Density, Displacement, and Weight in fluids - PHY103

Apparatus: Digital balance, dual pan balance, table clamp, metal rod to fit mounting hole on dual pan balance, lab jack, 50 ml graduated cylinder, tri-pour beaker, lead sinker, steel bolt, and rubber cork (all three of which fit easily in graduated cylinder), paper clips, string, eye dropper, golf ball.

Density is defined as the mass divided by the volume of a material, mass being the amount of matter present and volume being the amount of space the matter takes up. Standard SI measurement units of mass are kilograms (kg) while SI units of volume are cubic meters (m^3), so density has SI units of kg/ m^3. Densities reported in units of g/cm^3 are not SI, but are common because the relatively small samples used in experiments are more simply measured with tools calibrated for smaller units. Still, as with most given physics equations, it is necessary to convert all quantities to standard SI unit form prior to doing calculations to be certain you will obtain correct answers.

Any kind of substance can be found in various quantities, so knowing just the mass or just the volume doesn't say anything about the type of material. For example, a 1000 kg mass could be a large pile of cotton or a small pile of lead, while a 1 m^3 volume could be a light load of Styrofoam plastic or a massive amount of steel. On the other hand, the ratio of mass to volume tells exactly how much stuff exists per unit volume, and for pure substances will be characteristic only to very specific types of materials based on the particular type of atoms, the spacing between them, and the environmental conditions affecting them. These principles apply to matter in solid, liquid, and gaseous states alike.

Be aware: No units are given on this sheet, so you will need to include those when filling in the blanks!! Make sure that all measured data is recorded precisely with units exactly as taken from the measurement tool in the first blank (including your visual estimate of the last decimal place) and then also recorded separately in standard S.I. units in the second blank. As always, show at least one clearly notated sample of each unique type of calculation used.

When asked, be sure to explain your methods clearly:

1. Find the mass of the golf ball, lead sinker, rubber cork, and steel bolt both on the mechanical dual pan balance and on the electronic digital pan balance. Which measurement device do you believe is more precise? Why?

Mass of golf ball: ________________ _________________

Mass of lead sinker: ________________ _________________

Mass of rubber cork: ________________ _________________

Mass of steel bolt: ________________ _________________

2. Find the weight of each item. How is this different from the mass?

Weight of golf ball: _______________

Weight of lead sinker: _______________

Weight of rubber cork: _______________

Weight of steel bolt: _______________

3. Use the equipment at your disposal to find the most accurate and precise experimental volume for each object. Explain how it was done. Be concise!

Actual Volume of golf ball: _______________ _______________

Volume of lead sinker: _______________ _______________

Volume of rubber cork: _______________ _______________

Volume of steel bolt: _______________ _______________

4. Calculate the actual density of each object and also the density of a sample of water using your own experimental data.

Sinker_____________ Standard Textbook Values: lead: 11300 kg/cubic meter

Cork______________ rubber: 1350 kg/cubic meter

Bolt______________ steel: 7860 kg/cubic meter

Water_____________ water: 1000 kg/cubic meter

5. For the golf ball, approximate the volume theoretically using the standard formula for the volume of a sphere. $V_{sphere} = 4*pi*r^3/3$, where r is the radius of the sphere. (This is only an approximation because the golf ball isn't truly a smooth sphere, right?) Then find the combined volume of fluid that can be held by all of the dimples in the surface of the ball.

Calculation of ball volume:

Combined volume of all dimples in ball:

6. Effect of Upward Force Due to Immersion in a Fluid, aka Buoyancy:
   Suspend each object from the hook below the rod-mounted dual pan balance, and measure what the mass of each seems to be when it's completely submerged in water. (Be sure that the object is completely surrounded by water and does not touch the sides or bottom of the beaker.) Also, find the weight of the water that is displaced by each object. (Put water volume equal to object volume on balance OR multiply textbook water density by volume of object and g.)

Apparent mass & weight of object while under water
and Weight of the water displaced by each object:

Mass sinker: _________Weight: _________ Water Weight: ___________

Mass cork: _________ Weight: _________ Water Weight: ___________

Mass bolt: _________ Weight: _________ Water Weight: ___________

7. How does the weight of each object in air found in step 2 differ from the weight of each object when under water? Calculate the differences and compare to the respective weights of the displaced water. How could you compare quantitatively?

Lab or At Home Challenge!! - Try to judge and compare the densities of two sample objects by size alone without feeling their weight. Then try to judge the density of objects hidden from view and direct touch, feeling only their weight. (Have someone else hide each object in separate boxes, and you just feel the weight of each box.) Does knowing the volume alone help you guess? Does weight alone? Finally, hold the two objects directly, one in each hand, feeling both the weight and volume of each simultaneously. Do you now have a more confident guess for which has a greater or lesser density?