

# Problem Set 1

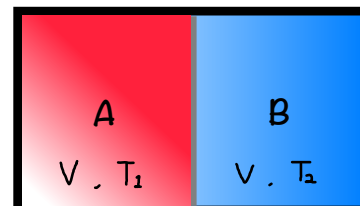
Physics 5C, UC Berkeley, Spring 2024

Due Monday, 1/29, at 11:59PM

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## Problem 1

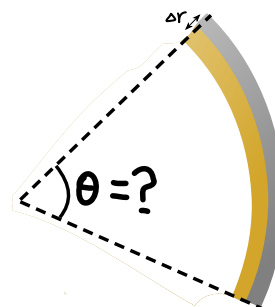
As shown in the right figure, a thermally insulated container have two chambers of equal volume  $V$ . The two chambers respectively contain  $N_1$  and  $N_2$  of ideal gas molecules of the same type, with absolute temperatures of  $T_1$  and  $T_2$  respectively.



- (a) What is the ratio of the two chambers' pressures,  $P_1/P_2$ ?
- (b) Suppose we remove the divider between the two chambers, what is the final temperature of the mixed gas?
- (c) Continuing from part (b), what is the pressure of the mixed gas?
- (d) Find the number of gas molecules that flow from chamber  $A$  to chamber  $B$ .

## Problem 2

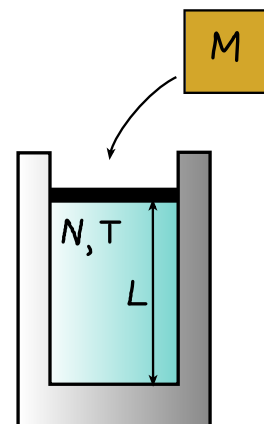
A bimetallic metal strip consist of two ribbons of metals with linear expansion coefficient  $\alpha_1$  and  $\alpha_2$  respectively, with  $\alpha_2 > \alpha_1$ . The two metals are bonded together. At the initial temperature  $T_0$ , both metals have the same initial length  $L_0$ . The distance between the centers of the two strips is  $\Delta r$ , where  $\Delta r \ll L_0$  so that the thermal expansion along that dimension is negligible compared with the expansion of the length. When we raise the temperature by an amount  $\Delta T$ , the bimetallic strip bends due to the difference in expansion coefficient. Find the angle of the curvature  $\theta$  in terms of  $L_0$ ,  $\alpha_1$ ,  $\alpha_2$ ,  $\Delta r$  and  $\Delta T$ .



## Problem 3

A container filled with  $N$  particles of ideal gas is originally in equilibrium with temperature  $T$ , and the frictionless movable piston is at a height  $L$ . The cross-sectional area of the container is constant. We now place a block of mass  $M$  on the piston and release it from rest. In below, we assume the temperature of the gas is maintained at  $T$ , and the variation of the piston's height  $\delta h$  is much smaller than  $L$  so that we can expand our equations to the order of  $\delta h/L$ .

- (a) After releasing the block, the piston oscillates. What is the amplitude of the oscillation?
- (b) What is the frequency of the oscillation?



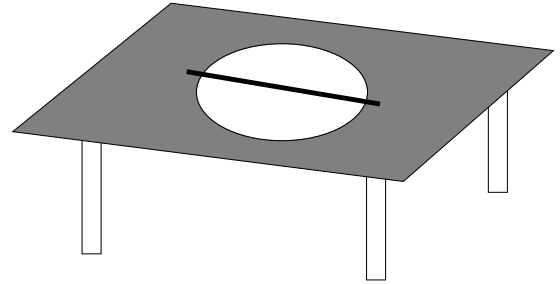
Below are selected optional problems. We do not collect your work, but you are encouraged to do as many practice problems as you can.

#### Problem 4

- Assuming that you are nearly all water, how many water molecules are there in your body?
- How many drops of water are there in all the oceans of the world? The mass of the world's ocean is about  $10^{21}$  kg. And you can assume the radius of a droplet is about 1 mm.

#### Problem 5

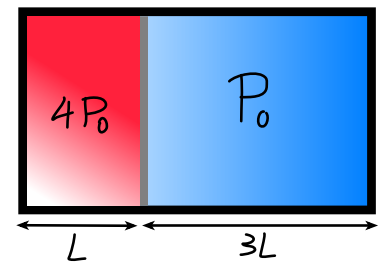
A rod made out of aluminum (linear expansion coefficient  $\alpha_{\text{Al}} = 25 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$ ) has a length  $L_0 = 100$  cm at  $100^\circ\text{C}$ . It rests on top of a circular hole in a steel plate (linear expansion coefficient  $\alpha_{\text{Fe}} = 12 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$ ) that forms the top of a table. This hole has a radius  $R = 49.7$  cm at  $20^\circ\text{C}$ . The center of the rod lies at the center of the hole. The temperature of the system is then changed to  $T$ . Is there a  $T$  below which the rod will fall through the hole? Neglect the thickness of the rod, and the friction between the rod and the plate.



(Physics 7B, UC Berkeley, Spring 2014)

#### Problem 6

A cuboid chamber is divided by a movable piston. The left chamber initially has a pressure  $4P_0$  and a width  $L$ . The right chamber has a pressure  $P_0$  and a width  $3L$ . The two chambers have the same temperature maintained throughout the process. What will be the final width of the left chamber when equilibrium is reached?



#### Problem 7

Two rods made of material with linear expansion coefficient  $\alpha_1$  and  $\alpha_2 = 1.2\alpha_1$  have a length difference  $\Delta L$  at temperature  $T_0$ . As we heat up the rods, the length difference between the two rods remains the same. Assuming the expansion coefficient is temperature-independent and  $\alpha \Delta T \ll 1$  where  $\Delta T$  is the temperature variation, find the lengths of the two rods at  $T_0$ . Express your answer in terms of  $\Delta L$ .

#### Problem 8

Wine bottles are never completely filled as some headspace is needed due to wine's large coefficient of expansion. In this problem we model this by considering a cylindrical glass container of inner radius  $R_0$  and height  $L_0$ , both measured at a reference temperature  $T_0$ . Suppose we want to leave some headspace such that the alcohol will not fully fill up the headspace until a critical temperature  $T_c$ , how much headspace  $H_0$  (the length between the top surface of the alcohol and the top surface of the glass container) do we need at temperature  $T_0$ ? Express your answer in terms of  $L_0$ , coefficient of *volume* expansion for alcohol and glass,  $\beta_a$  and  $\beta_g$  respectively, the reference temperature  $T_0$ , and the critical temperature  $T_c$ .

