PHYSICS 2D QUIZ 2 WINTER QUARTER 2011
PROF. HIRSCH JANUARY 28th, 2011

Formulas:

Time dilation; Length contraction: $\Delta t = \gamma\Delta t' \equiv \gamma\, \Delta t_p$; $L = L_p/\gamma$; $c = 3\times 10^8 m/s$

Lorentz transformation: $x' = \gamma(x - vt)$; $y' = y$; $z' = z$; $t' = \gamma(t - vx/c^2)$; inverse: $v \to -v$

Spacetime interval: $(\Delta s)^2 = (c\Delta t)^2 - [\Delta x^2 + \Delta y^2 + \Delta z^2]$

Velocity transformation: $u_x' = \dfrac{u_x - v}{1 - u_x v/c^2}$; $u_y' = \dfrac{u_y}{\gamma(1 - u_x v/c^2)}$; inverse: $v \to -v$

Relativistic Doppler shift: $f_{obs} = f_{source}\sqrt{1 + v/c}\ /\ \sqrt{1 - v/c}$ (approaching)

Momentum: $\vec{p} = \gamma m\vec{u}$; Energy: $E = \gamma mc^2$; Kinetic energy: $K = (\gamma - 1)mc^2$

Rest energy: $E_0 = mc^2$; $E = \sqrt{p^2c^2 + m^2c^4}$

Electron: $m_e = 0.511\ MeV/c^2$ Proton: $m_p = 938.26\ MeV/c^2$ Neutron: $m_n = 939.55\ MeV/c^2$

Atomic mass unit: $1\ u = 931.5\ MeV/c^2$; electron volt: $1\text{eV} = 1.6\times 10^{-19}$ J

Stefan's law: $e_{tot} = \sigma T^4$, e_{tot} = power/unit area ; $\sigma = 5.67\times 10^{-8} W/m^2K^4$

$e_{tot} = cU/4$, U = energy density = $\int_0^\infty u(\lambda,T)d\lambda$; Wien's law: $\lambda_m T = \dfrac{hc}{4.96k_B}$

Boltzmann distribution: $P(E) = Ce^{-E/(k_BT)}$

Planck's law: $u_\lambda(\lambda,T) = N_\lambda(\lambda)\times \overline{E}(\lambda,T) = \dfrac{8\pi}{\lambda^4}\times\dfrac{hc/\lambda}{e^{hc/\lambda k_BT} - 1}$; $N(f) = \dfrac{8\pi f^2}{c^3}$

Photons: $E = hf = pc$; $f = c/\lambda$; $hc = 12{,}400\ eV\,A$; $k_B = (1/11{,}600)eV/K$

Photoelectric effect: $eV_s = K_{\max} = hf - \phi$, $\phi \equiv$ work function; Bragg equation: $n\lambda = 2d\sin\vartheta$

Compton scattering: $\lambda' - \lambda = \dfrac{h}{m_ec}(1 - \cos\theta)$; $\dfrac{h}{m_ec} = 0.0243A$

Justify all your answers to all problems. Write clearly.

<u>Problem 1</u> (10 points)

The tungsten filament of the light bulb in a flashlight emits radiation approximately as a black body. When it is connected to a 3 Volt battery it emits 10 W of power. Maximum power is emitted for wavelengths around 8,000 A.

(a) What is the surface area of this filament? Give your answer in mm^2 ($1mm=10^{-3}m$).

(b) When it is connected to a 6 Volt battery, by what factor does the temperature of the filament change? Does it increase or decrease by that factor?
<u>Hint</u>: you learned in Physics 2B that the power dissipated in a resistor R is V^2/R. Assume all the power is dissipated by radiation.

(c) Compare the power emitted by this light bulb for wavelengths 200,000A and 400,000A when it is connected to the 6 Volt battery. By what factor do they differ? Your answer may be approximate if the approximation is well justified.

Problem 2 (10 points)

A source emits light with wavelengths in the range 2,500 A to 7,500 A, with the same intensity for all wavelengths in that range. The light from this source is incident on a metal surface, and the maximum kinetic energy of the emitted electrons is found to be 2eV.

(a) If a filter is inserted between this source and this metal that blocks the light with wavelengths smaller than 5,000A, what will be the maximum kinetic energy of the emitted electrons?

(b) If instead a filter is inserted between this source and this metal that blocks the light with wavelengths greater than 5,000A, what will be the maximum kinetic energy of the emitted electrons?

(c) What is the work function of this metal? Give your answer in eV.

Problem 3 (10 points)

In a Compton scattering experiment, the scattered photon has wavelength 0.5A and the scattered electron has kinetic energy 1,033 eV.

(a) Find the wavelength of the incident photon.

(b) Find the angle at which the photon is scattered relative to the direction of incidence (in degrees).

(c) Find the y-component of the momentum of the scattered electron, in units eV/c, where y is the direction perpendicular to the incidence direction in the plane where the scattering occurs.