國立成功大學
111學年度碩士班招生考試試題

編　號：39

系　所：物理學系

科　目：近代物理學

日　期：0220

節　次：第 3 節

備　註：不可使用計算機

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第1頁，共3頁

※ 考生請注意：本試題不可使用計算機。請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

一、 單選題：每題 5 分，16 題，共 80 分

$h = 6.63 \times 10^{-34}\ J \cdot s$,　$c = 3.00 \times 10^{8}\ m/s$,　$e = 1.60 \times 10^{-19}$ c

1. The hypothesis that electron possesses spin is qualitatively significant for the explanation of all of following topics EXCEPT the
(A) structure of the periodic table (B) specific heat of metals (C) anomalous Zeeman effect (D) deflection of a moving electron by a uniform magnetic field (E) fine structure of atomic spectra

2. A nickel target (Z=28) is bombarded with fast electrons. The minimum electron kinetic energy needed to produce x-ray in the K series is most nearly
(A) 10 eV (B) 100 eV (C) 1000 eV (D) 10,000eV (E) 100,000 eV

3. The configuration of the potassium atom in its ground state is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$. Which is the following statements about potassium is true?
(A) Its n=3 shell is completely filled (B) Its 4s subshell is completely filled (C) Its least tightly bound electron has ℓ=4 (D) Its atomic number is 17 (E) Its electron charge distribution is spherically symmetrical

4. Eigenfunctions for a rigid dumbbell rotating about its center have a ϕ dependence of the form $\psi(\phi) = Ae^{im\phi}$, where m is a quantum number and A is a constant. Which of the following values of A will properly normalize the eigenfunction?
(A) $\sqrt{2\pi}$ (B) 2π (C) $(2\pi)^2$ (D) $\frac{1}{\sqrt{2\pi}}$ (E) $\frac{1}{2\pi}$

5. The characteristic distance at which quantum gravitational effects are significant, the Planck length, can be determined from a suitable combination of the physical constants G, $\hbar$, and c. Which of the following correctly gives the Planck length?
(A) $G\hbar c$ (B) $G\hbar^2c^3$ (C) $G^2\hbar c$ (D) $\sqrt{G}\hbar^2 c$ (E) $\sqrt{G\hbar/c^3}$

6. Light of wavelength 500 nanometers is incident on sodium, with work function 2.28 electron volts. What is the maximum kinetic energy of the ejected photoelectrons?
(A) 0.03 eV (B) 0.2 eV (C) 0.6 eV (D) 1.3 eV (E) 2.0 eV

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7. The solution to the Schrödinger equation for a particle bound in a one-dimensional, infinitely deep potential well, indexed by quantum number n, indicates that in the middle of well the probability density vanishes for
(A) the ground state (n=1) only (B) states of even n (n=2,4, ...) (C) states of odd n (n=1,3,...) (D) all states (n=1,2,3,...) (E) all states except the ground state

8. At a given instant of time, a rigid rotator is in the state $\psi(\theta,\phi)=\sqrt{3/4\pi}\sin\theta\cos\phi$, where θ is the polar angle relative to the z-axis and ϕ is the azimuthal angle. Measurement will find which of the following possible values of the z-component of the angular momentum L_z?
(A) 0 (B) $\hbar/2,-\hbar/2$ (C) $\hbar,-\hbar$ (D) $2\hbar,-2\hbar$ (E) $\hbar,0,-\hbar$

9. Positronium is the bound state of an electron and positron. Consider only the states of zero orbital angular momentum ($\ell=0$). The most probable decay product of any such state of positronium with spin zero (singlet) is
(A) 0 photon (B) 1 photon (C) 2 photons (D) 3 photons (E) 4 photons

10. The state $\psi=\frac{1}{\sqrt{6}}\psi_{-1}+\frac{1}{\sqrt{2}}\psi_1+\frac{1}{\sqrt{3}}\psi_2$ is a linear combination of three orthonormal eigenstates of the operator $\hat{O}$ corresponding to eigenvalues -1, 1, and 2. What is the expectation value of $\hat{O}$ for this state?
(A) 2/3 (B) $\sqrt{7/6}$ (C) 1 (D) 4/3 (E) $(\sqrt{3}+2\sqrt{2}-1)/\sqrt{6}$

11. The wave function of a particle is $e^{i(kx-\omega t)}$, where x is a distance, t is time, and k and ω are positive real numbers. The x-component of the momentum of the particle is
(A) 0 (B) $\hbar\omega$ (C) $\hbar k$ (D) $\hbar\omega/c$ (E) $\hbar k/\omega$

12. The longest wavelength x-ray that can undergo Bragg diffraction in a crystal for a given family of planes of spacing d is
(A) d/4 (B) d/2 (C) d (D) 2d (E) 4d

13. If the absolute temperature of a blackbody is increased by a factor of 3, the energy radiated per second per unit area does which of the following?
(A) Decreased by a factor of 81 (B) Decreased by a factor of 9 (C) Increased by a factor of 9 (D) Increased by a factor of 27 (E) Increased by a factor of 81

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14. Given that the binding energy of the hydrogen atom ground state is $E_0 = 13.6$ eV, the binding energy of the n=2 state of positronium (positron-electron system) is
(A) $8E_0$ (B) $4E_0$ (C) E_0 (D) $E_0/4$ (E) $E_0/8$

15. A system is known to be in the normalized state described by the wave function $\psi(\theta,\phi) = \frac{1}{\sqrt{30}}(5Y_4^3 + Y_6^3 - 2Y_6^0)$, where the $Y_\ell^m(\theta,\phi)$ are spherical harmonics. The probability of finding the system in a state with azimuthal orbital quantum number $\mathrm{m} = 3$ is
(A) 0 (B) 1/15 (C) 1/6 (D) 1/3 (E) 13/15

16. If a freely moving electron is localized in a space to within Δx_0 of x_0, its wave function can be described by a wave packet $\psi(\mathrm{x,t}) = \int_{-\infty}^{\infty} e^{i(kx-\omega t)}\, f(k)dk$, where $f(k)$ is peaked around a central value k_0. Which of the of the following is most nearly the width of the peak in k ?
(A) $\Delta\mathrm{k} = 1/x_0$ (B) $\Delta\mathrm{k} = 1/\Delta x_0$ (C) $\Delta\mathrm{k} = \Delta x_0/x_0^2$ (D) $\Delta\mathrm{k} = k_0(\Delta x_0/x_0)$ (E) $\Delta\mathrm{k} = \sqrt{k_0^2 + 1/x_0^2}$

二、計算題：20 分

1. Consider the Bohr model for the hydrogen atom. Show that energy of this system is quantized using (a) the total conserved energy of the system, (b) centripetal force of the system, and (c) Bohr's postulate (the condition for quantizing angular momentum). Please express your result in terms of some constants such as the speed of light, the reduced mass and the fine structure constant, $\alpha \equiv \frac{e^2}{4\pi\epsilon_0\hbar c}$.