AP Physics 2: Summer Assignment

Welcome to AP Physics!

Hello! Welcome to AP Physics 2. This course will build upon the laws of motion you learned in your first physics class and apply those laws to atoms, electrons, and light. AP Physics is a fascinating and challenging course that requires a solid foundation in mathematics to be able to study how the world moves. To make sure you have the proper mathematics background please complete the following packet and submit it as you walk into class on the first day of school. On the second day of school you will take the AP Physics 2 entrance exam to make sure that AP Physics 2 is a good fit. The entrance exam will cover the material on this summer assignment and you will need to score higher than an 80% on that to remain in AP Physics 2. Students who score less than an 80% might be better suited in another class. I'm looking forward to meeting you on the first day of school and be sure to check out the helpful links throughout this assignment to get refreshers with the math skills and watch the necessary video for the graphing portion of the assignment.

Sincerely,

Mr. Templin

Part 1: Goals for AP Physics 2

1) What are your goals for AP Physics 2?

2) Which topic in AP Physics 2 are you most looking forward to? Explain.

3) Have a great time with the summer assignment! Show all necessary work in the space provided. Answers without work will be graded as zeros. Draw a dachshund in the space below to confirm that you will show all of your work.

Part 2: Measuring Skills

A ruler will be required for this section of the summer assignment. An AP Physics 2 student should have no problem converting units and measuring objects. Students that can not do common conversions from centimeters to meters in their head are not prepared for AP Physics 2. For now, ignore the uncertainty of your measurements. We'll handle that in class.

1) Find an object and take a picture of it. Email this picture to stemplin@htps.us with the subject "AP Physics 2 Summer Assignment Object" . The object must be recognizable to an elementary school student. A prize will be given to the AP Physics 2 student who finds the smallest object and largest object.

2) Measure the height of your object in meters. Record this height to the right: _____

3) Convert your measurement to cm.

4) Convert your measurement to μm.

5) Convert your measurement to mm.

6) Convert your measurement to feet.

7) Convert your measurement to miles.

8) Estimate the volume of your object.

Part 3: Analyzing the Buoyant Force at an AP Level

Start off by watching this video from <u>PBS - Crash Course Physics</u>[1] about fluids at rest, Archimedes' Principle, and the buoyant force.

1) Explain Archimedes' Principle.

2) Starting Archimedes' Principle from the video (at 7:53) , show how the buoyant force can be represented as it is on the AP Physics 2 equation sheet, $F_b = \varrho V g$.

3) Fill in the table below regarding the variables used to describe the buoyant force.

Variable	Physical Quantity	Units	Definition
F_b	The Buoyant Force pushing on an object	N (Newtons)	the upward push exerted by any fluid upon a body placed in it
m_F	The mass of the displaced fluid		
ϱ (the greek letter rho)			
V			
g	The strength of the Gravitational Field that an object is in.	N / kg (Newtons per kilogram)	

Make sure you didn't give a one word answer for ϱ or V. When students say ϱ is simply "density" or V is simply "volume" they are not analyzing the buoyant force at a college level. Students with one word definitions are easily fooled by a problem that gives them the density of an object and the density of the fluid, because they don't know which density they care about. Students with one word definitions are clueless in laboratory situations that ask them to calculate the volume of the object, volume of the fluid, and the volume of fluid displaced by the object. With a one word definition students are not sure what the buoyant force tells them. Always be sure that your definitions are specific and solid.

4) Speaking of college level, here is a problem that I'd like you to solve that is *not* college level by itself. Box your answers and now and for the rest of the year include units in your answer.

A bowling ball is placed in the ocean so that it floats. The density of salt water is 1025 kg/m^3, the volume of salt water displaced by the bowling ball is 5.1×10^{-3} kg, the volume of the bowling ball itself is 5.3×10^{-3} kg, and the gravitational field strength is 9.8 N/kg at the location of the ball.

(a) Determine the buoyant force acting on the bowling ball.

(b) Determine the density of the bowling ball.

5) It might have been surprising to hear that this mathematical problem was not college level. The reason is that this problem required very little thought and problem solving strategies. It does require knowledge of the variables that affect the buoyant force as well as competency with multiplication. Before calculators and computers existed this type of problem was very important and absolutely college level. To be a scientist or engineer 60 years ago meant you had memorized lots of different formulas and could perform lots of different calculations. Today there are online calculators that can calculate the buoyant force[2] way quicker than you can, so college physics has changed the way they prepare scientists and engineers. Not only do you have to be able to perform those calculations quickly, you also have to be problem-solve in a way that computers cannot easily do (yet[3]). One thing you can easily do to make sure you understand a calculation at a college level is to explain. Take a look at your answer to 4(b). Explain why it makes sense.
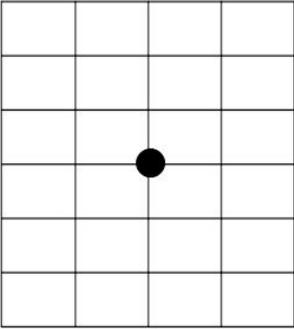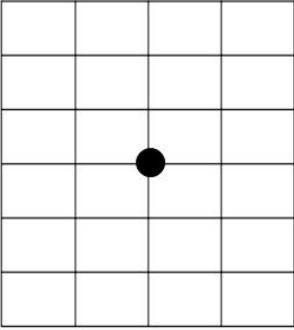
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[2] https://www.omnicalculator.com/physics/buoyancy
[3] Yes I know this video is from 2011. But computers are still bad at coming up with creative and correct conversational topics after a few sentences.

6) Here is a set of problems that require you to apply your knowledge of forces, Newton's 2nd Law, and the buoyant force. First, watch this video demonstration where bowling balls of different densities are placed in a tank of water[4]. In the following scenarios draw a force diagram that accurately shows the forces acting on a bowling ball in the given scenarios. Then, support your force diagram with an explanation showing why you included the forces you did and why you drew the forces with the magnitude you did. In your explanation be sure to relate the forces on the ball to the acceleration[5] of the ball. In all the scenarios the density of water is 1000 kg/m^3, the bowling balls have identical volumes, and frictional forces can be ignored.

Scenario	Force Diagram	Explanation
A bowling ball of density 1000 kg/m^3 is suspended at rest in the middle of the water.		
A bowling ball of density 1000 kg/m^3 is traveling upwards at a constant velocity in the middle of the water.		
A bowling ball of density 800 kg/m^3 is submerged completely underwater.		
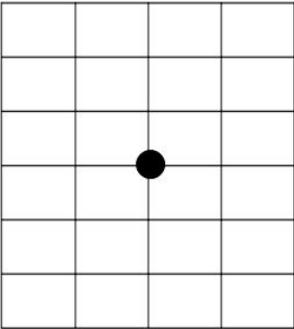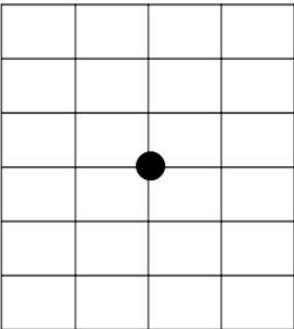
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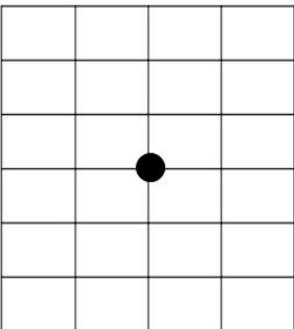
[4] https://www.youtube.com/watch?v=NqNGW0oOXE4
[5] Remember, if an object is changing its velocity as time goes on it is accelerating.

A bowling ball of density 800 kg/m³ is suspended at rest at the top of the water.		
A bowling ball of density 1200 kg/m³ is submerged completely underwater.		
A bowling ball of density 1200 kg/m³ is suspended at rest on the bottom of the water tank.		
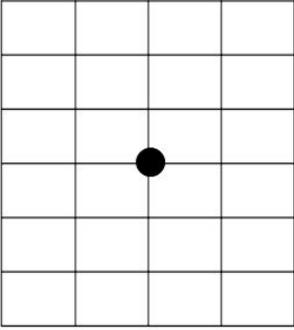
Check to make sure the following is true in your force diagrams:

❏ The bowling ball with the largest density has the largest weight (or force of gravity) and the bowling ball with the smallest density has the smallest weight. This is true because each of the bowling balls has the same volume.

❏ Any ball that is accelerating has unbalanced forces acting on it.

❏ Any ball that is at a constant velocity (which could mean the ball is stationary) has balanced forces acting on it.

❏ Every submerged ball has the same buoyant force acting on it. This is true because the balls are all displacing the same amount of water. If you missed this fact, review Archimedes' Principle.

❏ The ball at the bottom of the tank has a normal force acting on it that is 20% of the size of the buoyant force.

7) A student looks at the blue bowling ball of density less than water, floating at the top of the tank. The student makes the following statement.

"If you added salt to the water, this will increase the buoyant force acting on the blue bowling ball. This is true because the density of salt water is higher than the density of freshwater. As the density of the fluid increases, the buoyant force increases because $F_b = \varrho V g$, which means ϱ and F_b are directly proportional."

In a coherent and comprehensive paragraph length response, describe what about the students statement is correct and what is incorrect. Before answering, review the Expectations for the Paragraph Length Response in AP Physics 2[6].

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[6] https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf

8) Head to the following website to access the oPhysics Digital Buoyant Force Lab[7]. You'll be performing a digital lab to analyze the relationship between the buoyant force on an object and the volume of the fluid that is displaced by the object.

9) Change the Fluid Density to 3 g/cm³ and select the option to 'Show Free-Body Diagram' as shown below.
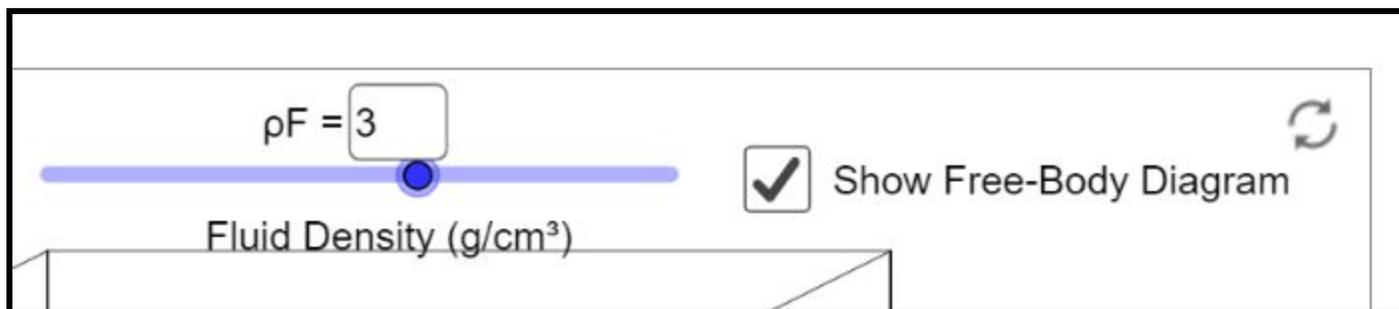
10) Click 'Run' and leave the simulation running throughout the experiment.
11) Let the block come to rest.
12) Click the 'Show Numbers' option.
13) Record the measured and calculated values in the table below. Repeat the experiment for blocks of various densities. To ensure accuracy, perform 10 trials. Never include 0 as a data point and keep the fluid density at a constant 3 g/cm³ .

Density of Object, ϱ_O (g/cm³)	Density of Object, ϱ_O (kg/m³)	Volume of Fluid Displaced, V_F (cm³)	Volume of Fluid Displaced, V_F (m³)	Buoyant Force, F_b (N)

14) What happened to the buoyant force as the density of the object went above 3.0 g/cm³ ? Explain.

15)   On the graph below, draw a graph of the Buoyant Force on the vertical axis and the Volume of Fluid Displaced on the horizontal axis. Be sure you have done the following:

  ❏ Each axis needs to be correctly labeled with units.
  ❏ Your graph needs to be scaled correctly, with each grid representing the same value.
  ❏ Your graph should include a trendline that does not connect the points, but shows the trend in the data. If the data shows a linear trend, draw a linear trendline. If the data shows an exponential trend, draw a parabolic trendline.
  ❏ Making college level graphs is a skill that an AP Physics 2 student should find easy and is a required skill to enter this course.
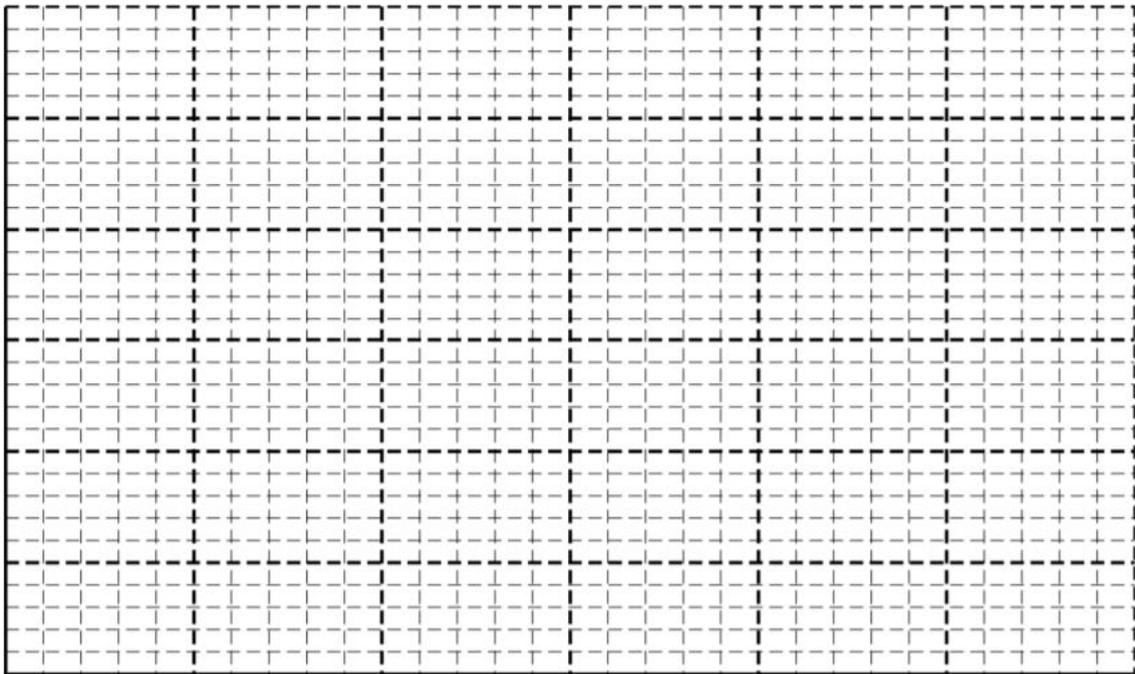
16)   Calculate the slope of your trendline. Include units in your calculations and answer. Remember from last year's physics class what the dimensions of a newton are.

17) Using the formula for buoyant force, $F_b = \rho V g$, what does the slope of your trendline represent? Box two different answers, one in terms of F_b and V and the other in terms of ρ and g.

18) Using the answers to the previous two questions, show that the gravitational field that the box is in is equal to 9.8 N/kg.

Part 4: Question about Buoyancy

Now that you have performed a lot of practice with the buoyant force, take a look at this question to test your skills. This problem should take you about 10-15 minutes to complete. Feel free to use the AP Physics 2 Equation Sheet, however you should know the equations in AP Physics 2 so well you do not need an equation sheet.
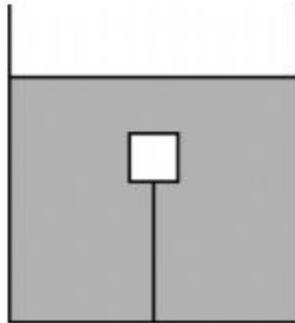
A cube of mass m and side length L is completely submerged in a tank of water and is attached to the bottom of the tank by a string, as shown in the figure above. The tension in the string is 0.25 times the weight of the cube. The density of water is 1000 kg/m^3

(a) On the dot below that represents the cube, draw and label the forces (not components) that act on the cube while it is attached to the string. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.

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(b) Calculate the density of the cube.

(c) The string is now cut. Calculate the magnitude of the acceleration of the cube immediately after the string is cut. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

(d) Indicate whether the magnitude of the buoyant force on the cube increases, decreases, or remains the same while the cube is rising, but before it reaches the surface.

___ Increases   ___ Decreases   ___ Remains the same

Justify your answer.

(e) Check out the solutions to the problem here[8]. The solutions start on page 4. Make sure that your response can easily get a 10 out of 10.

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[8] https://secure-media.collegeboard.org/digitalServices/pdf/ap/ap14_physics_b_scoring_guidelines.pdf

Part 5: The Boat Riddle

A classic AP Physics 2 problem dealing with the principles of buoyancy is the boat riddle. Here is the riddle:

You are sitting in a boat in a pool while holding a rock. You throw the rock into the water. Does the water level of the pool rise, fall, or stay the same?

Take 5 minutes and give a real, thoughtful answer. This is a really important aspect of an AP Physics class, to give a real good effort and to not be afraid of being wrong. The best physics students are not necessarily the ones who are the smartest, but the ones who stay with problems the longest. Take all summer to answer this question if you need to.

"It's not that I'm so smart, it's just that I stay with problems longer."
- Albert Einstein

Once you have given an effort that you can be proud of, check out this video by [Physics Girl](https://www.youtube.com/watch?v=nVT1c0tr8NE)[9] for a video version of the riddle and solution.

In the space below, state the solution in your own words. An AP Level response will contain force diagrams, equations, and relevant physics principles to aid in your response.

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[9] https://www.youtube.com/watch?v=nVT1c0tr8NE