PHYSICS 415 - Fall Semester 2025 - ODU

## Nuclear and Particle Physics - Problem Set 3

### Problem 1)

An electron beam of 2.5 GeV energy impinges on a proton target. Calculate the elastic differential cross section $d\sigma/d\Omega$ for a scattering angle $\theta = 90^o$. Use Eqs. (5.39, 6.1-6.3, 6.6, 6.10) and the dipole form factors given in Eq. (6.12) in the book. List all relevant kinematic variables (E', $Q^2$, $\nu$, $\tau$…) Compare your result to the case where the proton is a point-like elementary particle, i.e., all form factors are equal to 1.
*Hinst*: For elastic scattering, $E' = \frac{E}{1+\frac{2E}{M}(\sin\theta/2)^2}$. Keep in mind that you can ignore all factors of *c* if you use $\alpha = 1/137.033$ and $\hbar c = 0.19733$ fm·GeV.

### Problem 2)

For the case described above, assume someone at Jefferson Lab wants to measure this cross section (take your result for the real form factors) with a detector of aperture 1cm x 1cm at a distance of 0.2 m from the target. Assume the latter consists of a 5 cm long "can" with liquid hydrogen at 20K in it. (Quote your reference for the density! You may ignore the complications from a finite target length in calculating the solid angle – just use the middle of the target as your reference point and assume the detector sits at 90 degrees relative to that). Also assume that you can run a current of 100 μA electrons into that target. How long will your experiment need to run to measure the cross section with at least 10% accuracy?
*Hint*: Remember Poisson statistics: if the expectation for the number of counts is N, then the statistical uncertainty on that number is $\sqrt{N}$.