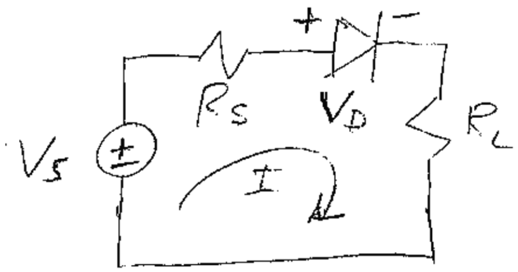
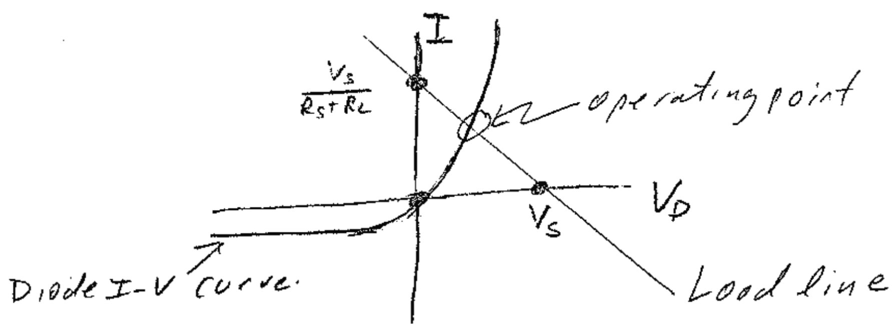
Load line analysis for a diode circuit (I versus V_D)



$$-V_S + IR_S + V_D + IR_L = 0$$

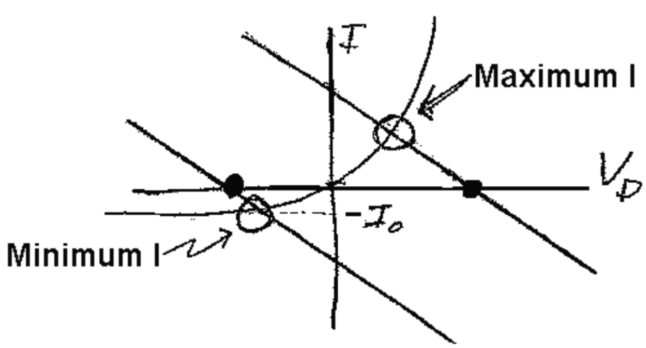
$$\therefore I = \frac{V_S - V_D}{R_S + R_L}$$

A plot of the current, I, versus the voltage drop across the diode, V_D, will yield a straight line, called the "Load Line", of possible values of current flow in the circuit. We form the line by noting that I = 0 at $V_D = V_S$ and that $I = V_D/(R_S + R_L)$ at $V_S = 0$, as shown below:

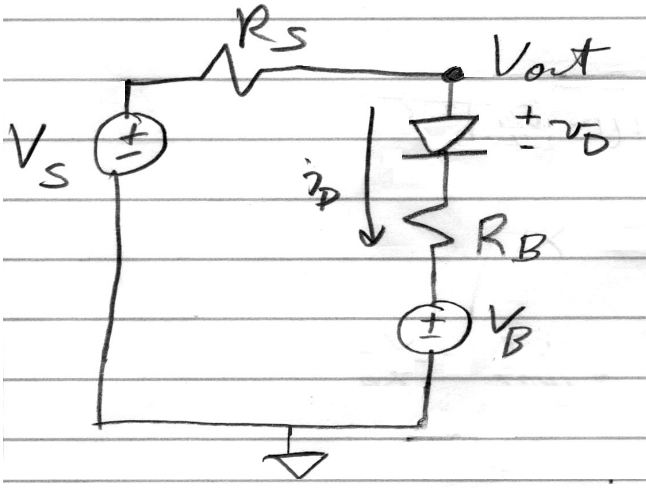


The so called "Operating Point" is found through the second equation that relates I and V_D, namely the diode equation $I = I_0[\exp(V_D/K_BT) - 1]$. The I-V relation for the diode will cross the Load Line at the Operation Point (open circle above). This provides a graphical solution for the currents and voltages in a circuit with a diode.

What happens when the source voltage changes with time, i.e., $V_S = V_S(t)$? Here the Load Line varies with time; the slope is constant at $dI/dV = -1/(R_S + R_L)$ while the intercept shifts, as shown below. When $V_S(t)$ varies symmetrically around zero, as with the AC line, we see that the maximum positive value of $V_S(t)$ leads to the maximum current flow, while the maximum negative value of $V_S(t)$ leads to a minimal current, so that asymptotically $I(V_S \to -\infty) \to -I_0$. The rhythmic change in Operating Point (open circles below) is the basis of the half-wave rectifier that you constructed.



Just to emphasize what we learned, let's look at a second slightly more complicated load-line situation in which we have two supplies, V_S and V_B. We ignore the resistance of the diode, r_D, calculated as $r_D = (dV_D/dI)^{-1}$, in writing Kirchhoff's voltage law:



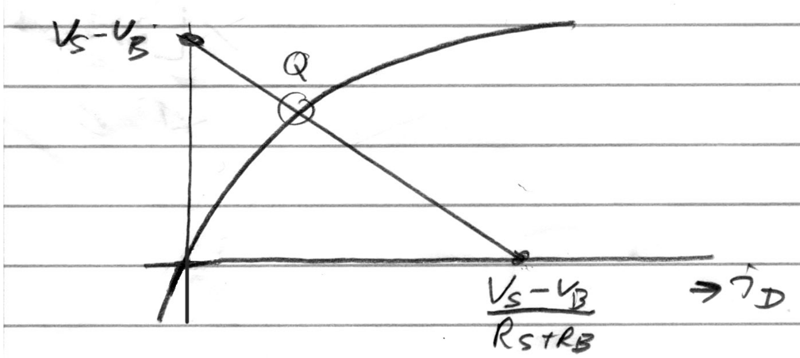
$$i_D = I_0 \left(e^{e v_D/kT} - 1\right)$$

$$r_D = \frac{kT}{eI_0} \Big/ \left(1 + i_D/I_0\right)$$

$$'' = \underbrace{\frac{kT}{eI_0}}_{1k\Omega} \underbrace{e^{-e v_D/kT}}_{<<1}$$

$$-V_S + R_S i_D + v_D + i_D R_B + V_B = 0$$

$$\underbrace{v_D}_{\frac{kT}{e} \log\{1 + i_D/I_0\}} = (V_S - V_B) - i_D (R_S + R_B)$$



For a value of R_B that is too large, the operating or Q-point moves to the left and, if it moves too close to the origin, the diode conducts poorly (and r_D cannot be neglected).