1. **Juggling Charges** *(YF 13th ed. 21.8)*. Two small aluminum spheres, each having mass 0.0250kg are separated by 0.80m.
(a) How many electrons does each sphere contain? (The atomic mass of aluminum is 26.982g/mol and its atomic number is 13.)
(b) How many electrons would have to be removed from one sphere and added to the other to cause an attractive force between the spheres of magnitude 1.00×10^4N (roughly 1 ton)? Assume that the spheres may be treated as point charges.
(c) What fraction of all the electrons in each sphere does this represent?

a) $n_e = ?$; $\mathcal{M} = 26.982\ g/mol$

$$N_{moles} = \frac{m}{\mathcal{M}}$$

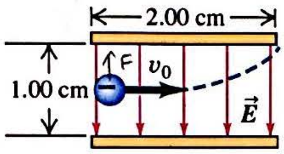
$$N_{atoms} = N_{moles} * N_A$$

$$n_e = 13 \times N_{atoms} = 13 * N_A * \frac{m}{\mathcal{M}} = 13 * 6.022 \times 10^{23} * \frac{25}{26.982} = 7.25 \times 10^{24} \text{ electrons}$$

b) $$F_e = \frac{k_e q^2 N^2}{r^2} \Rightarrow N = \sqrt{\frac{Fr^2}{k_e q^2}} = \sqrt{\frac{Fr^2 4\pi\varepsilon_0}{q^2}} = 5.27 \times 10^{15} \text{ electrons}$$

c) $$\frac{N}{n_e} = 7.27 \times 10^{-10}$$

2. **Electric Avenue** *(YF 13th ed. 21.33)*. An electron is projected with an initial speed $v_0 = 1.60 \times 10^6$ m/s into the uniform field between the parallel plates. Assume that the field between the plates is uniform and directed vertically downward, and that the field outside the plates is zero. The electron enters the field at a point midway between the plates. (a) If the electron just misses the upper plate as it emerges from the field, find the magnitude of the electric field. (b) Suppose that the electron is replaced by a proton with the same initial speed v_0. Would the proton hit one of the plates? If the proton would not hit one of the plates, what would be the magnitude and direction of its vertical displacement as it exits the region between the plates? (c) Compare the paths traveled by the electron and the proton and explain the differences. (d) Discuss whether it is reasonable to ignore the effects of gravity for each particle.



a) $E = ?$

$F = qE = ma$

$\Rightarrow a_y = \frac{q}{m} E$

$v_y = \frac{q}{m} E t + v_{0y}^{\,0}$

$y = y_0 + \frac{1}{2} a t^2 = y_0 + \frac{qE}{2m} t^2 = y_0 + \frac{qE}{2m_e} \frac{\Delta x^2}{v_0^2}$

$\Delta x = v_0 t \Rightarrow t = \frac{2\text{cm}}{v_0}$

$\Rightarrow E = \frac{2 m_e v_0^2 \Delta y}{q \Delta x^2} = 364\ N/C$;

b) $\Delta y_p = \frac{qE\Delta x^2}{2 m_p v_0^2} = \Delta y_e \frac{m_e}{m_p}$

$m_e/m_p = \frac{1}{1836} \Rightarrow$ will not hit.

$\Delta y_p \ll \Delta y_e$

deflection down by $\frac{0.005\text{m}}{1836}$.

c) opposite direction. same force but different inertia, so different deflection size.

d) $a_e = \frac{-e}{m_e} \cdot 364\ N/C \gg g$

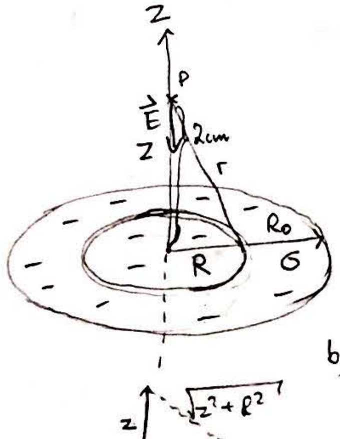
$a_p = \frac{+e}{m_p} \cdot 364\ N/C \gg g$

3. **Bonus** *(YF 13th ed. 21.55)*. A charge of −6.50nC is spread uniformly over the surface of one face of a nonconducting disk of radius 1.25 cm (a) Find the magnitude and direction of the electric field this disk produces at a point P on the axis of the disk a distance of 2.00cm from its center. (b) Suppose that the charge were all pushed away from the center and distributed uniformly on the outer rim of the disk. Find the magnitude and direction of the electric field at point . (c) If the charge is all brought to the center of the disk, find the magnitude and direction of the electric field at point . (d) Why is the field in part (a) stronger than the field in part (b)? Why is the field in part (c) the strongest of the three fields?

a) $\sigma = \frac{Q}{A}$ = surface charge density ; $V = \int_V \frac{k_e \rho(r)}{r} dV = \int_0^r \frac{k_e \sigma 2\pi R dR}{r}$

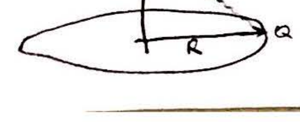
$V = \int_0^r \frac{k_e \sigma 2\pi}{r} R dR = \frac{2\pi k_e Q}{A} \int_0^{R_0} \frac{R dR}{\sqrt{z^2+R^2}} = \frac{2\pi k_e Q}{A} \left[\sqrt{z^2+R^2} \right]_0^{R_0}$

$r = \sqrt{z^2+R^2}$



$\vec{E} = -\frac{\partial V}{\partial z} \hat{z} = \frac{2\pi k_e Q}{A} \left[1 - \frac{z}{\sqrt{z^2+R_0^2}} \right] = -1.14 \times 10^5\ N/C\ \hat{z}$

b) $E = \frac{k_e Q z}{(z^2+a^2)^{3/2}} (-\hat{z}) = 8.92 \times 10^4 \frac{N}{C}$ (from $V = \frac{k_e Q}{\sqrt{z^2+R^2}}$)



c) $E = k_e q / r^2 (\hat{r}) \Rightarrow E = 1.46 \times 10^5\ N/C$

d) • ring has more charge further away
• parallel components cancel
• point = closest, radial direction