BENG 186B Winter 2025 HW #5

Due *Friday, February 28* at 11:59pm on Canvas (Gradescope)

Parts of the homework done collectively in-class (Friday, February 21) are indicated below with **[IC]**.

1. [**20 pts**] An automated sphygmomanometer tightens around a patient's arm at a pressure of 200 mmHg, and gradually relieves pressure at a rate of 5 mmHg/sec. An microphone in the cuff records the onset of Korotkoff sounds after 15 seconds, and the sounds end after 25 seconds.

   (a) **[IC]** [10 pts] What are the systolic and diastolic blood pressure values?

   (b) [10 pts] Are these pressure values in the normal range, or are any of these two abnormally high or low? Suggest possible causes for any abnormalities. Cite any sources you used.

2. [**30 pts**] A magnetic field of 1 T is induced across a blood vessel in the positive z direction (elevation $\phi = 0$ in spherical coordinates). The arterior blood vessel has a diameter of 5 mm and is oriented along direction with azimuth $\theta = 0°$ and elevation $\phi = 90°$ in spherical coordinates. Blood flows in the vessel along this direction.

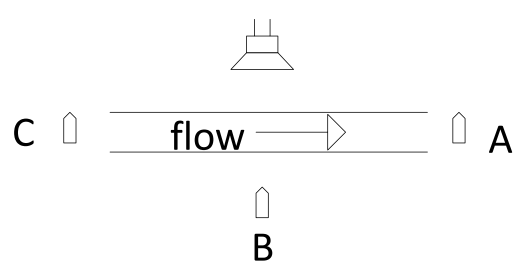
   (a) **[IC]** [10 pts] In what direction does the induced electric field point?

   (b) [20 pts] If the voltage across the diameter of the vessel in this direction is measured as 10 mV, what is the volumetric flow rate of blood through the vessel?

3. [**20 pts**] The Doppler effect can be applied to achieve noninvasive blood flow velocity measurement with high precision. Consider a simplified model of Doppler blood flow velocity measurement with a single blood vessel, an ultrasonic transmitter, and an ultrasonic receiver placed either at positions A, B, or C on the body as shown below. The frequency of the ultrasound emitted from the transmitter is 2 MHz, and the speed of sound in body tissue $c \approx$ 1,500 m/s.

   (a) **[IC]** [10 pts] The receiver located at position A observes the signal with frequency 2.000394 MHz. What is the velocity of blood flow in the vessel?

   (b) [10 pts] Now moving the location of the receiver, find the frequency of the signal observed when the receiver is in position B, and when it is in position C. In which of the three locations A, B, and C do you obtain the highest sensitivity to blood flow velocity?



4. **Design Problem [30 pts]:**

   Design a system for measuring intravascular blood pressure, transducing this pressure at its input to a voltage at its output, using the following components:

(a) a fluid-filled catheter of at least 20 cm in length, that is critically-damped and operates in the frequency range from 0 to 40 Hz;

(b) a fluid chamber between the catheter and a membrane registering pressure as strain with Young's modulus 20 MPa;

(c) a strain gauge with nominal resistance R_G = 100 kΩ at zero strain, and with gauge factor $G = 100$;

(d) a Wheatstone bridge circuit to convert pressure to voltage;

(e) any additional passive or active circuit components;

and the following specifications:

(a) Use a single 1.2V battery.

(b) The target sensitivity is 1 mV/mmHg.

(c) The operating range of blood pressure is 0-250 mmHg.

(d) When the pressure reaches higher than 150 mmHg, then an alert should be triggered by lighting a red LED.

As always, be sure to show a complete diagram of your design, and specify all components including the types and values where applicable, including, for instance, the internal diameter of the catheter and its length. Provide reasoning for justifying your design choices, and state all assumptions supporting the reasoning. You may find it useful to check the operation of your circuit and observe its behavior using an electronic simulator such as the Falstad Java applet with several circuit examples posted at https://www.falstad.com/circuit/.