Chapter 21 Summary – AC Circuits and Electromagnetic Waves

►If an AC circuit consists of a generator and a resistor, the current in the circuit is in phase with the voltage. That is, the current and voltage reach their maximum values at the same time.

►**RMS current and voltage**. The RMS values of current and voltage (I and ΔV) are related to the maximum values of these quantities (I_m and ΔV_m) by $I=I_m/\sqrt{2}$ and $\Delta V=\Delta V_m/\sqrt{2}$. The RMS voltage across a resistor is related to the RMS current through the resistor by Ohm's law, $\Delta V_R = IR$.

►If an AC circuit consists of a generator and a capacitor, the voltage lags behind the current by 90°. That is, the voltage reaches its maximum value one quarter of a period after the current reaches its maximum value.

The impeding effect of a capacitor on current in an AC circuit is given by the **capacitive reactance X_C**, defined as

$$X_C = \frac{1}{2\pi fC}$$

(f = frequency, C = capacitance) The RMS voltage and RMS current for a capacitor are related by $\Delta V_C = I X_C$.

►If an AC circuit consists of a generator and an inductor, the voltage leads the current by 90°. That is, the voltage reaches its maximum value one quarter of a period before the current reaches its maximum value.

The effective impedance of a coil in an AC circuit is given by the **inductive reactance**, X_L, defined as

$$X_L = 2\pi fL$$

(f = frequency, L = inductance) The RMS voltage and RMS current for an inductor are related by $\Delta V_C = I X_C$.

►In an RLC series AC circuit, the applied RMS voltage, ΔV, is related to the RMS voltages across the resistor (ΔV_R), capacitor (ΔV_C) and inductor (ΔV_L) by

$$\Delta V = \sqrt{(\Delta V_R)^2 + (\Delta V_L - \Delta V_C)^2}$$

If an AC circuit contains a resistor, an inductor, and a capacitor, the limit they place on the current is described by the impedance, Z, of the circuit, defined as

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

The relationship between the RMS voltage supplied to an RLC circuit and the RMS current in the circuit is $\Delta V = IZ$.

►In an RLC series AC circuit, the applied RMS voltage and current are out of phase. The phase angle, ϕ, between the current and voltage is given by

$$\tan\phi = \frac{X_L - X_C}{R}$$

The **average power** delivered by the generator in an RLC series AC circuit is

$$Pav = I\,\Delta V \cos\phi$$

The constant $\cos\phi$ is called the **power factor**.

►**Electromagnetic waves** were predicted by James Clerk Maxwell and later generated and detected by Heinrich Hertz. These waves have the following properties:

1. Electromagnetic waves are transverse waves, because the electric and magnetic fields are perpendicular to the direction of travel.

2. Electromagnetic waves travel with the speed of tight.

3. The ratio of the electric field to the magnetic field in an electromagnetic wave equals the speed of light, E/B = c.

4. Electromagnetic waves carry energy as they travel through space. 'The average power per unit area is

$$\frac{P_{av}}{A} = \frac{E_m B_m}{2\mu_0}$$

where E_m and B_m are the maximum electric and magnetic fields.

5. The speed c, frequency f, and wavelength λ of an electromagnetic wave are related by $\lambda f = c$.