PHY1124 A
Assignment # 3, Winter 2017
Due date: Tuesday Jan. 31 at 4:00 p.m.

Scan and send your solutions to phy1124assignments@gmail.com.

Solutions will be reviewed during the DGD on Jan. 31.

1. (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?

1. a) $U = \frac{1}{4\pi\epsilon_0}\frac{qq_0}{r}$, $W = \Delta U = U_2 - U_1 = \frac{1}{4\pi\epsilon_0}\left(\frac{e^2}{r_2} - \frac{e^2}{r_1}\right)$

$W = 7.68 \times 10^{-14}$ J

b) $\Delta U = K_1 + K_2 = 2\left(\frac{1}{2}mv^2\right)$

$v = \sqrt{\frac{\Delta U}{m}} = 6.78 \times 10^6$ m/s

2. (a) An electron is to be accelerated from 3.00×10^6m/s to 8.00×10^6m/s. Through what potential difference must the electron pass to accomplish this? (b) Through what potential difference must the electron pass if it is to be slowed from 8.00×10^6m/s to a halt?

a) $K_1 + qV_1 = K_2 + qV_2 \Rightarrow q(V_2 - V_1) = K_1 - K_2$

$\Delta V = V_2 - V_1 = \frac{K_1 - K_2}{q} = 156$ V

b) $\Delta V = \frac{K_1 - K_2}{q} = -182$ V

3. A small sphere with mass 1.50 g hangs by a thread between two parallel vertical plates 5.00 cm apart (Fig. 1). The plates are insulating and have uniform surface charge densities $+\sigma$ and $-\sigma$. The charge on the sphere is $q = 8.90 \times 10^{-6}$ C. What potential difference between the plates will cause the thread to assume an angle of 30.0° with the vertical?

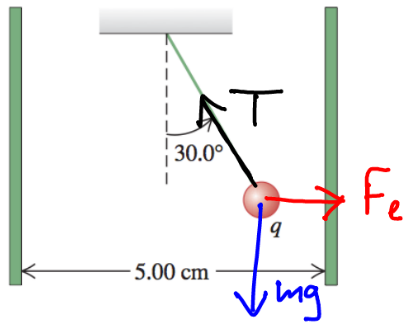


FIG. 1: Charge on a string for Problem 3.

$$\sum F_x = 0$$
$$\sum F_y = 0$$

$$\begin{cases} T\cos\theta = mg \\ T\sin\theta = F_e \end{cases}$$

$$F_e = mg\tan\theta = 8.5 \times 10^{-3}\ \text{N}$$

$$F_e = Eq = \frac{Vq}{d} \Rightarrow V = \frac{Fd}{q} = 47.8\ \text{V}$$

4. When an electron moves from A to B along an electric field line in Fig. 2, the electric field does 3.94×10^{-19} J of work on it. What are the electric potential differences (a) $V_B - V_A$, (b) $V_C - V_A$, and (c) $V_C - V_B$?

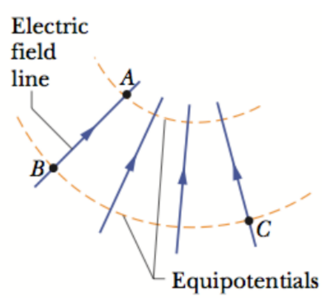


FIG. 2: Electric field line for Problem 4.

a) $V_B - V_A = \frac{\Delta U}{q} = -\frac{W}{-e} = 2.46$ V

b) $V_C - V_A = V_B - V_A = 2.46$ V

c) $V_C - V_B = 0$

5. The plates of a spherical capacitor have radii 38.0 mm and 40.0 mm. (a) Calculate the capacitance. (b) What must be the plate area of a parallel-plate capacitor with the same plate separation and capacitance?

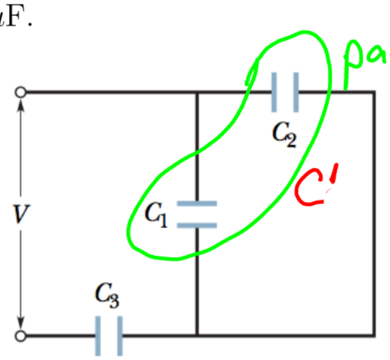
a) $C = 4\pi\varepsilon_0 \dfrac{r_a r_b}{r_b - r_a} = 84.5 \times 10^{-12}$ F

b) A - area required

$$C = \frac{\varepsilon_0 A}{r_b - r_a}$$

$$A = \frac{C(r_b - r_a)}{\varepsilon_0} = 191 \text{ cm}^2$$

6. In Fig. 3 find the equivalent capacitance of the combination. Assume that $C_1 \times 10.0\ \mu$F, $C_2 = 5.00\ \mu$F, and $C_3 = 4.00\ \mu$F.



C_3 is in series with C'

$C_{eq} = 3.16 \times 10^{-6}$ F

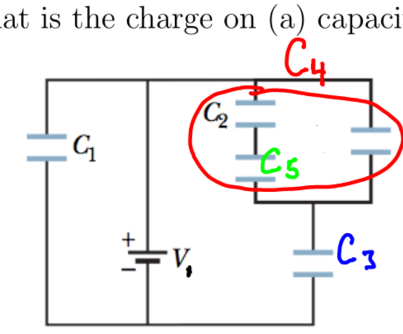
FIG. 3: Capacitor combination for Problem 6.

7. Two parallel-plate capacitors, 6.0 μF each, are connected in parallel to a 10 V battery. One of the capacitors is then squeezed so that its plate separation is 50.0% of its initial value. Because of the squeezing, (a) how much additional charge is transferred to the capacitors by the battery and (b) what is the increase in the total charge stored on the capacitors?

$q_{total} = C_{eq}V = (12\ \mu F)(10.0\ V) = 120\ \mu C$, $\Delta q_{total} = \Delta C_{eq} V = (6\ \mu F)(10.0\ V) = 60\ \mu C$

8. In Fig. 4, the battery has a potential difference of $V = 10.0$ V and the five capacitors each have a capacitance of 10.0 μF. What is the charge on (a) capacitor 1 and (b) capacitor 2?

a) $Q_1 = C_1 V_1$
$= (10.0\ \mu F)(10.0\ V)$
$= 1.00 \times 10^{-4}$ C



b) $C_4 = 1.50\ (10.0\ \mu F)$

C_4 and C_3 in series, so the charge on each is the same.

↓

FIG. 4: Capacitor combination for Problem 8.

$$\frac{1}{C_{eq}} = \frac{1}{C_4} + \frac{1}{C_3}$$

$$= \frac{1}{15\,\mu F} + \frac{1}{10\,\mu F}$$

$$C_{eq} = 6.0\ \mu F$$

$$Q = V_1 C_{eq}$$
$$= (10.0\ V)(6.0\ \mu F)$$
$$= 6.00 \times 10^{-5}\ C$$

$$V_3 = \frac{Q}{C_3} = \frac{6.00 \times 10^{-5} C}{10\ \mu F}$$
$$= 6.0\ V$$

Therefore the potential drop across C_4 is $10.0\ V - 6.0\ V = 4.0\ V$

This is the potential drop across C_2 and C_5, which are equal so the potential is 2.0 V across each.

$$Q_2 = C_2 V_2 = (10.0\ \mu F)(2.0\ V)$$
$$= 2.00 \times 10^{-5}\ C$$