Name $\qquad$
Physics 111 Quiz \#2, January 22, 2021
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.

1. Suppose you have the two-point charges shown below, $q_{1}=q_{2}=+30 n C$. Point-charge $q_{1}$ is located at $(x, y)=(-a, y)$, while point-charge $q_{2}$ is located at $(x, y)=(a, y)$, where $a=10 \mathrm{~cm}$ and $y=50 \mathrm{~cm}$. What is the magnitude of the electric field at the origin $(0,0)$ ? Hint: do not assume that $y \gg a$.

$$
\begin{aligned}
& E_{n e t, x}=E_{1} \cos \theta-E_{2} \cos \theta=E_{1} \cos \theta-E_{1} \cos \theta=0 \\
& E_{\text {net }, y}=-E_{1} \sin \theta-E_{2} \sin \theta=-2 E_{1} \sin \theta \\
& \quad E_{n e t, y}=-2 \times \frac{k q}{\left(a^{2}+y^{2}\right)} \times \frac{y}{\sqrt{a^{2}+y^{2}}}=\frac{2 k q y}{\left(a^{2}+y^{2}\right)^{\frac{3}{2}}} \\
& \quad E_{n e t, y}=-\frac{2 \times 9 \times 10^{9} \frac{\mathrm{Nm}^{2}}{C^{2}} \times 30 \times 10^{-9} C \times 0.5 m}{\left((0.1 m)^{2}+(0.5 m)^{2}\right)^{\frac{3}{2}}}=2037 \frac{N}{C} \\
& E_{\text {net }}=\sqrt{E_{n e t, x}^{2}+E_{n e t, y}^{2}}=\sqrt{\left(0 \frac{N}{C}\right)^{2}+\left(2073 \frac{N}{C}\right)^{2}}=2073 \frac{N}{C}
\end{aligned}
$$


2. What is the direction of the electric field at the origin due to these two point-charges? To earn full credit, justify your answer with a calculation for a sentence or two.

From the vector diagram, since the horizontal components vanish, there is only a vertical component to the electric field and this component points vertically down. Thus, the direction of the net electric field vector is in the negative $y$-direction. We can also see this from:

$$
\phi=\tan ^{-1}\left(\frac{E_{\text {net }, y}}{E_{\text {net }, x}}\right)=\tan ^{-1}\left(\frac{-2037 \frac{N}{C}}{0}\right)=-90^{\circ}
$$

3. Suppose that a third point-charge $q_{3}=-3 n C$ is placed at the origin. What net electric force would $q_{3}$ feel?

The magnitude of the electric forces is: $F=q_{3} E_{\text {net }}=3 \times 10^{-9} \mathrm{C} \times 2037 \frac{\mathrm{~N}}{\mathrm{C}}=6.11 \times 10^{-6} \mathrm{~N}$
The direction is vertically up, opposite to the direction of the electric field, since $q_{3}$ is negative.
4. A set of parallel metal plates are shown below. In the middle of the upper plate there is a small hole drilled. The plates are separated by a distance $d=10 \mathrm{~cm}$ and a uniform electric field with magnitude $E=50,000 \frac{N}{C}$ exists between the plates due to the equal and opposite charges on the plates. A proton if fired vertically down through the hole in the upper plate. What speed would the proton need to have at the upper plate, as it passes through the hole in order, to just come to rest at the lower plate?


$$
\begin{aligned}
& v_{f y}^{2}=v_{i y}^{2}+2 a_{y} \Delta y \rightarrow 0=v_{i y}^{2}+2 \frac{F}{m}(-d-0)=v_{i y}^{2}-2\left(\frac{e E}{m}\right) d \\
& \rightarrow v_{i y}=\sqrt{\frac{2 e E d}{m}}=\sqrt{\frac{2 \times 1.6 \times 10^{-19} \mathrm{C} \times 50000 \frac{\mathrm{~N}}{\mathrm{C}} \times 0.1 \mathrm{~m}}{1.67 \times 10^{-27} \mathrm{~kg}}}=9.8 \times 10^{5} \frac{\mathrm{~m}}{\mathrm{~s}}
\end{aligned}
$$

5. Which of the following gives the charge on the lower plate and the direction of the electric field between the plates?
a. The charge on the lower plate is $+Q$ and the electric field points from the lower to the upper plate.
b. The charge on the lower plate is $+Q$ and the electric field points from the upper to the lower plate.
c. The charge on the lower plate is $-Q$ and the electric field points from the lower to the upper plate.
d. The charge on the lower plate is $-Q$ and the electric field points from the upper to the lower plate.
e. None of the above choices are correct.

## 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

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

## Constants

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

Electric Circuits

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

Light as a Particle \& Relativity

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

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

$$
\begin{aligned}
& c=f=\frac{1}{\sqrt{o o}} \\
& S(t)=\frac{\text { energy }}{\text { time area }}=c_{o} E^{2}(t)=c \frac{B^{2}(t)}{0} \\
& I=S_{\text {avg }}=\frac{1}{2} c{ }_{o} E_{\max }^{2}=c \frac{B_{\max }^{2}}{2} \\
& P=\frac{S}{c}=\frac{\text { Force }}{\text { Area }} \\
& S=S_{o} \cos ^{2} \\
& v=\frac{1}{\sqrt{v}}=\frac{c}{n} \\
& \text { inc }={ }_{\text {ref }} \\
& n_{1} \sin { }_{1}=n_{2} \sin { }_{2} \\
& \frac{1}{f}=\frac{1}{d_{o}}+\frac{1}{d_{i}} \\
& M=\frac{h_{i}}{h_{o}}=\frac{d_{i}}{d_{o}} \\
& M_{\text {total }}={ }_{i=1}^{N} M_{i} \\
& S_{\text {out }}=S_{i n} e \\
& H U=\frac{w}{w}
\end{aligned}
$$

Nuclear Physics

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

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

