Phys 362
Spring 2026

Statistical and Thermal Physics: Homework 1

Due: 23 January 2026

Some homework problems and class exercises will use simulations developed by the text authors. These can be found at the website Statistical and Thermal Physics Programs. The simulations are run from a web browser.

Clicking on a particular program provides a "controller" window which allows you to control the program. The output will appear in a separate window inside the browser.

General tips about running the simulations:

1. The controller window lets you set parameters. Clicking Initialize will open the simulation usually with some other graphical windows. Clicking Start will actually run the simulation.

2. The data that is generated by the simulation can be accessed in tabular form by following Tools → Data Tool, selecting one or more of the starred objects and clicking OK. This contains an Analyze option that allows access to the statistics that will computer averages and deviations. Data that goes into such a calculation can be selected by highlighting the relevant entries in the columns.

1 Particles in a box with two sections

Suppose that N particles are placed in a box with two sections ("left" and "right"). Suppose that initially all particles are in the left section and at $t = 0$ a partition between the sections is removed. Let $n(t)$ be the number of particles in the left section at time t.

a) How do you expect $n(t)$ will evolve as time passes?

This can be simulated using one of the text programs. From the program website, follow STP Programs → Thermal Physics → Two Parts MD. This will open a controller window where the number of particles can be adjusted by setting N in the relevant box (and hitting Initialize). The simulation describes the number of particles on a single side of the box. Once you initialize the program, it will open two windows, one displaying the physical situation and the other a graph of the data.

b) Starting with $N = 10$, run the simulation. Does n appear to approach a fixed value? If so what is the fixed value? How large are the typical fluctuations in n? Does n ever return to 10?

c) Starting with $N = 100$, run the simulation. Does n appear to approach a fixed value? If so what is the fixed value? How large are the typical fluctuations in n? Does n ever return to 100?

d) Starting with $N = 1000$, run the simulation. Does n appear to approach a fixed value? If so what is the fixed value? How large are the typical fluctuations in n? Does n ever return to 1000?

e) In which case, $N = 10$, $N = 100$ or $N = 1000$, is there are more distinct equilibrium state. What is the equilibrium state?

f) The simulation lets you record the mean number of particles $\overline{n}$ and the standard deviation (sd) in the number of particles, σ, which quantifies the fluctuations in n. In each case, after the simulation has appeared to reach equilibrium, determine $\overline{n}$ and σ for a period during which the system is close to equilibrium. A measure of the typical size of fluctuations is $\sigma/\overline{n}$. Determine this for each case. How does it behave as N increases? What does this imply about the precision of the equilibrium state as N increases?

2 Interacting systems in equilibrium

Much of thermodynamics deals with systems that interact. The usual consideration here, is that there are two isolated systems that are in equilibrium states. These are brought into thermal contact and they than reach a new equilibrium state. The issue is to find the common property that describes this new equilibrium state. The simulation Thermal Contact explores this. The simulation shows two systems, which by default are thermally isolated. They can be brought into thermal contact by clicking the "Contact" button.

a) Run the simulation with the two systems isolated (the program default), using the default settings. The simulation will display fluctuating energies for both systems. By averaging over a reasonable duration, record the average kinetic and potential energies per particle for each system. Use these to determine the total energy for each subsystem. Are any of these quantities the same for each system?

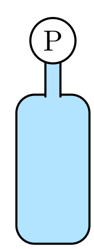
b) Without resetting, click the "Contact" button. Which of the energies change appreciably?

c) After the systems have reached a common equilibrium record the average kinetic and potential energies per particle for each system. Use these to determine the total energy for each subsystem. From which system did energy flow?

d) After the two systems have reached a common thermal equilibrium, which quantity is roughly the same for the two systems? Given that the temperature of two systems in thermal equilibrium must be the same, which quantity best represents temperature?

3 Constant volume gas thermometer

A constant volume gas thermometer consists of a gas inside a flask whose volume is fixed. The pressure of the gas is monitored. The container can be immersed inside any fluid and the pressure can be monitored. The flask is immersed into fluid A and the pressure is monitored. After the pressure has settled it is recorded, giving a pressure of 10 kPa. Then the flask is removed and immersed in fluid B, which is isolated from fluid A. After the pressure has settled it is recorded, giving a pressure of 20 kPa.



a) List the variables that can be used to describe the state of the gas inside the flask. For each variable, describe whether it is the same (after settling) for fluid A as for fluid B. Is the state of the gas the same for fluid A as for fluid B? Explain your answer.

b) Would fluid A and fluid B be in thermal equilibrium at the moment that they were placed into contact with each other? Do they have the same or different temperatures? Explain your answers.

4 Venus' atmosphere

The atmosphere of Venus consists of 96.5% carbon dioxide and 3.5% molecular nitrogen (N_2).

a) Determine the mass of one mole (6.02×10^{23} molecules) of Venus' "air."

b) The surface temperature of Venus is 740 K and the surface pressure 9.2×10^6 Pa. Determine the density of Venus' atmosphere in standard SI units.

c) How does the density of Venus' atmosphere compare to that of Earth?