PH 102-1 / LeClair Summer II 2008

Final Exam

Part I: Multiple Choice (75%)

Instructions

1. **Answer all questions below.** All questions have equal weight.
2. Clearly mark the answer you choose using the tick boxes.
3. **There will be no partial credit given on this section.**
4. You are allowed 2 sides of a standard 8.5x11 in piece of paper with notes/formulas and a calculator.

1. If a moving clock as a time dilation factor of 10, what is its speed?

- ■ 0.995c
- □ 0.800c
- □ 0.570c
- □ 0.230c

2. Neutrons have an average lifetime of 15 minutes when at rest in the laboratory. What is the average lifetime (measured in the lab) of a neutron moving at a speed of 50% of the speed of light?

- □ 7.89 min
- □ 25.4 min
- □ 13.0 min
- ■ 17.3 min

3. If two charges of $+1\,\mu$C are separated by 1 cm ($= 10^{-2}$ m), what is the force between them?

- □ 1.8×10^{-9} N
- ■ 90 N
- □ 8.2×10^{13} N
- □ 1.0×10^{-4} N

4. A "free" electron and a "free" proton are placed in an identical electric field. Which of the following statements are true? *Check all that apply.*

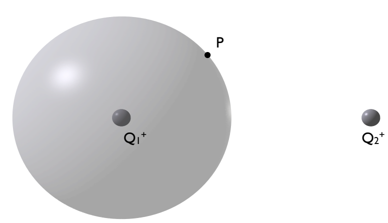
- □ Each particle is acted on by the same electric force and has the same acceleration.
- □ The electric force on the proton is greater in magnitude than the force on the electron, but in the opposite direction.
- ■ The electric force on the proton is equal in magnitude to the force on the electron, but in the opposite direction.
- ■ The magnitude of the acceleration of the electron is greater than that of the proton.
- □ Both particles have the same acceleration.

5. Consider a simple parallel-plate capacitor whose plates are given equal and opposite charges and are separated by a distance D. The capacitor is not connected to a battery. Suppose the plates are pushed together until they are separated by a distance $d < D$. How does the final electrostatic energy stored in the capacitor compare to the initial energy?

- ■ The final stored energy is smaller than the initial stored energy.
- □ The final stored energy is greater than the initial stored energy.
- □ They are the same.

6. In the figure below, a point charge $1Q^+$ is at the center of an imaginary spherical Gaussian surface and another point charge $2Q^+$ is outside of the Gaussian surface. Point P is on the surface of the sphere. Which one of the following statements is true?

- □ Both contribute to the net electric flux through the sphere but only charge $1Q^+$ contributes to the electric field at point P.
- □ Both charges contribute to the net electric flux through the sphere but only charge $2Q^+$ contributes to the electric field at point P.
- ■ Only the charge $1Q^+$ contributes to the net electric flux through the sphere but both charges contribute to the electric field at point P.
- □ Only the charge $2Q^+$ contributes to the net electric flux through the sphere but both charges contribute to the electric field at point P.
- □ Only the charge $1Q^+$ contributes to the net electric flux through the sphere and to the electric field at point P on the sphere.
- □ Only the charge $2Q^+$ contributes to the net electric flux through the sphere and to the electric field at point P on the sphere.
- □ I don't know (this answer is worth 1/10 of full credit)



7. If you place a negatively charged particle in an electric field, the charge will move

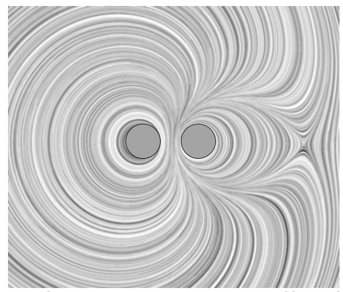
- □ from higher to lower electric potential and from lower to higher potential energy.
- □ from higher to lower electric potential and from higher to lower potential energy.
- □ from lower to higher electric potential and from lower to higher potential energy.
- ■ from lower to higher electric potential and from higher to lower potential energy.

8. A pyramid has a square base of side a, and four faces which are equilateral triangles. A charge Q is placed on the center of the base of the pyramid. What is the net flux of electric field emerging from one of the triangular faces of the pyramid?

- □ Uncertain: we must know whether Q is just above or below the base.

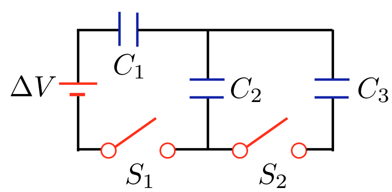
- ☐ 0
- ■ $\frac{Q}{8\epsilon_0}$
- ☐ $\frac{Qa^2}{2\epsilon_0}$
- ☐ $\frac{Q}{2\epsilon_0}$

9. Two charges lie on the x-axis. A representation of the equipotentials of the electric potential of these two charges is shown at right. The "streaks" in this representation are parallel to the equipotential curves. Which one of the following statements is true?



- ☐ The two charges have opposite signs and the charge on the left is smaller in magnitude than the charge on the right.
- ■ The two charges have opposite signs and the charge on the left is larger in magnitude than the charge on the right.
- ☐ The two charges have the same sign and the charge on the left is smaller in magnitude than the charge on the right.
- ☐ The two charges have the same sign and the charge on the left is larger in magnitude than the charge on the right.

10. In the circuit at right, $C_1 = 2.0\,\mu\text{F}$, $C_2 = 6.0\,\mu\text{F}$, $C_3 = 3.0\,\mu\text{F}$, and $\Delta V = 10.0\,\text{V}$. Initially all capacitors are uncharged and the switches are open. What is the charge on C_2 when switch S_1 is open and switch S_2 is closed?



- ■ 0
- ☐ $5\,\mu\text{C}$
- ☐ $10\,\mu\text{C}$
- ☐ $15\,\mu\text{C}$

11. Referring to the previous figure, what is the charge on C_1 when S_1 is closed and switch S_2 is open?

- ☐ 0
- ☐ $5\,\mu\text{C}$
- ☐ $10\,\mu\text{C}$
- ■ $15\,\mu\text{C}$

12. Car batteries are often rated in ampere-hours. This unit by itself designates the amount of which of the following that can be drawn from the battery?

- ■ charge
- ☐ power
- ☐ energy
- ☐ current

13. How many 103 W light bulbs can you use in a 125 V circuit without tripping a 15 A circuit breaker? (The bulbs are connected in parallel, which means that the potential difference across each lightbulb is 125 V.)

- ☐ 3
- ☐ 5

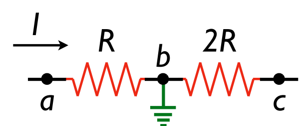
- ☐ 10
- ■ 18

14. A charged particle moves in a straight line through a region of space. Which of the following answers *must* be true in that region of space? (Assume any other fields are negligible.)

- ☐ The magnetic field has a magnitude of zero.
- ■ The magnetic field has a zero component perpendicular to the particle's velocity.
- ☐ The magnetic field has a zero component parallel to the particle's velocity.
- ☐ The magnetic field is opposite the direction of motion.

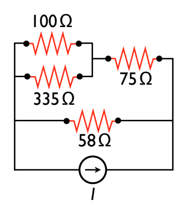
15. A current I flows through two resistors in series of values R and $2R$. The wire connecting the two resistors is connected to ground at point b. Assume that these resistors are part of a larger complete circuit, such that the current I is constant in magnitude and direction. What is the electric potential relative to ground at points **a** and **c**, V_a and V_b, respectively? *Hint: what is the potential of a ground point?*

- ☐ $V_a = -IR$, $V_b = -2IR$
- ☐ $V_a = 0$, $V_b = -3IR$
- ☐ $V_a = +IR$, $V_b = +2IR$
- ■ $V_a = +IR$, $V_b = -2IR$



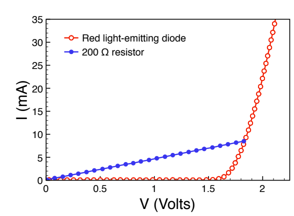
16. What is the equivalent resistance of the arrangement of resistors at left? You do not need to include the current source in your analysis.

- ■ 42 Ω
- ☐ 122 Ω
- ☐ 175 Ω
- ☐ 31 Ω



17. The figure below shows the current-voltage relationship for a light-emitting diode (LED) and a resistor. When the voltage is 1.8 V, which has the **higher resistance**? *Hint: what does the slope of this plot mean?*

- ☐ The resistor.
- ■ The LED.
- ☐ Cannot be determined.
- ☐ They have the same resistance.



18. Suppose you move along a current-carrying wire at the same speed $v_d \ll c$ as the drift speed of electrons in the wire. Do you now measure a magnetic field of zero?

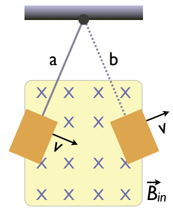
- ☐ No, because the electrons are still in motion relative to the wire.
- ■ No, because now the positive ions appear to move backwards, creating the same current.
- ☐ Yes, because you are at rest relative to the electrons; hence there is no current.
- ☐ Yes,

19. What should happen to the length of a spring if a large current passes through it? (*Hint: Think about the current in neighboring spring coils.*

- ■ It shortens
- □ It lengthens
- □ Nothing

20. A flat metal plate swings at the end of a bar as a pendulum, as shown. When the pendulum is at position **a**, what are the directions of the induced currents and (magnetic) force on the bar, respectively?

- ■ Counterclockwise; to the left
- □ Clockwise; to the left
- □ Counterclockwise; to the right
- □ Clockwise; to the right



21. During an in-class demonstration, we dropped a magnet and a non-magnet of equal weight and size through a copper tube. The non-magnet fell through the tube at the expected rate, but the magnet took many times longer to fall out, due to eddy current braking. Is it possible to have a magnet strong enough (or a tube conductive enough, *etc*) that it would actually *stop* inside the tube?

- □ Yes, provided the tube is conducting enough to carry strong eddy currents.
- □ No, eddy current braking can only balance the force of gravity
- ■ No, eddy current braking only occurs when the magnet is in motion.
- □ Yes, provided the magnet is strong enough that its magnetic field can counter its own weight.

22. An inverted image of an object is viewed on a screen from the side facing a converging lens. An opaque card is then introduced covering *only the upper half* of the lens. What happens to the image on the screen?

- □ Half the image would disappear.
- □ Half the image would disappear and be dimmer.
- □ The entire image would appear and remain unchanged.
- ■ The entire image would appear, but would be dimmer.

23. While looking at her image in a cosmetic mirror, Dina notes that her face is highly magnified when she is close to the mirror, but as she backs away from the mirror, her image first becomes blurry, then disappears when she is about 38.0 cm from the mirror, and then inverts when she is beyond 38.0 cm. What type of mirror does Dina have?

- ■ concave
- □ convex
- □ flat

24. Referring to the previous question, what is the focal length of Dina's mirror?

- □ 76 cm
- □ 19 cm
- ■ 38 cm

- ☐ more information is required

25. An object is placed to the left of a converging lens. Which of the following statements are true and which are false?

1. The image is always to the right of the lens
2. The image can be upright or inverted
3. The image is always smaller or the same size as the object

- ☐ 1 and 2 are true, 3 is true
- ☐ 2 and 3 are false, 1 is true
- ■ 1 and 3 are false, 2 is true
- ☐ 2 and 3 are true, 1 is false

26. An inductor is connected to a 60 Hz, 115 V voltage source. Suppose that a piece of iron is inserted into the inductor so that the value of the inductance increases by a factor of 10. By what factor is the new current amplitude in the inductor related to the old one? By what factor is the new inductive reactance related to the old?

- ☐ $10, 10$
- ☐ $10, 100$
- ☐ $\frac{1}{10}, 1$
- ■ $\frac{1}{10}, 10$
- ☐ $\frac{1}{10}, 100$

27. The wavelength of green light is 5.5×10^{-7} m. What is the approximate frequency of this kind of light?

- ■ 5.5×10^{14} Hz
- ☐ 2.1×10^{-15} Hz
- ☐ 1.7×10^{8} Hz
- ☐ 8.2×10^{19} Hz

Part II: Problems (25%)

Instructions:

- Answer any two problems in *each of the two sections below*, for a total of four problems.
- All problems have equal weight.
- Indicate which problems you have attempted by filling in the adjacent box.
- Show your work for full credit. Significant partial credit will be given.

Section A: solve any two problems

☐ **1.** Three capacitors of 2, 4, and 6 μF, respectively, are connected in series, and a potential difference of 200 V is established across the whole combination by connecting the free terminals to the battery. **(a)**

Calculate the charge on each capacitor. **(b)** Find the potential difference across each capacitor.

▫ **2.** Three equal positive charges, each of magnitude Q, are held fixed at the corners of a square of side a. **(a)** Find the magnitude and direction of the electric field at the fourth corner. **(b)** Find the potential at the fourth corner. **(c)** How much work would be done in moving a fourth charge q to the fourth corner. *Hint: What is the change in the energy of the system?*

▫ **3.** An aluminum wire with a cross-sectional area of $4.00 \times 10^{-6}\,\text{m}^2$ carries a current of 5.00 A. Find the drift speed of the electrons in the wire. The density of aluminum is $2.70\,\text{g/cm}^3$; assume each Al atom provides a single electron for conduction. *Hint: how many atoms per unit volume are there?* The atomic mass of aluminum is 27 g/mol.

▫ **4.** A scuba diver is underwater; from there, the sun appears to be at 30° from the vertical. At what actual angle is the sun located (with respect to directly overhead)? The index of refraction of water may be taken as $n_{\text{water}} = 1.33$, while that of the air may be taken as $n_{\text{air}} = 1.00$.

The angle the scuba diver appears to see is the *refracted* angle, where the rays would appear to be coming from if they weren't refracted at the air-water interface. We can apply Snell's law to find the actual angle of the sun with respect to the surface normal of the water (which is with respect to directly overhead).

$$n_{\text{water}} \sin 30^\circ = n_{\text{air}} \sin \theta_i$$
$$\implies \quad \theta_i \approx 42^\circ$$

▫ **5.** Object O_1 is 14.8 cm to the left of a converging lens with a 9.0 cm focal length. A second lens is positioned 10.0 cm to the right of the first lens and is observed to form a final image at the position of the original object, O_1. **(a)** What is the focal length of the second lens? **(b)** What is the overall magnification of this system? **(c)** What is the nature (i.e., real or virtual, upright or inverted) of the final image?

−8.51 cm; 2.97 times; virtual and upright

Section B: solve any two problems

▫ **1.** A dedicated sports car enthusiast polishes the inside and outside surfaces of a hubcap that is a section of a sphere. When he looks into one side of the hubcap, he sees an image of his face 28.0 cm in back of the hubcap. He then turns the hubcap over, keeping it the same distance from his face. He now sees an image of his face 10.8 cm in back of it. **(a)** How far is his face from the hubcap? **(b)** What is the radius of curvature of the hubcap?

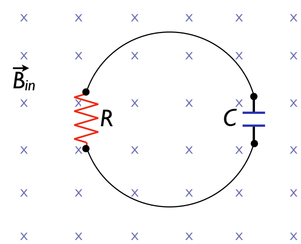
15.6 cm; 70.3 cm

▫ **2.** A Klingon space ship moves away from Earth at a speed of $0.700c$. The starship Enterprise pursues at a speed of $0.900c$ relative to Earth. Observers on Earth see the Enterprise overtaking the Klingon ship at a relative speed of $0.200c$. With what speed is the Enterprise overtaking the Klingon ship as seen by the crew of the Enterprise?

▫ **3.** A regular tetrahedron is a pyramid with a triangular base. Six $14.0\,\Omega$ resistors are placed along its six edges, with junctions at its four vertices. A 9.0 V battery is connected to any two of the vertices. **(a)** Find the equivalent resistance of the tetrahedron between these vertices. **(b)** Find the current in the battery.

▫ **4.** If the voltage at the terminals of an automobile battery drops from 12.3 to 9.8 V when a $0.5\,\Omega$ resistor is connected across the battery, what is the internal resistance of the battery?

▫ **5.** In the figure at right, a uniform magnetic field *decreases* at a constant rate $\Delta B/\Delta t = -K$, where K is a positive constant. A circular loop of wire of radius a containing a resistance R and a capacitance C is placed with its plane normal to the field. **(a)** Find the charge Q on the capacitor when it is fully charged. **(b)** Is the upper or lower plate of the capacitor at a higher potential?



$\pi C a^2 K$; upper

Constants:

$$
\begin{aligned}
N_A &= 6.022\times10^{23}\,\text{things/mol}\\
k_e &= 8.98755\times10^{9}\,\text{N}\cdot\text{m}^2\cdot\text{C}^{-2}\\
\mu_0 &\equiv 4\pi\times10^{-7}\,\text{T}\cdot\text{m/A}\\
\epsilon_0 &= 8.85\times10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2\\
e &= 1.60218\times10^{-19}\,\text{C}\\
h &= 6.6261\times10^{-34}\,\text{J}\cdot\text{s} = 4.1357\times10^{-15}\,\text{eV}\cdot\text{s}\\
\hbar &= \frac{h}{2\pi}\\
c &= \frac{1}{\sqrt{\mu_0\epsilon_0}} = 2.99792\times10^{8}\,\text{m/s}\\
m_{e^-} &= 9.10938\times10^{-31}\,\text{kg} = 0.510998\,\text{MeV}/c^2\\
m_{p^+} &= 1.67262\times10^{-27}\,\text{kg} = 938.272\,\text{MeV}/c^2\\
m_{n^0} &= 1.67493\times10^{-27}\,\text{kg} = 939.565\,\text{MeV}/c^2\\
1\,\text{u} &= 931.494\,\text{MeV}/c^2\\
hc &= 1239.84\,\text{eV}\cdot\text{nm}
\end{aligned}
$$

Quadratic formula:

$$0 = ax^2 + bx^2 + c \Longrightarrow x = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

Basic Equations:

$$
\begin{aligned}
\vec{\mathbf{F}}_{\text{net}} &= m\vec{\mathbf{a}}\ \text{Newton's Second Law}\\
\vec{\mathbf{F}}_{\text{centr}} &= -\frac{mv^2}{r}\hat{\boldsymbol{r}}\ \text{Centripetal}
\end{aligned}
$$

Magnetism

$$
\begin{aligned}
|\vec{F}_B| &= q|\vec{v}||\vec{B}|\sin\theta_{vB}\\
|\vec{F}_B| &= BIl\sin\theta\ \text{wire}\\
|\vec{\tau}| &= BIAN\sin\theta\ \text{torque current loop}\\
\vec{B} &= \frac{\mu_0 I}{2\pi r}\hat{\theta}\ \text{wire}\\
\vec{B} &= \frac{\mu_0 I}{2r}\hat{\theta}\ \text{loop}\\
\vec{B} &= \mu_0\frac{N}{L}I\,\hat{\boldsymbol{z}} \equiv \mu_0 nI\,\hat{\boldsymbol{z}}\ \text{solenoid}\\
\frac{|\vec{F}_{12}|}{l} &= \frac{\mu_0 I_1 I_2}{2\pi d}\ \text{2 wires, force per length}
\end{aligned}
$$

Current:

$$
\begin{aligned}
I &= \frac{\Delta Q}{\Delta t} = nqAv_d\\
J &= \frac{I}{A} = nqv_d\\
v_d &= \frac{-e\tau}{m}E \quad \tau = \text{scattering time}\\
\varrho &= \frac{m}{ne^2\tau}\\
\Delta V &= \frac{\varrho l}{A}I = RI\\
R &= \frac{\Delta V}{I} = \frac{\varrho l}{A}\\
\mathscr{P} &= E\cdot\Delta t = I\Delta V = I^2R = \frac{[\Delta V]^2}{R}\ \text{power}
\end{aligned}
$$

Ohm:

$$
\begin{aligned}
\Delta V &= IR\\
\mathscr{P} &= E\cdot\Delta t = I\Delta V = I^2R = \frac{[\Delta V]^2}{R}\quad\text{power}
\end{aligned}
$$

EM Waves:

$$
\begin{aligned}
c &= \lambda f = \frac{|\vec{E}|}{|\vec{B}|}\\
\mathcal{I} &= \left[\frac{\text{photons}}{\text{time}}\right]\left[\frac{\text{energy}}{\text{photon}}\right]\left[\frac{1}{\text{Area}}\right]\\
\mathcal{I} &= \frac{\text{energy}}{\text{time}\cdot\text{area}} = \frac{E_{\max}B_{\max}}{2\mu_0} = \frac{\text{power }(\mathscr{P})}{\text{area}} = \frac{E^2_{\max}}{2\mu_0 c}
\end{aligned}
$$

Electric Potential:

$$
\begin{aligned}
\Delta V &= V_B - V_A = \frac{\Delta\text{PE}}{q}\\
\Delta PE &= q\Delta V = -q|\vec{E}||\Delta\vec{x}|\cos\theta = -qE_x\Delta x\\
&\quad\uparrow\ \text{constant E field}\\
V_{\text{point charge}} &= k_e\frac{q}{r}\\
PE_{\text{pair of point charges}} &= k_e\frac{q_1q_2}{r_{12}}\\
PE_{\text{system}} &= \text{sum over unique pairs of charges} = \sum_{\text{pairs } ij}\frac{k_e q_i q_j}{r_{ij}}\\
-W &= \Delta\text{PE} = q(V_B - V_A)
\end{aligned}
$$

Optics:

$$
\begin{aligned}
\mathscr{E} &= hf = \frac{hc}{\lambda}\\
n &= \frac{\text{speed of light in vacuum}}{\text{speed of light in a medium}} = \frac{c}{v}\\
\frac{\lambda_1}{\lambda_2} &= \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1}\quad\text{refraction}\\
n_1\sin\theta_1 &= n_2\sin\theta_2\quad\text{Snell's refraction}\\
\lambda f &= c\\
M &= \frac{h'}{h} = -\frac{q}{p}\\
\frac{1}{f} &= \frac{1}{p}+\frac{1}{q} = \frac{2}{R}\quad\text{mirror \& lens}\\
\frac{n_1}{p}+\frac{n_2}{q} &= \frac{n_2-n_1}{R}\quad\text{spherical refracting}\\
q &= -\frac{n_2}{n_1}p\quad\text{flat refracting}\\
\frac{1}{f} &= \left(\frac{n_2-n_1}{n_1}\right)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]\quad\text{lensmaker's}
\end{aligned}
$$

Electric Force & Field

$$
\begin{aligned}
\vec{F}_{e,12} &= q\vec{E}_{12} = \frac{k_e q_1 q_2}{r^2_{12}}\hat{\boldsymbol{r}}_{12}\\
\vec{E} &= k_e\frac{|q|}{r^2}\\
\Phi_E &= |\vec{E}|A\cos\theta_{EA} = \frac{Q_{\text{inside}}}{\epsilon_0}\\
\Delta PE &= -W = -q|\vec{E}||\Delta\vec{x}|\cos\theta = -qE_x\Delta x\\
&\quad\uparrow\ \text{constant E field}
\end{aligned}
$$

Capacitors:

$$Q_{\text{capacitor}} = C\Delta V$$
$$C_{\text{parallel plate}} = \frac{\epsilon_0 A}{d}$$
$$E_{\text{capacitor}} = \frac{1}{2}Q\Delta V = \frac{Q^2}{2C}$$
$$C_{\text{eq, par}} = C_1 + C_2$$
$$C_{\text{eq, series}} = \frac{C_1 C_2}{C_1 + C_2}$$
$$C_{\text{with dielectric}} = \kappa C_{\text{without}}$$

Resistors:

$$I_{\text{V source}} = \frac{\Delta V}{R + r}$$
$$\Delta V_{\text{V source}} = \Delta V_{\text{rated}} \frac{R}{r + R}$$
$$I_{\text{I source}} = I_{\text{rated}} \frac{r}{r + R}$$
$$R_{\text{eq, series}} = R_1 + R_2$$
$$\frac{1}{R_{\text{eq, par}}} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$R_{\text{eq, par}} = \frac{R_1 R_2}{R_1 + R_2}$$

RC circuits

$$Q_C(t) = Q_0\left[1 - e^{-t/\tau}\right] \quad \text{charging}$$
$$Q_C(t) = Q_0 e^{-t/\tau} \quad \text{discharging}$$
$$Q(t) = C\Delta V(t)$$
$$\tau = RC$$

Vectors:

$$|\vec{F}\,| = \sqrt{F_x^2 + F_y^2} \ \text{magnitude}$$
$$\theta = \tan^{-1}\left[\frac{F_y}{F_x}\right] \ \text{direction}$$

Induction:

$$\Phi_B = B_\perp A = BA\cos\theta_{BA}$$
$$\Delta V = -N\frac{\Delta\Phi_B}{\Delta t}$$
$$L = N\frac{\Delta\Phi_B}{\Delta I} = \frac{N\Phi_B}{I}$$
$$\Delta V = |\vec{v}\,||\vec{B}\,|l = |\vec{E}\,|l \ \text{motional voltage}$$

ac Circuits

$$\tau = L/R \ \text{RL circuit}$$
$$\tau = RC \ \text{RC circuit}$$
$$X_C = \frac{1}{2\pi f C} \ \text{“resistance” of a capacitor for ac}$$
$$X_L = 2\pi f L \ \text{“resistance” of an inductor for ac}$$
$$\omega_{\text{cutoff}} = \frac{1}{\tau} = 2\pi f$$

Relativity

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$
$$\Delta t'_{\text{moving}} = \gamma\Delta t_{\text{stationary}} = \gamma\Delta t_p$$
$$L'_{\text{moving}} = \frac{L_{\text{stationary}}}{\gamma} = \frac{L_p}{\gamma} x' = \gamma\,(x - vt)$$
$$\Delta t' = t'_1 - t'_2 = \gamma\left(\Delta t - \frac{v\Delta x}{c^2}\right)$$
$$p = \gamma m v$$
$$v_{\text{obj}} = \frac{v + v'_{\text{obj}}}{1 + \frac{v v'_{\text{obj}}}{c^2}} \qquad v'_{\text{obj}} = \frac{v_{\text{obj}} - v}{1 - \frac{v v_{\text{obj}}}{c^2}}$$
$$\text{KE} = (\gamma - 1)mc^2$$
$$E_{\text{rest}} = mc^2$$
$$E^2 = p^2c^2 + m^2c^4$$

Right-hand rule #1

1. Point the fingers of your right hand along the direction of $\vec{v}$.
2. Point your thumb in the direction of $\vec{B}$.
3. The magnetic force on a + charge points out from the back of your hand.

Right-hand rule #2:
Point your thumb on your right hand along the wire in the direction of the current. Your fingers naturally curl around the direction of the magnetic field caused by the current, which circulates around the wire.

Derived unit	**Symbol**	**equivalent to**
newton	N	$kg{\cdot}m/s^2$
joule	J	$kg{\cdot}m^2/s^2 = N{\cdot}m$
watt	W	$J/s{=}m^2{\cdot}kg/s^3$
coulomb	C	$A{\cdot}s$
V	$W/A = m^2{\cdot}kg/{\cdot}s^3{\cdot}A$	
farad	F	$C/V = A^2{\cdot}s^4/m^2{\cdot}kg$
ohm	Ω	$V/A = m^2{\cdot}kg/s^3{\cdot}A^2$
tesla	T	$Wb/m^2 = kg/s^2{\cdot}A$
electron volt	eV	1.6×10^{-19} J
-	$1\,T \cdot m/A$	$1\,N/A^2$
-	$1\,T \cdot m^2$	$1\,V \cdot s$
-	$1\,N/C$	$1\,V/m$

Power	**Prefix**	**Abbreviation**
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	µ
10^{-3}	milli	m
10^{-2}	centi	c
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T