Upward and downward force

[Subheading]

Predict, Explain, Observe, Explain

[Subject symbol Matter & Energy, M&E]

[For icons]

Time

15 minutes

Scope

Class 4

Concepts: weight, buoyant force, action/reaction, pressure

[Introductory box]

This is a typical example of a Predict-Explain-Observe-Explain demonstration about weight and buoyant force. Students predict what happens to the mass indicated on the scale when a weight is hung in water. They also need to explain their prediction. There is a lot of confusion, even among physicists who have not seen this before.

[End of introductory box]

[Top left 08\_MvW\_1a]

Figure 1a and 1b. A cup of water on an electronic balance.

[Bottom left 08\_EvdB\_1b]

[Top right 08\_MvW\_2a]

Figure 2a and 2b. We hang a substantial screw in the water or another metal object.

[Bottom right 08\_EvdB\_2b]

[See the PDF for placement]

**Required**

Electronic scale (accuracy to 0.1 g); beaker or drinking glass; string; substantial screw or other solid metal object; spring balance (e.g., 10 g)

**Preparation**

Set up materials on the table.

**Execution**

Present the setup (figures 1a and 2a). Explain that you will lower the screw into the water and ask for individual predictions in multiple-choice format, as follows:

What will happen to the mass indicated on the balance?

1. Will increase

2. Will remain the same

3. Will decrease

How do you explain this?

1. The weight of the screw is fully supported by the string.

2. There is an upward force on the screw and therefore an equal force downward on the cup.

3. The screw displaces some water by pushing it upward.

4. Other, namely ...... (fill in).

Allow students to discuss their predictions with each other.

Plenary: Survey the predictions and the arguments for them.

Conduct the experiment and write down the results on the board.

Next, have students write down a complete explanation before the discussion starts.

If we rest the screw on the bottom, what will the scale indicate? Why?

The teacher writes down some student explanations on the board. And now, the discussion begins!

Don't forget to conclude the discussion with a brief but complete explanation on the board including a force diagram.

Repeat with string attached to spring balance instead of stand.

**Physics background**

The screw experiences an upward force equal to the weight of the displaced liquid. Therefore, there is an upward force from the water on the screw (F\_water on screw) and hence a downward force from the screw on the water (F\_screw on water) according to Newton's 3rd law. The latter force acts on the scale. An alternative way to explain is that the water level rises, increasing the pressure on the bottom (p = F/A = ρhg) and thus also the force on the scale.

If the string is connected to a spring balance, the increase on the scale will be exactly equal to the decrease in force on the spring balance. This can be demonstrated at the end. Use the setup without the spring balance for the start.

**Tip**

There will be clever students who still get it wrong. Console them with the information that many physicists also make mistakes here.

[Box at the bottom]

The demo is derived from the demo "the-bolt-in-the-beaker" from the York Science Education Center.

[Tim, in the shaded formula, the letter ρ in ρhg is the Greek letter rho.

At the italicized letter F a few lines above, the subscripts are marked by me]