Name: 1B Discussion - Week 6

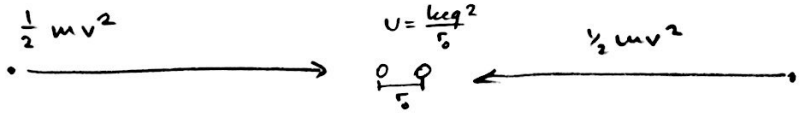
1. **Nuclear fusion and decay** *(YF 13th ed. 23.4).* (a) How much work would it take to push two protons very slowly from a separation of 2.00×10^{-10}m (a typical atomic distance) to 3.00×10^{-15}m (a typical nuclear distance)? (b) If the protons are both released from rest at the closer distance in part (a), how fast are they moving when they reach their original separation?

a) $\Delta W = -\Delta E$; $\Delta E = \frac{k_e q^2}{r_f} - \frac{k_e q^2}{r_i} = k_e q^2 \left(\frac{r_i - r_f}{r_i r_f} \right) = 7.68 \times 10^{-14}$ J

b) $\Delta W = -\Delta E = \frac{1}{2} m v^2 = \Delta V = k_e q^2 \left(\frac{r_i - r_f}{r_i r_f} \right)$

$\Rightarrow v = \sqrt{\frac{k_e q^2}{m} \left(\frac{r_i - r_f}{r_i r_f} \right)} = 6.78 \times 10^6$ m/s

2. **Cyclotron** *(YF 13th ed. 23.12).* Starting from a separation of several meters, two protons are aimed directly toward each other by a cyclotron accelerator with speeds of 1000 km/s, measured relative to the earth. Find the maximum electrical force that these protons will exert on each other.

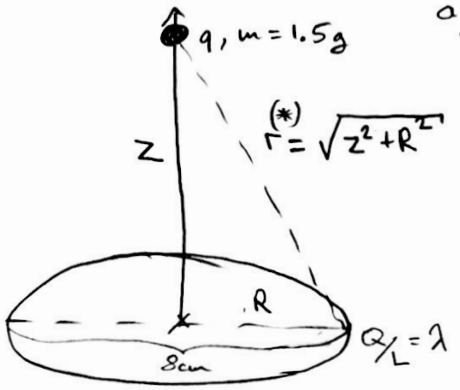


$\Rightarrow \frac{k_e q^2}{r_0} = m v^2$

$\Rightarrow r_0 = \frac{k_e q^2}{m v^2} = 1.38 \times 10^{-13}$ m

$F = \frac{k_e q^2}{r_0^2} = \frac{m^2 v^4}{k_e q^2} = 0.012$ N

3. **Ring of Wire** *(YF 13th ed. 23.34).* A ring of diameter 8.00 cm is fixed in place and carries a charge of $+5.00\mu C$ uniformly spread over its circumference. (a) How much work does it take to move a tiny charged ball of mass 1.50g from very far away to the center of the ring? (b) Is it necessary to take a path along the axis of the ring? Why? (c) If the ball is slightly displaced from the center of the ring, what will it do and what is the maximum speed it will reach?



a) $V(z) = \dfrac{k_e q Q}{r} = \dfrac{k_e q Q}{\sqrt{z^2+R^2}}$, $V(0) = \dfrac{k_e q Q}{R}$

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

$\Delta W = \Delta V = V(0) - V(\infty) = \dfrac{k_e q Q}{R} = 3.38\,J$

b) Potential is path indep. ⇒ can take any path.

c) Net force away from ring ⇒ will accel. away.

$\frac{1}{2}mv^2 = \dfrac{k_e q Q}{R} \Rightarrow \boxed{v = \left(\dfrac{2k_e q Q}{mR}\right)^{1/2}}$

4. **Balloon** *(YF 13th ed. 23.41).* (a) Show that V for a spherical shell of radius R, that has charge distributed uniformly over its surface, is the same as for a solid conductor with radius R and charge q. (b) You rub an inflated balloon on the carpet and it acquires a potential that is 1560 V lower than its potential before it became charged. If the charge is uniformly distributed over the surface of the balloon and if the radius of the balloon is 15cm, what is the net charge on the balloon? (c) In light of its 1200 potential difference relative to you, do you think this balloon is dangerous? Explain.

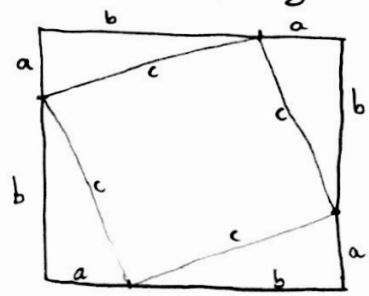
a) The electric field outside the shell is the same as for a point charge at the center ⇒ $V(r) = \dfrac{k_e q}{r}$ for $r > R$.

$E(r) = 0$ for $r \le R$ ⇒ $V(r) = \text{const.} = \dfrac{k_e q}{R}$ $r \le R$.

b) $V = \dfrac{k_e q}{R}$ = inside ⇒ $q = \dfrac{RV}{k_e} = -20\,nC$

c) Total electric energy is only $U = qV = (20\,nC)(1200\,J/C) = 2.4 \times 10^{-5}\,J$.

(*) nb/ Cute proof of Pythagorean Theorem:



Area $= (a+b)^2 = a^2 + b^2 + 2ab$

and

Area $= c^2 + 4(\frac{1}{2}ab) = c^2 + 2ab$

⇒ cross-terms cancel to give

$c^2 = a^2 + b^2$ ■