Announcements

1. **First hour exam – Monday, February 10, 2003 – covering Chapters 23-28.**
   - 5 problems – show your work and reasoning for possible partial credit.
   - May bring 1 8½" x 11" sheet of paper to the exam (to be turned in with your exam papers).
   - The exam will be proctored by Professor Salsbury.
2. Practice exam available on website.
3. **Extra review session today (2/7/03) – 3-4 PM.**
4. Today's lecture –
   What to do about HW9 ?   Midnight for HW due time?
   Advice for studying   Systematic review

2. [SB5 28.P.24. (47539)] In the circuit of Figure P28.24, determine the current in each resistor and the voltage across the 70 Ω resistor. (Indicate the direction of the current flow through each resistor through the sign of your answer. Take upward current flow as positive.)

[0.0666666666667] ✗ [1] A (200 Ω)

[0.0666666666667] ✗ [3] A (80.0 Ω)

[0.0666666666667] ✗ [-8] A (20.0 Ω)

[0.0666666666667] ✗ [4] A (70.0 Ω)

voltage across 70 Ω resistor

[0.0666666666667] ✗ [280] V

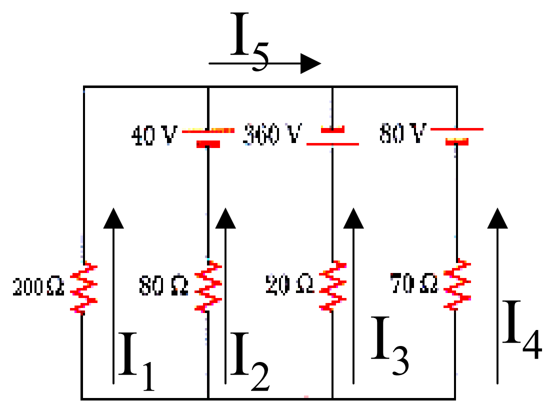


Figure P28.24.

$$-200I_1 - 40V + 80I_2 = 0$$

$$-80I_2 + 40V + 360V + 20I_3 = 0$$

$$-20I_3 - 360V - 80V + 70I_4 = 0$$

$$I_1 + I_2 = I_5$$

$$I_3 + I_4 + I_5 = 0$$

3. [SB5 28.P.28. (47540)]

$$E - 2I_1 - RI_2 = 0$$

$$-RI_2 + RI_4 = 0$$

$$-RI_4 + 2I_5 - 20V = 0$$

$$I_1 = I_2 + I_3$$

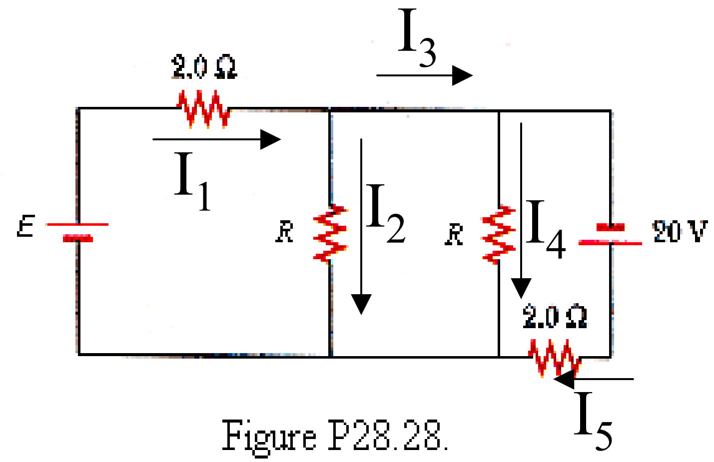


Figure P28.28.

Calculate the power delivered to each of the resistors in Figure P28.28 (E = 52 V, R = 3.0 Ω.)

[0.06666666667] ✗ [899] W (2.0 Ω resistor in loop with 52 V source.)

[0.06666666667] ✗ [30.7] W (3.0 Ω resistor in loop with 52 V source.)

[0.06666666667] ✗ [30.7] W (3.0 Ω resistor in loop with 20 V source.)

[0.06666666667] ✗ [438] W (2.0 Ω resistor in loop with 20 V source.)

4. [SB5 28.P.32. (61683)] In the circuit of Figure P28.32, (R = 90.0 kΩ) the switch S has been open for a long time. It is then suddenly closed.

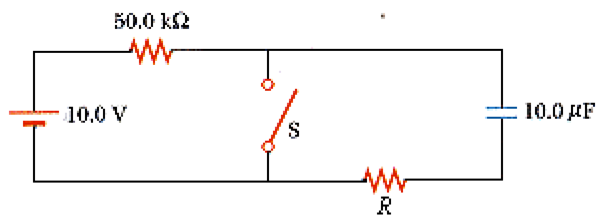


Figure P28.32

(a) Determine the time constant before the switch is closed.

[0.0666666666667] [1.4] s

(b) What is the time constant after the switch is closed?

[0.0666666666667] [0.9] s

(c) If the switch is closed at $t = 0$ s, determine the current through it as a function of time.

- 200 μA - $e^{(-t/0.9\ s)}$(66.66 μA)
- 200 μA + $e^{(-t/0.9\ s)}$(66.66 μA)
- 100 μA - $e^{(-t/0.9\ s)}$(66.66 μA)
- 200 μA + $e^{(-t/0.9\ s)}$(111 μA) - **Correct!**
- 200 μA - $e^{(-t/0.9\ s)}$(111 μA)
- 100 μA + $e^{(-t/0.9\ s)}$(111 μA)
- 100 μA - $e^{(-t/0.9\ s)}$(111 μA)
- 100 μA + $e^{(-t/0.9\ s)}$(66.66 μA)

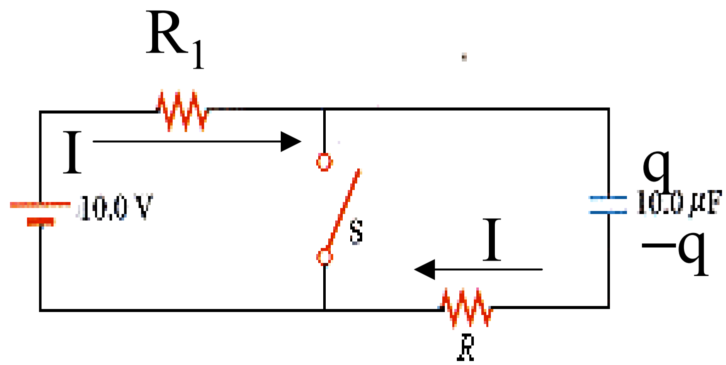


Figure P28.32

$$I = \frac{dq}{dt}$$

$$10V - R_1 I - \frac{q}{C} - IR = 0$$

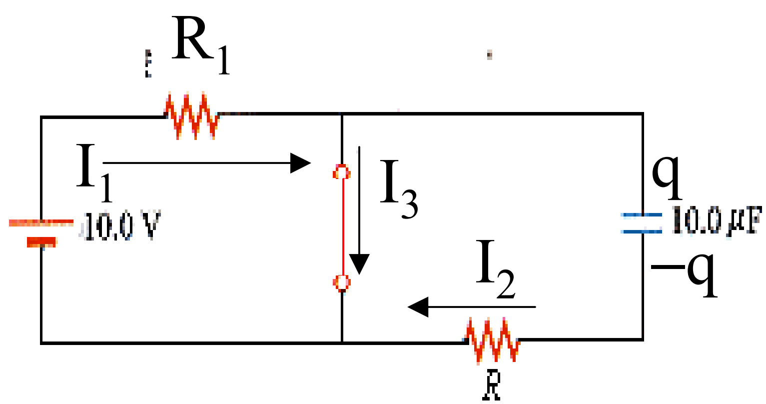


Figure P28.32

$$10V - R_1 I_1 = 0$$

$$-\frac{q}{C} - RI_2 = 0$$

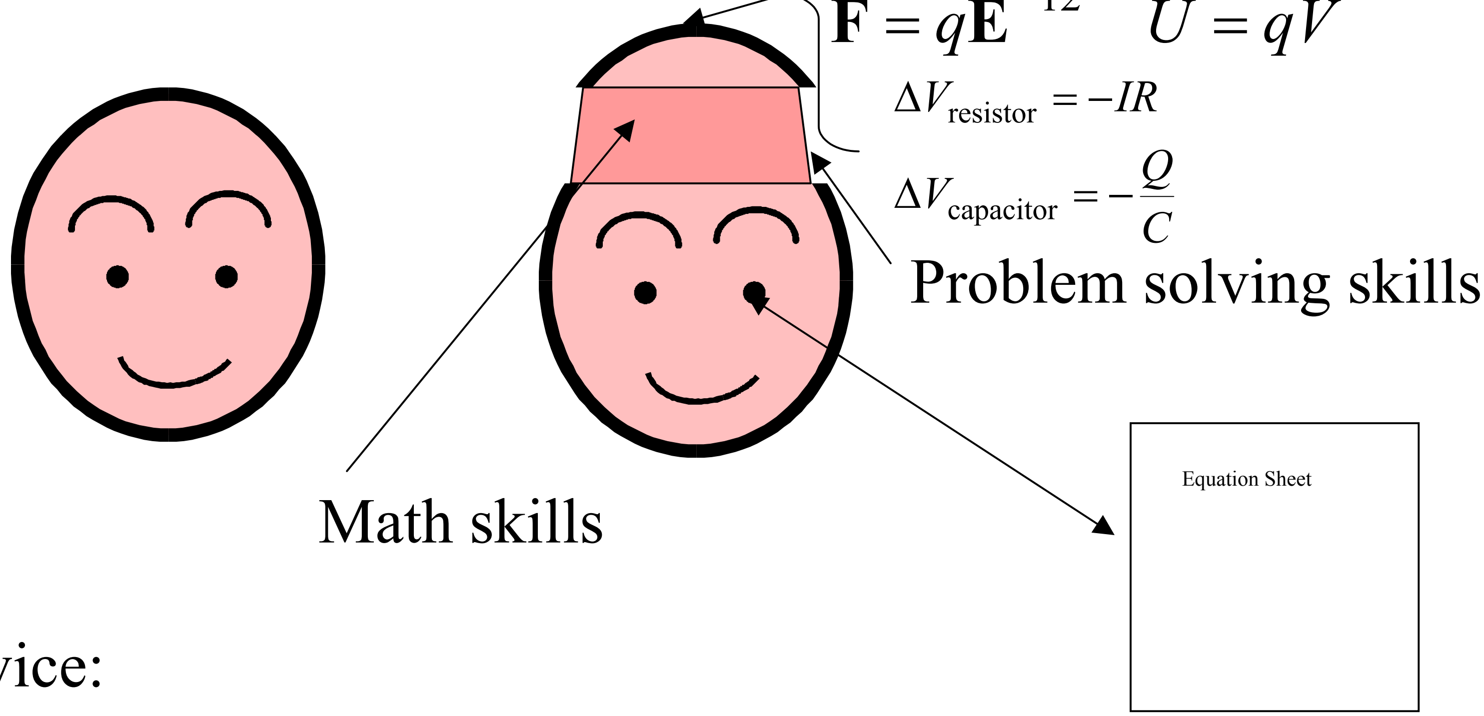
$$-I_1 + I_2 + I_3 = 0$$

$$\mathbf{F} = \frac{k_e q_1 q_2}{r_{12}^2}\hat{\mathbf{r}}_{12}$$

$$\mathbf{F} = q\mathbf{E} \qquad U = qV$$

$$\Delta V_{\text{resistor}} = -IR$$

$$\Delta V_{\text{capacitor}} = -\frac{Q}{C}$$



Advice:

1. Keep basic concepts and equations at the top of your head.
2. Practice problem solving and math skills
3. Develop an equation sheet that you can consult.

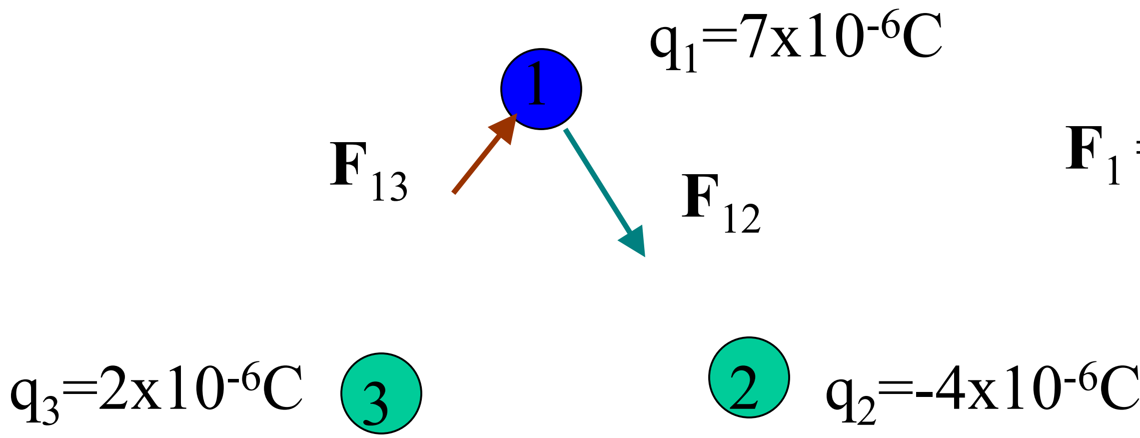
Problem solving steps

1. Visualize problem – labeling variables
2. Determine which basic physical principle(s) apply
3. Write down the appropriate equations using the variables defined in step 1.
4. Check whether you have the correct amount of information to solve the problem (same number of knowns and unknowns).
5. Solve the equations.
6. Check whether your answer makes sense (units, order of magnitude, etc.).

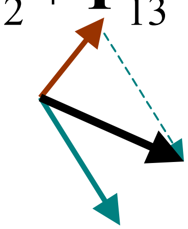
Coulomb's law:

$$\mathbf{F} = k_e \frac{q_1 q_2}{|\mathbf{r}_1 - \mathbf{r}_2|^2} \hat{\mathbf{r}}_{12} \qquad k_e = \frac{1}{4\pi\varepsilon_0}$$

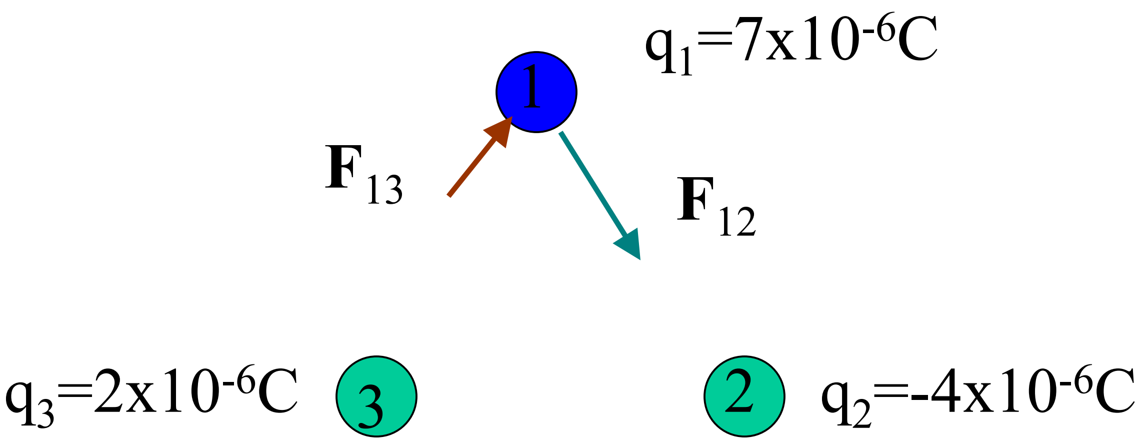
$8.987551787 \times 10^9\ \mathrm{N \cdot m^2/C^2}$



$$\mathbf{F}_1 = \mathbf{F}_{12} + \mathbf{F}_{13}$$



Relationship of electric field with Coulomb's law force



$$\mathbf{F}_1 = k_e \frac{q_1 q_2}{|\mathbf{r}_1 - \mathbf{r}_2|^2}\hat{\mathbf{r}}_{12} + k_e \frac{q_1 q_3}{|\mathbf{r}_1 - \mathbf{r}_3|^2}\hat{\mathbf{r}}_{13}$$

$$= q_1\left(k_e \frac{q_2}{|\mathbf{r}_1 - \mathbf{r}_2|^2}\hat{\mathbf{r}}_{12} + k_e \frac{q_3}{|\mathbf{r}_1 - \mathbf{r}_3|^2}\hat{\mathbf{r}}_{13}\right)$$

$$\mathbf{E}(\mathbf{r}_1) \equiv \mathbf{F}_1 / q_1 = k_e \frac{q_2}{|\mathbf{r}_1 - \mathbf{r}_2|^2}\hat{\mathbf{r}}_{12} + k_e \frac{q_3}{|\mathbf{r}_1 - \mathbf{r}_3|^2}\hat{\mathbf{r}}_{13}$$

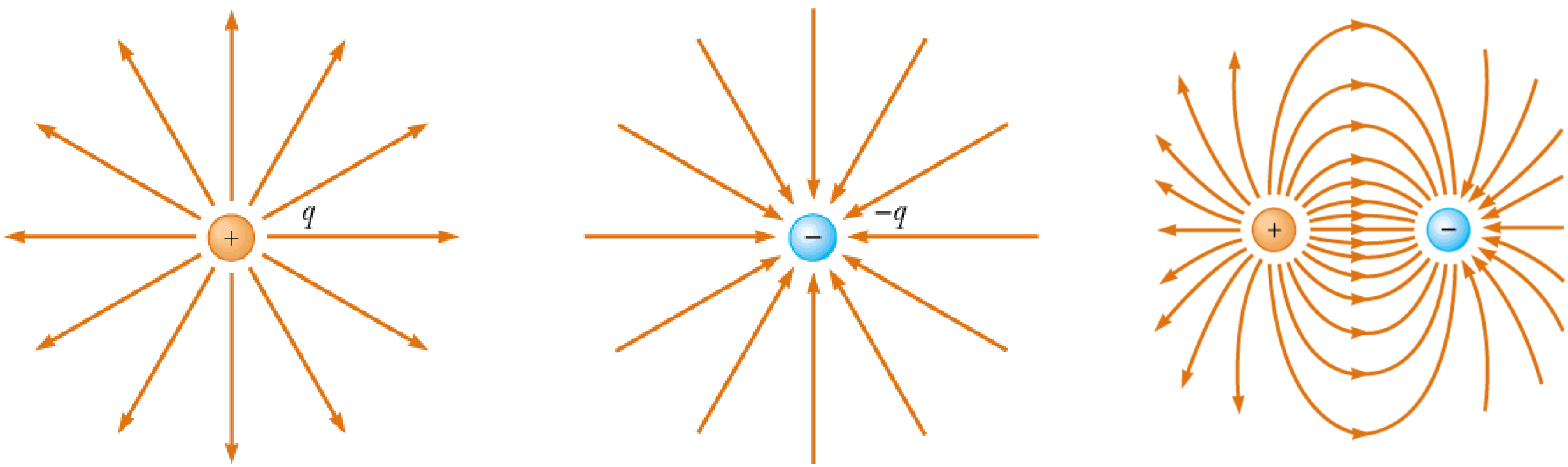
Electric field == force on q_1 if it were 1 Coulomb

Electric field:

$$\mathbf{E}(\mathbf{r}_1) = \sum_i k_e \frac{q_i}{|\mathbf{r}_1 - \mathbf{r}_i|^2} \hat{\mathbf{r}}_{1i}$$

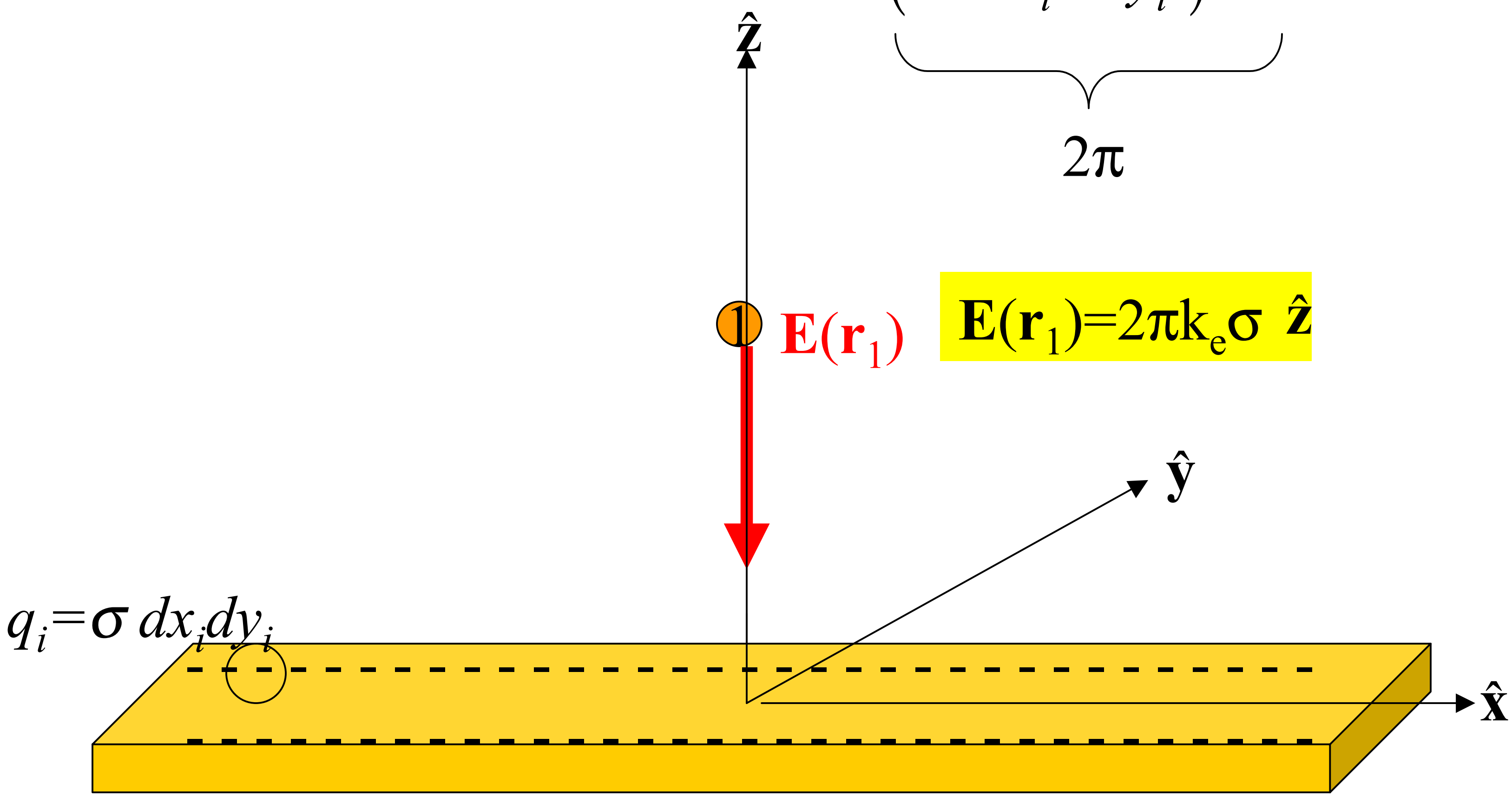
The force on a 1 C charge placed at r_1.

Field lines help to visualize electric field:



Electric field due to large uniformly charge plate:

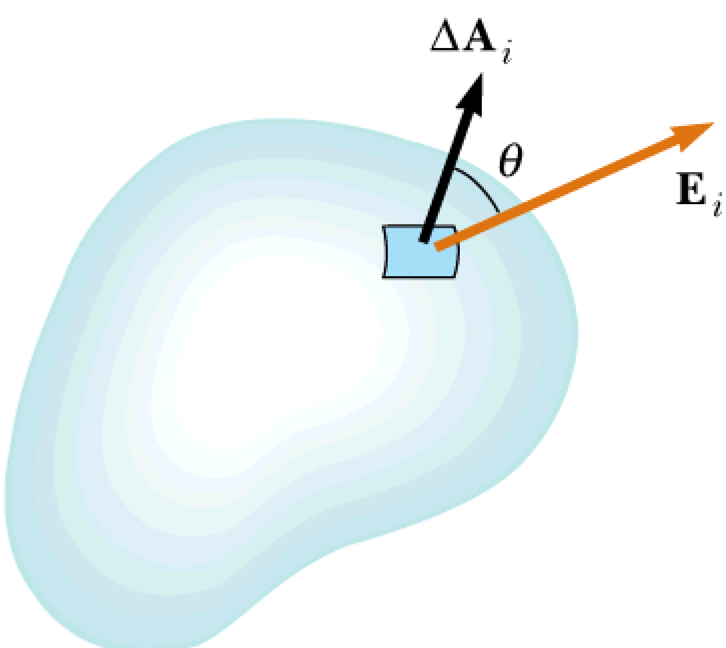
$$\mathbf{E}(\mathbf{r}_1) = \sum_i k_e \frac{q_i}{|\mathbf{r}_1 - \mathbf{r}_i|^2}\hat{\mathbf{r}}_{1i} = k_e \sigma \hat{\mathbf{z}} \underbrace{\int_{-\infty}^{\infty} \frac{z\,dx_i\,dy_i}{\left(z^2 + x_i^2 + y_i^2\right)^{3/2}}}_{2\pi}$$



$$\mathbf{E}(\mathbf{r}_1) = 2\pi k_e \sigma\ \hat{\mathbf{z}}$$

An alternative method for calculating electric fields – Gauss's Law

Define electric "flux":



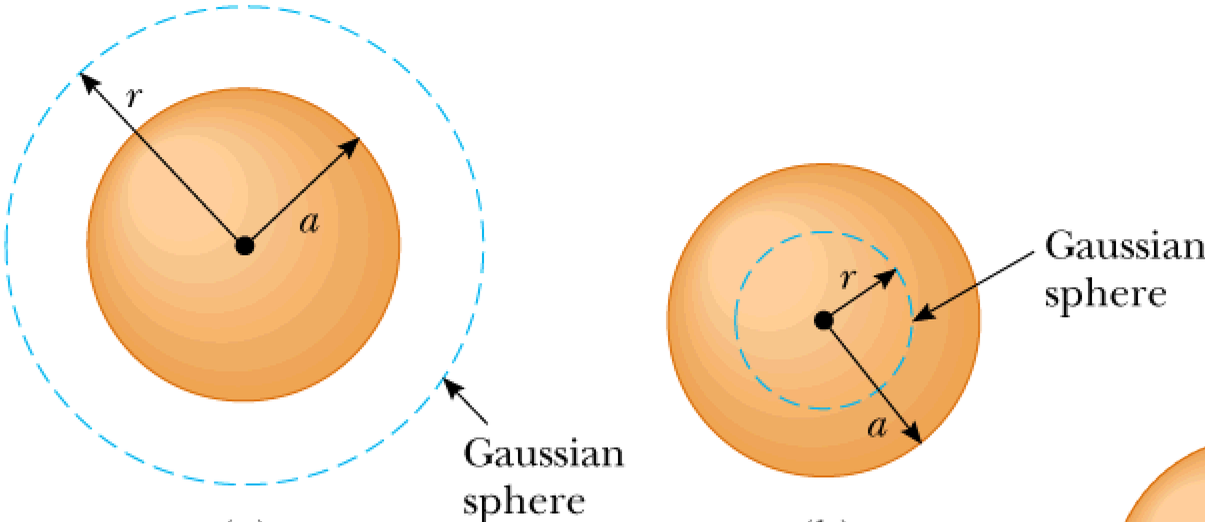
$$\Phi_E \equiv \int \mathbf{E} \cdot d\mathbf{A}$$
$$= \int E\,dA \cos\theta$$

Gauss's law says:

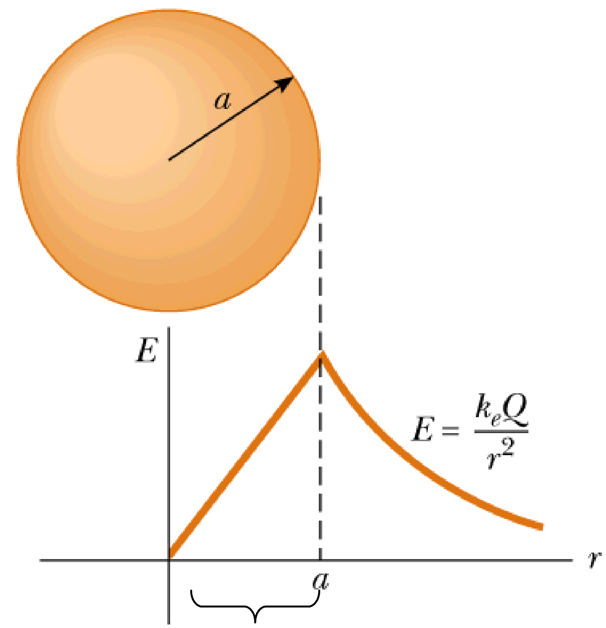
$$\oint \mathbf{E} \cdot d\mathbf{A} = 4\pi k_e q_{in} = \frac{q_{in}}{\varepsilon_0}$$

Integral of surrounding surface

Electric field inside and outside uniformly charged sphere:



(a) (b)



$$E = \frac{k_e Q r}{a^3}$$

Electrostatic potential

$$V = U/q$$

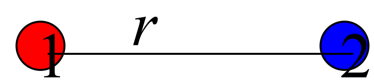
Note:

$$U(\mathbf{r}) = -\int_{\mathbf{r}_{ref}}^{\mathbf{r}} \mathbf{F} \cdot d\mathbf{r}$$

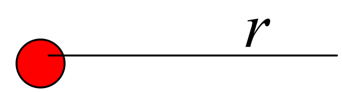
$$V(\mathbf{r}) = -\int_{\mathbf{r}_{ref}}^{\mathbf{r}} E \cdot d\mathbf{r}$$

Volt=J/C

N/C



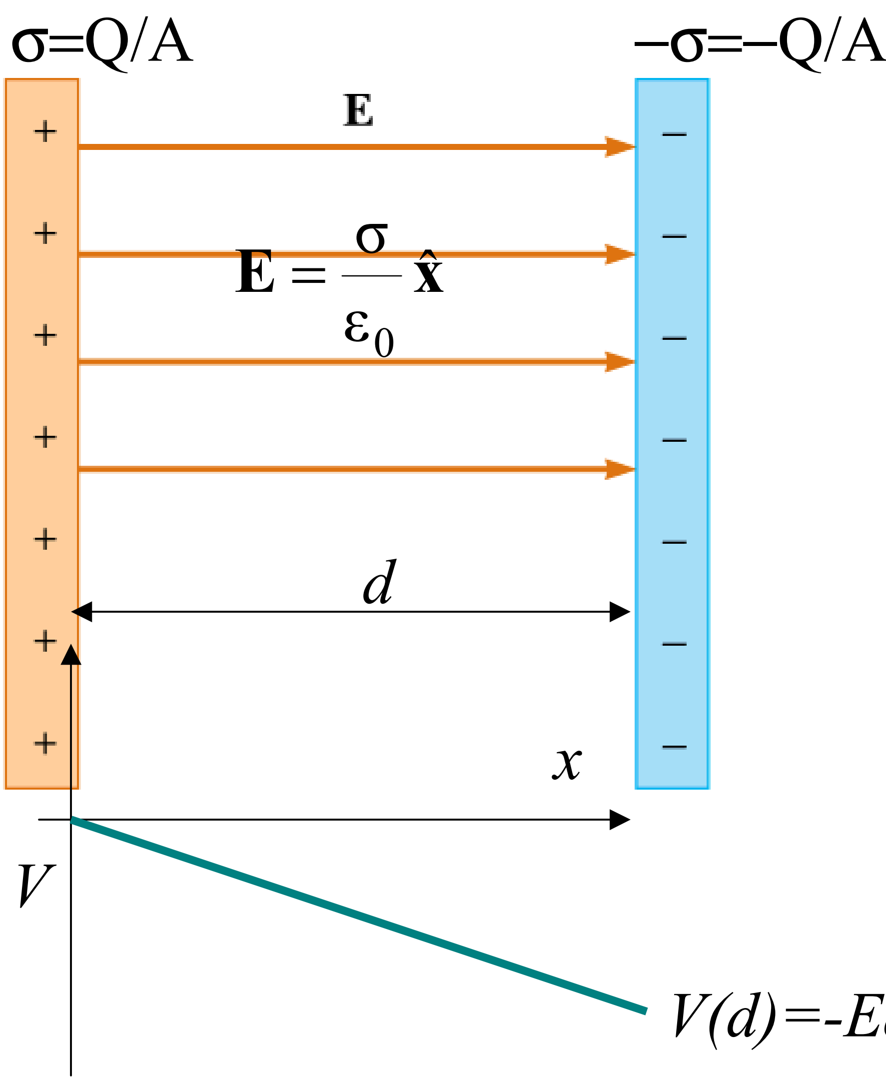
$$U(r) = k_e \frac{q_1 q_2}{r}$$



$$V(r) = k_e \frac{q}{r}$$

For a point charge, a convenient choice is $r_{ref}=\infty$.

Electrostatic potential between two parallel plates



$$\mathbf{E} = \frac{\sigma}{\varepsilon_0}\hat{\mathbf{x}}$$

$$V(d) = -Ed = -\sigma\, d/\varepsilon_0$$

Example:

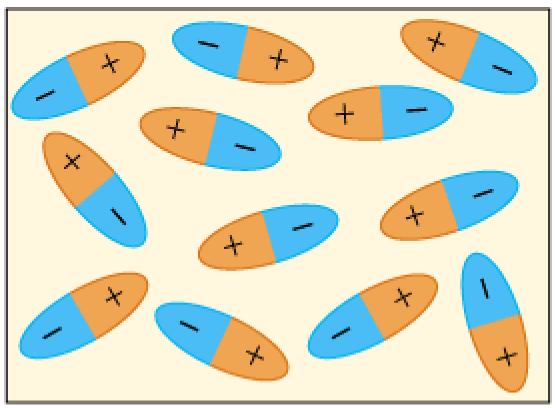
If $V = 1$ Volt
and $d = 0.01$ m

$\sigma = 8.854 \times 10^{-10} \text{C/m}^2$

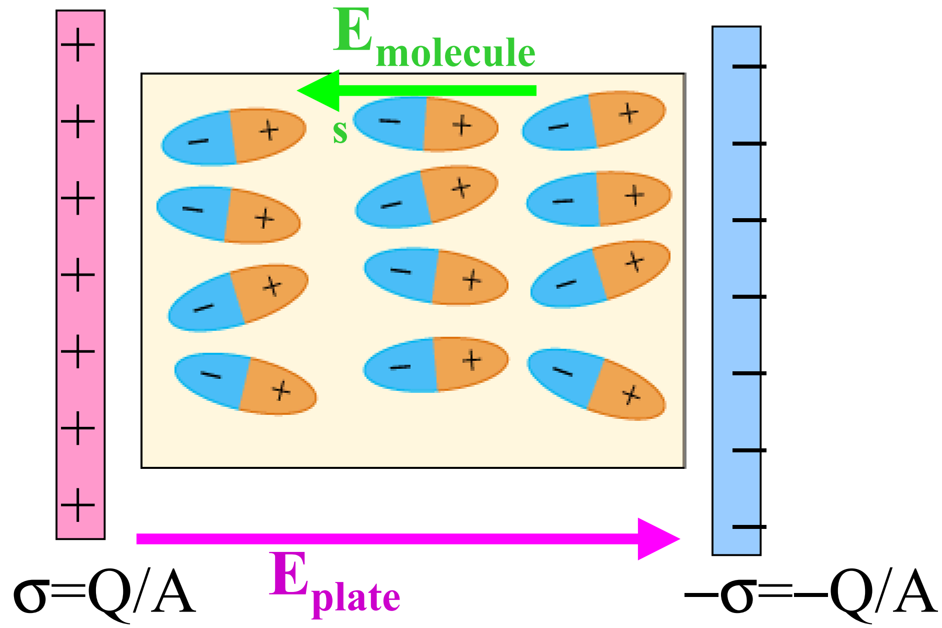
$$\Delta V = -\frac{Q}{C} \quad \text{where} \quad C \equiv \frac{\varepsilon_0 A}{d}$$

How dielectrics work:

Polar molecules in the absense of external forces:



Polar molecules in the aligned between two charged plates:



$$\mathbf{E}_{\mathbf{total}} = \mathbf{E}_{\mathbf{plate}} + \mathbf{E}_{\mathbf{molecules}} = \mathbf{E}_{\mathbf{plate}} / \kappa$$

$$V_{total} = V_{plate} + V_{molecules} = V_{plate} / \kappa$$

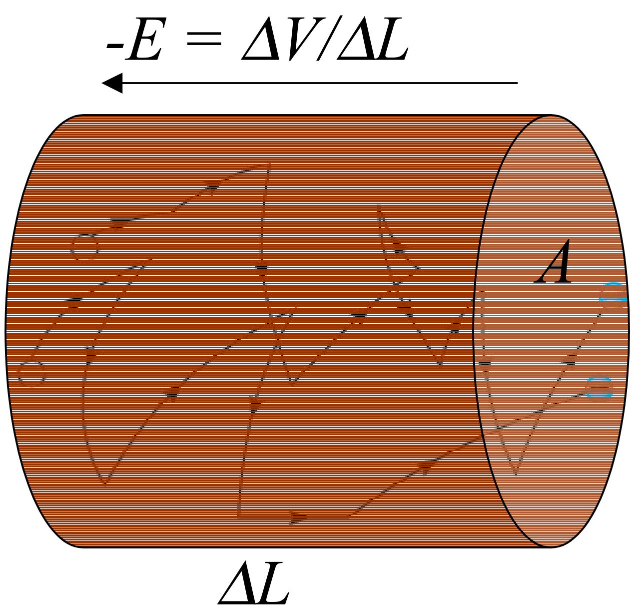
$$\boxed{V_{total} = \frac{Qd}{A\kappa\varepsilon_0} \Rightarrow C(\kappa) = \frac{A\kappa\varepsilon_0}{d}}$$

Electrical current in a wire

Approximately follows Ohm's law: $\Delta V = IR$

The resistance R depends on properties of the materials

$$R = \frac{m\Delta L}{q^2 n\tau A} \equiv \rho \frac{\Delta L}{A}$$



m electron mass

q electron charge

n number of electrons/volume

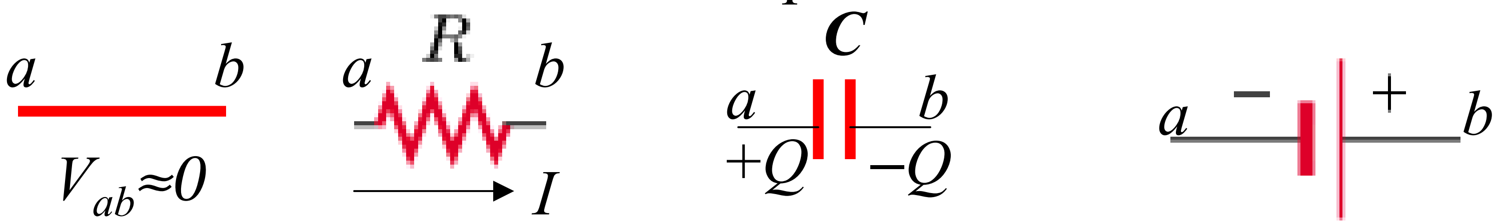
τ time between collisions

In general R depends on temperature T.

Analysis of DC circuits:

Elements:

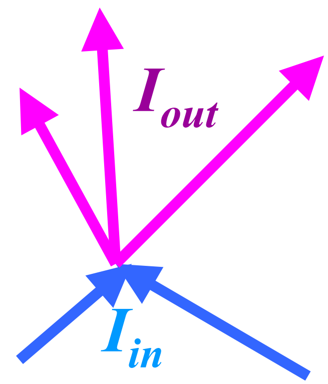
wire | resistor | capacitor | emf



$V_{ab} \approx 0$ | $V_{ab} = -IR$ | $V_{ab} = -Q/C$ | $V_{ab} = \mathcal{E}$

The principles:

Kirchhoff's rules



At any wire junction: $\sum I_{in} = \sum I_{out}$

For any closed wire loop: $\sum \Delta V = 0$