Physics 4B
Fall 2011

Name Answer Key

Lab ____________________

Quiz #9: EM Oscillations and Alternating Current

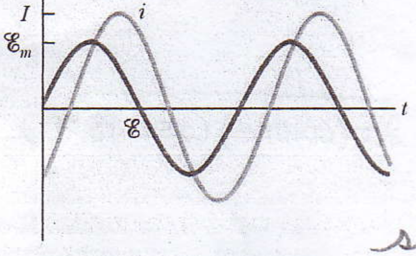
Problem 1 (1 point)
An RLC series circuit is driven by a sinusoidal emf with angular frequency ω_d. If ω_d is increased without changing the amplitude of the emf, the current amplitude increases. This means that:

$\boxed{D}$

a) $\omega_d L > R$
b) $\omega_d L < R$
c) $\omega_d L > 1/\omega_d C$
[✓ d)] $\omega_d L < 1/\omega_d C$
e) $\omega_d L = 1/\omega_d C$

the circuit is getting closer to resonance ($X_L = X_c$) when ω_d is increased so $\omega_d L < 1/\omega_d C$

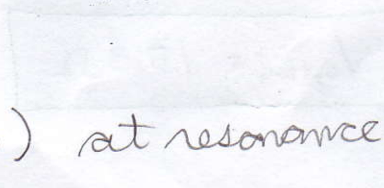
Problem 2 (2 points)
The figure below shows the current *i* and driving emf ε for a series RLC circuit driven at frequency f_d. What effect (increase, decrease, or no change) would each of the following changes have on **(a)** the current amplitude I and **(b)** the phase angle φ?



	Effect on I	Effect on φ
Increase L	decrease	increase
Increase R	decrease	decrease
Increase C	decrease	increase
Increase f_d	decrease	increase

since i lags $\mathcal{E}$, circuit is mainly inductive $(\mathcal{E} \angle I)$
so $X_L < X_c$, $\omega_d > \omega$; $\phi > 0$

Problem 3 (2 points)
The current amplitude I versus driving frequency ω_d for a series RLC circuit is given in the figure below (**Note**: the driving angular frequency is given in units of **1000** rad/s). The inductance is 175 uH and the emf amplitude is $\mathcal{E}_m = 125$ V. What are the values of (a) C and (b) R?



note: from the graph, the resonant angular frequency is $\omega = 25 \times 10^3$ rad/s

$$\omega = 1/\sqrt{LC} \rightarrow \omega^2 = \frac{1}{LC} \rightarrow C = 1/\omega^2 L$$

$$C = \frac{1}{(25\times10^3 \text{rad/s})^2 (175\times10^{-6}\text{H})} \longrightarrow \boxed{C = 9.14\times10^{-6}\text{F} = 9.14\,\text{uF}}$$

(b) at resonance ($X_L = X_c$), $Z = R$

$$I = \mathcal{E}_m/Z = \mathcal{E}_m/R \longrightarrow R = \mathcal{E}_m/I = \frac{125\text{V}}{4.0\text{A}} = \boxed{31.3\,\Omega}$$

Problem 4 (2 points)
In an oscillating LC circuit, L = 30.0 mH and C = 7.50 μF. At time t = 1.50 s, the current is 9.0 mA and the charge on the capacitor is 3.50 μC. **(a)** What is the maximum charge on the capacitor? **(b)** What is the maximum current?

$L = 30.0\,mH$

$C = 7.50\,\mu F$

$i = 9.0\,mA$

$q = 3.50\,\mu C$

$$U_{total} = \tfrac{1}{2}\,q^2/C + \tfrac{1}{2}Li^2$$

$$= \tfrac{1}{2}\frac{(3.50\times10^{-6}C)^2}{(7.50\times10^{-6}F)} + \tfrac{1}{2}(30.0\times10^{-3}H)(9.0\times10^{-3}A)^2$$

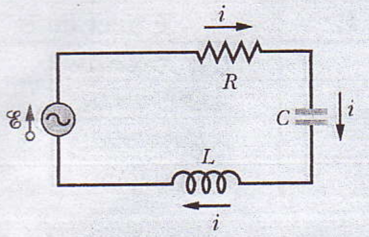
$$= 2.03\times10^{-6}J$$

$$(a)\ U_{total} = \tfrac{1}{2}Q^2/C \rightarrow Q = \sqrt{2UC} = \sqrt{2(2.03\times10^{-6}J)(7.50\times10^{-6}F)}$$

$$= \boxed{5.52\,\mu C}$$

$$(b)\ U_{total} = \tfrac{1}{2}LI^2 \rightarrow I = \sqrt{\frac{2U}{L}} = \sqrt{\frac{2(2.03\times10^{-6}J)}{30.0\times10^{-3}H}} \rightarrow \boxed{I = 11.6\,mA}$$

Problem 5 (3 points)
In the figure below, let $R = 100.0\,\Omega$, $C = 25.0\,\mu F$, L = 200.0 mH, f_d = 60.0 Hz, and ξ_m = 30.0 V.
(a) What is the maximum current in the circuit? **(b)** What are the rms voltages across the resistor, capacitor, and the inductor?



$$X_L = \omega_d L = (2\pi f_d)L = 2\pi(60.0Hz)(200.0\times10^{-3}H)$$

$$= \underline{75.4\,\Omega}$$

$$X_C = \frac{1}{\omega_d C} = \frac{1}{(2\pi f_d)C} = \frac{1}{2\pi(60.0Hz)(25.0\times10^{-6}F)}$$

$$= \underline{106\,\Omega}$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(100.0\Omega)^2 + (75.4\Omega - 106\Omega)^2} = \underline{104.6\,\Omega}$$

$$a)\quad I = \mathcal{E}_m/Z = \frac{30.0V}{104.6\Omega} \longrightarrow \boxed{I = 0.287A = 287mA}$$

$$b)\quad V_R = IR = (0.287A)(100.0\Omega) = 28.7\Omega \quad \boxed{V_{rms} = \frac{V}{\sqrt{2}} = 20.3\Omega}$$

$$V_C = IX_C = (0.287A)(106\Omega) = 30.4\Omega \quad \boxed{V_{C,rms} = 21.5\Omega}$$

$$V_L = IX_L = (0.287A)(75.4\Omega) = 21.6\Omega \quad \boxed{V_{L,rms} = 15.3\Omega}$$