STONY BROOK UNIVERSITY
DEPARTMENT OF PHYSICS AND ASTRONOMY

Placement Examination **Electricity and Magnetism**, August 31, 2006

General instructions: Three problems are given. You should do any two. Each problem counts 20 points and the solution should typically take less than 45 minutes. Use one exam book for each problem and label it carefully with your name, the name of the problem's author and the date. You may use a one page help sheet, a calculator, and with the proctors approval a foreign language dictionary. No other materials may be used.

EM1

Consider a spherically symmetric charge distribution with density

$$\rho(r) = C\exp(-r/r_0).$$

a) (5 points) Calculate the total charge.
b) (7 points) Find and sketch the electric field distribution $E(r)$.
c) (8 points) Find and sketch the electrostatic potential distribution $\varphi(r)$.

EM2

A hollow waveguide of rectangular cross-section $a \times b$ is used for the transmission of electromagnetic waves. Assume that the walls are perfect conductors.

a) (5 points) For the lowest transverse electric (TE) mode, calculate and sketch the dispersion relation, i. e. the relation between frequency ω and longitudinal wavenumber k. (In TE modes, the electric field is perpendicular to the propagation direction at all points.)
b) (3 points) For $a = 3$ cm and $b = 1$ cm, find the "cutoff" (lowest) frequency ω_c of this mode.
c) (7 points) For the same waveguide as in (b), find the frequency range in which the lowest TE wave is the only propagating mode.
d) (5 points) Now let the waveguide be excited, at its end, by a source of frequency $\omega_c / 2$. Calculate the ratio of electric field amplitudes at the distances 5 cm and 10 cm from the end.

EM3

A radiating electric dipole consists of a rod of length l with charge $+q$ at one end and charge $-q$ at the other end. The rod lies in the $[x, y]$ plane and rotates about the $z-$axis with angular velocity ω. Calculate:

a) (4 points) the dipole moment,
b) (8 points) the angular distribution of the radiation power, $dP/d\theta$, and
c) (8 points) the total radiation power P.