Boğaziçi University
Department of Physics

Phys 311 Fall 2006

Midterm #1

1 Nov 2006

Closed book/notes – No calculators – 50 minutes

Useful constants and formulae.

$h = 6.6261 \times 10^{-34}$ J·s	$c = 2.9979 \times 10^{8}$ m/s	$N_A = 6.022 \times 10^{23}$
$c = 2.9979 \times 10^{8}$ m/s	$\alpha = 1/137.036$	$\sigma = 5.68 \times 10^{-8}$ W/(m^2·K^4)
$\mathrm{d}R/\mathrm{d}\lambda = \frac{2\pi hc^2}{\lambda^5(e^{hc/\lambda kT}-1)}$	$\lambda_{max} = \frac{2.9\times10^{6}\ \mathrm{nm}\cdot K}{T}$	$m_p \approx m_n \approx 1.67 \times 10^{-27}$ kg
$-q_e = q_p = 1.6 \times 10^{-19}$ C	1 eV $= 1.6 \times 10^{-19}$ J	$m_p \approx m_n \approx 938$ MeV/c^2

Question 1: (20 pts)
List all known fundamental forces in nature. Make a table showing **a)** their relative strengths (in words or numbers), **b)** the range in which they are noticeable (in words), **c)** their force carriers (mediators), **d)** give example particle pairs between which this force can be effective.

Question 2: (20 pts)
Assume that you have a large amount of antiprotons contained by a system. There is a beam of very low energy protons bombarding this antiproton container with a constant rate, and each proton entering the container is being annihilated with an antiproton ($p + \bar{p} \rightarrow \gamma + \gamma$); the mass energy is converted to radiation, consequently it is heating the system. What should be the current of proton beam in mA (milli-amperes) in order to get 2 MW of power by means of heat from this system?

Question 3: (25 pts)
Two protons approach each other with same kinetic energies in the lab-frame (S-frame); $T_1 = T_2 = 938$ MeV. If we observe the system in a frame where one of the proton is at rest (S'-frame):

a) What would be the kinetic energy of the other proton?

b) Compare this to the total kinetic energy of the system in the lab-frame. Which frame of reference has the advantage in using less total energy for exactly the same reaction?

[Hint 1: This question is perfectly doable without a calculator using the relativistic speed conversion formula. However, if you use the fact that the square of the total of four-momentums of two particles are *invariant* under frame transformations, you may find the answer quickly. Hint 2: Take $c = 1$ in order not to make any mistake in units, then restore it when needed.]

Question 4: (20 pts)
Say, we send a spherical probe toward Sun with various delicate electronics onboard. If the upper limit of temperature for the normal operation of electronics is T_{max}, how close can this probe approach to Sun before the electronics fail? Give your result in terms of L_{sun} (total power output of Sun), σ, and T_{max}.

Question 5: (15 pts)
If we put a piece of cold metal into a very hot oven, does it glow red or blue first? State your reasoning clearly.