CHAPTER 31
ALTERNATING CURRENT

Discussion Questions

Q31.1 At the higher voltage, the same power can be transmitted at lower current so there is less I^2R power loss in the transmission wires. The higher voltage is more of a safety risk.

Q31.2 The polarity of the source voltages reverses when the current direction reverses. Current always enters the $-$ terminal and exits the + terminal as it passes through the source. The moving charge always gains electrical energy as it moves back and forth in the source. At a resistive load the moving charges in the current always lose electrical energy as they pass through the load in either direction. The oscillating charge at the source causes oscillating charge at the load. Electrical energy is put into the circuit at the source and consumed at the load.

Q31.3 In the inductor or capacitor electrical energy is stored and then released back to the circuit. In the resistor electrical energy is dissipated by transformation to thermal energy and not returned to the circuit.

Q31.4 When the charge on the left plate is positive but decreasing in time $|q|$ is decreasing so dq/dt is negative. The current is clockwise so is negative and $i = dq/dt$ is correct. When the charge on the right plate is positive and increasing, $|q|$ is increasing. But q refers to the charge on the left plate so is negative. A negative q that is getting larger in magnitude corresponds to $dq/dt < 0$. i is clockwise so is negative and $i = dq/dt$ is correct. When the charge on the right plate is positive and decreasing, $dq/dt > 0$ since q is negative and decreasing in magnitude. i is counterclockwise so is positive and $i = dq/dt$ is correct.

Q31.5 A resistor would dissipate electrical energy but no electrical energy is dissipated in the inductor. Electrical energy is temporarily stored in the magnetic field of the inductor but at a later time all this energy is returned to the circuit.

Q31.6 current to right through L and increasing: i is in the positive direction and increasing in magnitude so $di/dt > 0$. By Lenz's law the induced emf in the inductor is directed to oppose the increase in the current. The induced emf is therefore to the left in Fig.31.8a and this corresponds to $v_a > v_b$.
current to the right through L and decreasing: i is in the positive direction and is decreasing in magnitude so $di/dt < 0$. By Lenz's law the induced emf in the inductor is directed to oppose the decrease in the current. The induced emf is therefore to the right and this corresponds to $v_a < v_b$. v_{ab} is negative and di/dt is negative so $v_{ab} = L(di/dt)$ is still correct.
current to the left through L and increasing: i is in the negative direction and is increasing in magnitude so $di/dt < 0$. By Lenz's law the induced emf in the inductor is directed to oppose the increase in the current. The induced emf is therefore to the right and this corresponds to $v_a < v_b$. v_{ab} is negative and di/dt is negative so $v_{ab} = L(di/dt)$ is still correct.
current to the left through L and decreasing: i is in the negative direction and is decreasing in magnitude so $di/dt > 0$. By Lenz's law the induced emf in the inductor is directed to oppose the decrease in the current. The induced emf is therefore to the left and this corresponds to $v_a > v_b$. v_{ab} is positive and di/dt is positive so $v_{ab} = L(di/dt)$ is still correct.

Q31.7 No. The power factor is $\cos\phi$, where $\tan\phi = \dfrac{\omega L - 1/\omega C}{R}$. Mathematically, $\cos\phi = 0$ only if

$\phi = 90^\circ$. $\phi = 90^\circ$ gives $\tan\phi \to \infty$. This happens if $R \to 0$. This is consistent with the equation $P_{\rm av} = \frac{1}{2}VI\cos\phi$ for the average power input to the circuit. As long as $R \neq 0$ there is some electrical power consumed in the resistor and the power factor isn't zero.

Q31.8 At any instant in time $v = v_R + v_L + v_C$. v_L and v_C are 180° out of phase so have opposite sign. v_R and $(v_L + v_C)$ are 90° out of phase and $v^2 = v_R^2 + (v_L + v_C)^2$. $|v_R|$ and $|v_L + v_C|$ must each be less than the magnitude $|v|$ of the source voltage. But since $|v_L + v_C| = ||v_L| - |v_C||$, $|v_L|$ and $|v_C|$ can each be larger than $|v|$.

Q31.9 When the circuit is far from resonance X_L and X_C differ. So if $R << X_L$ and $R << X_C$, then it will also be true that $R << |X_L - X_C|$. $|\tan\phi| = |X_L - X_C|/R$, so $|\tan\phi|$ is large and ϕ is close to $+90^\circ$ or -90°. The power factor $\cos\phi$ is close to zero. The current and source voltage are close to 90° out of phase and little power is delivered by the source. Since R is small, little power is consumed in the resistor and this agrees with little power delivered by the source.

Q31.10 See Q31.8. The voltages across the inductor and capacitor are 180° out of phase, so at all times have opposite polarity and subtract from each other when the loop rule is applied. The net voltage at any time across the capacitor and inductor combination can't exceed 120 V, but the capacitor voltage can be much larger than this.

Q31.11 The inductor doesn't affect R but it does increase the impedance Z of the circuit. $I_{\rm rms}$ and therefore $P = I_{\rm rms}^2 R$ decrease.

Q31.12 $X_C = 1/(\omega C)$. Inserting the dielectric increases C and therefore decreases X_C. This in turn decreases Z. The rms current in the circuit increases and the bulb becomes brighter when the dielectric is inserted.

Q31.13 Inserting the iron rod increases the inductance L. $X_L = \omega L$ so X_L increases and Z increases. This in turn decreases the rms current in the circuit and the bulb becomes less bright.

Q31.14 The impedance is $Z = \sqrt{R^2 + (X_L - X_C)^2}$. An increase in Z decreases $I_{\rm rms}$ and the bulb becomes less bright. A decrease in Z increases $I_{\rm rms}$ and the bulb becomes brighter. Whether X_C^2 or $(X_L - X_C)^2$ is smaller depends on the numerical values of X_L and X_C. Similarly, whether X_L^2 or $(X_L - X_C)^2$ is smaller depends on the values of X_L and X_C. The change in brightness, whether it increases or decreases, depends on the values of X_L and X_C, and these in turn depend on L, C and the frequency f of the source.

Q31.15 Yes, this happens at the resonance frequency. At resonance $X_L = X_C$ and $Z = R$ with the capacitor and inductor present and $Z = R$ also when both are removed.

Q31.16 No. The transformer works using the induced emf that results in an ac circuit. If a transformer is connected to a dc line there is no current or voltage in the secondary.

Q31.17 (a) $V_2 = \left(\dfrac{N_2}{N_1}\right)V_1$. If N_2 is doubled, then V_2, the voltage amplitude in the secondary, doubles. (b) The effective resistance of the secondary is given by $R_{\text{eff}} = \dfrac{R}{\left(N_2 / N_1\right)^2}$. If N_2 is doubled the effective resistance is multiplied by a factor of $\dfrac{1}{4}$ and therefore decreases.

Q31.18 (a) The resonance angular frequency is given by $\omega_0 = \dfrac{1}{\sqrt{LC}}$. If L and C are both doubled the resonance is halved. (b) The inductive reactance is $X_L = \omega L$. If L is doubled then X_L increases by a factor of two. (c) The capacitive reactance is $X_C = \dfrac{1}{\omega C}$. Doubling C means X_C is halved. (d) The impedance is $Z = \sqrt{R^2 + (X_L - X_C)^2}$. Since R and X_L are doubled but X_C is halved, Z does not change by a simple factor of two.

Q31.19 The resonance angular frequency is $\omega_0 = \dfrac{1}{\sqrt{LC}}$. It is independent of R. To double ω_0, decrease L and C by multiplying each of them by $\frac{1}{2}$.