Physics 4311: Thermal Physics - Homework 5

due date: Tuesday, Mar 4, 2025, please upload your solution as a pdf on Canvas

Problem 1: Diesel engine (6 points)

A Diesel engine takes in air at ambient conditions (room temperature, 1 atm pressure) and compresses it rapidly to about 5% of its original volume.

a) Calculate the temperature of the air at the end of the compression. Assume that the compression is so fast that it can be assumed to be adiabatic. The adiabatic index for air is about 1.4.

b) Explain why a Diesel engine does not need spark plugs.

Problem 2: Thermal expansion coefficient (6 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 3: 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 an infinitesimal 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.

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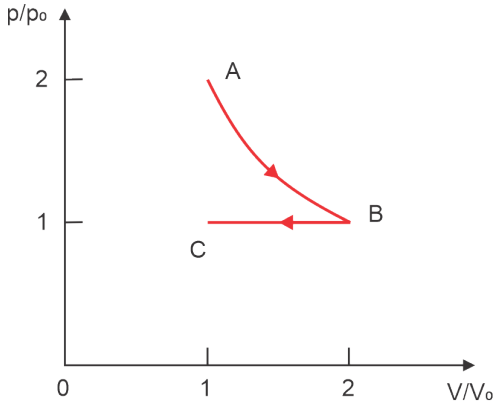
Problem 4: Gas expansion and compression (16 points)

An ideal gas of N atoms is taken quasi-statically from point A to B (at constant temperature) and then from B to C (at constant pressure) as shown in the pressure-volume diagram. Express all answers in terms of N, k_B, p_0, and V_0.



a) Find the temperatures T_A, T_B and T_C at points A, B, and C.

b) How much work is done on the gas from A to B?

c) How much heat is flowing into the gas from A to B?

d) How much work is done on the gas from B to C?

e) How much heat is flowing into the gas from B to C?