooling down?
    - How could weighing each system at the start and end of an experiment like today's first lab help us figure that out?

Developing a new plan

With your class

12. Discuss which variables would change and which ones would stay the same in this new experiment, compared to those in the previous experiment.

With your group

13. Record a new procedure on the top of your handout *Procedure: Measuring Changes in Mass in the Cups* for this next investigation based on what you would change from your old investigation and what you would keep the same (use both columns).
14. Make a new data table to record the relevant data for this investigation.

15. Your teacher may ask you to turn in this handout before the next step.

Cup Lid Lab 2: Make predictions

In your notebook

16. Record your predictions in the first row of the data table on *Procedure: Measuring Changes in Mass in the Cups*. Add this handout to your science notebook.

With your group

17. Carry out your investigation with your group.
18. Mark off the steps in your procedure as you complete them by putting a check mark next to each step as it is done.

Pooling our results: Mass change

With your class

19. Pool all of the results into a class data table. Your class data table will look like this:

Group	Change in mass (g) in cups with no lids	Change in mass (g) in cups with lids
1		
2		
3		
....		

With your group

20. Discuss the following and record it in your handout's *Making Sense* section:
    - Calculate and record the average difference in mass for conditions *A* and *B*.
    - Record your answer to these questions in the *Making Sense* section of your handout, *Procedure: Measuring Changes in Mass in the Cups*.
        - Which system(s) lost mass?
        - Matter has mass. So what matter might have left the system(s) that lost mass?

Developing a model

On your own

21. Develop a model to answer the question "What is happening to the liquid water that can explain why the mass of the cup system decreases over time?"
22. Then use your model to make a prediction.
23. Be ready to share your ideas with your class.

Analyzing time-lapse and slow-motion videos

Turn and talk

24. Discuss with your partner:
    - If we didn't have a scale to measure the mass, what are some other ways we could tell if the amount of water in the system was decreasing over time?

With your class

25. Share your thinking with your class about what is happening to the water, where it is going, and why we cannot see the water leaving the first container but we can see it leaving the second container.

Developing and using a model we can manipulate

With a partner

26. You and your partner will need the handout *Manipulative Mat for a Model of Matter at the Surface of the Liquid* and a bag of 19 blue chips (or something similar provided by your teacher).
27. Add one blue chip to the key to represent one water molecule. Label your key.
28. Use the remaining chips to represent the liquid water in the cup system right near the surface.
29. Move the chips around to show
    - how the water level could drop over time and
    - where the mass that is lost by the system goes.
30. Add a yellow chip to represent other gas particles that make up the air (that are not water molecules).

Updating our class Progress Tracker

You will add this class Progress Tracker sheet to your notebook on a new page in your Progress Tracker section. Today's Progress Tracker is different from other entries you have made. Before today, you focused on what you figured out individually. Now, your class will decide what the class has figured out and agreed upon.

With your class

31. On your class Progress Tracker, write the lesson question "How does a lid affect what happens to the liquid in the cup?"
32. Then add the sources of data you used and the evidence you collected as you investigated this question.
33. Add key ideas to your class Progress Tracker using words and pictures.
34. Once you finish, attach the class Progress Tracker handout to the page in your notebook with tape or glue.

Individual explanations and predictions

On your own

35. Use the ideas we developed to answer the questions on your handout, *Explanations and Predictions of Lids and Covers*.
36. After you write a response, circle the part of the response that uses some of the ideas we added to our class Progress Tracker today.

Lesson 5: Where does the water on the outside of the cold cup system come from?

Navigation

Turn and talk

1. We've noticed that water droplets formed on the outside of some of the cup systems.
   - Where do you think these water droplets came from?

Ideas for the Water Droplet Investigation

With your group

2. Discuss the following:
   - How might we test our ideas?
   - What are some important things we need to consider as we plan and conduct our investigation?

Water Droplet Investigation - Part A

With your class

3. Gather in a Scientists Circle. Bring your science notebook with you.
4. Review the procedures for *Water Droplet Investigation Part A*.
   - Do the procedures make sense to you?
   - Is there anything you want to change or add?
5. Conduct *Part A* of the investigation. Record the starting mass for each cup in the data table on your handout.

6. After recording the starting mass, go to the *Make a prediction* section. What might we see when we measure the mass after water droplets form on the outside of the cups? There are 2 possible sources of the water. Write your prediction and explain your thinking for each source in the table.

Water Droplet Investigation - Part B

With your class

7. Watch as your classmates set up *Part B*.
8. Go to the *Make a prediction* section. Since we added food coloring to the water in each cup system, what might you expect to see when water droplets form on the outside? There are 2 possible sources of the water. Write your prediction and explain your thinking for each source in the table.

Part A and Part B: Analyze data and draw conclusions

With your class

9. Return to the *Part A* setup to make new observations.
   a. Look closely at the water on the outside of the 2 cups.
   b. Record the final mass for each cup after 10 minutes on your handout.
   c. Calculate the mass change in grams (g). Record it on your handout.
   d. Draw your observations on your handout.
10. Return to the *Part B* setup to make new observations.
   a. Look closely at the water on the outside of the 2 cups.
   b. Wipe the water off the outside with a white paper towel or tissue, and make observations of the towel or tissue. Record your observations on your handout.
   c. Draw your observations on your handout.

With your group

11. Stay in your Scientists Circle but form a small group with 2 other students sitting near you.
12. Work on the *Analyze data and draw conclusions* questions for *Part A*.
13. Work on the *Analyze data and draw conclusions* questions for *Part B*.

Discuss observations and data in a Scientists Circle

With your class

14. Brainstorm where you have seen this phenomenon of water collecting on a surface.
    - Where have you seen this phenomenon happen?
    - What conditions were present when this happened?
15. Find and record patterns on the class chart. This chart should have patterns, which are things in common across all your experiences of water droplets collecting on the surface of something. See if your *Part A* and *Part B* also match these patterns.
16. Return to *Analyze data and draw conclusions* in *Part A*. Share your thinking with your class.
    - Does the *Part A* investigation match your patterns on the class chart?
17. Return to *Analyze data and draw conclusions* in *Part B*. Share your thinking with your class.
    - Does the *Part B* investigation match your patterns on the class chart?

Cold Lemonade on a Hot Day!

Check your learning

18. Return to your seat.
19. Read the 3 claims by Sarah, Regina, and Michael on the handout, *Cold Lemonade on a Hot Day!*.
20. Pick the claim that you most agree with.
21. Use words and pictures to explain why you agree with it, and support your thinking with evidence from our investigation.
22. Turn in the handout to your teacher.

Lesson 6: How can we explain the effect of a lid on what happens to the liquid in the cup over time?

Navigation

Turn and talk

1. Think back to the investigations when we put cold and hot liquids in a cup with a lid and a cup without a lid.
    - What did measuring the mass of each of these systems help us figure out?

Developing and using models with manipulatives

With your class

2. Discuss: What did we show and explain last time we used plastic chips of different colors to represent particles of water and air?
3. Imagine we could zoom in to a point where the air in the cup meets the lid. What do we think is happening to water molecules that are in the air there? Do they leave the cup when they reach that point?
4. Imagine we could zoom in to a point where the liquid meets the wall of the cup. What do we think is happening to water molecules there? Do they leave the cup when they reach that point?
5. Add the handout *Analogy Map for Chips and Marbles* to your science notebook. Compare the different ways we have modeled particles.

Manipulative in a previous activity . . .	*manipulative in this activity . . .*	*is like this thing in the cup system. . .*
A blue plastic chip		
A yellow plastic chip		

With your class

6. Think about the double layer of magnetic marbles representing the layers of particles that make up a solid plastic cup. Then discuss:
    a. How does this model help you visualize why water molecules can move freely between other water molecules but can't go through the particles the plastic cup wall is made of?

With your group

7. Use the magnetic marbles to make an outline in the shape of a cup on the tray, with a single layer of particles representing the bottom and walls of the cup.
8. Prop up the back of the tray a couple of inches (e.g., with a book) so that it is tilted up.
9. Add regular marbles to the inside of the cup outline to represent water molecules. Show what happens to these water molecules over time as they evaporate out of a cup with no lid.
10. Add more magnetic marbles to represent putting a lid on the cup.
11. Show why putting on a lid causes the system to stop losing mass.

Developing and using a diagrammatic model

Turn and talk

11. Look at the left side of the handout *Particle Representations for Matter in the Cup System*. Discuss these questions with a elbow partner:
    - How do the particles of matter shown in the key compare to the other ways we modeled these particles of matter?
    - What type(s) of particles would we want to show in a zoomed-in view at these locations in the cup: *A*? *B*? *C*?

With your class

12. Work to together as a class to develop couple-sentence summary of that answers questions A, B, and C. Record these answers on the right page of your science notebook.
13. Develop a way to represent the movement of particle through the air and add this to your model key. Update the zoom-in views for B and C to show movement.

With your group

14. Complete parts D and E with you group. Note: part E doesn't have a molecular model yet, and you will need to draw one to illustrate your thinking using the representations we have been using in A through C.

Class Progress Tracker

With your class

12. Let's get ready to have a Consensus Discussion to add to what we figured out about the question **"How can we explain the effect of a lid on what happens to the liquid in the cup over time?"**
13. Find a new page in your science notebook in the Progress Tracker section.
14. Attach the handout provided by your teacher.
15. Record the question you have been investigating.
16. Record the evidence you have collected.
17. Develop a model for explaining how the lid affects what happens to the liquid in the cup.

Explaining different lid designs

On your own

18. Read the handout *Explaining the Effect of Different Lid Designs* provided by your teacher.
19. Use the ideas we developed as a class to help Alex plan an investigation, and explain the predicted performance of each design.

Navigation

This container has an airtight lid. Hot water was added to it and then sealed for 24 hours. The container was then emptied. Cold water was added to it and then sealed for 24 hours. Measurements and calculations of the temperatures changes of the water and the mass changes of the system are reported below.

Turn and talk

19. Look at the patterns in the data below. Then discuss:
    a. How can the liquid inside the container change temperature even when no matter is leaving or entering? What are the different ways this might happen?

Conditions tested	Temperature in °C			Mass of water and container in grams (g)		
	Starting	Final (24 hours later)	Change	Starting	Final (24 hours later)	Change
Hot water added	125.5	70.1	↓ 55.4	205.4	205.4	0.0
Cold water added	42.0	70.1	↑ 38.1	206.2	206.2	0.0

Lesson 7: If matter cannot enter or exit a closed system, how does a liquid in the system change temperature?

Navigation

Turn and talk

1. Think about the following questions
    - What have we learned about closed cup systems?
    - How did we figure this out?
    - What do we still need to figure out?
2. Then, discuss the questions with a elbow partner.

Brainstorm possible causes of the temperature change

With your group

3. In your small groups, use these questions to guide your discussion:
    - What else could be causing the temperature of the liquid inside the closed cup system to change?
    - Can anything else, besides matter, go into, out of, or through the closed cup system?

Using models to represent our thinking

In your notebook

4. On the next 2 blank pages of your science notebook, write the following titles:
    - Across the top of both pages write: “Modeling Interactions between the Cup System and Energy”.
        - On the left page add “1) A cup system and light”.
        - On the right page add “2) A cup system and heat or cold”.

With your class

5. Use the questions below to help you brainstorm with your class what you need to include in your models for light and heat or cold interactions with the cup.

Light	Heat or Cold
How does light interact with different materials, such as clear plastic and metal? How might light shining on the closed cup system cause the liquid inside to change in temperature? How might you represent your thinking using a model?	How does heat move? Does cold move too? How might heat or cold cause the liquid inside the closed cup system to change in temperature? How might you represent your thinking using a model?

In your notebook

6. Work on your own to construct 2 models: 1 for light and 1 for heat or cold. Each model should show
    - how each form of energy interacts with the closed cup system and
    - how those interactions could be causing the temperature of the liquid inside the system to change.
7. Then make a claim for each model, which should address this question:
    - How do you think this type of energy causes the temperature of the liquid inside a closed cup system to change?

Lesson 8: How does a cup's surface affect how light warms up a liquid inside the cup?

Navigation and predictions

With your class

1. Discuss the following question with the whole group:
    - What were your ideas from the last class about how light could affect the temperature of water inside the clear plastic cup?

Turn and talk

2. Discuss this question with a elbow partner:
    - Do you think light would affect water in an opaque cup in the same way as in the clear plastic cup?

Lidya Nada

Light and Temperature Investigation

With your class

3. Look at the cups your teacher has displayed at the front of the classroom.
4. Read the investigation questions on your handout *Investigating Light's Effect on Warming Up Water*:
    - Does light affect the temperature of the water inside the cup system?
    - How does the cup surface affect how light warms up the water inside the cup?

Turn and talk

5. Discuss the following question with a partner:
    - In which cup do you think water would warm up the most? The least?
6. Record your predictions on your handout.

With your class

7. Get your lab assignment: Group A, Group B, or the Dark Group.
8. Preview the materials you will need for your investigation.
9. Listen as your teacher reviews the procedures.

With your group

10. Gather your materials and follow the procedures on your handout.
11. Set up your lab investigation and record your starting temperature.
12. Gather with your class in a Scientists Circle for light measurements.

With your class

13. Participate in the Scientists Circle to take light measurements. Measure the light measurements 2-3 times and average the measurements as a class.
14. Record the lux data in the light measurement data table on your handout.

Light Measurements (lux)

Condition	Incoming	Transmitted	Reflected
Clear			
Foil			
Black			
White			

15. Complete step 3 on your handout by calculating the percentages of incoming light that transmit through and reflect off the cup wall.

$$\%\ Transmitted\ light\ = \frac{Amount\ of\ transmitted\ light\ (lux)}{Amount\ of\ incoming\ light\ (lux)}$$

$$\%\ Reflected\ light\ = \frac{Amount\ of\ reflected\ light\ (lux)}{Amount\ of\ incoming\ light\ (lux)}$$

Condition	Transmitted	Reflected
Clear		
Foil		
Black		
White		

With your group

16. After 15 minutes have passed since the initial temperature measurement, return to your small-group investigation to record the final cup temperatures.
17. Record your group's data on the class *Temperature Change* table following your teacher's instructions.
18. Clean up your lab area and return supplies to the appropriate area.
19. Return to your seat to average your data with the groups testing similar cups.

Analyzing and interpreting class data

With your class

20. Discuss:
    - What could we do to help us understand the relationship between the temperature changes in the water and the amount of reflected and transmitted light?

On your own

21. Record the combined average temperature data and light data on the data table in the *Analysis* section of your handout.

Average Water Temperature Change vs. Light Measurements (% Incoming Light)

	Condition	ΔT	Incoming	Transmitted	Reflected
Light	Clear				
	Foil				
	White				
	Black				
Dark	Clear		0	0	0
	Foil		0	0	0
	White		0	0	0
	Black		0	0	0

Turn and talk

22. Record what you notice and wonder about this data on your handout.
23. Be prepared to share with your class as the class develops a Notice and Wonder chart together.

Building Understandings Discussion

With your class

24. Discuss:
    - How does the amount of transmitted light affect the water's temperature?
    - How does the amount of reflected light affect the water's temperature?
    - Where does the rest of the light go if it doesn't transmit through or reflect off the cup walls?
    - Does this light affect the water temperature in some way?

Develop models to explain temperature change

On your own

25. Use the handout *Explaining Temperature Changes in Each Cup* to develop models for explaining how light interacts with cups to result in temperature changes in the water inside.

Turn and talk

26. Share your models with a partner.
27. Edit your models as you think of things you would like to change or add.

With your class

28. Share your models with your classmates. As you share, support your ideas with evidence from the class investigations and your personal experiences.
29. Edit your models as you hear new things you would like to change.

Update your Progress Tracker

In your notebook

30. Draw a line under your last entry or start a new page.
31. Write the new question we are working on in the left column:
    - How does a cup's surface affect how light warms up a liquid inside the cup?
32. Write what you figured out in the column on the right. You can use pictures and words. Take as much space as you need to record your thoughts.

Lesson 9: How does the temperature of a liquid on one side of a cup wall affect the temperature of a liquid on the other side of the wall?

Navigation

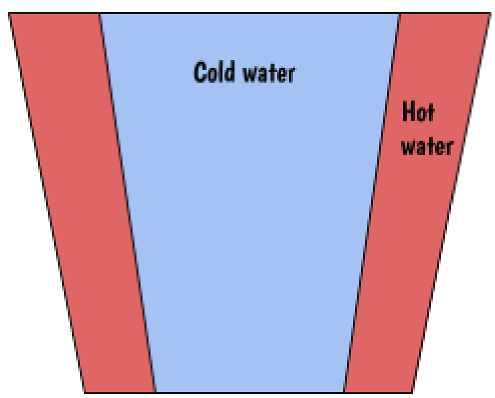
Turn and talk

1. Discuss with a partner:
    - How is light related to our iced drink warming up?
    - What other ideas did we have for things that could cause the drink to warm up?

Ideas about testing the movement of heat or cold

With your class

2. Think about the following question:
    - How would changing the temperature of the air outside the cup affect the temperature of the water inside the cup?
3. Discuss the question with a eblow partner.
4. Brainstorm related experiences of when you have put something in really hot or really cold air, or a hot or cold liquid, or a solid, and gotten a temperature change.
5. Given those experiences, do you think heat or cold would move in this situation?



Water Bath Lab

With your class

6. Review the handout, *Class Investigation: Heat or Cold through the Cup Wall*.
7. Review and edit the investigation plan.
    a. Decide on a testable investigation question.
    b. Review the independent variables.
    c. Decide how to measure the dependent variables to collect accurate data.
    d. List variables that should be controlled between the different conditions.
    e. Read the procedures and make notes of anything we will change when carrying out the investigation.
8. When the first temperature measurements are collected, record them on your handout's *Data Table*.
9. While we wait, make predictions about what will happen in each condition and share with a partner, then with the class.
10. When the final temperature measurements are collected, record them on your handout's *Data Table*.
11. Calculate and record the change in temperature.

Making sense of the Water Bath Lab

With your class

12. Think about our data, and then answer the questions on your handout.
    - What patterns do you notice in the data?
    - What patterns do you notice about the final temperature measurements?
    - What happens when the temperature difference between the water inside the cup and the water outside the cup is increased?
13. Share your ideas with a partner and then with the class.
14. Think about this question: If the iced drink warms up, does that mean the air right outside the cup is cooling down?

Exit Ticket

On your own

15. Complete the exit ticket on a note card and give to your teacher before leaving the classroom.

Imagine a cup of hot tea and a cup of iced tea. The cup of hot tea has a lot of "heat" and the cup of iced tea has a lot of "cold". If we zoomed in to the particles that make up the tea in the 2 cups, what would be similar or different about them?

Lesson 10: What is the difference between a hot and a cold liquid?

Updating your Progress Tracker

In your notebook

1. Draw a line under your last Progress Tracker entry or start a new page.
2. Write the new question we are working on in the left column:
   - What is the difference between hotter and colder liquid?
3. Write what you have figured out so far in the column on the right. You can use pictures and/or words. Take as much space as you need to record your thoughts.

A look back: hot and iced tea

Turn and talk

4. Discuss the following questions with a elbow partner:
   - How are hot tea and iced tea similar and different?
   - What do you think we would see if we zoomed in and looked really closely at hot tea and iced tea?
   - What could be similar or different at the particle scale?

Predictions

Turn and talk

5. Discuss the following questions with your partner:
   - If we zoomed in to the original cup of cold water at 0 minutes and later at 30 minutes, how would the particles be the same or different?
   - If we zoomed in to a cup of hot water at 0 minutes and later at 30 minutes, how would the particles be the same or different?

With your class

6. Discuss the following questions:
   - Do we think any particles in the hot water are moving before they turn to steam?
   - What about in the cold water?

Exploring a related phenomenon

In your notebook

7. Find a new page in your science notebook and title it “Candy in Water”. Make a Notice and Wonder chart on the page. Watch the video demonstration.
   - Record your initial thoughts after watching the video.
   - Share your observations with a elbow partner.
   - Record your additional thoughts after listening to your partner and watching the video a second time.
   - Be prepared to discuss what you notice and wonder with the class.

Navigation

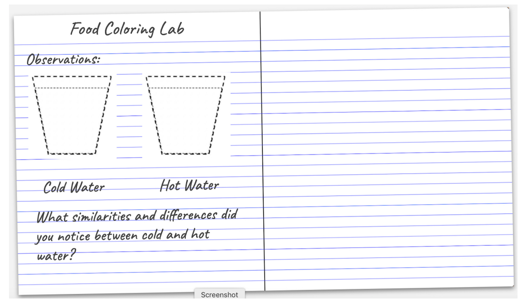
Turn and talk

8. Discuss the following questions with your partner:
    - What if we only had a cup of plain hot or cold water--do you think there are particles moving around that we cannot see?
    - What could we do to see them?

Food Coloring Lab

In your notebook

9. Set up your science notebook as follows:
    - Write the title “Food Coloring Lab” on a new page.
    - Write the heading “Observations” and draw 2 plastic cups with water. Label the first cup “Cold water” and the second cup “Hot water”.



10. Gather the materials for your lab setup:
    - 3 9-oz plastic cups
    - 1 250-mL beaker
    - Cold, hot, and room-temperature water (your teacher will bring you the hot water)
    - Food coloring
11. Conduct the lab as follows:
    - When prompted by your teacher, pour 250 mL of cold water into your first plastic cup and 250 mL of hot water into your second plastic cup.
    - Put 1 drop of food coloring into each cup at the same time.
12. Record your observations in your notebook by drawing and writing on the 2 cup drawings.
13. After completing your observations, write down and answer the following question in your notebook: “What similarities and differences did you notice between the cold and hot water?”

In your notebook

14. On the next page in your notebook, write the heading “Room-Temperature Water”.
15. Draw 2 plastic cups with water. Label the first cup “Prediction” and the second cup “Observation”.
16. In the cup labeled “Prediction”, draw and write what you think will happen when food coloring is put into room-temperature water.
17. When prompted by your teacher, pour 250 mL of room-temperature water into your third plastic up and add 1 drop of food coloring to the water.
18. Record your observations by drawing and writing on the cup drawing labeled “Observation”.

Navigation

Turn and talk

19. With a new partner, share your observations (drawings) from the *Food Coloring Lab*. Then discuss the following questions:
    - What was something similar about the way you showed food coloring in the cold, hot, and room-temperature water?
    - What was something different?
20. Be prepared to share with the whole class.

Reading: Joule's historical experiment

Use close reading strategies to learn about James Joule's famous experiment in which he built a device to investigate the relationship between water movement and temperature.

Turn and talk

21. Identify the question(s) you are trying to answer in the reading.
    a. Circle the question at the top of your handout: "How is the movement in water related to temperature?"

Read the text

On your own

22. Read once for understanding to see what the reading is about.
23. Read a second time to highlight a few key ideas that help answer your questions.

Summarize key ideas and record new questions

With a partner

24. Summarize the key ideas in your own words, in diagrams, or both.

In your notebook

25. Jot down new questions that this raises for you.

Reading discussion

With your class

26. What key ideas did you summarize that help us answer our question "How is the movement in water related to its temperature?"

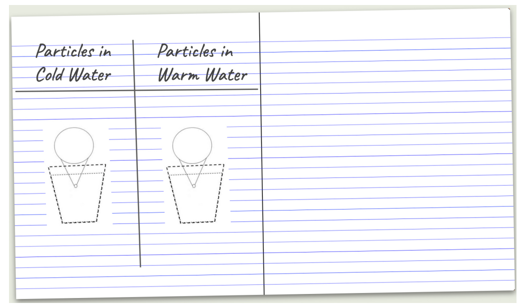
Making sense of multiple sources of information

Turn and talk

27. Using information from the video, the lab, and the reading, discuss your answer(s) to the following question with your partner:
    - What is the difference between a cold and a hot liquid?

In your notebook

28. In your notebook, draw a T-chart in which you can compare the particles in cold and room-temperature water.



29. Work on your own to develop models for particles in cold water and then those same particles in room-temperature water.
    - In the left column, draw what you think the particles are doing in cold water.
    - In the right column, draw what you think the particles are doing after the cold water has warmed up.

Turn and talk

30. Compare your drawings to a partner's:
    - How are your drawings similar?
    - How are they different?

Exit Ticket

On your own

31. Before leaving class, write your answers to the following questions on a note card:
    - When a cup of ice-water is left out and eventually warms up, what causes the motion of particles in the ice-water to change over time?
    - How is this connected to the idea of heat or cold moving?
32. Please turn in your note card to your teacher.

Lesson 11: Why do particles move more in hot liquids?

Navigation

With your class

1. Consider the following claims, and then discuss: Does our evidence support one or both of these claims or neither one?
    - Claim 1: Heat is entering the cup.
    - Claim 2: Cold is leaving the cup.

Question we are trying to answer

With your class

2. Think about the new question we are trying to answer:
    - Why do particles move more in hot liquids?
3. Brainstorm with your class how to investigate this new question.

Examining particle motion up close

When we are trying to figure something out, it's important to question whether something is happening at a scale too small, too large, or too long for us to observe. In this case, we are trying to figure out what particles are doing at a scale that we cannot see. We can collect evidence of what we can see and measure. We can also use computer models to help us make sense of things that are not observable.

In your notebook

4. Set up your science notebook for the simulation:
    - Title a new page "Heating and Cooling a Liquid Simulation".
    - Draw a Notice and Wonder chart to record your observations and questions.

With your class

5. Make observations from the video when the liquid is cold, warm, and hot.
6. Write these observations on the "Notice" side of your chart.
7. Add any questions you have to the "Wonder" side of your chart.
8. Share your noticings and wonderings with a partner.
9. Make more observations when we view the simulation for a second time.

Participate in a Building Understandings Discussion

With your class

10. Share your noticings and wonderings with your class.
    - What did you notice in the simulation?
    - What new questions do you have?
    - Drawing on evidence from the *Food Coloring Lab*, the peppermint candy video, the reading about Joule, and this simulation, what can we summarize about the differences between particles in a cold liquid and particles in a hot liquid?
11. Record a new vocabulary term: How fast or slow particles move is called **kinetic energy**.
    - In the simulation, which particles had the most kinetic energy?
    - Which particles had the least kinetic energy?
12. Particles in liquids move around freely at different speeds. Faster-moving particles have more kinetic energy. Slower-moving particles have less kinetic energy. What about gases?
    - Do particles in gases move around like particles in liquids?
    - What can we expect if we spray perfume at one side of the room?

With a partner

13. In your science notebook, find your models from the *Food Coloring Lab*.
14. Brainstorm where to add kinetic energy to your models and how to add it.
15. Be prepared to share your ideas with the class.

Construct an explanation

With your class

16. Discuss how to answer the question "Why did the food coloring particles spread out more in hot water than in cold water?" Use the following format as a guide:
    - Our claim is that the food coloring spread out more in hot water because __________. Our evidence is ____________ and _______________.

In your notebook

17. Write an explanation, using the same format, in your notebook.
18. Make sure to use new ideas about kinetic energy of particles in your explanation.

Navigation

With your class

19. Consider our original iced drink in the regular plastic cup that warmed up over time.
    - What is happening to the kinetic energy of the particles in the drink?

Turn and talk

20. Discuss these questions with a partner:
    - How are particles in our drink getting more energy?
    - Where did that energy come from?

Lesson 12: How does the motion of particles compare in a sample of matter at a given temperature?

Navigation

Turn and talk

1. Discuss this question: What have we figured out about the particles that make up warmer and cooler matter?
    - Use evidence that we have documented on our three claims posters to support your thinking.

Preparing to use the interactive simulation

In your notebook

2. Record this question in your science notebook:
    - How does the motion of the particles compare in a sample of matter at a given temperature?

Understanding how the simulation works

With your class

3. Listen to your teacher's introduction to the simulation and how to change settings in the control panel.

Part A: Exploring the interactive simulation

With your group

4. Preview the handout *Particle Interactions in Gases*.
5. Complete *Part A: Exploring the Interactive Simulation.* Use your handout for instructions.

Turn and talk

6. Based on our exploration of the simulation, discuss what we have figured out about
    - the kinetic energy of the particles in a gas,
    - the total kinetic energy of the particles in the gas, and
    - the temperature of the gas.

Part B: Collecting data

With your group

7. Follow the instructions on your handout to complete *Part B: Collecting Data.*
    - Conduct 4 trials, using the settings assigned to your group.
    - Make sure you use “Follow a particle” to observe what happens to an individual particle over time.
    - Feel free to adjust “Visualize particle speeds” as needed.
    - On pages 5-6, record your data for each trial, then record additional observations in the space provided.

Progress Tracker

In your notebook

8. Attach the Progress Tracker to your science notebook.
9. Record the question we have been working on in the upper left column:
    - How does the motion of the particles compare in a sample of matter at a given temperature?
10. In the bottom section of the Progress Tracker, use words and/or pictures to document what we have figured out about
    - the kinetic energy of the particles in a substance,
    - the temperature of the substance, and
    - the total kinetic energy of all the particles in the substance.
11. Document our evidence in the upper right column.

Navigation

With your class

12. Think about this question: What happens when two different kinds of matter, like air and a solid, of different temperatures come into contact?

Lesson 13: How could the motion of particles on one side of a solid wall affect the motion of the particles on the other side of that wall?

Navigation

Previously, we added room-temperature water to a cup and surrounded it with cold water. The cold water outside the cup warmed up and the room-temperature water inside the cup cooled down.

With your class

1. Discuss these questions:
   - What happens to the speed of the particles in the liquid when the temperature drops?
   - How about when the temperature goes up?
   - What were some things that seemed to cause changes in speed for a single particle as it moved about?

Analyzing the motion of colliding particles in a computer simulation: Activity #1

With your class

2. Explore changes in particle speed in each of these simulations as a class:
   - Simulation 1: https://openscied.org/gas-particle-motion/
   - Simulation 2: http://modelingcommons.org/browse/one_model/6070#model_tabs_browse_nlw

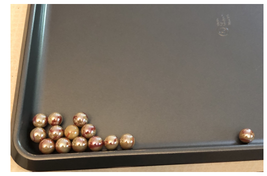
Investigating changes in particle motion in colliding marbles: Activity #2

With your group

3. Work with marble manipulatives to conduct an investigation into speed changes in collisions between particles in a gas:
   a. Prop the back of the tray up a couple inches (e.g., with a book), so that is tilted up.
   b. Place 2 marbles on the left side of the tray:
   c. Have one partner slowly roll the right-most marble slowly to the right.
   d. Have the second partner roll the other marble even faster to the right so that it collides with the first rolling marble about midway along the tray bottom.
   e. Observe how the collision affects the speed of both marbles.
   f. Repeat the previous steps until you have determined whether what you saw happening to the speeds of the simulated particles in a collision is also happening here.
4. Discuss and fill in the first row of the table on the handout *Investigating Particle Collisions in Different States of Matter* as a class.

Investigating changes in particle motion in colliding marbles: Activity #3

With your group



5. Work with marbles to conduct an investigation into speed changes in collisions between a gas particle and particles in a liquid.
    a. Prop the back of the tray up a couple inches (e.g., with a book), so that the back right corner is tilted up.
    b. Place all but 1 of the marbles on the left side of the tray so they cluster together:
    c. Have one partner slowly roll the 1 marble along the bottom of the tray from right to left, so that it eventually collides with the marble cluster. Try this at different speeds.
    d. Observe how the collision affects the motion of all the marbles.
6. Fill in the row for Activity #3 on *Investigating Particle Collisions in Different States of Matter*. Add "A gas particle colliding with particles in a liquid" to the second column. Complete the remaining columns with your small group.

Investigating changes in particle motion in colliding marbles: Activity #4

With your group

7. Work with marbles to conduct an investigation into speed changes between a gas particle colliding with particles in a solid, with particles of a liquid on the other side.
    a. Prop the back of the tray up a couple inches (e.g., with a book), so that is tilted up.
    b. Make an outline of a cup with magnetic marbles.
    c. Fill the cup outline with all but 1 of the glass marbles.
    d. Roll the 1 remaining glass marble into either side wall of the magnetic marble cup outline.
    e. Observe how the collision affects the motion and speed of all the glass marbles in the system.
    f. Do this again, this time looking closely for evidence in any changes in the motion of the magnetic marbles during the collision too.
    g. Sort the marbles back into the 3 cups when you are done (2 glass marbles in one cup, 13 glass marbles in another, and the magnetic marbles in the third).
8. Fill in the row for Activity #4 on *Investigating Particle Collisions in Different States of Matter*. Add "A gas particle colliding with particles in a solid, with particles of a liquid on the other side" to the second column. Complete the remaining columns with your small group.

Developing an explanation

In your notebook

9. Complete the "Making Sense" question on *Investigating Particle Collisions in Different States of Matter*. Apply what you just did to the particles of matter in our cup experiments: we put room-temperature water inside a cup and surrounded it with cold water. The cold water outside the cup increased in temperature and the room-temperature water inside the cup decreased in temperature. What did you figure out today about particle collisions that could help explain these temperature changes?

Navigation

Turn and talk

10. Discuss:
    - How do our results from our investigations yesterday with marbles help explain what is happening between all the particles that make up the matter in our cup systems?

Particles in solids are always moving. Unlike liquids and gases, though, they can't move about freely. They can only vibrate back and forth in place.

With your class

11. Discuss these questions:
    - How do you think the motion of particles in a solid at a lower temperature would compare with the motion of particles in a solid at a higher temperature?
    - Do you think particles in solids can transfer kinetic energy to neighboring particles through collisions?

Preparing to use an interactive simulation

The interactive simulation we will use shows how particles in a solid move at different temperatures and when there are different points of contact between them.

In your notebook

12. Attach the handout *Particle Collisions within and between Solids* to your science notebook.
13. Read the investigation question for activity #5 on *Particle Collisions within and between Solids*.
14. Write your prediction in the second column of your handout.

With your class

15. Review the control panels of the simulation as a class.

Investigating changes in particle motion in an interactive simulation: Activity #5

With your group

16. Use an interactive simulation to investigate the question "How will the motion of particles in a solid at a lower temperature compare with the motion of particles in a solid at a higher temperature?"
    a. Open the simulation: http://modelingcommons.org/browse/one_model/6092#model_tabs_browse_nlw .
    b. Click on "Setup/Reset" and then "Go/Pause" to run the simulation.
    c. Zoom in to inspect the motion of the particles in each solid up close.

d. Observe and compare the motion of the particles in the solids at different temperatures.
e. Zoom back out.
f. Adjust any of the starting temperatures you wish.
g. Click on “Setup/Reset” and then “Go/Pause” to run the simulation again.
h. Summarize your observations in response to the investigation question in your data table on *Particle Collisions within and between Solids*.

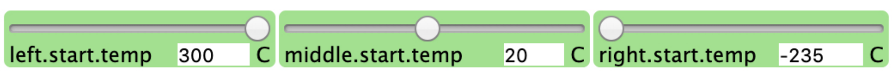
Investigating changes in particle motion in an interactive simulation: Activity #6

In your notebook

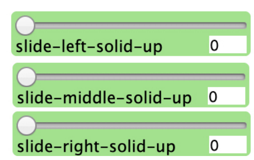
17. Read the question for activity #6.
18. Write your prediction in the second column of your handout.

With your group

19. Use an interactive simulation to investigate the question “What will happen to the motion of the particles over time in a hot solid and a cold solid when they are touching each other?”
    a. Open the simulation: http://modelingcommons.org/browse/one_model/6092#model_tabs_browse_nlw
    b. Reset the starting temperatures to these values:



    c. Press SETUP to restart the simulation. Use any of these sliders to slide the solids up and down, until each solid makes contact with another solid.



    d. Observe what happens to the motion of the particles in the solids over time.
    e. Watch the graph. Run the simulation until the temperatures of the 3 solids are nearly the same.
    f. Press “Setup/Reset” and then “Go/Pause” to run the simulation again. Record your observations.
    g. Summarize your observations in response to the investigation question in your data table.

Investigating changes in particle motion in an interactive simulation: Activity #7

In your notebook

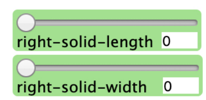
20. Read the investigation question for activity #7 on *Particle Collisions within and between Solids*.
21. Write your prediction in the second column of your handout.

With your class

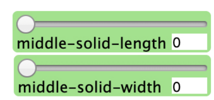
22. Review the new control panel for the next simulation.

With your group

23. Use an interactive simulation to investigate the question "How does the amount of particles in 2 solids in contact with each other affect the amount of temperature change in both solids?"
    a. Open the simulation: http://modelingcommons.org/browse/one_model/6091#model_tabs_browse_nlw
    b. Set the simulation to automatically stop at a time of 5.
    c. Set the middle starting temperature to -235°C.
    d. Remove the right solid by setting these slider values to 0:



    e. Run an experiment to determine how the amount of particles in each solid affects the amount of temperature change in both solids. Use these sliders to adjust the width of each object and then press SETUP:



    f. Record how much the temperature of each solid changes for each condition.
    g. Summarize your observations in response to the investigation question in your data table.

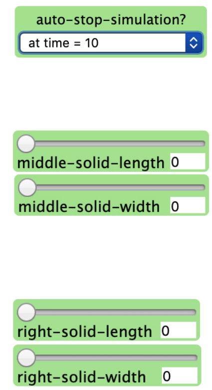
Investigating changes in particle motion in an interactive simulation: Activity #8

In your notebook

24. Read the investigation question for activity #8 on *Particle Collisions within and between Solids*.
25. Write your prediction in the second column of your handout.

With your group

26. Use an interactive simulation to investigate the question "How does the amount of a solid's surface in contact with another solid's surface affect the amount of temperature change in both solids?"
    a. Open the simulation: http://modelingcommons.org/browse/one_model/6091#model_tabs_browse_nlw
    b. Set the simulation to automatically stop at a time of 20:
    c. Run an experiment to determine how changing the amount of particles in 2 different solids in contact with each other affects the amount of temperature change in both. Use these sliders to adjust the width of each object:
    d. Record how much the temperature of each solid changes for each condition you test.
    e. Summarize your observations in response to the investigation question in your data table.



Navigation

Turn and talk

27. Discuss these questions:
    - How can warm matter outside a cup cause a cold liquid inside the cup to warm up?
    - What have you figured out today about energy transfer in solids that can help you explain how this happens at a particle level? (Be prepared to share your ideas with the class next time.)

Lesson 14: Does our evidence support that cold is leaving the system or that heat is entering the system?

Navigation

With your class

1. Discuss this question as a class:
   - What are some of the claims we've discussed about what caused the cold water in our cup system to warm up?

Evidence Sorting Activity

With your group

2. Review the list of evidence that we've collected from Lessons 10-13.

#	Evidence
1	*Food Coloring Lab*: Food coloring spread through hot water faster than cold water.
2	*Peppermint Dye*: Peppermint dye spread through hot water faster than cold water.
3	*Water Bath Lab*: When a cup of cold water was placed in a container of warm water, the cold water warmed up and the warm water cooled down.
4	*Joule's Experiment*: Spinning water very fast caused the water to heat up.
5	*Temperature and KE:* Simulations showed that warmer liquids and solids have particles with more KE.
6	*Particles colliding:* Simulations showed that when particles collide, one slows down and the other speeds up.
7	*Marbles collide:* When you roll a marble into another marble(s), the faster marble slows down and the slower marble (or resting marbles) speeds up.
8	*Marbles into a solid wall*: When you roll a marble into a wall of marbles, it slows down after the collision, but a marble on the other side of the wall speeds up.
9	*Amount of contact:* Simulations showed that when solids have more contact, energy transfers faster from the hotter solid to the cooler solid compared to when there is less contact.

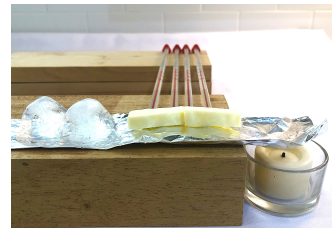
3. Determine whether each piece of evidence can be used to support claims about whether heat or cold moving leads to temperature changes, or whether the evidence supports both or neither one.
4. Write each evidence number- numbers 1-9- on a small piece of paper or sticky note.
5. Attach each paper or sticky note (piece of evidence) on your handout *Evidence Sorting chart* for the claim it supports. If the evidence can be used to support both claims, attach it in the "Heat and cold moving" section.

With your class

6. Sort the evidence on the class' three claims posters.

Butter Demonstration

To provide further evidence for what is moving and in what direction, we will do an additional investigation. Your teacher will place strips of butter on a piece of aluminum foil. On one end of the foil, your teacher will place 2 ice cubes, and at the other end, a candle.



Turn and talk

7. Discuss these questions with a partner:
   - What do you think will happen once the candle is lit at one end and the ice cubes are placed on the other end?
   - What do you predict will happen if cold leaves the ice and enters the butter?

With your class

8. Record the starting temperature for each thermometer.
9. Light the candle.
10. Record the temperatures after 1 minute.
11. After 2 minutes, add ice cubes and record the temperatures.
12. Record the temperatures every 2 minutes for 8 total minutes.

Turn and talk

13. Discuss these questions with a partner:
    - Is what we observed due to heat or cold moving?
    - How could we use what we've previously figured out to explain our new observations?
14. Share your ideas with the class.

In your notebook

15. Record the evidence for today's investigation in *Evidence Sorting chart* and consider any additional revisions to how you sorted our evidence.
16. Attach *Evidence Sorting chart* to your science notebook.

Home Learning

Home learning

17. Identify either (1) a system in which heat moves through the system or (2) two systems where heat moves between the systems.
18. Write down your example on a piece of paper and be prepared to share it at the beginning of the next class.

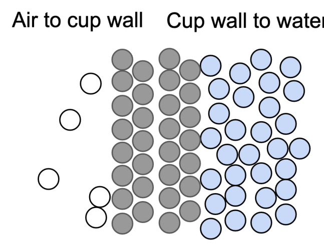
Navigation

With your group

19. Share your example with your group.
    - If you are speaking, describe whether heat is moving within a system or between two systems.
    - If you are listening, ask the speaker *how* the heat moves in the example being shared.
20. Make connections to what you know about particle movement and particle collisions.

Revise the cup system model

The purpose of yesterday's investigation was to understand what caused the cold water in our cup system to warm up. How can we use what we have figured out thus far to revise our cup system model? What is happening on both sides of location A (1) between the air and the cup wall and (2) between the cup wall and the water that leads to the water in the cup system warming up?



On your own

21. Review the handout *Modeling What Is Happening at the Cup Wall.*
22. Annotate the diagrams on your handout by drawing and writing descriptions on them to explain what is happening (1) between the air and the cup wall and (2) between the cup wall and the water. Add a key to the handout to explain what your symbols and colors mean.

With your group

23. Share the models on your handout with your group members.
    - What was similar or different about how your group showed the flow of energy into the cup?

With your class

24. Agree on representations with your class and create a key.
25. Represent how the drink warms up using symbols and written description.

Answer questions from the Driving Question Board

In your notebook

26. Identify questions you can now answers on the Driving Question Board.
27. Pick one question to answer.
28. Find the next page in your Progress Tracker in your science notebook.
29. Write the question in the left column.
30. Write what you have figured out so far in the column on the right. You can use pictures and/or words. Take as much space as you need to record your thoughts.

Co-construct an explanation for the cup

With your class

31. Work with your class to write an explanation together that answers this question.
32. Use evidence from the investigations you carried out.

Write an explanation for a related phenomenon

In your notebook

33. Pick a related phenomena from the related phenomena poster. Brainstorm how you can explain the new phenomenon using science ideas you used to explain the cup.
34. Share your thinking with a partner to get feedback.
35. Find a new page in your notebook. Write down the new phenomenon. Then write an explanation of how it works.

Icing Injuries Assessment

Use what you've learned to explain how applying an ice pack can treat an injury. Two athletic trainers, Steve and Sophie, are stating different claims about what's moving and the direction in which it's moving.

On your own

36. Complete the handout *Icing Injuries Assessment*.
    - Decide which of our pieces of evidence can be used to support each athletic trainer's claim.
    - Construct models to explain what happens when the ice pack comes into contact with the skin. Make sure you include particles for the ice pack, particles for the skin, how the particles are moving in each system based on their temperatures, and how energy is entering or leaving the systems.
37. Turn your assessment in to your teacher when you are finished.

Lesson 15: How do certain design features slow down the transfer of energy into a cup?

The Cold Cup Challenge

Turn and talk

1. ***Criteria*** are the things that will tell us if our design is successful.
   - What are some criteria that you think we might include in the *Cold Cup Challenge*?
2. ***Constraints*** describe the limits we need to set on what we design.
   - What are some constraints that you think we might include in the *Cold Cup Challenge*?

What do we know, and what don't we know?

With your group

3. Your teacher will pass around some cups. Look closely at each of the cup designs. Attach the handout *Features of Cups that Keep Drinks Cool* in your science notebook. For each cup, discuss and record these things on the handout:
   - at least 1 feature that helps slow thermal energy transfer into the cup
   - why you think that feature works
   - what you still don't understand about how that feature works

Gaps in our explanations

Turn and talk

4. What is inside the walls of a double-walled cup that prevents energy transfer?
5. How does blocking light from getting into the liquid prevent energy transfer?
6. How do cardboard coffee cup sleeves, koozies, and styrene prevent energy transfer?

Jigsaw the gaps in our explanation

With your group

7. Do a close reading of your handout with your group by following these steps:
   - What question(s) are you are trying to answer with the reading? Discuss with your group. Record the question(s) at the top of the page.
   - Read the handout once on your own. As you read, <u>underline</u> ideas that you think are important. Add a question mark (?) to indicate things that you have questions about. Circle words that are new to you.
   - Read the handout again with your group and answer the question(s) together.

Making posters

With your group

8. Make a poster to share with your classmates.
   - Your poster should represent the big ideas from your reading and fill the gaps in our knowledge.
   - Use the questions on your handout to get you started.
   - Include a diagram to illustrate the phenomenon you read about, and words to explain what is happening in the diagram.

Navigation and Exit Ticket

On your own

Goal of the Cold Cup Challenge: Using everyday materials, design a cup that uses the best design features we know about to keep a drink almost as cold as the store-bought cups do.

9. Complete an exit ticket answering the following: *What is 1 design feature you want to include in your design, and why do you think it will minimize energy transfer?*

Gallery walk

With your group

10. Go to each poster set with your group and look for similarities and differences.
    - Spend 5 minutes at each poster set. Your teacher will tell you when to move on to the next set.
    - Begin by reading each poster in the set on your own.
    - When everyone in your group has read the posters, rejoin your group and identify agreements and disagreements across all of the posters in the set.
    - Once you have identified agreements and disagreements, record these things in a comparison T-chart:
        - 1 thing that your group noticed that was the same across all of the posters in the set (an agreement)
        - 1 thing that your group noticed that was different (a disagreement)

Coming to consensus

With your class

11. Attach the *Final Cup Consensus Model* to your science notebook in the section of your notebook used for the Progress Tracker.
12. Develop a class consensus model that explains how that design feature slows energy transfer into the cup. For each model, add a sketch and words to explain how energy transfers in each situation.

Navigation

Turn and talk

13. What ideas do you have about how to test the designs we will make in the *Cold Cup Challenge*?

Lesson 16: How can we design a cup system to slow energy transfer into the liquid inside it?

Design features to slow energy transfer

Turn and talk

1. What design features do you think will slow energy transfer into the cup?
    - Identify the design feature.
    - Explain how it slows energy transfer.

Cold Cup Challenge

With your class

2. Your teacher will give you a design packet. Keep the packet with your science notebook through the entire *Cold Cup Challenge*.
3. Review the problem and goal for the *Cold Cup Challenge.*
    - **Problem:** Iced drinks bought from coffee shops and restaurants warm up and water down too quickly, especially on warm, sunny days. The stores sell reusable cups that keep the drink colder longer and reduce environmental impacts, but these cups can be expensive.
    - **Goal:** Using everyday materials, design a cup that uses the best design features we know about, to keep a drink almost as cold as the store-bought cups.
4. Discuss:
    - What are some initial things we need to think about with our designs?
5. Review the criteria for the design challenge.
    - Temperature change of less than 1°C after 12 minutes in regular light.
    - Temperature change of less than 2°C after 12 minutes in bright light.
6. Review the constraints for the design challenge.
    - Use no more than two 16 oz plastic cups.
    - Materials must be recyclable or reusable to reduce waste if cup is thrown away. Cannot use styrofoam because this material is harmful to the environment.
    - Can use up to 3 materials, not including the cup itself.
    - Fit is a typical car cup holder (10 cm wide x 8 cm deep).
    - Keep cost low and affordable (less than $0.50 for the whole cup).
7. Review the tests you will carry out on your cup designs.
    - How will the each test help us know if our cup designs satisfy the criteria and/or constraints?
    - What are other things we need to check about our designs to make sure they satisfy the criteria and constraints?

Design and build your first cup

With your group

8. Discuss the design features you think will slow energy transfer.
9. Decide which ones you want to include in your design.
10. Sketch your design.
11. Pick three design features and label them 1, 2, and 3 on your sketch.
12. Draw or write about how each design features slows energy transfer.
13. Compare your design against the criteria and constraints.

Test your first cup design

With your group

14. Conduct the regular light - temperature test first.
15. While you wait, conduct the price check test.
16. Then, empty your water and refill.
17. Conduct the bright light - temperature test next.
18. While you wait, conduct the diameter test and environmental impact test.

Evaluate your design

With your group

19. Look back at each criteria and constraints. Discuss with your group:
    - How well did your cup meet the criteria and constraints?
    - Where did your cup not meet the criteria or follow the constraints?
    - Where can it be improved?

Evaluate another group's design

With your group

20. Gather another group's cup and *Part 3 Test 1* results.
21. Write the test results on your feedback form and then make observations of the group's cup.
22. Discuss in your group:
    - What do you think works well about the design?
    - How can this group improve their design so that it performs even better? What can they change and how might it help?
23. Write feedback to the other group.

Lesson 17: How can we improve our first design to slow energy transfer into the cup system even more?

Patterns across design features

With your class

1. Identify cups that met the regular light-temperature and bright light-temperature criteria.
2. What patterns do you notice about cups that met the criteria?
    - Identify a pattern across the cups.
    - Offer an explanation about why that pattern in the designs slowed energy transfer.

Reflection: Criteria and constraints

With your class

3. Discuss:
    - What went well in our first design cycle?
    - Where can we improve in the process?
    - Do we need to prioritize any criteria or constraints?
    - What trade-offs are we willing to make to get a cup that meets the criteria?

Redesign your cup

With your group

4. Discuss how to modify your design features to slow energy transfer.
5. Decide which changes you want to make to your design.
6. Sketch your new design.
7. Pick three design features and label them 1, 2, and 3 on your sketch.
8. Draw or write about how each design features slows energy transfer.
9. Pick 1-2 things that you changed about your design and describe: 1) which test you expect it to perform better on, and 2) why you think the change will help.

Test your second cup design

With your group

10. Conduct the regular light - temperature test first.
11. While you wait conduct the price check test.
12. Then, empty your water and refill.
13. Conduct the bright light - temperature test next.
14. While you wait, conduct the diameter test and environmental impact test.

Evaluate your designs

With your group

15. Look at your test results for Cup Design 1 and Cup Design 2.
    - Identify how each cup compared on the 5 tests. Record notes on your handout in *Part 7: Evaluate your 2nd design*.
    - Then, decide which cup met the criteria and constraints the best and share test results on your class chart and place the cup with other group's best performer.

Share ideas for a 3rd design

On your own

20. Given the test results for your group's 2 cups and what you see in the data from other groups' cups...

    if you were going to build a 3rd design, what would you change and why?
21. Record your ideas at the bottom of *Part 7: Evaluate your 2nd design*.
22. Leave your science notebook and design packet with your teacher.

Lesson 18: How can containers keep stuff from warming up or cooling down?

Patterns in the Cold Cup Challenge Class Data

Turn and talk

1. Discuss
   - What patterns do you notice in the class data?
   - Did cups meeting both criteria also meet the constraints?

Analysis of the Cold Cup Challenge Data

With your class

2. Examine the class data.
3. Then decide: If you had to select only one cup to build to sell to other people, which cup would you choose and why?
4. Share your thoughts with a partner.
5. Vote on the best performing cup and explain your choice.

Redesign the Ultimate Cold Cup

On your own

6. Look at the best performing cups.
7. Then, complete *Part 8: The best performing design features* of your design packet.
8. Sketch a third design.
9. Pick three design features and label them 1, 2, and 3 on your sketch.
10. Draw or write about how each design feature slows energy transfer.
11. Be prepared to share your ideas.

With your class

12. Meet in a Scientists Circle and bring your science notebook and design packet.
13. Work with your class to determine 3-4 critical features to include in a cup. Represent these features in a new sketch of the Ultimate Cold Cup.

Slow Down and Speed Up Energy Transfer

In your notebook

14. Find a new page in your science notebook and title the page: "Energy Transfer Models."
15. Draw a line through the middle of the page to create a top half and bottom half.
16. On the top half, write "slow down energy transfer" and draw a box to represent a system.
17. On the bottom half, write "speed up energy transfer" and draw a box to represent a system.

With a partner

18. Draw a model to show 2-3 important factors that slow down energy transfer.
19. Then draw a model to show 2-3 important factors that speed up energy transfer.

Home Learning

Home learning

20. Identify a device, object, or situation in which energy transfer is slowed down or sped up.
    - You can bring the object to school if it is small and your guardians give you permission. You can also take a photograph with your phone camera or make a sketch of the object in your notebook.

Explaining Related Phenomena

With your group

21. Identify whether the object, device, or situation is one for which we want to slow down or speed up energy transfer.
22. Use your Energy Transfer Models to explain how it works.
    - Add to your models if you notice you are missing important details.
23. Participate in a Consensus Discussion with your class to agree upon a general model for explaining how to speed up or slow down energy transfer.

Demonstrate Understanding on an Assessment Task

On your own

24. Use what you've figured out to demonstrate your learning on an end of unit assessment.

Navigation & Home Learning

Home learning

25. Look through our questions on our DQB. Mark questions that you think the class has answered by putting different symbols next to each question:
    - We did not answer this question or any parts of it yet: **?**
    - Our class answered some parts of this question, or the ideas we developed help me see how I could now answer some parts of this question: ✓
    - Our class answered this question, or the ideas we developed help me see how I could now answer this question: ✓✓
26. Pick three of the questions you marked and write what you think that answer would be.

Navigation: Evaluate Our DQB Questions

With a partner

27. Take out your home learning *Let's Answer Questions from Our Driving Question Board!* and tape it into your science notebook. Compare your notes about which questions you think we've answered on our DQB.

Symbols:

- We did not answer this question or any parts of it yet: **?**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓✓

Revisit Our Driving Question Board

With your class

28. In your Scientists Circle, add sticky dots to mark questions answered, mostly answered, or not answered at all. Look for patterns in the sticky dots. Work together to answer the following questions:
    - Which questions have we made the most progress on?
    - What have we figured out?

Quick Write: Reflect on Our Experiences

On your own

29. Answer the following questions in your science notebook:
    - What was most challenging in this unit?
    - What was most rewarding?
    - Think about how you engaged in sensemaking discussions with classmates. How would you want to engage in those experiences the next time around?
        - What would you do the same?
        - What would you do differently?

With your class

30. Be prepared to share your thoughts with your class.

References

Regular light and temperature test

Purpose

To measure temperature change of cold water inside the cup system in regular light and average air temperature conditions for 12 minutes.

Materials

Designed cup, 1 thermometer, 1 500-mL graduated cylinder or beaker, 400-mL cold water

Procedures

1. Retrieve 400-mL of cold water (~6°C).
2. Pour water into your cup.
3. Take the starting temperature measurement and record on Part 3 Test 1 of your design packet.
4. Seal your cup with a lid if your design includes one.
5. Wait 12 minutes before measuring the final temperature.
6. While you wait, complete the price check test.

Bright light and temperature test

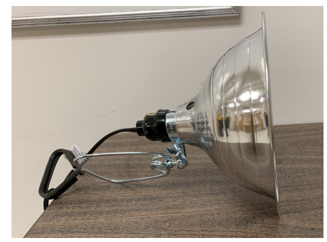
Purpose

To measure temperature change of cold water inside the cup system in bright light and average air temperature conditions for 12 minutes.

Materials

Designed cup, 1 thermometer, 1 500-mL graduated cylinder or beaker, 400-mL cold water, lamp with 100-watt bulb, 1 ruler

Procedures



1. Arrange the lamp so that it is as close to perpendicular to the table as possible and able to shine directly at your cup.
2. Place cup approximately 12 inches from the lamp.
3. Retrieve 400-mL of cold water (~6°C).
4. Pour water into your cup.
5. Take the starting temperature measurement and record on Part 3 Test 1 of your design packet.
6. Seal your cup with a lid if your design includes one.
7. Turn on the lamp.
8. Wait 12 minutes before measuring the final temperature.
9. While you wait, complete the environmental impact test and diameter test.

SAFETY PRECAUTIONS

Do not touch the lamp shield at all during this investigation. The shield can become very hot and burn you, should you touch it.

Environmental Impact Test

Purpose

To determine which parts of the cup are reusable, recyclable, or waste for the landfill.

Reusable, Recyclable, Landfill

Item or material	Reusable	Recyclable	Landfill
16 oz single wall plastic cup	●	●	
12 inch x 12 inch sheet of aluminum foil	◐	●	
1 straw	◐		●
1 cotton ball			●
6 inch x 9 inch foam sheet	●		
16 oz paper cup		●	
1 inch of clear tape			●
1 rubber band			●
12 inch x 12 inch plastic wrap			●
6 inch x 6 inch felt	●		
12 inch x 12 inch corrugated cardboard wrap		●	
Paint for cover of cup			●
Plastic lid	●		
1 strip of regular school glue			●
3 dots of hot glue			●
8.5 x 11 paper		●	
12 inch x 12 inch paper towel		●	

◐ sometimes

● always

Price check test

Purpose
To add up the cost of the materials of your cup design.

Price per material

Item or material	Cost
16 oz single wall plastic cup	**$0.15**
12 inch x 12 inch sheet of aluminum foil	**$0.05**
1 straw	**$0.02**
1 cotton ball	**$0.02**
6 inch x 9 inch foam sheet	**$0.15**
16 oz paper cup	**$0.10**
1 inch of clear tape	**$0.01**
1 rubber band	**$0.01**
12 inch x 12 inch plastic wrap	**$0.03**
6 inch x 6 inch felt	**$0.15**
12 inch x 12 inch corrugated cardboard wrap	**$0.11**
Paint for cover of cup	**$0.15**
Plastic lid	**$0.03**
1 strip of regular school glue	**$0.02**
3 dots of hot glue	**$0.02**
8.5 x 11 paper	**$0.02**
12 inch x 12 inch paper towel	**$0.02**

Diameter test

Purpose

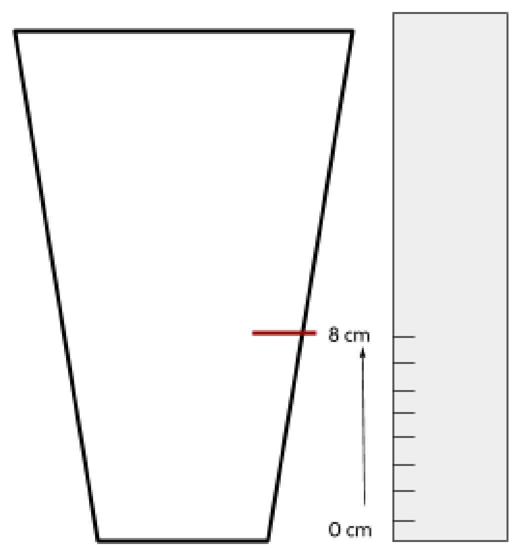
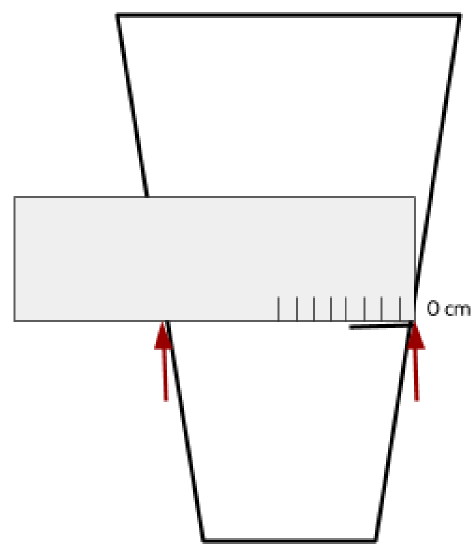
To measure to see if your cup will fit into a standard drink holder in a car.

Materials

1 ruler, 1 marker or pen

Procedure

1. Take your size measurements while your cup sits on the table top.
2. Place the ruler vertical from the table top with 0cm at the bottom.
3. Measure 8cm up from the bottom of the table.
4. Mark this height on your cup with a marker or pen.
5. Then, at the height you marked, measure across the cup.
6. Record how wide your cup is at this height on your design packet.

First, measure 8 cm up	Then, measure across. Record this amount.
	

Readings

Reading on James Joule's Experiment

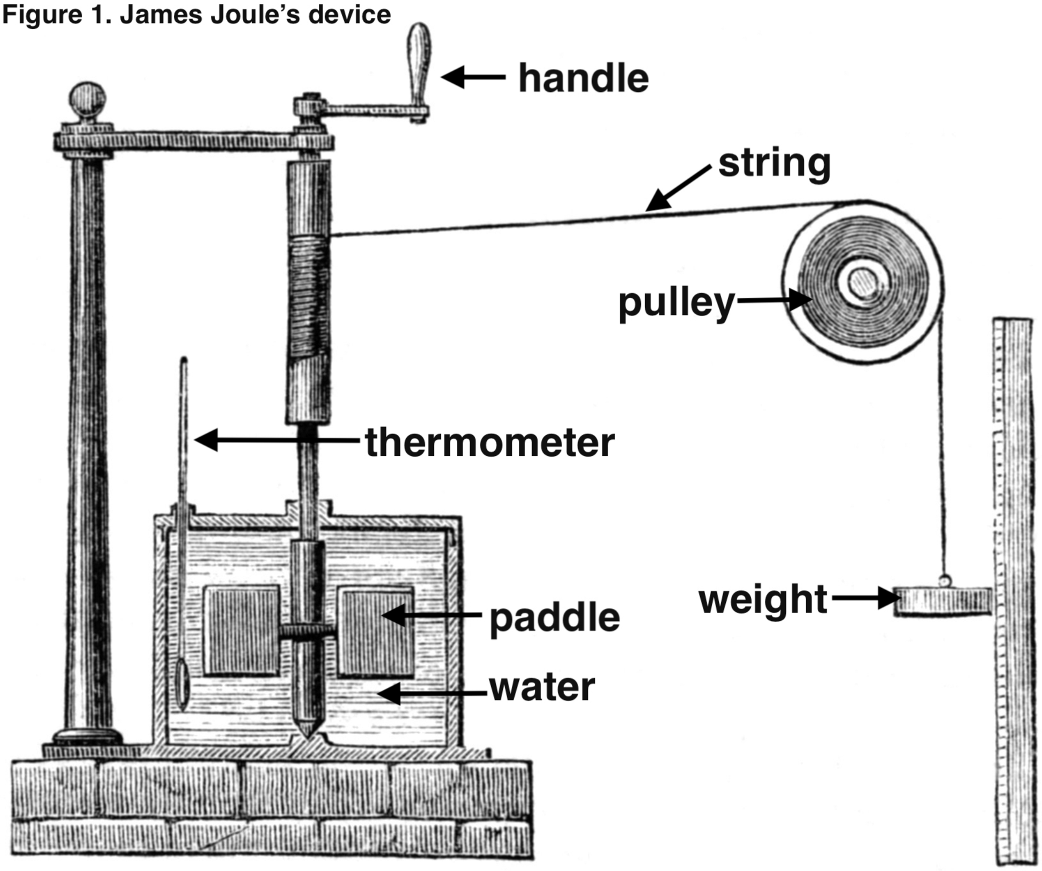
How is the movement in water related to its temperature?

In the early nineteenth century, Europe and the United States had lots of factories being built. Along with more factories, new inventions helped scientists carry out more careful investigations of scientific phenomena that had puzzled them for years. In 1850, a scientist named James Joule set out to solve a puzzle he had seen in many factories at the time--certain liquids got dangerously hot when they were pressed and pushed through pipes and machines.

James Joule's Experiment

To investigate this problem, Joule knew that he needed a lab setup where a liquid could be moved around inside a sealed container to create the same kinds of movements of liquids inside machinery. However, Joule also needed a way to measure the temperature of the liquid while it was moving. So, he designed and built the device you see in Figure 1.

Figure 1. James Joule's device



In this device, there is a weight that pulls on a string around a pulley, which then turns a handle. This handle is connected to a paddle that sits inside a sealed container of water. As the handle turns, it spins the paddle, which stirs the water in the container. Also sitting inside the container of water is a thermometer. As the paddle turns, the thermometer measures any temperature change in the water inside the container.

Joule's Findings

In operating the device, Joule observed that when the weight fell quickly, the paddle spun faster, and the temperature of the water increased quickly. The opposite also turned out to be true. If the weight fell slowly, the paddle spun slower, and the temperature of the water increased slowly. Joule's device helped scientists observe and accurately measure temperature change caused by the movement of liquids.