Last Name:________________First Name_________________NetID_______________
Discussion Section:________Discussion TA Name:______________________________

Instructions—
Turn off your cell phone and put it away.
Keep your calculator on your own desk. Calculators may not be shared.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil; do **not** use a mechanical pencil or a pen. Fill in completely (until there is no white space visible) the circle for each intended input – both on the identification side of your answer sheet and on the side on which you mark your answers. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner.

2. Print your last name in the **YOUR LAST NAME** boxes on your answer sheet and print the first letter of your first name in the **FIRST NAME INI** box. Mark (as described above) the corresponding circle below each of these letters.

3. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

4. You may find the version of **this Exam Booklet at the top of page 2**. Mark the **version** circle in the **TEST FORM** box in the bottom right of your answer sheet. **DO THIS NOW!**

5. Do not write in or mark the circles in any of the other boxes (STUDENT NUMBER, DATE, SECTION, SCORES, SPECIAL CODE).

6. Sign your name **(DO NOT PRINT)** on the **STUDENT SIGNATURE** line.

7. On the **SECTION** line, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. You should have 11 ***numbered pages*** *plus two Formula Sheets at the end.*

*Academic Integrity—***Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including expulsion.**

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box in the bottom right of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of 91 points, composed of two types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

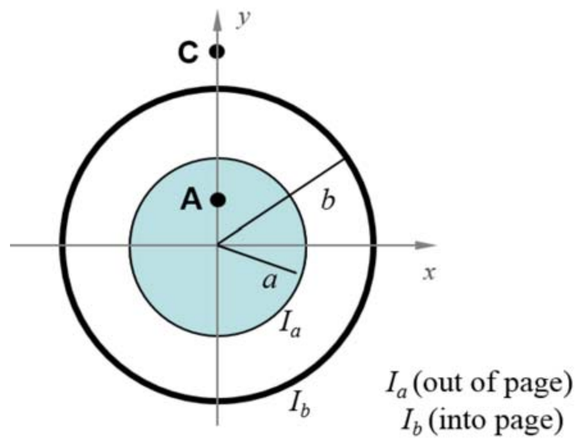
(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

The next three questions pertain to the situation described below.

Consider two infinitely long, concentric cylinders, with their axes along the z-axis. The inner solid cylinder has radius a = 0.08 m and carries a current I_a=4.5 A directed out of the page. This current is uniformly distributed throughout the cylinder. The outer (hollow) cylinder has radius b = 0.16 m, and carries current I_b = 7.5 A into the page as shown in the figure.



1) What is the magnitude of the magnetic field at point A (y=0.04 m) due to the current in the two cylinders?

a. $|B_A| = 2.25 \times 10^{-5}$ T
b. $|B_A| = 1.5 \times 10^{-5}$ T
c. $|B_A| = 5.62 \times 10^{-6}$ T
d. $|B_A| = 3.19 \times 10^{-5}$ T
e. $|B_A| = 1.12 \times 10^{-5}$ T

2) What is the direction of the magnetic field at point A (y=0.04 m) due to the current in the two cylinders?

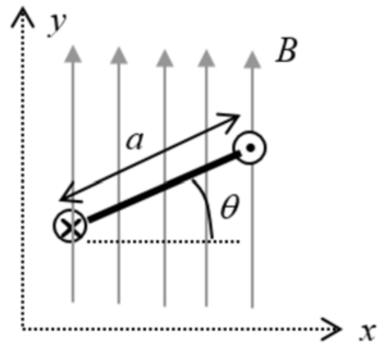
a. -x
b. +y
c. -y

3) What is the magnitude of the magnetic field at point C (y=0.24 m) due to the current in the two cylinders?

a. $|B_C| = 1.87 \times 10^{-6}$ T
b. $|B_C| = 2.5 \times 10^{-6}$ T
c. $|B_C| = 10^{-5}$ T

The next three questions pertain to the situation described below.

A square conducting loop of wire, of side a = 0.3 m, carries an electrical current I = 1.4 A as indicated in the figure. The wire in the x-y plane makes an angle θ = 25° relative to the x axis as shown in the figure. The loop is placed in a region with a uniform external magnetic field in the positive y direction.



4) What is the magnitude of the magnetic moment for this current loop?

a. $|\boldsymbol{\mu}| = 0.126$ A m^2
b. $|\boldsymbol{\mu}| = 0.114$ A m^2
c. $|\boldsymbol{\mu}| = 0.0532$ A m^2

5) For which value(s) of the angle θ, in the range 0° ≤ θ ≤ 360°, is the torque exerted on the loop equal to zero?

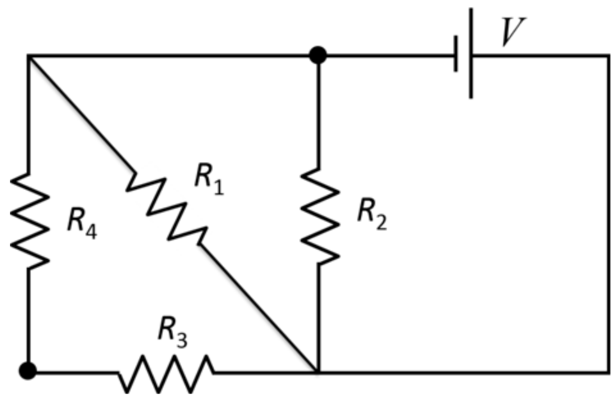
a. θ = 0° or θ = 180°
b. θ = 90° only
c. θ = 90° or θ = 270°
d. θ = 0° only
e. θ = 270° only

6) Which of the following orientations has the greatest potential energy?

a. θ = 0°
b. θ = 120°
c. θ = 60°

The next four questions pertain to the situation described below.

Consider the electrical circuit shown to the right. It consists of an ideal battery V = 24 V, and four resistors, whose values are: R_1 = 8 Ω, R_2 = R_3 = R_4 = 6 Ω.



7) Resistors R_1 and R_2 are in

a. Parallel
b. Neither series nor parallel
c. Series

8) What is the equivalent resistance of the four resistors in this circuit?

a. 4.62 Ω
b. 17 Ω
c. 1.6 Ω
d. 2.67 Ω
e. 26 Ω

9) What is the magnitude of the current I_3 through resistor R_3?

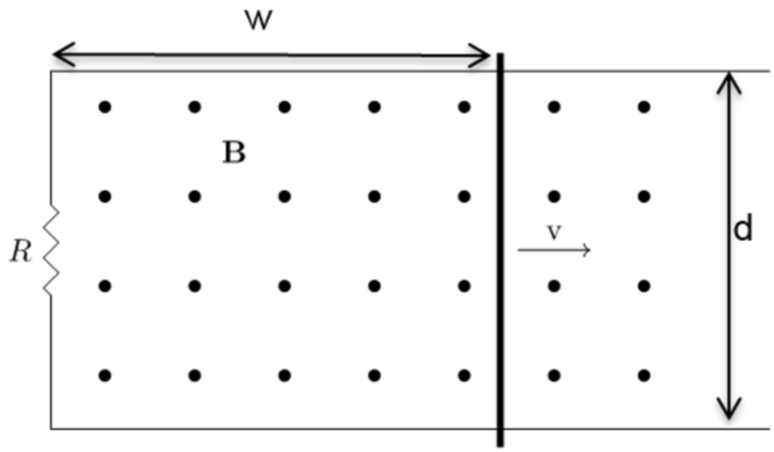
a. $|I_3|$ = 4 A
b. $|I_3|$ = 8.99 A
c. $|I_3|$ = 2 A

10) In order to include the effects of a physical battery, we could add a resistor $R_{battery}$. This resistor should be placed

a. in series with the ideal battery.
b. in parallel with the ideal battery.

The next three questions pertain to the situation described below.

A conducting bar of mass m=0.3 kg slides with negligible friction along a pair of horizontal conducting tracks separated by a distance d = 0.15 m, as shown in the figure below. The left side of the loop contains a resistor with resistance R=30 Ω. There is a constant magnetic field, B = 2 T, directed out of the page.



11) What is the current through the resistor when the metallic bar is a distance w = 0.225 m from the end sliding with a constant speed v = 6 m/s?

a. I = 0.06 A
b. I = 0.00225 A
c. I = 0.09 A

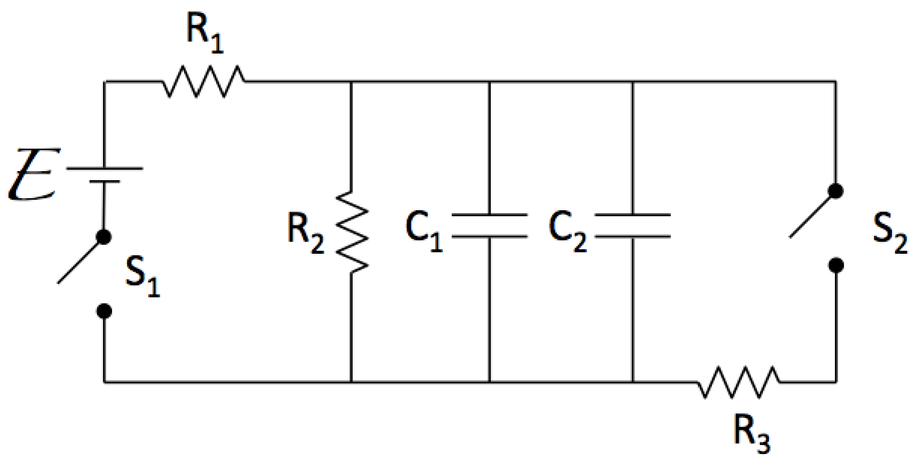
12) What direction does the current flow, when the bar is sliding to the right with a constant speed v = 6 m/s?

a. Clockwise, up through the resistor.
b. Counter clockwise, down through the resistor.

13) The resistor R represents the filament of an incandescent bulb that requires 1.5 W of power to light. What is the minimum speed v at which the bar needs to slide in order to light the bulb?

a. v = 22.4 m/s
b. v = 3.16 m/s
c. v = 2.1 m/s
d. v = 6.67 m/s
e. v = 0.45 m/s

The next five questions pertain to the situation described below.



Consider the electrical circuit shown above. It consists of two switches, an ideal battery E = 24 V, three resistors R_1 = 20 Ω, R_2 = 40 Ω, R_3 = 60 Ω, and two capacitors C_1 = 30 μF, C_2 = 50 μF . The capacitors are initially uncharged, and both switches are open.

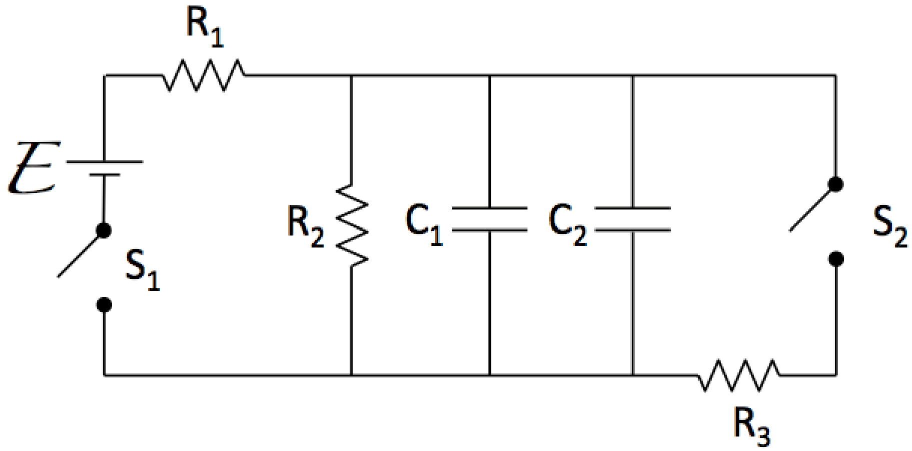
14) At time t=0, the switch S_1 is closed (S_2 remains open). Which statement can be made for all time t>0 about the relationship between the currents I_1 and I_2, which flow through the resistors R_1 and R_2, respectively?

a. $I_1 \le I_2$ for all t > 0.
b. Neither of the other two statements hold for all time t > 0.
c. $I_1 \ge I_2$ for all t > 0.

15) After a very long time, what is the relationship between the currents I_1 and I_2?

a. $I_1 = I_2R_2/(R_1+R_2)$
b. $I_1 = I_2R_1/(R_1+R_2)$
c. $I_1 = I_2$

16) (Figure repeated and text repeated from previous page.)



Consider the electrical circuit shown above. It consists of two switches, an ideal battery E = 24 V, three resistors R_1 = 20 Ω, R_2 = 40 Ω, R_3 = 60 Ω, and two capacitors C_1 = 30 μF, C_2 = 50 μF . The capacitors are initially uncharged, and both switches are open. At time t=0, the switch S_1 is closed (S_2 remains open).

After a very long time, what is the charge stored on capacitor C_1?

a. Q_1 = 240 μC
b. Q_1 = 480 μC
c. Q_1 = 1280 μC
d. Q_1 = 720 μC
e. Q_1 = 450 μC

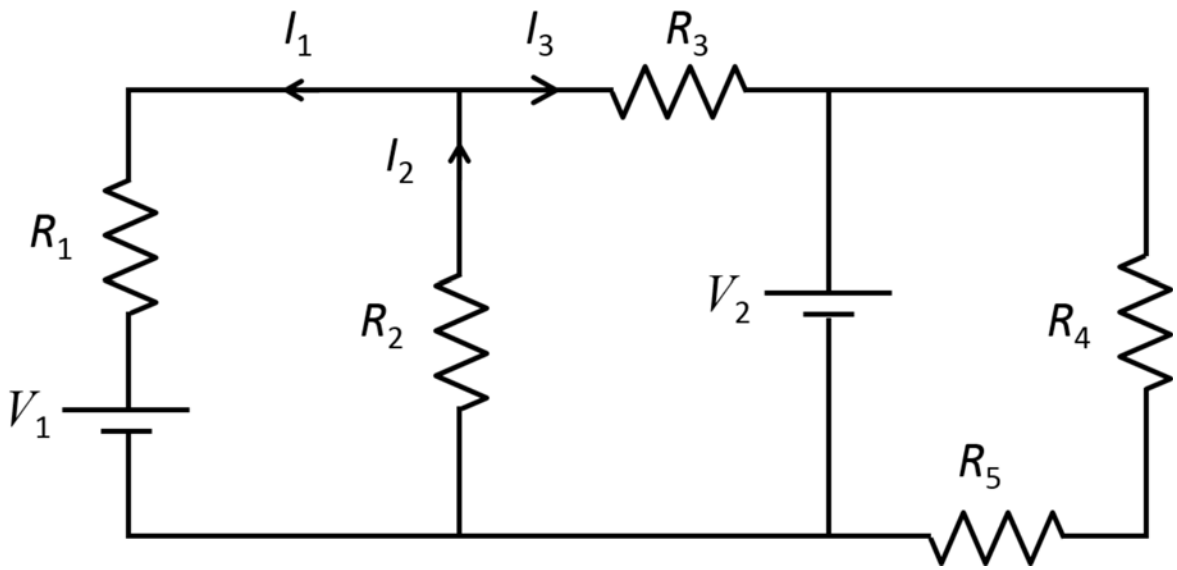
17) After a very long time, the switch S_1 is opened at exactly the same time switch S_2 is closed. What is the current I_3 that flows through resistor R_3 immediately after switch S_2 is closed?

a. I_3 = 0.267 A
b. I_3 = 0.667 A
c. I_3 = 0.16 A

18) After switch S_1 is opened and switch S_2 is closed. What is the time constant τ that determines the rate at which the capacitors discharge?

a. τ = 0.00192 s
b. τ = 0.00244 s
c. τ = 0.003 s
d. τ = 0.00112 s
e. τ = 0.0048 s

The next two questions pertain to the situation described below.



Consider the electrical circuit shown above. It consists of two identical ideal batteries, $V_1 = V_2 = 24$ V, and five resistors.

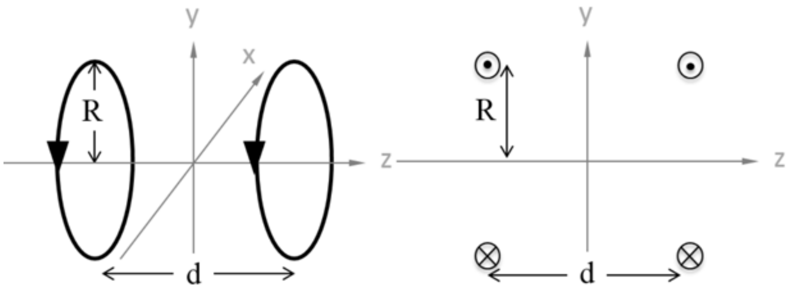
19) Which of the following equations is <u>not</u> valid?

a. $I_2 = I_1 + I_3$
b. $I_1R_1 + I_2R_2 - V_1 = 0$
c. $I_2R_2 + I_3R_3 + V_2 = 0$

20) Suppose the resistor R_3 is shorted out, so that it acts like a wire. What can we say about the current labelled I_1?

a. I_1 is zero.
b. I_1 is negative.
c. I_1 is positive.

The next two questions pertain to the situation described below.



Two identical circular conducting loops with radius R and negligible thickness are placed a distance d apart and carry current I in the same counterclockwise when viewed from the positive z axis, i.e. the current at the top of the loop comes out of the page, the current at the bottom of the loop goes into the page. The axes of both loops are oriented along the z-axis, as shown in the figure.

21) What is the direction of the magnetic field at the point on the z axis midway between the center of the two loops(z=0)?

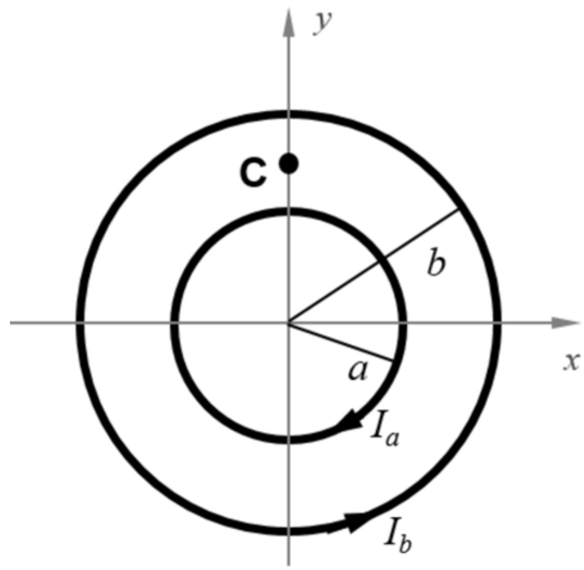
a. zero
b. left (-z)
c. right (+z)

22) What is the direction of the net force on the left loop, due to the magnetic field produced by the right loop.

a. left (-z)
b. zero
c. right (+z)

The next two questions pertain to the situation described below.

Consider two infinitely long, concentric **solenoids**, with their axes along the z-axis The each have 2500 turns/meter. The inner solenoid has radius a = 0.4 m and carries a current I_a=2.5 A clockwise. The outer solenoid has radius b = 0.8 m, and carries current I_b = 6 A counter clockwise as shown in the figure.



23) What is the magnitude of the magnetic field at point **C** (y=0.6 m) due to the current in the two solenoids?

a. $|B_C|$ = 0.00785 T
b. $|B_C|$ = 0.011 T
c. $|B_C|$ = 0.0188 T

24) What is the direction of the magnetic field at point **C** (y=0.6 m) due to the current in the two solenoids?

a. Into the page.
b. Out of the page.
c. Up (+y)

25) A muon and an electron are travelling parallel to each other with identical kinetic energy. They enter a region with uniform magnetic field perpendicular to the direction of motion of both particles. What is the ratio of the radius of the muon orbit to the electron orbit ($r_{muon}/r_{electron}$)? Note electrons and muons have the same charge $q = -1.6 \times 10^{-19}$ C and $m_{electron} = 9.1 \times 10^{-31}$ kg and $m_{muon} = 1.9 \times 10^{-28}$ kg.

a. $r_{muon}/r_{electron} = 0.07$
b. $r_{muon}/r_{electron} = 14.4$
c. $r_{muon}/r_{electron} = 209$

Physics 212 Formula Sheet

Electrostatics:

$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}^2}\hat{r}$

$\vec{E} \equiv \frac{\vec{F}}{q_0}$

$\Phi_E = \int \vec{E}\cdot d\vec{S}$

$\oint \vec{E}\cdot d\vec{S} = \frac{Q_{encl}}{\varepsilon_0}$

$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$

$\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\hat{r}$

$\vec{E} = \pm\frac{\sigma}{2\varepsilon_0}\hat{x}$

$V_B - V_A \equiv \frac{W_{AB}}{q_0} = -\int_A^B \vec{E}\cdot d\vec{l}$

$\vec{E} = -\vec{\nabla}V$

$U = q_0 V$

$U_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$

$V(r) = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

$\Delta V = \pm Ed$

Capacitors and RC Circuits:

$C \equiv \frac{Q}{V}$

$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

$C = C_1 + C_2$

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$

$C_0 = \frac{\varepsilon_0 A}{d}$

$C_0 = \frac{4\pi\varepsilon_0 ab}{(b-a)}$

$C_0 = \frac{2\pi\varepsilon_0 L}{\ln(b/a)}$

$C = \kappa C_0$

$Q(t) = Q(\infty)\left(1 - e^{-t/\tau}\right)$

$Q(t) = Q(0)e^{-t/\tau}$

$\tau = RC$

$u_E = \frac{1}{2}\varepsilon_0 E^2 \kappa$

Simple Circuits:

$R = \frac{V}{I}$

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

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

$R = R_1 + R_2$

$P = IV = I^2 R$

Magnetostatics:

$\vec{F} = q\vec{E} + q\vec{v}\times\vec{B}$

$d\vec{F} = Id\vec{l}\times\vec{B}$

$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$

$\oint \vec{B}\cdot d\vec{l} = \mu_0 I$

$B = \frac{\mu_0}{2\pi}\frac{I}{r}$

$B_z = \frac{\mu_0 I R^2}{2(z^2 + R^2)^{3/2}}$

$B = \mu_0 n I$

$\vec{\mu} = NI\vec{A}$

$\vec{\tau} = \vec{\mu}\times\vec{B}$

$U = -\vec{\mu}\cdot\vec{B}$

Induction and RL Circuits:

$EMF = -\frac{d\Phi_B}{dt}$

$\Phi_B = \int \vec{B}\cdot d\vec{S}$

$L \equiv \frac{\Phi_B}{I}$

$V = L\frac{dI}{dt}$

$U = \frac{1}{2}LI^2$

$L = L_1 + L_2$

$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$

$I(t) = I(0)e^{-t/\tau}$

$I(t) = I(\infty)\left(1 - e^{-t/\tau}\right)$

$\tau = \frac{L}{R}$

$u_B = \frac{1}{2}\frac{B^2}{\mu_0}$

LC, LCR, and AC Circuits:

$$\omega_0 = \frac{1}{\sqrt{LC}} \qquad X_C \equiv \frac{1}{\omega C} \qquad X_L \equiv \omega L \qquad \tan\phi = \frac{X_L - X_C}{R}$$

$$Z \equiv \sqrt{R^2 + (X_L - X_C)^2} \qquad \varepsilon_{\max} = I_{\max} Z \qquad \varepsilon_{rms} = \frac{1}{\sqrt{2}}\varepsilon_{\max} \qquad V_2 = \frac{N_2}{N_1} V_1$$

$$< P >= \varepsilon_{rms} I_{rms} \cos\phi = \frac{1}{2}\varepsilon_{\max} I_{\max} \cos\phi = I_{rms}^2 R \qquad Q = \frac{\omega_0 L}{R} \approx \frac{\omega_0}{FWHM} \qquad I_1 V_1 = I_2 V_2$$

EM Waves, Polarization, Reflection and Refraction:

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I + \mu_0 I_D \qquad I_D = \varepsilon_0 \frac{d\phi_E}{dt} \qquad E = cB \qquad I = c\langle u\rangle = \frac{\langle E^2\rangle}{Z_0} = \frac{1}{2}\frac{E_{\max}^2}{Z_0} = \frac{\langle P\rangle}{area}$$

$$\vec{S} \equiv \frac{\vec{E}\times\vec{B}}{\mu_0} \qquad \vec{B} = \hat{s}\times\frac{\vec{E}}{c} \qquad u = \varepsilon_0 E^2 \qquad \frac{I}{c} = \frac{force}{area} \qquad E_{rms} = \frac{1}{\sqrt{2}} E_{\max}$$

$$\omega = 2\pi \mathrm{f} \qquad \mathrm{v} = \lambda f = \frac{\omega}{k} \qquad I_2 = I_1 \cos^2(\theta_1 - \theta_2) \qquad \mathrm{v} = c/n \qquad \frac{\lambda_1}{\lambda_2} = \frac{\mathrm{v}_1}{\mathrm{v}_2} = \frac{n_2}{n_1}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad \sin\theta_c = \frac{n_2}{n_1} \qquad f' = f\sqrt{\frac{1 \pm \mathrm{v/c}}{1 \mp \mathrm{v/c}}} \qquad f' \approx f\left(1 \pm \mathrm{v/c}\right)$$

Mirrors and lenses:

$$f = \frac{R}{2} \qquad \frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \qquad \frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad m = -\frac{s'}{s} \qquad power = \frac{1}{f}\,[Diopters]$$

Energy:

$$K = \frac{1}{2} m\mathrm{v}^2 \qquad E = K + U = \text{const.}$$

Centripetal Force:

$$F_c = m\frac{\mathrm{v}^2}{r}$$

Important Constants:

$$k \equiv \frac{1}{4\pi\varepsilon_\circ} = 9\times 10^9\ \frac{\mathrm{Nm}^2}{\mathrm{C}^2} \qquad \varepsilon_0 = 8.85\times 10^{-12}\ \frac{C^2}{Nm^2} \qquad \frac{\mu_0}{4\pi} \equiv 1\times 10^{-7}\ \frac{\mathrm{N}}{\mathrm{A}^2} = 1\times 10^{-7}\ T_m/A$$

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = 3\times 10^8\ \mathrm{m/s} \qquad e = 1.60\times 10^{-19}\ \mathrm{C} \qquad Z_0 = \mu_0 c = 377\ \Omega$$

SI Prefixes

Power	Prefix	Symbol
10^6	mega	M
10^3	kilo	k
10^0	—	—
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Geometry

Circle

$\text{area} = \pi R^2$

$\text{circumf.} = 2\pi R$

Sphere

$\text{area} = 4\pi R^2$

$\text{volume} = \frac{4}{3}\pi R^3$

$$\vec{\nabla} V = \hat{x}\frac{\partial V}{\partial x} + \hat{y}\frac{\partial V}{\partial y} + \hat{z}\frac{\partial V}{\partial z}$$