Name $\qquad$
Physics 111 Quiz \#6, November 3, 2017
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. An unstable particle is at rest and suddenly decays into two fragments. No external forces act as the particle breaks apart. One of the fragments is a proton ( $m_{p}=1.007 u$ ) wtih a speed of $0.72 c$. The second particle's mass is unknown, but it is found to have a speed of $0.26 c$. What is the mass of the unknown fragment in atomic mass units? (Keep three decimal places in your numbers and final answer.)

$$
\begin{aligned}
& F_{e x t}=\frac{\Delta p_{\text {system }}}{\Delta t}=0 \rightarrow \Delta p_{\text {system }}=p_{f, \text { system }}-p_{i, \text { system }}=0 \rightarrow p_{i, \text { system }}=p_{f, \text { system }} \\
& 0=-p_{p}+p_{u n k} \rightarrow p_{u n k}=p_{p} \\
& \gamma_{p} m_{p} v_{p}=\gamma_{u n k} m_{u n k} v_{u n k} \\
& m_{u n k}=\left(\frac{\gamma_{p} v_{p}}{\gamma_{u n k} v_{u n k}}\right) m_{p}=\left(\frac{\sqrt{1-\frac{v_{v a k}^{2}}{c^{2}}} v_{p}}{\sqrt{1-\frac{v_{p}^{2}}{c^{2}}} v_{u n k}}\right) m_{p}=\left(\frac{\sqrt{1-(0.26)^{2}} 0.72 c}{\sqrt{1-(0.72)^{2}} 0.26 c}\right) 1.007 u=3.880 u
\end{aligned}
$$

2. What was the rest mass (in atomic mass units) of the unstable particle? (Keep three decimal places in your numbers and final answer.)

$$
\begin{aligned}
& E_{\text {parent }}=K_{p}+E_{p}+K_{u n k}+E_{\text {unk }}=\left(\gamma_{p}-1\right) m_{p} c^{2}+m_{p} c^{2}+\left(\gamma_{u n k}-1\right) m_{u n k} c^{2}+m_{u n k} c^{2} \\
& E_{\text {parent }}=\gamma_{\text {parent }} m_{\text {parent }} c^{2}=m_{\text {parent }} c^{2}=\gamma_{p} m_{p} c^{2}+\gamma_{u n k} m_{u n k} c^{2} \\
& m_{p a r e n t}=\gamma_{p} m_{p}+\gamma_{u n k} m_{u n k}=\left(\frac{1}{\sqrt{1-(0.72)^{2}}}\right) 1.0077 u+\left(\frac{1}{\sqrt{1-(0.26)^{2}}}\right) 3.880 u=5.471 u
\end{aligned}
$$

3. A photoelectric effect experiment was conducted on an unknown metal surface. Different colors of light were shone on the metal surface and the stopping potentials for the ejected electrons were measured. The data are plotted below. Using the table and the graph below, what is the unknown metal surface on which the photons were incident?

| Element | $\phi(\mathrm{eV})$ |
| :---: | :---: |
| Na | 2.28 |
| K | 2.30 |
| Cs | 2.10 |
| Mg | 3.68 |
| Al | 4.08 |
| Cu | 4.70 |


$K=e V_{\text {stop }}=h f-\phi \rightarrow V_{\text {stop }}=\frac{h}{e} f-\frac{\phi}{e}$
$\rightarrow-2.30 \mathrm{~V}=-\frac{\phi}{e} \rightarrow \phi=2.30 \mathrm{eV}$
and this is potassium, $K$.
4. What is the minimum frequency of the light that could be used to eject photoelectrons?

$$
\begin{aligned}
& K=0=e V_{\text {stop }}=h f_{\min }-\phi \rightarrow 0=h f_{\min }-\phi \\
& \rightarrow f_{\min }=\frac{\phi}{h}=\frac{2.3 \mathrm{eV} \times \frac{1.6 \times 10^{-19} \mathrm{~J}}{1 . V}}{6.63 \times 10^{-34} \mathrm{Js}}=5.55 \times 10^{14} \mathrm{~s}^{-1}
\end{aligned}
$$

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

## Constants

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

## Electric Circuits

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

Light as a Particle \& Relativity

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

## Geometry

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

Light as a Wave

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

Nuclear Physics

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

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

