\[ F = \frac{kQ_1Q_2}{r^2} \quad F = qE \quad E_{\text{point charge}} = \frac{kQ}{r^2} \quad E_{\text{sheet}} = \sigma/\varepsilon_0 \quad \sigma = \frac{Q}{A} \]

E field lines start on positives, end on negatives. They never cross. Number of lines is prop. to charge. E fields strongest when lines closer together.

\[ PE = U = \frac{kq_1q_2}{r} \quad k = 9 \times 10^9 \ \text{N-m}^2/\text{C}^2 \quad \varepsilon_0 = 8.85 \times 10^{-12} \ \text{C}^2/\text{N-m}^2 \]

Potential: \( V = U/q \) \quad so \quad \Delta U = q \Delta V

Point Charge: \( V = \frac{kQ}{r} \)

Uniform E-field: \( \Delta V = E d \quad Q_{\text{proton}} = -Q_{\text{electron}} = 1.6 \times 10^{-19} \ \text{Coulombs} \)

Capacitor: \( C = Q/\Delta V \) (Q is charge on each plate)

\[ \text{micro: } 10^{-6} \quad \text{nano: } 10^{-9} \quad \text{pico: } 10^{-12} \]

Parallel Plate: \( C = \kappa A \varepsilon_0 /d \quad \kappa = \text{dielectric constant} \)

Energy: \( U = (1/2) C (\Delta V)^2 = (1/2) Q \Delta V = (1/2)Q^2/C \)

I = \( \Delta Q/\Delta t \) \quad drift vel.: \( I = neVdA \quad R = \rho L/A \quad \rho = \rho_0 (1 + \alpha \Delta T) \)

\( \Delta V = IR \) \quad internal resistance: \( V = \varepsilon - I r \)

Series: \( R = R_1 + R_2 + \ldots \quad 1/C = 1/C_1 + 1/C_2 + \ldots \)

Parallel: \( 1/R = 1/R_1 + 1/R_2 + \ldots \quad C = C_1 + C_2 + \ldots \)

\( P = I^2R = I \ V = V^2/R \quad \tau = RC \quad V(\text{discharging}) = V_0 e^{-\tau/RC} \)

\( V(\text{charging}) = V_0 (1-e^{-\tau/RC}) \)

Magnetic force \( |F_B| = qvB \sin\theta \) \quad direction = right hand rule

1 Tesla = 10000 Gauss. \( |F_B| = ILB \sin\theta \)

\[ \text{mass spec: } \frac{mv^2}{r} = qvB \quad \text{and } qV = (1/2) mv^2 \]

velocity selector: \( qE = qvB \)