

**Midterm #1**

Some useful constants and relations:

$m_e = 9.11 \cdot 10^{-31} \text{ kg}$	$e = 1.6022 \cdot 10^{-19} \text{ C}$	$h = 6.6261 \cdot 10^{-34} \text{ J-s}$
$m_e = 0.511 \text{ MeV} / c^2$	$W = q V$	$h = 4.1357 \cdot 10^{-15} \text{ eV-s}$
$m_\mu = 106 \text{ MeV} / c^2$	$1 \text{ eV} = 1.6022 \cdot 10^{-19} \text{ J}$	$hc = 1240 \text{ eV-nm}$
$c = 3.0 \cdot 10^8 \text{ m/s}$	$1 \text{ MeV} = 10^6 \text{ eV}$	$\hbar = h / 2\pi = 1.0546 \cdot 10^{-34} \text{ J-s}$
$\lambda v = c$	$1 \text{ GeV} = 10^9 \text{ eV}$	$\hbar = 6.5821 \cdot 10^{-16} \text{ eV-s}$
$1 \text{ nm} = 10^{-9} \text{ m}$	$R_\infty = \frac{E_0}{hc} = 1.09737 \cdot 10^7 \text{ m}^{-1}$	$a_0 = \frac{4\pi\epsilon_0 \hbar^2}{me^2} = 0.53 \cdot 10^{-10} \text{ m}$
$1 \text{ MHz} = 10^6 \text{ s}^{-1}$	$\lambda T = 2.898 \cdot 10^{-3} \text{ m-K}$	
$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$	$\int dx \sin^2 x = \frac{x}{2} - \frac{1}{4} \sin 2x$	

1. [4 points] The muon has a lifetime of  $2.2 \cdot 10^{-8} \text{ s}$  in its rest frame, after which it decays into an electron and two neutrinos.

(a) How far does it travel at a velocity  $v = 0.98c$  before decaying? The velocity and distance are measured in a laboratory considered to be at rest.

(b) Calculate the kinetic energy available in the muon decay in the rest frame of the muon (not the laboratory frame). The muon has a mass 207 times larger than the electron ( $m_\mu c^2 = 106 \text{ MeV}$ ). The neutrinos are considered massless.

2. [4 points] The work function for magnesium is  $\phi = 3.7 \text{ eV}$ .
- (a) What is the threshold frequency for the photoelectric effect on magnesium?
- (b) What is the stopping potential if the wavelength of the incident light is 248 nm?
3. [3 points] Estimate the surface temperature of the Sun if the emitted electromagnetic radiation peaks at a wavelength of 500 nm.
4. [3 points] Calculate the wavelength of the first spectral line in Balmer series, which is a transition from  $n = 3$  to  $n = 2$  in the Bohr model.

5. [3 points] Electromagnetic radiation of wavelength 102.5 nm is incident upon the hydrogen atom in its ground state. What is the highest state to which hydrogen can be excited?
6. [3 points] Calculate the deBroglie wavelength of a muon travelling at a velocity of  $v = 0.98c$ . The muon has a mass 207 times larger than the electron ( $m_e c^2 = 0.511 \text{ MeV}$ ).
7. [3 points] An unstable particle called the Z particle is measured to have an average mass of 91 GeV with a spread of 2.5 GeV (energy width) around this value. What is the minimum bound on its lifetime? ( $1 \text{ GeV} = 10^9 \text{ eV}$ ).
8. [3 points] An electron is located to a precision of  $0.5 \cdot 10^{-10} \text{ m}$  along the x-axis. What is the minimum uncertainty of its velocity along this axis?