

Name \_\_\_\_\_

Physics 111 Quiz #2, September 26, 2014

*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 and a  $28.1M\Omega$  resistor are wired in series with a  $67V$  battery and a switch. Initially the capacitor is uncharged and when the switch is closed the capacitor begins to charge. The time constant for this circuit is  $1ms$ .

- a. What is the value of the capacitance of the circuit?

$$\tau = RC \rightarrow C = \frac{\tau}{R} = \frac{1 \times 10^{-3} s}{28.1 \times 10^6 \Omega} = 3.6 \times 10^{-11} F$$

- b. How much energy will be stored in the capacitor when it is fully charged?

The energy stored is given by  $E = \frac{1}{2}qV$ ,  $E = \frac{1}{2}CV^2$ , or  $E = \frac{q^2}{2C}$ . Using  $E = \frac{1}{2}CV^2$  we have

$$E = \frac{1}{2}CV^2 = \frac{1}{2} \times 3.6 \times 10^{-11} F \times (67V)^2 = 8 \times 10^{-8} J.$$

- c. If the battery were removed from the circuit and the fully charged capacitor were connected just to the resistor, what initial current would flow in the circuit?

The current is given by Ohm's law:  $V = IR \rightarrow I = \frac{V_C}{R} = \frac{67V}{28.1 \times 10^6 \Omega} = 2.4 \times 10^{-6} A$

d. While the capacitor is discharging through the resistor,

1.  $V_C \uparrow$  and  $V_R \uparrow$ .
2.  $V_C \downarrow$  and  $V_R \uparrow$ .
3.  $V_C \uparrow$  and  $V_R \downarrow$ .
4.  $V_C \downarrow$  and  $V_R \downarrow$ .

e. If the capacitor were constructed from two square metal plates with sides of length  $10\text{cm}$  and separated by a  $3\text{cm}$  thick piece of insulator, what the most likely material used as the dielectric?

$$C = \frac{\kappa \epsilon_0 A}{d} \rightarrow \kappa = \frac{Cd}{\epsilon_0 A} = \frac{3.6 \times 10^{-11} \text{F} \times 0.03 \text{m}}{8.85 \times 10^{-12} \frac{\text{C}^2}{\text{Nm}^2} \times (0.1 \text{m})^2} = 12.2.$$

Thus the most likely material from the table below would be glass.

## 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

$$F = qvB \sin \theta$$

$$F = IlB \sin \theta$$

$$\tau = NIAB \sin \theta = \mu B \sin \theta$$

$$PE = -\mu B \cos \theta$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$\mathcal{E}_{induced} = -N \frac{\Delta \phi_B}{\Delta t} = -N \frac{\Delta(BA \cos \theta)}{\Delta t}$$

### Constants

$$g = 9.8 \frac{m}{s^2}$$

$$1e = 1.6 \times 10^{-19} C$$

$$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{Nm^2}{C^2}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

$$1eV = 1.6 \times 10^{-19} J$$

$$\mu_0 = 4\pi \times 10^{-7} \frac{Tm}{A}$$

$$c = 3 \times 10^8 \frac{m}{s}$$

$$h = 6.63 \times 10^{-34} Js$$

$$m_e = 9.11 \times 10^{-31} kg = \frac{0.511 MeV}{c^2}$$

$$m_p = 1.67 \times 10^{-27} kg = \frac{937.1 MeV}{c^2}$$

$$m_n = 1.69 \times 10^{-27} kg = \frac{948.3 MeV}{c^2}$$

$$1amu = 1.66 \times 10^{-27} kg = \frac{931.5 MeV}{c^2}$$

$$N_A = 6.02 \times 10^{23}$$

$$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

### Electric Circuits

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

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

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

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

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

$$Q = CV = \left( \frac{\kappa \epsilon_0 A}{d} \right) V = (\kappa C_0) V$$

$$PE = \frac{1}{2} QV = \frac{1}{2} CV^2 = \frac{Q^2}{2C}$$

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

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

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

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

### Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$

$$KE_{max} = hf - \phi = eV_{stop}$$

$$\Delta \lambda = \frac{h}{m_e c} (1 - \cos \phi)$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$p = \gamma mv$$

$$E_{total} = KE + E_{rest} = \gamma mc^2$$

$$E_{total}^2 = p^2 c^2 + m^2 c^4$$

$$E_{rest} = mc^2$$

$$KE = (\gamma - 1)mc^2$$

### Geometry

$$\text{Circles: } C = 2\pi r = \pi D \quad A = \pi r^2$$

$$\text{Triangles: } A = \frac{1}{2} bh$$

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

### Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

$$S(t) = \frac{\text{energy}}{\text{time} \times \text{area}} = c\epsilon_0 E^2(t) = c \frac{B^2(t)}{\mu_0}$$

$$I = S_{avg} = \frac{1}{2} c\epsilon_0 E_{max}^2 = c \frac{B_{max}^2}{2\mu_0}$$

$$P = \frac{S}{c} = \frac{\text{Force}}{\text{Area}}$$

$$S = S_o \cos^2 \theta$$

$$v = \frac{1}{\sqrt{\epsilon \mu}} = \frac{c}{n}$$

$$\theta_{inc} = \theta_{refl}$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$M_{total} = \prod_{i=1}^N M_i$$

$$d \sin \theta = m\lambda \quad \text{or} \quad (m + \frac{1}{2})\lambda$$

$$a \sin \phi = m' \lambda$$

### 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

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

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

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

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

$$PE_{gravity} = mgy$$

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

Table of dielectric constants: <http://www.csgnetwork.com/dieconstantstable.html>

Material	Min.	Max.	Material	Min.	Max.
Air	1	1	Lucite	2.5	2.5
Amber	2.6	2.7	Paper	1.5	3
Asbestos fiber	3.1	4.8	Paraffin	2	3
Bakelite	5	22	Plexiglass	2.6	3.5
Barium Titanate	100	1250	Polycarbonate	2.9	3.2
Beeswax	2.4	2.8	Polyethylene	2.5	2.5
Cambric	4	4	Polyimide	3.4	3.5
Carbon Tetrachloride	2.17	2.17	Polystyrene	2.4	3
Celluloid	4	4	Porcelain	5	6.5
Cellulose Acetate	2.9	4.5	Quartz	5	5
Durite	4.7	5.1	Rubber	2	4
Ebonite	2.7	2.7	Ruby Mica	5.4	5.4
Epoxy Resin	3.4	3.7	Selenium	6	6
Fiber	5	5	Shellac	2.9	3.9
Formica	3.6	6	Silicone	3.2	4.7
Glass	3.8	14.5	Slate	7	7
Glass Pyrex	4.6	5	Soil dry	2.4	2.9
Kevlar	3.5	4.5	Wood dry	1.4	2.9

Isolantite	6.1	6.1	Styrofoam	1.03	1.03
Kevlar	3.5	4.5	Teflon	2.1	2.1
Lucite	2.5	2.5	Titanium Dioxide	100	100
Mica	4	9	Vaseline	2.16	2.16
Micarta	3.2	5.5	Vynylite	2.7	7.5
Mycalex	7.3	9.3	Water distilled	34	78
Neoprene	4	6.7	Waxes, Mineral	2.2	2.3
			Wood dry	1.4	2.9