**Equation Sheet**

### Constants

- \( m_0 = 9.109 \times 10^{-31} \text{ kg} \)
- \( m_p = 1.673 \times 10^{-27} \text{ kg} \)
- \( m_n = 1.675 \times 10^{-27} \text{ kg} \)
- \( k = 9 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \)
- \( \varepsilon_0 = 8.854 \times 10^{-12} \frac{\text{F}}{\text{m}} \)
- \( e = -1.6022 \times 10^{-19} \text{ C} \) (electron charge)
- \( eV = 1.6022 \times 10^{-19} \text{ J} \) (electron volt)

### Resistors

- \( R = \frac{\rho L}{A} \)
- \( V = IR \)
- \( P = IV \)
- \( R_{eq} = R_1 + R_2 + R_3 + \ldots \) Series
- \( \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots \) Parallel

### Magnetism

- \( 1 \text{T} = \frac{1 \text{V} \cdot \text{s}}{\text{m}^2} = \frac{1 \text{N}}{\text{A} \cdot \text{m}} = 10000 \text{ gauss} \)
- \( \mu_0 = 4\pi \times 10^{-7} \frac{\text{H}}{\text{m}} \)
- \( \vec{F} = q(\vec{v} \times \vec{B}) \)
- \( \vec{B} = \frac{\mu_0}{4\pi} \frac{q \vec{v} \times \vec{r}}{r^2} \) straight wire

### Coulomb's Law; Electric Field

- \( F = \frac{1}{4\pi \varepsilon_0} \frac{|q_1 q_2|}{r^2} \)
- \( \vec{E} = \vec{F} = \frac{1}{q} \frac{q}{4\pi \varepsilon_0} \frac{\vec{r}}{r^2} \)

### Potential Energy; Potential

- \( U = \frac{1}{4\pi \varepsilon_0} \sum \frac{q_i q_j}{r_{ij}} \)
- \( V = \frac{U}{q_0} \)
- \( V = \frac{1}{4\pi \varepsilon_0} \sum \frac{q_i}{r_i} \) point charges
- \( V_a - V_b = Ed \) parallel plates

### Capacitors

- \( C = \frac{Q}{V_{ab}} \)
- \( 1 \text{F} = 1 \text{C/}\text{V} \)
- \( C = \frac{k\varepsilon_0 A}{d} \) parallel plates
- \( U = \frac{Q^2}{2C} = \frac{1}{2} CV^2 = \frac{1}{2} QV \)
- \( \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots \) series
- \( C_{eq} = C_1 + C_2 + C_3 + \ldots \) parallel

### Kirchoff's Rules

- \( \Sigma V = 0 \) for a closed loop
- \( \Sigma I = 0 \) for a junction

### R-C circuit time constant

- \( \tau = RC \)

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**Diagram**

- **P** = power
- **V** = voltage
- **R** = resistance
- **I** = current
- **X** = inductive reactance
- **R** = resistance
- **C** = capacitance
- **V** = voltage
- **P** = power
1. (2 pts) What is the direction of the velocity of a positive charge that experiences the magnetic force shown in the diagram?

   (a) Left
   (b) Right
   (c) Up
   (d) Down
   (e) Into the page
   (f) Out of the page
   (g) No force

2. (2 pts) A 1 mF, a 2 mF, and a 3 mF capacitor are connected in series, the combination being connected across a 9 volt battery. The capacitor with the greatest charge on it is

   (a) the 3 mF
   (b) the 1 mF
   (c) the 2 mF
   (d) cannot be determined
   (e) they all have the same charge

3. (4 pts) What current is required to produce a magnetic field of 50 μT at a distance of 3.2 cm from a long straight wire?

   \[ B = \frac{\mu_0 I}{2\pi r} \]
   \[ \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A} \]
   \[ B = 50 \times 10^{-6} \text{ T} \]
   \[ r = 0.032 \text{ m} \]
   \[ I = \frac{(50 \times 10^{-6} \text{ T})(2\pi)(0.032 \text{ m})}{2 \times 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A}} = 8.0 \text{ A} \]

4. (4 pts) A capacitor stores 0.042 J of energy. What is its capacitance if the initial voltage supplied is 91 V?

   \[ U = \frac{1}{2} CV^2 \]
   \[ C = \frac{2U}{V^2} \]
   \[ V = 91 \text{ V} \]
   \[ U = 0.042 \text{ J} \]
   \[ C = \frac{2(0.042)}{(91 \text{ V})^2} = 1.014 \times 10^{-5} \text{ F} \]
   \[ = 10.14 \mu \text{F} \]
5. (10 pts) The resistivity of a copper wire is $1.71 \times 10^{-8} \, \Omega \, \text{m}$. The wire has a radius of 0.5 mm and has a potential difference 0.75 V from one end of the wire to the other end when a current of 4 A is applied. Determine the length of the wire.

\[
R = \frac{\rho L}{A} \quad \rho = 1.71 \times 10^{-8} \, \Omega \, \text{m} \\
A = \pi r^2 \quad r = 0.5 \, \text{mm} = 0.0005 \, \text{m} \\
V = 0.75 \, \text{V} \quad I = 4 \, \text{A} \\
R = \frac{V}{I} = \frac{0.75 \, \text{V}}{4 \, \text{A}} = 0.1875 \, \Omega \\
L = \frac{RA}{\rho} = \frac{RA}{1.71 \times 10^{-8} \, \Omega \, \text{m}} = 8.612 \, \text{m}
\]

6. (10 pts) Determine the magnitude and direction of the maximum force on an aluminum rod with a -2.7 μC charge that passes between the poles of a 1.5 T permanent magnet at a speed of 4.0 km/s.

\[
F = q (\vec{v} \times \vec{B}) \\
q = -2.7 \times 10^{-6} \, \text{C} \\
B = 1.5 \, \text{T} \\
\vec{v} = 4.0 \, \text{km/s} \times \left( \frac{1000 \, \text{m/s}}{1 \, \text{km/s}} \right) \\
= -2.7 \times 10^{-6} \, \text{C} \left( 60 \, \text{Tm/s} \, \hat{j} \right) \\
= -1.62 \times 10^{-5} \, \text{N} \, \hat{j}
\]
7. (12 pts) The net force on \( q_2 \) is zero when it is placed between two charges as shown. Determine the charge of \( q_3 \).

\[ q_1 = -3.5 \, \mu C \quad q_2 = +1.3 \, \mu C \]

\[ F_{12} = F_{23} \]

\[ \frac{K(q_1)(q_2)}{(r_{12})^2} = \frac{K(q_2)(q_3)}{(r_{23})^2} \]

\[ \frac{3.5 \, \mu C}{(0.3 \, m)^2} = \frac{q_3}{(0.4 \, m)^2} \]

\[ q_3 = -6.222 \, \mu C \]

8. (14 pts) Determine the magnitude and direction of the electric field at point P.

\[ E_A = \frac{1}{4\pi\epsilon_0} \frac{q_A}{r^2} \]

\[ = \frac{8.988 \times 10^9}{(0.4 \, m)^2} \frac{(5 \times 10^{-7} \, C)}{2.809 \times 10^4 \, \text{N/C}} = 16.6 \times 10^4 \, \text{N/C} \]

\[ E_B = -8.988 \times 10^9 \frac{N \cdot m^2}{C^2} \frac{(6 \times 10^{-9} \, C)}{(0.3 \, m)^2} \]

\[ = -5.992 \times 10^4 \, \text{N/C} \]

\[ \sum E = 16.6 \times 10^4 \, \text{N/C} \angle 64.88^\circ \]
9. (14 pts) Consider the circuit shown. Determine the power dissipated by the 20 Ω resistor.

\[ \text{Entire circuit:} \]
\[ V = IR_{\text{total}} \]
\[ I = \frac{V}{R} = \frac{12V}{22\Omega} = 0.5455 \text{ A} \]

Current will be the same through both series resistors

So for the \( R_{\text{eq}} = 12\Omega \)

\[ V = IR = (0.5455\text{ A})(12\Omega) \text{ series:} \]
\[ = 6.546 \text{ V} \]

Voltage drop will be constant for both parallel resistors

\[ R = 20\Omega \quad V = 6.546 \text{ V} \quad P = \frac{V^2}{R} = 2.142 \text{ W} \]

10. (14 pts) Two identical capacitors in series are in parallel with a third identical capacitor. A battery supplies 20 V to the circuit. The total energy stored in the circuit is 530 µJ. Determine the capacitance of an individual capacitor, \( C \).

\[ U = 530 \times 10^{-6} \text{ J} \]

\[ U = \frac{1}{2} CV^2 \]

\[ 530 \times 10^{-6} = \frac{1}{2} \left( \frac{3C}{2} \right) (20 \text{ V})^2 \]

\[ C = 1.767 \mu \text{F} \]
11. (14 pts) Determine the current $I_2$ in the circuit below.

-2 units
-5 not solving matrix
-2 incorrect sign
-3 not including junction equation

\[ J_a = I_1 - I_3 - I_2 = 0 \]

Loop 1: \[ +17V - 20\Omega I_2 - 10\Omega I_1 = 0 \]

Loop 2: \[ +13V + 20\Omega I_2 - 30\Omega I_3 = 0 \]

\[ I_1 - I_a - I_3 = 0 \]
\[ -10I_1 - 20I_2 + 0 = -17 \]
\[ 0 + 20I_2 - 30I_3 = -13 \]

\[ I_1 = 1.009 \text{ amps} \]
\[ I_2 = 0.3454 \text{ amps} \]
\[ I_3 = 0.6636 \text{ amps} \]