Name $\qquad$
Physics 111 Quiz \#3, January 25, 2019
Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

A capacitor is constructed out of two circular metal plates each with radius 20 cm separated by 3 mm . This capacitor is connected to a $10 \mathrm{k} \Omega$ resistor and a 1000 V battery. The system is allowed to fully charge.

1. What is the capacitance of the system and how much charge has been stored on a plate?

$$
\begin{aligned}
& C=\frac{\kappa \varepsilon_{0} A}{d}=\frac{1 \times 8.85 \times 10^{-12} \frac{C^{2}}{N m^{2}} \times \pi(0.2 \mathrm{~m})^{2}}{3 \times 10^{-3} \mathrm{~m}}=3.7 \times 10^{-10} \mathrm{~F} \\
& Q=C V=3.7 \times 10^{-10} \mathrm{~F} \times 1000 \mathrm{~V}=3.7 \times 10^{-7} \mathrm{C}
\end{aligned}
$$

2. How much energy is stored in the system when the capacitor is fully charged and what time constant characterizes the system?

$$
\begin{aligned}
& W=\frac{1}{2} Q V=\frac{Q^{2}}{2 C}=\frac{1}{2} C V^{2}=\frac{1}{2} \times 3.7 \times 10^{-10} F \times(1000 \mathrm{~V})^{2}=1.85 \times 10^{-4} J \\
& \tau=R C=3.7 \times 10^{-10} F \times 10000 \Omega=3.7 \times 10^{-6} s=3.7 \mu s
\end{aligned}
$$

3. When the battery is connected to the resistor and initially uncharged capacitor, current begins to flow in the circuit. As the capacitor charges which of the following is true?
a. The voltage across the capacitor and resistor both increase.
b. The voltage across the capacitor and resistor both decrease.
c. The voltage across the resistor increases while the voltage across the capacitor decreases.
d. The voltage across the capacitor increases while the voltage across the resistor decreases.
e. The voltage across the resistor and capacitor both change, but the exact relationship cannot be determined from the information given.
4. Suppose that you wanted to use this capacitor to accelerate singly ionized carbon ions from rest for an experiment. To conduct this experiment, you drill a small hole in one of the capacitor plates and accelerate the singly ionized carbon ions from rest starting at the plate without the hole towards the plate with the hole. With what speed will the singly charged carbon ions leave this particle accelerator? Hints: Singly ionized means you have removed one electron from the atom and ${ }_{6}^{12} \mathrm{C}$ has a mass of $1.992 \times 10^{-26} \mathrm{~kg}$ and assume that the capacitor is fully charged.

$$
\begin{aligned}
& W=-q \Delta V=\Delta K=\frac{1}{2} m v_{f}^{2}-\frac{1}{2} m v_{i}^{2}=\frac{1}{2} m v_{f}^{2} \\
& \rightarrow v_{f}=\sqrt{\frac{-2 q \Delta V}{m}}=\sqrt{\frac{-2 \times 1.6 \times 10^{-19} \mathrm{C} \times(-1000 \mathrm{~V})}{1.992 \times 10^{-26} \mathrm{~kg}}}=1.3 \times 10^{5} \frac{\mathrm{~m}}{\mathrm{~s}}
\end{aligned}
$$

5. Suppose that you direct this singly ionized carbon atom at a platinum $\left({ }_{78}^{195} \mathrm{Pt}\right)$ nucleus. What is the distance of closest approach that the singly ionized carbon atom gets from the platinum nucleus? Assume that the carbon ion is initially very far from the platinum atom.

$$
\begin{aligned}
& W=-q \Delta V=\Delta K=\frac{1}{2} m v_{f}^{2}-\frac{1}{2} m v_{i}^{2}=-\frac{1}{2} m v_{i}^{2}=-K_{i} \\
& \rightarrow-q \Delta V=-q\left[\frac{k Q_{P t}}{r_{f}}-\frac{k Q_{P t}}{r_{i}}\right]=-\frac{1}{2} m v_{i}^{2} \\
& \therefore r_{f}=\frac{2 k q Q_{P_{t}}}{m v_{i}^{2}}=\frac{2 k Z e^{2}}{m v_{i}^{2}}=\frac{2 \times 9 \times 10^{9} \frac{\mathrm{C}^{2}}{N m^{2}} \times 78 \times\left(1.6 \times 10^{-19} \mathrm{C}\right)^{2}}{1.992 \times 10^{-26} \mathrm{~kg}\left(1.3 \times 10^{5} \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2}}=1.1 \times 10^{-10} \mathrm{~m}
\end{aligned}
$$

## Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$
\begin{aligned}
& \vec{F}=k \frac{Q_{1} Q_{2}}{r^{2}} \hat{r} \\
& \vec{E}=\frac{\vec{F}}{q} \\
& \vec{E}_{Q}=k \frac{Q}{r^{2}} \hat{r} \\
& P E=k \frac{Q_{1} Q_{2}}{r} \\
& V(r)=k \frac{Q}{r} \\
& E_{x}=-\frac{\Delta V}{\Delta x} \\
& W=-q \Delta V_{f, i}
\end{aligned}
$$

Magnetic Forces and Fields

$$
\begin{aligned}
& F=q \nu B \sin \theta \\
& F=I l B \sin \theta \\
& \tau=N I A B \sin \theta=\mu B \sin \theta \\
& P E=-\mu B \cos \theta \\
& B=\frac{\mu_{0} I}{2 \pi r} \\
& \varepsilon_{\text {induced }}=-N \frac{\Delta \phi_{B}}{\Delta t}=-N \frac{\Delta(B A \cos \theta)}{\Delta t}
\end{aligned}
$$

## Constants

$g=9.8 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}$
$1 e=1.6 \times 10^{-19} \mathrm{C}$
$k=\frac{1}{4 \pi \varepsilon_{o}}=9 \times 10^{9} \frac{\mathrm{Nm} m^{2}}{\mathrm{C}^{2}}$
$\varepsilon_{o}=8.85 \times 10^{-12} \frac{\mathrm{C}^{2}}{\mathrm{Nm}{ }^{2}}$
$1 \mathrm{eV}=1.6 \times 10^{-19} \mathrm{~J}$
$\mu_{o}=4 \pi \times 10^{-7} \frac{\mathrm{Tm}}{\mathrm{A}}$
$c=3 \times 10^{8} \frac{\mathrm{~m}}{\mathrm{~s}}$
$h=6.63 \times 10^{-34} \mathrm{~J} s$
$m_{e}=9.11 \times 10^{-31} \mathrm{~kg}=\frac{0.511 \mathrm{MeV}}{c^{2}}$
$m_{p}=1.67 \times 10^{-27} \mathrm{~kg}=\frac{937.1 \mathrm{MeV}}{c^{2}}$
$m_{n}=1.69 \times 10^{-27} \mathrm{~kg}=\frac{948.3 \mathrm{MeV}}{c^{2}}$
$1 \mathrm{amu}=1.66 \times 10^{-27} \mathrm{~kg}=\frac{931.5 \mathrm{MeV}}{\mathrm{c}^{2}}$
$N_{A}=6.02 \times 10^{23}$
$A x^{2}+B x+C=0 \rightarrow x=\frac{-B \pm \sqrt{B^{2}-4 A C}}{2 A}$

Electric Circuits

$$
\begin{aligned}
& I=\frac{\Delta Q}{\Delta t} \\
& V=I R=I\left(\frac{\rho L}{A}\right) \\
& R_{\text {series }}=\sum_{i=1}^{N} R_{i} \\
& \frac{1}{R_{\text {parallel }}}=\sum_{i=1}^{N} \frac{1}{R_{i}} \\
& P=I V=I^{2} R=\frac{V^{2}}{R} \\
& Q=C V=\left(\frac{\kappa \varepsilon_{0} A}{d}\right) V=\left(\kappa C_{0}\right) V \\
& P E=\frac{1}{2} Q V=\frac{1}{2} C V^{2}=\frac{Q^{2}}{2 C} \\
& Q_{\text {charge }}(t)=Q_{\max }\left(1-e^{-\frac{t}{R C}}\right) \\
& Q_{\text {discharge }}(t)=Q_{\max } e^{-\frac{t}{R C}} \\
& C_{\text {parallel }}=\sum_{i=1}^{N} C_{i} \\
& \frac{1}{C_{\text {series }}}=\sum_{i=1}^{N} \frac{1}{C_{i}}
\end{aligned}
$$

Light as a Particle \& Relativity

$$
\begin{aligned}
& E=h f=\frac{h c}{\lambda}=p c \\
& K E_{\max }=h f-\phi=e V_{\text {stop }} \\
& \Delta \lambda=\frac{h}{m_{e} c}(1-\cos \phi) \\
& \gamma=\frac{1}{\sqrt{1-\frac{v^{2}}{c^{2}}}} \\
& p=\gamma m v \\
& E_{\text {total }}=K E+E_{r e s t}=\gamma m c^{2} \\
& E_{\text {total }}^{2}=p^{2} c^{2}+m^{2} c^{4} \\
& E_{\text {rest }}=m c^{2}
\end{aligned}
$$

$$
K E=(\gamma-1) m c^{2}
$$

## Geometry

Circles: $C=2 \pi r=\pi D \quad A=\pi r^{2}$
Triangles: $A=\frac{1}{2} b h$
Spheres: $A=4 \pi r^{2} \quad V=\frac{4}{3} \pi r^{3}$

Light as a Wave

$$
\begin{aligned}
& c=f \lambda=\frac{1}{\sqrt{\varepsilon_{o} \mu_{o}}} \\
& S(t)=\frac{\text { energy }}{\text { time } \times \text { area }}=c \varepsilon_{o} E^{2}(t)=c \frac{B^{2}(t)}{\mu_{0}} \\
& I=S_{\text {avg }}=\frac{1}{2} c \varepsilon_{o} E_{\max }^{2}=c \frac{B_{\max }^{2}}{2 \mu_{0}} \\
& P=\frac{S}{c}=\frac{\text { Force }}{\text { Area }} \\
& S=S_{o} \cos ^{2} \theta \\
& v=\frac{1}{\sqrt{\varepsilon \mu}}=\frac{c}{n} \\
& \theta_{\text {inc }}=\theta_{\text {ref }} \\
& n_{1} \sin \theta_{1}=n_{2} \sin \theta_{2} \\
& \frac{1}{f}=\frac{1}{d_{o}}+\frac{1}{d_{i}} \\
& M=\frac{h_{i}}{h_{o}}=-\frac{d_{i}}{d_{o}} \\
& M_{\text {total }}=\prod_{i=1}^{N} M_{i} \\
& S_{\text {out }}=S_{\text {in }} e e^{-\sum_{i} x_{i}} \\
& H U=\frac{\mu_{w}-\mu_{m}}{\mu_{w}}
\end{aligned}
$$

Nuclear Physics

$$
\begin{aligned}
& E_{\text {binding }}=\left(Z m_{p}+N m_{n}-m_{r ब t}\right) c^{2} \\
& \frac{\Delta N}{\Delta t}=-\lambda N_{o} \rightarrow N(t)=N_{o} e^{-\lambda t} \\
& A(t)=A_{o} e^{-\lambda t} \\
& m(t)=m_{o} e^{-\lambda t} \\
& t_{\frac{1}{2}}=\frac{\ln 2}{\lambda}
\end{aligned}
$$

Misc. Physics 110 Formulae
$\vec{F}=\frac{\Delta \vec{p}}{\Delta t}=\frac{\Delta(m v)}{\Delta t}=m \vec{a}$
$\vec{F}=-k \vec{y}$
$\vec{F}_{C}=m \frac{v^{2}}{R} \hat{r}$
$W=\Delta K E=\frac{1}{2} m\left(v_{f}^{2}-v_{i}^{2}\right)=-\Delta P E$
$P E_{\text {gravity }}=m g y$
$P E_{\text {spring }}=\frac{1}{2} k y^{2}$
$|\vec{A}|=\sqrt{A_{x}^{2}+A_{y}^{2}}$
$\phi=\tan ^{-1}\left(\frac{A_{y}}{A_{x}}\right)$
$\vec{v}_{f}=\vec{v}_{i}+\vec{a} t$
$v_{f}^{2}=v_{i}^{2}+2 a \Delta x$
$\vec{x}_{f}=\vec{x}_{i}+\vec{v}_{i} t+\frac{1}{2} \vec{a} t^{2}$

