Fluids, Thermodynamics, Waves, & Optics
Fluids
Lab 4
Ideal Gas

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Overview

- Purpose
- Theory
- Lab activities

Purpose of the Lab

To investigate the behavior of an ideal gas and experimentally determine Boltzmann's constant using Boyle's, Charles's, and Gay-Lussac's Laws.

You will use the "Ideal" piece of the Gas Properties PhET simulation to study a simulated ideal gas.

You will vary the volume of the gas at constant temperature and measure the resulting pressure, plot a graph, and thereby deduce Boltzmann's constant.

Then you can choose the variables to vary and hold constant to find Boltzmann's constant in another way.

Ideal Gas Equation

The equation of state for an ideal gas:

$$PV = nRT$$

where

- P is pressure
- V is volume
- n is the number of moles (amount of gas)
- $R = 8.314$ J mol^{-1} K^{-1} is the universal gas constant
- T is temperature **measured in Kelvin**

The LHS and RHS of this equation both have SI units of Joules (energy).

Ideal Gas Equation

The equation of state for an ideal gas:

$$PV = nRT$$

Can also be written:

$$PV = Nk_B T$$

where

- P is pressure
- V is volume
- N is the number of molecules
- $k_B = 1.380649 \times 10^{-23}$ J K^{-1} is Boltzmann's constant
- T is temperature

Lab Activity

The ideal gas model in the simulation is a microscopic model (the individual particles of gas are shown).

Therefore, you will use this equation for an ideal gas:

$$PV = Nk_B T$$

N will be relatively small, and V will be extremely small.

Part 3.1: Boyle's Law

Boyle's Law states that for constant temperature, the pressure of an ideal gas is inversely proportional to its volume.

$$P \propto \frac{1}{V}$$

Part 3.1

You will hold temperature, T, constant, while varying the volume, and measure the resulting pressure.

$$P = (Nk_B T)\frac{1}{V}$$

Then you will plot P against $\frac{1}{V}$ and make a best-fit line. From the slope of the line, and knowing N and T, you will find Boltzmann's constant k_B experimentally.

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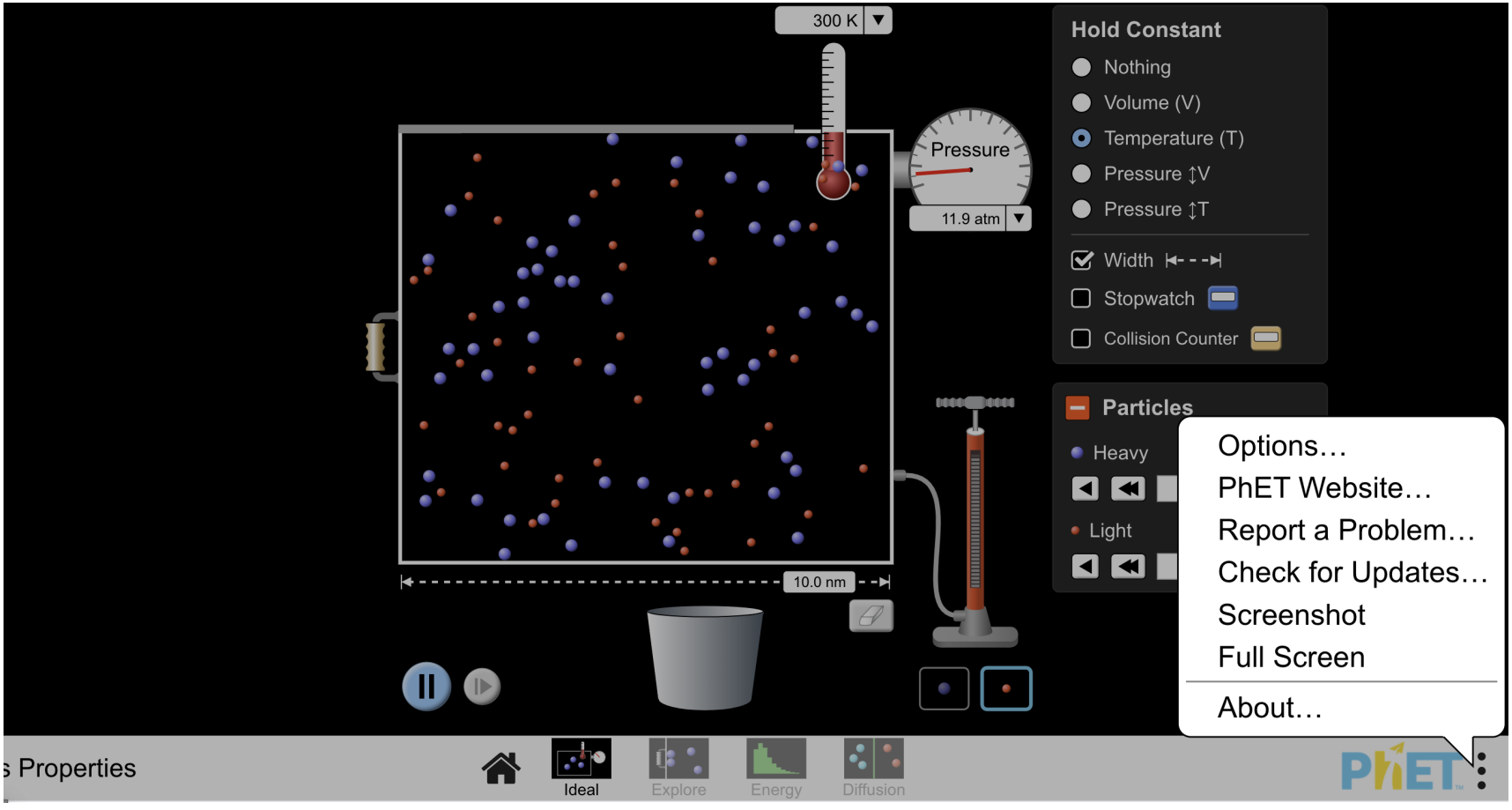
Compare your result to the accepted value:

$$k_B = 1.380649 \times 10^{-23}\ \text{J K}^{-1}$$

using the percentage error.

$$\%\ \text{error} = \frac{k_{B,\text{exp}} - k_{B,\text{acc}}}{k_{B,\text{acc}}}$$

The Setup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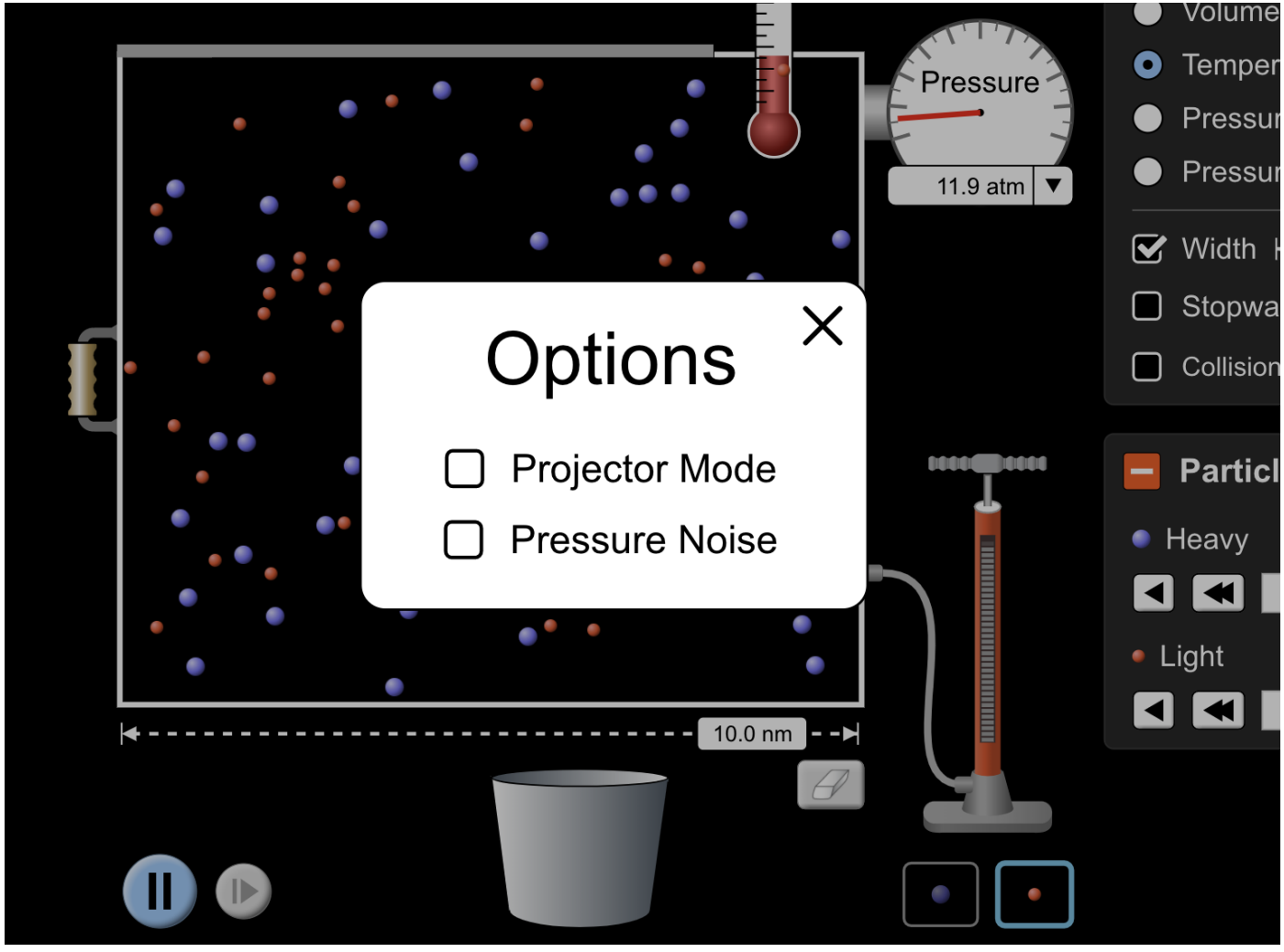
The Setup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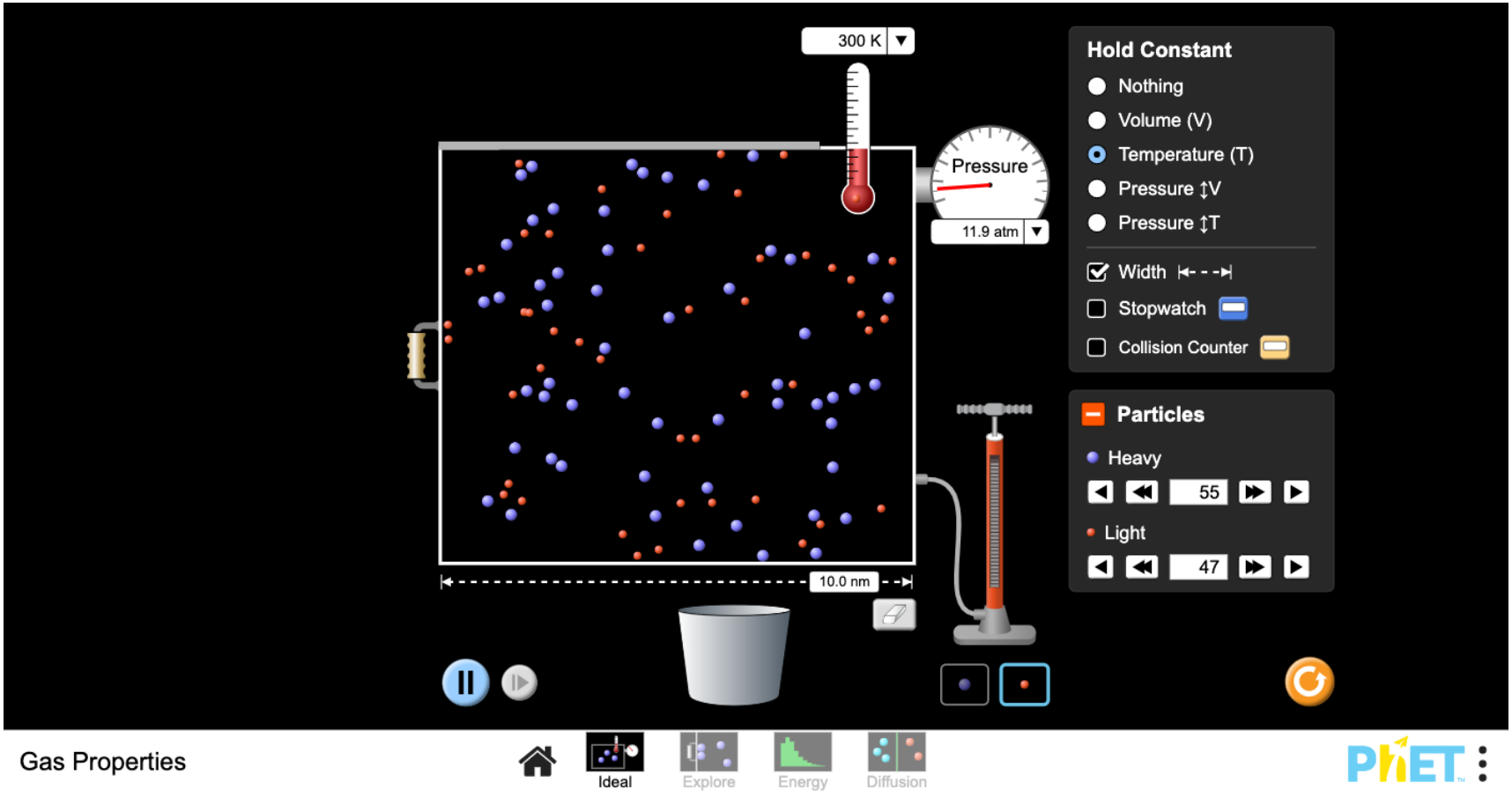
The Setup for 3.1



The Part 3.2: Charles's Law or Gay-Lussac's Law

Charles's Law states that the volume of a gas is proportional to its temperature when the pressure is held constant.

$$V \propto T \qquad \text{(For P = constant)}$$

Gay-Lussac's Law states that for constant volume, pressure and temperature are directly proportional.

$$P \propto T \qquad \text{(For V = constant)}$$

Use one of these to do a similar experiment to Part 3.1 and make another, independent measurement of Boltzmann's constant.

Reminder: Roles

It is hard to look at many files and applications on one screen, so work together.

Three roles, one for each person:

- "director" - reads the instruction sheet out loud to the others and says what to do
- "operator" - runs the PhET sim while sharing their screen to the group, so everyone can see what's happening
- "recorder" - records experimental values and writes and uploads the Canvas Assignment. This person should share their screen while you discuss the answers to the questions.

Change who does which role! Try to do a role you haven't done before.

Reminder: Groups

Very first thing! Go to Canvas:

People > Groups > Lab4

and add yourself to your lab group (MGroup#).