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.**

(25 problems)

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 96 points, composed of two types of questions.

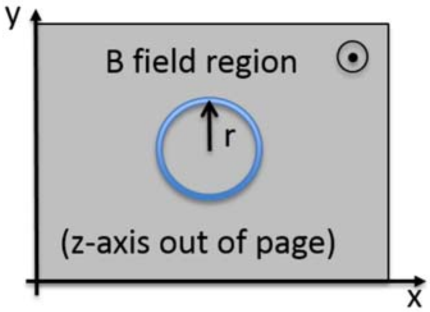
MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

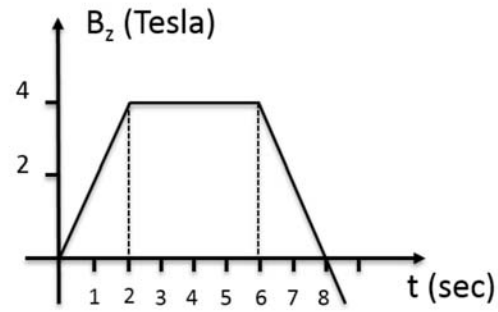
(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more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





A loop of wire of radius r = 0.25 m and resistivity 8 Ohms per meter lies in the x-y plane. The loop is fully contained in a spatially constant, but time-varying magnetic field. A graph of the time-dependence of the magnetic field is shown.

1) What is the direction of the induced current in the loop at t = 8 seconds?

a. Clockwise
b. The induced current is zero at t = 8 seconds
c. Counter-clockwise

2) What is the magnitude of the induced current at t = 1.5 seconds?

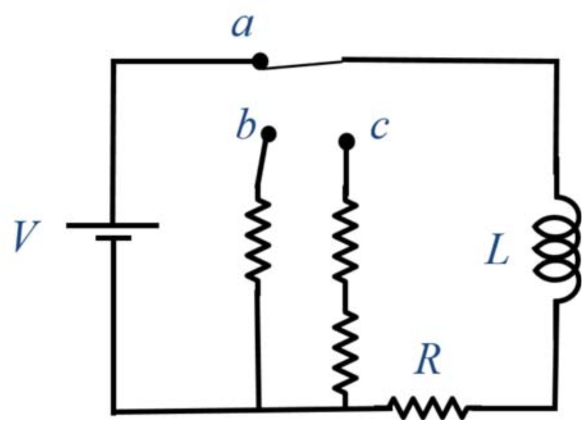
a. $I_{1.5} = 0.159$ A
b. $I_{1.5} = 0.0156$ A
c. $I_{1.5} = 0.0312$ A
d. $I_{1.5} = 0.0468$ A
e. $I_{1.5} = 0$ A

3) Compare the magnitude of the current at t = 4 seconds to the magnitude of the current at t = 7 seconds.

a. $|I_4| > |I_7|$
b. $|I_4| = |I_7|$
c. $|I_4| < |I_7|$

The next four questions pertain to the situation described below.

Consider the electrical circuit shown. It consists of an ideal 18 Volt battery and four 36 Ω resistors and an 24 mH inductor. The switch has been in position **a** as shown for a long time.



4) What is the voltage across the inductor after the switch has been in position **a** for a long time?

a. $V_L = 0$ Volts
b. $V_L = 9$ Volts
c. $V_L = 18$ Volts

5) How much energy is stored in the inductor after the switch has been in position **a** for a long time?

a. $U_L = 0$ Joules
b. $U_L = 9$ Joules
c. $U_L = 0.003$ Joules

6) After being in position **a** for a long time, the switch is instantaneously moved to position **c**. What is the voltage across the inductor immediately after the switch is in position **c**?

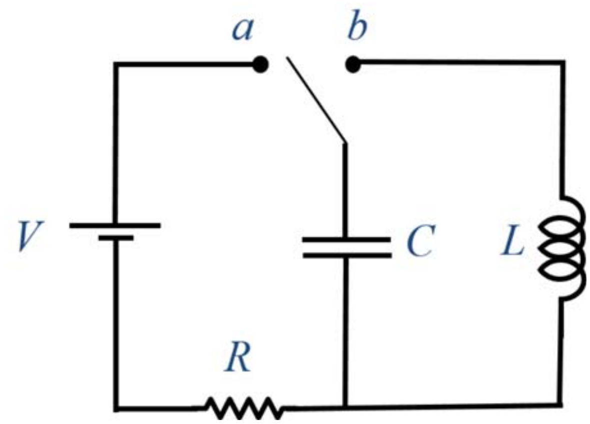
a. $V_L = 6$ Volts
b. $V_L = 18$ Volts
c. $V_L = 54$ Volts

7) After being in position **a** for a long time, you have the option to instantaneously move the switch to either position **b** or position **c**. Which position will result in the energy in the inductor being dissipated the fastest?

a. Position **c**
b. Both positions will dissipate energy at the same rate.
c. Position **b**

The next three questions pertain to the situation described below.

Consider the electrical circuit shown. It consists of an ideal 18 Volt battery a 3.6 Ω resistor a 15 mF capacitor and a 24 mH inductor. The switch has been in position **a** for a long time.



8) After being in position **a** for a long time, the switch is moved to position **b**. What is the rate at which the current through the inductor is changing immediately after the switch is in position **b**?

a. $dI_L/dt = 0.675$ A/s
b. $dI_L/dt = 5$ A/s
c. $dI_L/dt = 750$ A/s

9) Let I_{max} represent the maximum current that flows through the inductor while the switch is in position **b**. After the switch is moved to position b, what is the current through the inductor when the charge on the capacitor is ¼ its maximum value?

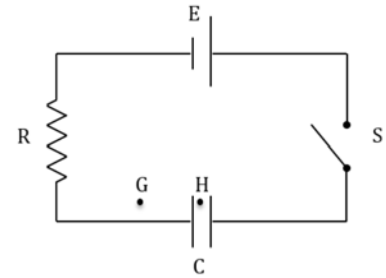
a. $I_{1/4} = 0.97\ I_{max}$
b. $I_{1/4} = 0.25\ I_{max}$
c. $I_{1/4} = 0.063\ I_{max}$
d. $I_{1/4} = 0.75\ I_{max}$
e. $I_{1/4} = 0.5\ I_{max}$

10) Which expression best represents the charge on the top plate of the capacitor if t=0 corresponds to the moment the switch was moved from position **a** to position **b**?

a. $Q(t) = 0$
b. $Q(t) = -Q_{max}\cos(\omega t)$
c. $Q(t) = -Q_{max}\sin(\omega t)$
d. $Q(t) = +Q_{max}\cos(\omega t)$
e. $Q(t) = +Q_{max}\sin(\omega t)$

The next two questions pertain to the situation described below.

Consider the RC circuit shown. It consists of an ideal 18 Volt battery a 30 Ω resistor and a 15 mF capacitor. The capacitor consists of two circular plates separated by a small distance, and is initially uncharged. At time t=0, the switch is closed.



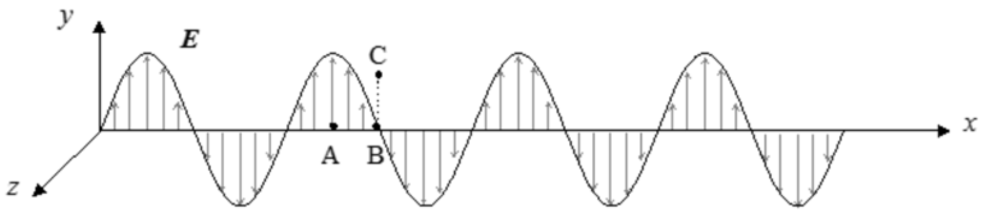
11) Compare the magnitude of the magnetic field at point G, a distance *d* above the wire, and point H, midway between the plates of the capacitor and a distance *d* above its center just after the switch is closed. Note $d<r$ the radius of the capacitor plate.

a. $B_G < B_H$
b. $B_G > B_H$
c. $B_G = B_H$

12) How fast is the electric flux between the capacitor plates changing just after the switch is closed?

a. $d\Phi_E/dt = 6.78 \times 10^{10}\ Nm^2C^{-1}s^{-1}$
b. $d\Phi_E/dt = 3.39 \times 10^{10}\ Nm^2C^{-1}s^{-1}$
c. $d\Phi_E/dt = 4.79 \times 10^{10}\ Nm^2C^{-1}s^{-1}$

The next three questions pertain to the situation described below.



A linearly polarized electromagnetic wave propagates in vacuum. The electric field associated with the wave is:

$\vec{E} = E_0 \sin(kx + \omega t)\hat{y}$

The figure above shows a snapshot of the electric field at t=0.

13) At t = 0, which option best describes the relative magnitudes of the electric field at points A, B and C? Note that A, B and C lie on the x-y plane.

a. $E_A > E_C > E_B = 0$;
b. $E_C > E_A = E_B = 0$;
c. $E_A > E_C = E_B = 0$

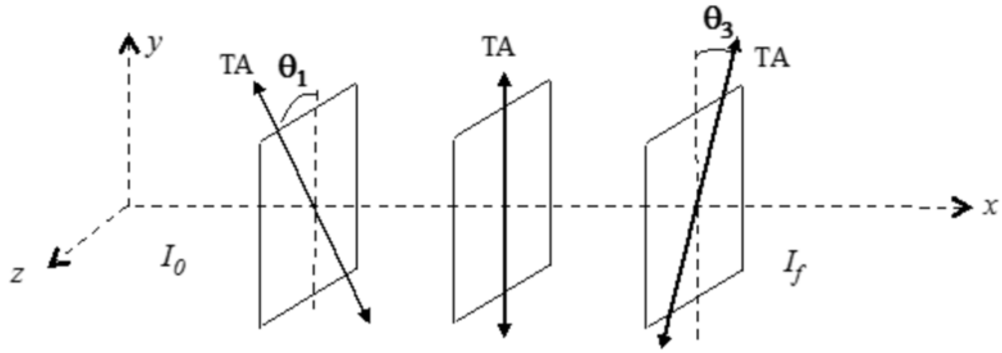
14) Which of the following best describes the magnetic field associated with the electromagnetic wave? Note $E_0 > 0$ and $B_0 > 0$.

a. $\vec{B} = -B_0 \sin(kx - \omega t)\hat{y}$
b. $\vec{B} = B_0 \cos(kx + \omega t)\hat{y}$
c. $\vec{B} = -B_0 \sin(kx + \omega t)\hat{z}$
d. $\vec{B} = -B_0 \sin(kx + \omega t)\hat{y}$
e. $\vec{B} = B_0 \sin(kx + \omega t)\hat{z}$

15) If the amplitude of the magnetic field is $B_0 = 6 \times 10^{-5}$ T, what is the average intensity of the wave?

a. 4.3×10^5 W/m^2
b. 6.08×10^5 W/m^2
c. 2.05×10^5 W/m^2
d. 3.04×10^5 W/m^2
e. 7.74×10^5 W/m^2

The next three questions pertain to the situation described below.



Consider a beam of unpolarized light with initial intensity I_0 traveling in the +x direction. The beam traverses three linear polarizers parallel to the yz plane whose transmission axes (TA) are indicated in the figure above with $\theta_1 = 25°$ and $\theta_3 = 65°$.

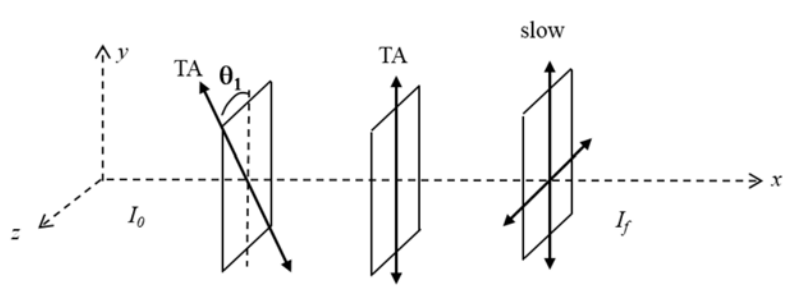
16) Which of the following best describes the relationship between the initial intensity I_f, and the final intensity I_f?

a. $I_f = 0$
b. $I_f = 0.121\ I_0$
c. $I_f = 0.0734\ I_0$

17) Consider the situation where the 2nd and 3rd polarizers are exchanged with each other, how does the final intensity change?

a. I_f will be zero.
b. I_f will increase.
c. I_f will not change.

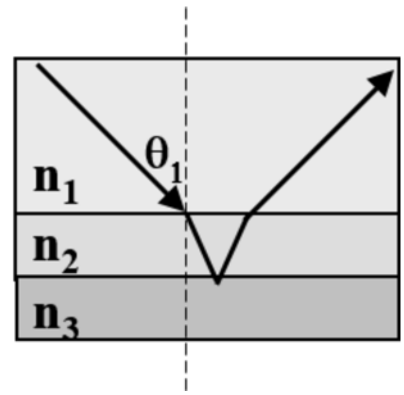
18) Now consider the situation where the third polarizer is replaced with a birefringent material whose slow and fast axes are aligned with the y and z axes respectively as shown in the figure. What is the polarization of the outgoing wave?



a. Left circularly polarized.
b. Right circularly polarized.
c. Linearly polarized.

The next two questions pertain to the situation described below.

Consider the case of light traveling through three different materials in layers with indices of refraction n_1, n_2 and n_3, as shown in the figure.



19) Given the transition between layers 1 and 2 shown in the figure above, what can be concluded about these two materials?

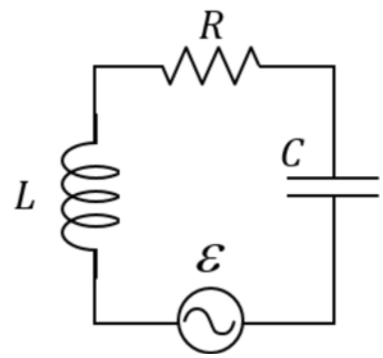
a. $n_1 > n_2$
b. $n_1 < n_2$
c. $n_1 = n_2$

20) If the light is totally reflected between material 2 and 3, which of the following holds?

a. $n_3 \geq n_1 \sin(\theta_1)$
b. $n_3 \geq n_1$
c. $n_3 \leq n_1 \sin(\theta_1)$

The next five questions pertain to the situation described below.

Consider the electrical AC circuit shown. It consists of a variable frequency AC generator providing a voltage $V(t) = 18 \sin(\omega t)$ Volts, a 10 Ω resistor, a 15 μ F capacitor, and a 24 mH inductor.



21) To what frequency ω should the generator be set in order to maximize the peak voltage across the resistor?

a. $\omega = 0$ rad/s
b. $\omega = 1670$ rad/s
c. The peak voltage across the resistor does not depend on the frequency of the generator.

22) The generator is now set to the resonant frequency for this circuit. What is the maximum energy stored in the inductor at this frequency?

a. $U_{max} = 0.0389$ J
b. $U_{max} = 32.4$ J
c. $U_{max} = 16.2$ J

23) With the generator set to the resonant frequency for this circuit, what is the average power dissipated by the resistor?

a. $<P_R> = 16.2$ W
b. $<P_R> = 64.8$ W
c. $<P_R> = 32.4$ W

24) The generator frequency is now set to 1330 rad/s. Which element has the largest peak voltage?

a. capacitor
b. inductor
c. resistor
d. They all have the same peak voltage.
e. generator

25) With the generator frequency still set to 1330 rad/s, what is the first time after t=0, that the magnitude of the voltage across the resistor is a maximum?

a. $t = 3.78 \times 10^{-4}$ s
b. $t = 8.03 \times 10^{-4}$ s
c. $t = 0.00118$ s

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:

$$\vec{F} = q\vec{E} + q\vec{v}\times\vec{B}$$ $$d\vec{F} = I d\vec{l}\times\vec{B}$$ $$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I d\vec{l}\times\hat{r}}{r^2}$$ $$\oint \vec{B}\cdot d\vec{l} = \mu_0 I$$

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$ $$B_z = \frac{\mu_0 I R^2}{2(z^2 + R^2)^{3/2}}$$ $$B = \mu_0 n I$$ $$\vec{\mu} = N I\vec{A}$$

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

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:

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

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

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

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

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:

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

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

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

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

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

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