IHAD Summer Camp Activities

Outline

Day 1: Is it a solid, liquid or gas?

Tuesday, July 11

1. **Pre-activity preparation**
2. **Introduction and "Wow" Demo**
   - Both classes in same room
   - Make nametags, "Wow" demo, instructor introductions
2. **Nature of Science discussion**
   - We have a subset of questions taken from the CLASS, EBAPS, VASS, and VNOST and modified to present to the students.
3. **Describe solids, liquids and gasses (5 – 10 minutes)**
   - Individuals each draw two pictures of different states of matter one 'life size' and one zoomed in. This will be used as one form of content pre-assessment. Then we will put students into groups with white boards to brainstorm and share ideas to present to the class.
4. **Group Assignments (10 minutes)**
5. **Mystery matter (20 minutes)**
   - State of matter categorization with materials with balloons in groups with defined roles (recorder, equipment manager, skeptic, spokesperson). The balloons will be numbered, so that each # balloon has the same unknown substance in it. Begin with easy and familiar objects and then present unclear, difficult to categorize materials
6. **Class discussion (15 minutes)**
   - The student groups come up with defining characteristics for each state and discuss as a class.
7. **Break (10 minutes)**
8. **Student Molecules (20 minutes)**
   - Students begin to see the particle nature of matter by being a molecule in "student matter"
9. **What State of Matter is Oobleck? (45 minutes)**
   - Through experimentation with the Oobleck have the students come up with a list of 'tests' or experiments that you could perform on a substance to determine its state.

10. Conclusion (20 minutes)

- Concluding class discussion, share lists of 'tests'

11. Review (5 minutes)

* See detailed outline of Day 1

Day 2 : How does temperature affect matter?

Wednesday, July 12

1. Pre-activity preparation

2. Recap properties of solids, liquids and gasses (10 minutes)

- Have the students recall the activities from Day 1

3. PhET Simulation (___ minutes)

- Students use their understanding of states of matter to form a microscopic picture of temperature with respect to gases.
    - PhET simulations explicitly model the particle nature of matter
    - Additionally use this activity to gauge the student's comfort level with technology

4. Imploding Pop Can Demo (10 minutes)

- This activity will introduce the idea of pressure.

5. Relationship between the temperature and volume of gasses (30 min)

6. Class Discussion (10 minutes)

- Share group explanations of how temperature affects matter

*** OR ***

5. Heavy Air: Air has mass (30 min)

6. Class Discussion (10 minutes)

7. Break (10 minutes)

8. Phase change with Liquid Nitrogen Demo (10 minutes)

- This demo is a good transition from the balloon activity into introducing phase change

9. Introduction to SAM (___ minutes)

- Demonstrate SAM by reenacting part of the "Student Molecules" activity using a "story board"
- The students will then brainstorm the big ideas from the two days from which they will pick the topic of their group's movie. Narrow to 5 topics to choose from.

* See detailed outline of Day 2

Day 3: Using SAM as an Assessment Tool

Thursday, July 13

1. **Class Reflection and Review:**
   - Brainstorm activities and results, and big ideas.
2. **Time to 'story board' and collect materials**
3. **Production of the movie**
   - Burn CDs of the movies for the students to keep.
4. **Cumulative assessment:**
   - Students transfer understanding to explain a new phenomenon

Day 4: Fieldtrip to CU

Friday, July 14

1. **Students arrive at CU-Boulder at 10:30am (60 minutes)**
   - We will meet the busses and walk the students to JILA Auditorium
   - Introduce JILA , rules for the day, how to act in the Labs and Machine shop, etc.
2. **JILA Lab Tour / Machine Shop Tour (30 minutes)**
   - One class will go to the Lab and the other to the Machine Shop for 15 minutes tours. Then, the classes will switch and take the other tour for 15 minutes
3. **Tour Engineering ITL laboratories (30 minutes)**
   - With the time remaining after the tours before lunch, the students will spend time in this lab at the hands-on stations in their groups.
4. **Lunch at 12:30pm (30 minutes)**
   - We will most likely eat outside on the grass, depending on the weather.
5. **Brief post-assessment**
6. **Student Presentations of Movies in JILA Auditorium (30 minutes)**
   - Each group will introduce themselves, talk about the movie they made and then we will show their movie with the Auditorium projector.
7. **Physics Wizard show presented by Physics Professor Mike Dubson (60 minutes)**
8. **Students leave CU at 3:00pm**

Detailed Daily Activities

Day 1: Is it a solid, liquid or gas?

Objectives: Students will be able to…

- classify different forms of matter as solids, liquids or gases by determining shared properties of each category.
- classify Oobleck as either a solid or a liquid

Materials:

- Mystery Matter
  - 3 balloons filled with solids (ice, Lego, ball)
  - 3 balloons filled with liquids (water, glue, dish soap)
  - 2 balloons filled with gases (air, helium)
  - 1 balloon filled with sugar
- Student Molecules
  - Masking tape
- Oobleck
  - Utensils
  - Mixing containers
  - 1 Ziploc bag for each student to keep their Oobleck
  - Recipe for Oobleck (write on large Post-it at the front of the room)
    - Fill Dixie Cup ½ full of water
    - ¼ box of cornstarch (will be measured out in a Ziploc bag)
    - 1-2 drops of food coloring
    - Put the water and food coloring in a large bowl and begin adding the corn starch and mixing. Eventually the mixture will get thicker. Keep adding cornstarch and stirring until it is hard to stir. Then you will have Oobleck!

Instructors:

- As the students are working, the instructors should move from group to group
  - The instructors should:
    - Keep students on task
    - Ask questions to check for understanding
    - Help guide the students to recognize and correct their own mistakes

Background:

The term "Oobleck" is derived from the book ***Bartholomew and the Oobleck,*** by Dr. Seuss. Experimenting with Oobleck is much more than having fun with a weird substance. As students participate in this activity, they will develop important skills in scientific observation.

Oobleck is a non-Newtonian fluid. This means that when a small amount of force is used, it acts like a liquid, but when more force is applied, it acts like a solid. For instance, one can slowly put a spoon in Oobleck, but it is impossible to stir it quickly. Some students might have seen glass in very old buildings that is thin at the top and thick at the bottom. That is because glass is also a non-Newtonian fluid and is slowly flowing out of the pane.

The following is a lesson plan that lets students make there own assumptions about solids and liquids and then test those assumptions -- just like real scientists!

Activity:

1. Pre-activity preparation

- Fill the balloons with the solids, liquids and gasses described above.
- Number each balloon (balloons with the same substance have the same number)
- Prepare materials for Oobleck activity.
- Write “Solids, Liquids, Gasses” at the front of the room on Post-its. These vocabulary words will be referred to throughout the activity. Leave enough room to write properties and examples for each.
- Place desks or table/chairs into groups of four.

2. Introduction and “Wow” Demo

- Both classes will begin in one classroom
- Each student will create a nametag for themselves.
- “Wow” demo – Professor Noah Finkelstein
    - Will possibly include:
        - Freezing a flower, banana, etc in liquid nitrogen
        - Inverting a balloon inside a beaker
- Instructors introduce themselves
    - Who we are, why we are here and why we are scientists
- Camp Overview: We will be studying ***states of matter*** this week. The students will be making a movie about states of matter in their groups. They will get to show it in the JILA Auditorium at the University of Colorado in Boulder. So, as we do different activities, they should be thinking about what topic they want their group’s movie to be about.
- Separate into the two classes

3. Nature of Science Discussion

- We have a subset of questions taken from the CLASS, EBAPS, VASS, and VNOST and modified to present to the students. The types of questions will include personal interest, aspirations, organization of scientific knowledge, and real-world relevance of science. (see survey questions).
- Pass out the survey. Then have a class discussion about the meaning of the questions without swaying the students' answers. (Turhan and Chandra will take field notes through this discussion.)
- The students will write down their own personal answers to the questions.

4. Describe solids, liquids and gasses (5 – 10 minutes)

- Introduce the students to the idea that there are three states of matter. Do not give examples or properties.
- Hand out worksheet and Explain directions:
    - Have the students draw an example for each category.
    - Tell the students that they will tape their drawings to the front of the room when they finish.
    - (WORKSHEET 1, one for every student)
- After all the students finish, brainstorm ideas of what it means to be a solid, liquid or gas as a class.
- Have the student share ideas of properties and examples
- Write the ideas for each category at the front of the room on the labeled large Post-it paper.

5. Group Assignments (10 minutes)

- *Each class should have four groups of equal size*
- Have the class vote for either self-selecting or assigning groups of four
    - Tell the class that the instructor will re-assign the groups if need be.
- Have an already prepared method of selecting the groups if they choose group assignments (note cards with pictures, counting off to four, etc.)
- Allow students to move to groups
- Give the groups a couple minutes to come up with a group name.
    - Write the group names on a large Post-it.
- Have students in each group count off from 1 to 4
    - this will be their number for the entire week
    - if there is a group of three, combine Material Manager and the Measurer
- Assign each number a role: And explain the different roles (role play *skeptic*)

    1. **Equipment Manager** – gathers all materials and returns them at the end
    2. **Reporter** – shares the group's results and reasoning with the class
    3. **Skeptic** – questions the group's reasoning and writes down results

4. **Measurer** – makes the measurements, collects data and performs tests

*** *ALL* group members help with cleanup***

5. Mystery matter (20 minutes)

- Hand out the worksheet for the activity. (WORKSHEET 2, one per group)
- Explain the directions
    - Each group will classify the contents of each balloon as solid, liquid or gas
    - They will write down observations that support their claims
    - The members of the group should discuss their reasoning and come to an agreement about the classification
- **For the Mystery Matter activity (written on large Post-it):**
    1. **Equipment Manager** – gathers mystery matter balloons and returns them at the end
    2. **Reporter** –writes the group's name and results on the class chart at the front of the room (Enter "S" for solid, "L" for liquid and "G" for gas)
    3. **Skeptic** – questions the group's reasoning and writes down results on the group worksheet
    4. **Measurer** – primary balloon tester, helps group make observations about what is inside the balloons

6. Class discussion (15 minutes)

- Go through the groups results to come to a conclusion as a class. For the balloons that the groups disagree on, ask a couple reporters to share their group's reasoning for that balloon
- Then ask for the reasoning from a few groups for the sugar filled balloon
- Discuss the arguments for it being both a liquid and a solid
    - Refer back to this balloon when discussing particle nature of matter

7. Break (10 minutes)

- Set up for *Student Molecules* Activity—Make a container using chairs set up in a circle with the backs of the chairs facing in. Use masking tape to delineate the container's bottom.

8. Student Molecules (20 minutes)

- Start by asking the students to draw a zoomed in picture of the boundary of a piece of wood in an open container and what is outside the container, through at magnifying glass, (see worksheet). (5 min) (WORKSHEET 3, one per student)
    - Have a few volunteers share their ideas with the class
    - They should have some since of a microscopic picture

- Now move into the activity: The tell the students that they get to be molecules in a substance called "student matter" (10 min)
    - Tell all the kids in the class to sit squished close together on the floor in a circle of chairs. They might be able to rotate their heads or wiggle their bodies, but they would not be able to go anywhere. This is what happens to the *molecules* in a solid. *The solid made out of students keeps its shape and retains its same volume.*
    - Now we imagine that we raise the temperature of the student matter past the melting point. When that happens, the students can stand up and walk around within the circle of chairs (imaginary container). This would be a liquid—they are just as close together and still cannot go off on their own, but now they can move and change places. *Their volume is fixed but not their shape.*
    - Now we imagine that we raise the temperature past the boiling point. This changes the student matter into the next phase: a gas. The kids are too hyper to remain in the container and are able to jump out and run free spreading out everywhere in the room. *Since a gas does not have a fixed volume and does not have a fixed shape, it will spread out and take the shape of its container.*
- Brief recap/evaluation: Ask the class the following: (5 min)
    - What happens to a liquid if the temperature increases past its boiling point?
    - What happens to a liquid if the temperature decreases past its melting point?
    - Did the *number* of students change?
    - (See if they can make sense of the process backward—decreasing temp)

9. What State of Matter is Oobleck? (45 minutes)

- Go over directions
- Ask the groups to discuss are the differences between every solid and every liquid and how they could test that. What tests could you do? For example: They could come up with the following four tests:
    1. Push Test – can you push into it?
    2. Pick-up Test – if you pick some up, does it all come up?
    3. Pour Test – does it pour out smoothly, or does it just fall out in a clump?
    4. Shape test – does it keep the same shape?

- Have each group make a chart of these rules on their white board so that they can test any new materials by seeing if they match. (10 min)
    - Wait for all groups to finish before having the Material Manager get the materials for making Oobleck.

- **For the Oobleck activity (written on large Post-it):**

1. **Reporter** – shares the group's results and reasoning with the class
2. **Skeptic** – questions the group's reasoning and writes the group's tests, observations and conclusions on the worksheet.
3. **Measurer** – makes the Oobleck following the recipe posted at the front of the room
4. **Equipment Manager** – gathers materials needed to make Oobleck

- Hand out Oobleck Worksheet (WORKSHEET 4, one per group)
- Hand out Oobleck
    - Students make Oobleck
        - The recipe should be written at the front of the room
    - Allow some time for student to play with the Oobleck (5 min)
    - Instructors: Encourage the students to pour a little Oobleck in the palm of their hand and make observations about its behavior. (They can watch it puddle like a liquid. Then make a fist and quickly open their hand. The Oobleck will have formed a hard ball from the pressure of their fist; but when the pressure is release, it will seem to "melt" into a liquid again.) (5 min)
- Have the Skeptic wash their hands so that they can record the groups observations.
- The students will make observations and write them on the observation sheet
    - (25 min)
- Based on these observations the groups will classify the Oobleck
- Clean up (10 min)

10. Conclusion (20 minutes)

- Ask each group to share their tests, observations and conclusions
    - The Reporter can demonstrate the tests they performed on the Oobleck for the class
- What does the class conclude?
    - Behaves like both a liquid and a solid
- Make sure that the students understand that in science, things aren't always what you expect and that not everything falls into neat categories (non-Newtonian fluid).
    - Oobleck is fun, non-intuitive, and you can come up with parameters to classify it
    - Models have utility—understand that Oobleck acts like a solid under certain circumstances and a liquid in others. It is something in between a solid and a liquid.

11. Review (5 minutes)

- Walk through the activities of the day utilizing the Post-its throughout the room
    - Ask probing questions to guide the students through the review:

- What are the properties of a solid?
- How did we classify the states of matter in the balloons?
- What did we decide Oobleck is?
- Etc.

Day 2: How does temperature affect matter?

Objectives: Students will be able to…

- predict how temperature affects the volume of gases.
- illustrate what happens to particles when matter goes through temperature changes.
- communicate what happens when the temperature of matter changes enough for it to change state (beyond its boiling point or melting point).
- create a particulate model of gases using discussion and diagrams
- become familiar with the SAM program.

Materials:

- Pop can demo
  - A few empty pop cans
  - Hot plate
  - Ice water
  - Oven mitt
  - Rubber coated tongs
- Volume of balloon
  - Balloons
  - Ice
  - Hot plate
  - 2 Buckets per group, one filled with ice water and one with hot water
  - Access to a refrigerator and freezer (or cooler filled with ice)
- Liquid nitrogen demo
  - Liquid nitrogen
  - Gloves
  - A balloon filled with air
- PhET Sim
- SAM
  - Computers with program and cameras up and ready to go
  - Art supplies

Instructors:

- As the students are working, the instructors should move from group to group
    - The instructors should:
        - Keep students on task
        - Ask questions to check for understanding
        - Help guide the students to recognize and correct their own mistakes

Background:

Heat causes molecules to move faster (increases energy) and molecules spread apart, while the cold slows them down (decreased energy) and molecules get closer together. Emphasize that when the balloon contracted in the ice water, even though the volume changed, there were the *same* number of molecules in the balloon. EXAMPLE: You can make an analogy to a jar full of a 100 fruit flies. If you release the flies from the jar they will fly all over the room. There are still 100 fruit flies, they will now just occupy a larger space. What makes solids, liquids and gases different is the *movement* of the molecules:

Solids: In solids, molecules have a tightly packed structure held together by electrical attraction. **Crystals** are very strong because they have a regular and rigid shape. The molecules, however, are not motionless. They may vibrate or rotate in place but they CANNOT move out of place. Thus the solids kept their shape and retained the same volume in the freezer.

Liquids: In liquids, the molecules are still as close together as they are in solids, but they can slip over each other and change places. This would be a liquid—they are just as close together and still cannot go off on their own, but they can move and change places.

Gases: The molecules of a gas move even faster. They have too much energy (movement) to remain attached to each other. The molecules now bounce off of each other (particle collisions increase) and the walls of their container. A gas thus will spread out and take the shape of its container. Gases have NO fixed volume (as demonstrated by the balloons); the pressure exerted on it will determine the volume.

Note that **Absolute Zero** is the theoretical temperature where all motion of molecules would stop.

Activity:

1. Pre-activity preparation

- Set up SAM on enough computers for each group to have one to use.

- Display all Post-its from the day before. These vocabulary words will be referred to throughout the activity. Leave enough room to write properties and examples for each during recap.
- Do the same with the new vocabulary for the day (see vocab sheet)
- Place desks or table/chairs into groups of four.

2. Recap properties of solids, liquids and gasses (10 minutes)

- Have the students recall the activities from Day 1
- As a class, recall the properties of solids, liquids and gases on the Post-its at the front of the room.
    - Solid- has a fixed shape and volume
    - Liquid- has a definite volume, but takes the shape of the part of the container which it occupies
    - Gas- does not have a fixed shape or volume and will take the volume and shape of the container that holds it
- Do not bring up the fourth state of matter, plasma, unless prompted by the students. Note that plasma is not found naturally on earth (or our neighboring planets) because it requires extremely high temperatures. For plasma to form, the atoms must become ionized (lose electrons). Plasma consists of these ionized atoms and their loose electrons.

3. PhET Simulation (___ minutes)

- Assign pairs or let people chose a partner
    - One person will control the mouse and the other will be the recorder.
- Begin with a class discussion:
    - What phase (solid, liquid, or gas) is the air around us?
        - The hope is that they will say gas, but if not it may be a good idea to talk about that at this point. This would make a nice practical transition from the review beforehand.
    - Next, talk about how you can't see air and ask the students how (if you can't see it) they know its there.
    - Do you feel anything when you wave your hands around? *(wave hands around)* If so, what?
        - Use this to let them know that air like any other gas is made up of something. (Note: this may be review for them).
    - How is a gas different from a solid or a liquid?
        - If we fill a balloon up with air, what is in the balloon?
        - How is it different from an empty balloon?
            - Also review some of the things learned from the Oobleck and the Mystery matter activity from the previous day.
- Instructor Demo of the PhET Simulation on the computer
    - Have student pairs following along on their laptop computers
    - This is to show the students basically how to get the PhET simulation up and running.

- Students engage with the PhET Simulation working in pairs following a worksheet (WORKSHEET 5, one for each pair)
    - *Draw a picture of what a gas looks like in a container.*
        - The goal here is to get an idea of how closely students' initial perception of what a gas looks like matches with what the students perceive at the end. At this point any instructors should be walking around the class making sure that all the groups are on task and that they are not completely lost.
    - *Use the pump to put a few gas particles in the box.* (The students only need to pump once)
    - *Look at the gas particles' motion. Talk with your partner about how you think the gas molecules move and interact with each other based on your observations. Write down a few of these observations.*
    - *Raise the temperature of the box to 300K by turning on the burner. Then raise it to 1000K. What happens to the motion of the blue gas particles as you raise the temperature?*
        - Hopefully the students will see that the gas particles speed up when they heat up the container.
    - *Look at the right hand side of the Phet window at the number by the blue word Heavy Species. Did the number of blue particles ever change while you were heating the box?*
        - The students should <u>not</u> see a change in number of particles. However, if they get the temperature way above 1000K they will see a couple of particles disappear so if this problem occurs then this is most likely the cause.
    - *Lower the temperature to 500K by bringing the ice near the box. Next lower it to 100K. What happens to the motion of the gas particles as the temperature gets lower?*
    - *Now bring the ice near the box until you get the temperature as low as you can. Could you get the balls to stop moving? If so, at what temperature did they stop moving at?*
        - This would be a nice point to begin talking about the Kelvin scale when going over this question. Tell the students the temperature at which all matter supposedly stops.
    - *Draw a picture of what the motion of air in a container looks like when it is cold. Now when it is hot?*
- At the end of the activity, ask the students to share their ideas about pressure based on the activity and their background knowledge.
    - Refer to when the blue gas particles hit the walls and each other. Also may be a good idea to refer to the blowing up balloon example.
    - Talk about pushing.
    - Optional: Have two people demonstrate pushing back on each other's hands. Ask what would happen if one of them was not there. (The one pushing would fall into where the other was standing). This is like pressure.

4. Imploding Pop Can Demo (10 minutes)

- Fill two empty pop cans with ~two tablespoons of room temperature water.
- Ask the class what happens to water when you heat it.
    - Begin heating the 1st can on hotplate. Bring to a boil. (It takes 5 minutes for the water to boil)
- Ask the class what will happen if you turn the pop can over into ice water.
    - Using the tongs, flip the pop can upside down into a glass bowl full of ice water. Submerge the opening of the can in the ice water. Make sure that you set the can straight into the ice water to seal the opening of the pop can.
    - The can will implode.
- Have another can ready to repeat the demo for students to see it again.
    - Encourage them to think about why the can implodes.
- Discuss what happened in the demonstration as a class. Address the common misconception of sucking vs. pressure.
- **Discussion Questions:**

    1. What was in the can besides the water at the begining?
    2. What happens when water is boiled?
    3. What do you think will happen if the can is inverted in the bowl of water?
    4. What happens to the air in the can as water vapor is formed?
    5. What force is working on the outside of the can?

- EXPLANATION: Before heating, the can was filled with water and air. By boiling the water, it changed states, from liquid to gaseous state (water vapor). The water vapor (steam) pushed the air that was inside, out of the can. By inverting the can in water, we are cooling the vapor very quickly and constraining the potential for rapid flow of air back into the can by submerging the top in water. The cooling condenses the water vapor back to water. All of the vapor which took up the interior space of the can before is now turned into a few drops of water, which takes up much less space. This causes the pressure to drop and the atmospheric pressure is therefore pushing on the can and crushing it.

5. Relationship between the temperature and volume of gasses (30 min)

- **For the Temperature/Volume activity (written on large Post-it):**
    1. **Skeptic** – questions the group's reasoning and writes the group's observations and conclusions on the worksheet.
    2. **Measurer** – makes the measurements, collects data and performs tests
    3. **Equipment Manager** – gathers materials needed
    4. **Reporter** – shares the group's results and reasoning with the class
- Hand out worksheets (WORKSHEET 6, one for each group)

    - The groups will follow the worksheet
- Remind the groups to discuss as a group before making a decision
- The students will start tying a weight (rock) to the barrel of the syringe
- Then the will record the volume of air inside their syringe using the tick marks on the syringe.
    - Predict what will happen to the volume of air inside the syringe if the temperature is lowered.
- The students should next place the syringe in the ice water for three minutes. (10 min)
    - They should record the volume of the air in the syringe after being in the ice water and discuss in their groups what they think has happened and why.
    - Did their results match their predictions?
- Based on their observations, they should make a prediction about what will happen to the volume of air in the syringe if they raise the temperature instead.
- Then, they carefully place the syringe under hot water for 3 minutes and record the volume of air in the syringe. (10 min)
    - They should then record their results and in groups discuss what happened and why.
    - Did their results match their predictions?
- Repeat with dry ice bath.
- Have the students draw a picture of the gas inside the syringe at each stage.

6. Class Discussion (10 minutes)

- As a class, have the Reporters share their group's conclusions about the relationship between temperature and volume for a gas. (7 min)
    - Did the volume change? How?
    - Why do you think this happened?
    - Did the mass of the gas inside the syringe change?
        - Make sure that they understand that the mass does *not* change.
    - What happened to the number of molecules? (refer back to student molecules activity)
- Explanation: In gasses, as temperature increases, so does volume, and as temperature decreases, so does volume.

OR

5. Heavy Air: Air has mass (30 min)

- **For the Temperature/Volume activity (written on large Post-it):**
    1. **Skeptic** – questions the group's reasoning and writes the group's observations and conclusions on the worksheet.
    2. **Measurer** – makes the measurements, collects data and performs tests

3. **Equipment Manager** – gathers materials needed
4. **Reporter** – shares the group's results and reasoning with the class

- Hand out worksheets (WORKSHEET 6, one for each group)
  - The groups will follow the worksheet
- Materials for each group:

1. Two drinking straws.
2. Three pins or needles and two pieces of thread
3. Two identical un-inflated balloons.

- First, the students tie a piece of thread to each of the two balloons and tie the threads to the two ends of one of the straws.
- Then, balance this straw on your finger, push a pin through the straw where it is balancing and attach it to the other straw held vertically.
- Make sure that the straws are moving freely around the needle; balance the horizontal straw, then push a pin through at the spot where the threads are attached (to prevent them from sliding).
- Make sure that the two un-inflated balloons are in perfect balance; then blow air in one of them and tie a knot at the end. The balance will tip down at the end of the inflated balloon.

6. Class discussion (10 minutes):

1. What is inside the un-inflated balloons?
2. What kind of air was blown in one of the balloons?
3. What could happen if no pins were placed on the ends of the horizontal straw where the threads were attached?
4. What does the balance indicate after inflating one balloon?
5. What would you expect the balance would do if the other balloon was also inflated?
6. How else could we show that air has weight?

- Explanation: The straw balance may be adjusted by moving the threads further or closer to the end of the straw. In order to keep these attached threads from sliding, we need the pins. The air that was blown in the balloon was exhaled air, which is containing some water vapor but, for our purposes, may be neglected. By inflating the other balloon, the balance should be in equilibrium again. The air in the balloon is compressed by the balloon; therefore it is more dense and heavier than an equal volume of air at regular atmospheric pressure.

7. Break (10 minutes)

8. Phase change with Liquid Nitrogen Demo (10 minutes)

- This demo is a good transition from the syringe activity into introducing phase transitions.
- Demo putting a balloon filled with air and one with helium into liquid nitrogen.
    - Discuss what happens and why as a class.
    - Relate to syringe activity and volume
    - Introduce change of state. HOW?

9. Introduction to SAM (___ minutes)

- The instructor will introduce SAM by demonstrating how to make a movie using SAM and a projector (should already be set up)
    - Follow the steps outlined in the student worksheet
    - Start with a topic
        - Student Molecules
    - What part do we want to demonstrate?
        - Student Matter changing from a gas to a liquid, and then from a liquid to a solid
    - Create a story board
        - Using the Post-its, draw 4 – 5 story frames:

            1. Students running around classroom
            2. Students slowing down and condensing into a container (chairs)
            3. Students in the liquid state in the container
            4. Students cooling to a solid state
            5. Students in the solid state in the container

    - Shoot the "Student Molecules" movie using SAM and the student actors
    - Make sure to indicate how you take pictures, etc using SAM
    - Show the final movie to the class
    - The groups will be doing the same thing the next day
- **Brainstorming big ideas**
    - Write down all the ideas the students come up with on large Post-it
    - Include a review of the day similar to the review for day 1
    - Narrow down to the following five (adding these to the student list if they did not come up during the brainstorming)

        1. _____
        2. _____
        3. _____
        4. _____
        5. _____

Day 3: Using SAM as an Assessment Tool

1. **Class Reflection and Review:**
   - Brainstorm activities and results, and big ideas.
2. **Group Assignments**
   1. **Measurer** – makes the measurements, collects data and performs tests
   2. **Equipment Manager** – gathers all materials and returns them at the end
   3. **Reporter** – shares the group's results and reasoning with the class
   4. **Skeptic** – questions the group's reasoning and writes down results
3. **Using SAM (See student worksheet)**
4. **Time to 'story board' and collect materials**
5. **Production of the movie**
   - Burn CDs of the movies for the students to keep.
6. **Cumulative assessment:**
   - Students transfer understanding to explain a new phenomenon

Day 4: Fieldtrip to CU

1. **Students arrive at CU-Boulder at 10:30am (60 minutes)**
   - We will meet the busses and walk the students to JILA Auditorium
   - Introduce JILA , rules for the day, how to act in the Labs and Machine shop, etc.
2. **JILA Lab Tour / Machine Shop Tour (30 minutes)**
   - One class will go to the Lab and the other to the Machine Shop for 15 minutes tours. Then, the classes will switch and take the other tour for 15 minutes
3. **Tour Engineering ITL laboratories (30 minutes)**
   - With the time remaining after the tours before lunch, the students will spend time in this lab at the hands-on stations in their groups.
4. **Lunch at 12:30pm (30 minutes)**
   - We will most likely eat outside on the grass, depending on the weather.
5. **Brief post-assessment**
6. **Student Presentations of Movies in JILA Auditorium (30 minutes)**

- Each group will introduce themselves, talk about the movie they made and then we will show their movie with the Auditorium projector.

7. **Physics Wizard show presented by Physics Professor Mike Dubson (60 minutes)**

   Students leave CU at 3:00pm

Key Vocabulary

Day 1

Matter
Solid
Liquid
Gas
Molecule
Particle
“State of matter”
Phase
Analyze
Conclusion
Classify
Observation
Result

Day 2

Pressure
Volume
Weight
Mass
Change of State
Prediction