Name________________________________________

Physics 111 Quiz #2, September 21, 2018

*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.*

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A capacitor is made out of two metal plates with their faces parallel to each other. The plates are made out of copper and are circular (each with a diameter of $20cm$) and are separated by a $1.0cm$ thick piece of rubber ($\kappa = 2.8$).

a. What is the capacitance of the system and how much charge flows onto a plate if the capacitor is connected to a $100V$ battery?

$$C = \frac{\kappa \varepsilon_0 A}{d} = \frac{2.8 \times 8.85 \times 10^{-12} \frac{C^2}{Nm^2} \times \pi (0.1m)^2}{0.01m} = 7.8 \times 10^{-11} F$$

$$Q = CV = 7.8 \times 10^{-11} F \times 100V = 7.8 \times 10^{-9} C = 7.8nC$$

b. If the capacitor were charged using a $1000\Omega$ resistor and the $100V$ battery, what would be the magnitude and direction of the electric field between the capacitor plates when fully charged?

$\left|\vec{E}\right| \left| - \frac{\Delta V}{\Delta x} \right| = \frac{100V}{0.01m} = 10000 \frac{V}{m}$ and the field points from the positive plate towards the negative plate.

c. Suppose that you remove the rubber from between the capacitor plates (while the battery is still connected) and then you drill a small hole in the rightmost plate. The rightmost plate is connected to the negative terminal of the battery while the leftmost plate is connected to the positive terminal of the battery. A carbon ion (${}^{12}_{6}C^{+}$) is released from rest near the positively charged plate opposite the hole. What is the speed of the carbon ion when it passes through the hole?

$$W = -q\Delta V = -(e)\left[0V - 100V\right] = 100eV \times \frac{1.6 \times 10^{-17} J}{1eV} = 1.6 \times 10^{-19} J$$

$$W = \Delta K = \tfrac{1}{2} m v_f^2 - \tfrac{1}{2} m v_i^2 = \tfrac{1}{2} m v_f^2$$

$$\rightarrow v_f = \sqrt{\frac{2W}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} J}{6 \times (1.67 + 1.69) \times 10^{-27} kg}} = 4 \times 10^4 \frac{m}{s}$$

d. From the time the carbon ion was released from rest until it passes through the hole, which of the following is true?

1. The $\Delta EPE \uparrow$ and the $\Delta K \downarrow$.
2. The $\Delta EPE \uparrow$ and the $\Delta K \uparrow$.
3. The $\Delta EPE = 0$ and the $\Delta K = 0$.
4. The $\Delta EPE \downarrow$ and the $\Delta K \downarrow$.
5. The $\Delta EPE \downarrow$ and the $\Delta K \uparrow$.

e. Suppose that you wanted the carbon ion to just touch a platinum nucleus. If the carbon ion were initially very far away from the platinum nucleus, through what potential difference (different than in part c) would you need to accelerate the carbon ion? Hints: Assume that the nuclear radii of carbon and platinum are $r_C = 2.7\times10^{-15}\,m$ and $r_{Pt} = 5.4\times10^{-15}\,m$ respectively and that the spectroscopic information of platinum is ${}^{195}_{78}Pt$.

$$W = -q\Delta V_{acc} = -q\left[\frac{kQ_{Pt}}{r_{Pt}+r_C} - \frac{kQ_{Pt}}{r_i}\right]$$

$$\rightarrow \Delta V_{acc} = \frac{kQ_{Pt}}{r_{Pt}+r_C} = \frac{9\times10^{9}\,\frac{Nm^2}{C^2}\times78\times1.6\times10^{-19}\,C}{(2.7+5.4)\times10^{-15}\,m} = 1.4\times10^{7}\,V = 14\,MV$$

# Physics 111 Equation Sheet

## Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$
$$\vec{E} = \frac{\vec{F}}{q}$$
$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$
$$PE = k\frac{Q_1Q_2}{r}$$
$$V(r) = k\frac{Q}{r}$$
$$E_x = -\frac{\Delta V}{\Delta x}$$
$$W = -q\Delta V_{f,i}$$

## Magnetic Forces and Fields

$$F = qvB\sin\theta$$
$$F = IlB\sin\theta$$
$$\tau = NIAB\sin\theta = \mu B\sin\theta$$
$$PE = -\mu B\cos\theta$$
$$B = \frac{\mu_0 I}{2\pi r}$$
$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

## Constants

$$g = 9.8\tfrac{m}{s^2}$$
$$1e = 1.6\times10^{-19}C$$
$$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\tfrac{Nm^2}{C^2}$$
$$\varepsilon_o = 8.85\times10^{-12}\tfrac{C^2}{Nm^2}$$
$$1eV = 1.6\times10^{-19}J$$
$$\mu_o = 4\pi\times10^{-7}\tfrac{Tm}{A}$$
$$c = 3\times10^8\tfrac{m}{s}$$
$$h = 6.63\times10^{-34}Js$$
$$m_e = 9.11\times10^{-31}kg = \frac{0.511MeV}{c^2}$$
$$m_p = 1.67\times10^{-27}kg = \frac{937.1MeV}{c^2}$$
$$m_n = 1.69\times10^{-27}kg = \frac{948.3MeV}{c^2}$$
$$1amu = 1.66\times10^{-27}kg = \frac{931.5MeV}{c^2}$$
$$N_A = 6.02\times10^{23}$$
$$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$$

## Electric Circuits

$$I = \frac{\Delta Q}{\Delta t}$$
$$V = IR = I\left(\frac{\rho L}{A}\right)$$
$$R_{series} = \sum_{i=1}^{N} R_i$$
$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$
$$P = IV = I^2R = \frac{V^2}{R}$$
$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$
$$PE = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$
$$Q_{\text{charge}}(t) = Q_{\max}\left(1 - e^{-\frac{t}{RC}}\right)$$
$$Q_{\text{discharge}}(t) = Q_{\max}e^{-\frac{t}{RC}}$$
$$C_{parallel} = \sum_{i=1}^{N} C_i$$
$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

## Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$
$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$
$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$
$$P = \frac{S}{c} = \frac{Force}{Area}$$
$$S = S_o\cos^2\theta$$
$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$
$$\theta_{inc} = \theta_{refl}$$
$$n_1\sin\theta_1 = n_2\sin\theta_2$$
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$M_{total} = \prod_{i=1}^{N} M_i$$
$$S_{out} = S_{in}e^{-\sum_i \mu_i x_i}$$
$$HU = \frac{\mu_w - \mu_m}{\mu_w}$$

## Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$
$$KE_{\max} = hf - \phi = eV_{stop}$$
$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$
$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$
$$p = \gamma mv$$
$$E_{total} = KE + E_{rest} = \gamma mc^2$$
$$E_{total}^2 = p^2c^2 + m^2c^4$$
$$E_{rest} = mc^2$$
$$KE = (\gamma - 1)mc^2$$

## Nuclear Physics

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$
$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$
$$A(t) = A_o e^{-\lambda t}$$
$$m(t) = m_o e^{-\lambda t}$$
$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

## Misc. Physics 110 Formulae

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$
$$\vec{F} = -k\vec{y}$$
$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$
$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$
$$PE_{gravity} = mgy$$
$$PE_{spring} = \tfrac{1}{2}ky^2$$
$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$
$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$
$$\vec{v}_f = \vec{v}_i + \vec{a}t$$
$$v_f^2 = v_i^2 + 2a\Delta x$$
$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$

## Geometry

$Circles:\ C = 2\pi r = \pi D \qquad A = \pi r^2$

$Triangles:\ A = \tfrac{1}{2}bh$

$Spheres:\ A = 4\pi r^2 \qquad V = \tfrac{4}{3}\pi r^3$