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 109 學年度碩士班考試入學試題

系所班組別：生命科學院
丙組

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. 作答中如有發現試題印刷不清，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. 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 109 學年度碩士班考試入學試題

系所班組別：生命科學院丙組

考試科目（代碼）：近代物理(0602)

1. (20%) The theory of blackbody radiation plays an essential role in the development of modern physics. Several theories were proposed to explain the experimentally measured energy distribution curve. Rayleigh-Jeans Law was developed based on the assumption of continuous distribution of classical oscillator energies and gives $\rho(\lambda) = 8\pi kT/\lambda^4$. However, this expression only correctly describes the observed curve at large λ. On the other hand, Planck's Law was developed based on discretized oscillator energies and he reached a different formula, $\rho(\lambda) = \frac{8\pi hc}{\lambda^5}\left(\frac{1}{e^{hc/\lambda kT}-1}\right)$. His formula accurately reproduces the observed curve in the whole range of λ. λ is wavelength, h is Planck constant, c is the speed of light, k is Boltzmann constant and T is temperature. Please answer the following questions: **A.** What is blackbody radiation? Please provide a concise description. **B.** Show that at the large λ limit, Planck's Law agrees with Rayleigh-Jeans Law.

2. (20%) In 1925, two physicists Clinton Davisson and Lester Germer observed a diffraction pattern formed by an electron beam scattered by the surface of a crystal of nickel metal. Answer the following questions: **A.** Explain why this discovery challenged the classical view of particles. **B.** Using the Louis de Broglie's theory $\lambda = h/p$, explain why this phenomenon could only be observed at the microscopic, i.e. atomic or molecular, scales but not in our everyday life.

3. (20%) In classical mechanics, the energy E of a particle of mass m making rotational motion on a 2D plane is $E = \frac{J^2}{2mr^2}$, where r is the radius of rotation, $J = pr$ is the angular momentum of the particle. Now, use de Broglie's theory stated above (Question 2) and the cyclic boundary conditions to derive that, in quantum mechanics, **A.** the acceptable wavelengths of the particle is $\lambda = \frac{2\pi r}{n}$, where $n = 0, 1, 2, \ldots$ and **B.** the permitted energies are $E_n = \frac{n^2\hbar^2}{2mr^2}$.

4. (22%) Electron microscopy (EM) uses an electron beam as a source of illumination. EM breaks the limitation of resolution in the conventional light microscopy and therefore makes a profound impact on research in biology. Answer the following questions: **A.** Explain why there is a resolution limitation in light microscopy. **B.** Explain why EM provides a much higher resolution?

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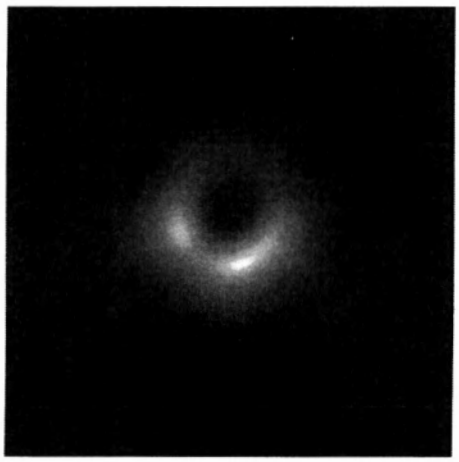
5. (18%) The first image (see below) of a black hole was released on 10 April, 2019 by the Event Horizon Telescope project, in which Taiwanese researchers actively participated in. The modern theory of black holes was developed by Karl Schwarzschild as a solution to Einstein's field equations in his theory of general relativity. Please answer the following questions: **A.** what are the key differences between Einstein's special and general theories of relativity **B.** What is a black hole. **C.** Why do we see a bright "ring" in the black hole image below?



The image of a black hole in the M87 galaxy