# Pre-Lab Information

Purpose Explore the process for determining the density of a solid using a laboratory procedure.

Time Approximately 45 minutes

Question How can the density of an object be determined?

Hypothesis If the mass and volume of an object can be measured, then its density can be determined, because density equals mass over volume.

Variables PART I: Regularly Shaped Solids

Independent Variable: the mass of the ball

Dependent Variable: the ball’s ability to float

Controlled Variable: the volume of the ball

PART II: Irregularly Shaped Solids

Independent Variable: the volume of the ball

Dependent Variable: the ball’s ability to float

Controlled Variable: the mass of the ball

Part III: Identifying a Substance Using Its Density

Independent Variable: the source of the baseball

Dependent Variable: the density of the baseballs

Summary You are part of a records investigation team at your school. At last night’s game, a pitcher surpassed the school record for the most strikeouts in a single game. Before the pitcher’s accomplishment can go in the school record books, you need to test the baseball to ensure the integrity of the game. You and your friends will use your scientific skills to either uphold the record or expose this attempt as a fraud.

First, you will demonstrate your understanding of the density for regular solids, including a table tennis ball and a golf ball, and an irregular solid, such as a deflated football. You will explore the relationship between density, mass, and volume. Then, you will apply these techniques to determine the density of the baseball in question.

# Safety

* Always wear a lab coat and safety goggles when performing an experiment.
* Make sure that all behavior in the lab is purposeful.
* Do not throw around any of the athletic equipment used in this exercise.
* Be careful not to spill when transferring water from the water displacement procedure, which could cause people to slip and fall.
* Check containers, such as beakers, graduated cylinders, and buckets, for cracks or chips prior to use.
* Report all accidents—no matter how big or small—to your teacher.

# Procedure

1. **Gather materials.**

|  |  |  |
| --- | --- | --- |
| * 1 table tennis ball * 1 inflatable football * 1 golf ball * 1 questionable baseball * 1 inflation pin | * 1 air pump * A 5-gallon bucket of water * 1 large storage container (to fit under the bucket) * 1 towel | * 1 mass balance * 1 wide-mouth 500 ml graduated cylinder * 1 metric ruler or tape measure |

**Part I: Regularly Shaped Solids**

1. **Determine the mass of the regularly shaped balls.**
   1. Use a mass balance to record the masses of the table tennis ball and golf ball in grams. Record the mass of each in Table A.
2. **Estimate the volume of the regularly shaped balls.**
   1. Use a ruler to determine the diameter of the table tennis ball in cm. Record this in Table A.
   2. Use the equation radius = diameter/2 to calculate the radius of the ball. Record this in Table A.
   3. Use the equation volume = 4/3π*r*3 to estimate the volume of the ball. Record this in Table A.
   4. Repeat Steps 3a–c for the golf ball.
3. **Calculate the estimated density of each regularly shaped ball.**
   1. Use the equation density = mass/volume to calculate the estimated density of each ball. Record your estimate in Table A.
   2. Given that the density of water is 1.0 g/cm3, make a prediction about whether each ball will float in water. Record your prediction in Table A.
4. **Measure the volume of each regularly shaped ball.**
   1. Fill up a wide-mouthed 500 ml graduated cylinder with 300 ml of water. Record this initial volume in Table A in cm3. Recall that 1 ml = 1 cm3.
   2. Drop the table tennis ball into the graduated cylinder. Record in Table A whether the ball floats.
   3. If necessary, use the ruler to submerge the table tennis ball in the water. Be careful to push the ball just beneath the surface so that the ruler is not also submerged.
   4. The water level in the graduated cylinder should have risen, because some of that water was displaced by the presence of the ball. Record the total volume of the water and the ball in Table A.
   5. Calculate the measured volume of the tennis ball by subtracting the initial volume of water in the graduated cylinder from the final volume of the water after the ball was submerged. Record this calculation in Table A, and compare it with the volume that you estimated earlier.
   6. Repeat Steps 5a–e for the golf ball.
5. **Calculate the density of each regularly shaped ball.**
   1. Use the equation density = mass/volume to calculate the density of each ball, based on the measured volumes from Step 5. Record your calculations in Table A.
   2. Compare these densities with those that were estimated in Step 4. Perform an “error analysis” using your data from Table A, by applying the following formula:

Report your error as a percentage in Table A.

**Part II: Irregularly Shaped Solids**

1. **Determine the mass of the irregularly shaped football while it is inflated.**
   1. Use a mass balance to record the mass of the football. Record this mass in Table B.
2. **Estimate the volume of the football while it is inflated.**
   1. The smaller balls were spherical, so we used a formula for the volume. The football has a more complex shape, so you will make a comparative estimate of volume. Knowing the volume of the golf and table tennis balls, make a reasonable estimate about the volume of the football. Is it ten times larger than the golf ball? One hundred times larger? One thousand times larger? Record your estimated volume in Table B.
3. **Calculate the estimated density of the inflated football.**
   1. Use the equation density = mass/volume to calculate the estimated density of the inflated football. Record your estimate in Table B.
   2. Given that the density of water is 1.0 g/cm3, make a prediction about whether the inflated football will float in water. Record your prediction in Table B.
4. **Determine the volume of the football while it is inflated.**
   1. Place a bucket within the larger storage container. Carefully fill the bucket to the very top with water. The storage container should stay dry; make sure that no excess water spills into it at this point.
   2. Slowly place the inflated football into the bucket of water. Some water will spill over the edge and into the container. Record in Table B whether the ball floats.
   3. If necessary, use the ruler to submerge the football in the water. Be careful to push the ball just beneath the surface so that the ruler is not also submerged. More water should spill over the edge of the bucket and collect in the storage container. This happens because some of that water was displaced by the presence of the ball.
   4. Carefully remove the bucket and ball from the storage container. Transfer the displaced water to the graduated cylinder, and determine how much water was displaced by the football. This may require multiple transfers of water if the volume exceeds that of the top gradation (500 ml) of the graduated cylinder. If so, be sure to add up all measurements before you record the displaced water volume in Table B.
5. **Calculate the density of the inflated football.**
   1. Calculate the actual density of the football using the mass from Step 7, the measured volume from Step 10e, and the equation density = mass/volume. Compare this calculated density with the estimated density from Step 9.
6. **Determine the mass of the irregularly shaped football after it is deflated.**
   1. Dry off the football and the storage bin with a towel.
   2. Insert the inflation needle into the pin port on the side of the football. Squeeze the football until you have squeezed out as much air as possible.
   3. Use a mass balance to measure the mass of the deflated football. Record this measurement in Table B.
7. **Estimate the volume of the irregularly shaped football while it is deflated.**
   1. Given the volume of the inflated football, make a reasonable estimate about the volume of the deflated football. Is it ten times less than that of the inflated version? Five times less? Half as large? Record your estimate in Table B.
8. **Determine the volume of the irregularly shaped football after it is deflated.**
   1. Place the bucket back into the storage bin, and refill it to the top with water. Be careful not to spill water into the storage container.
   2. Slowly place the deflated football in the bucket of water. Some water will spill over the edge and into the container. Record in Table B whether the ball floats.
   3. If necessary, use the ruler to submerge the football in the water. Be careful to push the ball just beneath the surface so that the ruler is not also submerged. More water should spill over the edge of the bucket and collect in the storage container.
   4. Carefully remove the bucket and ball from the storage container. Transfer the displaced water to the graduated cylinder, and determine how much water was displaced by the football. This may require multiple transfers of water if the volume exceeds that of the top gradation (500 ml) of the graduated cylinder. If so, be sure to add up all of the measurements before you record the displaced water volume in Table B.
9. **Calculate the density of the deflated football.**
   1. Calculate the actual density of the deflated football using the mass recorded in Step 12c, the measured volume from Step 14d, and the equation density = mass/volume.
10. **Calculate the error between the estimated and calculated densities.**
    1. Compare your calculated densities with your estimated densities for both the inflated and deflated football. Perform an error analysis similar to what you did for the golf and table tennis balls, by using your data from Table B and applying the error formula:

Report your error as a percentage in Table B.

**Part III: Identifying a Substance Using Its Density**

**Step 17:** **Calculate the density of the questionable ball for validation.**

* 1. Obtain the “questionable ball” from your teacher. Use a mass balance to determine its mass, and record your measurements in Table C.
  2. Use the water displacement method (Steps 14a–d) to measure the volume of the ball, and then record the measurement in Table C.
  3. Calculate the density of the questionable ball using the equation density = mass/volume.
  4. Compare the density of the questionable ball to the acceptable range of densities for official baseballs, provided in Table C. Make an evaluation, and circle one of the conclusions in Table C.

**Step 18: Dispose of, dry off, and reinflate all materials according to your teacher’s directions.**

# Data

Record your data either in your lab notebook or in the space below.

**Table A: Calculation of Density for Regularly Shaped Solids**

|  |  |  |
| --- | --- | --- |
|  | **Table tennis**  **ball** | **Golf**  **ball** |
| Mass  (g) |  |  |
| Diameter  (cm) |  |  |
| Radius  (cm) |  |  |
| Estimated volume  (cm3) |  |  |
| Estimated density  (g/cm3) |  |  |
| Prediction of buoyancy  *Circle one.* | Float Sink | Float Sink |
| Observation of buoyancy  *Circle one.* | Float Sink | Float Sink |
| Initial volume of water  (cm3) |  |  |
| Final volume of water  (cm3) |  |  |
| Change in volume  (cm3) |  |  |
| Calculated density  (g/cm3) |  |  |
| Error  (%) |  |  |

**Table B: Calculation of Density for Irregularly Shaped Solids**

|  |  |  |
| --- | --- | --- |
|  | **Inflated**  **football** | **Deflated**  **football** |
| Mass  (g) |  |  |
| Estimated volume  (cm3) |  |  |
| Estimated density  (g/cm3) |  |  |
| Prediction of buoyancy  *Circle one.* | Float Sink | Float Sink |
| Observation of buoyancy  *Circle one.* | Float Sink | Float Sink |
| Volume of displaced water  (cm3) |  |  |
| Calculated density  (g/cm3) |  |  |
| Error  (%) |  |  |

**Table C: Density Analysis of the Questionable Baseball**

|  |  |
| --- | --- |
|  | **Questionable baseball** |
| Mass  (g) |  |
| Volume of displaced water  (cm3) |  |
| Calculated density  (g/cm3) |  |
| The acceptable density range of official baseballs is between 0.70 g/cm3 and 0.80 g/cm3. | |
| According to the density analysis, is the questionable baseball legitimate or altered? | Legitimate Altered |