※ 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。

Boltzmann's constant : $k_B = 8.617 \times 10^{-5} eV / K$　　*Speed of light in free space* : $c = 3 \times 10^8 \, m/s$

Mass of electron : $m_e = 9.1 \times 10^{-31} \, Kg$　　　*Planck's constant* : $h = 6.626 \times 10^{-34} \, J \cdot s$

Mass of unit : $u = 1.66 \times 10^{-27} \, Kg$　　　　*Electron charge* : $e = 1.602 \times 10^{-19} \, C$

Speed of light : $c = 3 \times 10^8 \, m/s$　　　　　*Permeability of free space* : $\mu_0 = 4\pi \times 10^{-7} N / A^2$

1. The 2014 Nobel prizes in both <u>Physics</u> and <u>Chemistry</u> were awarded for developments in Photonics. Please describe briefly the both significant achievements and their possible applications. (10%)

2. A distant galaxy is moving away from the Earth at such high speed that the blue hydrogen line at a wavelength of 434 nm is recorded at 600 nm, in the red range of the spectrum. What is the speed of the galaxy relative to the Earth? (10%)

3. Calculate the surface temperature of the Sun from the following information. Assume that the Sun is a black body. The Sun's radius is given by R and the average Earth-Sun distance is D. The power per unit area (at all frequencies) from the Sun is measured at the Earth to be I. (10%)

4. The work function of a cesium (Cs) surface is 1.9 eV.
   (a) If blue radiation of wavelength 450 nm is incident onto the Cs photocathode, what should be the voltage required on the opposite electrode to extinguish the external photocurrent? (5%)
   (b) Light of wavelength 450 nm with an intensity of 30 mW cm^{-2} is incident on a Cs photocathode that is a circular disk of diameter 6 mm. If 25% of the incident photons eject the photoelectrons, find the photocurrent. (5%)

5. Certain waves travel with a phase velocity $V_{phase} = \sqrt{\dfrac{g\lambda}{2\pi}}$, where g is the acceleration due to gravity. What is the group velocity of a "wave packet" of these waves? (5%)

6. Explain why a four level laser can be more efficient than a three-level laser. (5%)

7. Compute the expectation value of the x component of the momentum of a particle of mass m in the $n = 3$ level of a one-dimensional infinite square well of width L. Reconcile your answer with the fact that the kinetic energy of the particle in this level is $9\pi^2\hbar^2/2mL^2$. (10%)

8. Compute the spacing between adjacent energy levels per unit energy, i.e., $\Delta E_n/E_n$, for the quantum harmonic oscillator and show that the result agrees with Bohr's corresponding principle by letting n $\rightarrow \infty$. (10%)

9. A hydrogen atom is in the $3D$ state ($n = 3$, $l = 2$).
   (a) What are the possible values of j? (2%)
   (b) What are the possible values of the magnitude of the total angular momentum? (3%)
   (c) What are the possible z components of the total angular momentum? (5%)

10. A monatomic gas is confined to move in two dimensions so that the energy of an atom is $E_k = \frac{1}{2}mv_x^2 + \frac{1}{2}mv_y^2$. What are C_v, C_p, and γ for this gas? Where the C_v and C_p are the heat capacities at constant volume and pressure, respectively, and $\gamma = C_p/C_v$. (10%)

11. Consider a two dimensional box of length a and width b. If the particle is confined to this box, find the allowed wave functions and energies. (10%)