Duke University
Department of Physics

Physics 271 Spring Term 2017

WUN2K FOR LECTURE 4

These are notes summarizing the main concepts you need to understand and be able to apply.

- "AC" stands for "alternating current" (in contrast to "DC" which stands for "direct current"). Strictly it refers to *sinusoidal* time dependence $y(t) = A\cos(\omega t + \theta)$, where y is voltage or current, A is amplitude, ω is angular frequency, and θ is a phase set by initial conditions, of current and voltage in a circuit with a time-average of zero, although we often use "AC" to refer more generally to any circuit with time-dependent behavior. The behavior will often be *periodic* (repeating in time) but could also show *transients* (non-repeating behavior). It's possible to have a superposition of DC (constant voltage or current) and AC behavior.

- *Capacitance* is a property of an object, and quantifies its ability to hold a charge separation $+Q$ and $-Q$ for a given potential difference V: $C = Q/V$. The canonical capacitor is a set of parallel conducting plates (which is a configuration that tends to have large capacitance). A real-life parallel plate capacitor often has a dielectric in between its plates, and $C = \frac{\kappa\epsilon_0 A}{d}$ for an ideal such capacitor, where κ is the dielectric constant, ϵ_0 is the permittivity of free space, A is the area of the plates and d is the separation of the plates.

- *Inductance* (strictly, "self-inductance") is a property of an object, and quantifies its ability to resist a change in current (according to Faraday's Law and Lenz's Rule). For a changing current, the potential difference V across inductor L is $V = L\frac{dI}{dt}$. A solenoid is the canonical inductor.

- Kirchoff's Laws still work for time-dependent circuits (because they are based on conservation of charge and energy, which are true at every moment in time). One can solve circuits with combinations of L, R, and C by setting up differential equations using Kirchoff's Loop rules, the expressions for potential drop across these elements, and $I = dQ/dt$. The solutions to these differential equations will give you $V(t)$ and $I(t)$, with the initial conditions specifying a unique solution. Without any driving sources:

  - LR and RC series circuits exhibit exponential decay of V and I.
  - LC circuits exhibit sinusoidal oscillation (energy sloshes between the capacitor and the inductor).
  - LRC circuits show a combination of sinusoidal and exponential decay behavior: they act like damped oscillators, with the oscillations depending on the relative amount of energy storage (capacitance/inductance) versus dissipation (resistance) in the circuit.

  Note that these circuits have an exact mechanical analog: a mass on a string with damping gives exactly the same differential equations and behavior!