2. Referring to Eq. 22-6, we use the binomial expansion (see Appendix E) but keeping higher order terms than are shown in Eq. 22-7:

$$E = \frac{q}{4\pi\varepsilon_o z^2}\left(\left(1 + \frac{d}{z} + \frac{3}{4}\frac{d^2}{z^2} + \frac{1}{2}\frac{d^3}{z^3} + \dots\right) - \left(1 - \frac{d}{z} + \frac{3}{4}\frac{d^2}{z^2} - \frac{1}{2}\frac{d^3}{z^3} + \dots\right)\right)$$

$$= \frac{q\,d}{2\pi\varepsilon_o z^3} + \frac{q\,d^3}{4\pi\varepsilon_o z^5} + \dots$$

Therefore, in the terminology of the problem, $E_{\text{next}} = q\,d^3/\,4\pi\varepsilon_0 z^5$.

3. Our system is a uniformly charged disk of radius R. We compare the field strengths at different points on its axis of symmetry. At a point on the axis of a uniformly charged disk a distance z above the center of the disk, the magnitude of the electric field is given by Eq. 22-26:

$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{z}{\sqrt{z^2 + R^2}}\right]$$

where R is the radius of the disk and σ is the surface charge density on the disk. The magnitude of the field at the center of the disk (z = 0) is $E_c = \sigma/2\varepsilon_0$. We want to solve for the value of z such that $E/E_c = 1/4$. This means

$$1 - \frac{z}{\sqrt{z^2 + R^2}} = \frac{1}{4} \quad \Rightarrow \quad \frac{z}{\sqrt{z^2 + R^2}} = \frac{3}{4}.$$

Squaring both sides, then multiplying them by $z^2 + R^2$, we obtain $16z^2 = 9(z^2 + R^2)$. Thus, $z^2 = 9R^2/7$, or $z = 3R/\sqrt{7}$. With R = 0.600 m, we have z = 0.680 m.

11. From symmetry, we see that the net field at P is twice the field caused by the upper semicircular charge $+q = \lambda(\pi R)$ (and that it points downward). Adapting the steps leading to Eq. 22-21, we find

$$\vec{E}_{\text{net}} = 2\left(-\hat{\text{j}}\right)\frac{\lambda}{4\pi\varepsilon_0 R}\sin\theta\Big|_{-90°}^{90°} = -\left(\frac{q}{\varepsilon_0\pi^2 R^2}\right)\hat{\text{j}}.$$

(a) With $R = 4.25\times10^{-2}$ m and $q = 1.50\times10^{-11}$ C, we obtain

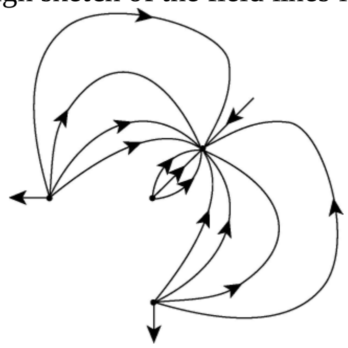
$$|\vec{E}_{\text{net}}| = \frac{q}{\varepsilon_0\pi^2R^2} = \frac{1.50\times10^{-11}\,\text{C}}{(8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2)\pi^2(4.25\times10^{-2}\ \text{m})^2} = 95.1\ \text{N/C}.$$

(b) The net electric field $\vec{E}_{\text{net}}$ points in the $-\hat{\text{j}}$ direction, or $-90°$ counterclockwise from the $+x$ axis.

32. We place the origin of our coordinate system at point P and orient our y axis in the direction of the $q_4 = -12q$ charge (passing through the $q_3 = +3q$ charge). The x axis is perpendicular to the y axis, and thus passes through the identical $q_1 = q_2 = +5q$ charges. The individual magnitudes $|\vec{E}_1|$, $|\vec{E}_2|$, $|\vec{E}_3|$, and $|\vec{E}_4|$ are figured from Eq. 22-3, where the absolute value signs for q_1, q_2, and q_3 are unnecessary since those charges are positive (assuming $q > 0$). We note that the contribution from q_1 cancels that of q_2 (that is, $|\vec{E}_1| = |\vec{E}_2|$), and the net field (if there is any) should be along the y axis, with magnitude equal to

$$\vec{E}_{\text{net}} = \frac{1}{4\pi\varepsilon_0}\left(\frac{|q_4|}{(2d)^2} - \frac{q_3}{d^2}\right)\hat{\text{j}} = \frac{1}{4\pi\varepsilon_0}\left(\frac{12q}{4d^2} - \frac{3q}{d^2}\right)\hat{\text{j}}$$

which is seen to be zero. A rough sketch of the field lines is shown below:



50. Due to the fact that the electron is negatively charged, then (as a consequence of Eq. 22-28 and Newton's second law) the field $\vec{E}$ pointing in the $+y$ direction (which we will call "upward") leads to a downward acceleration. This is exactly like a projectile motion problem as treated in Chapter 4 (but with g replaced with $a = eE/m = 8.78 \times 10^{11}$ m/s^2). Thus, Eq. 4-21 gives

$$t = \frac{x}{v_0 \cos\theta_0} = \frac{3.00 \text{ m}}{(4.00\times10^6 \text{ m/s})\cos 40.0°} = 9.80\times10^{-7} \text{ s} .$$

This leads (using Eq. 4-23) to

$$\begin{aligned} v_y &= v_0 \sin\theta_0 - at = (4.00\times10^6 \text{ m/s})\sin 40.0° - (8.78\times10^{11} \text{ m/s}^2)(9.80\times10^{-7} \text{ s}) \\ &= 1.71\times10^6 \text{ m/s} . \end{aligned}$$

Since the x component of velocity does not change, then the final velocity is

$$\vec{v} = (3.06 \times 10^6 \text{ m/s})\,\hat{\text{i}} + (1.71 \times 10^6 \text{ m/s})\,\hat{\text{j}} .$$

59. (a) The smallest arc is of length $L_1 = \pi r_1/2 = \pi R/2$; the middle-sized arc has length $L_2 = \pi r_2/2 = \pi(2R)/2 = \pi R$; and, the largest arc has $L_3 = \pi(3R)/2$. The charge per unit length for each arc is $\lambda = q/L$ where each charge q is specified in the figure. Thus, we find the net electric field to be

$$E_{\text{net}} = \frac{\lambda_1(2\sin 45°)}{4\pi\varepsilon_0 r_1} + \frac{\lambda_2(2\sin 45°)}{4\pi\varepsilon_0 r_2} + \frac{\lambda_3(2\sin 45°)}{4\pi\varepsilon_0 r_3} = \frac{4Q}{\sqrt{2}\pi(4\pi\varepsilon_0)R^2}$$

$$= \frac{4(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(4.00\times10^{-6}\ \text{C})}{\sqrt{2}\pi(0.050\ \text{m})^2} = 1.30\times10^7\ \text{N/C}$$

(b) The direction is – 45°, measured counterclockwise from the $+x$ axis.