23.2 (a) $F_e = \frac{k_e q_1 q_2}{r^2} = \frac{(8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(1.60 \times 10^{-19}\text{ C})^2}{(3.80 \times 10^{-10}\text{ m})^2} = \boxed{1.59 \times 10^{-9}\text{ N}}$ (repulsion)

(b) $F_g = \frac{G m_1 m_2}{r^2} = \frac{(6.67 \times 10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(1.67 \times 10^{-27}\text{ kg})^2}{(3.80 \times 10^{-10}\text{ m})^2} = \boxed{1.29 \times 10^{-45}\text{ N}}$

The electric force is $\boxed{\text{larger by } 1.24 \times 10^{36} \text{ times}}$

(c) If $k_e \frac{q_1 q_2}{r^2} = G\frac{m_1 m_2}{r^2}$ with $q_1 = q_2 = q$ and $m_1 = m_2 = m$, then

$$\frac{q}{m} = \sqrt{\frac{G}{k_e}} = \sqrt{\frac{6.67 \times 10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2}{8.99 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2}} = \boxed{8.61 \times 10^{-11}\text{ C/kg}}$$

23.7

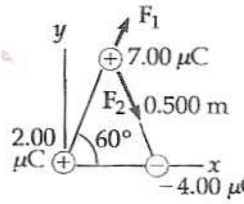
$$F_1 = k_e\frac{q_1 q_2}{r^2} = \frac{(8.99\times10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(7.00\times10^{-6}\text{ C})(2.00\times10^{-6}\text{ C})}{(0.500\text{ m})^2} = 0.503\text{ N}$$

$$F_2 = k_e\frac{q_1 q_2}{r^2} = \frac{(8.99\times10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(7.00\times10^{-6}\text{ C})(4.00\times10^{-6}\text{ C})}{(0.500\text{ m})^2} = 1.01\text{ N}$$

$F_x = (0.503 + 1.01)\cos 60.0° = 0.755\text{ N}$

$F_y = (0.503 - 1.01)\sin 60.0° = -0.436\text{ N}$

$\mathbf{F} = (0.755\text{ N})\mathbf{i} - (0.436\text{ N})\mathbf{j} = \boxed{0.872\text{ N at an angle of } 330°}$



23.11 For equilibrium, $\mathbf{F}_e = -\mathbf{F}_g$, or $q\mathbf{E} = -mg(-\mathbf{j})$. Thus, $\mathbf{E} = \frac{mg}{q}\mathbf{j}$.

(a) $\mathbf{E} = \frac{mg}{q}\mathbf{j} = \frac{(9.11\times10^{-31}\text{ kg})(9.80\text{ m/s}^2)}{(-1.60\times10^{-19}\text{ C})}\mathbf{j} = \boxed{-(5.58\times10^{-11}\text{ N/C})\mathbf{j}}$

(b) $\mathbf{E} = \frac{mg}{q}\mathbf{j} = \frac{(1.67\times10^{-27}\text{ kg})(9.80\text{ m/s}^2)}{(1.60\times10^{-19}\text{ C})}\mathbf{j} = \boxed{(1.02\times10^{-7}\text{ N/C})\mathbf{j}}$

23.14 If we treat the concentrations as point charges,

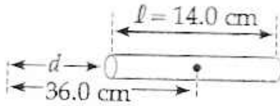
$$\mathbf{E}_+ = k_e\frac{q}{r^2} = \left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(40.0\text{ C})}{(1000\text{ m})^2}(-\mathbf{j}) = 3.60\times10^5\text{ N/C}(-\mathbf{j}) \text{ (downward)}$$

$$\mathbf{E}_- = k_e\frac{q}{r^2} = \left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(40.0\text{ C})}{(1000\text{ m})^2}(-\mathbf{j}) = 3.60\times10^5\text{ N/C}(-\mathbf{j}) \text{ (downward)}$$

$\mathbf{E} = \mathbf{E}_+ + \mathbf{E}_- = \boxed{7.20\times10^5\text{ N/C downward}}$

23.23 $\mathbf{E} = \sum \frac{k_e q}{r^2}\hat{\mathbf{r}} = \frac{k_e q}{a^2}(-\mathbf{i}) + \frac{k_e q}{(2a)^2}(-\mathbf{i}) + \frac{k_e q}{(3a)^2}(-\mathbf{i}) + \ \dots = \frac{-k_e q \mathbf{i}}{a^2}\left(1 + \frac{1}{2^2} + \frac{1}{3^3} + \ \dots\right) = \boxed{-\frac{\pi^2 k_e q}{6a^2}\mathbf{i}}$

23.24 $E = \frac{k_e \lambda \ell}{d(\ell + d)} = \frac{k_e (Q/\ell)\ell}{d(\ell+d)} = \frac{k_e Q}{d(\ell + d)} = \frac{(8.99 \times 10^9)(22.0 \times 10^{-6})}{(0.290)(0.140 + 0.290)}$



$\mathbf{E} = \boxed{1.59 \times 10^6 \text{ N/C}}$, $\boxed{\text{directed toward the rod}}$.

23.25 $E = \int \frac{k_e\, dq}{x^2}$ where $dq = \lambda_0\, dx$

$E = k_e \lambda_0 \int_{x_0}^{\infty} \frac{dx}{x^2} = k_e\left(-\frac{1}{x}\right)\bigg|_{x_0}^{\infty} = \boxed{\frac{k_e \lambda_0}{x_0}}$ $\boxed{\text{The direction is } -\mathbf{i} \text{ or left for } \lambda_0 > 0}$

23.30 (a) From Example 23.9: $E = 2\pi k_e \sigma\left(1 - \frac{x}{\sqrt{x^2 + R^2}}\right)$

$\sigma = \frac{Q}{\pi R^2} = 1.84 \times 10^{-3} \text{ C/m}^2$

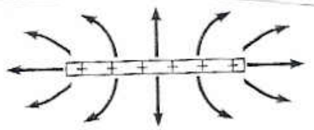
$E = (1.04 \times 10^8 \text{ N/C})(0.900) = 9.36 \times 10^7 \text{ N/C} = \boxed{93.6 \text{ MN/C}}$

appx: $E = 2\pi k_e \sigma = \boxed{104 \text{ MN/C (about 11\% high)}}$

(b) $E = (1.04 \times 10^8 \text{ N/C})\left(1 - \frac{30.0 \text{ cm}}{\sqrt{30.0^2 + 3.00^2} \text{ cm}}\right) = (1.04 \times 10^8 \text{ N/C})(0.00496) = \boxed{0.516 \text{ MN/C}}$

appx: $E = k_e \frac{Q}{r^2} = (8.99 \times 10^9)\frac{5.20 \times 10^{-6}}{(0.30)^2} = \boxed{0.519 \text{ MN/C (about 0.6\% high)}}$

22.38



23.46 The acceleration is given by $v^2 = v_i^2 + 2a(x - x_i)$ or $v^2 = 0 + 2a(-h)$

Solving, $a = -\frac{v^2}{2h}$

Now $\sum \mathbf{F} = m\mathbf{a}$: $-mg\mathbf{j} + q\mathbf{E} = -\frac{mv^2\,\mathbf{j}}{2h}$

Therefore $q\mathbf{E} = \left(-\frac{mv^2}{2h} + mg\right)\mathbf{j}$

(a) Gravity alone would give the bead downward impact velocity

$\sqrt{2(9.80 \text{ m/s}^2)(5.00 \text{ m})} = 9.90 \text{ m/s}$

To change this to 21.0 m/s down, a $\boxed{\text{downward}}$ electric field must exert a downward electric force.

(b) $q = \frac{m}{E}\left(\frac{v^2}{2h} - g\right) = \frac{1.00 \times 10^{-3} \text{ kg}}{1.00 \times 10^4 \text{ N/C}}\left(\frac{\text{N} \cdot \text{s}^2}{\text{kg} \cdot \text{m}}\right)\left(\frac{(21.0 \text{ m/s})^2}{2(5.00 \text{ m})} - 9.80 \text{ m/s}^2\right) = \boxed{3.43\ \mu\text{C}}$