PHYSICS 2D QUIZ 2 FALL QUARTER 2022
PROF. HIRSCH

Justify all your answers to all problems. Write clearly.

Time dilation; Length contraction: $\Delta t = \gamma \Delta t_0$; $L = L_0 / \gamma$; $c = 3\times 10^8 m/s$

Lorentz transformation: $x' = \gamma(x - ut)$; $y' = y$; $t' = \gamma(t - ux/c^2)$

Velocity: $v_x' = \dfrac{v_x - u}{1 - uv_x/c^2}$; $v_y' = \dfrac{v_y}{\gamma(1 - uv_x/c^2)}$; $\gamma = \dfrac{1}{\sqrt{1 - u^2/c^2}}$

Inverse transformations: $u \to -u$, *primed* $\leftrightarrow$ *unprimed*; Doppler: $f' = f\sqrt{\dfrac{1 \pm u/c}{1 \mp u/c}}$

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

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

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

Photoelectric effect: $eV_s = K_{\max} = hf - \phi = hc/\lambda - \phi$; ϕ = work function

Stefan law: $I = \sigma T^4$, $\sigma = 5.67037\times 10^{-8} W/m^2 \cdot K^4$; Wien's law: $\lambda_m T = 2.8978\times 10^{-3} m\cdot K$

$I(T) = \int_0^\infty I(\lambda, T)\, d\lambda$; $I = (c/4)u$; $u(\lambda, T) = N(\lambda) E_{av}(\lambda, T)$; $N(\lambda) = \dfrac{8\pi}{\lambda^4}$

Boltzmann distribution: $N(E) = Ce^{-E/kT}$; $N = \int_0^\infty N(E)\, dE$; $E_{av} = \dfrac{1}{N}\int_0^\infty EN(E)\, dE$

Classical: $E_{av} = kT$; Planck: $E_n = n\varepsilon = nhf$; $N = \sum_{n=0}^\infty N(E_n)$; $E_{av} = \dfrac{1}{N}\sum_{n=0}^\infty E_n N(E_n)$

Planck: $E_{av} = \dfrac{hc/\lambda}{e^{hc/\lambda kT} - 1}$; $hc = 1{,}240 eV\cdot nm$; $\lambda_m T = hc/4.96k$; $\sigma = \dfrac{2\pi^5 k^4}{15c^2h^3}$

Boltzmann constant: $k = (1/11{,}604) eV/K$; 1Å=1A=0.1nm

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

de Broglie: $\lambda = \dfrac{h}{p}$; $f = \dfrac{E}{h}$; $\omega = 2\pi f$; $k = \dfrac{2\pi}{\lambda}$; $E = \hbar\omega$; $p = \hbar k$; $E = \dfrac{p^2}{2m}$

Uncertainty: $\Delta x \Delta k \sim 1$ $\Delta t \Delta\omega \sim 1$; $\Delta x \Delta p \sim \hbar$ $\Delta t \Delta E \sim \hbar$; $\Delta A = \sqrt{< A^2 > - < A >^2}$

$\hbar c = 197.3$ eV nm

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Problem 1 (6 points)
When light with wavelengths in the range 200 nm to 700 nm is incident on a metal surface, the stopping potential is 3.5 Volts.
(a) What is the stopping potential when the incident light has wavelengths in the range 400 nm to 600 nm? Give your answer in Volts.
(b) For what range of incident wavelengths will no photoelectric occur for this metal? I.e. no photoelectron will be emitted? Give your answers in nm.

Problem 2 (6 points)
Assume that you are floating naked in outer space far from any star (so no light is incident on you), and that you emit radiation as a black body. And that you are alive and don't have a fever.
(a) At what wavelength do you emit maximum power per unit wavelength? Give your answer in nm. Will another person floating near you see you? Justify your answer qualitatively.
(b) Estimate how many hamburgers do you have to eat every day to keep your temperature steady. A food calorie is 4184 Joules. Justify your answer.

Problem 3 (6 points)
In a Compton scattering experiment with incident photons of wavelength $\lambda_c=h/(m_e c)=0.00243$nm, the kinetic energy of some of the outcoming electrons is $m_e c^2/2=255{,}500$ eV.
(a) What is the wavelength of the photons that scattered off those electrons, in nm?
(b) At what angle do those scattered photon move relative to the incident direction? Give your answer in degrees.
Hint: for this problem it is easier to deal with symbols instead of with numbers.

Problem 4 (6 points)
An electron and a positron are moving towards each other, each has momentum $p=\sqrt{3}m_e c$. When they annihilate, two photons are emitted that move in opposite direction. Find
(a) The momentum of each photon, in units eV/c.
(b) The wavelength of each photon, in nm.

Problem 5 (6 points)
A beam of electron each with momentum 2000eV/c is moving in the horizontal direction towards a screen alligned perpendicular to the beam, that has an opening of diameter 1nm. Using the uncertainty principle, estimate at which range of angles with respect to the horizontal direction will the electrons emerge on the other side of the screen. Give your answer in degrees.