Exam II: Chapters 16–17

1. Capacitors: What's the point?
   A) Capacitors are batteries; the terms are interchangeable. You must have a capacitor to make charge flow.
   B) Capacitors can be charged and discharged, but they are not batteries. They can store or release charge, but are not a voltage source or power supply.
   C) Capacitors increase the capacity of whatever they are paired with. A capacitor will increase the resistance of a resistor, or increase the voltage of a battery, depending on where you put it in your circuit.

2. A 1-μF parallel plate capacitor has an initial plate separation d. What happens if the plate separation is decreased to half its original value? The new capacitance will be
   A) one fourth the original value.
   B) half the original value.
   C) unchanged; plate separation doesn't matter.
   D) twice the original value.
   E) four times the original value.
   F) infinite!

3. For electric charges to flow,
   A) they must be pulled by a gravitational force.
   B) the resistance of the medium must be extremely high.
   C) a potential difference must exist. Negative charges flow from low to high potential.
   D) a potential difference must exist. But the negative charges flow from high to low potential!

4. One amp (or ampere) of electrical current means
   A) 1 e^- traveling at a speed of 1 m/s.
   B) 1 e^- is traveling at c, the speed of light.
   C) 1 C of charge per every second of time.
   D) 1 C of charge per electron traveling at 1 m/s.

5. The dial on the ammeter shows that $I = 0.5$amps of current flows through the circuit you have just built.
   A) This means that electrons are pushed away from the negative terminal of the power supply, and travel all the way around the circuit until they reach the positive terminal of the power supply.
   B) Electrons are moving, but not all the way around the circuit. They move locally, and if the electrons are moving to the left, the sign convention says that current flows to the right.
   C) Electrons are sort of moving. If the current was 1amp, this would mean 1 electron was moving around the circuit; I = 0.5amps is impossible because it would mean only half an electron moved!
   D) Electrons are not moving at all. The definition of current says that (+) charges are moving. If the ammeter reads 0.5amps, it's because protons are moving around the circuit from (+) to (–).
   E) Electrons and protons are both moving, and in opposite directions. There will be 0.25amp of electrons moving (+) to (–) around the circuit, and 0.25amp of protons moving in the opposite direction, (–) to (+).

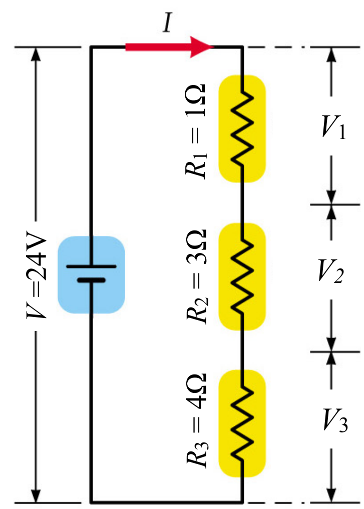
6. Current and drift velocity are the same thing.
   A) Sure. It's a difference in vocabulary between America and the rest of the world; we say "current," but everyone else calls it "drift velocity" (much in the same way they insist upon using that ridiculous "metric system").
   B) Current measures the instantaneous velocity of an electron, while drift velocity measures the average velocity. And we know that average and instantaneous velocity are not the same thing.
   C) Drift velocity is a misnomer. It isn't a velocity at all; it really ought to be drift frequency, because it is a measure of how many charges pass a specific point n a given amount of time. Current is the true measure of how fast the individual charges are moving.
   D) Ok, that's just backwards. Current measures the number of charges per time, while drift velocity measures the speed of the individual charges.

7. Two wires are made of the same copper.
   A) For wires with the same diameter, the longer wire will have more resistance then the shorter wire.
   B) For wires with the same length, the thicker wire will have more resistance than the thinner wire.
   C) The wires will have the same resistance, no matter the length or thickness, because they are both made of copper.
   D) The wire with the thicker coating of insulation will have greater resistance regardless of the material or geometry of the wire.

8. The resistance of a tungsten bulb filament
   A) increases as filament temperature increases.
   B) remains constant regardless of temperature.
   C) decreases as filament temperature increases.
   D) may increase or decrease with temperature.

9. Two wires have the same length and the same diameter. One is copper ($\rho_{Cu} = 1.70\times10^{-8}\Omega\cdot m$), the other is NiChrome ($\rho_{NiCr} = 100\times10^{-8}\Omega\cdot m$). At room temperature ($T$ =20°C), the copper wire
   A) will have greater resistance than the NiChrome.
   B) will have a smaller resistance than the NiChrome wire.
   C) will have exactly the same resistance as the NiChrome wire.
   D) cannot be compared to the NiChrome; there is no way to predict which wire will have greater resistance.

10. You have two copper wires of the same length. The first wire has twice the diameter of the second.
    A) The thicker wire will have the greater resistivity.
    B) The thinner wire will have the greater resistivity.
    C) Trick question! Since they are both copper, they will have the same resistivity.



Three devices (each has a different resistance) are wired in series with a **24-V** battery as shown on the left.

11. Replacing the three resistors shown with a single equivalent resistor R_{eq}
    A) will increase the voltage.
    B) will decrease the voltage.
    C) will increase the total amount of current drawn.
    D) will decrease the total amount of current drawn.
    E) will have no effect on either the voltage or the total amount of current drawn.

12. What is the equivalent resistance R_{eq}? Answer numerically:

$$R_{eq} = R_1 + R_2 + R_3 = 1\Omega + 3\Omega + 4\Omega = 8\Omega$$

13. How much current I does this circuit draw? Answer numerically:

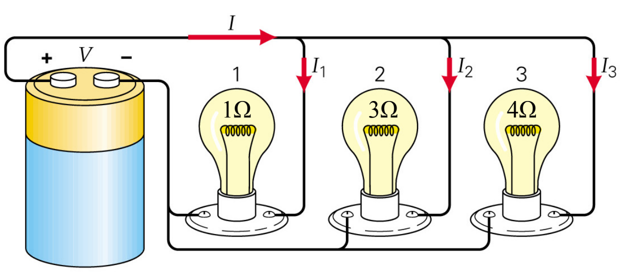
$$V = IR_{eq} \implies 24V = I(8\Omega) \implies I = 3A$$

14. What is the voltage V_2 across resistor R_2? Answer numerically:

$$V_2 = IR_2 \implies V_2 = (3A)(3\Omega) = 9V$$

15. True or false: In this series circuit, **Bulb**$_1$ is the brightest (and **Bulb**$_3$ is dimmest).

16. True or false: Adding a fourth bulb in series will decrease the total current drawn.



The same three bulbs on the right are now wired in parallel to the **24V** battery as shown.

17. How much total current does this circuit draw? Answer numerically.

$$I = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

$$I = \frac{24V}{1\Omega} + \frac{24V}{3\Omega} + \frac{24V}{4\Omega}$$

$$I = (24 + 8 + 6) = 38A$$

18. What is the equivalent resistance? Answer numerically.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{eq}} = \frac{1}{1\Omega} + \frac{1}{3\Omega} + \frac{1}{4\Omega}$$

$$R_{eq} = 0.632\Omega$$

19. Determine the wattage of Bulb2. Answer numerically.

$$P_2 = \frac{V^2}{R_2} = \frac{(24V)^2}{3\Omega} = 192W$$

20. True or false: The voltage across **Bulb**$_2$ is less than the voltage across **Bulb**$_3$.

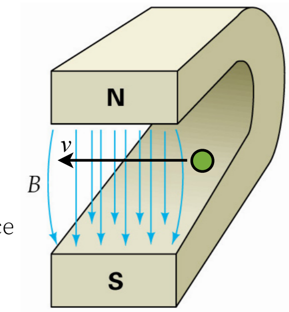
21. Rank the bulbs in order of brightness.
    A) **Bulb**$_1$ is brightest **Bulb**$_3$ is the dimmest.
    B) **Bulb**$_2$ is brightest. **Bulb**$_1$ is the dimmest.
    C) **Bulb**$_2$ is brightest. **Bulb**$_3$ is the dimmest.
    D) **Bulb**$_3$ is brightest. **Bulb**$_1$ is the dimmest.
    E) Trick question! All the bulbs have exactly the same brightness!

22. If we continue to add bulbs to the circuit, wiring each in parallel,
    A) the battery voltage decreases.
    B) the total current decreases.
    C) the equivalent resistance decreases.
    D) voltage, current, and resistance all decrease.

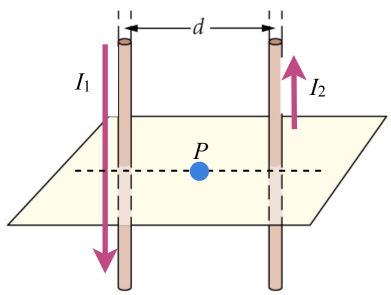
23. Every magnet has
    A) a single pole at the very center of the magnet.
    B) two poles, either a pair of North poles or a pair of South poles.
    C) two poles, one negative and one positive.
    D) a pair of poles, one North and one South.
    E) at least 50% iron in its composition.

24. The magnetic force
    A) causes opposite poles to repel each other.
    B) causes opposite poles to attract each other.

A **singly charged positive ion** $(+q)$ enters the uniform magnetic field B $(-y$ direction) shown on the right, traveling with a horizontal velocity v in the $-x$ direction.



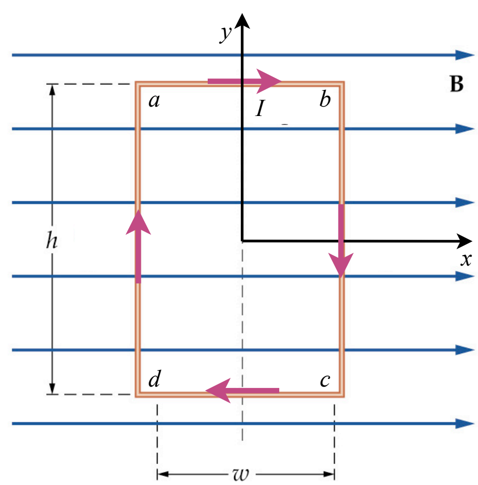
25. What is the direction of the force F exerted on the particle by the magnetic field?
    A) $+x$ C) $+y$ E) $+z$
    B) $-x$ D) $-y$ F) $-z$
26. True or false: A particle with twice the charge $(+2q)$ will experience double the force.
27. True or false: A singly charged positive particle $(+q)$ with twice the velocity $(2v)$ will experience half the magnetic force.
28. True or false: A singly charged particle $(+q)$ with twice the mass $(2m)$ will experience exactly the same magnetic force.
29. To reverse the direction of the force on the particle, you should
    A) reverse the magnetic field. C) increase the particle's mass.
    B) increase the particle's velocity. D) increase the particle's charge.



Two long, straight parallel wires are oriented parallel to the y–axis. The current flowing through each wire points in the direction shown. The current $I_1 = 3I_2$. The plane shown (xz–plane) is perpendicular to the plane of the page (xy–plane).

30. Where will the net magnetic field to be **exactly zero** $(B_1 + B_2 = 0)$?
    A) To the left of Wire_1.
    B) To the right of Wire_2.
    C) Nowhere. The magnitude will always be some non-zero value.
    D) In between the wires, at some location closer to wire 2 than wire 1.
    E) In between the wires, at some location closer to wire 1 than wire 2.
31. At a point P on the x-axis between the wires, the direction of the net magnetic field $(B = B_1 + B_2)$ points
    A) $+x$ B) $-x$ C) $+y$ D) $-y$ E) $+z$ F) $-z$
32. What is the direction of the force on Wire_1 because of the magnetic field created by Wire_2? Wire_1 is
    A) pulled directly towards Wire_2 $(+x$ direction).
    B) pushed directly away from Wire_2 $(-x$ direction).
    C) pushed out of the plane of the paper $(+z$ direction).
    D) pulled into the plane of the paper $(-z$ direction).
    E) neither pushed nor pulled nor poked nor tugged nor anything. No force on Wire_2 because Wire_1!

The rectangular loop of wire on the right initially lies in the xy plane of the page as shown. The uniform magnetic field B remains constant in the $+x$ direction, and a clockwise current I is induced when the loop is connected to a voltage source (not shown).

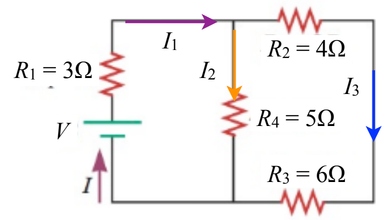


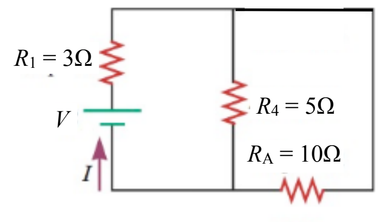
33. What are the directions of the forces F_{ab} and F_{bc}, exerted on the segments ab and bc of the wire?
    A) Both forces are in the $+z$ direction.
    B) Both forces are in the $-z$ direction.
    C) The force F_{ab} points in the $+x$ direction, but the force F_{bc} points in the $-y$ direction.
    D) The force $F_{ab} = 0$, but the force F_{bc} points in the $+z$ direction.
    E) The force $F_{bc} = 0$, but the force F_{ab} points in the $+x$ direction.
34. What is the direction of the torque the loop?
    A) The loop will spin about the x-axis. Segment ab is pulled out of the page, while segment cd is pushed into the page.
    B) The loop will spin about the y-axis. Segment bc is pulled out of the page, while segment da is pushed into the page.
    C) The loop will spin about the z-axis. The entire loop remains in the xy-plane, and starts to spin in a clockwise direction about the origin.
    D) Trick question! There is no torque on the loop, because there is no net force on the loop!

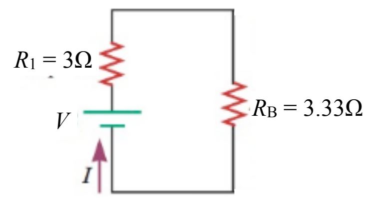
Part II: Problem Solving

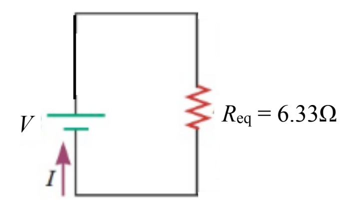
Solve each of the following problems to the best of your ability. Please work in the space provided, and if you need scratch paper, it will be provided for you. Please work as neatly as you can, and make your reasoning/logic/math as clear as possible.

35. The circuit on the right must be solved by reducing it to a single equivalent resistance, and applying Ohm's Law. The circuit is connected to a $V = 24\text{V}$ power supply.









A) (4 points) Determine the total equivalent resistance R_{eq}.

$$R_A = R_2 + R_3 = 4\Omega + 6\Omega = 10\Omega$$

$$\frac{1}{R_B} = \frac{1}{R_A} + \frac{1}{R_4} = \frac{1}{10\Omega} + \frac{1}{5\Omega} = 0.3$$

$$R_B = \frac{1}{0.3} = 3.33\Omega$$

$$R_{eq} = R_B + R_1 = 3.33\Omega + 3\Omega = 6.33\Omega$$

B) (4 points) Find the current through each branch of the circuit. Please label your diagram to clearly indicate which current corresponds to which branch.

C) (4 points) Calculate the voltage across each of the resistors.

$$V = IR_{eq} \qquad (24\text{V}) = I(6.33\Omega) \qquad I = 3.79\text{A}$$

$$I_1 = I = 3.79\text{A} \qquad V_1 = I_1 R_1 = (3.79\text{A})(3\Omega) = 11.4\text{V}$$

$$I_B = I = 3.79\text{A} \qquad V_B = I_B R_B = (3.79\text{A})(3.33\Omega) = 12.6\text{V}$$

$$V_4 = V_B = 12.6\text{V} \qquad I_2 = \frac{V_4}{R_4} = \frac{12.6\text{V}}{5\Omega} = 2.53\text{A}$$

$$V_A = V_B = 12.6\text{V} \qquad I_A = \frac{V_A}{R_A} = \frac{12.6\text{V}}{10\Omega} = 1.26\text{A}$$

$$I_3 = I_A = 1.26\text{A} \qquad V_2 = I_3 R_2 = (1.26\text{A})(4\Omega) = 5.05\text{V}$$

$$I_3 = I_A = 1.26\text{A} \qquad V_3 = I_3 R_3 = (1.26\text{A})(6\Omega) = 7.58\text{V}$$

D) (4 points) Assume the devices are light bulbs, and indicate which bulb is the brightest, and calculate the power P dissipated by that bulb (wattage!).

$$P = I^2 R \qquad P = (3.79\text{A})^2 (6.33\Omega) = 90.0\text{W}$$

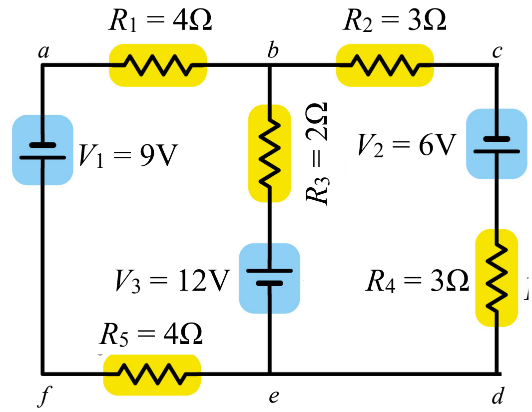
$$R_1 = 3\Omega \qquad I_1 = 3.79\text{A} \qquad V_1 = 11.4\text{V} \qquad P_1 = (3.79)^2(3) = 43\text{W}$$

$$R_2 = 4\Omega \qquad I_3 = 1.26\text{A} \qquad V_2 = 5.05\text{V} \qquad P_2 = (1.26)^2(4) = 6.35\text{W}$$

$$R_3 = 6\Omega \qquad I_3 = 1.26\text{A} \qquad V_3 = 7.58\text{V} \qquad P_3 = (1.26)^2(6) = 9.53\text{W}$$

$$R_4 = 5\Omega \qquad I_2 = 2.53\text{A} \qquad V_4 = 12.6\text{V} \qquad P_4 = (2.53)^2(5) = 32\text{W}$$

36. The circuit on the right must be solved using Kirchhoff's rules.
Current I_1 flows through the branch containing R_1, V_1 and R_5
Current I_2 through the branch containing R_2, V_2, and R_4
Current I_3 flows through the branch containing V_3 and I_3



A) (4 points) Apply Kirchhoff's Junction Rule. Indicate on the diagram which node you select, and write the appropriate equation.

$$\text{Junction Rule: } I_{in} = I_{out}$$
$$\text{Node } b\text{: } I_3 = I_1 + I_2$$
$$\text{Node } e\text{: } I_1 + I_2 = I_3$$

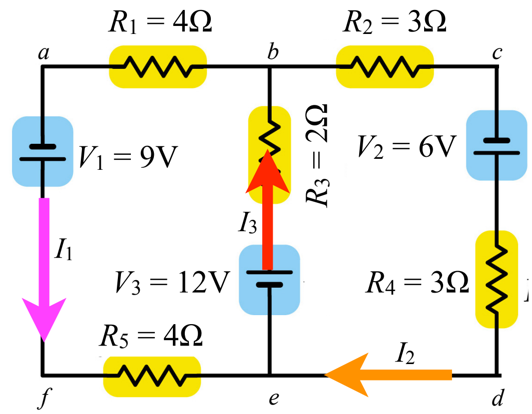
B) (4 points) Choose one loop and apply Kirchhoff's Loop Rule. Clearly identify which loop you are analyzing, and write the appropriate equation.

$$\text{Loop Rule: } energy_{in} = work_{out}$$
$$\text{Loop } afeba\text{: } V_1 - I_1 R_5 + V_3 - I_3 R_3 - I_1 R_1 = 0$$
$$(9\text{V}) - I_1(4\Omega) + (12\text{V}) - I_3(2\Omega) - I_I(4\Omega) = 0$$
$$21 - 8I_1 - 2I_3 = 0$$

C) (4 points) Choose a second, different loop, and apply the Loop Rule once more. Again, clearly identify which loop you are analyzing, and write the appropriate equation.

$$\text{Loop Rule: } energy_{in} = work_{out}$$
$$\text{Loop } cdebc\text{: } V_2 - I_2 R_4 + V_3 - I_3 R_3 - I_2 R_2 = 0$$
$$(6\text{V}) - I_2(3\Omega) + (12\text{V}) - I_3(2\Omega) - I_2(3\Omega) = 0$$
$$18 - 6I_2 - 2I_3 = 0$$

$$\text{Loop Rule: } energy_{in} = work_{out}$$
$$\text{Loop } afdca\text{: } V_1 - I_1 R_5 + I_2 R_4 - V_2 + I_2 R_2 - I_1 R_1 = 0$$
$$(9\text{V}) - I_1(4\Omega) + I_2(3\Omega) - (6\text{V}) + I_2(3\Omega) - I_1(4\Omega) = 0$$
$$3 - 8I_1 + 6I_2 = 0$$

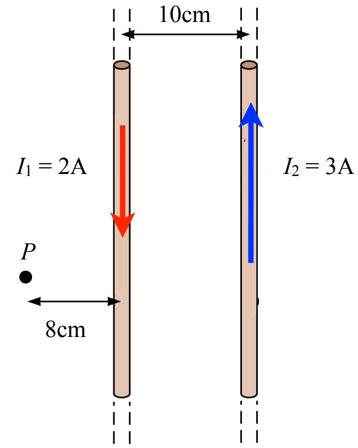


D) (4 points) Solve the system of equations for the values of the current.

Solve equations A), B), and C):

$I_1 + I_2 = I_3$	$I_1 = 1.73\text{A}$
$21 - 8I_1 - 2I_3 = 0$	$I_2 = 1.81\text{A}$
$18 - 6I_2 - 2I_3 = 0$	$I_3 = 3.54\text{A}$

37. Two parallel wires are oriented in the y-direction, and carry current as shown.



A) (4 points) What magnetic field B_1 is created by current I_1 at point P? Be sure to clearly indicate the direction of the field as well as its magnitude!

Using RHR, the magnetic field B_1 points into the page ($-z$ direction) at point P.

$$I_1 = 2\text{A} \qquad d_1 = 0.08\text{m} \qquad B_1 = \frac{\mu_o I_1}{2\pi d_1}$$

$$B_1 = \frac{(4\pi\times10^{-7}\text{T}\cdot\text{m/A})(2\text{A})}{2\pi(0.08\text{m})} = 5.0\mu\text{T}$$

B) (4 points) What magnetic field B_2 is created by current I_2 at point P? Be sure to clearly indicate the direction of the field as well as its magnitude!

Using RHR, the magnetic field B_2 points out of the page ($+z$ direction) at point P.

$$I_2 = 3\text{A} \qquad d_2 = 0.18\text{m} \qquad B_2 = \frac{\mu_o I_2}{2\pi d_2}$$

$$B_2 = \frac{(4\pi\times10^{-7}\text{T}\cdot\text{m/A})(3\text{A})}{2\pi(0.18\text{m})} = 3.3\mu\text{T}$$

C) (4 points) What is the **force per unit length** exerted on Wire$_2$ by the current I_2? Be sure to indicate the direction of the force as well as its magnitude!

The wires repel, which means the forc eon Wire$_2$ is to the right ($+x$ direction).

$$I_2 = 3\text{A} \qquad d_1 = 0.10\text{m} \qquad B_1 = \frac{\mu_o I_1}{2\pi d_1} \qquad \theta = 90°$$

$$\frac{F_2}{L} = I_2 B_1 \sin\theta = \frac{(4\pi\times10^{-7}\text{T}\cdot\text{m/A})(2\text{A})(3\text{A})}{2\pi(0.10\text{m})} = 12\mu\text{N/m}$$

Formula Sheet for Chapters 16–17

proton: $m = 1.67x10^{-27}\text{kg}$

$q = +1.6x10^{-19}\text{C}$

electron: $m = 9.1x10^{-31}\text{kg}$

$e^{-} = -1.6x10^{-19}C$

Coulomb's Law: $F = k\dfrac{q_1 q_2}{r^2}$

Electric Field: $\vec{F} = q\vec{E}$

Point Charge: $E = k\dfrac{Q}{r^2}$

Parallel Plates: $E = \dfrac{4\pi kQ}{A}$

Gravitational Potential Energy: $U_g = mgh$

Electrical Potential Energy: $U = (qE)d$

Potential Difference:

$$\Delta V = \frac{\Delta U}{q} = \frac{W}{q}$$

Parallel Plates: $V = \dfrac{W}{q} = \dfrac{(qE)d}{q} = Ed$

Point Charge: $V = \dfrac{kQ}{r}$

$\Delta V = V_B - V_A$ $\qquad \Delta V = \dfrac{kQ}{r_B} - \dfrac{kQ}{r_A}$

Work to Assemble Point Charges: $U_{12} = \dfrac{kq_1 q_2}{r_{12}}$

Capacitance: $Q = CV$

Parallel Plate Capacitor: $C = \dfrac{\varepsilon_o A}{d}$

Permittivity of Free Space: $\dfrac{1}{4\pi k} = \varepsilon_o = 8.85x10^{-12}\ \dfrac{\text{C}^2}{\text{N}\cdot\text{m}^2}$

Energy Stored by a Capacitor: $U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \dfrac{Q^2}{2C}$

Parallel Plate Capacitor With Dielectric: $C = \kappa\dfrac{\varepsilon_o A}{d}$

Dielectric Constant: $\kappa = \dfrac{V_o}{V} = \dfrac{E_o}{E}$

$C = \kappa C_o$

Electric Current: $I = \dfrac{\Delta q}{\Delta t}$

$\Delta q = ne^{-} = I(\Delta t)$

Ohm's Law: $V = IR$

Resistivity: $R = \rho\left(\dfrac{L}{A}\right)$

Electric Power: $P = \dfrac{W}{t} = \dfrac{qV}{t}$ $\qquad P = IV = I^2 R = \dfrac{V^2}{R}$

Series Resistors: $R_s = \sum R_n$

$V = \sum V_n$ $\qquad I_1 = I_2 = \cdots = I_n$

Parallel Resistors: $\dfrac{1}{R_p} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \cdots + \dfrac{1}{R_n}$

$V_1 = V_2 = \cdots = V_n$ $\qquad I = I_1 + I_2 + \cdots + I_n$

Kirchhoff's Junction Rule: $\sum I_n = 0$

Kirchhoff's Loop Rule: $\sum V_n = 0$

Magnetic Field: $B = \dfrac{F}{qv}$

Magnetic Force on a Moving Charge: $\vec{F} = q(\vec{v} \times \vec{B})$

$\vec{F} = qvB\sin\theta$

Force on Wire in Magnetic Field: $F = ILB\sin\theta$

Magnetic torque: $\vec{\tau} = \vec{r} \times \vec{F}$

$\tau = N(IAB\sin\theta)$

Permeability of Free Space: $\mu_o = 4\pi \times 10^{-7}\ \dfrac{\text{T}\cdot\text{m}}{\text{A}}$

Magnetic Field of Long Straight Wire: $B = \dfrac{\mu_o I}{2\pi d}$

Magnetic Field of a Flat Wire Loop With *N* turns:

$$B = \frac{\mu_o NI}{2r}$$

Magnetic Field of a Solenoid With *N* Turns: $B = \dfrac{\mu_o NI}{L}$