Name________________________________________

Physics 111 Quiz #2, January 20, 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.*

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A capacitor is constructed out of two circular plates of diameter $D = 15.2cm$ and separated by $d = 4mm$. The space between the two plates is filled with rubber ($\kappa = 6.7$).

1. The capacitor is connected to a $10000V$ battery. How much charge is stored on the plates when the capacitor is fully charged?

$$C = \frac{\kappa\varepsilon_0 A}{d} = \frac{6.7\times 8.85\times 10^{-12}\,\frac{C^2}{Nm^2}\times\pi\times(0.076m)^2}{4\times 10^{-3}m} = 2.7\times 10^{-10}F$$

$$Q = CV = 2.7\times 10^{-10}F\times 10000V = 2.7\times 10^{-6}C = 2.7\mu C$$

2. How much energy is stored in the capacitor when fully charged?

$$W = \tfrac{1}{2}CV^2 = \tfrac{1}{2}\times 2.7\times 10^{-10}F\times(10000V)^2 = 0.0135J = 13.5mJ$$

$$W = \tfrac{1}{2}QV = \tfrac{1}{2}\times 2.7\times 10^{-6}C\times 10000V = 0.0135J = 13.5mJ$$

$$W = \frac{Q^2}{2C} = \frac{(2.7\times 10^{-6}C)^2}{2\times 2.7\times 10^{-10}F} = 0.0135J = 13.5mJ$$

3. Suppose that the fully charged capacitor is disconnected from the battery and then connected in series with a resistor of unknown resistance. If you wanted to be able to dissipate $98\%$ of the stored energy in a time $t = 0.5s$, what is the value of the resistance you would need?

$$E(t) = \frac{1}{2C}\left[Q_{\max} e^{-\frac{t}{RC}}\right]^2 = \frac{Q_{\max}^2}{2C} e^{-\frac{2t}{RC}} = E_{\max} e^{-\frac{2t}{RC}}$$

$$R = -\frac{2t}{\ln\left(\frac{E(t)}{}\right)C} = -\frac{2 \times 0.5s}{\ln\left(\frac{0.02E_{\max}}{E_{\max}}\right) \times 2.7 \times 10^{-10} F} = 9.5 \times 10^{6}\,\Omega = 950 M\Omega$$

4. Suppose that you reconnect your capacitor to the $10000V$ battery and allow the capacitor to fully charge. When the capacitor is fully charged you grab one of the plates of the capacitor and pull that plate away from the other plate so that the distance between the plates increases. In this case, which of the following quantities, if any, change? There may be more than one answer. Circle all that apply.
   a. The charge on the plates.
   b. The potential difference across the plates.
   c. The electric field between the plates.
   d. The capacitance of the capacitor.
   e. The energy stored in the capacitor.
   f. None of the above quantities change.

# Physics 111 Equation Sheet

## Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1 Q_2}{r^2}\hat{r}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$

$$PE = k\frac{Q_1 Q_2}{r}$$

$$V(r) = k\frac{Q}{r}$$

$$E_x = -\frac{\Delta V}{\Delta x}$$

$$W = -q\Delta V_{f,i}$$

## 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

$$I = \frac{\Delta Q}{\Delta t}$$

$$V = IR = I\left(\frac{\rho L}{A}\right)$$

$$R_{series} = \sum_{i=1}^{N} R_i$$

$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$

$$W = U = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$

$$Q_{\text{charge}}(t) = Q_{\max}\left(1 - e^{-\frac{t}{RC}}\right)$$

$$Q_{\text{discharge}}(t) = Q_{\max}e^{-\frac{t}{RC}}$$

$$C_{parallel} = \sum_{i=1}^{N} C_i$$

$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

## 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

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$

$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$

$$A(t) = A_o e^{-\lambda t}$$

$$m(t) = m_o e^{-\lambda t}$$

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

## Geometry

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

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

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

## Misc. Physics 110 Formulae

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$

$$\vec{F} = -k\vec{y}$$

$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$

$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$

$$PE_{gravity} = mgy$$

$$PE_{spring} = \tfrac{1}{2}ky^2$$

$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$

$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$