注意：考試開始鈴響前，不得翻閱試題，並不得書寫、畫記、作答。

國立清華大學 115 學年度碩士班考試入學試題

系所班組別：生命科學暨醫學院
丙組(計算生物與人工智慧組)

科目代碼：0602

考試科目：近代物理

—作答注意事項—

1. 請核對答案卷（卡）上之准考證號、科目名稱是否正確。
2. 考試開始後，請於作答前先翻閱整份試題，是否有污損或試題印刷不清，得舉手請監試人員處理，但不得要求解釋題意。
3. 考生限在答案卷上標記「由此開始作答」區內作答，且不可書寫姓名、准考證號或與作答無關之其他文字或符號。
4. 答案卷用盡不得要求加頁。
5. 答案卷可用任何書寫工具作答，惟為方便閱卷辨識，請儘量使用藍色或黑色書寫；答案卡限用 2B 鉛筆畫記；如畫記不清（含未依範例畫記）致光學閱讀機無法辨識答案者，其後果一律由考生自行負責。
6. 提早交卷者不可攜出試題，請將試題連同答案卷(卡)交予監考人員，攜出將以違規論處。當節考試結束後試題將置於講台，可自行取回，本試場不負保管責任。
7. 其他應考規則、違規處理及扣分方式，請自行詳閱准考證明上「**國立清華大學試場規則及違規處理辦法**」，無法因本試題封面作答注意事項中未列明而稱未知悉。

國立清華大學 115 學年度碩士班考試入學試題

系所班組別：生命科學暨醫學院丙組

考試科目（代碼）：近代物理(0602)

(可用中文或英文作答)

1. **The James Webb Space Telescope (JWST), launched in late 2021, is the most powerful infrared space telescope ever built. JWST was designed primarily to detect infrared radiation rather than visible light to observe the earliest stars and galaxies formed in the universe.**
   The relativistic Doppler formula for the observed frequency f' is given by:

$$f' = f\sqrt{\frac{1-v/c}{1+v/c}}$$

   Using this formula and the relationship between frequency (f), wavelength (λ), and the speed of light (c), show how the observed wavelength λ' changes relative to the emitted wavelength λ as the recession velocity v of a galaxy increases. Based on this, why is an infrared detector essential for JWST to "see" further back in time? (10%)

2. **The concept of Wave-Particle Duality is a cornerstone of modern physics, fundamentally changing our understanding of matter at the microscopic level.**

   A. (15%) In 1924, Louis de Broglie proposed that particles, such as electrons, possess wave-like properties with a wavelength $\lambda = h/p$, where h is Planck's constant and p is momentum. Explain why this wave nature is not observable for macroscopic objects in our daily lives (e.g., a moving baseball or a walking person), yet it becomes the dominant factor in determining the resolution of an electron microscope.

   B. (20%) Consider a "Double-Slit Experiment" performed with a beam of electrons.

   1. If the electrons are sent through the slits one by one, an interference pattern still emerges on the detector over time. What does this suggest about the "nature" of a single electron?

2. According to the **Heisenberg Uncertainty Principle**, if we place a detector at the slits to determine exactly which slit each electron passes through, the interference pattern disappears. Provide a conceptual explanation for why the act of "observation" destroys the wave-like interference.

3. **The 2024 Nobel Prize in Physics was awarded to John Hopfield for his work on artificial neural networks. His "Hopfield Network" model was inspired by the collective behavior of physical systems known as "Spin Glasses" in quantum and statistical mechanics.**

A. (15%) The Physics of Spin Glasses
In a spin glass system, the total energy E is determined by the configuration of magnetic spins ($s_i = \pm 1$) and their mutual interactions, expressed by the formula:

$$E = -\sum_{i<j} J_{ij} s_i s_j$$

where J_{ij} represents the coupling constant between spin i and spin j. Please explain how the system evolves to reach a local minimum.

B. (10%) Mapping Physics to Neural Networks
Hopfield realized that a neuron's state (firing or silent) could be mapped to a spin's state (up or down). In a biological brain, neurons communicate via synapses that can either be excitatory (stimulating the connected neuron to fire) or inhibitory (preventing the connected neuron from firing). Using the energy formula provided in Part A, how would you represent an excitatory relationship between two neurons i and j using the term J_{ij}? How would you represent an inhibitory relationship?

4. **The theory of blackbody radiation played an essential role in the development of modern physics. While classical physics failed to explain the energy distribution of radiation, Max Planck's proposal of discretized energy levels solved the problem.**

   A. (10%) What is a "blackbody"? How does the peak wavelength of the radiation spectrum change with the temperature?

   B. (10%) Rayleigh-Jeans Law, based on classical oscillators, predicts the energy density as $\rho_\lambda = \frac{8\pi kT}{\lambda^4}$. Why is this equation catastrophic?

   C. (10%) How does Planck's assumption of $E = nhf$ (where n is an integer) prevented the energy density from reaching infinity at very short wavelengths?