UNIVERSITY OF GHANA

BSC. ENGINEERING
FIRST SEMESTER EXAMINATIONS: 2015/2016

DEPARTMENT OF BIOMEDICAL ENGINEERING
BMEN 405: CARDIOVASCULAR MECHANICS (2 CREDITS)

INSTRUCTIONS:

Attempt all questions
All questions should be answered in the booklet provided
Calculations should be detailed and systematic. Marks allocated to steps
Relevant formulae are provided at the end of the question sets
All symbols used have their usual meanings

TIME ALLOWED: ***TWO (2) HOURS***

1. Indicate how changes in the following factors influence the ventricular preload. Fill in the table with *increase* or *decrease*.

Factor	Change in Factor	Effect on Ventricular Preload
Venous filling pressure		
Heart rate		
Ventricular compliance		
Atrial contraction		
Inflow resistance		
Ventricular inotropy		
Outflow resistance		

(14 marks)

2. The 2-element Windkessel model of the arterial system relates pressure and flow by the equation given below. It is observed in an experiment that the diastolic phase takes 3 milliseconds for a pressure drop from 120 mmHg to 80 mmHg. [1 mmHg = 133 Pa]

$$q_{in} = C\frac{dp}{dt} + \frac{p}{R}$$

   a. Sketch the electrical analogue of the 2-element Windkessel.

(3 marks)

   b. Calculate the characteristic decay time associated with this model during the diastolic phase.

(10 marks)

   c. Would you expect the diastolic phase to last longer with an increased arterial resistance for the same pressure drop and arterial compliance? Explain.

(6 marks)

d. Given an arterial compliance of 4.5 ml/mmHg, calculate the associated peripheral resistance.

(3 marks)

e. What is the mean flow in this model if the aortic pressure is measured to be 120 mmHg and the venous pressure is 4 mmHg?

(4 marks)

3. Stenosis is the narrowing of a blood vessel that affects flow through the vessel. At a decrease of >70% of the vessel radius (critical stenosis), an intervention is usually made.
    a. What effect does the narrowing of the vessel have on the resistance of the vessel? Explain the basis for you answer.

    (4 marks)

    b. Give one cardiovascular prosthetic device which may be used in this case.

    (3 marks)

    c. List two problems associated with using the above-mentioned device.

    (4 marks)

4. Capillary exchange is dependent on the balance between two opposing forces and is summarized by Starling's Hypothesis.
    a. Explain Starling's Hypothesis.

    (5 marks)

    b. List any two (2) mechanisms of capillary exchange.

    (4 marks)

    c. Put the following under the appropriate column: BHP, IFHP, IFOP and BCOP.

Filtration	Reabsorption

(4 marks)

d. Given BHP = 40 mmHg, IFHP = 4 mmHg, BCOP = 31 mmHg and IFOP = 1.5 mmHg,
    i. Calculate the net filtration pressure.

    (3 marks)

    ii. Would there be a net inward/outward flow?

    (2 marks)

e. Major changes in which of the competing pressures would most likely cause the condition of oedema?

(2 marks)

5. A healthy individual inadvertently takes a drug which increases the cardiac muscle contractility of the ventricular wall. With the aid of a pressure-volume graph,
    a. Explain how this influences the cardiac output of the individual, assuming all other parameters remain constant.

    (10 marks)

6. The Herschel-Bulkley model is used to model the behaviour of non-Newtonian fluids. Blood is shown to behave as a Bingham plastic under certain conditions.
   a. Define the terms in the Herschel-Bulkley model.

   (4 marks)

   b. What values do the coefficients of this model take to depict the behaviour of a Bingham plastic?

   (3 marks)

   c. Sketch and explain the stress-strain rate diagram given these values of the model coefficients.

   (8 marks)

   d. Differentiate between a shear thinning fluid and a shear thickening fluid.

   (4 marks)

Formula Bank:

$$Q = \frac{dV}{dt}$$

$$EF = \frac{SV}{EDV}$$

$$\tau = \mu \frac{\partial u}{\partial y}$$

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

$$\sigma = \Delta P \frac{\pi r^2}{2\pi r L} = \frac{\Delta P r}{2L}$$

$$\sigma = \mathrm{m}\left[\frac{\mathrm{du}}{\mathrm{dy}}\right]^n + \sigma_0$$

$$Q_o = \frac{P_a - P_v}{R}$$

$$Q = \frac{\pi \Delta p R^4}{8\mu L}$$

$$C = \frac{\Delta V}{\Delta P}$$

$$NFP = BHP + IFOP + BCOP + IFHP$$