ESS 100 (Stapleton) Name: _____

Modeling Astronomy Concepts: Exploring Physics and Chemistry concepts that help explain Astronomy

- Important Concepts:
  - Definitions of mass, volume, density, and weight
  - How changes in temperature relate to motions of molecules and pressure
  - How squeezing and releasing a gas can cause its temperature to change.
- Culminating Activity: Make a Stirling Engine.

Part 1: Physical Properties of Matter, with an emphasis on Density

Match each term to the appropriate description: Volume, Mass, Weight, Density

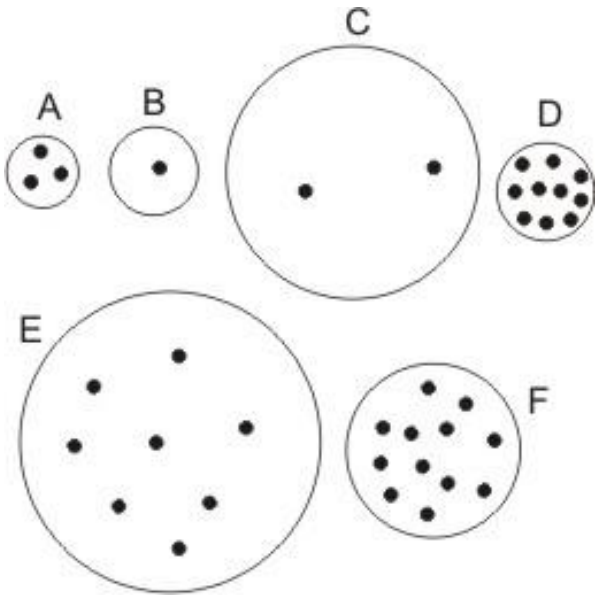
1. _____ The amount of "**stuff**" in something.

2. _____ The amount of space something takes up; how big something is; **size** in three dimensions

3. _____ How compressed or **crowded** the stuff inside an object is; a ratio of stuff to size. $Density = \frac{mass}{volume}$

4. _____ The **force of gravity** pulling an object toward a planet.

The circles on the right represent objects with varying masses, volumes, and densities. The dots inside the objects represent identical particles of "stuff." You could imagine that each dot is a bb. The rest of the object is empty space, and the circle has no mass; it just shows where the edge is.



5. Which object has the greatest volume? _____
6. Which object has the least volume? _____

7. Which object has the greatest mass? _____
8. Which object has the least mass? _____

9. Which object has the greatest density? _____
10 Which object has the least density? _____

11. *Which object has the greatest weight? _____
12. *Which object has the least weight? _____

13. There are asterisks above because, in special circumstances, all of the objects can have the same weight. Explain.

Read the descriptions below and decide whether each property increases (+), decreases (-), or stays the same (=). *Some answers will vary depending on your assumptions (such as whether air has significant mass).*

Description of Change	**Property**	**Change in Property (+, -, or =)**	**Explanation**
14. A ball of aluminum foil is squeezed into a much smaller ball of aluminum foil.	Mass		
	Volume		
	Density		
	Weight		
15. A piece of paper loses its corner when the corner is cut off and thrown away.	Mass		
	Volume		
	Density		
	Weight		
16. A balloon is inflated with a bike pump.	Mass		
	Volume		
	Density		
	Weight		
17. A moon rock is taken to the Earth.	Mass		
	Volume		
	Density		
	Weight		
19. A film canister submarine transitions from sitting on the bottom of a tank to floating upward.	Mass		
	Volume		
	Density		
	Weight		

20. A plastic bottle of water splits open when the water inside freezes and expands.	Mass		
	Volume		
	Density		
	Weight		

21. An astronaut travels from the Earth's surface to outer space, inside a space ship.	Mass		
	Volume		
	Density		
	Weight		

22. Someone opens an empty water bottle, inserts some rocks, and closes it again.	Mass		
	Volume		
	Density		
	Weight		

23. Someone exercises and gets much, much stronger, but her weight does not change.	Mass		
	Volume		
	Density		
	Weight		

24. A hot air balloon is hovering over your town. The pilot turns on the flame, and the balloon begins to rise.	Mass		
	Volume		
	Density		
	Weight		

ESS 100 (Stapleton) Names: _____
The Floating, Sinking, Floating, Sinking, Floating Challenge

Materials: Pennies (as many as you need), film Canister, Ziplock container with lid, 2-liter bottle with the top cut off, water

Directions: Start with a penny as your object. The penny sinks (test it if you want). Each challenge requires you to change the object in a way that changes its density, causing it to sink float. You can change the object by adding or removing one or more things to or from the object. You can't remove everything; at least one part of the object must remain from the last challenge.

The goal is to complete all of the challenges while following the rules above. It is likely that you will get to an impossible situation. If that happens, you may need to go back a few steps and redo the earlier challenges in a different way.

Draw and label each of your objects. Use pencil in case you need to change your answers. Let me know when you are finished. I may select your solutions and test them!

Challenge 1: Your starting object is a penny. The penny sinks. Change your object in a way that increases its mass and causes it to float. You have to keep the penny, but you can add things to it. Draw your new object in the space below and label its parts.

Challenge 2: Change your object in a way that increases its volume and causes it to sink. You must keep at least one of the old parts. Draw your new object in the space below and label its parts.

Challenge 3: Change your object in a way that decreases its mass and causes it to float. You must keep at least one of the old parts. Draw your new object in the space below and label its parts.

Challenge 4: Change your object in a way that decreases its mass and causes it to sink. You must keep at least one of the old parts. Draw your new object in the space below and label its parts.

Challenge 5: Change your object in a way that decreases its volume and causes it to float. You must keep at least one of the old parts. Draw your new object in the space below and label its parts.

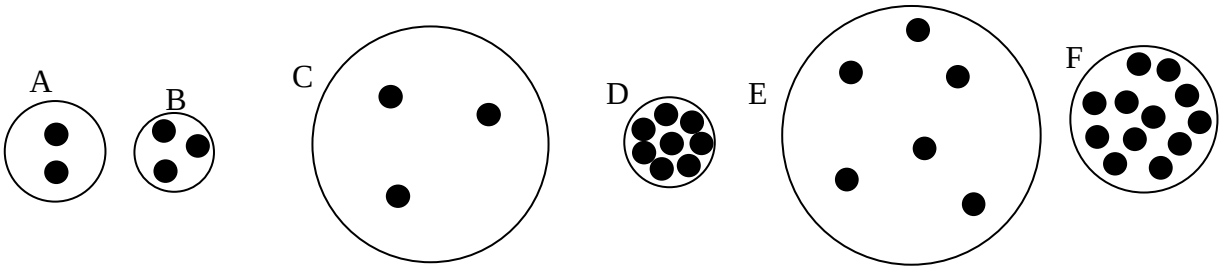
**Go back and test your solutions before turning this in!

ESS 100 Stapleton Name: _____
Practice: Physical Properties of Matter

Part I:

The objects below are mostly empty space. The circle is the edge of each object. The dots inside represent all of each object's mass. The empty space inside the objects has no air or mass of any kind. All of the objects are in similar locations on the same planet.

1. Which object has the most weight? A B C D E F
2. Which object has the least weight? A B C D E F
3. Which object has the most volume? A B C D E F
4. Which object has the least volume? A B C D E F
5. Which object is most dense? A B C D E F
6. Which object is least dense? A B C D E F
7. Which object has the most mass? A B C D E F
8. Which object has the least mass? A B C D E F



Part II: For the following questions, tell whether each property increases, decreases, or stays the same. Circle correct symbol, either +,-, or =. Assume that the objects in these situations stay in the same location!

9-12. A container stays the same size, but more stuff is placed inside the container.

9. mass + - =
10. volume + - =
11. density + - =
12. weight + - =

13-16. Something gets bigger, but the amount of stuff in it does not change. What is happening to its…

13. mass + - =
14. volume + - =
15. density + - =
16. weight + - =

Part 2: How Temperature Changes Affect Volume and Pressure:

Kinetic Molecular Theory: a way of understanding physical properties of matter by thinking about matter as being made up of tiny, moving particles. This is the theory we will be using and exploring on this handout.

Kinetic Energy: Energy of motion; more speed = more energy

Temperature: the average kinetic energy of the molecules or atoms in a substance

Pressure: A pushing force. Gases like air have pressure when their individual particles push outward (like the air in a car tire).

States of Matter (a.k.a. phases of matter):

- **Solid phase:** Molecules (or individual atoms)are locked in place, touching one another, vibrating. Hotter solids vibrate more violently.
- **Liquid phase:** Molecules are touching one another, but sliding and bumping around and changing positions; flowing. Hotter liquid molecules slide and bump around faster.
- **Gas phase:** Molecules flying free, but occasionally bumping into one another. Hotter gas molecules fly faster.

Open the PhET States of Matter Simulation: Choose **solid**, and click on any substance other than water.

1. Heat up the substance and describe what happens to the motion of the particles.

2. Cool down the substance and describe what happens to the motion of the particles.

3. Reset. Select either Neon, Argon, or Oxygen. Heat up the substance. When you heat it up, what happens to its overall…

	What happens?	How can you tell?
Mass		
Volume		
Density		
Weight		

4. Switch the simulation mode to "phase changes." What happens to the pressure inside the container…

a. Heat up the substance and describe what happens to the pressure.

b. Cool down the substance and describe what happens to the pressure.

c. What do you think is causing the pressure inside the container?

5-6. Inflate something (like a balloon or a Ziplock bag) and seal it so that no air can escape. Heat it up and cool it down. Use your observations to describe and explain what is happening to its mass, volume, density, weight, and pressure.

5. What happens when the object is heated?

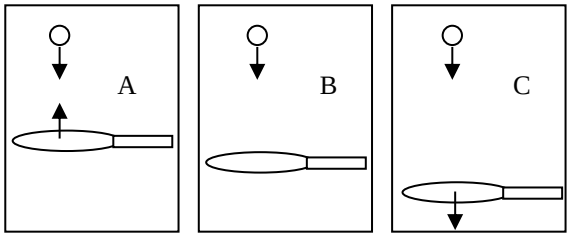
	What happens?	What causes this change? (or why is there no change)
Mass		
Volume		
Density		
Weight		
Pressure		

6. What happens when the object is cooled?

	What happens?	Why? or How can you tell?
Mass		
Volume		
Density		
Weight		
Pressure		

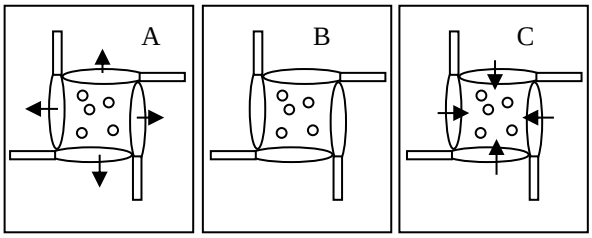
Part 3: How Pressure and Volume Changes Affect Temperature

In the three pictures on the right, a "perfectly bouncy" ping pong ball is dropped onto a "perfectly bouncy" ping pong paddle.



1. In which situation will the ball speed up the most (and bounce highest) after being hit by the paddle?
2. In which situation will the ball slow down the most (and bounce the least) after being hit by the paddle?
3. In which situation will the ball's speed remain approximately the same after hitting the paddle?

The three pictures on the right show "boxes" which have tennis rackets for walls. Inside the boxes, tennis balls are bouncing around. In one box, the walls are pushing inward against the balls. In another box, the rackets are relaxed, allowing the balls to push them out. In a third box the walls are held stationary.



4. In which "box" will the walls' behavior cause the balls to speed up?

5. In which "box" will the walls behavior cause the balls to slow down?

6. In which "box" will the walls behavior not affect the balls' speeds?

7. Why does rapidly compressing a gas cause the temperature to increase?

8. Why does allowing a gas to rapidly decompress cause its temperature to decrease?

Make a cloud in a bottle

Complete these steps and then answer the questions that follow:

Get a clear 2-Liter bottle with a cap.

a. Get the inside of the bottle wet by putting water in it and shaking the water around. Then pour out the water.
b. Light a match and get it burning well. Blow it out as you place it in the bottle. The point is to get some smoke the bottle. Cap the bottle tightly before the smoke escapes.
c. Now squeeze the bottle as hard as you can for one second.
d. Stop squeezing and let the bottle expand for one second.
e. Squeeze again for another second, with all of your might. But don't jump on the bottle. This should be a steady squeeze.
f. Release your squeeze.
g. Squeeze again….
h. Keep repeating this until you see a cloud forming and disappearing. Pay close attention to when the cloud is appearing and when it is disappearing. Holding the bottle in a bright light with a dark background will make the cloud easier to see.

1. When you squeeze the bottle, does that cause the temperature of the air in the bottle to increase or decrease?

2. When you release the bottle, does that cause the temperature of the air in the bottle to increase or decrease?

3. When the cloud appears in your bottle, the cloud is made mostly of water molecules that are

   _____ (solid, liquid, or gas). We know this because _____

   _____

4. When the cloud in your bottle disappears, those water molecules turn to _____ (solid,

   liquid, or gas). We know this because _____

   _____

5. Squeezing the bottle causes _____ (evaporation or condensation) and releasing causes

   _____ (evaporation or condensation).

6. Clean out your bottle. Remove the air and get fresh air. Will a cloud form if you don't use the smoke?

7. When you make a cloud in a bottle, that cloud is made of water, and it is floating in the air inside your bottle. Where does that water come from, and how does it get in the air?

Unit Practice: Physical Properties and Air Pressure

Part I (Mass, Volume, Density, Weight) :

The objects below are mostly empty space. The circle is the edge of each object. The dots inside represent all of each object's mass. The empty space inside the objects has no air or mass of any kind. All of the objects are in similar locations on the same planet.

1. Which object has the most mass?

2. Which object has the least mass?

3. Which object has the most volume?

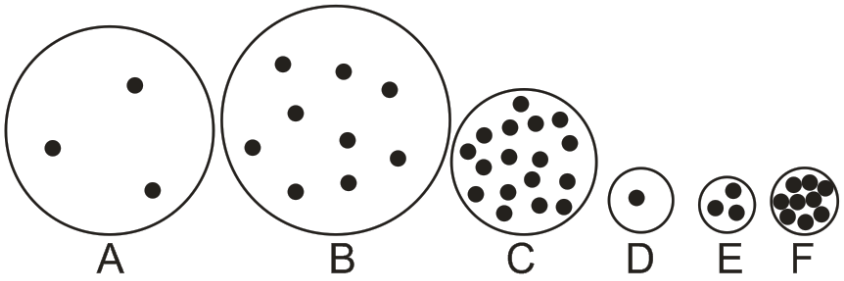
4. Which object has the least volume?

5. Which object is most dense?

6. Which object is least dense?

7. Which object has the most weight?

8. Which object has the least weight?



9-16. For the following questions, tell whether each property increases, decreases, or stays the same. Choose the correct symbol, either +,-, or =.

9-12. An object's size doesn't change, but more stuff is added to it.

9. mass + - = 10. volume + - =

11. density + - = 12. weight + - =

13-16. The particles inside an object become less crowded, but the amount of stuff in the object doesn't change.

13. mass + - = 14. volume + - =

15. density + - = 16. weight + - =

Part 2: How Temperature Changes Affect Volume and Pressure:

A sealed jar has air inside. The jar cannot change its size, and no air can enter or leave. What will happen when the jar and the air inside are **heated** up?

17. What will heating do to the motion of the molecules in the jar?

18. When the jar is heated, what will happen to the pressure inside the jar?

19. What is creating the pressure that is inside the jar?

A plastic Ziplock bag is filled with air and sealed. No air can enter or leave the bag. What will happen to the bag of air when it is **cooled** down?

20. How does cooling affect the overall mass of the bag and its air? (increase, decrease, or no change)

21. How does cooling affect the overall volume of the bag and its air? (increase, decrease, or no change)

22. How does cooling affect the overall density of the bag and its air? (increase, decrease, or no change)

23. How does cooling affect the overall weight of the bag and its air? (increase, decrease, or no change)

24. How does cooling affect the pressure inside the bag? (increase, decrease, or no change)

Part 3: How Pressure and Volume Changes Affect Temperature

Consider the same Ziplock bag filled with air and sealed. No air can enter or leave the bag.

25. What will happen to the temperature of the bag if you squeeze the bag (but not hard enough to pop the bag)?

26. Explain why squeezing changes the temperature in this way.

27. What will happen to the temperature of the air in the bag if you release it after you have been squeezing it for a while?

28. [This won't be on the quiz unless it's part of a bonus.] If you see a cloud suddenly <u>appear</u> in air, that mean's the air's temperature _____ (increased or decreased). If you see a cloud suddenly <u>disappear</u>, that means the temperature of the air around the cloud suddenly _____ (increased or decreased.)