PHY 556/714: Handout 1

Date: 09/11/2007

From: Krishna S. Kumar, mailto:kkumar@physics.umass.edu, LGRT 421, 5-1310

RE: *Topics, Reading & Assignment, lectures 1 thru 6, 09/04/07 thru 9/25/07*

We began the first lecture with a historical overview of subatomic physics. Next, we reviewed relativistic kinematics. We will now discuss scattering phenomena and decays. This will introduce us to the experimental foundations of the substructure of matter. In lecture 6, we will begin a three-lecture discussion of symmetries and conservation laws; these concepts form an important basis for the theoretical foundations of nuclear and particle physics.

Main Reading:

Griffiths: Chapters 2, 3 and the early parts of chapter 4.

Supplementary Reading:

Povh et. al., Chapters 4 thru 7

Frauenfelder and Henley, Chapters 5 and 6

Homework Assignment 1 *(due 9/27)*

1) Cosmic ray muons are produced high in the atmosphere (at 8000 m, say) and travel towards the earth at very nearly the speed of light (0.998 c, say)

   a. Given the lifetime of the muon (2.2×10^{-6} s), how far would it go before disintegrating, according to pre-relativistic physics? Would the muons make it to ground level?

   b. Now answer the same question using relativistic physics.

2) A pion is traveling at speed v decays into a muon and an anti-neutrino. If the anti-neutrino emerges at 90 degrees to the original pion direction, show that the muon comes off at an angle given by $\tan\theta = (1 - m_\mu^2 / m_\pi^2)/(2\beta\gamma^2)$.

3) Show that, if the pion were at rest, on average, the muon will travel (in vacuum) a distance $d = \left[\left(m_\pi^2 - m_\mu^2\right)/\left(2m_\pi m_\mu\right)\right]c\tau$. Here, τ is the lifetime of the muon in its own rest frame.

4) Determine the pion threshold kinetic energy for pions incident on a hydrogen target producing a Lambda and a Kaon: $p+\pi^- \rightarrow \Lambda^0 + K^0$. The masses (in units of MeV/c^2) of the 4 particles respectively, are 938.3, 139.6, 1115.7 and 497.7.

5) Suppose electrons are not point-like, but have a radius of 10^{-19} m. Estimate the energy to which electron and positron beams need to be accelerated in an e^+e^- collider experiment to establish this. (Hint: You start by figuring out the wavelength of the virtual photon that is required to probe the specific length scale, from which you can get an order-of-magnitude estimate of the squared 4-momentum transfer or q^2). What beam energy is required to obtain the same q^2 in collisions of energetic electrons on a heavy atom target (consisting of about 100 nucleons)?

6) In the elastic scattering of 200 MeV electrons through 11 degrees by a gold foil, it is found that the scattered intensity is 70% of what is expected for point nuclei. Calculate the r.m.s. radius of the gold nucleus.

Following for 556 students only:

7) What is the speed (expressed as a fraction of the speed of light) of a particle whose kinetic energy is equal to its rest energy?

8) What is the difference is speed of a 20 GeV electron and a 50 GeV electron, expressed in units of cm/s? (You should do this problem by hand, since your calculator is unlikely to be able to keep up with the required number of significant digits).

Following for 714 students only:

9) In electron scattering of ^{12}C nuclei with incident beam energy of 194 MeV and scattering angle of 135 degrees, a peak at $\nu = E - E'$= 5.58 MeV and a broad peak near ν = 51 MeV is observed. Account for their origin and speculate why the peak is broad.

10) (Compton Scattering) A photon of wavelength λ collides elastically with a charged particle of mass m at rest. If the photon scatters an angle θ, show that the outgoing photon wavelength is given by $\lambda' = \lambda + (h/mc)(1-\cos\vartheta)$