國立中山大學114學年度
碩士班考試入學招生考試試題

科目名稱：近代物理【物理系碩士班】

—作答注意事項—

考試時間：100分鐘

- **考試開始鈴響前不得翻閱試題，並不得書寫、劃記、作答。**請先檢查答案卷（卡）之應考證號碼、桌角號碼、應試科目是否正確，如有不同立即請監試人員處理。
- **答案卷限用藍、黑色筆(含鉛筆)書寫、繪圖或標示**，可攜帶橡皮擦、無色透明無文字墊板、尺規、修正液（帶）、手錶(未附計算器者)。每人每節限使用一份答案卷，請衡酌作答。
- 答案卡請以2B鉛筆劃記，不可使用修正液（帶）塗改，未使用2B鉛筆、劃記太輕或污損致光學閱讀機無法辨識答案者，後果由考生自負。
- 答案卷（卡）應保持清潔完整，不得折疊、破壞或塗改應考證號碼及條碼，亦不得書寫考生姓名、應考證號碼或與答案無關之任何文字或符號。
- 可否使用計算機請依試題資訊內標註為準，如「可以」使用，廠牌、功能不拘，唯不得攜帶書籍、紙張（應考證不得做計算紙書寫）、具有通訊、記憶、傳輸或收發等功能之相關電子產品或其他有礙試場安寧、考試公平之各類器材入場。
- **試題及答案卷（卡）請務必繳回，未繳回者該科成績以零分計算。**
- **試題採雙面列印，考生應注意試題頁數確實作答。**
- **違規者依本校招生考試試場規則及違規處理辦法處理。**

國立中山大學 114 學年度碩士班考試入學招生考試試題

科目名稱：近代物理【物理系碩士班】 **題號：423001**

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）(選擇題)

Single-choice questions: (20 questions in total, 5 points each)

In the following questions, $\hbar = 1.1 \times 10^{-34}$ J · s represents the reduced Planck constant, $c = 3.0 \times 10^{8}$ m · s^{-1} denotes the speed of light, and $e = 1.6 \times 10^{-19}$ C is the elementary charge.

1. What is the energy carried by a photon with a wavelength of 650 nm?
   A. 5.1×10^{-20} eV
   B. 3.1×10^{-1} eV
   C. 3.2×10^{-19} eV
   D. 2.0 eV
   E. 6.6×10^{-9} eV

2. Which of the following quantities is invariant under Lorentz transformation?
   A. Length
   B. Time
   C. Energy
   D. Momentum
   E. Mass

3. Two rockets approach Earth from opposite directions at a high speed v. What is the speed of a rocket as measured by the observer on the other rocket?
   A. $\frac{v}{\sqrt{2}}$
   B. $2v$
   C. $\frac{2v}{\sqrt{1-\frac{v^2}{c^2}}}$
   D. $\frac{2v}{1+\frac{v^2}{c^2}}$
   E. $v\sqrt{1-\frac{v^2}{c^2}}$

4. What is the expectation value of momentum squared $\langle p^2 \rangle$ for a particle described by the normalized wavefunction $\Psi(x,t) = \left(\frac{a}{\pi}\right)^{\frac{1}{4}} e^{\frac{-iEt}{\hbar}} e^{-\frac{ax^2}{2}}$, where E is a real constant and $a > 0$, in the position space? (Hint: $\int_{-\infty}^{\infty} dx\, e^{-\alpha x^2} = \sqrt{\frac{\pi}{\alpha}}$ for $\alpha > 0$)
   A. $\frac{a\hbar^2}{2}$
   B. $i\hbar$
   C. $i\frac{\hbar}{a}$
   D. $\frac{\sqrt{a\pi}\hbar^2}{2}$
   E. $\frac{\pi\hbar^2}{2a}$

5. What is the energy carried by a photon with momentum $\vec{p}$?
   A. $\hbar|\vec{p}|$
   B. $\hbar|\vec{p}|^2$
   C. $|\vec{p}|^2 c$
   D. $\hbar c|\vec{p}|$
   E. $\frac{|\vec{p}|^2}{2m}$

6. Which of the following distributions describes the statistical behavior of an ensemble of spin-1/2 identical particles at a low-temperature T? (k_B is Boltzmann's constant and E_F is Fermi energy.)
   A. $f(E) = \frac{1}{\exp\left(\frac{E-E_F}{k_B T}\right)-1}$
   B. $f(E) = \frac{1}{\exp\left(\frac{E-E_F}{k_B T}\right)+1}$
   C. $f(E) = \frac{1}{\exp\left(\frac{-E+E_F}{k_B T}\right)-1}$
   D. $f(E) = \exp\left(\frac{-E+E_F}{k_B T}\right)$
   E. $f(E) = \frac{1}{\exp\left(\frac{-E+E_F}{k_B T}\right)+1}$

7. Which of the following statements about superconductivity is correct?
   A. All materials become superconducting below 30 K
   B. The resistance of a superconductor is zero
   C. Superconductivity violates the first law of thermodynamics
   D. Superconductivity violates the second law of thermodynamics
   E. All the above are incorrect

8. Which of the following pairs of Nobel laureates and their major reasons for being awarded is incorrect?
   A. Niels Bohr --- atomic model
   B. Louis de Broglie --- wave-particle duality
   C. Albert Einstein --- quantum entanglement
   D. John Bardeen --- superconductivity
   E. Richard Feynman --- quantum electrodynamics

9. Which of the following discoveries did not contribute to the development of quantum mechanics?
   A. Hydrogen spectrum
   B. General relativity
   C. Energy quanta
   D. Wave-particle duality
   E. All the above did

10. Which of the following is not a property of a laser?
    A. High monochromaticity
    B. High coherence
    C. High directivity
    D. High propagation speed
    E. High intensity

11. If a quantum particle sees a potential shown in Figure 1, which of the following probability densities is most likely to be the ground state probability density?

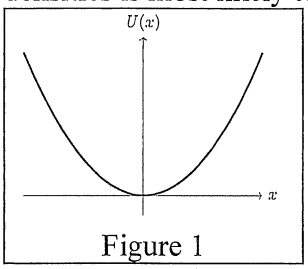
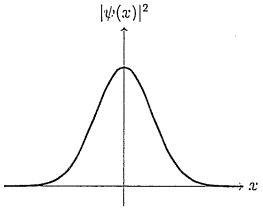


Figure 1

A.


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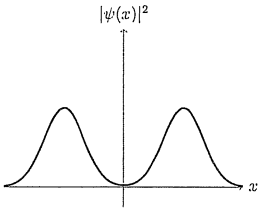

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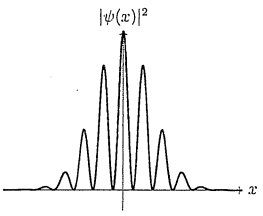
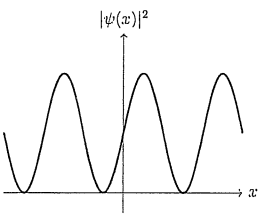
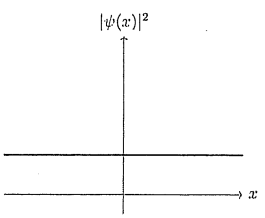


D.


E.


12. Given a particle with energy E in a finite potential $U(x)$, as shown in Figure 2, what is the form of the particle's wavefunction in Region III?
    A. $ce^{\kappa x}$, where $\kappa \in \mathbb{R}$
    B. cx^2
    C. $c_+e^{\kappa x} + c_-e^{-\kappa x}$, where $\kappa \in \mathbb{R}$
    D. $ce^{-\kappa x}$, where $\kappa \in \mathbb{R}$
    E. $c_+ \sin(kx) + c_- \cos(kx)$, where $k \in \mathbb{R}$

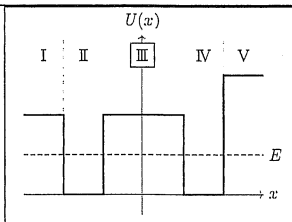


Figure 2

13. A photon is directed toward a stationary particle of mass m with momentum $\vec{p} = p\hat{e}_x$. After the collision, the photon reflects along the same path, i.e., $\overrightarrow{p'} = -p'\hat{e}_x$. What is p'?
    A. p
    B. $\frac{p}{\sqrt{1-\frac{p^2}{m^2c^2}}}$
    C. $\frac{p}{1+\frac{2p}{mc}}$
    D. $p - mc$
    E. 0

14. Which of the following masses is the smallest? (Hint: A neutron can decay into a proton, an electron, and an antineutrino.)
    A. The mass of a Helium-4 atom (a stable atom consisting of two protons, two neutrons, and two electrons)
    B. The total mass of an alpha particle (a helium ion consisting of two protons and two neutrons) and two electrons
    C. The total mass of two protons, two neutrons, and two electrons
    D. The total mass of one proton, three neutrons, and one electron
    E. All the above are the same

15. What is the magnitude of the spin angular momentum of a spin-1/2 particle?
    A. $s = \frac{\hbar}{2}$
    B. $s = \frac{\hbar}{4}$
    C. $s = \frac{\hbar}{\sqrt{2}}$
    D. $s = \frac{\sqrt{3}\hbar}{2}$
    E. $s = \hbar$

16. Alice and Bob are making measurements on a two-qubit system described by the quantum state $|\psi\rangle = 0.6\,|1\rangle_A \otimes |0\rangle_B + 0.8\,|0\rangle_A \otimes |1\rangle_B$, where $|m\rangle_A$ and $|n\rangle_B$ are Alice's and Bob's measurement eigenstates, with eigenvalues m and n, respectively. If Alice makes the measurement first and the outcome is 1, what possible outcomes can Bob obtain, and what are the probabilities?
    A. Both 0 and 1 with probability 36% and 64%, respectively
    B. Both 0 and 1 with probability 64% and 36%, respectively
    C. Both 0 and 1 with probability 50% and 50%, respectively
    D. Only 1 (i.e., with probability 100%)
    E. Only 0 (i.e., with probability 100%)

17. Which of the following forces primarily underlies the mechanism of nuclear power?
    A. Gravitational force
    B. Electric force
    C. Magnetic force
    D. Weak force
    E. Strong force

18. Let the wave function of two electrons at t = 0 be $\Psi(x_1, s_1; x_2, s_2)$, where x_1 and x_2 are the positions, and s_1 and s_2 are the spins of the electrons. Given that the wave function can be factorized into spatial and spin parts, namely, $\Psi(x_1, s_1; x_2, s_2) = \psi_a(x_1, x_2)\chi_a(s_1, s_2) + \psi_b(x_1, x_2)\chi_b(s_1, s_2)$, where $\chi_a(s_2, s_1) = -\chi_a(s_1, s_2)$ and $\chi_b(s_2, s_1) = \chi_b(s_1, s_2)$, which of the following statements is incorrect?
    A. $\psi_a(x_1, x_2) = -\psi_a(x_2, x_1)$
    B. $\psi_b(x, x) = 0$
    C. $\Psi(x_2, s_2; x_1, s_1) = -\Psi(x_1, s_1; x_2, s_2)$
    D. $\psi_a(x_2, x_1)\psi_b(x_2, x_1) = -\psi_a(x_1, x_2)\psi_b(x_1, x_2)$
    E. All the above are correct

19. If a muon with a lifetime of 2.0 μs is traveling at a speed of $0.60c$ relative to Earth, how far does it travel during its lifetime as observed by a stationary observer on Earth? (Gravitational effects can be neglected.)
    A. 2.9×10^2 m
    B. 3.6×10^2 m
    C. 4.5×10^2 m
    D. 6.0×10^2 m
    E. 9.0×10^3 m

20. Given a three-dimensional wave function $\Psi(x, y, z, t) = A \exp\left(i\frac{Et}{\hbar} - \frac{\sqrt{x^2+y^2+z^2}}{a}\right)$, where E and a are positive constants with units of energy and length, respectively, which of the following values of A ensures the wave function is normalized?
    A. $\frac{1}{8a^3\pi}$
    B. $\sqrt{\frac{1}{a^3\sqrt{\pi}}}$
    C. $\frac{1}{a^3\pi}$
    D. $\sqrt{\frac{1}{8a^3\pi}}$
    E. $\sqrt{\frac{1}{a^3\pi}}$