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 13 ***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—

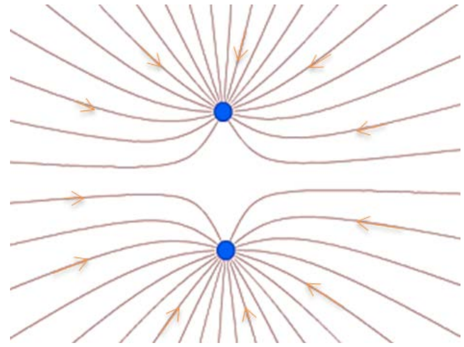
The exam is worth a total of 114 points, composed of two types of questions.

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.



1) Consider the configuration of charges and electric field lines shown at right. If Gauss' Law were used to calculate the electric field produced by these charges, which Gaussian surface could be used? Only consider regions far from the charges.

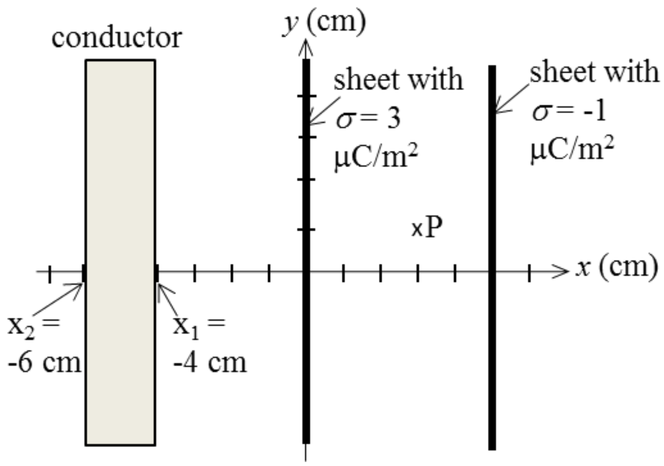
a. Sphere
b. Ellipse
c. Neither of the above.
d. Not enough information is given.
e. Gauss' Law is not useful in this situation.

2) A conducting spherical shell has radius of 3 cm and a surface charge density of +6 $\mu C/m^2$. A Gaussian sphere of radius 7 cm surrounds the shell. What is the total flux through the Gaussian surface?

a. 7.67×10^3 Nm^2/C
b. 1.25×10^5 Nm^2/C
c. 6.78×10^5 Nm^2/C

The next two questions pertain to the situation described below.

Two infinite sheets of charge, oriented perpendicular to the x-axis, pass through $x = 0$ and x = 5 cm, respectively, and have respective surface charge densities of $\sigma = 3$ μC/m^2 and $\sigma = -1$ μC/m^2, as shown below. In addition, a thick, infinite, uncharged conductor, also oriented perpendicular to the x-axis, occupies the region between $x_1 = -4$ cm and $x_2 = -6$ cm.



3) What is the surface charge density on the right side of the conducting slab (at x_1)?

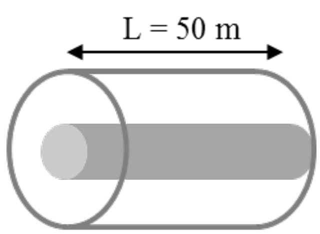
a. 0
b. 2 μC/m^2
c. −2 μC/m^2
d. 1 μC/m^2
e. −1 μC/m^2

4) Find the x-component of the electric field at the position (x,y) = (3 cm, 1 cm) (marked by "P" in the figure).

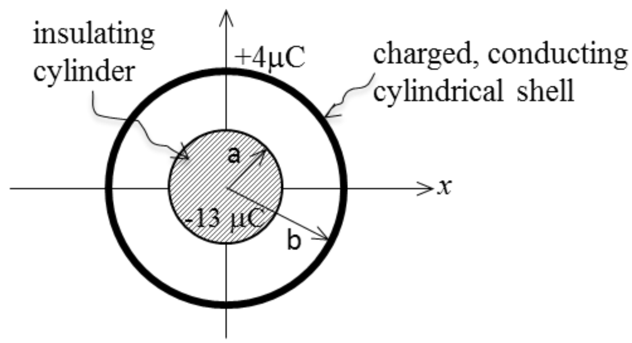
a. $E_x = 4.52 \times 10^5$ N/C
b. $E_x = -4.52 \times 10^5$ N/C
c. $E_x = 2.26 \times 10^5$ N/C
d. $E_x = 1.13 \times 10^5$ N/C
e. $E_x = -1.13 \times 10^5$ N/C

The next two questions pertain to the situation described below.

A charged conducting cylindrical shell is coaxial with a cylindrical insulator, as shown below. The insulator has a radius of $a = 3$ cm, a length of 50 m, and carries a total charge of −13 μC. The conducting outer shell is located at a radius of $b = 6$ cm, has a length of 50 m, and carries a total charge of +4 μC. (Note that since the length is much greater than the radius for both cylinders, they may be considered in the infinite length approximation).



Perspective view



Cross sectional view

5) Find the magnitude of the electric field at a radius $r = 8$ cm (*i.e.*, outside the conducting shell).

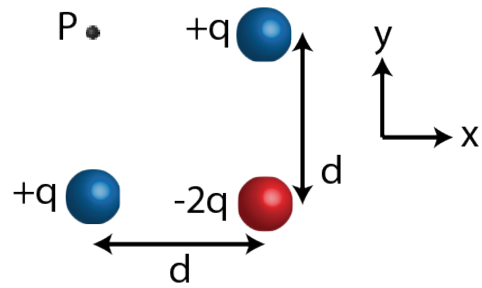
a. $E = 2.02 \times 10^6$ N/C
b. $E = 4.05 \times 10^4$ N/C
c. $E = 5.85 \times 10^4$ N/C

6) Find the magnitude of the electric field at a radius $r = 2$ cm (*i.e.*, inside the insulator).

a. $E = 1.68 \times 10^5$ N/C
b. $E = 1.32 \times 10^4$ N/C
c. $E = 3.00 \times 10^5$ N/C
d. $E = 1.04 \times 10^5$ N/C
e. $E = 5.01 \times 10^3$ N/C

The next three questions pertain to the situation described below.

Three charges are assembled from infinitely far away to the corners of a square of side d as shown in the figure. Note $+x$ is to the right and $+y$ is up as indicated in the diagram.



7) What is the electric field at the fourth corner point **P**, the one without a charge, resulting from the other three charges?

a. $E_x = 0$, $E_y = 0$

b. $\boldsymbol{E_x = -\frac{kq}{d^2}\left(1 - \frac{1}{\sqrt{2}}\right), E_y = \frac{kq}{d^2}\left(1 - \frac{1}{\sqrt{2}}\right)}$

c. $\boldsymbol{E_x = \frac{kq}{d^2}, E_y = -\frac{kq}{d^2}}$

d. $\boldsymbol{E_x = \frac{kq}{d^2}\left(1 - \frac{1}{\sqrt{2}}\right), E_y = -\frac{kq}{d^2}\left(1 - \frac{1}{\sqrt{2}}\right)}$

e. $\boldsymbol{E_x = -\frac{kq}{d^2}, E_y = \frac{kq}{d^2}}$

8) What is the electric potential $\boldsymbol{V}$ at the fourth corner P with respect to a point infinitely far away?

a. $\boldsymbol{V = \frac{2kq}{d}\sqrt{2}}$

b. $\boldsymbol{V = \frac{2kq}{d}\left(1 + \frac{1}{\sqrt{2}}\right)}$

c. $\boldsymbol{V = \frac{2kq}{d}\left(1 - \frac{1}{\sqrt{2}}\right)}$

9) The energy required to assemble this configuration of three charges is $\boldsymbol{U_0}$. Now consider the case where an additional positive charge $\boldsymbol{q}$ is brought in from infinity and placed at point **P**. Suppose this charge is then released: what is the asymptotic velocity v of the additional charge at infinity? Note $\boldsymbol{V}$ is the same as in question 8.

a. $\boldsymbol{v = \sqrt{\frac{2(U_0+V)}{m}}}$

b. $\boldsymbol{v = \sqrt{\frac{2(U_0+qV)}{m}}}$

c. $\boldsymbol{v = \sqrt{\frac{2qV}{m}}}$

d. $\boldsymbol{v = \sqrt{\frac{2V}{m}}}$

e. $\boldsymbol{v = \sqrt{\frac{2V}{qm}}}$

The next two questions pertain to the situation described below.

Consider a charged system that gives rise to an electric potential with the following form

$V = V_0\, 2\,(x^2 + y^2)$ for $(x^2 + y^2) < 1$
$V = V_0\left[-1 + 2\,\ln\left(\sqrt{x^2 + y^2}\right)\right]$ for $(x^2 + y^2) > 1$

where V_0 is a constant. Recall that $r = \sqrt{x^2 + y^2}$ and note that this problem is in three dimensions.

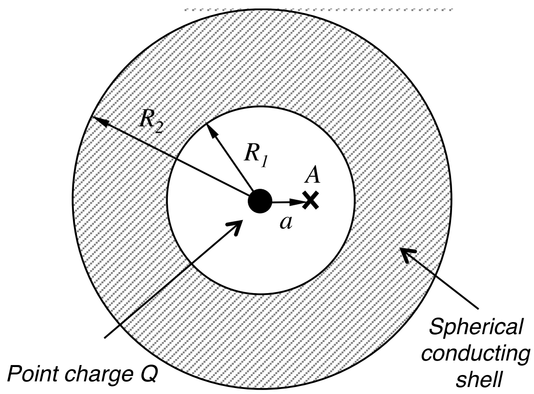
10) What is the magnitude of the electric field for $(x^2 + y^2) < 1$?

a. $V_0\, 4\,(x^2 + y^2)$
b. $V_0\, 2\,(x^2 + y^2)$
c. $V_0\, 4\sqrt{x^2 + y^2}$
d. $V_0\, 2\sqrt{x^2 + y^2}$
e. $V_0\,(x^2 + y^2)\,/4$

11) Which of the following charge distributions gives rise to the electric potential above?

a. Sphere of uniform charge density and radius $r = \sqrt{x^2 + y^2} = 1$
b. Cylinder of uniform charge density and radius $r = \sqrt{x^2 + y^2} = 1$
c. Two point charges separated by a distance $r = \sqrt{x^2 + y^2} = 1$

The following two questions pertain to the situation described below.



A point charge of magnitude Q is placed at the center of an uncharged spherical conducting shell with inner radius R_1 and outer radius R_2 as shown in the figure.

12) What is the value of the electric potential at a point A inside the spherical conducting shell at a radius $a < R_1$? Assume the potential is zero at infinity.

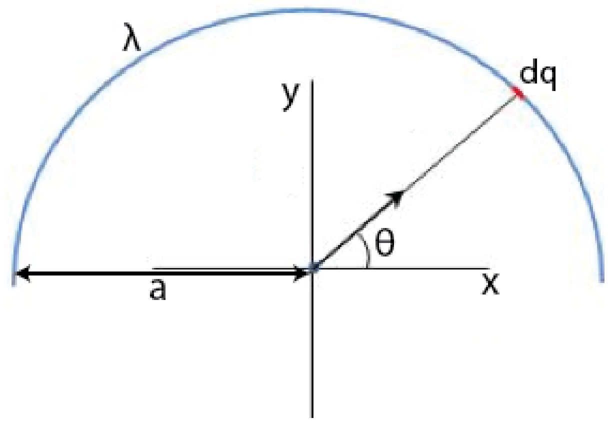
a. $\boldsymbol{V(a) = kQ\left(\frac{1}{R_2} + \frac{1}{R_1} - \frac{1}{a}\right)}$
b. $\boldsymbol{V(a) = kQ\left(\frac{1}{R_2} - \frac{1}{R_1} - \frac{1}{a}\right)}$
c. $\boldsymbol{V(a) = kQ\left(\frac{1}{R_2} - \frac{1}{R_1} + \frac{1}{a}\right)}$
d. $\boldsymbol{V(a) = kQ\left(\frac{1}{a}\right)}$
e. $\boldsymbol{V(a) = kQ\left(\frac{1}{a} - \frac{1}{R_1}\right)}$

13) The work done by the electric field to move a particle of negative charge $-q$ from a point with radius a to a point with radius $a/2$ is

a. positive.
b. negative.
c. zero.

The next three questions pertain to the charge distribution pictured to the right.

A half ring of charge is centered about the origin as shown. The ring has uniform charge density $\lambda = +4$ μC/m and a radius a = 2 cm.



14) What is the total charge Q on the ring?

a. 2.5×10^{-7} C
b. 5.0×10^{-7} C
c. 6.0×10^{-5} C

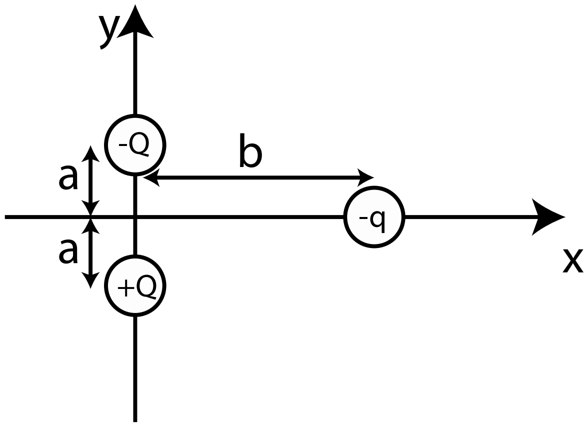
15) We would like to place a positive charge q somewhere in space such that the electric field at the origin ($x = 0, y = 0$) is zero. Where should charge q be placed?

a. $+y$ axis, $y > a$
b. $+y$ axis, $y < a$
c. $-y$ axis
d. at the origin ($x = 0, y = 0$)
e. there is no such position

16) What is the magnitude of the electric field at the origin due to the half ring of charge?

a. $\frac{2k\lambda}{a}$
b. $\frac{2k\lambda}{a^2}$
c. $\frac{4k\lambda}{a}$
d. $\frac{2k}{a^2}$
e. 0

The next two questions pertain to the figure at the below



Three charges are placed in space as shown, with magnitudes $+Q = 4\ \mu C$, $-Q = -4\ \mu C$, and $-q = -1\ \mu C$. The distances labeled are: $a = 1$ cm, and $b = \sqrt{3}$ cm.

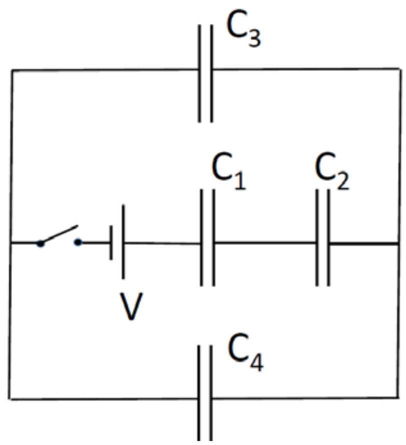
17) At the charge $-q$ what is the direction of the x-component of the electric field due to $+Q$ and $-Q$?

a. zero
b. positive
c. negative

18) What is the magnitude of the force on $-q$ due to $+Q$ and $-Q$?

a. 45 N
b. 180 N
c. 90 N

The next three questions pertain to the following situation:



Four parallel plate capacitors are connected to a battery as shown in the circuit diagram. For the problems below, the switch has been closed for a long time, and the combined charge, Q_3+Q_4, on capacitors C_3 and C_4 is observed to be $1.0\ \mu C = 1.0 \times 10^{-6}\ C$.

$C_1 = 0.5\ \mu F$
$C_2 = 2.0\ \mu F$
$C_3 = 1.3\ \mu F$
$C_4 = 0.7\ \mu F$

19) Which capacitors carry the same charge?

a. C_3 and C_4
b. C_3 and C_1
c. C_2 and C_1

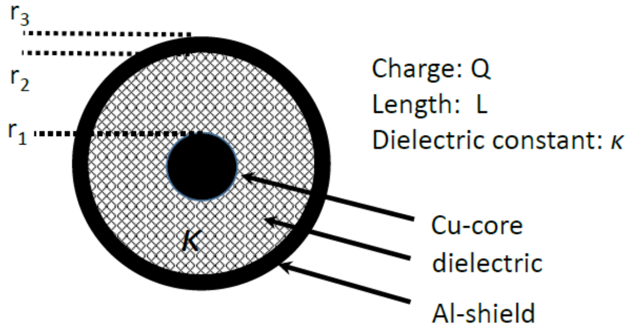
20) What is C_{1234}, the equivalent capacitance for the combination of the four capacitors?

a. $C_{1234} = 2.75\ \mu F$
b. $C_{1234} = 1.33\ \mu F$
c. $C_{1234} = 1.11\ \mu F$
d. $C_{1234} = 0.33\ \mu F$
e. $C_{1234} = 0.11\ \mu F$

21) What is the voltage across C_3?

a. $0.33\ V$
b. $0.50\ V$
c. $0.66\ V$
d. $1.00\ V$
e. $1.33\ V$

The next two questions pertain to the following situation



A coaxial cable of length L consists of a Copper (*Cu)* core surrounded by a dielectric insulator and a braided aluminum *(Al)* shield. The dielectric constant of the insulator is $\kappa = 2.3$. The radius of the *Cu*-core is r_1, the inner- and outer radii of the Al-shield are r_2 and r_3, respectively. A negative charge $-Q$ is present on the *Cu* core and a positive charge, $+Q$, on the *Al* shield.

22) Which statement characterizes best the location of the electric charges within the conductors of the coaxial cable?

a. $-Q$ is distributed across the outside surface of the *Cu* core and $+Q$ across the outside surface of the *Al* shield.
b. $-Q$ is distributed across the outside surface of the *C*u core and $+Q$ across the inside surface of the *Al* shield.
c. $-Q$ and $+Q$ are distributed uniformly in core and shield.

23) Using Gauss' law, an engineer determines that the electric field at a distance r from the center of the coaxial cable inside the dielectric is given as

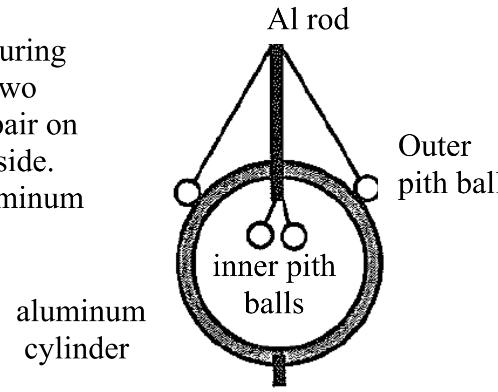
$$E(r) = \frac{QE_0}{\kappa r}$$

where E_0 is a constant. Use this information to determine the capacitance of the cable:

a. $E_0/(\kappa L\, r_2)$
b. $\kappa L/(E_0\, r_3)$
c. $E_0/(\kappa\, ln\, {}^{r_2}/_{r_1})$
d. $\kappa/(E_0 ln\, {}^{r_2}/_{r_1})$
e. $\kappa/(E_0 ln\, {}^{r_3}/_{r_1})$

The following problem relates to the setup shown in the figure below.

Consider the aluminum cylinder used for experiments during the first laboratory session of Physics 212. There were two pairs of pith balls suspended on insulating strings: one pair on the outside of the cylinder and the second pair on the inside. The pith ball strings were attached to the ends of an aluminum rod.



24) You have been informed that the setup has been modified and subsequently the following experiment is carried out: A charge, Q, is carefully transferred to the inner pair of pith balls without touching the inner walls of the cylinder. It is observed that the outer pair of pith balls are repelled from the surface of the aluminum cylinder while the inner pair of pith balls remain in place.

Which of the following changes to the setup can explain this observation?

a. The aluminum cylinder was replaced by a cylinder of insulating material.
b. All strings suspending pith ball pairs were replaced with thin Copper wires.
c. The aluminum rod was replaced by an insulating plastic rod.
d. The strings suspending the inner pith balls were replaced with thin Copper wires.
e. The strings suspending the outer pith balls were replaced by thin Copper wires.

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:

$$C \equiv \frac{Q}{V}$$ $$U = \tfrac{1}{2}CV^2 = \tfrac{1}{2}\frac{Q^2}{C}$$ $$C = C_1 + C_2$$ $$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_0 = \frac{\varepsilon_0 A}{d}$$ $$C_0 = \frac{4\pi\varepsilon_0 ab}{(b-a)}$$ $$C_0 = \frac{2\pi\varepsilon_0 L}{\ln(b/a)}$$ $$C = \kappa C_0$$

$$Q(t) = Q(\infty)\left(1 - e^{-t/\tau}\right)$$ $$Q(t) = Q(0)e^{-t/\tau}$$ $$\tau = RC$$ $$u_E = \frac{1}{2}\varepsilon_0 E^2 \kappa$$

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:

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

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

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

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

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:

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

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

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

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

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

Sphere

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

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

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