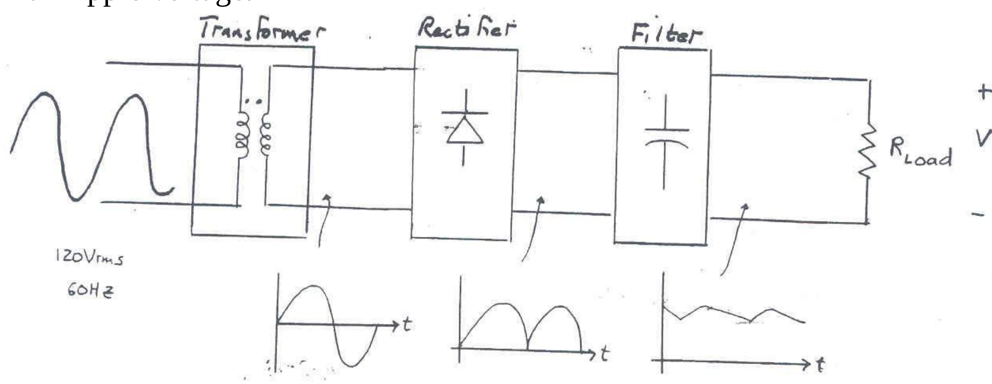
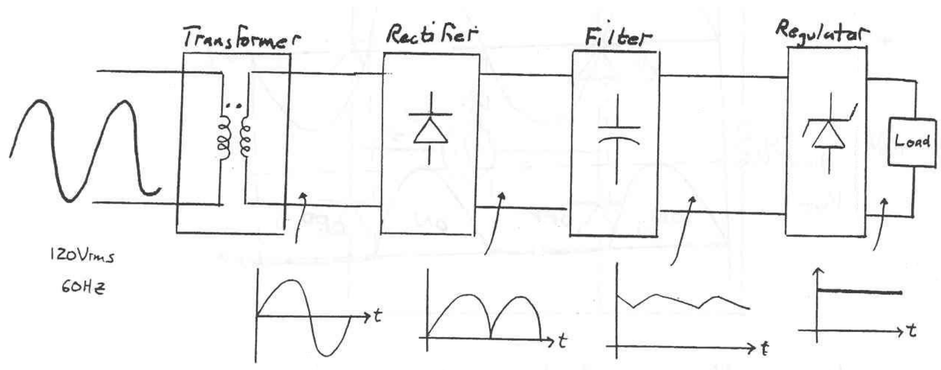
Lesson 35: Zener diodes

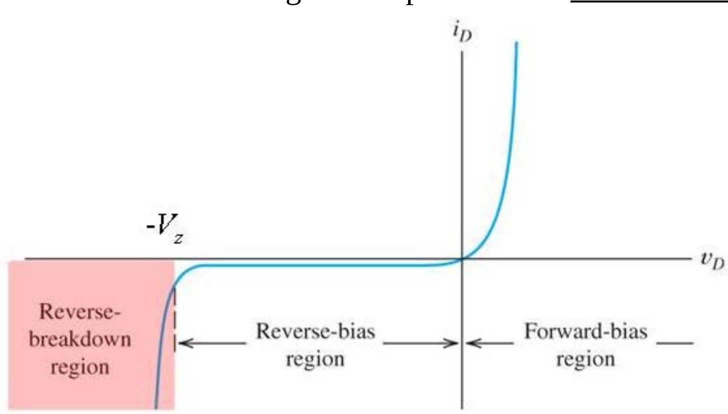
Overview
In the quest to construct a dc power supply, so far we're able to produce "dc-like" output with a small ripple voltage.



However, many electronic loads require a more precise dc voltage with even less ripple.
We need to add a regulator that will maintain a constant voltage for a range of loads.



Zener diode
The simplest such device is a specially designed diode called a ________ diode.
Recall the diode current-voltage characteristic.
The zener diode is designed to operate in the ___________ (avalanche) ___________ region.



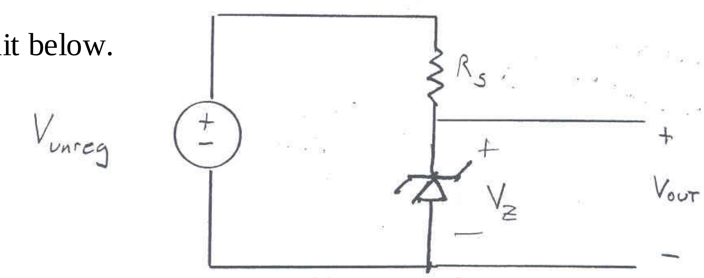
Zener diodes are manufactured to provide specific values of V_z.
We differentiate them from "regular Joe" diodes using the circuit symbol below.

(draw zener diode symbol here)

Note that we ____________ the normally indicated diode voltages and currents and re-label them V_z and i_z.

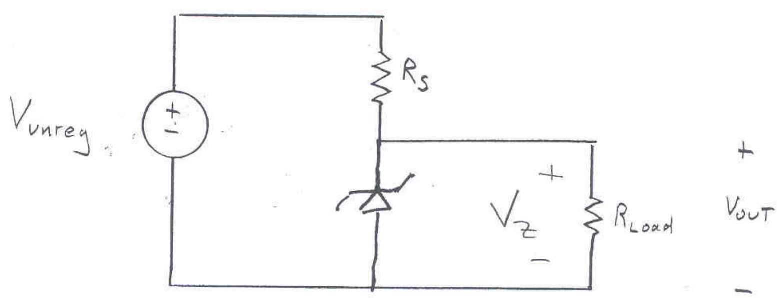
Voltage regulator (unload)
Consider the operation of a zener diode in the circuit below.

- If $V_{\text{unreg}} > V_z$, the what is V_{out}?



Voltage regulator (with load)
Now consider the regulator circuit with a load.

- How do we determine if the zener diode is operating in the breakdown region?



Analysis
Assume that it *is* in breakdown and replace it by a source voltage with value V_z.

- How can we solve for i_z?

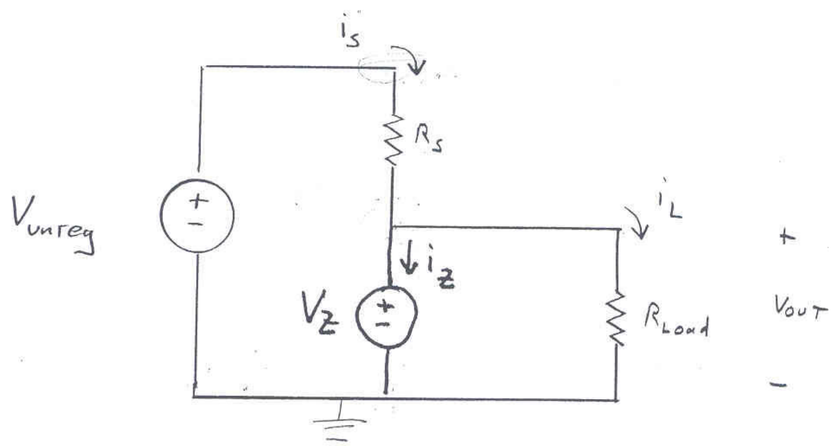
Using nodal analysis

i_L =

i_s =

Then, then from KCL

i_z =



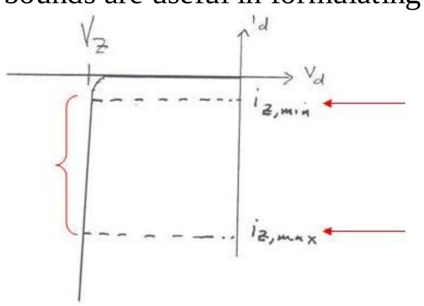
Zener diode limitations

Two factors restrict the zener current i_z

- We need sufficient current to keep the diode operating in the reverse breakdown region (beyond the zener "knee")
- The zener current cannot be too big (lest we _______ the diode).

Zener "rules of thumb"

The following bounds are useful in formulating our design



$i_{z,\min} =$

$i_{z,\max} =$

Choosing V_{unreg} & R_s

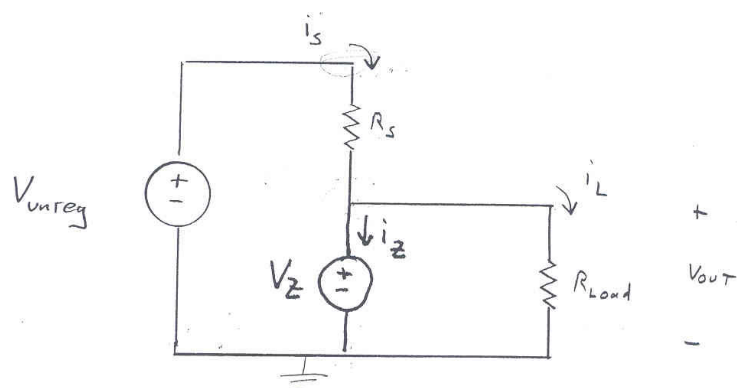
1. V_z set by desired _____ (what we want)
2. V_{unreg} will vary between a peak and minimum value (ripple voltage).
3. R_{load} varies from an open circuit ($R_{\text{load}} = \infty$) down to some minimum value $R_{\text{load,min}}$.

We also need to keep the diode operating in breakdown and prevent it from turning into smoke.

Recall our expression for the zener diode current.

$$i_z = i_s - i_L$$

$$= \frac{V_{\text{unreg}} - V_z}{R_s} - \frac{V_z}{R_{\text{load}}}$$



Max/min currents are given

$$i_{z,\max} = \frac{V_{\text{unreg,max}} - V_z}{R_s} - \frac{V_z}{R_{\text{load,max}}}$$

$$i_{z,\min} = \frac{V_{\text{unreg,min}} - V_z}{R_s} - \frac{V_z}{R_{\text{load,min}}}$$

where $R_{\text{load,min}} < R_{\text{load}} < R_{\text{load,max}}$

These constraints give us 2 equations, 3 unknowns (R_s, $V_{\text{unreg,max}}$, $V_{\text{unreg,min}}$)

Example Problem 1

Suppose you choose a 0.5 W, 9 V zener diode for a load application where 300-Ω < R_{load} < ∞. Determine the range of V_{unreg} for R_s = 20-Ω, 100-Ω , and 500-Ω .