I. Multiple Choice (單選題) 30% 每題 3%

Useful constants: $h = 6.626 \times 10^{-34}$ J·s, 1eV=1.602×10^{-19} J

1. An electron has a kinetic energy that is twice its rest energy. Determine its speed.

   a. 0.76 c
   b. 0.81 c
   c. 0.94 c
   d. 0.54 c
   e. 0.87 c

2. A helium-neon laser emits red light having a wavelength of 6.4×10^{-7} m and a power of 0.5 mW. How many photons are emitted each second?

   a. 6.4×10^{38}
   b. 1.6×10^{21}
   c. 3.2×10^{25}
   d. 2.6×10^{18}
   e. 1.6×10^{15}

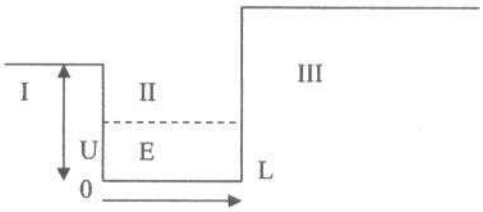
3. In an experiment different wavelengths of light, all able to eject photoelectrons, shine on a freshly prepared (oxide-free) zinc surface. Which statement is true?

   a. The number of photoelectrons emitted per second is independent of the intensity of the light for all the different wavelengths.
   b. The number of photoelectrons emitted per second is directly proportional to the frequency for all the different wavelengths.
   c. The maximum kinetic energy of the photoelectrons emitted is directly proportional to the frequency for each wavelength present.
   d. The maximum kinetic energy of the photoelectrons has a linear relationship with the frequency for each wavelength present.
   e. The maximum kinetic energy of the photoelectrons is proportional to the intensity of the light and independent of the frequency.

4. The allowed values of ℓ for the $n = 3$ shell in a Li^{2+} ion are

   a. 1, 2
   b. 0, 1
   c. 0, 1, 2
   d. 0, 1, 2, 3
   e. 1, 2, 3

5. A particle in a finite potential well has energy E, as shown below.



The wave function in region II where $x>0$ has the form $\psi_{II}=$

a. Ae^{-Cx}.
b. Ae^{Cx}.
c. $F\sin kx$.
d. $G\cos kx$.
e. $F\sin kx+G\cos kx$

6. An electron in a hydrogen atom makes a transition from the $n = 6$ to the $n = 2$ energy state. Determine the energy (in eV) of the emitted photon.

a. 0.66
b. 0.85
c. 1.51
d. 3.02
e. 4.87

7. A molecule makes a transition from the $J = 2$ to the $J = 1$ rotational energy state. The wavelength of the emitted photon is 2.6×10^{-3} m. What is the moment of inertia of the molecule (in $kg \cdot m^2$)?

a. 3.2×10^{-46}
b. 5.7×10^{-45}
c. 1.1×10^{-44}
d. 1.5×10^{-46}
e. 9.1×10^{-46}.

8 The energy gap (in eV) between the valance and conduction bands of an **insulator** is of the order

a. 0.001
b. 0.01
c. 0.1
d. 10.
e. 100

9 Which expression correctly describes the radioactive decay of a substance whose half-lift is T ?

- **a.** $N = N_0 e^{-t/(T \ln 2)}$
- **b.** $N = N_0 e^{-t/T}$
- **c.** $N = N_0 e^{-tT}$
- **d.** $N = N_0 e^{-tT\ln 2}$
- **e.** $N = N_0 e^{-(t\ln 2)/T}$

10 Perhaps the most famous observation is spectroscopy was the recognition that the yellow-orange line in spectrum of sodium is in fact a narrowly separated doublet. The explanation of this splitting is most closely related to

- **a.** the de Broglie wavelength of the electron.
- **b.** the existence of spin angular momentum of the electron.
- **c.** the exclusion principle.
- **d.** solution of the Schrodinger equation.
- **e.** the existence of quantized orbital angular momentum of the electron.

II. Discussion Questions (問答題) 30% 每題 5%

1. If matter has a wave nature, why is this wave-like characteristic not observable in our daily experiences?

2. Why is it impossible for the lowest-energy state of a harmonic oscillator to be zero?

3. How does the Compton effect differ from the photoelectric effect?

4. Which is easier to excite in a diatomic molecule, rotational or vibrational motion? Explain.

5. Describe the Stern-Gerlach experiment. Could the Stern-Gerlach experiment be performed with ions rather than the neutral atoms. Explain.

6. Explain p-type semiconductor and n-type semiconductor. Experimentally the addition of impurities to metals increases their resistivity, but the addition of impurities to semiconductors decreases their resistivity. Explain. Many insulators, however, are not very pure. Why do impurities not affect the resistivity of insulators?

III. Problems (計算題) 40% 每題10%

1. A particle of mass *m* moves in a potential well of length $2L$. Its potential energy is infinite for $x < -L$ and for $x > +L$. Inside the region $-L < x < L$, its potential energy is given by

$$U(x) = \frac{-\hbar^2 x^2}{mL^2(L^2 - x^2)}$$

In addition, the particle is in a stationary state that is described by the wave function $\psi(x) = A(1 - x^2/L^2)$ for $-L < x < +L$, and by $\psi(x) = 0$ elsewhere.

(a) Determine the energy of the particle in terms of $\hbar$, m, and L. (*Suggestion:* Use the Schrödinger equation.) (5%)

(b) Show that $A = (15/16L)^{1/2}$. (5%)

2. (a) Show that the frequency f and wavelength λ of a freely moving particle are related by the expression

$$\left(\frac{f}{c}\right)^2 = \frac{1}{\lambda^2} + \frac{1}{\lambda_C{}^2}$$

where $\lambda_C = h/mc$ is the Compton wavelength of the particle. (5%)

(b) Is it ever possible for a particle having nonzero mass to have the same wavelength *and* frequency as a photon? Explain. (5%)

3. (a) List the possible sets of quantum numbers (n, l, m_l, m_s) for an electron for $n = 1$, $n = 2$, and $n = 3$. Check your results and show that the number of sets of quantum numbers for a shell specified by a quantum number n is equal to $2n^2$. (6%)

(b) Give formula and numerical value accurate to at least on significant figure for

(1) fine structure constant. (2%)

(2) Bohr magneton (magnetic moment of free electron). (2%)

4. (a) If you wish to produce 1.0-nm x-rays in the laboratory, what is the minimum voltage you must use in accelerating the electrons? (5%)

(b) A ruby laser delivers a 10.0-ns pulse of 3.00 MW average power. How much energy is delivered in each pulse? If the photons have a wavelength of 662.6 nm, how many are contained in the pulse? (5%)