Physics 4311: Thermal Physics - Homework 5

due date: Tuesday, Feb 28, 2023, please upload your solution as a pdf on Canvas

Problem 1: Thermal expansion coefficient (8 points)

The (volume) thermal expansion coefficient α is defined as

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p$$

. Compute the thermal expansion coefficient for an ideal gas.

Problem 2: Surface tension of a droplet (12 points)

The surface tension σ of an interface between two substances is defined in terms of the work required to increase the interface area by an infinitesimal amount dA via $\delta W = \sigma dA$. Consider a spherical droplet of radius a of a fluid embedded in air at ambient pressure p_0. This problem aims at finding the pressure p inside the droplet.

a) Compute the work due to the volume expansion if the radius of the droplet is increased by da.

b) Compute the work due to the increase in surface area if the radius of the droplet is increased by da.

c) In equilibrium, the work due to the pressure and the work due to the surface tension should cancel. Use this to find the difference between p and p_0.

Problem 3: Oscillating ball (20 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.

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.)

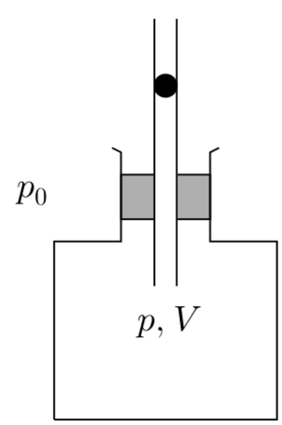

Fig. 12.2 Rüchhardt's apparatus for measuring γ. A ball of mass m oscillates up and down inside a tube.