Useful constants: \( c = 3.00 \times 10^8 \text{ m/s} \), \( k_B = 1.38 \times 10^{-23} \text{ J/K} \), \( h = 6.63 \times 10^{-34} \text{ J s} \), \( e = 1.60 \times 10^{-19} \text{ C} \), \( m_e = 9.11 \times 10^{-31} \text{ Kg} \).

1. (12%) A metal surface is irradiated with monochromatic light of variable wavelength. Above a wavelength of 5400 Å, no photoelectrons are emitted from the surface. With an unknown wavelength a stopping potential of 3 V is necessary to eliminate the photoelectric current. What is the unknown wavelength?

2. (15%) X-ray photons of wavelength 0.712 Å undergo Compton collision in carbon. What is the wavelength change of the line scattered at 90° if the scattering particle is
   (a) an outer electron?
   (b) the whole carbon atom?

3. (15%) Find the deBroglie wavelength of the waves associated with an electron that has been accelerated from rest through a potential difference of
   (a) 100 V.
   (b) 800,000 V.

4. (13%) Measurements of the mass of a subatomic particle yielded a mass distribution which is centered at 1230 MeV/c², and with full width at half maximum about 110 MeV/c². Estimate the lifetime of the particle.

5. (15%) Determine the mass of a free particle whose wave function is the plane wave

\[ \Psi(x,t) = A e^{i(2.5 \times 10^{11} x - 2.1 \times 10^{13} t)} \]

where distance \((x)\) is in meters and time \((t)\) in seconds.

6. (15%) One of the excited states of the hydrogen atom has the wavefunction

\[ \Psi = A r e^{-r/2a} \cos \theta \]

where \(a\) is the Bohr radius.
   (a) Find the normalization constant \(A\).
   (b) Find the most probable value of \(r\).

7. (15%) (a) Write all possible total angular momentum states \((j, m_j)\) for a 3d electron in a hydrogen.
   (b) Assume that the spin-orbit interaction is not overwhelmed by an external magnetic field, what
       is the minimum angle that the total angular momentum vector \(\vec{J}\) may make with the z-axis for
       the 3d electron.
   (c) What are possible angles between vectors \(\vec{L}\) and \(\vec{S}\) for the 3d electron due to the spin-orbit
       interaction.