*This sheet is meant to supplement your learning. Please also refer to in-class demonstrations and explanations as well as your textbook.*

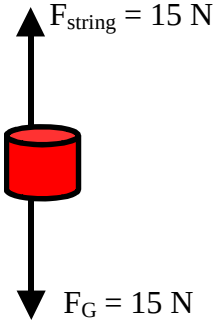
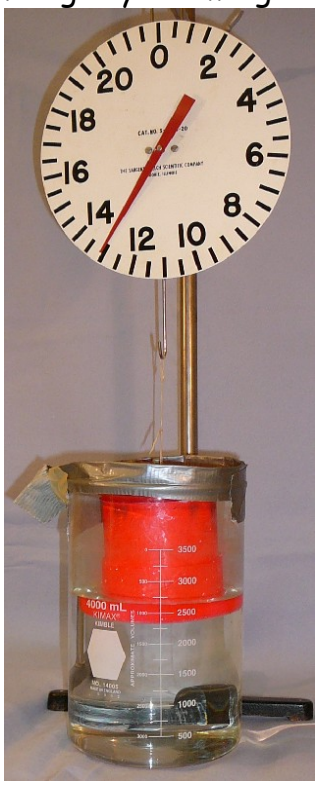
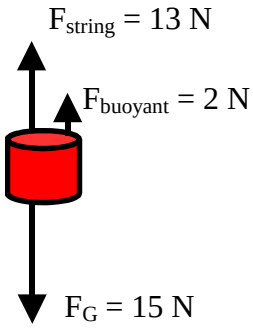
## Archimedes' Principle

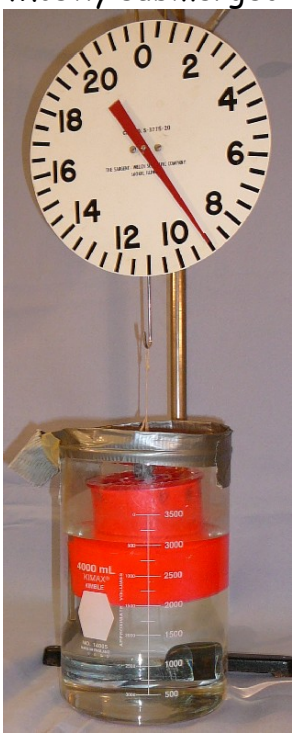
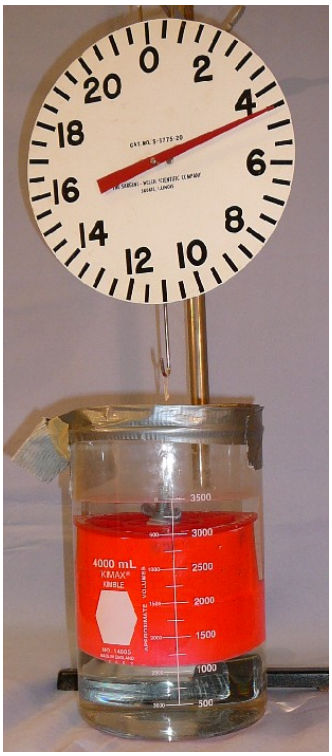
According to Hewitt[1], "An immersed body is buoyed up by a force equal to the weight of the fluid it displaces."

In the following example, a cylinder with a weight of 15 Newtons is considered. Therefore, the force of gravity, $F_G$, acting on the cylinder throughout the example is 15 N. There is also a force from the string, $F_{string}$, acting on the cylinder in all but the last scenario. The magnitude of $F_{string}$ is measured with the spring scale. The magnitudes of the buoyant force and support force will be deduced from the other known information.

Note that for each of the 6 scenarios below, the cylinder is stationary. This implies that the acceleration, and thus the net force, for each scenario is equal to zero.

[1] Hewitt, Paul G., John Suchocki, Leslie A. Hewitt. Conceptual Physical Science, 3rd Edition, Pearson/Addison Wesley, 2003.

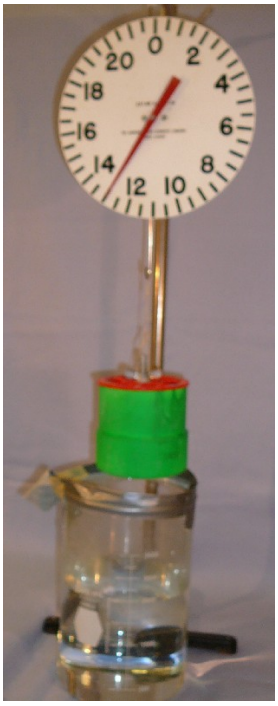
| Photograph | Force Diagram | Notes |
|---|---|---|
| 1. In air  |   | The only 2 forces acting on the cylinder are the force of the string and the weight of the cylinder ($F_G$). |
| 2. Slightly submerged  |   | The weight of the cylinder ($F_G$) is still 15 N. We know the force of the string is equal to the scale reading, which is 13 N. Since the acceleration of the cylinder is zero, we know there must be a 3rd force acting on the cylinder. The buoyant force must be 2 N upward in order for the cylinder to have a zero acceleration. |

| Photograph | Force Diagram | Notes |
|---|---|---|
| 3. Mostly submerged  | $F_{buoyant}$ =9 N<br>$F_{string}$ = 6 N<br>$F_G$ = 15 N | The scale reading, and thus the force of the string, has been reduced even further. $F_{string}$ is now 6 N with the buoyant force providing the other 9 N. |
| 4. Fully submerged, just beneath the surface of the water  | $F_{buoyant}$ =10.5 N<br>$F_{string}$ = 4.5 N<br>$F_G$ = 15 N | Based on the scale reading of 4.5 N, we deduce that the buoyant force is 10.5 N (15 N – 4.5 N = 10.5 N) . The cylinder is now occupying the volume that was previously occupied by 10.5 N of water. Since it displaced 10.5 N of water, we know the buoyant force acting on the cylinder must be 10.5 N. |

| Photograph | Force Diagram | Notes |
|---|---|---|
| 5. Fully submerged, just above the bottom of the container  | $F_{buoyant}$ =10.5 N<br>$F_{string}$ = 4.5 N<br>$F_G$ = 15 N | No change!! The buoyant force does not vary with depth. Look at the definition at the top of this sheet- the buoyant force only depends on the weight of fluid displaced. |
| 6. Resting on bottom of container  | $F_{buoyant}$ =10.5 N<br>$F_{support}$ = 4.5 N<br>$F_G$ = 15 N | Even though the cylinder is resting on the bottom, there is still a buoyant force acting. |

**Challenge Questions**

C-1) The yellow cylinder has the same volume as the pink cylinder used previously, but has a weight of 6 N. This cylinder is less dense than water and is shown floating below. Draw a force diagram for yellow cylinder floating on the water.


C-2) The green cylinder has the same volume as the pink cylinder used previously, but has a weight of 13 N. This cylinder is denser than water. Draw a force diagram for the green cylinder when it is fully submerged, but not touching the bottom of the container. Hint: How does the buoyant force on the fully submerged green cylinder compare to the buoyant force on the fully submerged pink cylinder?