Physics Lab 206 Mar 2016
Quiz #4 RLC Circuits

Name:

1) Pieter van Musschenbroek connects his capacitor with capacitance $C = 2.2$ mF to a battery with emf $\mathcal{E} = 4.0$ V and a resistor $R = 20$ kΩ in series. The capacitor was free of charge before connecting the circuit, at time $t = 0$.
a) Calculate the time constant, τ. [**2 pts**]
b) How long it takes for the capacitor to get charged with $Q = 4.4$ mC?
Remember that $V_C(t) = \mathcal{E}(1 - e^{-t/\tau})$ and $Q = CV$. How much is the current at this time? [**3 pts**]
c) Pieter measures the resistor voltage through time and fits a curve $y = 3.89e^{-0.023x} + 0.03$. Write down the units of these numerical fit parameters and compare them to the theoretical values. [**4 pts**]

a) $\tau = RC = 20\ k\Omega\ 2.2\ mF = 44\ s.$

b) We call the time t_1. We know,

$Q(t=t_1) = 4.4\ mC = C V_C(t=t_1) = 2.2\ mF \cdot \mathcal{E}(1 - e^{-t_1/\tau}) = 8.8\ (1 - e^{-t_1/\tau})\ mC.$

So $(1 - e^{-t_1/\tau}) = 0.50 \rightarrow t_1 = \tau \ln 2 = 30\ s.$

$V_C(t=t_1) = 2.0\ V \rightarrow V_R(t=t_1) = \mathcal{E} - V_C(t=t_1) = 2.0\ V \rightarrow I(t=t_1) = \frac{V_R(t=t_1)}{R} = 0.10\ mA.$

c) Theoretically $V_R(t) = \underline{\mathcal{E}}\, e^{-t/\tau} + \underline{0} \rightarrow y = \underline{(3.89\ V)}\, e^{-(.023\ \frac{1}{s})x} + \underline{0.03\ V}.$ $\frac{1}{\tau} = .023\ \frac{1}{s}.$

2) Hertha Ayrton uses the same setup that we had in 'RLC Circuits' lab, part B, (R and L and C in series connected to a battery) and measures the current I (or voltage V_R) vs time as shown in fig. 1. She knows $R = 100\Omega$ and wants to find L and C.
a) Roughly measure the period of oscillations, T. Calculate f and ω. [**3 pts**]
b) Roughly measure the time constant, τ. Remember that the peaks are roughly decaying like $e^{-t/\tau}$. [**3 pts**]
c) Find L and C. [**2 pts**]

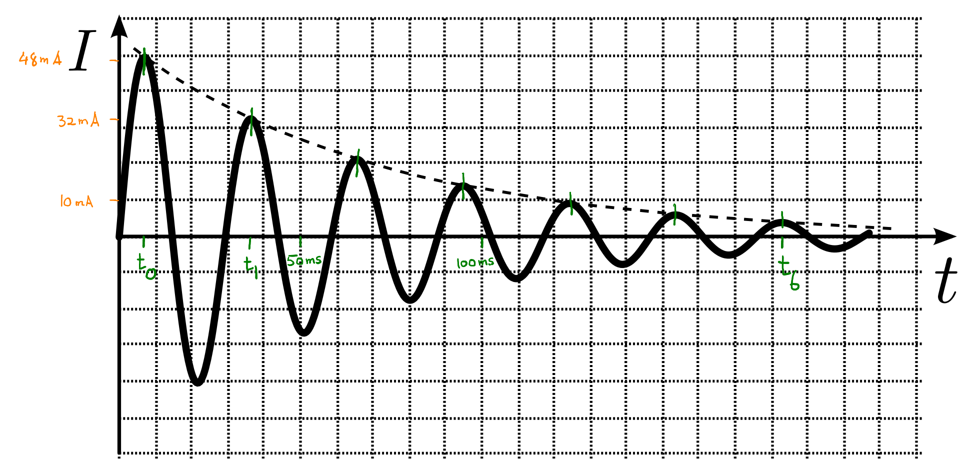

Figure 1: A series RLC circuit's current vs time. Each square in the grid is 10 mA by 10 ms.

a) $t_6 = t_0 + 6T.$ $t_6 = 183 \pm 1\ ms,\ t_1 = 7 \pm 1\ ms \rightarrow T = 29.3 \pm 0.2\ ms.$

$\omega = \frac{2\pi}{T} = 214\ \frac{rad}{s},\ f = \frac{1}{T} = 34.1\ Hz.$

b) $t_1 - t_0 = T = 29.3\ ms.$ $\frac{I(t_1)}{I(t_0)} \approx e^{-T/\tau} \rightarrow \tau = \frac{T}{\ln(\frac{48}{32})} = 72\ ms.$

c) $\tau = \frac{2L}{R} = 72\ ms \rightarrow L = \frac{\tau R}{2} = 3.6\ H.$

$\omega \approx \frac{1}{\sqrt{LC}} \rightarrow LC = 2.18 \times 10^{-5}\ s^2 \rightarrow C = 6.1\ \mu F.$