***Section instructor*___________________** ***Section number*_________**

***Last/First name*____**

Last 3 Digits of Student ID Number: _________

Show all work. Show all formulas used for each problem prior to substitution of numbers. Label diagrams and include appropriate units for your answers. *You may use an alphanumeric calculator during the exam as long as you do not program any formulas into memory. By using an alphanumeric calculator you agree to allow us to check its memory during the exam. Simple scientific calculators are always OK!*

A Formula Sheet Is Attached To The Back Of This Examination

Be Prepared to Show your Student ID Card

Score on each problem:

1. *(30)* ____
2. *(20)* ____
3. *(20)* ____
4. *(20)* ____
5. *(20)* ____
6. *(20)* ____
7. *(20)* ____

Total Score (out of 150 pts) ____

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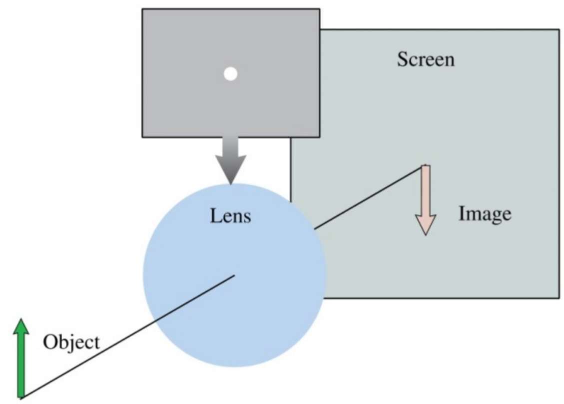
1. Conceptual Questions (30 point)

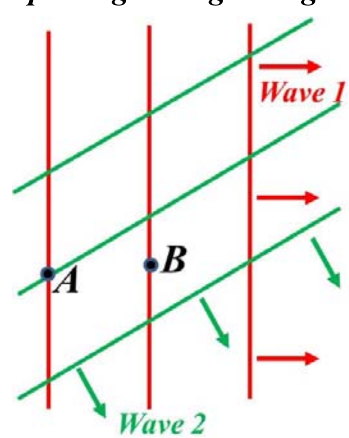
1.1. (6pts) A lens produces a sharply focused, inverted image on a screen. What will you see on the screen if the lens is covered by a dark mask having only a small hole in the center?



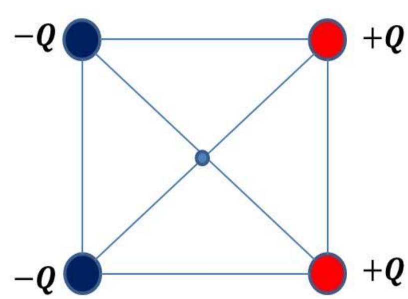
- ***A. An inverted but blurry image.***
- ***B. An image that is dimmer but otherwise unchanged.***
- ***C. Only the top half of the image.***
- ***D. Only the bottom half of the image.***
- ***E. No image at all.***

1.2. (6pts) Figure is a snapshot graph of two plane waves passing through a region of space. Each wave has a 2.0 mm amplitude and the same wavelength. What is the net displacement of the medium at points A and B?

Point	Amplitude
A	
B	

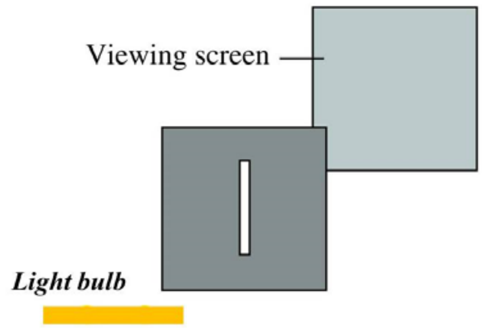


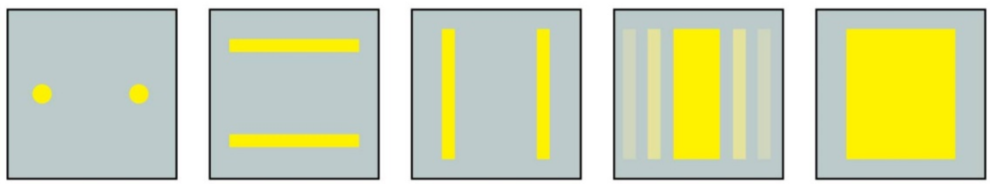
1.3 **(6pts)** ***Four point charges are arranged at the corners of a square. Find the electric field E and the potential V at the center of the square.***



- *A) E=0; V=0*
- *B) E=0; V≠0*
- *C) E≠0; V≠0*
- *D) E≠0; V=0*
- *E) E = V regardless of the value*

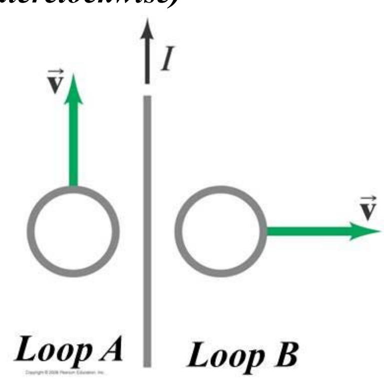
1.4 **(6pts*****)*** ***An extended light bulb (see the figure) illuminates a narrow vertical aperture in a dark screen. What do you see on the viewing screen?***
(Circle the right answer)





A. B. C. D. E.

1.5 **(6pts)** ***Two loops of wire are moving in the vicinity of a very long straight wire carrying a steady current. Find the direction of the induced current in each loop. (CW stands for clockwise direction; CCW – counterclockwise)***



<u>Loop A</u>:

A) CW

B) CCW

C) No current

<u>Loop B</u>:

A) CW

B) CCW

C) No current

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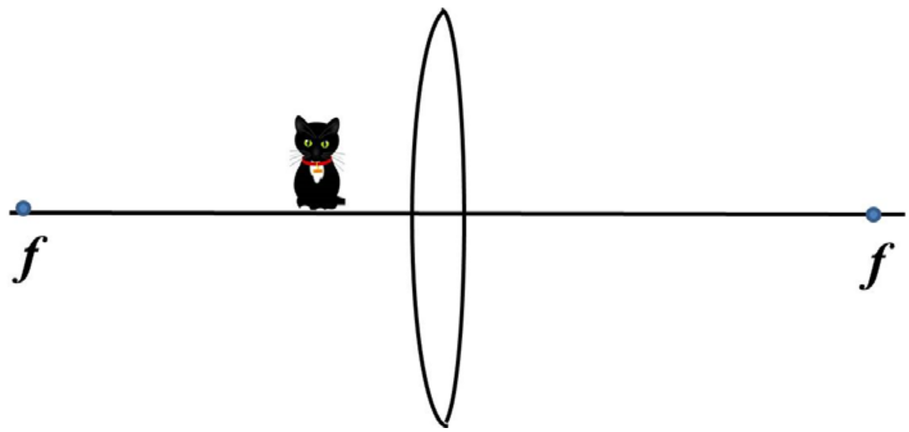
Problem 2. (20 pts)

A 0.1-m-tall cat is placed 20 cm from a 1-m-focal length converging lens.

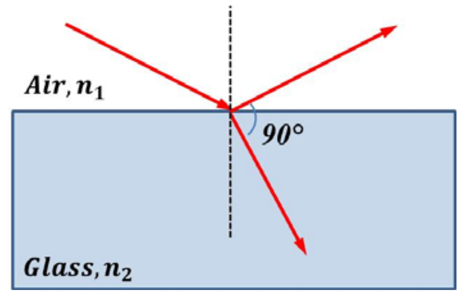
a) Determine the image position using ray tracing (draw it). Identify if the image is upright/inverted and real/virtual.

b) Calculate the image position and height.



Problem 3. (20 pts)

Light strikes a glass plate at an angle of incidence of 60^o; part of the beam is reflected and part is refracted. It is observed that the reflected and refracted portions make an angle of 90^o with each other (see the figure). What is the index of refraction of the glass?



Problem 4. (20 pts)

If the distance between the first and tenth maxima of a double-slit pattern is 18 mm and the slits are separated by 0.15 mm with the screen 50 cm from the slits, what is the wavelength of the light used?

Problem 5. (20 pts)

The magnetic field of an electromagnetic wave in a vacuum is $\boldsymbol{B_z = (2 \cdot 10^{-8} T)\,\mathrm{Sin}[kx + (3\pi \cdot 10^{16})t]\,;\, B_x = 0;\; B_y = 0}$ ***, where x is in meters and t is in seconds. What are the wave's***

a) (2pts) direction of propagation;

b) (3pts) wavenumber;

c) (3pts) wavelength;

d) (3pts) frequency;

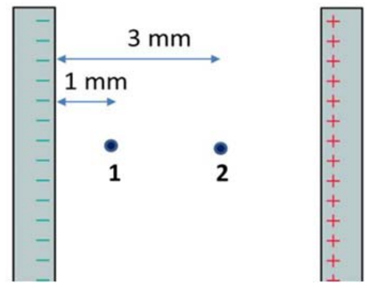
e) (3pts) electric field amplitude?

f) (3pts) mathematical expression for the electric field?

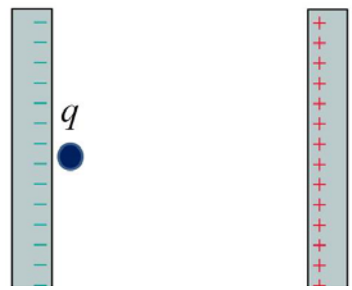
g) (3pts) intensity of the electromagnetic wave?

Problem 6. (20 pts)

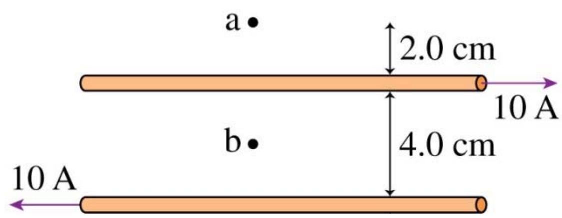
A) (6 pts) The figure shows two points inside a capacitor. Let $V=0$ V at the negative plate. What is the ratio V_2/V_1 of the electric potential at these two points?



B) (14 pts) An electron is accelerated from rest in a capacitor. A potential difference between the plates is 5000 V. What is the speed of the electron ($m=9.1\text{x}10^{-31}$ kg, $q= -1.6\text{x}10^{-19}$ C) as a result of this acceleration?

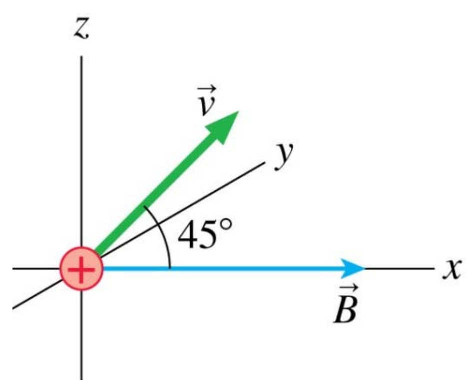


Problem 7.



A) ***(10 pts) What is the magnetic field strength and direction at points a and b in the figure. Point b is the midpoint between the wires.***

B) ***(10 pts) A proton moves in the magnetic field $\vec{B} = \mathbf{0.5}\hat{\imath}T$ with a speed of 1.0x10^{7}m/s in the direction shown in the figure. What is the magnetic force on the proton? Give your answers in component form.***



Formula Sheet: Electricity and Magnetism

Coulomb's law

$$F = k\frac{qQ}{r^2}$$

Electric Field

$$\vec{E} = \frac{\vec{F}}{q}$$

Field of a point charge

$$E = k\frac{Q}{r^2}$$

Electric field inside a capacitor

$$E = \frac{\eta}{\varepsilon_0}$$

Principle of superposition

$$\vec{E}_{net} = \sum_{i=1}^{N} \vec{E}_i$$

Electric flux

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

Gauss's law

$$\Phi = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0}$$

Electric potential

$$V = \frac{U}{q}$$

$$\Delta V = V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}$$

For a point charge $V(r) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$

For a paralle-plate capacitor

$$V = Es$$

Potential Energy

$$U = qV$$

Two point charges

$$U = k\frac{qQ}{r}$$

Capacitors

$$C = \frac{Q}{\Delta V}$$

Parallel-plate $C = \varepsilon_0 \frac{A}{d}$

Capacitors connected in parallel

$$C_{eq} = C_1 + C_2 + \cdots$$

Capacitors connected in series

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$$

Energy stored in a capacitor $U = \frac{Q^2}{2C}$

Ohm's law

$$V = IR$$

$$I = \frac{dQ}{dt}$$

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

$$\sum I_{in} = \sum I_{out}$$

$$\sum \Delta V_i = 0$$

Power

$$P = IV$$

Resistors connected in series

$$R_{eq} = R_1 + R_2 + R_3 + \cdots$$

Resistors connected in parallel

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

The potential difference across a charging capacitor in RC circuit

$$V(t) = \varepsilon(1 - e^{-t/RC})$$

A magnetic field exerts a force

$$\overrightarrow{dF} = I\overrightarrow{dl} \times \vec{B}$$

$$\vec{F} = I\vec{l} \times \vec{B}$$

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

The Biot-Savart Law

$$\vec{B} = \frac{\mu_0 q\vec{v} \times \hat{r}}{4\pi r^2}$$

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

The magnetic field of:

A straight line wire

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

A solenoid

$$B = \mu_0 n I$$

Magnetic flux

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

Inductance

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

$$L = \frac{\mu_0 N^2 A}{l}$$

$$\varepsilon = -L\frac{dI}{dt}$$

Maxwell's equations

$$\oint \vec{E} \cdot \overrightarrow{dA} = \frac{Q}{\varepsilon_0}$$

$$\oint \vec{B} \cdot \overrightarrow{dA} = 0$$

$$\mathcal{E} = \oint \vec{E} \cdot \overrightarrow{ds} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B} \cdot \overrightarrow{ds} = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$

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

The Poynting vector

$$\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B})$$

$$E_0 = cB_0$$

$$\mathrm{I} = \frac{E_0^2}{2c\mu_0}$$

Malus's Law

$$I = I\cos^2\theta$$

Traveling Wave

$$y(x,t) = A\sin(kx - \omega t + \varphi_0)$$

$$k = \frac{2\pi}{\lambda};\ \omega = \frac{2\pi}{T};\ v = \lambda f$$

Interference

$$\Delta\varphi = 2\pi\frac{\Delta r}{\lambda} + \Delta\varphi_0 = m2\pi\ (constr)$$

$$\Delta\varphi = 2\pi\frac{\Delta r}{\lambda} + \Delta\varphi_0$$
$$= (m + \frac{1}{2})2\pi\ (destr)$$

$$A = \left|2a\cos(\frac{\Delta\varphi}{2})\right|$$

Double Slit

$$y_m = \frac{m\lambda L}{d}$$

Diffraction grating

$$d \sin\theta_m = m\lambda$$

$$y_m = L \tan\theta_m$$

Thin-lens equation:

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$m = -\frac{s'}{s}; \quad |m| = \frac{h'}{h}$$

Snell's Law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\text{TIR:} \quad \sin\theta_c = \frac{n_2}{n_1}$$

Constants

Charge on electron

$e = 1.60 \cdot 10^{-19}\ C$

Electron mass $m = 9.11 \cdot 10^{-31}\ kg$

Proton mass $m = 1.67 \cdot 10^{-27}\ kg$

Permittivity of free space

$$\varepsilon_0 = 8.85 \cdot 10^{-12}\ C^2/Nm^2$$

Permeability of free space

$$\mu_0 = 4\pi \cdot 10^{-7}\ Tm/A$$

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \cdot 10^9\ Nm^2/C^2$$

$$c = \frac{1}{\sqrt{\varepsilon_0\mu_0}} = 3.0 \cdot 10^8 m/s$$

Kinematic eq-ns with const. Acc.:

$v(t) = v_{0x} + at$

$x(t) = x_0 + v_{0x}t + (1/2)\ at^2$

$v^2 = v_{0x}^2 + 2a(x - x_0)$

Centripetal acceleration $a_R = v^2/r$

$L = 2\pi R$

$A = \pi R^2$

$V = (4/3)\pi R^3$