I. Multiple Choice (40%) (單選題)

(Note: h=6.626x10^{-34} J.s, 1eV=1.602x10^{-19} J)

1. A spaceship moves at a speed of 0.95 *c* away from the Earth. It shoots a star wars torpedo toward the Earth at a speed of 0.90 *c* relative to the ship. What is the velocity of the torpedo relative to the Earth? (The direction in which the spaceship moves is the positive direction.)

   a. −0.35 *c*　**b.** 0.35 *c*　**c.** 0.06 *c*　**d.** −0.06 *c*　**e.** 0

2. A spaceship moving past the Earth with a speed of 0.800 *c* signals to the Earth with pulsed laser photons emitted at 10 second intervals according to the spaceship's clock. According to observers on Earth who see the flashes, the time interval they measure is

   a. 13.4 s　**b.** 16.7 s　**c.** 12.5 s　**d.** 9.7 s　**e.** 6.0 s

3. The half-life of a muon is 2.2 μs. How fast is it moving relative to an observer who says its half-life is 4.4 μs?

   a. 0.87 *c*　**b.** 0.75 *c*　**c.** 0.97 *c*　**d.** 0.72 *c*　**e.** 0.50 *c*

4. An electron (m = 9.11 × 10^{-31} kg) has a speed of 0.50 *c*. Determine the difference between its relativistic kinetic energy and the kinetic energy calculated without considering relativity.

   a. 3.0 × 10^{-15} J　**b.** 2.0 × 10^{-15} J　**c.** 1.5 × 10^{-15} J　**d.** 2.4 × 10^{-15} J
   e. 1.8 × 10^{-15} J

5. The threshold wavelength for photoelectric emission of a particular substance is 500 nm. What is the work function (in eV)?

   a. 4.2　**b.** 4.0 × 10^{-19}　**c.** 4.0 × 10^{-10}　**d.** 2.5 × 10^{-19}
   e. 2.5

6. What is the maximum kinetic energy (in eV) of a photoelectron emitted from a surface whose work function is 5.0 eV when illuminated by a light whose wavelength is 200 nm?

   a. 1.9　**b.** 1.2　**c.** 3.1　**d.** zero　**e.** 6.2

7. A photon collides with an electron. After the collision the wavelength of the scattered wave is

   a. greater than or equal to the initial wavelength.
   b. equal to the initial wavelength.
   c. less than or equal to the initial wavelength.
   d. greater than the initial wavelength.
   e. less or greater depending on the scattering angle.

8. A solid state pulsed laser has an energy of 400 mJ per pulse. If its wavelength is 1.06×10^{-6} m, how many photons are in each pulse?

   a. 2×10^{25}　b. 2×10^{21}　c. 3×10^{18}　d. 6×10^{38}　e. 2×10^{18}

9. An electron is accelerated through a potential difference of 25 000 V. What is the de Broglie wavelength of the electron (in m)?

   a. 5.9×10^{-12}　b. 6.8×10^{-12}　c. 6.5×10^{-12}　d. 7.8×10^{-12}　e. 5.5×10^{-12}

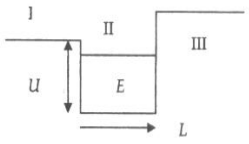
10. Film behind a double slit is exposed to light in the following way: First one slit is opened and light is allowed to go through that slit for time Δt. Then it is closed and the other slit is opened and light is allowed to go through that slit for the same time Δt. When the film is developed the pattern will be

    a. one single slit pattern.
    b. two superimposed single slit patterns, their centers displaced from each other by the distance between the two slits.
    c. one double slit pattern.
    d. two double slit patterns, their centers displaced from each other by the distance between the two slits.
    e. random darkening of the film. (no pattern at all)

11. The ground state energy of a harmonic oscillator is

    a. $E = \hbar\omega$　b. $E = \hbar\omega/2$　c. $E = (2/3)\hbar\omega$　d. $E = 3\hbar\omega/4$
    e. $E = \hbar\omega/4$　f. $E = 0$.

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



    The wave function in region **III** where $x > L$ has the form $\psi_{III} =$

    a. Ae^{-Cx}.　b. Ae^{Cx}.　c. $F\sin kx$.　d. $G\cos kx$.
    e. $F\sin kx + G\cos kx$.　f. none of the above.

13. In terms of a_0, where $a_0 = 0.0529\text{nm}$, the radii of the allowed orbits in the Bohr model of the hydrogen atom are given by $r_n =$

a. $\frac{1}{n^2}a_0$.　b. $\frac{a_0}{n}$.　c. $\sqrt{n}a_0$.　d. na_0.
e. $a_0/\sqrt{n}$.　f. n^2a_0.

14. Quantum physics agrees with the classical physics limit when
a. the total angular momentum is a small multiple of $\hbar$.
b. the total energy is a small multiple of the energy in the lowest quantized state.
c. the difference in energy between adjacent quantized levels becomes vanishingly small.
d. all electron spins are paired so that $L=0$.
e. there is a vacancy in an inner level in the atom.
f. (d) and (e) above.

15. In the Lennard-Jones model of the hydrogen atom, the potential is given by $U=\frac{A}{r^{12}}-\frac{B}{r^6}$. In this model, the minimum internuclear separation, r_0, is
a. $\left(\frac{A}{2B}\right)^{1/6}$.　b. $\left(\frac{A}{B}\right)^{1/2}$.　c. $\left(\frac{A}{B}\right)^{7/13}$.　d. $\left(\frac{2A}{B}\right)^{1/6}$.
e. $\left(\frac{2A}{B}\right)^{7/13}$.　f. $\left(\frac{2A}{B}\right)^{1/3}$.

16. The energy gap for germanium is 0.67 eV at room temperature. What wavelength must a photon have (in nm) to excite the electron to the conduction band?
a. 640　b. 1090　c. 1850　d. 2200
e. 925　f. 3050

17. When a molecule jumps from a rotational energy level characterized by the rotational quantum number J to one characterized by $J+1$, the change in energy, $E_{J+1}-E_J$, is
a. $-\frac{\hbar^2}{2I}J$.　b. $-\frac{\hbar^2}{I}(J+1)$.　c. $+\frac{\hbar^2}{2I}J$.　d. $+\frac{\hbar^2}{I}J$.
e. $+\frac{\hbar^2}{I}(J+1)$.　f. $-\frac{\hbar^2}{2I}(J+1)$.

18. What value of Z (atomic number) and A (mass number) result in the following β-decay?

$$^{14}_{6}\mathrm{C}\rightarrow {}^{A}_{Z}\mathrm{X}+e^{-}$$

a. $Z=5; A=14$　b. $Z=4; A=10$　c. $Z=6; A=13$
d. $Z=6; A=14$　e. $Z=7; A=13$　f. $Z=7; A=14$

19. When a beam of nuclear radiation of initial intensity I_0 passes through a thickness x of material, the intensity of the beam exiting the material is $I=$
a. $I_0e^{-\mu x}$.　b. $I_0e^{\mu x}$.　c. $I_0\left(e^{-\mu x}-1\right)$.　d. $I_0\left(e^{\mu x}-1\right)$.
e. $I_0\left(1-e^{-\mu x}\right)$.　f. $I_0\left(1+e^{-\mu x}\right)$.

20. The magnitude of the spin angular momentum for an electron is equal to

a. $\sqrt{3}\hbar$　b. $\frac{\sqrt{3}}{2}\hbar$　c. $\hbar/2$　d. $\pm\hbar/2$

e. $\frac{3}{4}\hbar$　f. $-\frac{3}{4}\hbar$

II. Questions (20%)

1. Give a physical argument that shows that it is impossible to accelerate an object of mass m to the speed of light, even with a continuous force acting on it.

2. Of the electromagnetic waves generated in a microwave oven and in your dentist's x-ray machine, which has (a) the greater wavelength, (b) the greater frequency, and (c) the greater photon energy ?

3. What is the Schrodinger equation ? How is it useful in describing quantum phenomena?

4. What is Pauli exclusion principle ? Explain the role of the Pauli exclusion principle in describing the electric properties of metals.

III. Problems (40%)

1. A moving rod is observed to have a length of 2.00 m and to be oriented at an angle of 30.0° with respect to the direction of motion, as shown in Figure 1. The rod has a speed of 0.995c. (a) What is the proper length of the rod? (b) What is the orientation angle in the proper frame?

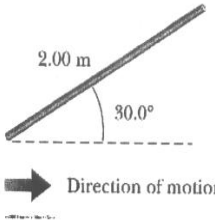


Figure 1

2. A 0.700-MeV photon scatters off a free electron such that the scattering angle of the photon is twice the scattering angle of the electron (Fig.2). Determine (a) the scattering angle for the electron and (b) the final speed of the electron.

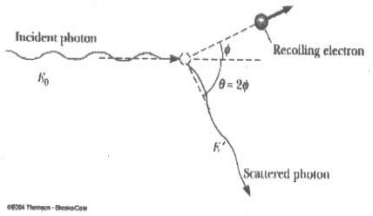


Figure 2

3. Four possible transitions for a hydrogen atom are as follows:

(i) $n_i = 2; n_f = 5$ (ii) $n_i = 5; n_f = 3$ (iii) $n_i = 7; n_f = 4$ (iv) $n_i = 4; n_f = 7$

(a) In which transition is light of the shortest wavelength **emitted**?
(b) In which transition does the atom **gain** the most energy?
(c) In which transition(s) does the atom **lose** energy?

4. A particle is described by the wave function

$$\psi(x) = \begin{cases} A\cos\left(\dfrac{2\pi x}{L}\right) & \text{for } -\dfrac{L}{4} \le x \le \dfrac{L}{4} \\ 0 & \text{for other values of } x \end{cases}$$

(a) Determine the normalization constant A. (b) What is the probability that the particle will be found between $x = 0$ and $x = L/8$ if its position is measured? (Useful integral: $\int\cos^2(ax)dx = \dfrac{x}{2} + \dfrac{\sin 2ax}{4a}$)