### Constants
- $m_e = 9.109 \times 10^{-31}$ kg
- $m_p = 1.673 \times 10^{-27}$ kg
- $m_n = 1.675 \times 10^{-27}$ kg

- $k = 9 \times 10^9 \text{ Nm}^2 \text{C}^{-2}$
- $\varepsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{Nm}^{-1} \text{ or } \frac{\text{F}}{\text{m}}$

- $q_e = -1.6022 \times 10^{-19} \text{ C}$ (electron charge)
- $q_p = 1.6022 \times 10^{-19} \text{ C}$ (proton charge)
- $eV = 1.6022 \times 10^{-19} \text{ J}$ (electron volt)

### Coulomb’s Law (electrostatic force)
- Electric Field – point charge
  - $\vec{r} \cdot$ unit vector from charge to a location
  - $\vec{F} = \frac{q \cdot \vec{r}}{\varepsilon_0 \cdot r^2}$

- Potential energy - point charges
  - $U = \frac{1}{4\pi \varepsilon_0} \sum_{i<j} \frac{q_i q_j}{r_{ij}}$

- Potential
  - $V = \frac{U}{q_0}$

- Potential of a set of point charges
  - $V = \frac{1}{4\pi \varepsilon_0} \sum_i \frac{q_i}{r_i}$

- Potential difference between two parallel plates
  - $V_a - V_b = Ed$

### Capacitance
- $C = \frac{Q}{V_{ab}}$ or $F = \frac{1}{IV}$

- Capacitance – parallel plates
  - $C = \frac{\varepsilon_0 A}{d}$ (in a vacuum)

- Capacitance – energy storage
  - $U = \frac{1}{2} \frac{Q^2}{C}$

- Capacitors in series
  - $C = \frac{1}{C_1 + C_2 + C_3 + ...}$

- Capacitors in parallel
  - $C = C_1 + C_2 + C_3 + ...$

- Resistors in series
  - $R = R_1 + R_2 + R_3 + ...$

- Resistors in parallel
  - $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$

- Current
  - $I = \frac{dQ}{dt}$

- Voltage, Resistance, Current, Power
  - $V=IR$
  - $P=IV$

- Resistance
  - $R = \frac{\rho L}{A}$

### Kirchhoff’s Rules
- $\sum V = 0$ for a closed loop
- $\sum I = 0$ for a junction

### R-C circuit time constant
- $\tau = RC$

### Magnetism
- $1 \text{T} = 1 \frac{\text{V} \cdot \text{s}}{\text{m}^2} = 1 \frac{\text{N} \cdot \text{m}}{\text{A} \cdot \text{m}} = 10000 \text{ gauss}$

- $\mu_0 = 4\pi \times 10^{-7} \text{T} \cdot \text{m} / \text{A}$

- Magnetic force on moving charged particle
  - $\vec{F} = q(\vec{v} \times \vec{B})$

- Magnetic field of a moving charged particle
  - $\vec{B} = \frac{\mu_0 q}{4\pi r^2}$

- Magnetic Field of a straight wire
  - $B = \frac{\mu_0 I}{2\pi r}$

- Magnetic field outside two parallel conductors with current in opposite directions
  - $B_{\text{tot}} = \frac{\mu_0 I d}{\pi x^2}$
  - $d$ – distance from the center line of the wire pair to the axis of one wire.
  - $x$ – distance from the center line of the wire pair to the point of interest.
  - $I$ – current in the wires

- Magnetic field along the axis of a looped wire
  - $B = \frac{\mu_0 N I a^2}{2(x^2 + a^2)^{3/2}}$
  - $a$ – radius of the loop
  - $x$ – distance from the center of the loop to point of interest on the axis.
  - $I$ – current in the wires
  - $N$ – number of loops
### Conservation of Energy

\[ mgh_0 + \frac{1}{2}mv_0^2 + \frac{1}{2}k\Delta x_0^2 + W_a = mgh_f + \frac{1}{2}mv_f^2 + \frac{1}{2}k\Delta x_f^2 + E_{int} \]

### Constant Acceleration

- \[ v_2 = v_1 + a\Delta t \]
- \[ s_2 = s_1 + \left( \frac{v_1 + v_2}{2} \right) \Delta t \]
- \[ s_2 = s_1 + v_1 \Delta t + \frac{1}{2}a\Delta t^2 \]
- \[ s_2 = s_1 + \frac{v_2^2 - v_1^2}{2a} \]

### Force and Acceleration

- \[ F_{net} = ma \]

### Projectile Motion

\[ y - y_0 = (x - x_0)\tan \theta - \frac{g}{2v_0^2} \left( 1 + \tan^2 \theta \right)(x - x_0)^2 \]

- \( \theta \) – launch angle
- \( v_0 \) – launch velocity
- \( x_0, y_0 \) – launch position, positive up

### Impulse / Momentum / Restitution

\[ \sum m\vec{v}' = \sum m\vec{v} + \int_0^t \sum \vec{F} \, dt \]

\[ m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}'_1 + m_2\vec{v}'_2 \]

\[ e = -\frac{(\vec{v}_2' - \vec{v}_1')}{\vec{v}_2' - \vec{v}_1'} \] (line of impact)
1. (2 pts) Two point charges separated by a distance $d$ are brought closer together, increasing the force between them by a factor of 25. The new distance between the charges is:
   a. $d/25$  
   b. $d/5$  
   c. $5d$  
   d. $25d$

2. (2 pts) The electric field for a positive point charge:
   a. acts away from the charge  
   b. acts towards the charge  
   c. is parallel to the charge  
   d. is perpendicular to the charge

3. (2 pts) The quantity electric potential is defined as the amount of _____.
   a. electric potential energy  
   b. force acting upon a charge  
   c. potential energy per charge  
   d. force per charge

4. (2 pts) What is the relationship between the resistances for the current flowing through the rectangular bar?
   a. $R < R'$  
   b. $R = R'$  
   c. $R > R'$

5. (2 pts) The direction of conventional current flow in the circuit to the right is:
   a. clockwise  
   b. counterclockwise  
   c. cannot determine

6. (2 pts) A capacitor is a device used to store:
   a. electric current  
   b. electric potential  
   c. electric charge  
   d. magnetic energy

7. (2 pts) Prof. Schleter claims he has a magnet that only has a north pole. What do you think of this statement?
   a. statement is true  
   b. statement is false  
   c. The good professor has not given us enough information
8. (14 pts) Three charges of values \(q_1 = +2.8 \, \mu C\), \(q_2 = -3.7 \, \mu C\), and \(q_3 = +5.1 \, \mu C\), are placed as shown. Determine the distance \(d\) such that the net force on charge \(q_2\) is 180 N.

9. (14 pts) A small 0.003 kg sphere with a charge of 4.2\(\mu\)C hangs from a thread between two parallel charged plates. The potential difference between the plates is 200V. Determine the angle \(\theta\) that the sphere hangs from the vertical.
10. (14 pts) A cauterizer, used to stop bleeding in surgery, puts out 2.00 mA at 15.0 kV.
   (a) What is its power output?
   (b) What is the resistance of the path?

11. (14 pts) Determine the equivalent capacitance of the four capacitors.
12. (14 pts) A particle with a charge of 22 nC moves at (-6 x 10\(^5\) \(\hat{i}\)) m/s through a uniform magnetic field of 
(5 \(\hat{j}\) + 2 \(\hat{k}\)) T. There is also a uniform electric field of (9 x 10\(^5\) \(\hat{i}\)) N/C. Determine the magnitude of net force 
from the magnetic and electric fields on the particle.

13. (16 pts) Determine the resistance of R1 and R2.

\begin{align*}
R1 &= \quad \\
R2 &= \quad 
\end{align*}