1. (20 pts) Consider a quadrupole ion trap mass analyzer that has the ideal electrode geometry (i.e. \( r_0^2 = 2z_0^2 \)). While maintaining its ideal geometry, suggest 4 ways that the mass range of a quadrupole ion trap can be extended.

2. (20 pts) Consider an ion with a m/z of 1000 that is oscillating in an FTICR cell that has a magnetic field of 9.4 T. How far will this ion travel during the detection event if its oscillation radius is 5 cm, and the detection event lasts for 10 sec? Assume that the ion does not undergo any collisions during this 10 sec detection event.

3. (10 pts) You are interested in measuring low ion signals (100 ions/sec) coming through a quadrupole mass analyzer. If you use a Faraday cup, how long would you need to integrate to obtain a signal-to-noise (S/N) ratio of 10, assuming the detector has a noise level of \( 0.4 \times 10^{-15} \) Amps? (Hint: the S/N ratio increases as the square root of the integration time.)

4. (10 pts) You are interested in measuring low ion signals (100 ions/sec) coming through a quadrupole mass analyzer. If you use an electron multiplier that has a gain of \( 10^5 \), how long would you need to integrate to obtain a signal-to-noise (S/N) ratio of 10, assuming the detector has a noise level of \( 0.4 \times 10^{-15} \) Amps? (Hint: the S/N ratio increases as the square root of the integration time.)

5. (20 pts) What is the frequency difference (in Hz) between ions at m/z 1000 and 1001 when the ion at m/z 1000 is stored at a \( q_x \) value of 0.2500 in a quadrupole ion trap operated with a rf drive frequency of 1.100 MHz? What is the frequency (in Hz) difference between ions at m/z 1000 and 1001 when the ion at m/z 1000 is stored at a \( q_x \) value of 0.7800 in the same quadrupole ion trap? The equations below will be helpful.

\[
\beta_z \approx \left( a_z + \frac{q_x^2}{2} \right)^{\frac{1}{2}}
\]

\[
\beta^2 = \frac{q^2}{2 + \beta^2} - \frac{q^2}{(4 + \beta^2 - a - \beta - \sqrt{a^2 + \beta^2 - a - \beta})^2} - \frac{q^2}{(\beta - 2)^2 - a - \beta - \sqrt{a^2 + \beta^2 - a - \beta})^2} - \frac{q^2}{(\beta - 4)^2 - a - \beta - \sqrt{a^2 + \beta^2 - a - \beta})^2} - \cdots
\]

6. (20 pts) Consider Selected Reaction Monitoring (SRM) in a “triple” quadrupole mass analyzer (See SRM article posted on-line for more details).
   a. Explain what is meant by a “dwell time” in SRM
   b. Why does SRM provide better signal-to-noise (S/N) ratios for a given analyte than regular mass analysis that is done on a scanning single quadrupole mass analyzer? For part of the answer to this question, consider the concept of dwell time and the fact that typical mass analysis on a quadrupole is done by scanning the quadrupole at 2000 Da/s. Use simple math to explain why the S/N would better in SRM than normal mass analysis.

**Important Note 1**: You are to work on this problem set by yourself. You are welcome to use any resource you want EXCEPT for another person in the class. *If you need help, then please ask me.*

**Important Note 2**: This problem set is due **Monday March 28, 2016**. Any problem set turned in late will be subject to a 25% penalty for each day that it is late.