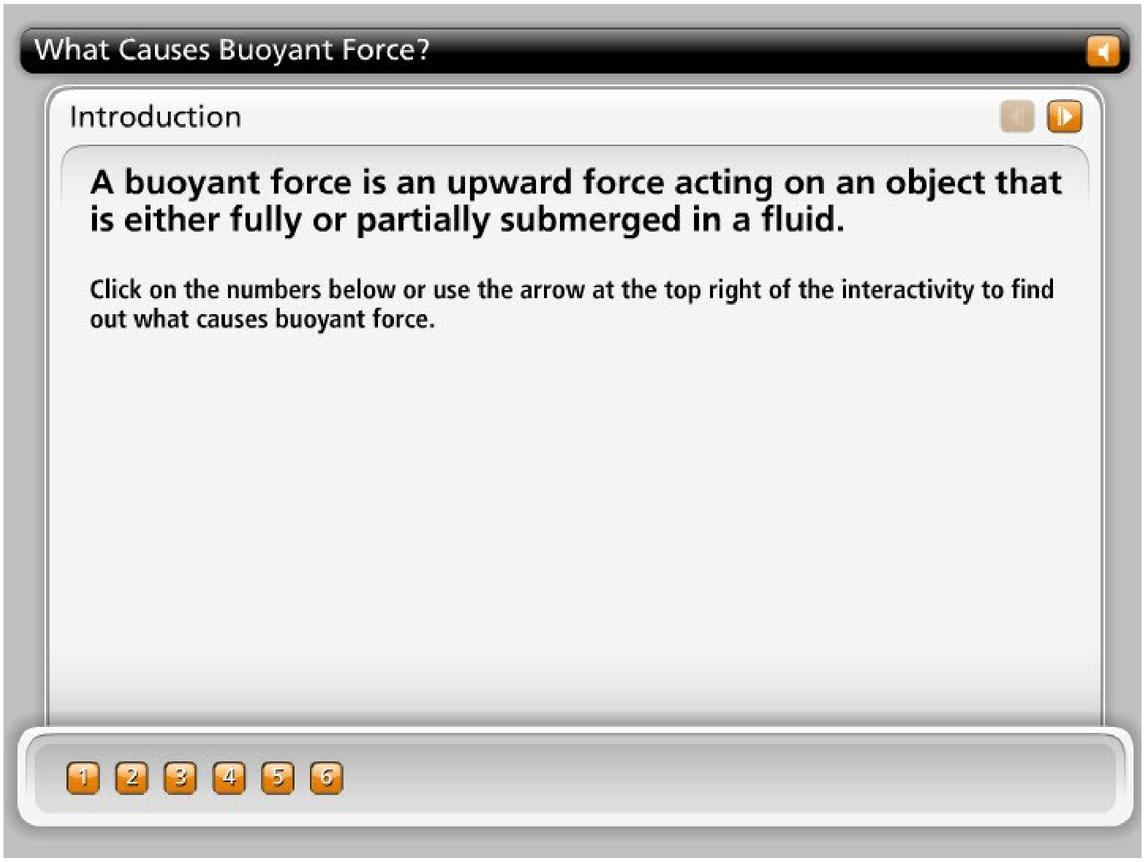
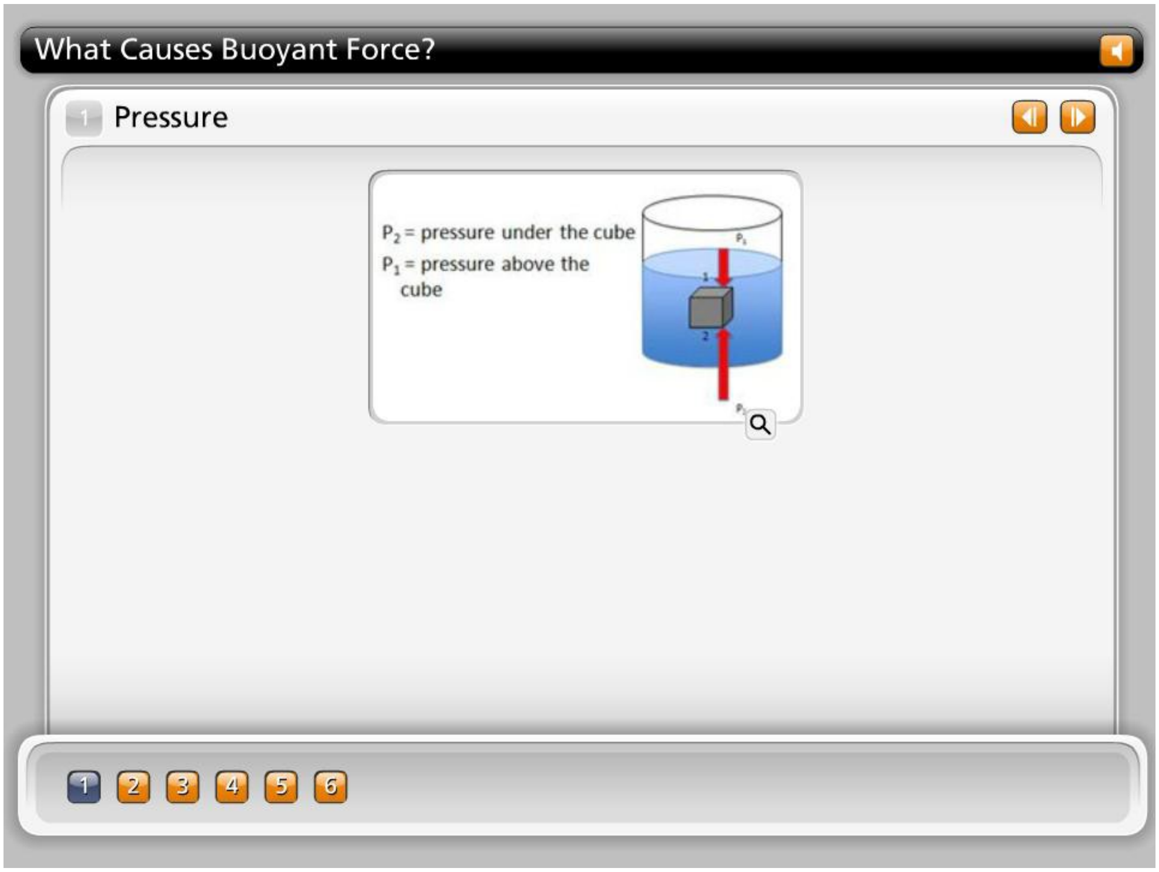
Module 9: Fluids

Topic 4 Application: Buoyancy, Density and Floating Presentation Notes



You might be wondering what a buoyant force is? A buoyant force is an upward force acting on an object that is either fully or partially submerged in a fluid.



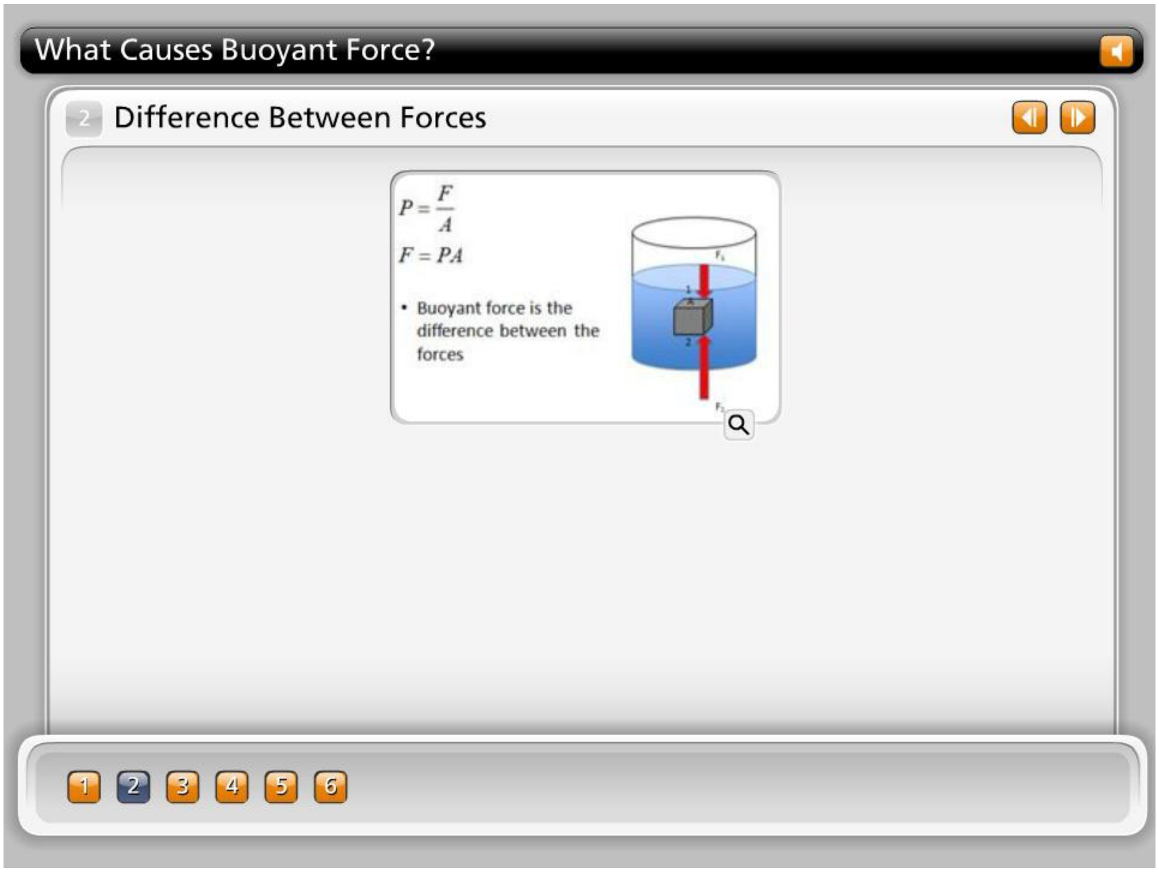
You learned how to find the pressure in a fluid in the previous topic. You will need to use that here to figure out how a buoyant force occurs when an object is submerged.

We know that pressure in a fluid is exerted in all directions. So, when the cube is submerged, the fluid pushes on it from all sides. The vertical sides of the cube are all at the same depth in the fluid, so the pressure there is the same. This means that the pressure pushing on each side is balanced by the pressure pushing on the other side.

But what about the pressures on the top and bottom of the cube? The depths are different, so the forces are different too. This is what creates the buoyant force. The buoyant force is big enough to balance the weight of the gray cube, this is why the cube can remain submerged without sinking or rising. The buoyant force and the weight are balanced.

First, lets compare the pressure just underneath the cube to the pressure at the top of the cube. Point 2 is just underneath the cube, point 1 is just above the surface of the cube.

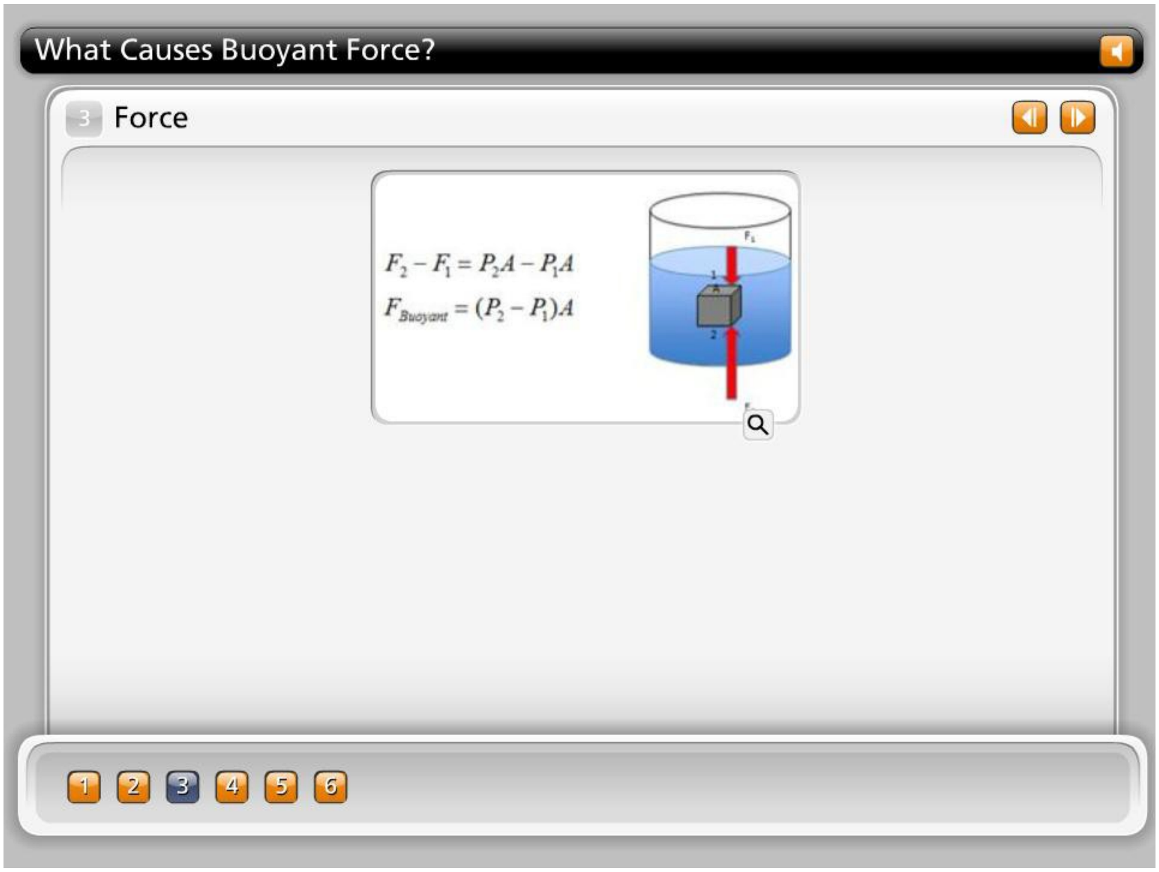
It is important to remember that at any point in a static fluid, pressure is exerted equally in all directions. So if you know the pressure at point two, that pressure is exerted upward on the cube. If we know the pressure at point one, that pressure is exerted downward on the cube.



You learned in the last topic that pressure is equal to force divided by area. For this example, A is the area of the upper and lower faces of the cube.

Let's rearrange the pressure equation to solve it for force, F.

We want to find the difference of force two and force one, which is the buoyant force.

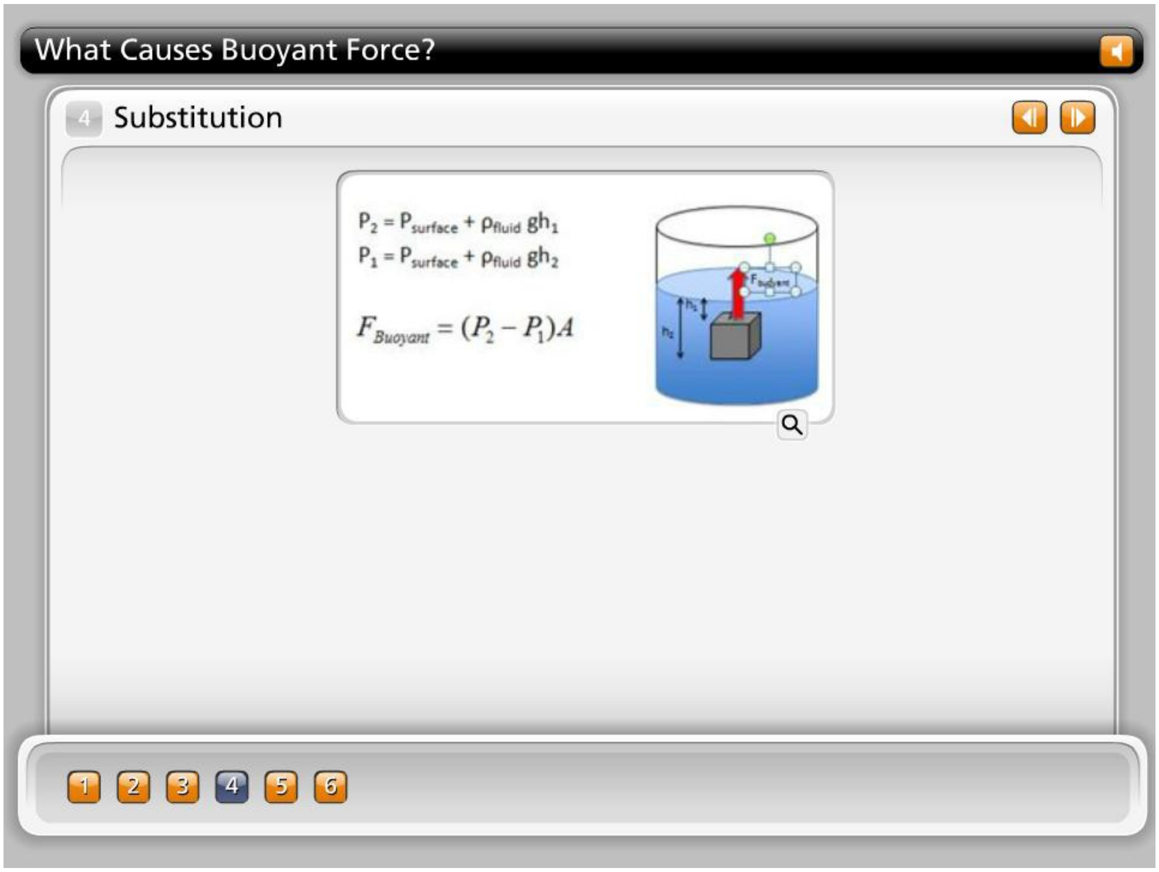


We can use force equals pressure times area for each of the forces.

If the upwards force exerted by the fluid on the bottom of the cube is greater than the downwards force exerted on the top of the cube, there will be a net upwards force. This is the buoyant force. We are really interested in the difference between the two forces, force two minus force one.

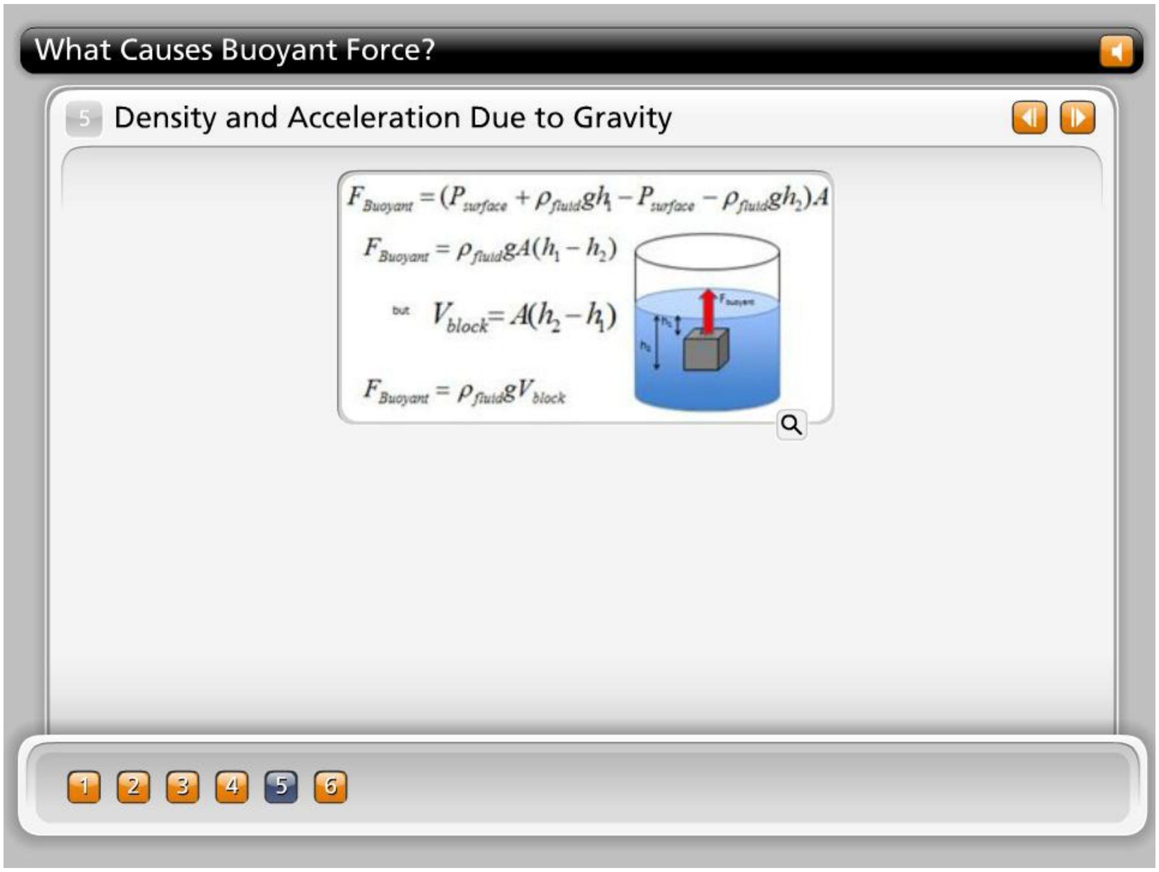
You can see that both terms have a common factor, area. Let's factor out the A.

So, if we can find the difference in pressure, we can multiply that by the area of the block that the forces are pushing on.



We can use the equation from the last lesson, the pressure-fluid-height relationship, to find the pressure at points one and two. P surface is the pressure that pushes on the surface of the liquid.

We will substitute these expressions into the buoyant force equation.

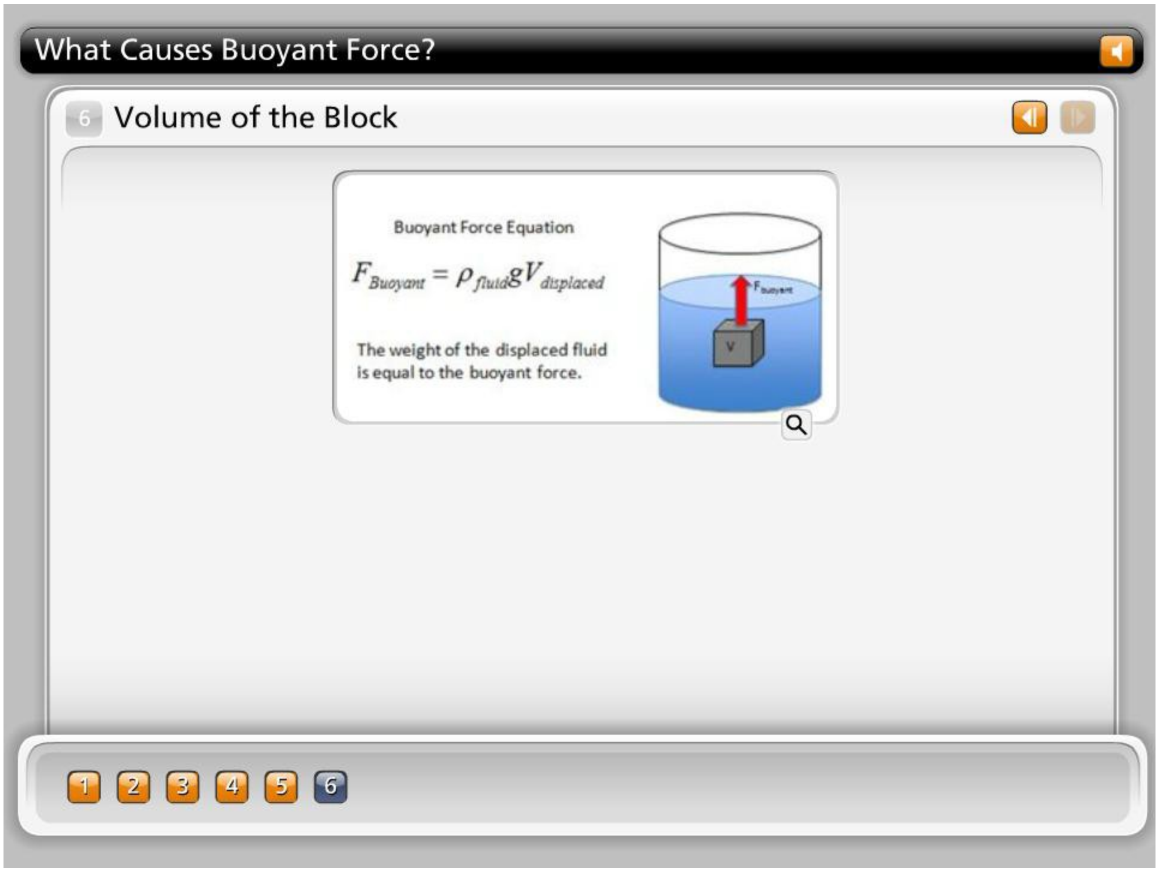


Once we substitute the two equations for pressure one and pressure two into the first equation, we see that the Pressure on the surface will cancel out.

We can see that we have two common factors, density and acceleration due to gravity.

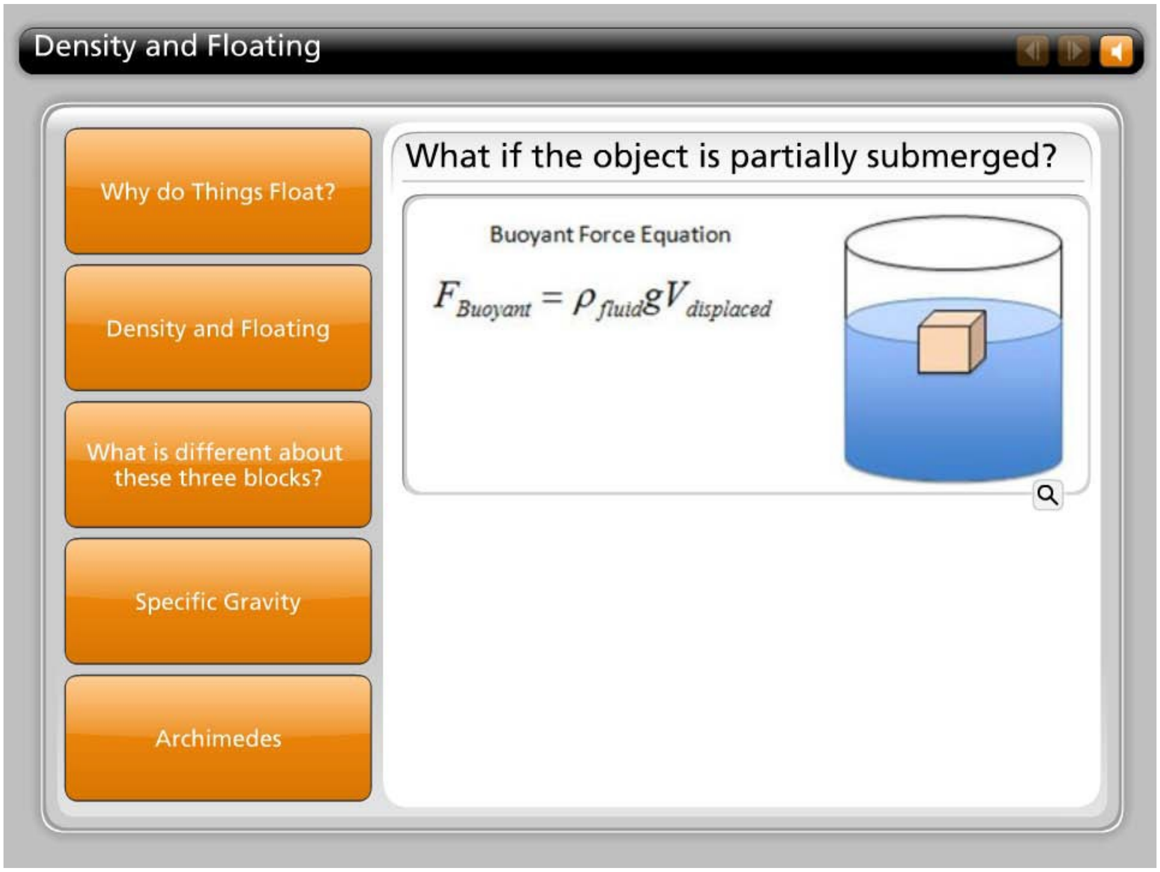
We are left with density times acceleration due to gravity times the change in height. One last thing we need to notice is that height two minus height one is the height of the block. Height times area is the volume of the block.

The buoyant force is equal to the density of the fluid times the acceleration due to gravity times the volume of the block.



Since the volume of the block is the volume of fluid that is displaced by the block, and density times volume is mass, the buoyant force is the same as the weight of the displaced fluid.

We have shown that the upward force acting on the block when it is submerged is equal to the weight of the fluid it displaces, or pushes out of the way.

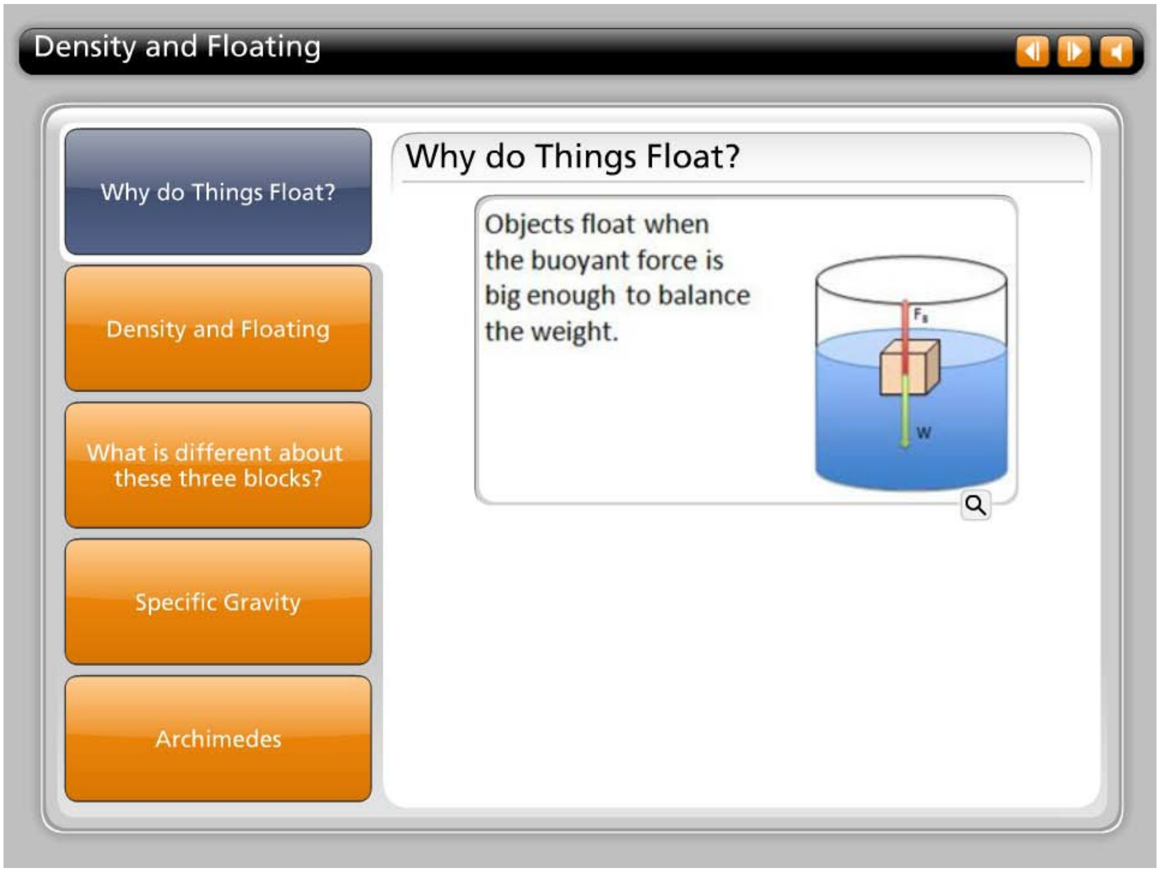


What if the object is partially submerged? Let's think about another cube that is the same size as the gray cube in our previous discussion.

If the cube is floating halfway submerged, then the displaced volume is only one-half of the volume of the cube.

You can see from the buoyant force equation that if displaced volume is cut in half, that will cut the buoyant force in half too. This is why we have to use the volume of the displaced fluid in the equation instead of the volume of the object.

Of course, if it is the same fluid, this cube could only be floating half submerged if it weighs half as much as the gray cube in our previous example. Since we are looking at cubes with identical volumes, when the weight is half as big, the density is half as big.

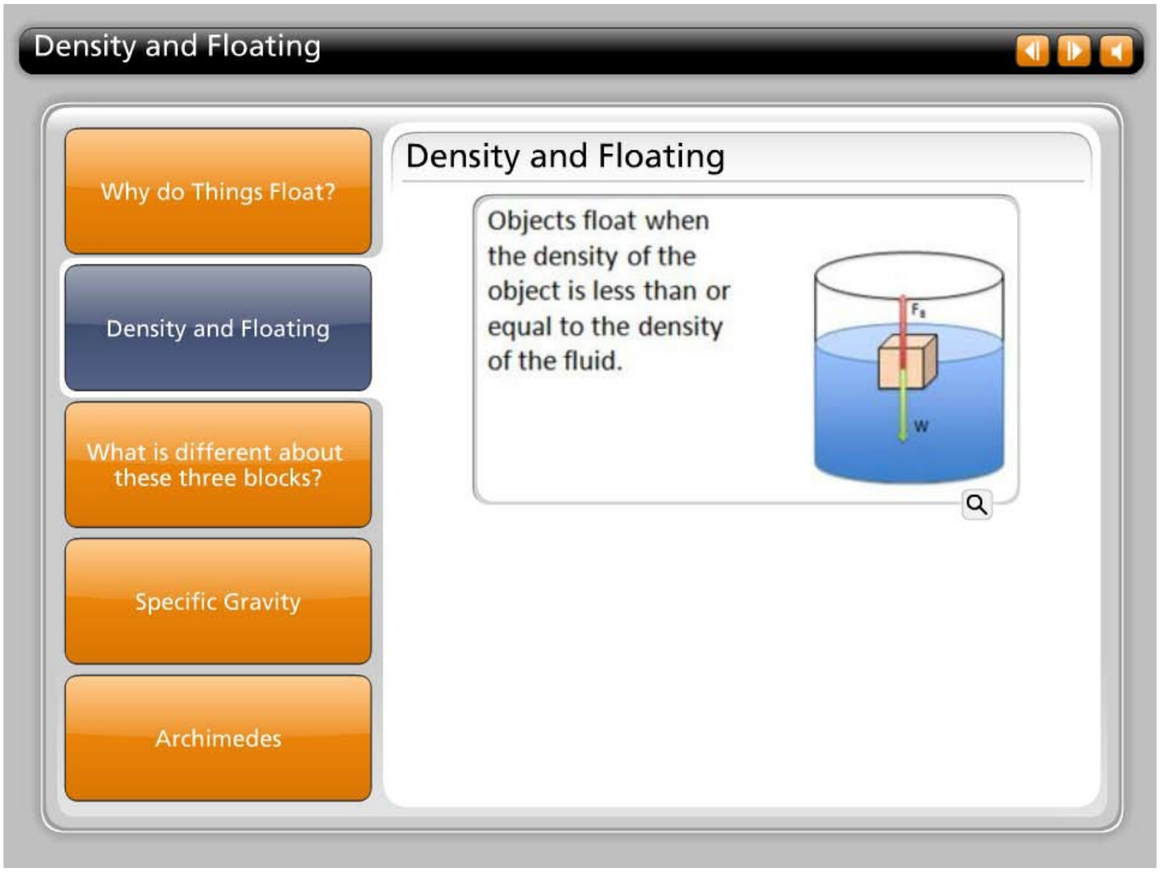


Now that you know where buoyant force comes from, let's figure out why things float.

If the cube is at rest, then you should know what the net force on the cube is. If the cube is not accelerating, the net force is zero. What forces act on the cube?

The force of gravity, or weight, pulls down on the block. The buoyant force pushes upwards on the block. If the block is at rest, the two forces must be equal and opposite.

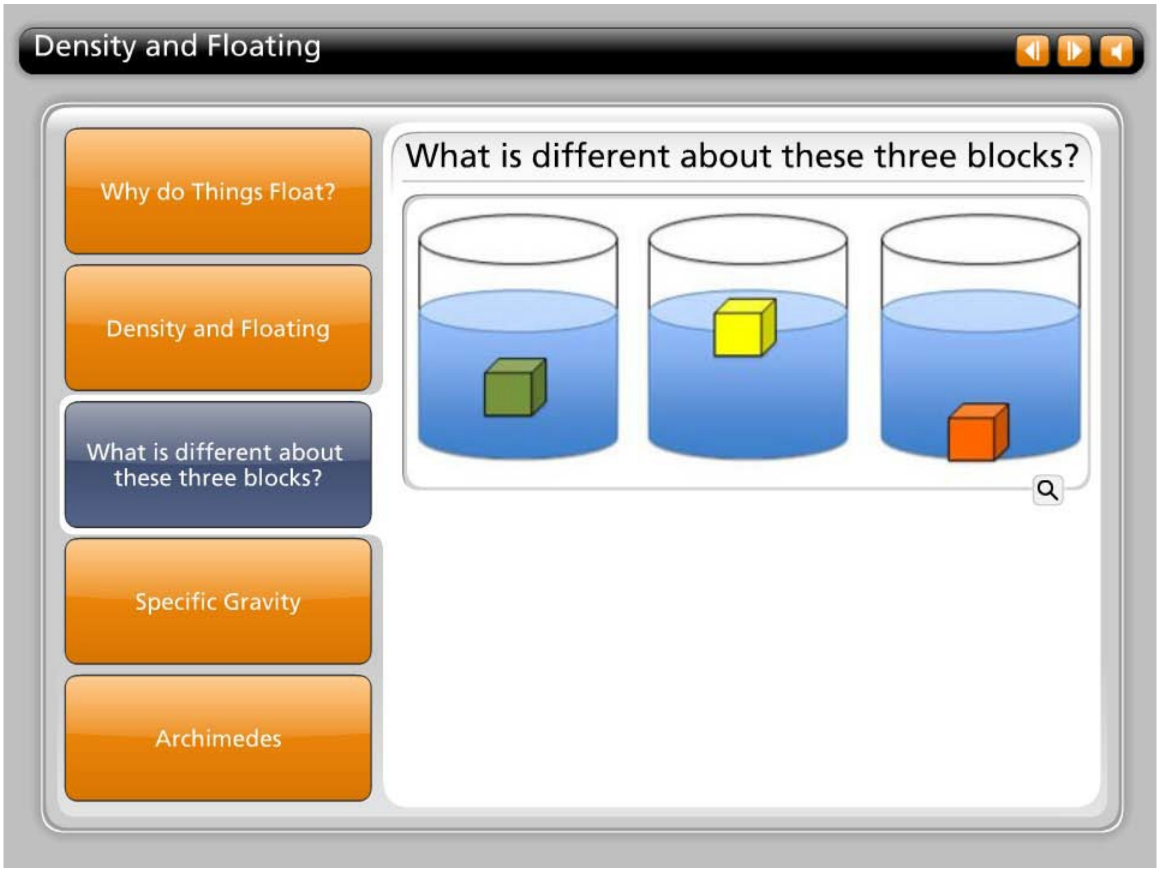
So, we see that objects float when the upward buoyant force is big enough to balance the weight of the object.



For an object to float, the fluid it displaces must weigh as much as the block. In this picture, you can see that the block is only half submerged. This means that the block's density is one-half the density of the water.

You might remember that we used specific gravity to compare the density of an object to the density of water. In this case, if the fluid is water, and the object is one-half as dense as water, it's specific gravity would be zero point five.

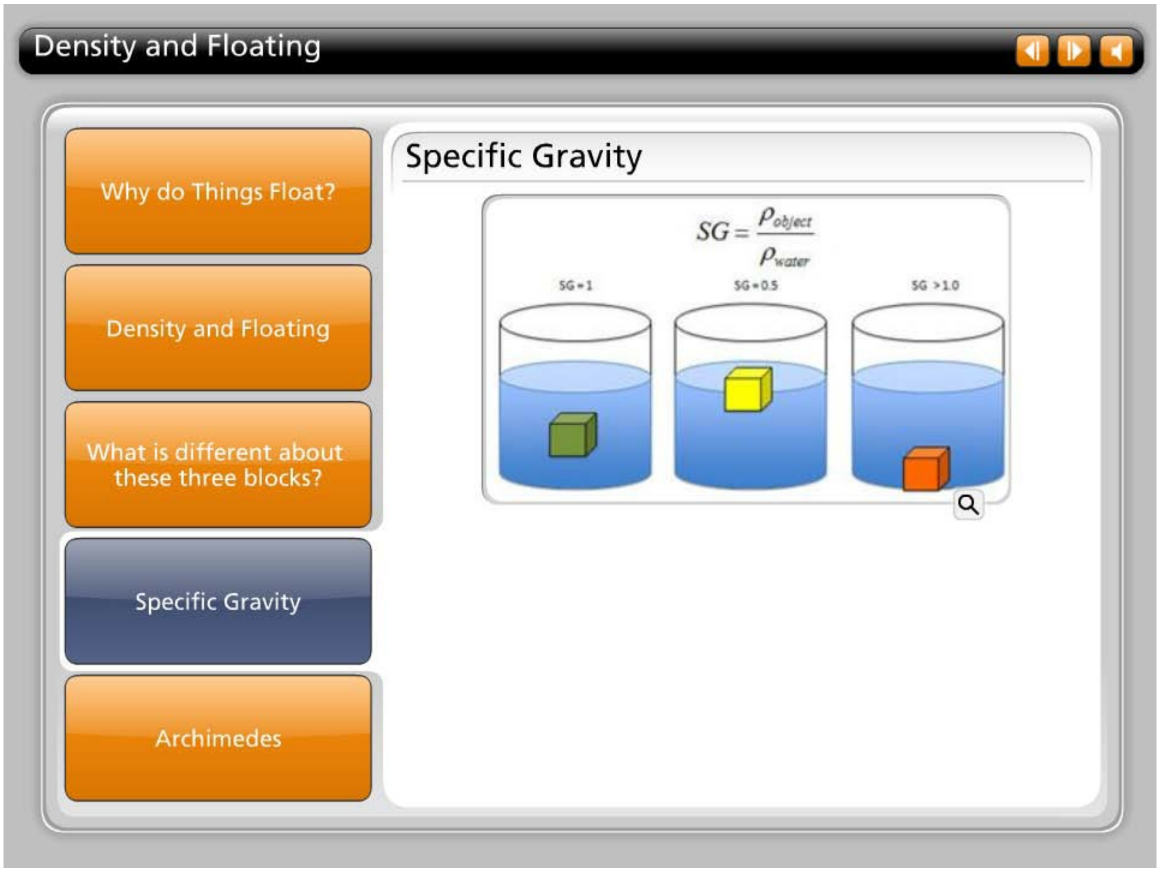
Specific Gravity is useful here because the value of the specific gravity tells you the percentage of the object that will be submerged.



We see that objects can float while being completely or partially submerged. When you put an object in water, it will move downward until it displaces enough liquid that the weight of the displaced liquid is equal to the weight of the object. If the object is more dense than water, the weight of the displaced liquid will not be able to compensate for the weight of the block and the block will sink to the bottom of the container. If the object has the same density as water, it will have to submerge completely to create enough buoyant force to balance its weight.

If the blocks all have the same volume, which block is the most dense? The block that must displace the most liquid to float must be the heaviest. Therefore, the orange block is the most dense.

The block that floats with most of it out of the water must be the lightest. Therefore, the yellow block is the least dense.



You might remember that when we introduced specific gravity, I mentioned that it would be used to explain floating. So let's review the definition of specific gravity. Specific gravity is the density of the object divided by the density of water.

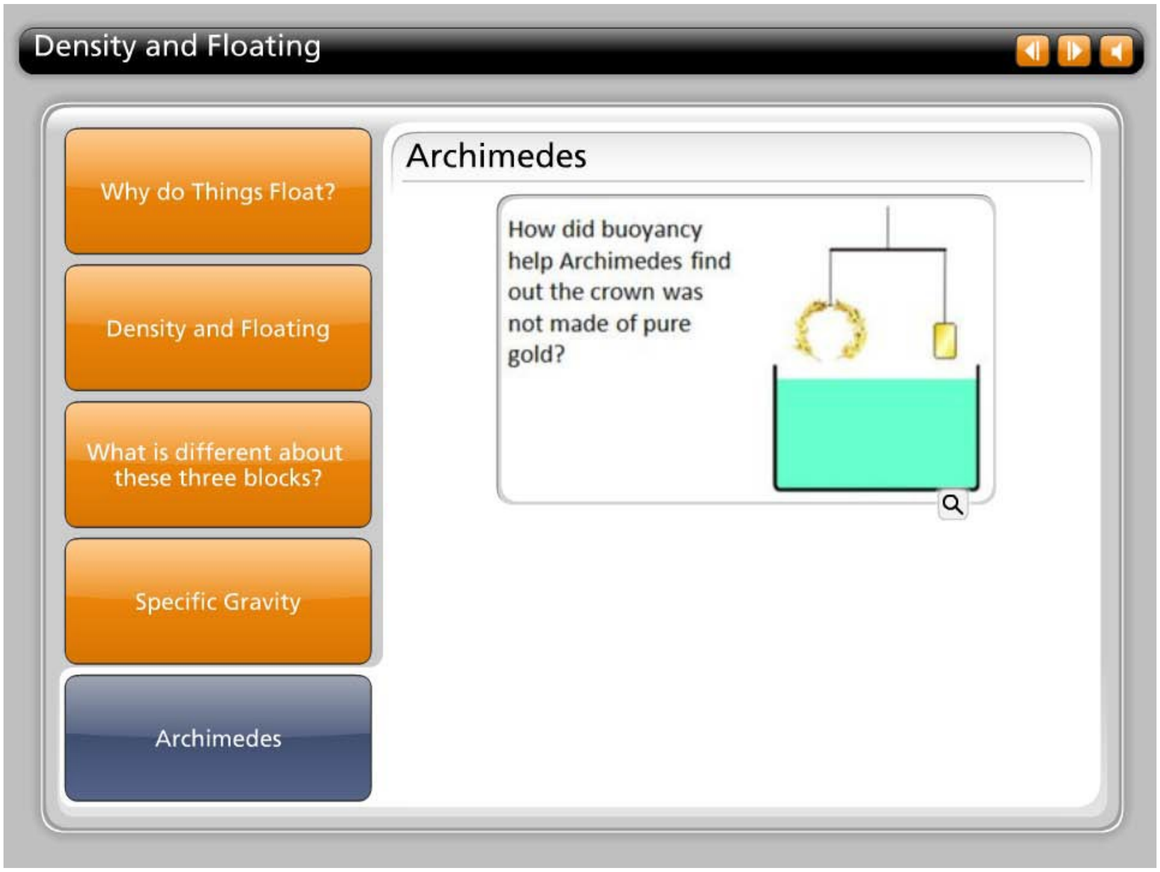
The green block has the same density as water, it's specific gravity is 1.0. The yellow block is less dense than water, it's specific gravity is less than 1.0.

The orange block is more dense than water, it's specific gravity is greater than one and it sinks to the bottom of the container.
We can use specific gravity to figure out if an object will float or not. As a general rule, if the specific gravity is less than 1.0, the object will float in water but will not submerge completely. If specific gravity is equal to 1.0 the object will float, but it will be completely submerged. If the specific gravity is greater than 1.0, the object will not float in water, it will sink to the bottom.

The specific gravity also tells you the percentage of the block that will be submerged.

Looking at the yellow block, what would be a good estimate for the specific gravity of the yellow block?

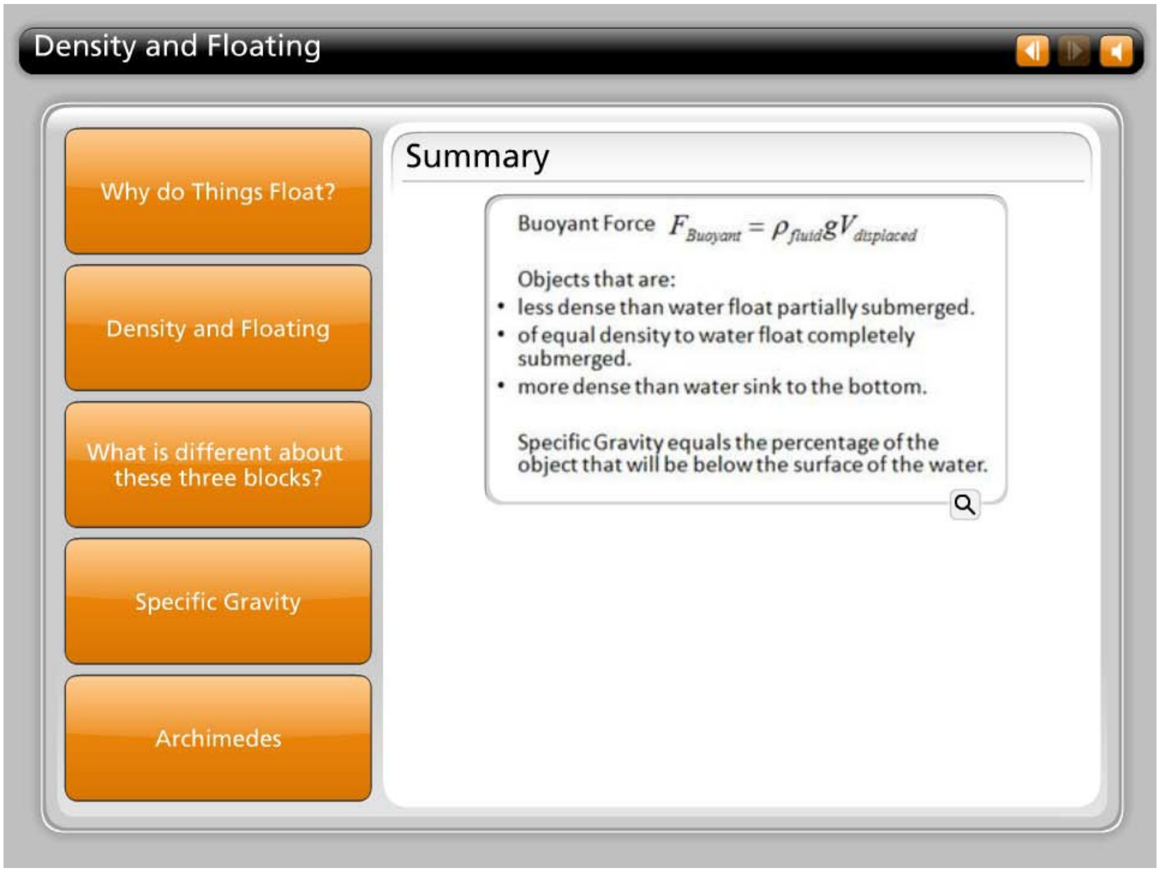
The yellow block is about halfway, or fifty percent submerged. The specific gravity is about zero point five.



Now that you have learned about buoyancy, how did it help Archimedes find out the crown was not made of pure gold?

In the animation, the right side of the balance is a piece of pure gold that weighs as much as the crown in air. However, when the balance is immersed, the crown experiences a greater buoyant force. This makes the scale tip to the right. What did this tell Archimedes about the crown?

This told Archimedes the crown displaced more volume than the piece of gold. If the mass was the same and the volume was bigger, the crown is less dense than gold So the crown was not made of pure gold.



In this lesson you learned the equation for the buoyant force, Buoyant force is equal to the density of the fluid times the acceleration due to gravity times the volume of fluid displaced by the object. In other words, the buoyant force is equal to the weight of the fluid displaced by the object.

We can tell if an object will float or sink by comparing its density to the density of water. Objects that are less dense than water float partially submerged. Objects that have the same density as water float completely submerged. Objects that are more dense than water will sink to the bottom.

Specific gravity is useful for buoyancy because the it is equal to the percentage of the object that will be below the surface of the water.