1. To the right, is a depiction of an electroscope similar to the one that will be used in the lab. It is composed of a metal sphere connected to the top of a metal rod and a folded piece of thin metallic foil attached at the bottom. These three components are connected conductively, but insulated from the outer shell of the electroscope. When the foil has no net-charge, the folds lie vertically, but when it does possess net charge, the folds repel each other.

   ![Diagram of an electroscope]

a) A charged rod is brought near to the surface of the sphere. What can be said about the net charge on the foil? Be specific.

   It has an induced charge of the same type as the rod
   \[ +1 \]

b) What is the net-charge of the electroscope? [1 pt]

   The net charge on the electroscope is zero
   \[ +1 \]

c) The charged rod makes contact with the sphere and is removed from the vicinity of the electroscope. What state is the electroscope in? [1 pt]

   The folds of the foil are repelling each other
   \[ +1 \]

d) With respect to part b), what is the net-charge on the foil? What is the net-charge of the electroscope? [1 pt]

   The foil now has the same charge as it did in part b). The net-charge on the electroscope is the same as it is on the foil
   \[ +1 \]

e) Based on your observations, can you deduce whether the charge on the rod is “positive” or “negative”? [1 pt]

   No, there is no way to tell what is positive or negative
   \[ +1 \]
f) Assume that the rod being used has had a "positive" charge which it gains after being rubbed vigorously with a cloth. Explain what is happening to the rod during this process.

The cloth is stripping the rod of electrons, creating a net positive charge.

\[ +1 \text{ For similar logical answers} \]

g) While touching the sphere with your finger, the rod is brought near the sphere. Then you remove your finger, followed by the rod. On the diagram below, sketch the foil and the charge distribution on the sphere and foil. What purpose is your finger serving? [2 pts]

My finger is acting as a "ground" or an infinite reservoir of charge. Thus, the positively charged rod is drawing electrons away from the foil and into the ground.

\[ \text{or similar} \quad +1 \]

h) What is the significance of the order you removed your finger and the rod in part g), what if the order were reversed? [1 pt]

If the order were reversed, your finger would ground the electroscope with no electric field present. Thus, it would possess no net-charge.

2. Two point charges are separated by a distance of 2 meters. Draw electric field lines of the point charges on the diagram below: [1 pt]

\[ \text{Diagram of electric field lines with charges labeled 1q and 2q, with field lines extending from charges to point P.} \]
The point $P$ is located 2 meters below the point charge on the right. If $q = 1 \text{nC}$, what is the contribution to the magnitude and direction of the electric field at point $P$:

$n = \text{nano-} = 10^{-9}$

a) ... from the $-2q$ charge?

$$E = \frac{kq}{r^2} = \frac{9 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2 \cdot -2 \mu\text{C}}{4 \text{m}^2}$$

$$\propto +4.50 \text{ N/C} \hat{y}$$

b) ... from the $+3q$ charge?

$$E = \frac{E_1}{r^2} = \frac{9 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2 \cdot 3 \mu\text{C}}{8 \text{m}^2}$$

$$\propto 3.38 \text{ N/C}$$

$$E_x = E \cos 15^\circ \approx 2.39 \text{ N/C}$$

$$E_y = E \sin 15^\circ \approx -2.39 \text{ N/C}$$

c) ... from both charges? Sketch a rough estimation of the direction on the diagram below.

[HINT: Pay attentions to vectors!] [2 pts]

$$E_{\text{Total}, x} = 2.39 \text{ N/C}$$

$$E_{\text{Total}, y} = 4.50 - 2.39 = 2.11 \text{ N/C}$$

$$\Rightarrow \theta \approx 45^\circ$$

$$E_{\text{Total}} = \sqrt{2.39^2 + 2.11^2} \propto 3.19 \text{ N/C}$$

d) What force would a point charge of $+2\text{nC}$ feel at point $P$? [1 pt]

$$F = qE = 2\text{nC} \cdot 3.19 \text{ N/C} \propto (6.39 \times 10^{-9} \text{ N})$$

e) At a distance of 1km from the original two charges, sketch the effective electric field of the system. What charge would be observed? [1 pt]

From far away, the distance between $+3q$ and $-2q$ is negligible so the charges cancel and the remaining effective charge is $1\text{nC}$. 
3. A point charge is placed on each corner of a pentagon as shown below. What is the electric field at point Q, at the exact center of this distribution? [1 pt]

\[ \cdot q \]
\[ \cdot q \quad \cdot p \quad \cdot q \]
\[ \cdot q \quad \cdot q \]

a) Sketch the contributions to the electric field at point P from each point charge:

b) What is the electric field at point P?

The field at Q is zero. The charges cancel each other out at this point.