CHUKA UNIVERSITY

UNIVERSITY EXAMINATIONS
THIRD YEAR EXAMINATION FOR THE AWARD OF DEGREE OF BSC (GENERAL)

PHYS 392: BIOPHYSICS **TIME: 2 HRS**
Streams: BSC **DAY/DATE:……**

INSTRUCTIONS:

- Answer Question One in Section A and any other Two Questions in Section B
- Do not write anything on the question paper
- This is a closed book exam, No reference materials are allowed in the examination room
- There will be No use of mobile phones or any other unauthorized materials
- Write your answers legibly and use your time wisely

Useful Constants

Density of blood $\boldsymbol{\rho_{lood}} = 1.04\, x10^3\ kg/m^3$
Viscosity of blood $\eta_{blood} = 4\ x\ 10^{-3}\ Pa.s$
Gravitational acceleration $g = 9.8\ m/s^2$

QUESTION ONE (30 MARKS)

a. Define the terms;
   i. Pseudoplastic-thixotropic material **(2 marks)**
   ii. Dilatant materials **(1 mark)**
b. List three origins of extracellular Electric fields **(3 marks)**
c. Using sketches explain the behavior of external electric fields of low and high strengths through a cell. **(3 marks)**
d. Consider the diagram in figure 1 a and b. The forces acting on the forearm include the upward force F_M exerted by the muscle and a force F_J exerted at the joint by the bone in the upper arm, both assumed to act vertically.
   i. How much force must the biceps muscle exert when a 5.0kg ball is held in the hand with the arm horizontal as in picture a? Assume that the mass of the forearm and hand together is 2.0 kg **(3 marks)**
   ii. How much force must the biceps muscle exert when a 5.0kg ball is held in the hand with the arm is at a 45^o angle as in picture b? Assume that the mass of the forearm and hand together is 2.0 kg. **(3 marks)**
e.
   i. What do you understand by moment of area? **(2 marks)**
   ii. Using a sketch diagram of a tubular bone, show how the moment of area can be calculated?

(3 marks)

f.

i. Sketch a flow profile and pressure distribution around a moving streamlined body. Explain the direction of pressures. **(2 marks)**

ii. Explain what may happen on increasing the velocity of the moving body. **(2 marks)**

g. Explain why human blood relative viscosity shows a pseudo plastic thixotropic behavior. **(3 marks)**

h. Sound enters the ear, travels through the auditory canal, and reaches the eardrum (see figure 2). The auditory canal is approximately a tube open at only one end. The other end is closed by the eardrum. A typical length of the auditory canal in an adult is about 2.4 cm. the speed of sound is 343 m/s. What is the fundamental frequency and wavelength of the canal (this is the frequency that humans are most sensitive to hearing)

(3 marks)

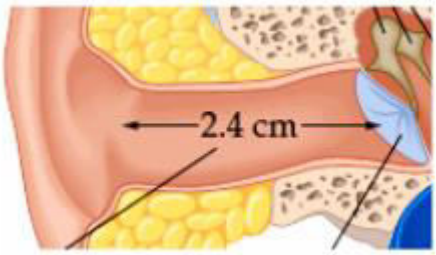

Figure 1

QUESTION TWO (20 MARKS)

a. For a fluid that experiences viscous grad forces with the walls of a pipe, Poiseuille's law states that there is pressure drop proportional to the resistance to the flow, $\Delta P = -QR$, and the resistance $R = \frac{8\eta l}{\pi r^4}$. This applies to a pipe with a constant cross-sectional radius r, length l and for a fluid with viscosity η. Derive the resistance equation assuming laminar flow. **(10 marks)**

b. In the cardiovascular system the arterioles provide most of the resistance to blood flow. Thus, by Poiseuille's law they have the largest drop in pressure of any blood vessel. The average blood pressure is 80 mm Hg as it enters an arteriole and is 20 mm Hg as it leaves the arteriole. The viscosity of blood is $3\,x\,10\,Pa.s$ and the arteriole has a radius of 0.1 mm and a length of 0.95 mm. Recall that $1\,atm = 10^5\,Pa = 720\,mm\,Hg$

i. What is the resistance to blood flow in the arteriole? **(3 marks)**

ii. What is the average flow rate Q in an arteriole, in m^3/s? **(3 marks)**

iii. Suppose plaque deposits in the arteriole decreased the radius from 0.1 mm to anew smaller radius r_{new}. If the resistance in the arterioles doubled as a result of this constriction, find r_{new} **(4 marks)**

QUESTION THREE (20 MARKS)

a. One first class lever system involves the extensor muscle which exerts a force M to hold head erect. The force W of the weight of the head acting at its center of gravity (cg) lies

forward of the force F exerted by the cervical vertebra (see sketch). The head has a mass of about 3 kg, or a weight of 30 N.

i. With sketches to show position of Resistance Load and Pivot, name two anatomical examples of the other two types of levers **(4 marks)**

ii. Find F and M in figure 3. **(6 marks)**

iii. The area of the first cervical vertebra on which the head rests is $5\ x\ 10^{-4}\ m^2$. Find the stress (force per unit area N/m^2) on it **(3 marks)**

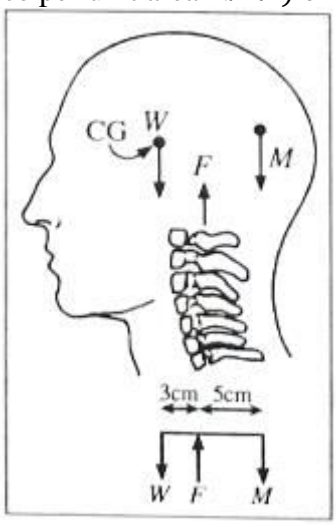

Figure 2

b. A 75 kg man stands on his toes by exerting an upward force through the Achilles tendon as in figure 2.

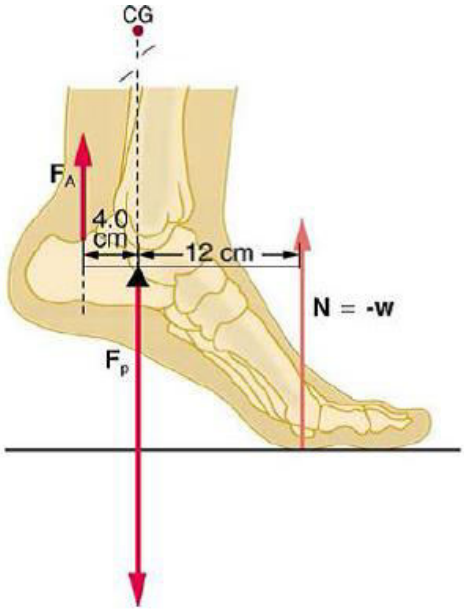

Figure 3

i. What is the force in the Achilles tendon if he stands on one foot? **(4 marks)**

ii. Calculate the force at the pivot of the simplified lever system shown. **(3 marks)**

QUESTION FOUR (20 MARKS)

A cell can be modeled as a spherical capacitor (see figure 5). Electric fields across the membrane (i.e. the cell wall) cause potassium or K^+ ions to move through it. A typical membrane is 7 nm thick and has an electric potential across it of -70 mV.

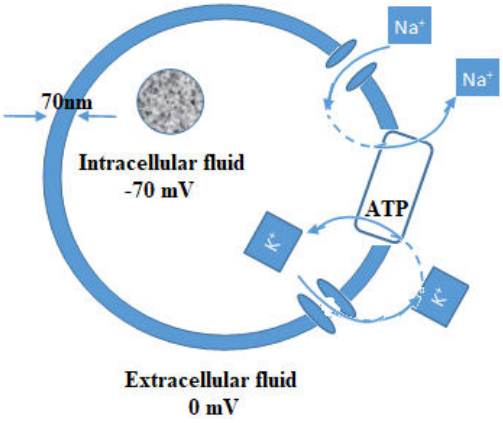

Figure 4

a. Find the capacitance of a cell with a radius of $10^{-5}m$? Recall the area of a sphere is $4\pi r^2$ and $\varepsilon_0 = 8.85\ x\ 10^{-12}\ \frac{C^2}{N.m^2}$ **(3 marks)**

b. How much total charge must be present on the membrane in order to produce this potential difference? **(3 marks)**

c. What is the magnitude of the electric field across the membrane? **(3 marks)**

d. What force does this electric field exert on a K^+ ion with charge +e? ($e = 1.6\ x10^{-19}C$) **(3 marks)**

e. How much energy does the K^+ ion gain after moving across the membrane? **(3 marks)**

f. How much energy is this in electron Volts (1 eV=$1.6\ x10^{-19}J$)? **(2 marks)**

g. How fast is it going when it gets across the membrane? Assume it was initially at rest (mass of potassium $= 6.5\ x\ 10^{-26}kg$)? **(4 marks)**

QUESTION FIVE (20 MARKS)

a. Why do we humans hear in the frequency range that we do (20 *Hz* – 20 *KHz*)? **(2 marks)**

b. "Two ears are better than one." Explain how we use the information in our auditory system to localize sounds of low and high frequencies. **(4 marks)**

c. Taking human ears separation distance to be 0.15 m,

i. Calculate the maximum frequency in air ($V_{air} = 343\ \frac{m}{s}$) that can be localized by humans **(4 marks)**

ii. Compare the arrival time distances of sound in human in the three given environments with that in air;

1. In water ($V_{water} = 1500\ \frac{m}{s}$) **(2 marks)**
2. In helium atmosphere ($V_{Helium} = 970\ \frac{m}{s}$) **(2 marks)**

3. In sulphur hexafluoride (SF_6) $(V_{SF_6} = 150\ \frac{m}{s})$ **(2 marks)**

d. Based on the results of a and b above, explain why do we find it difficult to localize pure tones with frequencies (1000-5000 Hz) where pitch perception is quite good? **(4 marks)**