PHYSICS 215 - Thermodynamics and Modern Physics

Practice Midterm Exam 2

Fall 2007

1. [6 points] An interstellar spaceship travels from the earth to a distant star 12 light years away (as measured in the earth's frame). The trip takes 15 years as measured on the ship.

(a) What is the speed of the ship relative to the earth?

(b) When the ship arrives at its destination, it sends a radio signal back to the earth. How much time elapses on earth between the departure of the spaceship and the arrival of the signal?

2. [6 points] A beam of X rays has an energy of 10 keV.

(a) What is the wavelength of these X rays?

(b) The X rays are then Compton-scattered from electrons at rest. The scattered beam is observed at an angle of 90° relative to the incident beam. What is the wavelength of the scattered X rays?

(c) What is the energy of the scattered photons?

(d) What is the kinetic energy of the scattered electrons

[Extra credit, 2 points] What is the angle of the scattered electrons?

3. [6 points] In an experiment done by scattering α particles on a thin gold foil, students find that 10,000 α particles are scattered at an angle of $\theta = 45^{\circ}$.

(a) How many α particles would they expect to see scattered at $\theta = 60^{\circ}$?

(b) If the gold foil ($Z = 79$) is replaced by an aluminum foil ($Z = 13$) with a similar number of scattering nuclei per unit area, how many α particles will now be scattered at 45°?

4. [6 points] An electron, initially at rest, is accelerated across a potential difference of 5 kV.

(a) What is its kinetic energy?

(b) What is its total energy??

(c) What is its momentum?

(d) What is its de Broglie wavelength?

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Useful Constants:

Avogadro's number, $N_A = 6.02E23\ mol^{-1}$
Speed of light, $c = 3.00E8$ m/s
Charge of an electron, $-e = -1.6E-19$ C
Mass of the electron, $m_e = 9.1E-31\ kg = 511\ keV/c^2$
Mass of the proton, $m_p = 1.67E-27\ kg = 938\ MeV/c^2$
Planck's constant, $h = 6.63E-34$ J.s $= 4.14E-15$ eV.s
Planck's reduced constant, $\hbar = h/2\pi = 1.05E-34$ J.s $= 6.58E-16$ eV.s
Compton Wavelength of the electron, $\lambda_c = h/m_e c = 2.4263E-12$ m

Useful Formulae:

Potential energy lost by a charge q in traversing a potential difference of V is $U = qV$

Wave relation: $v = \nu\lambda$ where v = velocity, ν = frequency, λ = wavelength.

$\beta = v/c \qquad \gamma = 1/\sqrt{(1-\beta^2)}$

Length Contraction: $L' = L/\gamma$ Time Dilation, $T' = \gamma T$

Addition of Velocities: $v' = (v + u)/(1 + vu/c^2)$

Relativistic Doppler Effect: $\nu' = \dfrac{\sqrt{(1-\beta)}}{\sqrt{(1+\beta)}}\nu$

Momentum – Energy relations: $E^2 = p^2c^2 + m^2c^4$
$E = \gamma mc^2 \qquad p = \gamma mv \qquad K = E - mc^2$

Planck's Relation: $E = h\nu$

Einstein's Photoelectric Law: $h\nu = K + \phi$

Compton Effect: $\Delta\lambda = \lambda' - \lambda = (1 - \cos\theta)h/m_e c$

Bohr Quantization Relation: $L = mvr = n\hbar$

Atomic Radii: $r_n = n^2 a_0/Z$ where $a_0 = 5.29E-11$ m
Atomic Energies: $E_n = -Z^2 E_0/n^2$ where $E_0 = 13.6$ eV

Rutherford Scattering: $N(\theta) = \dfrac{N_i\, n\, t\, e^4\, Z_1^2\, Z_2^2}{16\,(4\pi\varepsilon_0)^2\, r^2\, K^2 \sin^4(\theta/2)}$

de Broglie Wavelength: $\lambda = h/p$