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General Physics II, Midterm 2
PHYS10400, Class year 103-2
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## SN:

$\qquad$ , Name: $\qquad$

## ABSOLUTELY NO CHEATING!

## Problems (6 Problems, total 120 points)

1. Electric Force: (20\%) A proton is engaging a head-on collision directly with an atomic nucleus. Suppose the charge of the nucleus is $\mathbf{Z e}$, what is the distance of closest approach in this head-on collision? (10\%)
2. Bohr theory (30\%): Assume, for simplicity, the electron (charge $\boldsymbol{e}$ ) of hydrogen atom moves around the nucleus (with charge $\mathbf{Z e}$ ) in a circular orbit, (a) derive the orbital angular momentum of the electron according to classical model. (b) What is the total classical energy of this electron in the system? (c) What is the total energy in terms of charge and angular momentum? (d) However, experimentally, angular momentum was observed, "quantized" as $L=n \hbar$, where $\hbar=\frac{h}{2 \pi}=1.0545 \times 10^{-34} \mathrm{~J}$ s and $\boldsymbol{n}$ is a positive integer. What is the "quantized' energy obtained in (c)? When $n=1$, we said the electron is in its "ground state", that means the electron is closest to the nucleus possible. The radius of the electron can be expressed as $r=\frac{a_{0}}{Z} n^{2}$, where $\mathrm{a}_{0}$ is called $\underline{\text { Bohr radius. (e) }}$ What is the Bohr radius of the hydrogen electron? Note 1: $\boldsymbol{m}_{e}=$ the electron mass $=$ $9.1 \times 10^{-31} \mathrm{Kg} ; @_{0}=$ vacuum permitivity $=8.85 \times 10^{-12} \boldsymbol{N}^{-1} \boldsymbol{m}^{-2} \boldsymbol{C}^{2} ; \boldsymbol{e}=$ the charge of the electron $=1.6 \times 10^{-19} \boldsymbol{C}$. Note 2: However, it should be emphasized that the value of $r$ obtained in (d) must not be taken too literally. According to quantum mechanics it should be considered only as an indication of the order of magnitude of the region in which the electron is most likely to be found.
3. Current and Current density: As shown in the following figure, a metal rod of radius $\boldsymbol{r}_{\boldsymbol{1}}$ is concentric with a metal cylindrical shell of radius $\boldsymbol{r}_{\mathbf{2}}$ and length $\boldsymbol{L}$. The space between rod and cylinder is tightly packed with a high-resistance material of resistivity $\rho$. A battery having a terminal voltage $\boldsymbol{v}_{\boldsymbol{t}}$ is connected as shown. Neglecting resistance of rod and cylinder, derive expressions for (a) the total current $\boldsymbol{I}$, (b) the current density $\boldsymbol{J}$, the electric field $\boldsymbol{E}$ at any point between rod and cylinder, and (c) the resistance $\boldsymbol{R}$ between rod and cylinder. (20\%)

4. Electric Field: (20\%) A circular disk carries a surface charge $\sigma\left(\mathrm{C} / \mathrm{m}^{2}\right)$. Show that the electric field at any point on the axis of the disk depends only on $\sigma$ and the angle subtended there by the disk (20\%). Note in this problem, you should assume all the parameters you need to use.
5. Mass Spectrometer: (20\%) In the figure shown on the right, an essential mass spectrometer which can be used to measure the mass of an ion. An ion of mass $\boldsymbol{m}$ (to be measured) and charge $\boldsymbol{q}$ is produced in source $\boldsymbol{S}$. The initially stationary ion is accelerated by the electric field due to a potential difference $\boldsymbol{V}$. The ion leaves $\boldsymbol{S}$ and enter a separator chamber in which a uniform magnetic field $\boldsymbol{B}$ is perpendicular to the path of the ion. The magnetic field causes the ion to move in a semicircle, striking (and thus altering) a detector at a distance $\boldsymbol{x}$ from the entry slit. Suppose that in a
 certain trial $\boldsymbol{B}=80 \boldsymbol{m} \boldsymbol{T}$ and $\boldsymbol{V}=1000 \boldsymbol{V}$, and ion charge $=+1.6022 \times 10^{-19} \boldsymbol{C}$ strike the plate at $\boldsymbol{x}=1.6254 \boldsymbol{m}$. (a) what is the mass $\boldsymbol{m}$ of the individual ions? (10\%) (b) Why this instrument can only measure the charged particles? (10\%)
6. Magnetic field of a current carrying wire: (20\%) Suppose in a circular loop, a current I runs in a counter-clockwise direction. What is the magnetic field (direction and magnitude) measured at a vertical distance $\boldsymbol{x}$ from the center?
