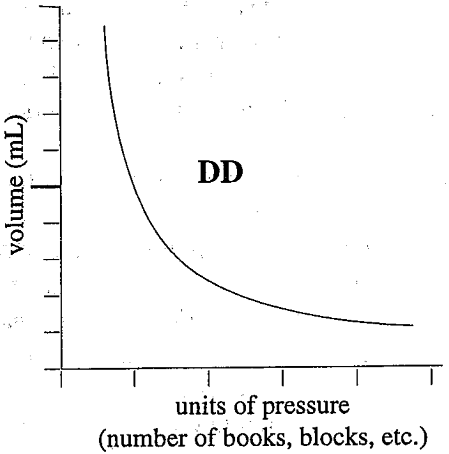
5.1.2 PRESSURE-VOLUME RELATIONSHIP OF GASES

Discussion: A plot of pressure versus volume shows the familiar inverse relationship, $PV = k$. As pressure increases, volume decreases (Figure DD). If we rearrange this equation, we get: $V = k\,(1/P)$, which is the equation of a straight line with slope k. You may wish to have students plot V versus $1/P$ to obtain a straight line plot with slope k.

The Cartesian "diver" is useful in illustrating several laws and principles of science. The "diver" is not just the dropper, but rather the dropper and the air and water contained within it. When the plastic bottle is squeezed, pressure is transmitted undiminished throughout the water according to



Pascal's principle. Air within the diver is compressed and water enters to fill space this air once occupied. Due to the compression of air and the entrance of water in the diver, the composite density of the diver (eyedropper, air and water) may eventually exceed the density of the surrounding water, causing the diver to descend. When pressure is released all processes work in reverse and the diver ascends. With just the right amount of pressure, the diver can be made to remain at any position in the bottle.

Archimedes' principle may be used to explain the diver. When floating, the diver displaces its own weight of water, the buoyant force of water is equal to the gravitational force and the diver is in equilibrium. When the container is squeezed, more water enters the diver, and at some point the weight of water displaced by the diver is less than the composite weight of the diver and it descends.

Answers: (1) See discussion. (2) When the bottle is squeezed, water enters the eyedropper, increasing the composite density of the diver, and causing it to sink. In a similar manner, submarines take on water in their ballast tanks, increasing their composite density and causing them to dive. When pressure is released from the bottle, water escapes from the dropper, lowering the composite density of the diver, and allowing the diver to rise. In a similar manner, the crew in a submarine may release compressed air into the ballast tanks, causing them to displace water. As water is displaced, the composite density of the submarine decreases, causing it to rise. (3) The balloon returns to its original size, but the shaving cream and marshmallows shrink smaller than their original sizes. The number of gas molecules within the balloon remains relatively constant because the walls allow few gaseous molecules across. By contrast, the air pockets in the shaving cream and marshmallow expand and eventually burst in the evacuated bell jar. When air is allowed to re-enter the jar, shaving cream and marshmallows shrivel under atmospheric pressure because of the lack of trapped air. (4) An increase in pressure on the gas forced the molecules closer together, increasing the density and decreasing the volume. (5) Student answers vary, but should express this concept: At constant temperature, the volume of a gas is inversely proportional to the pressure exerted on it. The volume vs. pressure graph should resemble Figure DD. (6) Increased pressure on a gas decreases the volume of the gas and increases its density. (7) According to Boyle's Law, the product of the initial volume and pressure is equal to the product of the final volume and pressure: $P_1V_1 = P_2V_2$. So (1 atm) × (? L) = (2.5 atm) × (10 L). 25 L of air will be required.