1. [3 points] Griffiths 2.43 (capacitance per unit length of concentric cylinders).

2. [4 points] Four conducting spheres of equal radii are arranged as shown in a perfect square pattern. We use the notation that $Q_i$ are the total charges on each sphere and $V_i$ are the potentials (referred to infinity as usual).

We start with all the spheres neutral (all $Q$’s and $V$’s are zero). Making use of uniqueness and symmetry, what can you say about the charges and potentials on the spheres after each step of the following process? (For example, I give the answer to part (a)).

(a) A charge $q$ is added to sphere 2. (Answer: $Q_2 = q$, $Q_1 = Q_3 = Q_4 = 0$; and we can’t say much about the $V$’s except $V_1 = V_4$.)
(b) A wire is temporarily connected between spheres 1 and 2 and then removed.
(c) Next, a charge $q$ (same amount as in step (a)) is added to sphere 3.
(d) Next, a wire is temporarily connected between spheres 3 and 4 and then removed.

3. [4 points] Consider Earnshaw’s theorem for the case of a positive test charge $Q$ at the origin surrounded by eight fixed positive charges $q$ at $r' = (\pm 1, \pm 1, \pm 1)$, i.e., on the corners of a surrounding cube. It seems like the charge $Q$ should be trapped. However, write a formula for how the potential $V(r)$ coming from the eight corner charges (i.e., ignoring $Q$) behaves along the $x$ axis, i.e., for $r = (x, 0, 0)$. Then use a calculator or other computational device to report the values of the potential energy $QV(r)$ of the test charge for several small values of $x$. What do you find? (You can express your results “in units of $Qq/4\pi \varepsilon_0$."

4. [4 points] Griffiths 3.7 (force on one of two point charges above conducting plane).

5. [5 points] An infinitely long cylinder of radius $a$ and carrying uniform interior charge density $\rho$ runs parallel to the $x$ direction with its axis lying a distance $d$ above a grounded conducting plane at $z=0$. (Of course, $a < d$.)

(a) Find the potential $V(x, y, z)$ in the region above the conducting plane and outside the cylinder. (Hint: You may use “standard results” for the potential from an infinite line charge.)
(b) Show that the surface charge induced on the conducting plane is $\sigma(x, y) = -a^2 \rho d/(y^2 + d^2)$. 