Graded Solutions for HW 4

Chapter 35

Exercise and Problems:

35.54. Model: Assume that the block absorbs the laser light completely. Use the particle model for the block. We assume that since the block absorbs light completely hence the entire momentum of the incident photon gets transferred to the block. There fore the power of the incident beam is the force exerted by the beam on the block times the velocity of the incident beam which is 'c'.

Now, from Equation of the radiation pressure

$$p_{\text{rad}} = \frac{F}{A} = \frac{P/A}{c} = \frac{I}{c}$$

since force exerted on the block is pressure times the area on the block on which the wave is incident.

$$F_{\text{rad}} = p_{\text{rad}} A = \frac{P}{c} = \frac{25\times10^{6}\ \text{W}}{3.0\times10^{8}\ \text{m/s}} = 0.0833\ \text{N}$$

once we have found the force on the block we calculate its acceleration applying Newton's second law,

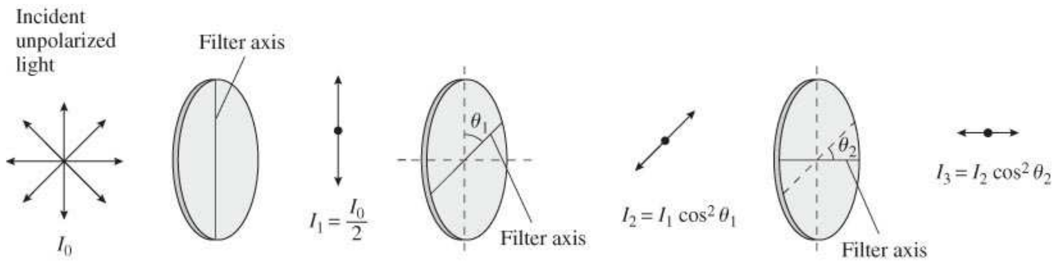
$$F_{\text{rad}} = ma = (100\ \text{kg})a \Rightarrow a = \frac{F_{\text{rad}}}{100\ \text{kg}} = \frac{0.0833\ \text{N}}{100\ \text{kg}} = 8.33\times10^{-4}\ \text{m/s}^2$$

From kinematics,

$$v_f^2 = v_i^2 + 2a(s_f - s_i) = 0\ \text{m}^2/\text{s}^2 + 2\left(8.33\times10^{-4}\ \text{m/s}^2\right)(100\ \text{m}) \Rightarrow v_f = 0.408\ \text{m/s}$$

Assess: This does not seem like a promising method for launching satellites.

35.56. Model: Use Malus's law for the polarized light.
Visualize:



For unpolarized light the net projection of the electric field on the horizontal as well as the vertical axes are equal. Hence the intensity observed by a horizontal or a vertical filter is the same. Since both of them sum up to give the original incident intensity hence the intensity through eithe axis is half of the original incident intensity. After passing through the first filter the wave is now polarized in the vertical direction therefore for succesive filters we can use Law of Malus to find out the emergent intensity from each. Therefore the following solution follows.

Solve: For unpolarized light, the electric field vector varies randomly through all possible values of θ. Because the average value of $\cos^2\theta$ is $\frac{1}{2}$, the intensity transmitted by a polarizing filter when the incident light is unpolarized is $I_1 = \frac{1}{2}I_0$. For polarized light, $I_{\text{transmitted}} = I_0 \cos^2\theta$. Therefore,

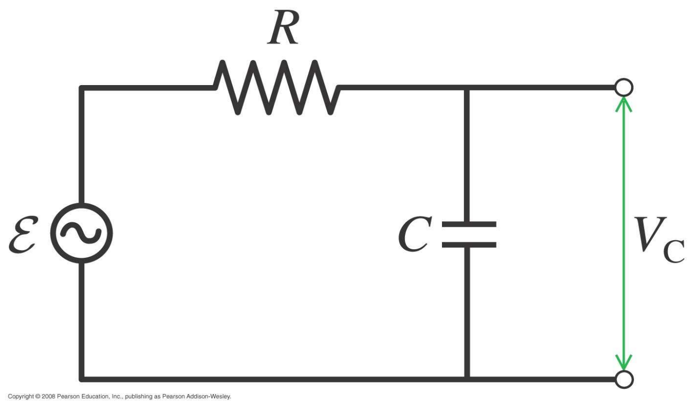
$$I_2 = I_1\cos^2 45° \quad I_3 = I_2\cos^2 45°$$

$$\Rightarrow I_3 = (I_1 \cos^2 45°)\cos^2 45° = \tfrac{1}{2} I_0(\cos^4 45°) = \tfrac{1}{8} I_0$$

Chapter 36

Conceptual problems:

36.4.



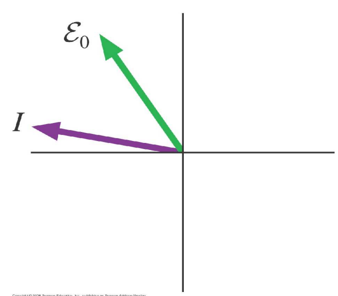
A low pass RC circuit has the following circuit

The expression for the cross over frequancy (frequancy at which the reactance of the capacitor = reactance of the resistor) is given by $\omega_c = 2\pi f_c = \frac{1}{RC}$

(a) f_c = 100 Hz.

(b) 100 Hz from the expression
(c) 200 Hz. Unchanged since the crossover frequency does not depend on the peak emf.

36.7.

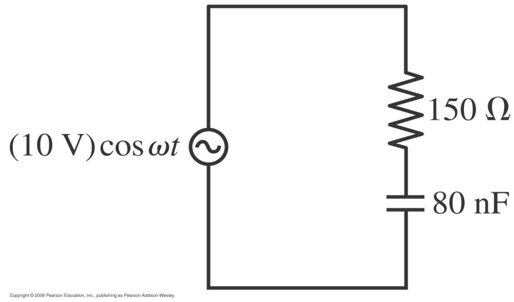


Current leads the voltage which implies that capacitive reactance is more than the the inductive reactance. Now we have the capacitive reactance behaving inversely with frequancy and inductive reactance behaving directly with frequency, hence frequency has to be less than the resonant frequency to increase the X_C and decrease X_L

Less than. Here the current leads the emf. $X_L < X_C$ and the phase angle □ is negative.

Problems and Exercises:

36.15.



Model: The current and voltage of a resistor are in phase, but the capacitor current leads the capacitor voltage by 90°.
Solve: THe reactance of the resistor is R wereas for the capacitor it is given by,

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC} = \frac{1}{2\pi(1\times10^4 \text{ Hz})(80\times10^{-4} \text{ F})} = 199\ \Omega$$

for the RC circuit we have the magnitude of peak current given by

$$I = \frac{\mathcal{E}_0}{\sqrt{R^2 + X_C^2}} = \frac{\mathcal{E}_0}{\sqrt{R^2 + 1/\omega^2 C^2}}$$

The peak current is

$$I = \frac{\mathcal{E}_0}{\sqrt{X_C^2 + R^2}} = \frac{10 \text{ V}}{\sqrt{(199\ \Omega)^2 + (150\ \Omega)^2}} = 0.0401 \text{ A}$$

Since the components are in series hence the same peak current flows through both of them at some instant and hence if we multiply this value of current with the reactance of each we will find the poeak voltage across each.

Therefore

, $V_R = (0.0401 \text{ A})(150\ \Omega) = 6.0 \text{ V}$ and

$V_C = IX_C = (0.0401 \text{ A})(199\ \Omega) = 8.0 \text{ V}$.

36.21. Model: The AC current through an inductor lags the inductor voltage by 90°.

Solve: (a) From Equation 36.21,

$$I_L = 50\text{ mA} = \frac{V_L}{X_L} = \frac{V_L}{2\pi fL} \Rightarrow f = \frac{5.0\text{ V}}{2\pi\left(50\times10^{-3}\text{ A}\right)\left(500\times10^{-6}\text{ H}\right)} = 3.2\times10^4\text{ Hz}$$

(b) The current and voltage for a simple one-inductor circuit are

$$i_L = I_L\cos\left(\omega t - \tfrac{1}{2}\pi\right) \qquad v_L = V_L\cos\omega t$$

For $i_L = I_L$, $\omega t - \frac{1}{2}\pi$ must be equal to $2n\pi$, where $n = 0, 1, 2, \ldots$. This means $\omega t = \left(2n\pi + \frac{1}{2}\pi\right)$.

Since the source voltage has the expression $V = V_m\sin(\omega t)$ Thus, the instantaneous value of the emf at the instant when $i_L = I_L$ is $v_L = 0$ V.

36.36. Solve: (a)

$$V_R = IR = \frac{\mathcal{E}_0 R}{\sqrt{R^2 + X_C^2}} = \frac{\mathcal{E}_0 R}{\sqrt{R^2 + 1/\omega^2 C^2}}$$

$$V_C = IX_C = \frac{\mathcal{E}_0 X_C}{\sqrt{R^2 + X_C^2}} = \frac{\mathcal{E}_0/\omega C}{\sqrt{R^2 + 1/\omega^2 C^2}}$$

We have the potential drops across the individual components given by the above equations in a RC circuit. Where I is the peak current that flows through the circuit.

Therefore.

$$V_C = \frac{\mathcal{E}_0/\omega C}{\sqrt{R^2 + \left(\omega_{cap}C\right)^{-2}}} = \frac{\mathcal{E}_0}{2} \Rightarrow R^2 + \frac{1}{\omega_{cap}^2 C^2} = \frac{4}{\omega_{cap}^2 C^2} \Rightarrow \omega_{cap} = \frac{\sqrt{3}}{RC}$$

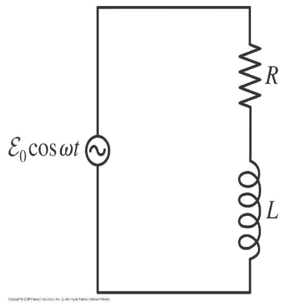
(b) At this frequency,

$$V_R = IR = \frac{\mathcal{E}_0 R}{\sqrt{R^2 + \left(\omega_{cap}C\right)^{-2}}} = \frac{\mathcal{E}_0 R}{\sqrt{R^2 + R^2/3}} = \frac{\sqrt{3}}{2}\mathcal{E}_0$$

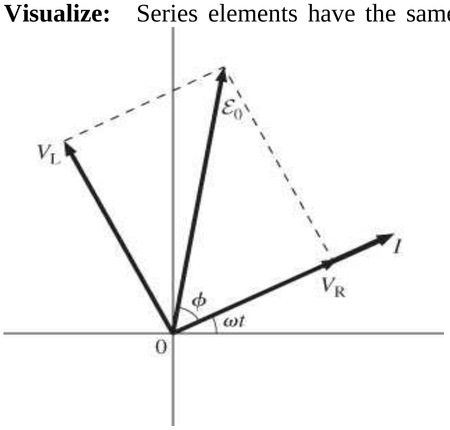
(c) The crossover frequency is

$$\omega_c = \frac{1}{RC} = 6280\text{ rad/s} \Rightarrow \omega_{cap} = \sqrt{3}\ \omega_c = 10{,}877\text{ rad/s}$$

36.47. **Model:** While the AC current through an inductor lags the inductor voltage by 90°, the current and the voltage are in phase for a resistor.



Visualize: Series elements have the same current, so we start with a common current phasor I for the inductor and resistor,



Solve: Because we have a series RL circuit, the current through the resistor and the inductor is the same. The voltage phasor V_R is along the same direction as the current phasor I. The voltage phasor V_L is ahead of the current phasor by 90°.

(a) From the phasors in the figure, $\mathcal{E}_0 = \sqrt{V_L^2 + V_R^2}$. Noting that $V_L = I\omega L$ and $V_R = IR$, $\mathcal{E}_0 = I\sqrt{\omega^2 L^2 + R^2}$ and

$$I = \frac{\mathcal{E}_0}{\sqrt{R^2 + \omega^2 L^2}} \qquad V_R = \frac{\mathcal{E}_0 R}{\sqrt{R^2 + \omega^2 L^2}} \qquad V_L = \frac{\mathcal{E}_0 \omega L}{\sqrt{R^2 + \omega^2 L^2}}$$

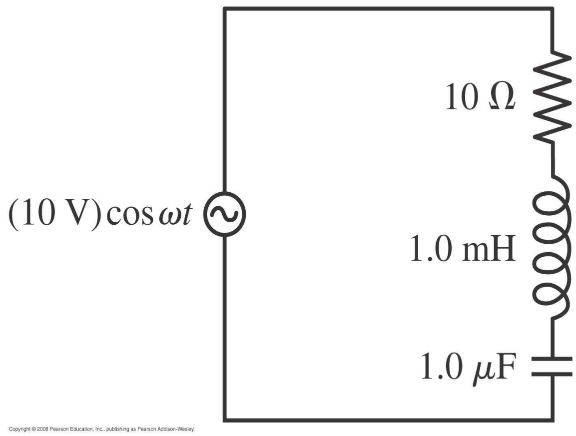
(b) As $\omega \to 0$ rad/s, $V_R \to \mathcal{E}_0 R/R = \mathcal{E}_0$ and as $\omega \to \infty$, $V_R \to 0$ V.

(c) The LR circuit will be a low-pass filter, if the output is taken from the resistor. This is because V_R is maximum when ω is low and goes to zero when ω becomes large.

(d) At the cross-over frequency, $V_L = V_R$. Hence,

$$I\omega_c L = IR \Rightarrow \omega_c = \frac{R}{L}$$

36.51.



Solve: **(a)** The resonance frequency of the circuit occurs when the reactance of the capacitor is the same as that of the inductor hence the voltage is in phase with the current. The resonant frequencyis given by,

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(1.0\times10^{-3}\text{ H})(1.0\times10^{-6}\text{ F})}} = 3.2\times10^{4}\text{ rad/s} \Rightarrow f = \frac{\omega}{2\pi} = 5.0\times10^{3}\text{ Hz}$$

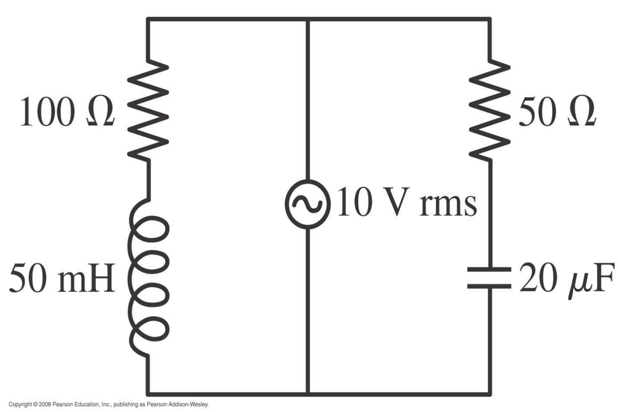
(b) At resonance $X_L = X_C$. So, the net reactance of the circuit is due to the resistance, hence the peak values are

$$I = \frac{\mathcal{E}_0}{R} = \frac{10\text{ V}}{10\ \Omega} = 1.0\text{ A} \Rightarrow V_R = IR = (1.0\text{ A})(10\ \Omega) = 10.0\text{ V}$$

$$\Rightarrow V_C = IX_C = I\left(\frac{1}{\omega C}\right) = \frac{1.0\text{ A}}{(3.16\times10^{4}\text{ rad/s})(1.0\times10^{-6}\text{ F})} = 32\text{ V}$$

(c) The instantaneous voltages must satisty $v_R + v_C + v_L = \mathcal{E}$ But v_C and v_L are out of phase at resonance and cancel. Consequently, it is entirely possible for their peak values V_C and V_L to exceed $\mathcal{E}_0$ since they give a perpendicular componenet to the potential and the net perpendicular component is $V_C - V_L$ hence either of them might be more than $\mathcal{E}_0$ but the difference is not .

36.52. **Visualize:** .



When the frequency is very small, $X_C = 1/\omega C$ becomes very large and $X_L = \omega L$ becomes very small. So, the branch in the circuit with the capacitor has a very large impedance and most of the current flows through the branch with the inductor. When the frequency is very large, the reverse is true and most of the current flows through the branch with the capacitor.

Solve: **(a)** When the frequency is very small, the branch with the inductor has a very small X_L, so $Z \cong R$. The current supplied by the emf is

$$I_{rms} = \frac{10\text{ V}}{100\ \Omega} = 0.10\text{ A}$$

this flows mostly through the inductor part of the circuit and the current through the capacitor is negligible. Hence this is the net current supplied by the AC source

(b) When the frequency is very large, the branch with the capacitor has a very small X_C, so $Z \cong R$. The current supplied by the emf is

$$I_{rms} = \frac{10\text{ V}}{50\ \Omega} = 0.20\text{ A}$$

Impedence in the inductor part of the circuit is high hence current through that loop of the circuit is negligible. Hence this is the net current supplied by the AC source.