Exam I

1) A particular Otto Cycle (Figure 1) goes through the following thermodynamic processes. One mole of an ideal gas expands adiabatically from an initial volume of 100 cm³ and an initial pressure of 100 kPa (point a) to one third of the initial volume and five times the initial pressure (point b). Next, the gas is ignited at a constant volume, causing the pressure to double (point c). As a result, the cylinder undergoes an adiabatic expansion back to the initial volume. Lastly, heat is rejected from the system in an isochoric process, until the initial pressure is reached.

   a) (30 points) What is the efficiency of this engine?
   b) (10 points) What is the maximum efficiency possible for an engine operating between these same temperatures?

The Otto Cycle

![Figure 1](image-url)
2) (30 points) You are given a very cold, long, slender lead rod and are asked to determine the linear coefficient of thermal expansion, \( \alpha \), for lead. The tools you have available are a scale, bucket, hot water, thermometer, and a meter stick. You bring 5 kg of water to a boil and quickly remove it from the burner such that you can assume no water has evaporated. You then place the 1 kg lead rod in the water and allow the two to come to thermal equilibrium at 98 °C, at which time you measure the length of the rod to have increased by 1%. You’re a good student, and recall from class that the molar heat capacity of lead can be closely approximated as \( C = 3R \), where \( R = 8.314 \) J/mol·K. You also know that the molar mass of lead is \( M = 0.207 \) kg/mol and that the specific heat capacity of water is \( c_w = 4190 \) J/kg·K. Given this information and your well designed experiment, what will you determine the linear coefficient of thermal expansion, \( \alpha \), for lead to be?
3) **a)** (20 points) What is the root mean squared velocity, $v_{rms}$, of Nitrogen gas (molar mass, $M_N = 0.014 \text{ kg/mol}$) at room temperature ($T = 27 \degree \text{C}$)?

**b)** (10 points) Given that the speed of sound is 340 m/s under these conditions, can you justify your answer to part (a) in one or two sentences?