

### Problem 3.4

~~Comparing cylindrical and spherical capacitors.~~

- ~~Compare the capacitance of a capacitor of 2 concentric spheres with  $R_1 = 6$  cm and  $R_2 = 9$  cm, with that of a cylindrical capacitor having the same radii and axial length of 15 cm. Why are the capacitance values nearly equal?~~
- ~~Show that, when  $R_1$  and  $R_2$  are nearly equal ( $R_2 = R_1 + \delta; \delta \ll R_1$ ) the formulas for the spherical and cylindrical capacitors may be approximated by the formula for the parallel plate capacitor,  $C = \epsilon_0 A/d$  (eq. 24-2). Hint: make use of Taylor's expansion in terms of  $\delta/R_1$ .~~

### Problem 3.5

~~The Van de Graaff~~

The spherical dome of a Van de Graaff electrostatic generator has a radius of  $R$  m. A rubberized belt 50 cm wide travels at a velocity of 30 m/sec. The belt is given a surface charge density which produces a field of approximately  $10^6$  V/m on each side of the belt. (see Figure 23-37 on page 612).

- What is the current carried by the belt?
- What is the maximum charge that the spherical dome can hold, and how long will it take to reach this value?
- What is the maximum electrostatic potential of the spherical dome?
- What are your answers under (b) and (c) for  $R = 0.15$  and  $R = 0.5$  m?

### Problem 3.6

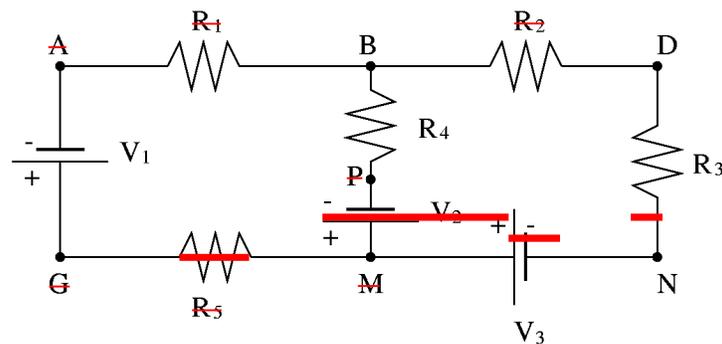
~~Resistor Circuit.~~

~~Giancoli 26-25~~

### Problem 3.7

~~Resistor Network.~~

~~A circuit consists of 5 resistors and 3 batteries (see diagram); the connecting wires have all a negligible resistance. The values for  $R_1, R_2, R_3, R_4,$  and  $R_5$  are  $10 \Omega, 30 \Omega, 50 \Omega, 70 \Omega,$  and  $100 \Omega,$  respectively. The batteries have a negligible internal resistance; their voltages  $V_1, V_2,$  and  $V_3,$  are  $12 \text{ V}, 24 \text{ V},$  and  $36 \text{ V},$  respectively (for their polarities, see the diagram).~~



- ~~Calculate the current (magnitude and direction) of the currents through each of the 5 resistors.~~
- ~~What is the potential difference (observe signs!) between the points A&P, P&N, and C&D.~~

### Problem 3.8

~~Wire resistance.~~

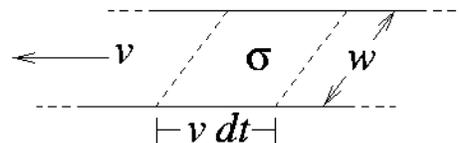
~~Giancoli 25-52.~~

**Problem 3.5***The Van de Graaff.*

(a) We are given that the electric field on either side of the belt is  $E = 10^6$  V/m. We can relate this to the surface charge density  $\sigma$  by the result of Giancoli Example 22-6 (p. 583):

$$E = \frac{\sigma}{2\epsilon_0} \Rightarrow \sigma = 2\epsilon_0 E = 2(8.85 \times 10^{-12})(10^6) = 18 \mu\text{C}/\text{m}^2 .$$

The belt is traveling with speed  $v = 30$  m/s and has width  $w = 0.5$  m. In a time interval  $dt$  a length  $v dt$  of the belt passes any given position (see diagram at right). The area of the belt that passes this position will be  $wv dt$ , and the charge passing by in time  $dt$  will be  $dQ = \sigma wv dt$ . So the current carried by the belt is



$$I = \frac{dQ}{dt} = \sigma wv = (18 \times 10^{-6})(0.5)(30) = 2.7 \times 10^{-4} \text{ A} .$$

(b) The maximum electric field just outside the spherical dome will be the breakdown field for air,  $E_{\text{max}} = 3 \times 10^6$  V/m (see Giancoli Example 23-5, p. 596, or problem 2.6 from Assignment #2.) The electric field just outside the surface of the dome will be related to the total charge on the dome by

$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{R^2} \quad (\text{Giancoli Example 23-4, p. 596}),$$

so the maximum charge that the dome can hold is

$$Q_{\text{max}} = 4\pi\epsilon_0 R^2 E_{\text{max}} = 4\pi(8.85 \times 10^{-12})(3 \times 10^6)R^2 = (3.3 \times 10^{-4} \text{ C})R^2$$

(for  $R$  measured in meters). If the dome is being charged at a rate of  $I = 2.7 \times 10^{-4}$  Coulombs/second, then the time required to charge the dome will be

$$\Delta t = Q_{\text{max}}/I = (1.2 \text{ s})R^2 .$$

(c) The maximum electrostatic potential of the dome is (again, see Giancoli Example 23-5, p. 596)

$$V_{\text{max}} = RE_{\text{max}} = (3 \times 10^6 \text{ V})R .$$

(d) For  $R = 0.15$  m,

$$Q_{\text{max}} = 7.4 \mu\text{C}, \quad \Delta t = 0.027 \text{ s} , \quad \text{and} \quad V_{\text{max}} = 4.5 \times 10^5 \text{ V} .$$

For  $R = 0.5$  m,

$$Q_{\text{max}} = 83 \mu\text{C}, \quad \Delta t = 0.3 \text{ s} , \quad \text{and} \quad V_{\text{max}} = 1.5 \times 10^6 \text{ V} .$$