The diode equation —

Remembering the formula.

① It's exponential (rapid growth in forward region, flat in reverse region)

$\Rightarrow e^x$

x is related to voltage

② Crosses through **zero** at $V=0$

e^x is always positive

approaches zero for negative x.

is 1 for $x=0$

What is like e^x but $=0$ for $x=0$?

$\Rightarrow e^x - 1$

③ Now, scale it for "reverse saturation current"

so that is the value for negative x.

(above formula is $= -1$)

$\Rightarrow I_s\left(e^x - 1\right)$

④ x is related to voltage, but how?

$x = f(V) = \frac{V}{\text{some\_V\_reference}}$

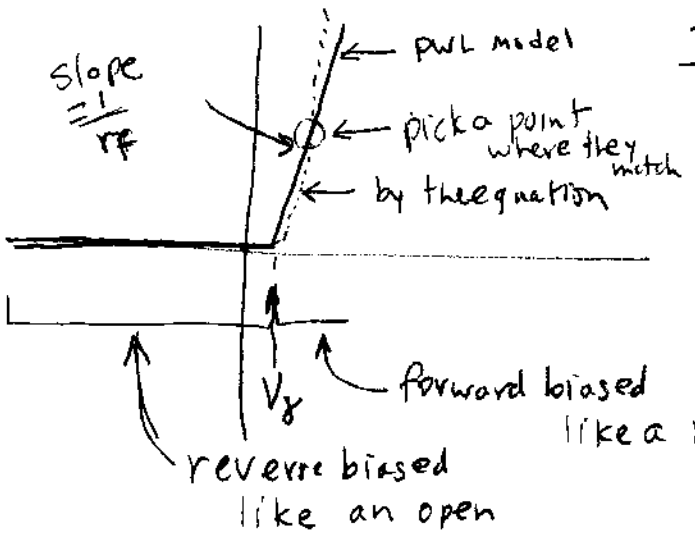
call the reference V_T (thermal voltage)

(and use n as a fudge factor)

$\Rightarrow I = I_s\left(e^{\frac{V}{nV_T}} - 1\right)$

Approximate model of a diode (1,3,2)

TC 2



It is close to this "piecewise linear model"

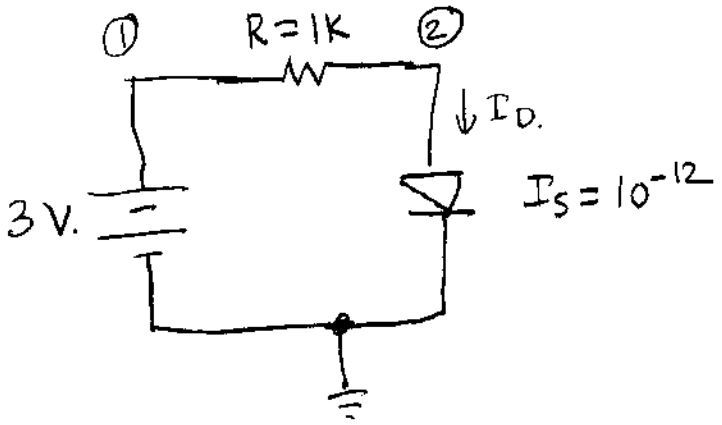
V_γ = turn-on voltage

r_f = forward resistance

↑ It varies, so measure at some point.

$$I = \begin{cases} 0 & V_D < V_\gamma \\ \dfrac{V_D - V_\gamma}{r_f} & V_D > V_\gamma \end{cases}$$

A circuit with a diode



What is V_D?

I_D?

Do nodal analysis at node 2.

Book uses a loop equation

$V_{battery} = V_R + V_D$

$$\frac{V_2 - V_1}{R} + I_S\left(e^{\frac{V_2}{V_T}} - 1\right) = 0$$

$$\frac{V_2 - 3}{1000} + 10^{-12}\left(e^{\frac{V_2}{.026}} - 1\right) = 0$$

How to solve this? → iteration.

Solve for V_2

$$V_2 - 3 + 10^{-9}\left(e^{\frac{V_2}{.026}} - 1\right) = 0$$

$$V_2 = 3 - 10^{-9}\left(e^{\frac{V_2}{.026}} - 1\right) = 0$$

Guess -- $V_2 = 1$

Iterate -- $V_2 = -50$

$V_2 = 4$ → diverges

Don't use this method.

Try bisection --

Guess	f(x)
1	5×10^7
0	−3
.5	−2.27
.75	3368
.625	25
.562	.0022
.531	−1.7
.546	−1.13
.554	−.65

$$f(x) = V_2 - 3 + 10^{-9}\left(e^{\frac{V_2}{.026}} - 1\right)$$

↑ Loop equation.

V = 0

between .554 and .562

call it .56.

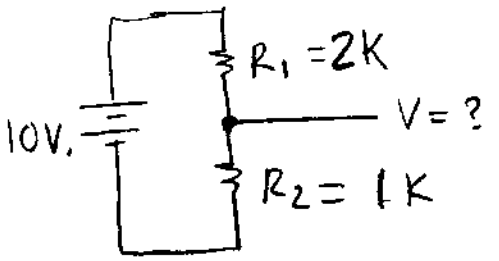
So → V = .56

I = .0022596

(using Octave)

Load line analysis

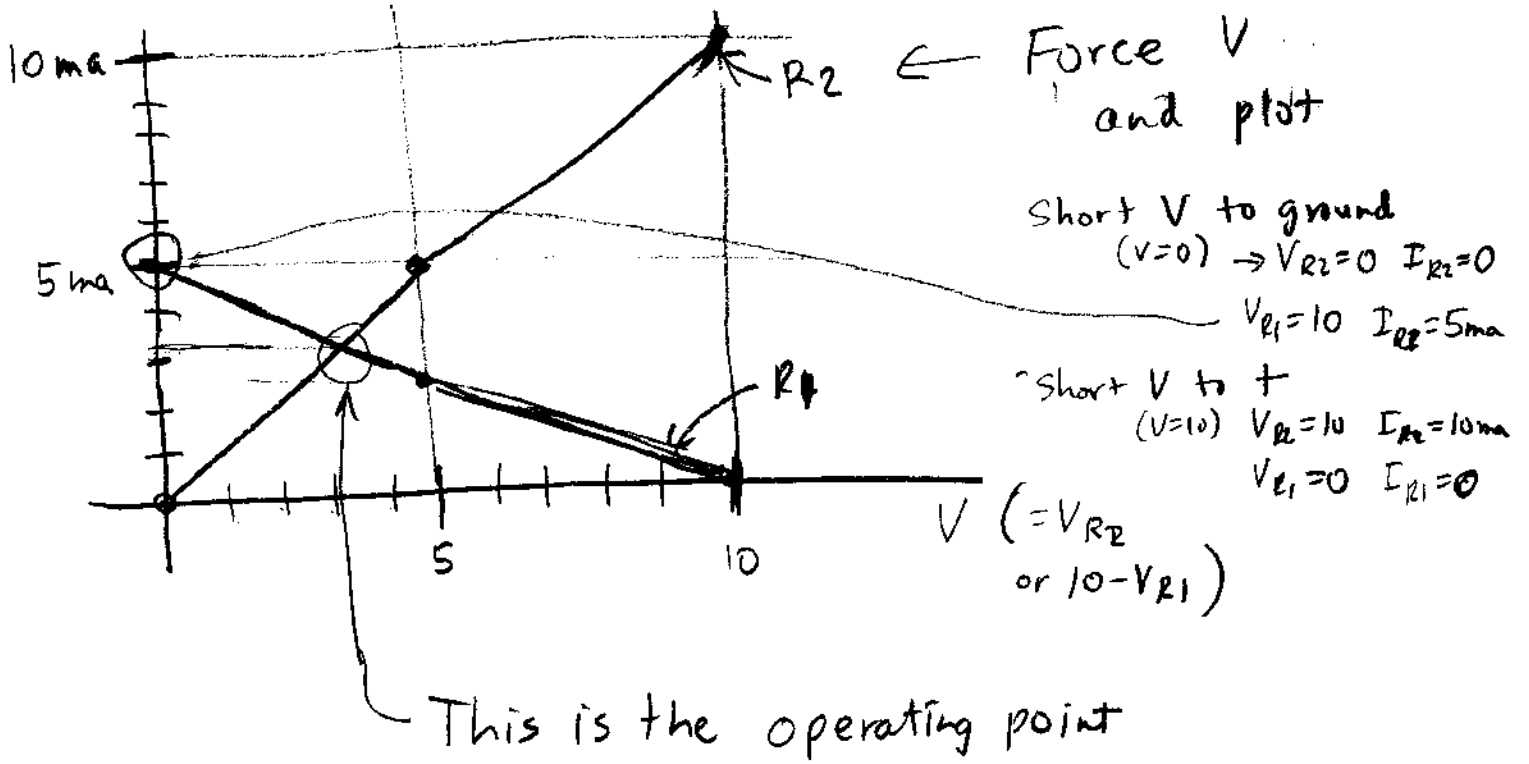
Try a simple circuit first..



The voltage V is somewhere between 0 and 10 volts.

Plot ① I_{R_2} Vs. V. → $V = V_{R_2}$

② I_{R_1} Vs. V. $V = 10 - V_{R_1}$



← Force V and plot

Short V to ground (V=0) → $V_{R_2}=0$ $I_{R_2}=0$

$V_{R_1}=10$ $I_{R_2}=5ma$

Short V to + (V=10) $V_{R_2}=10$ $I_{R_2}=10ma$

$V_{R_1}=0$ $I_{R_1}=0$

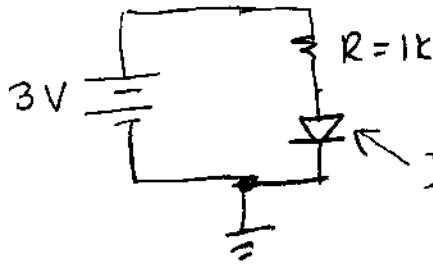
This is the operating point

$V \approx 3.3$ V

$I \approx 3.3$ ma

Read it from the graph.

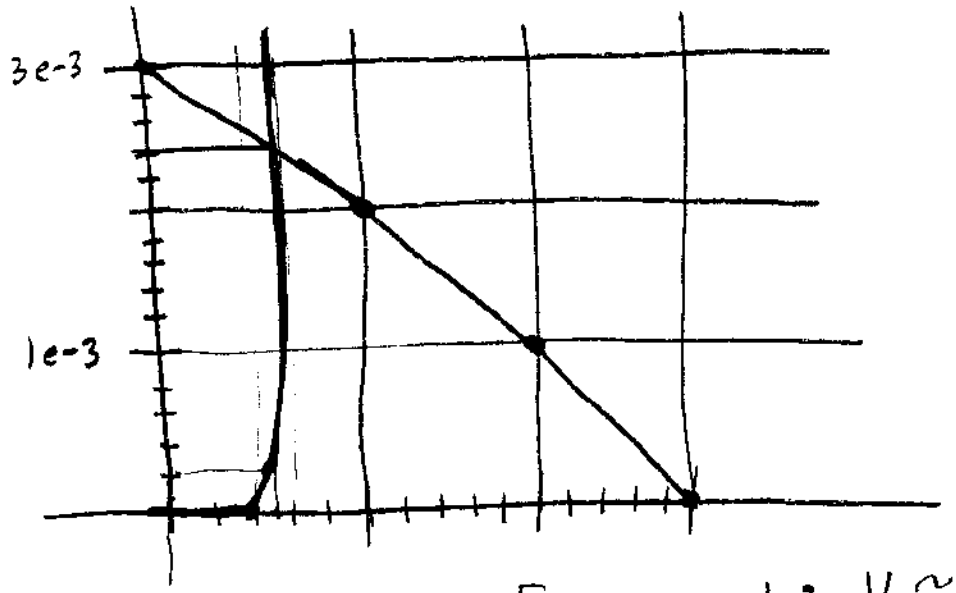
Load line analysis with diode



$$I = I_s\left(e^{\frac{V}{V_T}} - 1\right)$$

$$= 10^{-12}\left(e^{\frac{V}{V_T}} - 1\right)$$

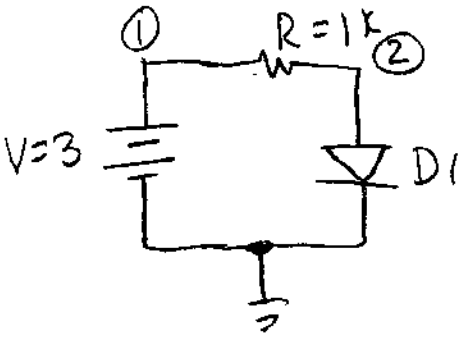
V	I
0	0
.1	4.6e-11
.2	2.9e-9
.3	1 e-7
.4	4.8e-6
.5	2.24e-4
.6	1.5e-2
.7	4.9e-1
.8	2.3e+1
.9	1.1e+3
1.0	5.1e+4



From graph: $V \approx .55$

$I \approx 2.4$ ma

Simulation (1.3.3)



Spice netlist:

```
V1    1    0    DC  3
R1    1    2    1K
D1    2    0    MYDIODE
.model mydiode D  IS=1E-12
.print op V(D1) I(D1)
.OP
```

New for Diode

V = .55907

I = .0024409

Diode element:

D1 | 2 | 0 | mydiode

- D1: Label
- 2: Anode
- 0: Cathode
- mydiode: Name of model

nodes

Diode model statement:

.model | mydiode | D | parameters [IS, N, (others)]

- .model: always — this is a model
- mydiode: its name
- D: D for diode

Exercises (not to hand in)

Page	Exercise	
26	13, 14	
29	15	Do c first.
	16	
44	25	
	27	Some added complexity — node or mesh analysis.
	32	