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Physics 111 Quiz #3, October 1, 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. A capacitor is constructed out of two circular metal plates each with a 50*cm* diameter and a dielectric made from rubber ($\kappa = 6.7$) is inserted between the plates. The initially uncharged capacitor is connected to a 10000 Ω resistor and allowed to charge. If the time constant of the circuit is needed to be $\tau = 38s$, what capacitance would be required?

 $\tau = RC \rightarrow C = \frac{\tau}{R} = \frac{38s}{10000\Omega} = 0.0038F$

2. In order to achieve the capacitance in question 1, what would the separation between the plates have to be?

$$C = \frac{\kappa\epsilon_0 A}{d} \to d = \frac{\kappa\epsilon_0 A}{C} = \frac{\kappa\epsilon_0 \pi r^2}{C} = \frac{6.7 \times 8.85 \times 10^{-12} \frac{C^2}{Nm^2} \times \pi (0.25m)^2}{0.0038F} = 3.1 \times 10^{-9} m$$

3. How much energy was stored in the capacitor when it is fully charged if the capacitor was charged using a 100V battery?

$$U_C = \frac{1}{2}CV^2 = \frac{1}{2} \times 0.0038F \times (100V)^2 = 19J$$

4. When fully charged by the 100V battery, how much charge was stored?

 $Q = CV = 0.0038F \times 100V = 0.38C$

5. This capacitor is charged through the resistor. At what time will the potential difference across the resistor equal the potential difference across the capacitor?

$$V_R = V_C \to V_{max} e^{-\frac{t}{RC}} = V_{max} \left(1 - e^{-\frac{t}{RC}} \right) \to 1 = 2e^{-\frac{t}{RC}} \to t = -RC \ln 2 = -38s \times \ln 2 = 26.3s$$

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
 $g = 9.8 \frac{m}{s^2}$
 $le = 1.6 \times 10^{-19} C$
 $k = \frac{1}{4\pi \varepsilon_o} = 9 \times 10^9 \frac{c^2}{Nm^2}$
 $\varepsilon_o = 8.85 \times 10^{-12} \frac{Nm^2}{C^2}$
 $leV = 1.6 \times 10^{-19} J$
 $\mu_o = 4\pi \times 10^{-7} \frac{Tm}{A}$
 $c = 3 \times 10^8 \frac{m}{s}$
 $h = 6.63 \times 10^{-34} Js$
 $m_e = 9.11 \times 10^{-31} kg = \frac{0.511MeV}{c^2}$
 $m_p = 1.67 \times 10^{-27} kg = \frac{937.1MeV}{c^2}$
 $m_n = 1.69 \times 10^{-27} kg = \frac{948.3MeV}{c^2}$
 $lamu = 1.66 \times 10^{-27} kg = \frac{931.5MeV}{c^2}$
 $N_A = 6.02 \times 10^{23}$
 $Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$

Electric Circuits

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

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

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

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

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

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

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

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

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

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

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

 $\Delta(BA\cos\theta)$ Light as a Particle & Relativity Nuclear Physics

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

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

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

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

$$p = \gamma mv$$

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

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

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

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

Geometry

 $Greles \quad C = 2\pi r = \pi D \qquad A = \pi r^2$ Triangles $A = \frac{1}{2}bh$ Spheres: $A = 4\pi r^2$ $V = \frac{4}{3}\pi r^3$

Light as a Wave

1

$$c = f I = \frac{1}{\sqrt{e_o m_o}}$$

$$S(t) = \frac{energy}{time \ area} = ce_o E^2(t) = c\frac{B^2(t)}{m_0}$$

$$I = S_{avg} = \frac{1}{2}ce_o E_{max}^2 = c\frac{B_{max}^2}{2m_0}$$

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

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

$$v = \frac{1}{\sqrt{em}} = \frac{c}{n}$$

$$q_{inc} = q_{refl}$$

$$n_1 \sin q_1 = n_2 \sin q_2$$

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

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

$$M_{total} = \bigotimes_{i=1}^{\infty} M_i$$

$$S_{out} = S_{in} e^{-\frac{c_i}{t}}$$

$$HU = \frac{m_w - m_m}{m_w}$$

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

Misc. Physics 110 Formulae

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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