Pressure 2

Phases of matter

We have started discussing states of matter. There are a lot of states of matter, but for the beginning we will talk about 3 of them. These are

1. **Solid** state (a solid object has both definite volume and shape).
2. **Liquid** state (liquids have definite volume – they are almost incompressible but have not a shape).
3. **Gas** state (both volume and shape are determined by the container).

Phase transitions. If some object is a solid, can it be made into a liquid or even into gas? In many cases the answer is yes. Think about water, for instance. Solid water is ice. At 0°C ice melts and becomes liquid water. If we continue increasing its temperature, at 100°C water boils and evaporates which means that it turns into vapor. Now if we go in the opposite direction and lower temperature starting from hot vapor, at 100°C vapor will condense which means it will become a liquid. And at 0°C liquid water freezes to become ice. Here we see that water exists in all three phases: solid (ice), liquid and gas (vapor).

Gases "work hard" for us in our everyday life – for example, hot gas expanding in the cylinder of the engine makes the car move. To design a machine which uses gas to produce work we must know in detail the behavior of gas at different conditions. As we learned, gas consists of huge number of microscopic particles called molecules or atoms (depending on the kind of the gas). It is not possible to track down or describe the motion of each molecule in a gas volume. Fortunately, we do not have to do that. We just must know three important parameters and the way how they depend on each other. The parameters are:

• Pressure • Volume • Temperature

We are going to discuss pressure first.

Pressure

Pressure shows how force is distributed over some area. If force F is applied perpendicularly to area A, the pressure is:

$$P = F/A$$

Units of pressure are N/m^2 and have a special name: Pascals, or Pa. This unit is called after a famous French mathematician, physicist and philosopher Blaise Pascal.

For **example**, let's calculate the pressure a person exerts on the floor when standing on two feet. Let us say for simplicity that each of the feet is a rectangle with sides 30 cm ×10 cm and mass of the person is 60 kg. Then pressure is:

$$p = \frac{F}{A} = \frac{mg}{A} = \frac{60 \cdot 10 \text{ N}}{2 \cdot 10 \cdot 30 \text{ cm}^2} = \frac{600}{0.06} \frac{\text{N}}{\text{m}^2} = 10000 \text{ Pa} = 10 \text{ kPa}$$

Normally we do not care too much about this pressure. However, if we try to walk on snow, it becomes important: if the pressure is too big, our feet will fall through the snow. In order to reduce pressure and prevent falling through the snow one could make the area of contact bigger by wearing snowshoes or skis.

Gas always applies pressure to the walls of the cylinder or any other vessel. The pressure can be low as in a balloon or high as in a barrel of a gun during the shot. Our atmosphere also produces pressure. It is ~ 100kPa (101,300Pa to be exact) at sea level.

Pressure in liquids

Due to gravity, the pressure increases as you go deeper in fluid.

$$p = \rho g h$$

ρ is the density of the fluid, g – free fall acceleration, h –depth under the surface.

Water pushes on the side walls as well: if there is a small opening in a container wall below the water level, water will start flowing out as a jet. The walls prevent the water from flowing out and experience water pressure as a result. So, fluids exert pressure in all directions and at a given point the pressure in all directions is equal.

Homework:

1) Sometimes on a summer evening one can see fog over the surface of a lake. What state of matter is the fog?
2) A 45kg boy has his ski on. The length of each ski is 1.5 m; the width is 10 cm. Find pressure that the boy is applying to the snow.
3) Calculate total force applied by the atmosphere to a square surface 30cm x 30cm.
4) You are designing a submarine, and you want it to have a round window for observations. Radius of the window is 10 cm^2. You can make the window withstand a force up to 50000 N. What is the maximal depth you can take the submarine to? Density of ocean water is 1030 kg/m^3.