Problem sheet 1 - Physics V - WS 2006/2007

Due: October 26/27, 2006

Problem 1.1 Resolution (20P)

Which photon energy (in eV) is needed to resolve the following objects?

1. virus   2. water molecule   3. proton

Problem 1.2 Particle Zoo (20P)

Give three examples for each of the following classes of particles:

1. hadron	2. meson	3. lepton
4. exchange boson	5. fermion	6. baryon

Problem 1.3 Comparing Forces (30P)

Quarks carry electric charge as well as color charge. The electric potential energy V_{Coulomb} between two quarks is simply given by

$$V_{\text{Coulomb}} = -\frac{\alpha}{r} q_1^e q_2^e,$$

where $\alpha = 1/137$ is the e.m. coupling constant, r is the distance between the two quarks, and $q_{1/2}^e$ are the electric charges of the quarks in fractions of the unit charge e. The potential energy due to exchange of gluons V_{color} between two quarks of different color is of the form

$$V_{\text{color}} = -\frac{4}{3}\frac{\alpha_S}{r} + kr,$$

where $k = 4.31\ \text{fm}^{-2}$ is an empirical factor quantifying the strength of the confinement, $-4/3$ is the color factor for two quarks of different color, and α_S is the strong coupling constant.

1. Calculate the size of the two forces between a pair of u-quarks at a distance of 2 fm in natural units and SI units. You may assume $\alpha_S \sim 1$, but is it important?
2. What is the gravitational force at that distance? (u-quark mass $m_u = 3$ MeV)
3. Calculate the ratio of electromagnetic and gravitational force F_C/F_G for a particle with unit charge e and Planck mass M_P, where in SI units $M_P = \sqrt{\frac{\hbar c}{G_N}} = 2.176 \times 10^{-8}$ kg.

Problem 1.4 Relativistic Kinematics (30P)

The particle A with mass M_a and four-momentum p_a^μ decays into two lighter particles B and C with masses m_b and m_c.

1. Give the total energy of particle B (E_b) in the rest frame of particle A as a function of M_a, m_b, and m_c.
2. Let A be a charged pion which decays into a lepton and a neutrino. Use the PDG particle listings [1] to look up the main decay channel of the π^- (99.99%). Use the approximation $m_\nu = 0$ for the mass of the neutrino and calculate the kinetic energy of the neutrino in the rest frame of the π^-.

[1] PDG: http://pdg.lbl.gov
PDG Particle listings: http://pdg.lbl.gov/2006/listings/contents_listings.html