UNIVERSITY OF GHANA

BSC. ENGINEERING FIRST SEMESTER EXAMINATIONS: 2018/2019
DEPARTMENT OF BIOMEDICAL ENGINEERING
BMEN 407: HAEMODYNAMICS (3 Credits)

INSTRUCTIONS:

ANSWER ANY FOUR QUESTIONS

TIME ALLOWED: TWO (2) HOURS

1. A nurse is concerned because a patient's cardiac output (CO) is low. The nurse would have to implement some therapeutic interventions to normalize the CO
   a. Which of the following parameter(s) would be affected by her interventions to bring back the CO to normal?
      i. Body mass Index (BMI)
      ii. Preload (the initial stretching of the cardiac muscles)
      iii. Contractility,
      iv. Heart rate
      v. Afterload (the force or load against which the heart must contract to eject blood)

      (5 marks)

   b. Explain the mechanisms by which the parameter(s) you chose would normalize the CO? (10 marks)

   c. An arteriole with resistance 3 mmHg/L/min divides into four capillary branches with resistances of 2,3,1, and 6 mmHg/L/min respectively. These capillaries combine into a single venule with resistance of 1 mmHg/L/min.
      i. What is the total resistance of this vascular bed? (5 marks)

ii. If the flow rate at the arteriole is 150 ml/min, what is the pressure gradient driving the flow in this vascular bed? (5 marks)

2. a. The aorta of an average adult human has a radius 1.3 $x10^{-2}$ m. what are the
   i. resistance (5 marks)
   ii. the pressure drop (5 marks)
   over a 0.2 m distance, assuming a flow rate of A = 10^{-4} m^3/s, and viscosity of blood at 37 °C to be 2.084 x 10^{-3} Pa.s

   b. Give two reasons why blood flow in the capillaries is the slowest among the blood vessels. (5 marks)

   c. Prolonged standing by School children during Independence Day parade may cause some of them to collapse. However, they do not collapse while marching. Explain. (10 marks)

3. a i. Explain the terms **Bulk flow** and **Net filtration pressure.** (4 marks)

   ii. Bulk flow is dependent upon four pressures that determine the direction of net fluid flow. Name and define these pressures? (4 marks)

   b. Edema is a medical condition which results from net fluid flow, explain the cause of Edema and measures you can take to avoid its occurrence. (5 marks)

   c. Describe the role of each of the following in Venous Return
      i. Skeletal muscles
      ii. Venous valves
      iii. Respiration.
      iv. Posture and gravity (12 marks)

4. a. Consider blood flows in an arteriole with a diameter of 0.01 cm and an average velocity of 0.05 cm/s. if blood is considered as a Casson fluid with yield stress of 0.00289 Pa and a constant s = 0.0229 $Pa^{1/2}$. Determine the wall shear stress, given the reduced average velocity U as

$$U = \frac{1}{2s^2}\left[\frac{\tau_\omega}{4} - \frac{4}{7}\tau_\omega^{1/2}\tau_y^{1/2} - \frac{1}{84}\frac{\tau_y^4}{\tau_\omega^3} + \frac{\tau_y}{3}\right]$$

where U the reduced average velocity is given by;

$$U = \frac{U_{ave}}{D},$$ (9 marks)

b. Given that the yield stress for normal blood at 37°C is about 0.004 Pa and the ratio $\frac{L}{R}$ of the blood vessel to be 200. Estimate the pressure drop in a small blood vessel that is needed to just overcome the yield stress τ_y. (6 marks)

c. An intravenous (IV) system is supplying saline solution to a patient at the rate of 0.12 cm^3/s through a needle of radius 0.150 mm and length 2.50 cm. what pressure is needed at the entrance of the needle to cause this flow, assuming the viscosity of the saline solution to be the same as that of water? The gauge pressure of the blood in the patient's vein is 8.00 mm Hg. [Assume viscosity of water at 20 °C to be $1.00x10^{-3}$ N.s/m2]. (6 marks)

d. Sketch the blood pressure changes or distributions in blood vessels (from aorta through the arteries to the veins) for both systemic and pulmonary circulation. (4 marks)

5 a. The equation for the velocity. **V**, at radius **r** of a Newtonian blood in a vessel of outer radius **R** under laminar flow condition is

$$V = \frac{R^2}{4\mu}\frac{\Delta P}{L}\left(1 - \frac{r^2}{R^2}\right)$$

where the symbols have their usual meanings.

If the shear stress is given by

$$\tau = \mu\left(\frac{dV}{dr}\right)$$

Derive an expression for the shear stress as a function of radius **r** and show that it is maximum at the walls of the vessel. (10 marks)

b. Sketch the distribution of shear stress across the diameter of the blood vessel. (5 marks)

c. During a marathon race, a runner's blood flow increases to 10 times her resting rate. Her blood viscosity has dropped to 95.0% of its normal value, and the blood pressure difference across the circulatory system has increased by 50.0 %. By what factor has the average radii of her blood vessels increased? (5 marks)

d. A glucose solution being administered with an IV has a flow rate of 4.00 cm^3/min. What will the new flow rate be if the glucose is replaced by whole blood having the same density but a viscosity 2.50 times that of the glucose? All other factors remain constant. (5 marks)