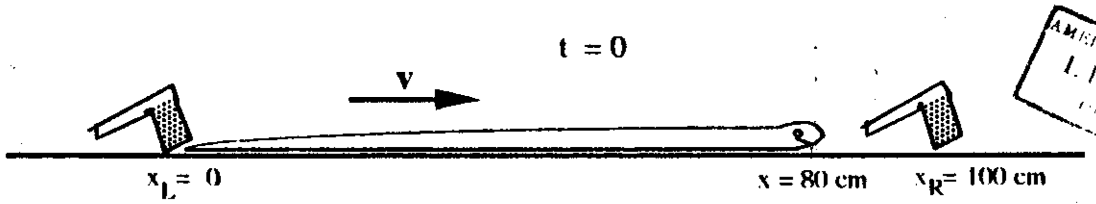
Final Exam **Phys. 212 (Intro. Mod.Physics)** 29 Jan., 1996

1)- A relativistic snake of proper length 100 cm is moving at speed $v = 0.6c$ to the right across a table. A mischievous boy, wishing to tease the snake, holds two hatchets 100 cm apart and plans to bounce them simultaneously on the table so that the left hatchet lands immediatly behind the snake's tail. The boy argues as follows: "The sanke is moving with $\beta = 0.6$. Therefore its length is contracted by a factor of $\gamma = 5/4$, and its length (as measured in my rest frame) is 80 cm. This implies that the right hatchet will fall 20 cm in the front of the snake, and the snake will be unharmed." (The boy's view of the experiment is shown below.) On the other hand, the snake argues thus: "The hatchets are approaching me with $\beta = 0.6$, and the distance between them is contracted to 80 cm. Since I am 100 cm long, I shall be cut in pieces when they fall." Use the Lorentz transformation to resolve this paradox.



[As seen in the boy's frame]

2)- A particle of unknown mass M decays into two particles of known masses $m_1 = 0.5$ Gev/c^2 and $m_2 = 1$ Gev/c^2, whose momenta are measured to be $P_1 = 2$ Gev/c along the y-axis and $P_2 = 1.5$ Gev/c along the x-axis. Find the unknown mass M and its speed.

3)- Observers in two separate spaceships O and O', travelling along the x-axis, have a relative speed v $= 2.4\times10^8$ m/s. Observer O' fires a space torpido <u>backward toward O</u> at a speed of 1.8×10^8 m/s What is the torpido's speed and travel direction according to observer O.

4)- A potassium chloride (KCl) crystal is cut so that the layers of adjacent atomic planes parallel to its surface have a spacing of 314 pm between them. A beamof 380-eV electrons is incident on the crystal surface. Calculate the angle of incidence θ required to obtain a strongly diffracted beam.

5)- An electron and a positron , each trevelling at 0.80c in opposite directions, collide and are annhilated in the form of radiation. Calculate (and compare) (a) the wavelengths and (b) the momenta of the positron and of the photons formed.

6)- The lifetime of an excited state in a hydrogen atom is about 10^{-8} sec. (It isthe time that the electron spends in the excited state before jumping to a lower state.)
(a) Compute the spread in energy of the emitted photon.
(b) If the emitted photons are in the visble spectrum ($\lambda \approx 4000$ A°), calculate the line width in angstroms.
(c) If the excited state has n = 4, thus according to the Bohr model, how many revolutions will the electron make before jumping to a lower state?

7)- Angular momentum is a vector and you might expect that it would take three quantum numbers to describe it, corresponding to three space components of a vector. Instead, in an atom only two quantum numbers characterize the angular momentum. Could you explain why.

8)- Label as true or false these statements involving the quantum numbers n, l, m_l.
(a) One of these subshells cannot exist: $n = 2, l = 1$; $n = 4, l = 3$; $n = 1, l = 1$.
(b) The number of values of m_l that are allowed depends on n and on l.
(c) The smallest value of n that can go with a given l is $l + 1$.
(d) Every shell contains $n - 1$ subshells.

9)- What is the wavelength of a photon that will induce a trasition of an electron spin from parallel to antiparallel orientation in a magnetic field of 190 mT? Assume that $l = 0$

10)- The energy associated with the fine structure splitting is given by: $\Delta E_{SO} = -\mu_s \cdot B_L$;
but μ_s is antiparallel to S, and B_L is parallel to L; hence we can also write: $\Delta E_{SO} = b\,\mathbf{L}\cdot\mathbf{S}$
where b is known as the spin-orbit interaction constant.
(a) Show (in terms of the quantum numbers j, l, and s) that the dot product
$\mathbf{L}\cdot\mathbf{S} = 1/2\{j(j + 1) - l(l + 1) - s(s + 1)\}\hbar^2$
(b) Prove that, for the case hydrogen or hydrogen-like atoms, we have $\Delta E_{SO} = 1/2b\, l(l + 1)\hbar^2$

11)- A neutron star is a stellar object whose density is about that of nuclear matter. (a) Estimate this density. (b) Suppose that the sun were to collapse into such a star without losing any of its present mass (2×10^{30} Kg),what would its expected radius be?

12)-
I) What information indicates that α decay must be a quantum mechanical tunnelling process?
II) Why did physicists believe in the existence of neutrinos for many years although they had not yet directly observed them? explain.

13)-
A) Briefly describe the ***liquid-drop model*** and the ***shell model*** (for the nucleus binding energy).
B) Which of these two models is useful in explaining:
i) Why $Z \approx N$ for small-mass nuclei?
ii) Why very large mass nuclei are unstable?
iii) The low B/A values for low-mass nuclei?
iv) The extraordinary stability of a nucleus with Z and/or N equal to a magic number?
Justify your answer.

SELECTED CONVERSION FACTORS

1 sec = 1.667×10^{-2} min = 2.778×10^{-4} h = 3.169×10^{-8} yr
1 m = 39.4 in. = 3.28 ft
1 Å (angstrom) = 10^{-10} m = 10^{-4} μ (micron)
1 AU (astronomical unit) = 1.496×10^{11} m
1 light year = 9.499×10^{15} m
1 kg = 2.205 lb
1 amu (atomic mass unit) = 1.6604×10^{-27} kg = 931.48 MeV
1 J = 0.239 cal = 6.242×10^{18} eV
1 cal = 4.186 J = 2.613×10^{19} eV
1 eV (electron volt) = 1.6022×10^{19} J
1 N = 0.225 lbf

MOST COMMON REST MASSES AND ENERGIES

NAME	SYMBOL	REST MASSES (kg)	REST MASSES (amu)	REST ENERGIES (J)	REST ENERGIES (MeV)
atomic mass unit	amu	1.6604×10^{-27}	1.000000	1.4922×10^{-10}	931.48
proton	m_p	1.6725×10^{-27}	1.007287	1.5031×10^{-10}	938.26
neutron	m_n	1.6748×10^{-27}	1.008665	1.5052×10^{-10}	939.55
electron	m_e	9.1091×10^{-31}	0.000549	0.8186×10^{-13}	0.5110
hydrogen atom	m_H	1.6734×10^{-27}	1.007829	1.5038×10^{-10}	938.72

PHYSICAL CONSTANTS

CONSTANT	SYMBOL	VALUE AND UNITS
Avogadro's number	N_A	6.0222×10^{26} (kg-mole)$^{-1}$
speed of light (vacuum)	c	2.9979×10^{8} m/sec
universal gas constant	R	8.3143 J/mole-°K
Boltzmann's constant	$k = R/N_A$	1.3806×10^{-23} J/°K
mechanical equivalent of heat	J	4.1855 J/cal
vacuum permittivity	ε_0	8.8541×10^{-12} F/m
vacuum permeability	μ_0	$4\pi \times 10^{-7}$ H/m
gravitational constant	G	6.673×10^{-11} N-m^2/kg^2
Planck's constant	h	6.6262×10^{-34} J-sec
Dirac's constant	$\hbar = h/2\pi$	1.0546×10^{-34} J-sec
electronic charge	e	-1.6022×10^{-19} C
electron Compton wavelength	λ_0	2.4262×10^{-12} m
gyromagnetic ratio	$e/2m_e$	8.7940×10^{10} C/kg
electron Bohr magneton	$\mu_B = e\hbar/2m_e$	9.273×10^{-24} J/T
proton Bohr magneton	$e\hbar/2m_p$	5.050×10^{-27} J/T
nuclear magneton	μ_N	5.090×10^{-27} J/T
proton magnetic moment	μ_{pz}	$2.7928\mu_N$
neutron magnetic moment	μ_{nz}	$-1.1913\mu_N$
Rydberg constant	R_∞	1.0974×10^{7} m^{-1}
Bohr radius	r_1	5.2917×10^{-11} m