1. (16 pts) (a) A physics professor on earth gives an exam to his students who are on a spaceship traveling at speed v relative to Earth. The moment the ship passes the professor, he signals the start of the exam. If he wishes his students to have time T_0 (spaceship time) to complete the exam, show that he should wait a time (Earth time) of

$$T = T_0[(1 - v/c)/(1 + v/c)]^{1/2}$$

before sending a light signal telling them to stop. (b) Newton's second law is given by $\mathbf{F} = d\mathbf{P}/dt$. If the force is always perpendicular to the velocity, show that $\mathbf{F} = \gamma m\mathbf{a}$, where **a** is the acceleration. If the force is always parallel to the velocity, show that $\mathbf{F} = \gamma^3 m\mathbf{a}$.

2. (12 pts) Answer the following questions:

(a) Suppose the photoelectric effect occurs in a ***gaseous*** target rather than a solid. Will photoelectrons be produced at ***all*** frequencies of the incident photon? Explain.

(b) How does the Compton effect differ from the photoelectric effect?

(c) All objects radiate energy. Why are we not able to see all objects in a dark room?

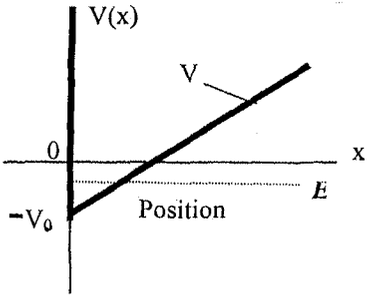
3. (10 pts)

(a) Construct an energy level diagram for the Li^{2+} ion, for which $Z = 3$.

(b) Ordinary hydrogen contains about one part in 6000 of *deuterium*, or heavy hydrogen. This is a hydrogen atom whose nucleus contains a **proton** and a **neutron**. How does the doubled nuclear mass affect the atomic spectrum? Give your calculation.

4. (20 pts)

(a) Consider a particle of energy E trapped inside the potential well shown in the right figure. Sketch a possible wave function **inside** and **outside** the potential well. Explain your sketch.



(b) For any eigenfunction φ_n of the infinite square well. Show that $\underline{\langle x\rangle = L/2}$ and that $\underline{\langle x^2\rangle = L^2/3 - L^2/2(n\pi)^2}$.

5. (16 pts)

(a) With no magnetic field, the spectral line representing the transition from the $^2P_{½}$ state to the $^2S_{½}$ state in sodium has the wavelength 589.76 *nm*. This is one of the two strong yellow lines in sodium. Calculate the difference in wavelength between the shortest and longest wavelength between these two states when placed in a magnetic field of 0.5T.

(b) Give the sources of electronic magnetic dipole moment $\boldsymbol{\mu}$ in an atom and write down the expression for each contribution.

6. (16 pts)

(a) Describe the principle of LASER in detail.

(b) Show that the **average** kinetic energy of a conduction electron in a **metal** at 0K is given by $E = 3E_F/5$. By way of contrast, *all* of the molecules in an ideal gas at 0K have **zero** energy.

接背面

8. (10 pts)

(a) Explain why many heavy nuclei undergo α-decay but do not spontaneously emit neutrons or protons.

(b) Why is the following inverse β-decay forbidden for a free proton?

$$P \rightarrow n + e^{+} + \nu$$

請參考隨附常數表

Some Fundamental Constants*

QUANTITY	SYMBOL	VALUE
Atomic mass unit	u	1.6605×10^{-27} kg 931.49 MeV/c^2
Avogadro's number	N_A	6.022×10^{23} particles/mole
Bohr magneton	$\mu_B = \frac{e\hbar}{2m_e}$	9.274×10^{-24} J/T 5.788×10^{-5} eV/T
Bohr radius	$a_0 = \frac{\hbar^2}{m_e e^2 k}$	0.5292×10^{-10} m
Boltzmann's constant	k_B	1.381×10^{-23} J/K 8.617×10^{-5} eV/K
Coulomb constant	$k = 1/(4\pi\epsilon_0)$	8.988×10^{9} N·m^2/C^2
Electron charge	e	1.602×10^{-19} C
Electron mass	m_e	9.109×10^{-31} kg 5.486×10^{-4} u 0.5110 MeV/c^2
Gravitational constant	G	6.673×10^{-11} N·m^2/kg^2
Hydrogen ground state energy	$E_0 = -\frac{m_e e^4 k^2}{2\hbar^2}$	−13.61 eV
Neutron mass	m_n	1.675×10^{-27} kg 1.009 u 939.6 MeV/c^2
Nuclear magneton	$\mu_n = \frac{e\hbar}{2m_p}$	5.051×10^{-27} J/T 3.152×10^{-8} eV/T
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Permittivity of free space	ϵ_0	8.854×10^{-12} C^2/N·m^2
Planck's constant	h	6.626×10^{-34} J·s 4.136×10^{-15} eV·s
	$\hbar = h/2\pi$	1.055×10^{-34} J·s 6.582×10^{-16} eV·s
Proton mass	m_p	1.673×10^{-27} kg 1.007 u 938.3 MeV/c^2
Rydberg constant	$R = \frac{m_e k^2 e^4}{4\pi c\hbar^3}$	1.097×10^{7} m^{-1}
Speed of light in vacuum	c	2.998×10^{8} m/s
Stefan-Boltzmann constant	σ	5.6705×10^{-8} W/m^2 K^4

* More precise values of physical constants are provided in Appendix A.

試題隨卷繳回