Concepts of Physics: Homework 2

Due: 8 September 2023

1 Hobson, *Physics, Concepts and Connections, 5ed*, Ch. 2 Review Question 2, page 51. This is asking for a phenomena that can be observed using light either with the naked eye or else some sort of optical microscope.

2 Heating air

A bottle is filled with air and then sealed. Does the pressure of the air inside increase, decrease or stay the same if heat is added to the bottle? Explain your answer in terms of the motion of the air molecules.

3 Gas escaping a balloon

A balloon is inflated with helium. Sometime later you allow the gas to escape from the balloon and notice that it feels much cooler than the normal room temperature.

a) What does imply about the typical speed just after they escape compared (smaller, larger, same) to just before they escape?

b) Could you use the atomic picture of the helium gas to predict that it should cool when it escape? To do this, consider a group of helium atoms as they leave the balloon. They will need to push some of the air outside aside to leave. What must happen to their speeds if they are to do this? What does this imply for their temperature?

You can try this but there is one complication. When you inflate a balloon warmer air enters from your lungs. The balloon will be warmer than the room. You need to wait a while for it to cool to room temperature before you let it escape.

4 Soda can implosion

A soda can implode in a simple home experiment. This involves heating a small amount of water in an open soda can until steam begins to escape. Then the soda can is held upside down in a bath of ice water so that the opening is submerged in the ice water. Soon after the can implodes. You can find videos of this by searching YouTube for "can crush."

Use the atomic model of gases to explain why the soda can is crushed in these experiments.

5 Microscopic description of air pressure

Air pressure, such as that which you measure for your car tires is a *macroscopic* quantity that has an explanation in terms of the *microscopic* picture of the gas as a collection of atoms. This exercise is intended to enable you to provide the connection between the microscopic and macroscopic pictures.

To answer these questions you will have to access the animation "Gas Properties" provided by the PhET group at the University of Colorado. The animation is available at:

https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties_en.html

The animation has several options, listed in the opening window or at the bottom. Select the tab labeled "Ideal." Most of this animation can be controlled using the panel on the right. The reset button at the bottom removes all the molecules. A given number of molecules can be supplied by opening the "Particles" tab and adjusting "Heavy". In this exercise you will need to keep the temperature constant. To do so, after you have added molecules, select "Temperature" from the "Hold Constant" section - this must be set throughout the exercise.

a) Supply 100 heavy species molecules and observe the temperature ("K" means Kelvin, a scientific unit of temperature) and pressure ("Atm" means atmospheres, a unit of pressure). When these have settled, note the numbers. Now reset and inject 200 heavy species molecules. How do the temperatures and the pressures compare in the two cases (same, larger, smaller)?

b) To explain the change in pressure consider reducing the number of molecules. Reset and inject 5 heavy species molecules and observe their collisions with the left wall (the collisions between particles are irrelevant). Do the same with 20 heavy species molecules. How do the typical speeds with which the molecules move for the "5" and "20" cases compare (same, larger, smaller)? How do the speeds with which they hit the wall compare (same, larger, smaller)? How do the frequencies with which they collide with the wall (number of collisions every minute) compare (same, larger, smaller)?

c) The pressure is related the typical speed with which the molecules collide with the wall *and* how frequently they collide. Specifically, as either of these increases, the pressure increases (this is a *microscopic description of pressure*). Is this consistent with your observations from the previous part?

d) Reset and inject 100 molecules. Note the pressure. Now move the left wall inward. How does the pressure compare after this adjustment to before (same, larger, smaller)? Describe why this occurred using the microscopic description of pressure.

6 Scientific notation

Some numbers in physics are too large or too small to express in ordinary decimal form. Consider the numbers 500000 and 400000.

a) If you multiplied these two numbers do you expect that the result will have more than, fewer than or exactly 10 digits (the maximum that my calculator can show)? Explain your answer.

b) Express each number in the form: $\text{number} \times 10^{(\text{power})}$ where, in each case, the "number" is a decimal number and "power" is a whole number (integer).

c) Use the powers of ten multiplication scheme to multiply the numbers. How many digits would it take to write the number in the usual form?

7 Multiplication and division with powers of ten

The usefulness of powers of ten is illustrated via an example on page 38 of Hobson, *Physics: Concepts and Connections.* The aim of this exercise is to follow that method. Consider the numbers 534 and 165.

a) Multiply 534 and 165, using your calculator.

b) Express each of 534 and 165 in the form: number $\times 10^2$ where, in each case, the number is a decimal number.

c) Use the method of multiplying with powers of ten to multiply 534 and 165 and check that your answer is the same as that of part (a).

d) Divide 5340 by 1335, using your calculator.

e) Use the method of dividing with powers of ten to divide 5340 by 1335 and check that your answer is the same as that of part (d).

8 Hobson, *Physics, Concepts and Connections, 5ed*, Ch. 2. Conceptual Exercise 32, page 52.

9 Estimating number of atoms

A bacterium has width approximately 1.0 micrometer $= 1.0 \times 10^{-6}$ m. An atom has width approximately 10^{-9}m. Estimate the number of atoms that span the width of the bacterium. Explain your answer.

10 Reading exercise: Galileo's thought experiments

Read section 3.2 on pages 55-57. This series of exercises offers examples and exercises that you could construct to check that you understand the content of the text correctly. The questions focus on the thought experiments involving balls sliding along ramps conducted by Galileo.

a) Galileo considered three experiments involving balls sliding on ramps. Describe the three experiments and the differences between them.

b) What idealization about the balls and ramps did Galileo make in order to simplify his thinking? According to him, what did this imply about the motion of a ball rolling along a horizontal surface?

c) What was different about Galileo's prediction (for the ball sliding along the horizontal surface) and that made according to Aristotle's theory?

d) Do Conceptual Exercise 1 on page 68. Check whether your answer agrees with the solution offered in the back of the text.