Additional and advanced problems

1. Using Planck's formula, find the power radiated by a unit area of a black body within a narrow wavelength interval $\Delta\lambda$ = 1.0 nm close to the maximum of spectral radiation density at a temperature T = 3000 K of the body.

2. A short light pulse of energy E = 7.5 J falls in the form of a narrow and almost parallel beam on a mirror plate whose reflection coefficient is 0.60. The angle of incidence is 30°. Representing light as particles, find the momentum transferred to the plate.

3. Illuminating the surface of a certain metal alternatively with light of wavelengths λ_1 = 350 nm and λ_2 = 0.54 nm, it was found that the corresponding maximum velocities of photoelectrons differ by a factor of 2.0. Find the work function of that metal.

4. A narrow monochromatic X-ray beam falls on a scattering substance. The wavelengths of radiation scattered at angles θ_1 = 60° and θ_2 = 120° differ by a factor of 2.0. Assuming the free electrons to be responsible for the scattering, find the wavelength of the incident radiation.

5. Calculate the orbital frequency of an electron occupying the second Bohr orbit of a He^+ ion.

6. What element (ion) has a hydrogen-like spectrum, except its lines have wavelengths four time shorter than those of atomic hydrogen?

7. The binding energy of an electron in the ground state of He atom is E_0 = 24.6 eV. Find the energy required to remove both electrons from the atom.

8. Find the velocity of photoelectrons liberated by electromagnetic radiation of wavelength λ = 18.0 nm from stationary He^+ ions in the ground state.

9. At what minimum kinetic energy must a hydrogen atom move for its inelastic head-on collision with another, stationary, hydrogen atom to make one of them capable of emitting a photon? Both atoms are in the ground state.

10. What amount of energy should be added to an electron to reduce its de Broglie wavelength from 100 to 50 pm?

11. At what value of kinetic energy is the de Broglie wavelength of an electron equal to its Compton wavelength?

12. Using the uncertainty principle, estimate the uncertainty of the velocity of an electron in a hydrogen atom if the size of the atom is 0.1 nm. Compare the obtain value with the velocity of an electron in the first Bohr orbit of the hydrogen atom.

Answers:

1. $\Delta P = 0.31$ W/cm^2
2. $p = 35$ nN/cm^2
3. $\varphi = 1.9$ eV
4. $\lambda = 1.2$ pm
5. $\omega = 2.07\text{x}10^{16}$ s^{-1}
6. He^+
7. $E = 79$ eV
8. $v = 2.3\text{x}10^6$ m/s
9. $KE_{min} = 20.5$ eV
10. 0.45 keV
11. KE = 0.21 MeV
12. $\Delta v = 1\text{x}10^{-16}$ m/s, $v_1 = 2.2\text{x}10^6$ m/s