Physics 4311: Thermal Physics - Homework 6

due date: Tuesday, March 11, 2025, please upload your solution as a pdf on Canvas

Problem 1: Rubber elasticity (15 points)

The equation of state of a rubber band can be modeled by the so-called Guth-James equation

$$F = aT\left[\frac{L}{L_0} - \frac{L_0^2}{L^2}\right] .$$

Here F is the tension force, L is the length of the rubber band (with $L_0 = 10$ cm being the unstretched length). T is temperature, and $a = 1.8 \times 10^{-2}$ N/K is a constant.

a) How much work is done if the rubber band is stretched isothermally from its original length of 5 cm to 15 cm? The temperature is kept at 293 K.

b) The rubber band is held at fixed (stretched) length. Will the tension increase as the temperature increases?

c) When the rubber band is heated at fixed tension, will its length increase or decrease with temperature?

Problem 2: Oscillating ball (25 points)

Consider the device shown in the figure: A ball of mass m is placed snugly in a tube of cross section A connected to a container containing an ideal gas. The ball can move up and down, but gas cannot escape. In the equilibrium position of the ball, the enclosed gas volume is V. The device is surrounded by air at ambient pressure p_0.

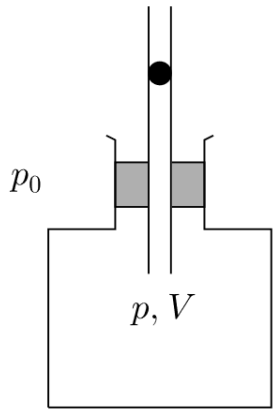

Fig. 12.2 Rüchhardt's apparatus for measuring γ. A ball of mass m oscillates up and down inside a tube.

a) Consider the forces acting on the ball, and find the pressure inside the gas if the ball is at rest in its equilibrium position.

b) The ball is now given a small downward displacement from its equilibrium position. Compute the force acting on the ball. (Assume that the displacement is fast enough so that the compression of the gas can be treated as adiabatic because no heat is exchanged with the environment.)

c) The ball is now released. Determine the period of its oscillations. (Assume that the system remains thermally isolated during the oscillations. Also neglect friction.)