Name: ______________________________

CWID: ______________________________

**Calculators Not Allowed**
**No Work = No Credit**
**Write Legibly**

| Question | Points | Score |
|---|---|---|
| 1 | 10 | |
| 2 | 10 | |
| Total: | 20 | |

1. [10 points] Using only a symmetry argument, find the direction of the electric field at a field point, $(0, y_o)$, due to a ring of charge with linear charge density $\lambda = -\lambda_o \cos\theta$, where $\lambda_o$ is a **positive constant** (see Fig. 1). **To receive full credit you must explain your symmetry argument clearly.**

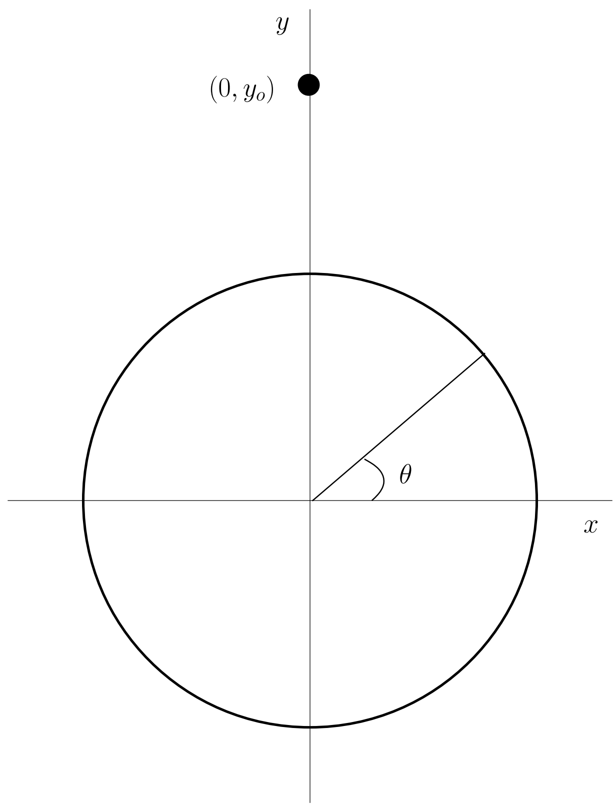


Figure 1: The circle has a linear charge density given by $\lambda = -\lambda_o \cos\theta$, where $\lambda_o$ is a **positive constant**.

2. Dipole in a 2-D world because the 3-D world is too damn hard!

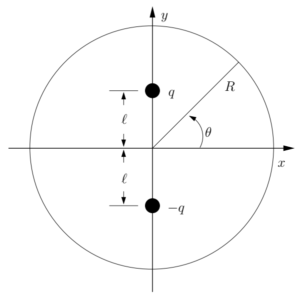


Figure 3: For the above electric dipole, $p = 2\ell q$.

(a) 6 points Find the electric field on a circle with radius $R$ due to a dipole (see Fig. 3).

(b) 4 points Find an approximate expression for the **y-component** of the electric field on the circle if $\ell/R \ll 1$ (see Fig. 3). Hint: Expand the denominator in Taylor series, $(1+\epsilon)^n = 1 + n\epsilon + \cdots$, if $|\epsilon| < 1$. You can drop any terms containing square or higher powers of $\frac{\ell}{R}$ because if $\frac{\ell}{R}$ is small, then $\left(\frac{\ell}{R}\right)^2$ is super-small. You may find the following formulas useful: $(a \mp c)(1 \pm b) = a \pm ab \mp c - bc$ and $(a + ab - c - bc) - (a - ab + c - bc) = 2(ab - c)$. It is interesting to note that $\vec{E} \cdot \hat{n} = \frac{2p\sin\theta}{4\pi\epsilon_o R^3}$.