THE OPEN UNIVERSITY OF SRI LANKA

B.SC DEGREE PROGRAMME

PHU5304/PYU3165 – BIO PHYSICS

FINAL EXAMINATION 2021/2022

Duration: Two hours (02 hrs)

Date: 16.10.2022 **Time: 9.00 am – 11.30 am**

Answer four (04) questions only

Q1. Here we consider a person bending forward to lift a box as the following figure 1. Two torques arise from the force of gravity. One is on the box and the other is on the upper body of the person. These forces together exert a force on the lower back, in particular on the fifth lumber vertebra. We can consider the lower back as a natural pivot; the spinal column being considered as a lever. Note that the gravitational torque on the object as a whole is the same as the gravitational torque exerted on a point mass with the same mass as the object located at the center of gravity(CM). There are four forces acting on the spinal column:

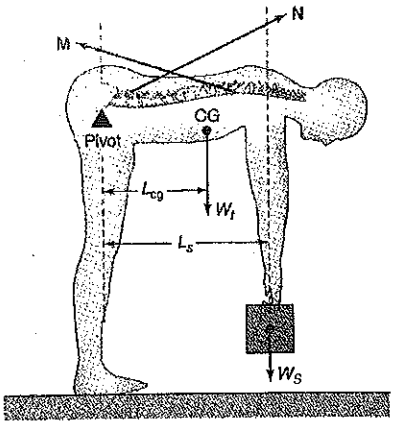


Figure 1

1. The gravitational force, W_t, acting on the CM of the torso. Assume that this lies at a distance $L_{CM} = 0.42$ m from the lower back and that its magnitude is 523 N.
2. The gravitational force on the box, W_s, which is transmitted by the arms and shoulders. Assume that this lies at a distance $L_s = 0.70$ m from the lower back and that its magnitude is 140 N.
3. The unknown force M exerted on the spinal column by the back muscle responsible for the lifting . Assume that this force applied at a distance $d = 0.7L_s$ from the lower back at an angle α of about 12^0 above the horizontal.
4. An unknown compressive reaction force, N, exerted on the pivot in the lower back. Let β be the angle between N and the horizontal.

(i) Draw the free body diagram for bending man. (10 Marks)

(ii) Calculate the magnitude of the force M and the force N. . (20 Marks)

(iii) Calculate the magnitude and direction of the force F, acting on the fifth lumbar vertebra for the person shown in the figure 2. (20 Marks)

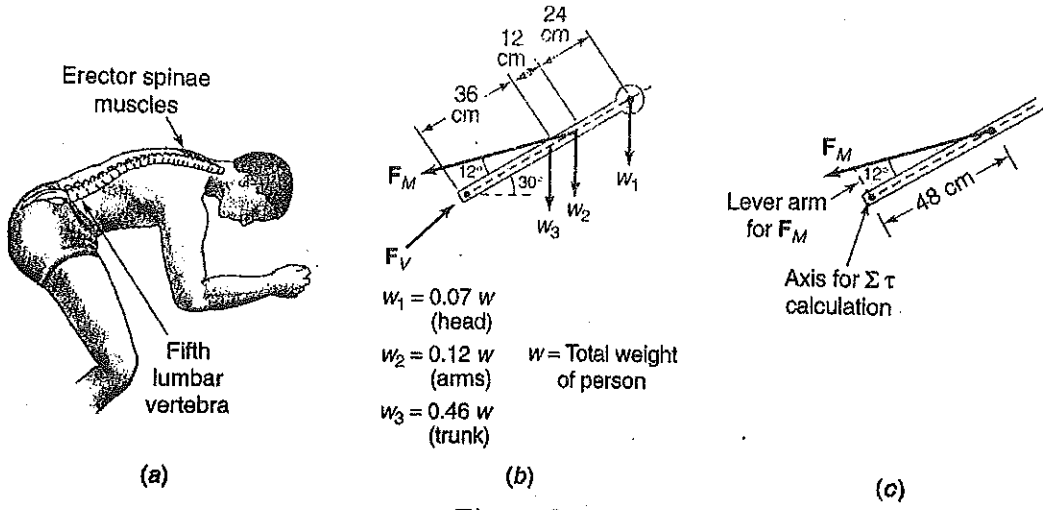


Figure 2

Q2. Blood flow in human body is usually laminar flow, which means that flow velocity is maximum along the axis of the vessel and drops down to zero along the walls.

(a) Calculate the average blood velocity in the major arteries of a healthy human. given that the aorta has a radius of 1.0×10^{-2} m, the blood velocity 0.03 ms^{-1} in the aorta, and the total cross-sectional area of the major arteries is $2.0 \times 10^{-3}\ m^2$. (10 Marks)

(b) What is the total blood flow rate in the body? (05 Marks)

(c) Calculate the kinetic power, pressure power and the total power generated by the left ventricle of the heart for this adult, given that the density of blood is $1.05 \times 10^3\ kgm^{-3}$ and the pressure is $1.60 \times 10^4\ Nm^{-2}$. (05 Marks)

(d) On the assumption that all the blood in the circulatory system goes through the capillaries and given that the average velocity of the blood in the capillaries is $3.0 \times 10^{-4}\ ms^{-1}$, what is the total cross-sectional area of the capillaries? (10 Marks)

(e) When a person eats a large meal, blood flow in the digestive system is increased by dilating blood vessels suppling that system. By what factor must the flow regulating vessels dilate to increase flow from $1.0 \times 10^{-3}\ m^3 min^{-1}$ to $5.0\ m^3 min^{-1}$. (10 Marks)

(f) Water soluble molecules such as glucose, albumin and hemoglobin encountered inside blood can be modeled as little spheres with diameter D. what is the dependance of the molar mass M on the radius? Assume that water-soluble molecules in blood generally have a density close to that of water. (10 Marks)

Q3. The human body is able to interpret, received, and respond to sensory stimuli by the transmission of electric signals through the nervous system along nerve fibers of network of individual cells. These later known as neurons. It consists of a cell body with a nucleus connected to dendrites which serves as the input for a signal. A long conducting tail, which is attached to the neuron, is called an axon and propagates the electrical signal or impulse away from the neuron.

(i) What is meant by an action potential and how can it be led to the production of an electrocardiogram. (10 Marks)

(ii) What are artifacts and how might they be minimized? (05 Marks)

(iii) Sketch a graph of the action potential as a function of time for a typical nerve axon, giving approximate scales on the axes. (05 Marks)

(iv) Assume that in 3.0s, 5.0×10^{-14} gramme molecules of Na^+ ions flow out of a biological cell. What current passes through the membrane? Avogadro's number $N_A = 6.02 \times 10^{23}$. Estimate the value of the current density for a cell whose surface area $A = 200\ \mu m^2$.

(10 Marks)

(v) A pacemaker applies 72 stimulating square-pulses per minute to the heart. The pulse length $\tau = 0.5$ ms, and the amplitude $U = 5$ V. Two electrodes convey the pulses from the pulse generator to the heart wall. The resistance of the heart tissue between the connecting electrodes is $R = 600\ \Omega$.

(a) What is the power of one pulse? (05 Marks)

(b) What is the energy of on pulse? (05 Marks)

(c) What is the average power of the Pacemaker? (05 Marks)

(d) For how many years can a pacemaker work if the total energy $W_T = 15$ kJ of its supply is used with an efficiency of 35%? (05 Marks)

Q4. Some blurring effect of retinal images always occurs due to aberration which increases with increasing pupil size and diffraction of light mainly as it passes through the pupil.

(a) Explain with the aid of a ray diagram the term ***depth of focus*** applied to the human eye.

(10 Marks)

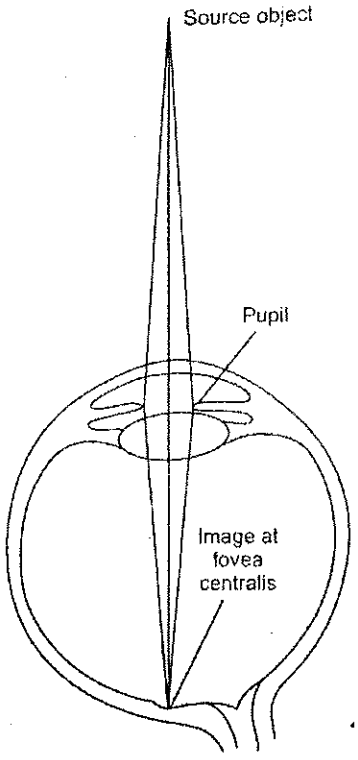
An object at a fixed distance from the eye is viewed when the pupil is

(i) large and (05 Marks)

(ii) small. State and explain which condition gives rise to the larger depth of focus, supporting your answer by means of a diagram. (05 Marks)

(b) A person with normal eyesight observes a bright light which flashes for 0.020s at intervals of 10s. Explain how the persons perception of the bright light changes as the intervals are progressively reduced and name the effect which is responsible. State one practical application of the effect. (15 Marks)

(c) Diffraction is bending of light rays at the boundaries of obstacles. This phenomenon is related to wave-nature of light. Light waves, incident from a particular direction, after being diffracted (or bent) by pupil-aperture, are focused by eye-lens. Waves diffracted along a particular direction from different parts of aperture interfere and produce a diffraction pattern on retina. Diffraction pattern shows circular interference fringes, the central disc being the first order maxima. Higher order circular maxima are progressively fainter. Hence , central bright spot principally determines the spread of the image I of the object located at O.



When central maxima from two distinct objects fall separately on retina, the objects can be resolved. This is called Rayleigh's criterion for resolution of an optical device. Wave theory of diffraction shows that if **D** is the diameter of aperture, the first minimum is formed at an angle **θ** is given by

$$\theta = 1.22\frac{\lambda_n}{D}$$

Where λ_n is the wave length of light in the medium in which light travels after refraction. If n is refractive index of the above medium, $\lambda = \frac{\lambda}{n}$, where λ is the wave length in vacuum.

The angular width of central maximum is **2θ.** If l is the diameter of central bright disc, we get (approximately),

$$l = f(2\theta) = 2.44\frac{\lambda}{D}\frac{f}{n}$$

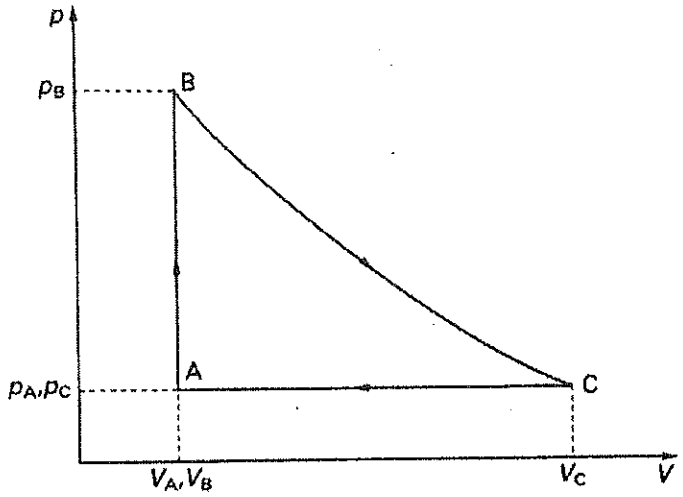
Where f is the focal length of eye-lens.

For human eye model, f=17 mm, n= 1; diameter of pupil under average light conditions is **D=4 mm**. For λ =550 nm, diameters of rods and cones in foveal region are of the order of 1-2 μm .

Considering the above-mentioned data of the human eye, justify that foveal region of the retina has better spatial resolution. (15 Marks)

Q5. **(i)** State the Second law of Thermodynamics. (05 Marks)

(ii) A certain mass of an ideal gas is contained in a cylinder by means of a well-fitting, frictionless piston. Starting from an equilibrium state A, in which the pressure **p** excreted by the gas is 1.00×10^5 Pa and the volume V occupied by the gas is 2.00×10^{-3} m^3, the gas under goes the reversible cyclic process shown in the figure below.



In equilibrium state B, the pressure exerted by the gas is 2.00×10^5 Pa and in equilibrium state C the volume occupied by the gas is 3.28×10^{-3} m^3. The process represented by the line BC is a reversible isothermal process and is described by the equation

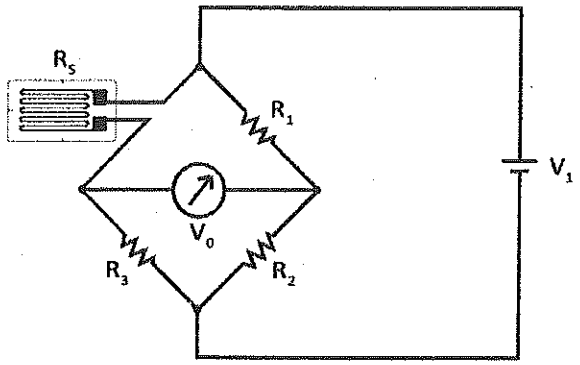
$PV = \text{Constant}.$

Calculate the work done on the gas in one cycle of operation. (45 Marks)

Q6. **(a)** **(i)** Describe, with the aid of a diagram, the structure of a pressure transducer based on variable resistance. (05 Marks)

(ii) Describe the changes which occur when pressure is applied to such a transducer and explain how the out-put is related to the applied pressure. (05 Marks)

(b) A strain gauge transducer uses a Wheatstone bridge circuit to measure strain resistance as shown in figure below. The maximum permissible instrument gauge current is 0.25 A.



At balance condition $R_1 = R_2 = R_3 = 120\ \Omega$. Assuming the instrument has finite input impedance,

(i) Determine the maximum permissible bridge excitation voltage. (10 Marks)

(ii) Verify that the voltage output is given by,

$$V = V_0 \left(\frac{R_S}{R_S + R_3} - \frac{R_1}{R_1 + R_2} \right)$$ (10 Marks)

(iii) When no strain is applied, show that the strain gauge resistance is given by,

$$R_S = \frac{R_1 R_3}{R_2}$$

Hence, determine the normal resistance of the stain gauge. (10 Marks)

(iv) If the input voltage applied is half of that calculated in part (b), (i) and the output voltage at a full strain of 10 mm is 50 mv. Determine the required sensitivity of the stain gauge.

(10 Marks)

END