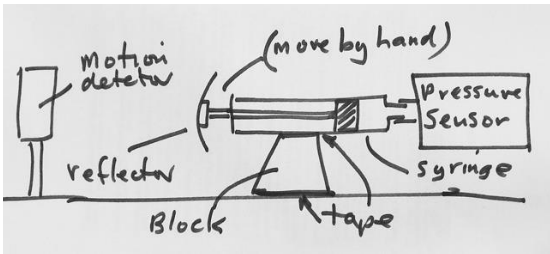
Isothermal and adiabatic processes

Question 1: Part 1



a

b It is not possible to keep the temperature inside the syringe exactly the same as the temperature outside, but moving the piston at 1 mm per second will give changes in PV that are less than the graph line-width.

c and d An isothermal process takes place at constant temperature. The enclosed air is slowly compressed from atmospheric pressure. Heat is transferred from the air to the cylinder walls, preventing any significant increase in temperature. A slow expansion follows. Heat is transferred from the walls to the enclosed air preventing any significant reduction in temperature.

Part 2

a An adiabatic process takes place without heat transfer in or out of the system. (The system is either thermally isolated from the surroundings or the process takes place very quickly.)

b The temperature is highest at **1** and lowest at **3**.

c Only points **2** and **4** lie on the same isotherm (at room temperature).

d The piston was not stationary at the high end of the loop but moved backwards a little. The transition 1-2 is not isochoric (isovolumetric).

Part3

a If the smaller syringe is used to demonstrate an almost isothermal cycle the piston of smaller cross sectional area can be moved by hand with less force. Smaller volumes tend to exchange heat more rapidly and so a near adiabatic change in a larger volume syringe does not need to be done quite as fast that in the smaller one.

Question 2

Part 1

a Their teacher asked them to put a little water in the bottle to make sure the air was saturated with water vapor. Water droplets condense on smoke particles. Cloud will form more quickly than in clean air.

b He asked for the short wait to ensure that air in the bottle was saturated at the higher pressure and at room temperature.

c The air expands and cools. The temperature drops below the dew point and water droplets condense.

d The bottle was put on a dark background so that the cloud could be easily seen.

Part 2

a Pressure is force per unit area. Half the weight of a 60 kg student is 300 N. The area of sandal in contact with the bottle is about 10x10 cm.

The increase in pressure is ~300/0.01 N/m^2 which is 30 000 pascals (less than one third of an atmosphere).

b Assuming that the volume is unchanged, that the change is adiabatic (very fast), that the pressure reduces suddenly to one atmosphere and that room temperature is 300 K ….

$$P_1/T_1 = P_2/T_2$$

$$T_2 = (100\,000/130\,000)300$$

$$= 230 \text{ K} \ldots \text{(close to -40 °C)}$$

c In practice the temperature will not reach such a low value because of rapid heat transfer from the bottle walls and the release of latent heat from condensing water droplets.

Part 3

a Both the condensation in the bottle and in the atmosphere are due to adiabatic cooling that reduces air temperature to below the dew point. The cloud in the atmosphere lasts longer because the system is so large that heat is not rapidly transferred by conduction (etc.).

Question 3

Part 1

a The compression ratio is the maximum pressure just before ignition over the minimum pressure in the cylinder.

B Diesel engines rely on adiabatic heating due to compression to ignite the fuel as it is injected.

c Pre-ignition (detonation) is the explosion of fuel in the cylinder before the spark plug fires due to adiabatic heating by compression and a low self-ignition temperature of the fuel.

d Tetraethyl lead lowered the self-ignition temperature of the petrol. It was removed because of lead contamination of the environment.

Part 2

a A parcel of dry air cools more rapidly than the surrounding air temperature drops with altitude. Almost immediately the parcel is colder than the surrounding air, more dense, and upward buoyancy forces disappear.

b A rising parcel of saturated air cools more slowly than the air temperature drops with altitude. The rising parcel cools rapidly but is warmer than the surrounding air, less dense, and buoyancy forces lift it upwards.

c Expanding saturated air cools less than expanding dry air because of the latent heat of evaporation released from the water droplets as they condense.

Part 3

a The mixing rate drops by almost one g/kg per 250 metres. The cloud density is ~1 g/m^3.

b The latent heat of vaporization of water is 2260 J/g. The temperature rise of one kg of air (close to one cubic metre) due to the condensation of this amount of water vapor would be given by $Q = mc_p\Delta T$.

$$\Delta T = \sim (-2)\ °C$$

The input of energy from latent heat reduces the rate of cooling of dry air due to expansion over the rise of 250 m.