國立成功大學

110學年度碩士班招生考試試題

編　號：40

系　所：光電科學與工程學系

科　目：近代物理

日　期：0203

節　次：第 1 節

備　註：不可使用計算機

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※ 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。

A lot of useful physics parameters are shown as below.

Speed of light	$c = 2.998 \times 10^{8}\ \mathrm{m/s}$
Electronic charge	$e = 1.602 \times 10^{-19}\ \mathrm{C}$
Boltzmann constant	$k = 1.381 \times 10^{-23}\ \mathrm{J/K} = 8.617 \times 10^{-5}\ \mathrm{eV/K}$
Planck's constant	$h = 6.626 \times 10^{-34}\ \mathrm{J \cdot s} = 4.136 \times 10^{-15}\ \mathrm{eV \cdot s}$
Avogadro's constant	$N_A = 6.022 \times 10^{23}\ \mathrm{mole}^{-1}$
Electron mass	$m_e = 5.49 \times 10^{-4}\ \mathrm{u} = 0.511\ \mathrm{MeV}/c^2$
Proton mass	$m_p = 1.007276\ \mathrm{u} = 938.3\ \mathrm{MeV}/c^2$
Neutron mass	$m_n = 1.008665\ \mathrm{u} = 939.6\ \mathrm{MeV}/c^2$
Bohr radius	$a_0 = 0.0529\ \mathrm{nm}$
Hydrogen ionization energy	13.6 eV
Thermal energy	$kT = 0.02525\ \mathrm{eV} \cong \frac{1}{40}\ \mathrm{eV}\ (T = 293\ \mathrm{K})$
$\hbar c = 1240$ eV·nm (MeV·fm)	$\hbar c = 197$ eV·nm (MeV·fm)
$\frac{e^2}{4\pi\varepsilon_0} = 1.440$ eV·nm (MeV·fm)	$1\ \mathrm{u} = 931.5\ \mathrm{MeV}/c^2$
	$1\ \mathrm{eV} = 1.602 \times 10^{-19}\ \mathrm{J}$

(Total 100%)

1. The work function for gold metal is 5.1 eV.
   (1) What is the cutoff wavelength (in nm) for gold? (5%)
   (2) What is the maximum kinetic energy of the electron when gold is illuminated with 198 nm light? (5%)
   (3) What is the stopping potential in (2). (5%)

2. The resolution of optical microscope is on the order of λ, which is the wavelength of the incident light. Please estimate the resolution of the electron microscope if the accelerating voltage is 200 kV (without relativistic effect). (10%)

3. The tunneling is a quantum effect. Scanning tunneling microscope is based on this effect. Assume tunneling current of a STM is

$$I \propto \exp\left(-2s\sqrt{\frac{2m}{\hbar^2}\left(\langle\phi\rangle - \frac{e|V|}{2}\right)}\right) \text{ and } \langle\phi\rangle - \frac{e|V|}{2} = 5\ \mathrm{eV}.$$

   What is the ratio of tunneling current if the distance S is moved from 1 nm to 1.1 nm. (10%)

4. Please solve the problem of a particle in a one-dimensional box. The potential energy function is defined as

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$$V(x)=\begin{cases}0 & for\ -\frac{a}{2}<x<\frac{a}{2}\\ \infty & for\ |x|\geqq\frac{a}{2}\end{cases}$$

(1) Please show the eigenfunctions (10%)

(2) Please show the eigen energy (5%)

5. A laser beam is aimed at the Moon from a distance 3.84×10^{8} m away. The angular spread of the beam is given by the diffraction formula (Rayleigh's criterion), $\sin\theta=1.22\lambda/D$, where D is the diameter of the laser tube or rod. Calculate the size of the beam on the Moon for $D=10$ cm and $\lambda=600$ nm. (5%)

6. (a) Stars typically emit the red light of atomic hydrogen with wavelength 656.3 nm. Compute the wavelength of that light observed at Earth from stars receding directly from us with relative speed $v=10^{-1}c$. (5%)
   (b) The rest energy of a proton is about 938 MeV. If its kinetic energy is also 938 MeV, find its momentum and speed. (5%)

7. (a) Consider a gas of electrons (fermions) and a gas of photons (bosons). Which has more states available at $T=1$ K? Explain why. (5%)
   (b) The Fermi energy for gold is 5.51 eV at $T=293$ K. Find the average energy of a conduction electron at that temperature. (5%)

8. Draw for a *3d* state all the possible orientations of the angular momentum vector $\vec{L}$. What is $L_x^2+L_y^2$ for the $m_l=-1$ component? (10%)

9. A hydrogen atom in an excited *5f* state is in a magnetic field of 3.00 T. How many energy states can the electron have in the *5f* subshell? (Ignore the magnetic spin effects) What is the energy of the *5f* state in the absence of a magnetic field? What will be the energy of each state in the magnetic field? (Hint: Bohr magneton $\mu_B=5.7884\times10^{-5}$ eV/T) (15%)