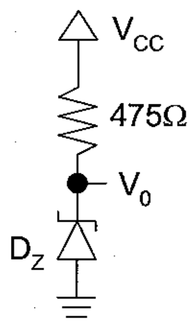
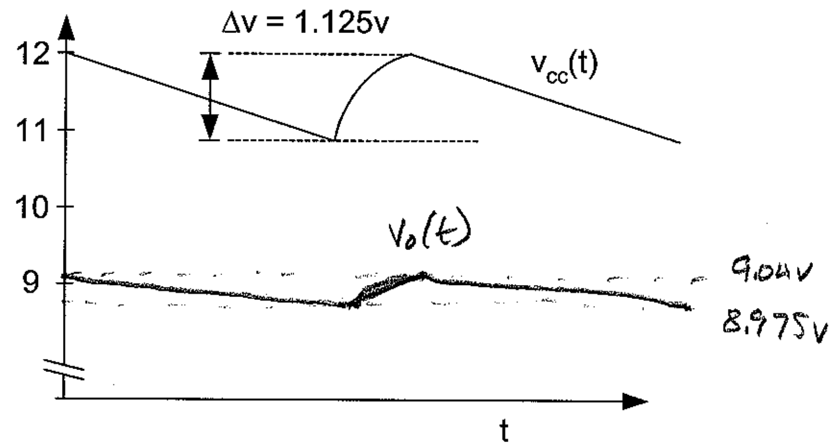
Assume that the circuit below is used as a voltage regulator for a DC power supply, whose output is V_{cc}. The Zener diode parameters are $V_z = 9$ volts when $I_z = 5$mA and $r_z = 25\ \Omega$. A sketch of Vcc is also given, which will be used in part (d) of this problem.





For this problem,

(a) Sketch a plot of the diode current versus diode voltage (i_z vs. v_z) on the graph on the next page for $v_z < 0$ (the reverse bias regime). Label the axes and indicate where V_{zo} is on your graph. Note that the polarity and direction of the current through the diode are indicated in the diode diagram below and that these may be opposite to those in the circuit.

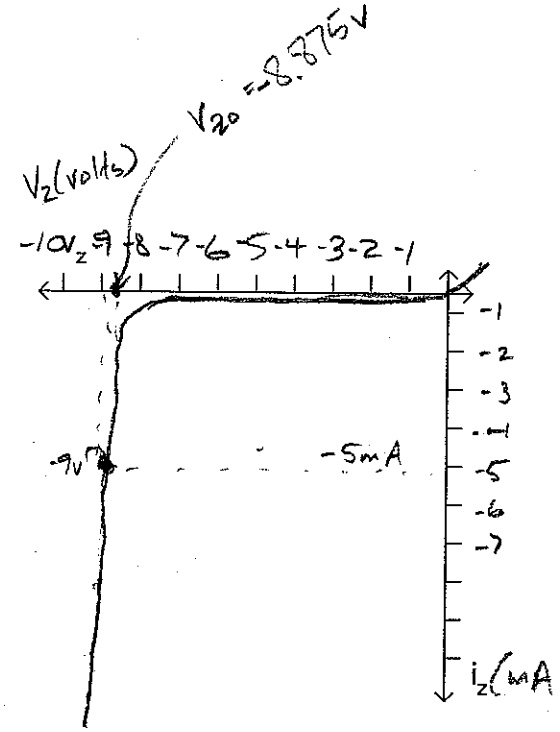
(b) Find the current flowing through the diode in the circuit when $V_{cc} = 12$ volts by using the piecewise-linear model for the Zener diode.

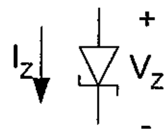
(c) What is V_o when $V_{cc} = 12$volts? When $V_{cc} = 10.875$ volts?

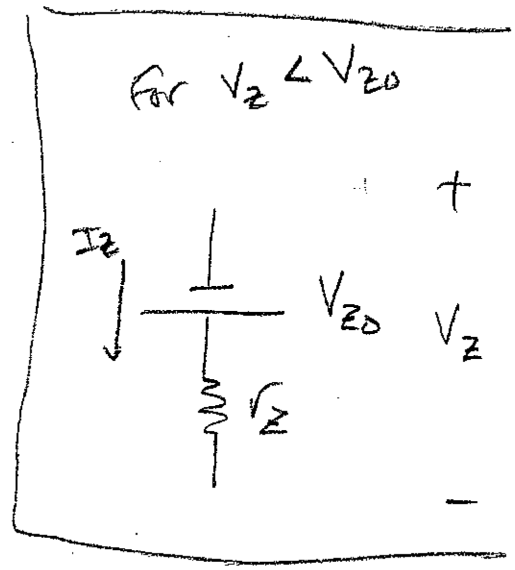
(d) Sketch $v_o(t)$ in the figure above alongside the sketch of $v_{cc}(t)$.

Bonus: what is the smallest load resistor value that can be connected to this circuit at V_o so that at least 0.5mA of current still flows through D_z?

(a)







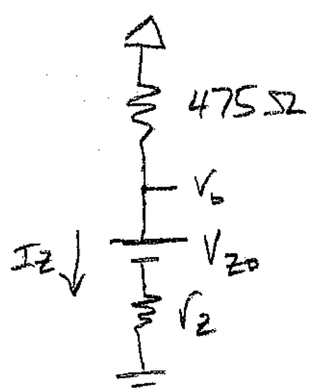
(b) since $-V_z = -V_{zo} - I_z r_z$ (from graph) or $V_z = V_{zo} + I_z r_z$

$$9 \text{ volts} = V_{zo} + 5mA \cdot 25\Omega$$

$$V_{zo} = 9 \text{ volts} - 125mV$$

$$= 8.875V$$

So



$$I_z = \frac{V_{cc} - V_{zo}}{475\Omega + 25\Omega}$$

$$= \frac{12V - 8.875V}{500\Omega}$$

$$= 3.125V \cdot \left(\frac{2}{1000\Omega}\right)$$

$$\boxed{I_z = 6.25mA}$$

(c) $V_o = V_{Z0} + I_Z r_Z$

$= 8.875\text{V} + 6.25\text{mA} \cdot 25\Omega$

$= 8.875\text{V} + (6 + 0.2 + 0.05)\text{mA} \cdot 25\Omega$

$= 8.875\text{V} + 150\text{mV} + 5\text{mV} + 1.25\text{mV}$

$= 8.875\text{V} + 0.15625\text{V}$

$= 9.04325\text{V}$

$\boxed{\approx 9.04 \text{ volts}}$

for $V_{CC} = 10.875$ volts

$V_o = V_{Z0} + I_Z r_Z$

$I_Z = \dfrac{10.875 - 8.875\text{V}}{500\Omega} = \dfrac{2\text{V}}{500\Omega} = 4\text{mA}$

so

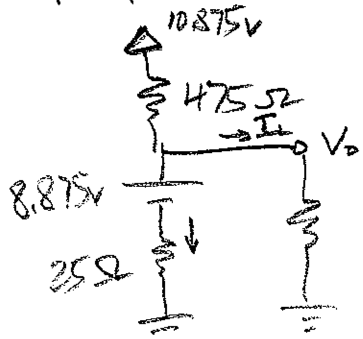
$V_o = 8.875\text{V} + 4\text{mA} \cdot 25\Omega$

$= 8.875\text{V} + 100\text{mV}$

$\boxed{= 8.975\text{V}}$

(d) see graph

bonus



when $V_{CC} = 10.875\text{V}$

$I_Z = 4\text{mA}$

if we want $I_Z > 0.5\text{mA}$

then $I_L < 3.5\text{mA}$

for $V_o \sim 9\text{V}$

$R_L > \dfrac{9\text{V}}{3.5\text{mA}} \approx 3\text{K}\Omega$