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 14 ***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 117 points, composed of two types of questions.

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

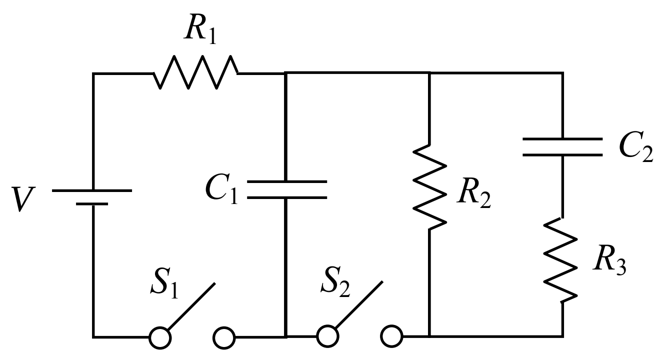
(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more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

Three resistors, two capacitors, two switches, and a battery are connected in the circuit shown below. The values of all circuit elements are given in the figure. Originally, both switches are open (as shown) and both capacitors are uncharged. At time $t = 0$, the switches S_1 and S_2 are simultaneously closed.



$V = 9$ V
$R_1 = R_2 = R_3 = 3\ \Omega$
$C_1 = 1\ \mu$F
$C_2 = 4\ \mu$F

1) What is the current I_1 through resistor R_1 immediately after the switches are closed?

a. $I_1 = 1.3$ A
b. $I_1 = 2$ A
c. $I_1 = 3$ A

2) A very long time after the switches are closed, what is the voltage across C_2?

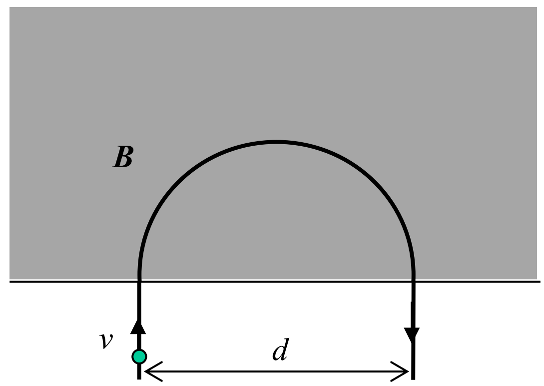
a. $V_2 = 9.0$ V
b. $V_2 = 4.5$ V
c. $V_2 = 3.0$ V
d. $V_2 = 2.3$ V
e. $V_2 = 0$ V

3) After a very long time with the switches in the closed position, capacitor C_2 is fully charged with total charge Q_0. Then both switches are simultaneously reopened. At a time t_1 after the switches are opened, the charge on capacitor C_2 has dropped to $Q(t_1)=0.2\ Q_0$. Find t_1:

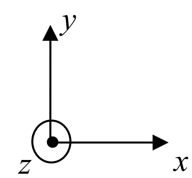
a. $t_1 = 11\ \mu$s
b. $t_1 = 13\ \mu$s
c. $t_1 = 22\ \mu$s
d. $t_1 = 39\ \mu$s
e. $t_1 = 44\ \mu$s

The following two questions refer to the diagram below:

A negatively charged particle enters a region of uniform magnetic field as shown in the figure. The direction of the magnetic field is unspecified. After completing a semicircular path in the *xy* plane, the particle exits the region of uniform field.



$q = -1.60 \times 10^{-19}$ C
$m = 1.20 \times 10^{-27}$ kg
$v = 5.00 \times 10^{6}$ m/s
$B = 3$ T



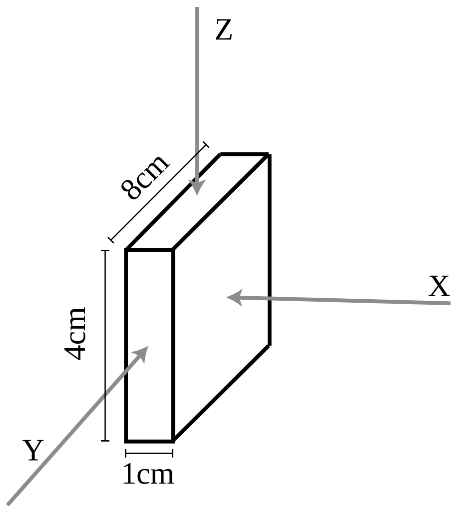
4) Determine the distance *d* between the entrance and exit points on the particle's trajectory.

a. $d = 25$ mm
b. $d = 50$ mm
c. $d = 60$ mm
d. $d = 210$ mm
e. Cannot be determined from information given.

5) If the magnitude of the magnetic field is increased, then the amount of time which the particle spends inside the region of magnetic field

a. increases
b. remains unchanged.
c. decreases.

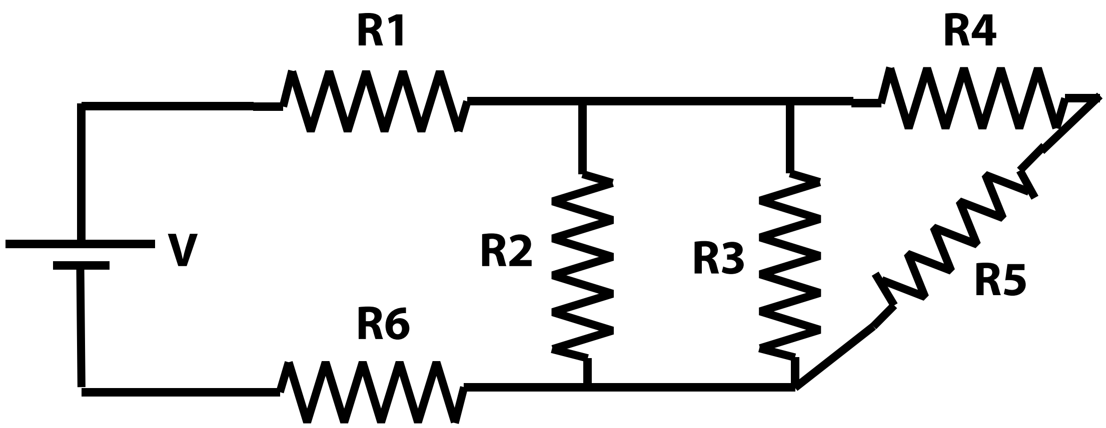
6) A block of material with uniform resistivity and with the dimensions labeled below can be used as a resistor along any of the three axes labeled (x,y or z). What is the relative magnitude of the resistances along the three directions?



a. Z > X > Y
b. Y > Z > X
c. X > Y > Z

The next two questions concern the circuit shown below.

V = 15 V, R1 = 2 Ohms, R2 = 4 Ohms, R3 = 4 Ohms, R4 = 6 Ohms, R5 = 10 Ohms, R6 = 1 Ohm.

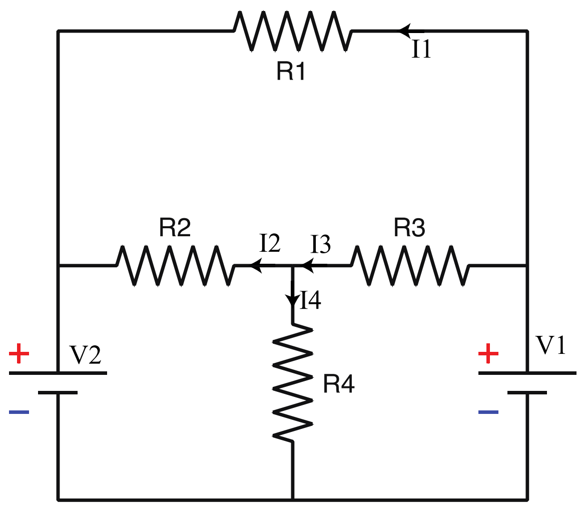


7) Resistors R3 and R5 are in which of the following configurations?
   a. Parallel
   b. Series
   c Neither

8) What is the current (I1) through resistor R1?
   a. 1.2 Amps
   b. 3.1 Amps
   c. 5.3 Amps
   d. 6.1 Amps
   e. 10 Amps

The next two questions consider the circuit shown below.

The current direction is labeled for each resistor in the circuit. The resistor values are: R1 = 1 Ohm, R2 = 3 Ohms, R3 = 2 Ohms, R4 = 4 Ohms, V1 = 20V.



9) Which of the following equations is NOT valid?

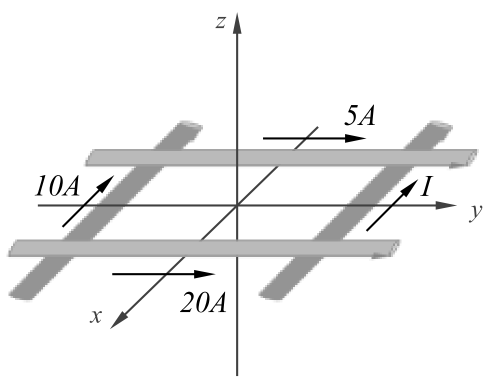
a. $I_2 = I_3 - I_4$
b. $-V_1 + I_3R_3 + I_4R_4 = 0$
c. $V_2 + I_3R_3 + I_2R_2 = V_1$
d. $-I_1R_1 = I_2R_2 + I_3R_3$
e. $I_4R_4 - V_2 - I_2R_2 = 0$

10) I4 is measured to be 3 Amps, and I3 is measured to be 4 Amps. What is the voltage V2?

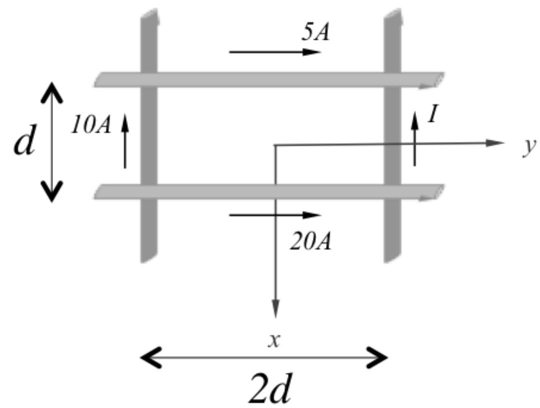
a. 9V
b. 12V
c. 6V
d. 16V
e. 11V

11) Four very long wires intersect in a plane forming a rectangle of sides *2d* and *d* in *x* and *y* respectively. They carry currents of magnitudes 5A, 10A, 20A and *I*, as shown in the figure. **What is the magnitude and direction of *I* that makes the magnetic field at the center of the rectangle zero?** Note that a positive current is in the direction of the arrow indicated next to *I*, while a negative current indicates the opposite direction.

3D view



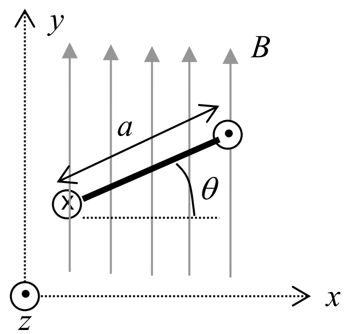
View from above



a. I = 0 A
b. I = +5A
c. I = -5A
d. I = +20A
e. I = -20A

The next three questions pertain to the situation described below.

A square conducting loop of wire, of side a, carries an electrical current I, circulating as shown in the figure below. It is placed in a region with a uniform external magnetic field $\boldsymbol{B} = B\,\hat{\boldsymbol{y}}$.



12) If the current is doubled, the magnitude of the magnetic dipole moment μ associated with this current-carrying loop changes by a factor of

a. 1/2
b. 2
c. 4

13) The direction of the torque $\boldsymbol{\tau}$ produced by the external magnetic field on the current-carrying loop is:

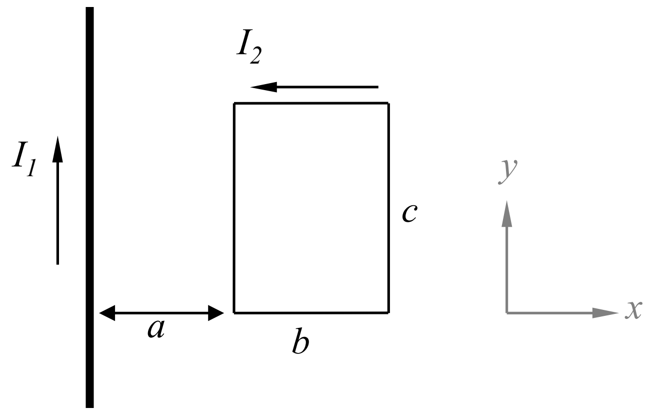
a. $\hat{\boldsymbol{y}}$
b. $\sin\theta\,\hat{\boldsymbol{x}} + \cos\theta\,\hat{\boldsymbol{y}}$
c. - $\sin\theta\,\hat{\boldsymbol{x}} + \cos\theta\,\hat{\boldsymbol{y}}$
d. $\hat{\boldsymbol{z}}$
e. $-\hat{\boldsymbol{z}}$

14) Which of the following statements is true? The potential energy of the loop is:

a. lower at $\theta = 30^\circ$ than $\theta = 0^\circ$.
b. higher at $\theta = 30^\circ$ than $\theta = 0^\circ$.
c. the same for all θ

The next two questions pertain to the situation described below.

Consider a long straight wire carrying current, I_1. Next to the wire is a rectangular loop of wire with dimensions *c* by *b*. The side of length *c* is parallel to the long straight wire, and the inner side of the loop is a distance *a* from the long wire, as shown in the figure. Assume the currents are constant.



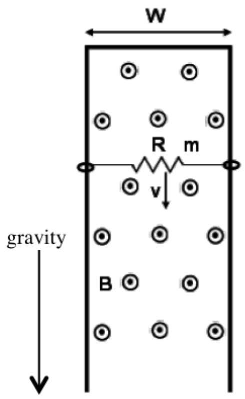
15) What is the magnitude of the net force on the loop due to the infinite wire?

a. $\frac{\mu_0 I_1 I_2 c}{2\pi}\left(\frac{1}{a+b}\right)$
b. $\frac{\mu_0 I_1 I_2 c}{2\pi}\left(\frac{2a+b}{a(a+b)}\right)$
c. $\frac{\mu_0 I_1 I_2 c}{2\pi}\left(\frac{2a-b}{a(a+b)}\right)$
d. $\frac{\mu_0 I_1 I_2 c}{2\pi}\left(\frac{b}{a(a+b)}\right)$
e. $\frac{\mu_0 I_1 I_2}{2\pi}\left(\frac{ab}{a+b}\right)$

16) What is the direction of this net force?

a. no force
b. attractive (towards the wire)
c. repulsive (away from the wire)

The next three questions pertain to the following situation:



A magnetic field, B= 1.2 T, is directed out of the page in a region containing a conductor forming a horizontal rail attached on each end to a vertical rail, as shown in the figure. The width between the rails is W = 0.4 m. A resistor of mass m and resistance R = 2 Ω, which can slide without friction on the vertical rails, is released from rest and starts falling in the presence of the earth's gravitational field, reaching a terminal speed v = 0.8 m/s.

17) Which statement characterizes best the induced current?

a. There is no induced current.
b. The induced current flows counter clockwise.
c. The induced current flows clock wise.

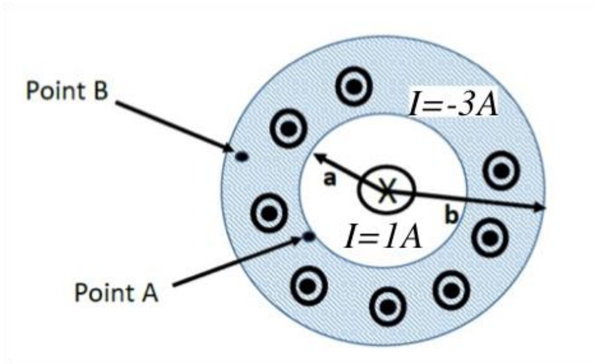
18) Which expression represent the current through the resistor?

a. $I = {}^{vBW}/_{R}$
b. $I = {}^{vB}/_{R}$
c. $I = {}^{vW}/_{BR}$

19) What is the mass of the resistor?

a. 20.4 g
b. 9.4 g
c. 4.2 g
d. 1.8 g
e. 0.8 g

The next two questions are related to the following situation:



A long, conducting cylinder with an outer diameter *b* and an inner diameter *a* carries a uniform current of -3A. At the center of the hollow conductor is a thin wire that carries a current of + 1A.

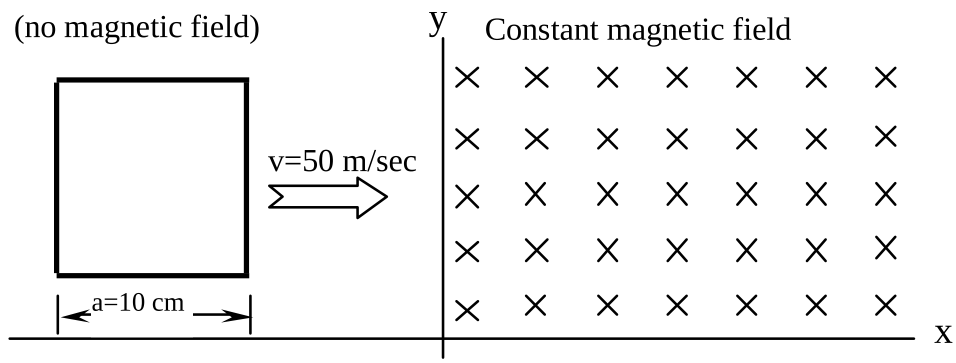
20) Which statement best characterizes the direction of the magnetic field inside the conductor (i.e., for a < *r* < b)?

a. The *B*-field direction is clockwise
b. The *B*-field direction is counter-clockwise
c. The *B*-field is clockwise at point A (near the inner surface of the conductor) and counter-clockwise at point B (near the outer surface of the conductor)
d. The *B*-field is counter-clockwise at point A (near the inner surface of the conductor) and clockwise at point B (near the outer surface of the conductor)
e. The *B*-field is zero everywhere inside both conductors

21) If anywhere, at what radius *r* is the magnetic field inside the conductor zero?

a. The magnetic field is not zero anywhere inside the hollow conductor
b. The magnetic field is zero at a radius of $r = \frac{1}{\sqrt{3}}\sqrt{b^2 + 2a^2}$
c. The magnetic field is zero at a radius of $r = (1/4)\sqrt{b^2 - a^2}$
d. The magnetic field is zero everywhere inside the conductor
e. The magnetic field is zero at a radius of $r = b - a/2$

The next two questions pertain to the following situation:



A square conducting loop (side a = 10 cm, resistance R = 10 Ω, mass m = 100 g) located in the xy plane coasts with constant velocity v_0 = 50 m/s in the xy plane parallel to the x-axis in a region of no magnetic field as shown in the diagram. At time t = 0 s the loop enters a region of constant uniform magnetic field B = 2 T directed in the $-z$ direction (into the page). In the following two questions, neglect any effect of magnetic fields that might be created by an induced current in the loop.

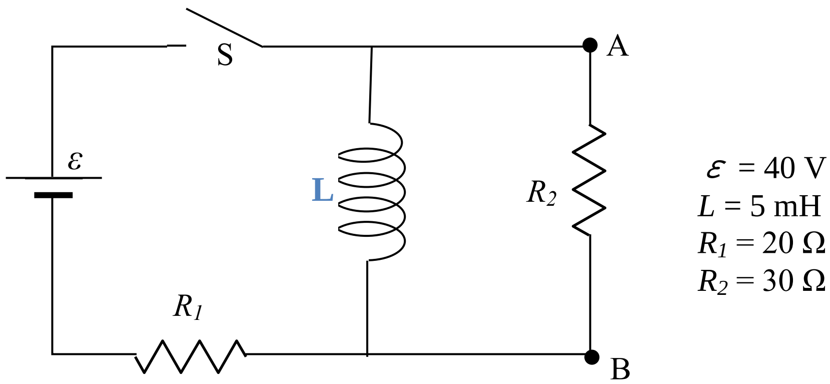
22) What is the **magnitude of the EMF** induced in the loop just after it enters the field? (Remember 1mV=10^{-3}V).

a. EMF = 100 mV
b. EMF = 1 V
c. EMF = 10 V
d. EMF = 100 V
e. EMF = 1000 V

23) Compare v_1, the speed at which the loop is moving at the time when half of it has entered the field, to v_0, its speed at the time that it just entered the field.

a. $v_1 < v_0$
b. $v_1 = v_0$
c. $v_1 > v_0$

The following two questions refer to the figure below:



24) Immediately after switch S is closed, what is V_L, the voltage across the inductor L?

a. $V_L = 0$ V
b. $V_L = 10$ V
c. $V_L = 24$ V

25) A long time after switch S is closed, what is U_L, the energy stored in the inductor?

a. $U_L = 0$
b. $U_L = 4.4$ mJ
c. $U_L = 10.0$ mJ
d. $U_L = 15.3$ mJ
e. $U_L = 25.7$ mJ

Check to make sure you bubbled in all your answers.
Did you bubble in your name, exam version and network-ID?

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:

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

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

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

EM Waves, Polarization, Reflection and Refraction:

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

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

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

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

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:

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

Centripetal Force:

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

Important Constants:

$$k \equiv \frac{1}{4\pi\varepsilon_\circ} = 9\times10^9\ \frac{\mathrm{Nm}^2}{\mathrm{C}^2} \qquad \varepsilon_0 = 8.85\times10^{-12}\ \frac{C^2}{Nm^2} \qquad \frac{\mu_0}{4\pi} \equiv 1\times10^{-7}\ \frac{\mathrm{N}}{\mathrm{A}^2} = 1\times10^{-7}\ T_m/A$$

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = 3\times10^8\,\mathrm{m/s} \qquad e = 1.60\times10^{-19}\ \mathrm{C} \qquad Z_0 = \mu_0 c = 377\,\Omega$$

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
area $= \pi R^2$
circumf. $= 2\pi R$

Sphere
area $= 4\pi R^2$
volume $= \frac{4}{3}\pi R^3$

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