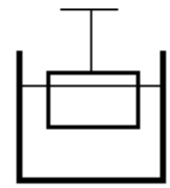
PY105S Worksheet for Unit 10 - Fluids
The Buoyant Force

Fluids exert an upward buoyant force on objects that are immersed (either completely or partly) in them. Let's work this force into our standard treatment of forces.

Situation 1:

A block of weight mg = 45.0 N has part of its volume submerged in a beaker of water. The block is partially supported by a string of fixed length. When 80.0% of the block's volume is submerged, the tension in the string is 5.00 N. Take the density of water to be 1000 kg/m^3.



a) What is the magnitude of the buoyant force acting on the block? Hint: try drawing a free-body diagram of the block and applying Newton's Second Law.

b) Water is steadily removed from the beaker, causing the block to become less submerged. The string breaks when its tension exceeds 35.0 N. What percent of the block's volume is submerged at the moment the string breaks? Hint: try drawing a free-body diagram of the block and applying Newton's Second Law to first find the buoyant force.

c) After the string breaks and the block comes to a new equilibrium position in the beaker, what percent of the block's volume is submerged? Hint: what does the free-body diagram look like now?

Situation 2:

A classic question in physics is the following: A boat containing a heavy anchor floats in a reservoir. If the anchor is thrown overboard and is completely submerged, what happens to the water level in the reservoir?

What's your prediction, and your reason?

The actual result is that the water level is lower after the anchor is completely submerged.

It might help if you complete the following sentences:

When the anchor is completely submerged the anchor displaces a volume of water that ____.

When the anchor is inside the boat the anchor is responsible for displacing a volume of water that _____________________________________.

Fluid Dynamics

How do we deal with flowing fluids? In some cases flowing fluids are too complicated to analyze. In others we can apply a simple model with two basic equations:

Continuity equation (based on mass conservation): $A_1 v_1 = A_2 v_2$.

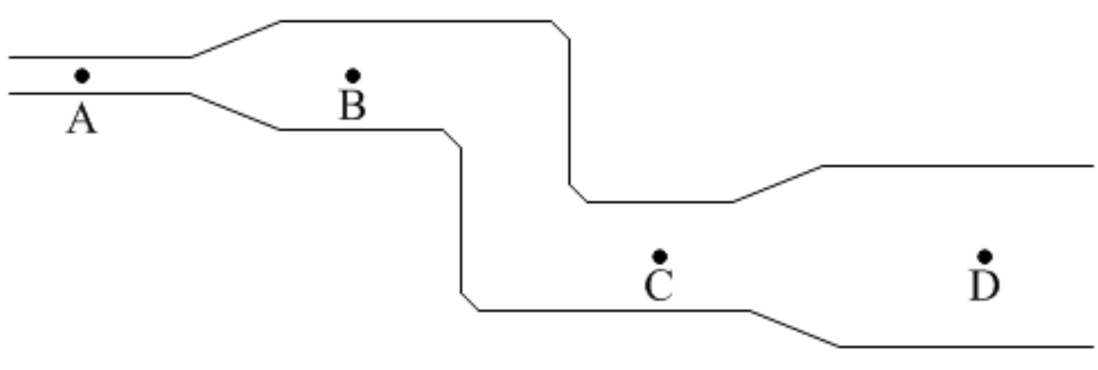
In a tube the continuity equation relates the flow speed and pipe area at one point to their values at another point.

Bernoulli's equation (energy conservation): $\rho g y_1 + \frac{1}{2}\rho v_1^2 + P_1 = \rho g y_2 + \frac{1}{2}\rho v_2^2 + P_2$

What are the units of the six terms in Bernoulli's equation?

Situation 3:

Four points are marked in a pipe containing a fluid. The pipe's cross-sectional area at B is



the same as that at C.

a) If the fluid is at rest in the tube, rank the four points based on their pressure, from largest to smallest.

b) Now the fluid is flowing to the right. Rank the four points, if possible, based on the speed of the flow, from largest to smallest.

c) In the situation of the fluid flowing to the right rank the four points based on their pressure, from largest to smallest.

d) Would your rankings change if the fluid was flowing to the left instead?

Situation 4:

A cylinder full of water stands upright on a table. The cylinder has three holes in its sides that are initially covered with tape. One hole is ¼ of the way down from the top, another is ½ way down, and the third is ¾ of the way down. When the tape is removed water shoots horizontally out of the holes and lands on the table.

Predict which hole shoots the water furthest horizontally on the table. Explain your answer.

Let's analyze the situation generally, using a cylinder with height *H* that is filled with water, and a hole that is a distance *h* from the top. Once the water emerges from the tube we have a projectile motion situation, which we know how to handle. What we need to know is the speed with which the water emerges from the cylinder.

Step 1 – Sketch a diagram of the situation.

Step 2 – To find the speed with which the water emerges from the hole, write down Bernoulli's equation. Let's take point 2 to be the point outside the cylinder where the fluid emerges from the hole. Pick a convenient point inside the cylinder (any point will actually work) to be point 1.

Step 3 – Define a zero for gravitational potential energy. Cross out all terms that are zero in the equation, and see if any terms cancel out.

Step 4 – Bring in the continuity equation to do something about v_1.

Step 5 – Solve for v_2, the speed at which the water emerges from the hole.