**Guide for Density 5E Cycles**

**(Note: Times are approximate and do not include transitions.)**

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Figure S1. Approximate timing of the three cycles across the week.

**Cycle 1: Divisibility of Matter (“Matter is matter, no matter how small!”)**

Step 1:

Teacher pretends to be standing on a scale and has a handful of Rice Krispies. The teacher asks the students to think about what will happen to the reading on the scale if they eat the cereal. Students have a minute to think and then the class shares out. Students are asked to provide possible justification for the scale increasing, decreasing, and remaining the same. (Teacher asks students to answer for each regardless of what they personally thought.) (5 min.)

Step 2:

Teacher asks the students what they think will happen to the Rice Krispies when the students crush them in their hands. Students are asked to provide a possible explanation for why the mass would increase, stay the same, or decrease (regardless of their particular opinions). (3 min.)

Step 3:

Introduce Rice Krispie activity. Students will be reminded of safety instructions: do not to eat the rice krispies or horse play with them during the experiment. Each lab group will get a ziplock bag and the materials manager will fill the bag with their desired amount of Rice Krispies (up to half full). (10 min.)

Step 4:

Discuss the mass of the bag and its relevance to the outcome of the activity. Students will use a scale to find the initial mass of the bag of Rice Krispies in the bag and record the mass in their science notebooks. Students will crush the Rice Krispies in the bag until powdery in appearance. Have students then find the mass of the bag of crushed Rice Krispies and write the mass down next to the previous mass from before in their science notebooks. Students calculated the mass gained or lost during crushing and recorded it on a teacher-drawn number line on the board. Clean up the Rice Krispies and dispose of them properly (25 min.)

Step 5:

Teacher leads discussion about the overall trend in the class data, and any possible outliers. For outliers, the teacher would ask the class to identify some possible causes (such as bag touching the table during measurement, or Rice Krispies escaping the bag).

The teacher asks the students which idea did the data supports--that crushing causes the mass to increase, decrease, or stay the same. (10 min.)

Step 6:

Show first part of dissolving sugar video, pause for predictions and reasons for predictions, then complete video. Teacher asks what this tells us about dissolving sugar--why does the mass stay the same? What other evidence could we have that the sugar is still there even though we can’t see it? (Thinking of sweetness). Teacher notes that some people say that “matter is matter, no matter how small.” How does this statement support our observation that the dissolved sugar still has mass? (5 min.)

Step 7:

Show first part of the ink on paper video, pause for predictions and reasons for predictions, then complete video. Teacher asks what this tells us about ink on paper--why does the mass increase? How does this relate to the idea that “matter is matter no matter how small?” (4 min.)

**Cycle 2: The Mass of Air**

Step 1:

Teacher leads a class discussion on the following review and extension questions:

Would the reading on the scale change if the person eats the Rice Krispies? How do you know?

Can something be crushed small enough to make its mass 0? How do you know?

One reason given that the mass of the bag of Rice Krispies stayed the same was that the bag is closed--nothing entered or left. But the volume went down even though no Rice Krispies entered or left. How do you explain this? (5 min.)

Step 2:

Show first part of balloon video, pause for predictions and reasons for predictions, then complete video. Teacher asks what this tells us about the mass of air? What other evidence could we have that the air in the balloon has mass even though we can’t see it? (Thinking of balloon expanding.) (5 min.)

Step 3:

Show two equally deflated volleyballs.

Show students that both deflated balls are the same mass by placing both deflated balls on a two-pan balance. Teacher asks students to discuss with their group what they think will happen. Teacher asks for possible reasoning for each possibility (that the inflated balloon is lighter, heavier, or has the same mass, regardless of their personal opinion). Teacher inflates one volleyball (being careful not to over-inflate) and places it back on the pan. (10 min.)

Step 4:

Teacher asks groups to draw side-by-side particle diagrams of the deflated and inflated volleyballs on large whiteboards. (10 min.)

Step 5:

As a class, students kneel in a circle, displaying everyone’s whiteboards to one another.

Students observe silently.

Teacher asks:

Why are the two diagrams different?

What caused the inflated ball to be heavier?

* Students possible responses: We added air so the ball is heavier.
	+ Teacher response: So you’re saying air has mass? What is air made of?
	+ Student possible responses: Air is made of Oxygen, Nitrogen, Carbon, H20...etc

So what is between the particles on your board?

* + Student anticipated response: air (correct response: nothing).

Didn’t you just say that air was made of particles of (Oxygen, Nitrogen, etc.) So if air is made of particles then what is between the particles of the air?

* + Students response: Nothing! (It may take several minutes to reach this point.)
	+ Teacher response: How do you know? (15 min.)

**Cycle 3: A Particle Model for Density**

Step 1:

Materials managers collect cylinder kits.

Teacher says: “Please place the cylinders in order from smallest volume to greatest volume.”

Teacher walks around the room checking group answers. If students do not agree, ask the group to agree on a definition of volume. If necessary the teacher may provide examples with other objects if necessary.

Teacher says: “Now try to place the cylinders in order from smallest mass to greatest mass.”

Teacher walks around the room observing group answers (do not comment).

Teacher distributes balances and asks students to check their answers.

After the students determine that the masses are equal, teacher asks: why did we think some were heavier than others? (Encourage a robust conversation but limit the conversation to a few minutes.) (15 min.)

Step 2:

Materials managers return cylinders and collect density cubes.

Teacher says: “Please place the cubes in order from smallest volume to greatest volume.”

Teacher walks around the room checking group answers. (Many groups laughed and said we were trying to trick them.)

Teacher says: “Without using the balance, place the cubes in order from smallest mass to greatest mass.”

Teacher walks around the room observing group answers (do not comment).

Teacher asks students to use the balances to check their answers. (10 min.)

Step 3:

Teacher asks groups to draw side-by-side particle diagrams of a light metal cube (on the left) and a heavy metal cube (on the right) on large whiteboards. (10 min.)

As a class, students kneel in a circle, displaying everyone’s whiteboards to one another.

Students observe silently.

Teacher asks:

How are the two diagrams different?

If only the “crowdedness” explanation emerges, leave it there. If the particle-mass model also emerges, discuss this idea after developing the crowdedness model.

Teacher asks what is between the particles of metal. Hoped-for answer: “Nothing.” Whether students answer “Nothing, “Air,” or something else, ask “How do you know?” Ask other students to comment/expand until an accurate explanation emerges. (15 min.)

Step 4:

Teacher asks: How are the two cubes different? Possible answers mass, weight, crowdedness, and density.

Teacher asks: “What do we mean by ‘density?’” Solicit student explanations. (Looking for the language of crowdedness. Watch for use of “mass,” “weight,” “size,” or “volume” when density is intended.)

Teacher explains that to calculate density, we divide an object’s mass by its volume.

* Sample problem: Draw a large sphere. A 450 gram object has a volume of 150 cm3.
	+ What is the object’s density?
	+ What are the units of the object’s density? How did you determine that?
	+ What does 3 grams per 1 cm3 mean? Ans: Each 1 cm3 piece has a mass of 3 grams.
	+ Draw a large object with a 1 cm3 piece to illustrate a single cm3. Then draw a second and and a third 1 cm3 piece, explaining that each 1 cm3 piece has a mass of 3 grams. (15 min.)

Step 5:

Organize students into work groups.

* Explain roles:
	+ Materials Manager--This person is responsible for collecting and returning all needed materials.
	+ Reader- This person reads the directions and problems aloud for all members to hear.
	+ Mass Measurer– This person is responsible for using the balance to find the mass of objects.
	+ Pace Monitor– This person helps keep track of time and keeps the group moving along together (no one moves ahead or gets left behind).
* Distribute guided activity sheet: <https://docs.google.com/document/d/1MlOxnMiA82WjF2KEIidaNvAIJPqq2SF4ceNTpT0CbEo/edit>

Ask students to work together to complete (40 min--Note that it is not expected that all groups will complete all items in the worksheet.) Teacher should be walking around and checking in with groups.

Step 6:

Each group receives a kit including four steel and four aluminum rods (identity of metals unknown to students). Point out that the volumes are written on the sides of the rods.

* Using the [Measuring the Density of Different Materials](https://docs.google.com/document/d/1_ZsOcO18ybNGHjwd4Jz0TrYrHRdze1D6Q8p2dHsoS_o/edit) worksheet as a guide, students measure and record each mass on the data table.
* Students calculate the density for each rod.
* Each density is recorded on the front board as an X on a teacher-drawn number line (ranging from 0 to 10 g/cm3.
* As an extension, teacher can discuss that the composition of the rods might not be pure steel or pure aluminum. (30 min.)

Step 7:

Teacher points to the number line and asks: “What do you notice?” (Two regions of values on the number line, any outliers; two regions indicate two different metals) (5 min.)