



## Introductory Physics

U.C. Berkeley

Physics 8B, Fall 2011

Section II

Exam 2

December 10, 2011

Notes: Correct answers without supporting derivations will not receive credit. You **must** show your work, and partial credit will be given. Answer the questions in your blue book. Please be clear and neat, and **indicate your final answer**. Ask for assistance if any problem is unclear.

*No electronics aids of any type are permitted on this exam. Electronic aids include calculators, computers, cell phones, etc.*

**Make sure you list your Name, SID, Section Number and Section Time in your Blue Book.**

### Possibly Useful Formulas

Force on a charged particle $\mathbf{F} = q\mathbf{E} + q\mathbf{v} \times \mathbf{B}$	Electric field from a plane $E = \frac{\sigma}{2\epsilon_0}$	Electric Field from a point $E = \frac{q}{4\pi\epsilon_0 r^2}$
Gauss's Law $\epsilon_0 \int \mathbf{E} \cdot d\mathbf{A} = q_{\text{enc}}$	Potential difference $\Delta V = -\int \mathbf{E} \cdot d\mathbf{x}$	Electric field from a line charge $E = \frac{\lambda}{2\pi\epsilon_0 r}$
Electric field between two oppositely charged planes $E = \frac{\sigma}{\epsilon_0}$	Power $P = IV$	Ohm's Law $V = IR$
Electric energy density $U = \frac{1}{2} \epsilon_0 E^2$	Resistance $R = \frac{\rho L}{A}$	Microscopic Resistance $\rho = \frac{2mv}{e^2 n \lambda}$
Capacitor formula $Q = CV$	Energy in a capacitor $U = \frac{1}{2} CV^2$	Parallel plate capacitance $C = \epsilon_0 \frac{A}{d}$
Resistors in series $R = R_1 + R_2$	Resistors in parallel $R = \frac{R_1 R_2}{R_1 + R_2}$	RC time constant $\tau = RC$
Discharge of a capacitor $Q(t) = Q_0 e^{-t/\tau}$	Capacitor charging $Q(t) = Q_0 (1 - e^{-t/\tau})$	Biot-Savart law $\mathbf{B} = \frac{\mu_0 I}{4\pi} \int \frac{d\mathbf{L} \times \mathbf{r}}{r^3}$
Ampere's law $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$	Field from a straight wire $\mathbf{B} = \frac{\mu_0 I}{2\pi r} \hat{\phi}$	Radius of orbit in uniform magnetic field $r = \frac{mv}{qB}$
Force on a wire $\mathbf{F} = I\mathbf{L} \times \mathbf{B}$	Magnetic Moment $\mu = NI A$	Torque on a magnetic moment $\tau = \mu \times \mathbf{B}$
Field in a solenoid $B = \mu_0 n I$	Field at the center of a loop of radius $R$ $B = \frac{\mu_0 I}{2R}$	Magnetic energy density $U = \frac{1}{2\mu_0} B^2$
Lenz's law $\mathcal{E} = -\frac{d\Phi_B}{dt}$	Faraday's law $\oint \mathbf{E} \cdot d\mathbf{l} = -\frac{d\Phi_B}{dt}$	Inductive EMF $V = -L \frac{dI}{dt}$
Inductance of a solenoid $L = \mu_0 n^2 A l$	RL time constant $\tau = \frac{L}{R}$	Flux in an inductor $\Phi = LI$

Discharge of an inductor $I(t) = I_0 e^{-t/\tau}$	Inductor charging $I(t) = I_0 (1 - e^{-t/\tau})$	Transformer ratio $I_2 = \frac{N_1}{N_2} I_1 \quad V_2 = \frac{N_2}{N_1} V_1$
Energy stored in an inductor $U = \frac{1}{2} L I^2$	LC time constant $\omega = \frac{1}{\sqrt{LC}}$	"Magnetic" Gauss's Law $\int \mathbf{B} \cdot d\mathbf{A} = 0$
Speed of Light $c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$	Snell's Law $n_1 \sin \theta_1 = n_2 \sin \theta_2$	Total internal reflection $\theta_c = \sin^{-1} \frac{n_2}{n_1}$
Lens/Mirror formula $\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$	Magnification $\frac{h_i}{h_o} = \frac{s_i}{s_o}$	Wavelength transformation $\lambda_n = \frac{\lambda}{n}$
Two slit maxima $d \sin \theta = m\lambda, \quad m = 0, 1, 2, \dots$	Two slit minima $d \sin \theta = (m + \frac{1}{2})\lambda,$ $m = 0, 1, 2, \dots$	Soap film interference maxima $\frac{2dn}{\lambda \sin \theta} = (m + \frac{1}{2}),$ $m = 0, 1, 2, \dots$
Soap film interference minima $\frac{2dn}{\lambda \sin \theta} = m, \quad m = 0, 1, 2, \dots$	Single slit diffraction minima $d \sin \theta = m\lambda, \quad m = 0, 1, 2, \dots$	Circular aperture diffraction $\sin \theta = 1.22 \frac{\lambda}{d}$

$c = 3 \times 10^8 \text{ m/s}$	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$	$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$
$e = 1.6 \times 10^{-19} \text{ C}$	$m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg}$	$m_{\text{proton}} = 1.67 \times 10^{-27} \text{ kg}$
$k = 1.38 \times 10^{-23} \text{ J/K}$	$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$	$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$

Note that all constants are given just for reference; you need not plug in the numeric values of the constants unless you are explicitly directed to give a purely numeric answer.

#### Kirchhoff's Rules

1. Wires carry currents without changing potentials
2. Traversing a battery increases the potential by the EMF of the battery.
3. Resistors decrease the potential by  $IR$ .
4. Current is conserved at a junction
5. The net potential difference along any closed circuit is zero.

#### Problem 1: [25 points]

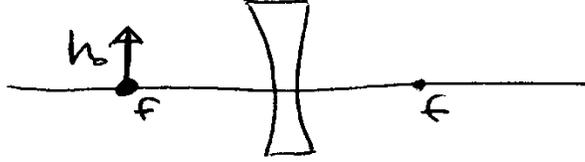
In the circuit shown below, there is voltage  $V_0$  across the capacitor  $C$  at time  $t=0$ . No current is flowing at this time. (The capacitor had been previously charged with a battery, not shown. At  $t=0$ , the battery was disconnected, and the inductor connected.)

- a) Draw qualitative graphs of the energy in the capacitor and the energy in the inductor  $L$  as a function of time. Calculate and label the maximum of energy in the inductor and in the capacitor. Hint-It may help you to draw graphs of the voltage across the capacitor and the current through the inductor as a function of time.
- b) What is the current in the inductor when the energy in the inductor equals the energy in the capacitor?
- c) What is the first time at which the condition in b) occurs?



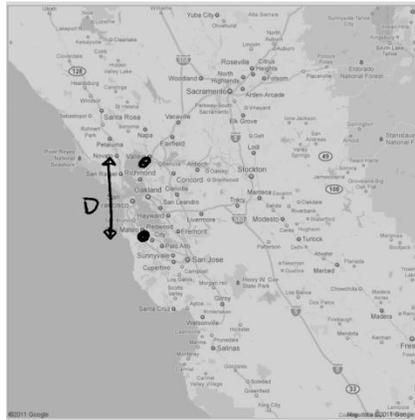
**Problem 2: [25 points]**

For the diverging lens below, and the indicated object, find the position of the image by ray tracing. (The object is at one of the focal points.) Is the image real or virtual? Right-side up or upside down? Magnified or demagnified? Then, using your ray diagram, derive the equation relating the position of the image  $s_i$  to the position of the object  $s_o$  and the focal length  $f$ .



**Problem 3: [25 points]**

A radio station broadcasts equal amplitude signals from two towers, oriented as shown below. The towers are separated by a distance  $D$  which is equal to half of a wavelength of the radio wave being broadcast by the station. What must be true about the signal being broadcast from each tower if very little power is sent to the East and West, but a lot of power is North and South? Fully explain your answer. (Note that the separation of the towers is not to scale. The towers are actually separated by a few hundred meters.)



**Problem 4: [25 points]**

A bright point of light is a distance  $L$  from a mask with a small circular hole of diameter  $d$ . A screen is placed some very large distance from the mask.

- Assuming, for the moment, that light behaves like a particle only, what will be angular smear of the point of light on the screen? Fully explain your answer, including drawing a picture.
- Will the smear increase in size or decrease in size as  $d$  is decreased?
- Now assume that the light has a wavelength  $\lambda$ . Draw a rough graph of the size of the angular smear as a function of  $d$ .
- Is there a minimum angular smear? If so, at approximately what  $d$  does this minimum occur?

