Duke University
Department of Physics

Physics 271 Spring Term 2017

WUN2K FOR LECTURE 13

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

- Diodes have a number of useful applications. You don't need to memorize these, but understand the basic behavior (which can be understood in our simplified model of diodes as one-way current valves) and be able to analyze the function of circuits like these.
  - *Voltage dropper*: set specific constant voltage level with V_{pn} drops.
  - *Clamp*: sets a DC level for a circuit with a capacitor.
  - *Clipping circuit*, or voltage limiter: limits voltage swing.
  - *Inductive surge protection:* protects a switch from inductive surge by redirecting current.
- *Transistors* are *active* solid-state devices— they allow manipulation of energy flow in a circuit (and they are very tiny). They can be used as switches, to turn current on and off. They are also used commonly as amplifiers, to increase and decrease current levels as desired.
- *Bipolar transistors* are usually made from silicon (sometimes germanium) configured as an npn or pnp sandwich of doped material. It's helpful to think of them as two adjacent diode junctions (although in practice they may have different geometry). We'll be discussing npn transistors only, as these are the most common; pnp transistors can be treated similarly just with some changes of sign.
- The npn transistor sandwich consists of a *collector* (C),a *base* (B) and an *emitter* (E). The base tends to be weakly doped with respect to the collector and emitter. In normal transistor operation, the base-emitter

junction is forward-biased, and the base-collector junction is reverse-biased. A small current flows from base to emitter; a large current flows from collector to emitter.

- Physically, what's going on is that electrons diffusing from the emitter to the base (with the diffusion enabled by the base-to-emitter bias voltage) drift through the base towards the collector; when they get to the large potential difference at the base-collector junction they get "kicked on through". Some of the electrons from the emitter recombine with holes in the base, and the base current replenishes the the holes. So long as the base-emitter junction is fully forward-biased (no depletion region on that side), the emitter to collector current tends to be greater than the base current by a constant factor of about 100.

- The I_c vs V_{ce} curve of a typical bipolar transistor shows a sharp turn-on followed by a fairly flat plateau in the BE forward-biased regime. This flat region is the normal operation regime, and the near-constant value of I_c in that region depends on I_c in a nearly-linear way: $I_c = \beta I_b$ to a good approximation, where β is called the *static forward current transfer ratio*. This behavior is the key to transistor action: one can control I_c by changing I_b. The circuit can be modeled by a current source in series with a forward-biased diode, in which the current is proportional to base current entering the + side of the diode.