

THE OPEN UNIVERSITY OF SRI LANKA

BACHELOR OF SCIENCE DEGREE PROGRAMME-LEVEL 04

FINAL EXAMINATION 2025/2026

BIOPHYSICS-PHU5304

Duration: TWO HOURS (2 hrs)



0050

Date: 30th November 2025

Time: 1.30 pm -3.30 pm

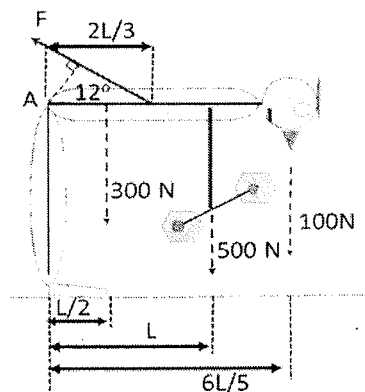
Answer Four (4) questions only

Stefan-Boltzmann constant (σ) = $5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$, Rydberg constant (R_H) = $1.09737 \times 10^7 \text{ m}^{-1}$, speed of light (c) = $3.0 \times 10^8 \text{ m s}^{-1}$, Planck's constant (h) = $6.63 \times 10^{-34} \text{ J s}$, Threshold intensity of hearing (I_0) = $1 \times 10^{-12} \text{ W m}^{-2}$ and Gravitational acceleration (g) = 9.8 m s^{-2} .

1.(a) An individual's total energy intake in a single day is 2800 kcal and spends 18.0 hours sitting in a relaxed state and 6.0 hours sleeping. Assuming that energy expenditure rates are $1.7 \text{ kcal} \cdot \text{min}^{-1}$ while sitting and $1.2 \text{ kcal} \cdot \text{min}^{-1}$ during sleep, and 1 kg of body fat corresponds to approximately 7700 kcal, calculate the mass of body fat (in grams) that would be gained during this day. (25 marks)

(b). A person has an average daily energy requirement of 12,000 kJ (3,000 kcal), but consumes 13,000 kJ per day. This excess energy intake would lead to gradual weight gain unless compensated by physical activity. Assuming that the person expends energy at a rate of 400 W while cycling at a moderate speed, calculate the duration of cycling (in minutes per day) required to burn off the additional 1,000 kJ of energy. (25 marks)

(c). The diagram below represents a simplified biomechanical model of a human body lifting 500 N load with the hands. The weight of the body (excluding the head) is 300 N, and the weight of the head is 100 N. Assuming the system is in static and rotational equilibrium, determine the magnitude of the force (F) acting on the back of the body that is required to maintain this posture.



(25 marks)

(d). A 25-year-old individual reports experiencing blurred vision for distant objects while being able to read nearby text clearly.

(i) Identify the optical defect of the eye and explain the reason for this condition., describe how this condition can be corrected.

(ii) Given that the person's far point is 1.5 m, calculate the focal length and the optical power of the corrective lens required to restore clear vision for distant objects. (25 marks)

2. (a). An ultrasound machine emits a sound wave with an intensity of, $2.0 \times 10^{-4} \text{ W m}^{-2}$ into a tissue. Calculate the intensity level of this ultrasound wave in decibels (dB), given that the reference (threshold) intensity is $1.0 \times 10^{-12} \text{ W m}^{-2}$. (25 marks)

(b). An ultrasound wave propagates through soft tissue having a density $\rho_1 = 1000 \text{ kg m}^{-3}$ and a sound velocity $v_1 = 1540 \text{ m s}^{-1}$. The wave encounters a boundary with bone, which has a density $\rho_2 = 1900 \text{ kg m}^{-3}$ and a sound velocity $v_2 = 4080 \text{ m s}^{-1}$. Calculate the reflection coefficient at the soft tissue–bone interface. (25 marks)

(c). Describe the mechanisms of heat exchange between the human body and its external environment. Discuss the physiological significance of this process in maintaining thermal balance and ensuring human survival. (25 marks)

(d). A human body with a surface temperature of 37°C radiates heat to the surrounding environment at 27°C . If the surface area of the body is 1.8 m^2 and the emissivity of the skin is 0.97, calculate the rate of heat loss by thermal radiation. (25 marks)

3.(a). A proton is moving with a velocity of $2.0 \times 10^6\text{ m s}^{-1}$.

(i) Using the de Broglie hypothesis, explain why heavier particles have significantly shorter wavelengths than lighter particle (electrons) moving at the same speed.

(ii) Calculate the de Broglie wavelength of the proton, given that its mass is $1.67 \times 10^{-27}\text{ kg}$.

(25 marks)

(b). An electron in a hydrogen atom moves in a circular orbit around the nucleus.

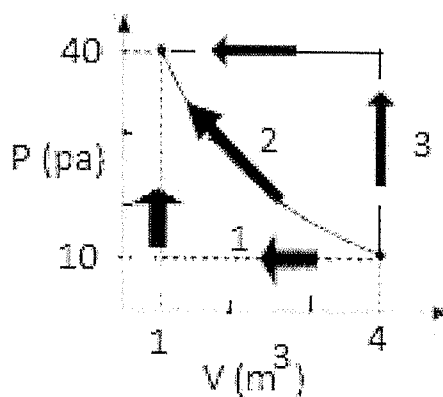
(i) Explain the main postulates of Bohr's atomic theory and how they account for the stability of electrons in the atom.

(ii) If the electron occupies the $n = 3$ orbit, calculate the radius of the orbit and the energy of the electron. (Use the relations, $r_n = n^2 a_0$ and $E_n = -13.6/n^2\text{ (eV)}$) (25 marks)

(c). Explain the concept of an isothermal process in thermodynamics. Discuss how the internal energy of the system changes and how work is performed during such a process. Provide a practical example illustrating an isothermal process. (25 marks)

(d). A sample of gas at 23°C containing 0.11 mol is compressed from a volume of 4.00 m^3 to 1.00 m^3 , during which its pressure increases from 10 Pa to 40 Pa. The figure below illustrates

three possible paths (Path 1, Path 2, and Path 3) connecting these two states, where Path 2 represents an isothermal process. Using the ideal gas constant $R = 8.314\text{ J mol}^{-1}\text{K}^{-1}$, determine the work done along the three different paths. What is the change in internal energy of the system in passing along path 2 ?



(25 marks)

4. (a). Define sedimentation of particles and explain the principle underlying this process. 0050

(25 marks)

(b). Define the terminal velocity of a particle moving through a viscous medium. Discuss the factors that influence terminal velocity and explain its significance in sedimentation process.

(25 marks)

(c). In a biochemical experiment, spherical virus particles of radius 5×10^{-8} m are allowed to settle under gravity in water at 25 °C. The dynamic viscosity of water at this temperature is 8.9×10^{-4} N s m⁻², and the densities of the virus particles and water are 1.25×10^3 kg m⁻³ and 1.00×10^3 kg m⁻³ respectively. Calculate the terminal velocity of the virus particles in water.

(25 marks)

(d). A biochemist studies the sedimentation of spherical DNA fragments with a radius of $r = 6 \times 10^{-8}$ m in a solution viscosity is 1×10^{-3} N s m⁻². The density of the fragments and the fluid are 1.4×10^3 kg m⁻³ and 1.0×10^3 kg m⁻³ respectively. Calculate the sedimentation coefficient of the DNA fragments.

(25 marks)

5. (a). Define interference of light and explain the conditions required to observe a clear and stable interference pattern, as in Young's double-slit experiment.

(25 marks)

(b). Define the coherence of light and explain its significance in producing interference patterns.

(25 marks)

(c). In a Young's double-slit experiment, the fringe separation on the screen is measured to be 0.65 mm. The distance between the slits and the screen is 0.80 m, and the wavelength of the light used is 5.9×10^{-7} m. Calculate the separation between the slits.

(25 marks)

(d). In a Young's double-slit experiment, interference fringes are produced using light of wavelength $\lambda=600$ nm. A thin film of thickness $t=3.6\times 10^{-3}$ cm is placed over one of the slits, causing the fringe pattern to shift by a distance equal to 30 fringe widths. Calculate the refractive index of the material of the film. (25 marks)

6.(a). Explain how the concepts of lattice, basis, and unit cell collectively define the crystal structure of a solid. (25 marks)

(b). A simple cubic crystal has a lattice constant $a=4.00$ Å. Using (Cu $K\alpha$) radiation with a wavelength $\lambda=1.54$ Å, a diffraction peak is observed at $2\theta=36.7^\circ$. Determine the Miller indices (hkl) of the planes responsible for this peak and explain the reasoning behind your choice. (25 marks)

(c). A simple cubic crystal gives a first-order peak at $2\theta=44.7^\circ$ (Cu $K\alpha$, $\lambda=1.54$ Å) that is indexed as the (1 1 0) planes. Find the interplanar spacing d_{110} and the cubic lattice constant a . (25 marks)

(d). Illustrate the crystal planes represented by (111), (100), (110), and (101). (25 marks)

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