PreLab 6: Spirometer
(10 problems for 30 pts)

The goal of Lab 6 is to build and test a pneumotachometer for spirometry. An off-the-shelf Lilly-type flow tube will be connected to a piezoresistive differential pressure sensor. The sensor output is amplified by the AD620 instrumentation amplifier, acquired by an Arduino, and processed in MATLAB.

PART 1: LUNG ANATOMY AND PHYSIOLOGY

- **Read Unit One of the Spirometry Training Guide (see course website) from the National Institute of Occupational Safety and Health (NIOSH)**. This provides information about basic lung anatomy and physiology.

- **Problem 1**: Explain how the respiratory system transports oxygen from the outside air into the blood stream. Approximately six to ten sentences should be sufficient. Include important anatomical features in your description. Do NOT simply write "Inhaled oxygen goes through the lungs and into the blood stream".

- **Problem 2**: Explain the differences between tidal volume (TV), vital capacity (VC), and forced vital capacity (FVC).

- **Read Unit Two of the Spirometry Training Guide (see course website) from the National Institute of Occupational Safety and Health (NIOSH)**. This provides basic information about spirometry.

- **Problem 3**: What is the definition of spirometry? What is the patient usually required to do during a spirometric test?

- **Problem 4**: Explain the difference between the two most common types of spirometers. What type of spirometer is the unit from Vernier, Inc.? The data sheet is on the course website.

- **Problem 5**: Explain the three most useful measurements obtained through spirometry. What would indicate a restrictive disease? How about an obstructive disease? Give an example of each type of respiratory disease.

- # PART 2: PNEUMOTACHOMETER

The most commonly used spirometer is a flow-resistance pneumotachometer with an approximately linear pressure-flow relationship. A piezoresistive sensor records the pressure difference across the flow-resistance element. When the air flow is laminar (as opposed to turbulent), the linear pressure-flow relationship is given by **ΔP = F×R**, where **ΔP** is the differential pressure on either side of the flow-resistive element, **F** is flow, and **R** is the flow-resistive element. It is worth noting that this equation is analogous to Ohm's law, where the air flow is electrical current and differential pressure is voltage. The American Thoracic Society (ATS) recommends that a pneumotachometer have R less than 150 Pa·s/L.

Assume a pneumotachometer has a flow resistance R = 36 Pa·s/L, and we want to measure a maximum flow rate of 16 L/s. The instrumentation amplifier is an AD620 chip powered by +10V and GND with a voltage reference Vref = 2.5V. Remember that the Arduino ADC operates from 0 to 5V with 10 bits. Suppose the noise voltage of the measurement system is 2 mV.

- **Problem 6**: This lab will use the MPX2010DP differential pressure sensor (see course website for data sheet). What is the responsivity of this sensor (mV/kPa)? What supply voltage should be used?

- **Problem 7**: What is the maximum instrumentation amplifier gain for this system?

- **Problem 8**: Would you use R_G = 10, 30, or 50 ohm? Choose the appropriate value and then compute the actual amplifier gain.

- **Problem 9**: Recall in Lab 1 (load cell), the measured voltage V_{MEAS} was converted to load by the following formula:

  Load = Calibration * (L_rated / (Ad*RO*Vs)) * (V_{MEAS} – Vref)

  The "Calibration" term was an experimentally derived number to compensate for imperfections in the system. Derive a similar expression for the spirometer to convert the measured voltage V_{MEAS} into flow F.

- **Problem 10**: Compute the minimum detectable flow ΔF_{MIN}. Express your answer in L/sec.

(End of PreLab6)