

Physics 122
Final Examination
May 11, 2006

Name: _____

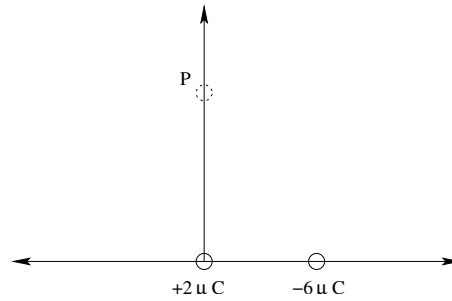
Recitation Section: _____

Lab Section: _____

	Score
Problem 1	
Problem 2	
Problem 3	
Problem 4	
Problem 5	
Problem 6	
Problem 7	
Problem 8	
Total	

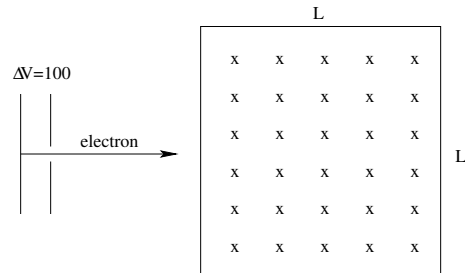
Constant	mks units	natural units
h	$6.626068 \times 10^{-34} \text{ J} \cdot \text{s}$	$4.1356668 \times 10^{-15} \text{ eV} \cdot \text{s}$
hc	$1.98644521 \times 10^{-25} \text{ J} \cdot \text{m}$	$1.240 \text{ eV} \cdot \mu\text{m}$
amu	$1.66053886 \times 10^{-27} \text{ kg}$	$931.5 \frac{\text{MeV}}{c^2}$

1. The figure below shows 2 point charges. The $+2 \mu\text{C}$ charge is located at the origin. The $-6 \mu\text{C}$ charge has (x,y) coordinates of $(3 \text{ m}, 0 \text{ m})$. The point P is located on the y-axis at the (x,y) coordinates $(0 \text{ m}, 4 \text{ m})$.



- (a) Calculate the electric field vector, $\vec{E} = E_x \hat{x} + E_y \hat{y}$, (*i.e.* in component form) at the point P.
- (b) Calculate the electric potential at the point P.

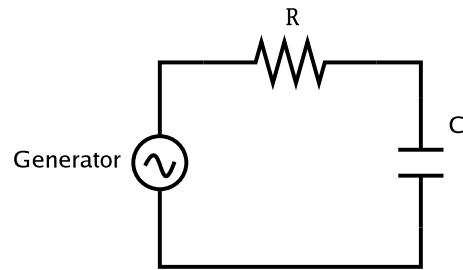
2. An electron is accelerated from rest through a potential difference of 100V. The electron then moves into an area of constant downward pointing magnetic field of 0.0084 T. The magnetic field extends over a square area of length and width $L = 1.6$ cm.



- What is the velocity of the electron after passing the potential difference?
- In which direction is the electron deflected by the magnetic field?
- Calculate the radius of curvature.
- Make a to-scale drawing of the trajectory of the electron in the magnetic field.

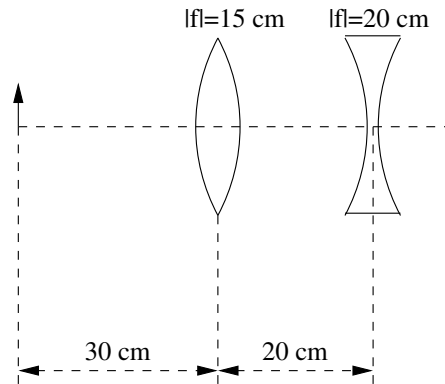
NOTE: The mass of an electron is: $m_e = 9.109 \times 10^{-31} \text{ kg} = 511 \frac{\text{keV}}{c^2}$

3. Shown below is an RC circuit driven by an AC power source.



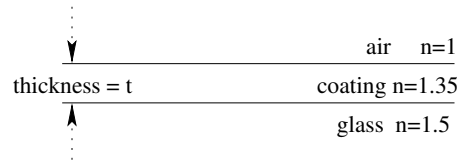
- Use a phasor diagram to determine the magnitude of the impedance, $|Z|$.
- Let the resistance be $R = 120\Omega$, the capacitance be $C = 3.0 \times 10^{-9}F$ and the voltage source have a peak voltage, $V_{peak} = 10V$, at a frequency of $f = 500kHz$. Determine the peak current through the circuit.
- You become bored with this circuit and decide to change it into a radio tuner designed to tune in this same frequency of 500 kHz. What circuit element do you add to make the new circuit (specify the type of circuit element and the value).

4. Shown in the figure below is a system containing an object, and two lenses. Use the shapes of the lenses in the figure to decide whether they are converging or diverging optical elements.

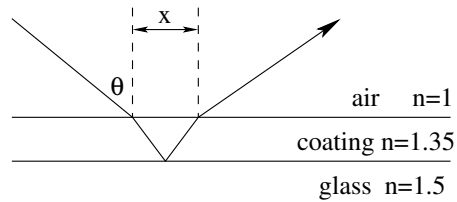


- (a) Find the image location **and magnification** of the first lens (assuming that only this lens exists). Specify this image location, q_1 , as some number of centimeters to the left or to the right of this lens.
- (b) The image of the first lens acts as the object for the second. Find the location **and magnification** of the image produced by the second lens. Specify this image location, q_2 , as some number of centimeters to the left or to the right of this lens.
- (c) Calculate the total magnification of this entire system.
- (d) Is the final image:
- real or virtual?
 - enlarged or shrunk?
 - right-side-up or up-side-down?

5. You are to design an ANTI-REFLECTIVE coating for a camera lens. The lens itself is made of glass ($n=1.5$) and the coating material will have an index of refraction $n=1.35$.



- (a) What minimum coating thickness that would prevent reflections of light whose wavelength in vacuum is $\lambda_0 = 500 \text{ nm}$? NOTE: For this part of the problem assume that the light enters the lens at normal incidence ($\theta=0$).



- (b) Now assume *instead* that the light enters with $\theta=50^\circ$. Using the thickness determined in part a, determine the distance x shown in the second figure.

6. Consider a ${}^4_2\text{He}^+$ ion of charge $+1e$ (*i.e.* a Helium atom with one missing electron). Since the ion has only one electron, it can be analyzed within the Bohr model.
- (a) If the electron changes from the $n=4$ state to the $n=2$ state, what is the wavelength of the emitted photon?
 - (b) This photon is then incident upon a metal whose work function is 5 eV . What is the maximum kinetic energy of the electron emitted from the metal?

7. The mass of a proton is 1.0078250 amu. The mass of a neutron is 1.0086649 amu. The mass of a ${}^6_6\text{C}$ nucleus is 14.0032420 amu. The 1/2 life of ${}^6_6\text{C}$ is 5730 years.
- (a) Calculate the binding energy of the ${}^6_6\text{C}$ nucleus in units of MeV/nucleon.
- (b) Living organisms contain ${}^6_6\text{C}$ in the ratio $\frac{{}^6_6\text{C}}{{}^{12}_6\text{C}} = 1.3 \times 10^{-12}$. When the organism dies, the ${}^6_6\text{C}$ decays but the ${}^{12}_6\text{C}$ does not. An ancient wooden spoon is found to have $\frac{{}^6_6\text{C}}{{}^{12}_6\text{C}} = 2.2 \times 10^{-13}$. How old is the spoon?
- (c) The ${}^6_6\text{C}$ decays via beta-decay. Write the reaction formula for this decay.

8. Medical Imaging. Provide 2 or 3 sentence answers where appropriate.

(a) Xrays.

- i. Sketch and describe an Xray tube including reference to:
 - A. Where the electrons come from
 - B. How they become energetic
 - C. What physical process causes them to give up their kinetic energy as a photon (no points lost for misspelling).
- ii. Take the accelerating voltage of your X-ray tube to be 50,000 V. Assuming that the entire energy of the electron were converted to one photon, calculate the wavelength of that photon.

(b) NMR. The “rule of thumb” for an NMR device is that protons will achieve resonance at a frequency of 42.58 MHz when they are immersed in a magnetic field of 1.0 Tesla. If the patient is placed in a magnetic field that varies according to the formula:

$B(x) = 1.0 \text{ Tesla} + 0.05 \frac{\text{Tesla}}{\text{m}} x$, where is a cancerous lesion located if it response to NMR at a frequency of 44 MHz?

(c) PET scanning.

- i. Name a nucleus commonly used for PET scanning and write the equation for its decay.
- ii. The mass of a positron is the same as the mass of an electron, $m_e = 9.109 \times 10^{-31} \text{ kg} = 511 \frac{\text{keV}}{c^2}$. Calculate the energy of each of the two photons emitted by the annihilation.
- iii. Explain why PET images have higher resolution than SPECT.

NOTE: An extra page has been included following this one to provide additional room for your answers.

NOTE: DOUBLE-CHECK that you have answered all parts of this question!!

