PHYSICS 2D QUIZ 2 FALL QUARTER 2023
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: $\lambda_m T = 2.8978\times 10^{-3} m\cdot K$

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

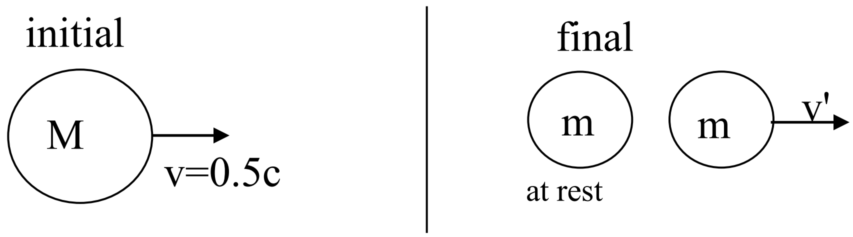
Boltzmann distribution: $N(E) = Ce^{-E/kT}$; $N = \int_0^\infty N(E)\, dE$; $E_{av} = \dfrac{1}{N}\int_0^\infty EN(E)\, dE$

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

Problem 1 (6 points)



A particle of given mass M is moving at speed v=0.5c. It undergoes a fission process resulting in two particles of equal mass m, one of them at rest and the other moving at speed v'.
(a) Assuming classical physics is valid, find m in terms of M and find v' as a number times c.
(b) Assuming relativity is valid, find m in terms of M.
HINT: transform to a frame O' moving with speed v to the right.
(c) Find the difference in the total kinetic energy of the particles before and after the fission process (in terms of M and c).

Problem 2 (6 points)
An electron has momentum p=0.511MeV/c
(a) Find its kinetic energy, in MeV.
(b) Find its speed. Give your answer as a number times c.
(c) Find the answers for (a) and (b) assuming classical physics is valid instead.

Problem 3 (6 points)
When light of wavelengths in the range 300 nm to 350 nm is incident on a metal, the maximum kinetic energy of emitted electrons is twice as large as when light of wavelengths in the range 400 nm to 500 nm is incident on that metal.
For what range of incident wavelengths will there be no photoelectrons emitted?

Problem 4 (6 points)
A sphere emits 5000 W of thermal radiation, with maximum intensity at wavelength 1000 nm. Assume the sphere is a blackbody.
(a) What is the temperature at the surface of the sphere?
(b) What is the radius of the sphere, in centimeters?
(c) What is the temperature at the center of the sphere?

Problem 5 (6 points)
A blackbody at temperature T emits maximum power per unit wavelength at wavelength λ=100nm. It emits 1,000 W/nm at that wavelength.
(a) How much power per unit wavelength does it emit at wavelength λ=200nm? Give your answer in W/nm.
(b) How much power per unit wavelength does it emit at wavelength λ=100nm if it's temperature is doubled? Give your answer in W/nm.