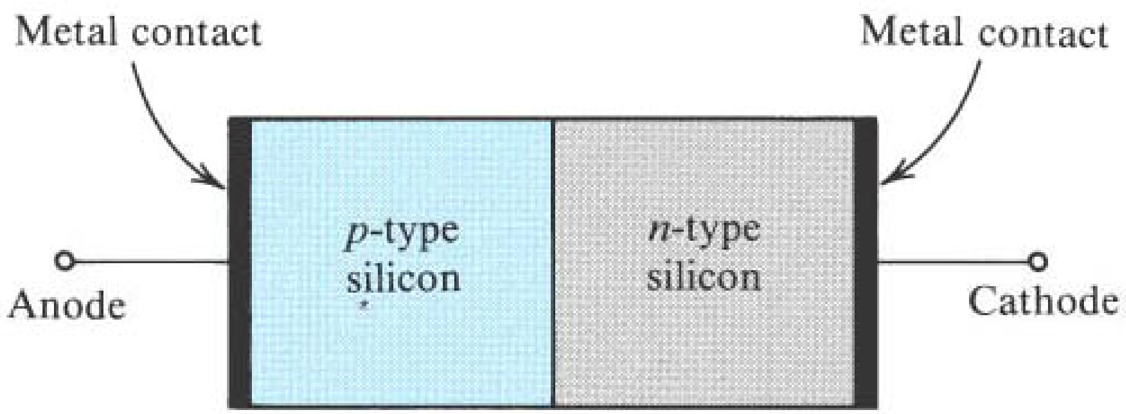
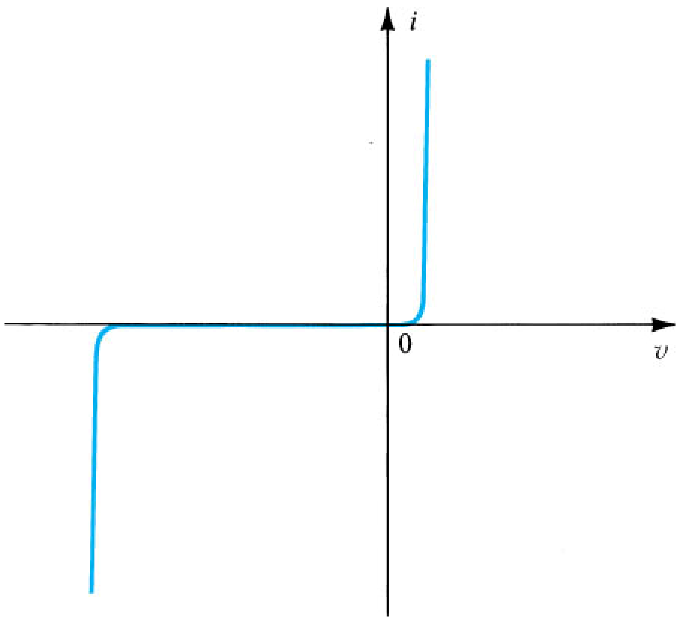
Lect. 5: PN Junction Diode (Razavi 2.2, 3.1)

What is a PN junction diode?





Questions:

I-V characteristics

Why the I-V characteristics?
What circuit applications?

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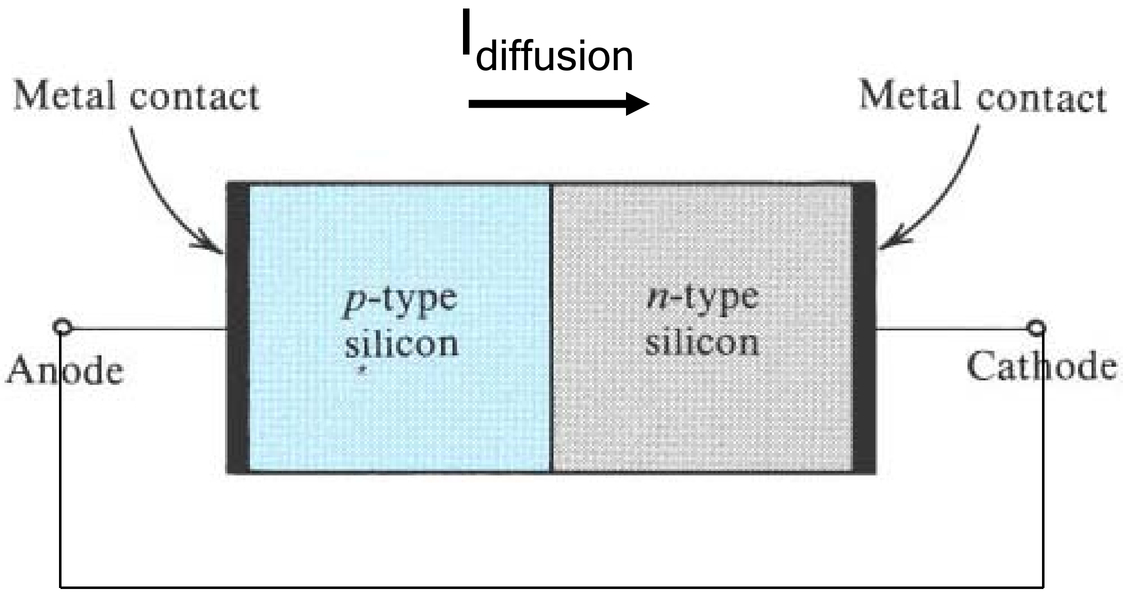
Do currents flow when two terminals are shorted?



Diffusion of holes (P to N) and electrons (N to P)

→ Diffusion currents (due to diffusion) to the right

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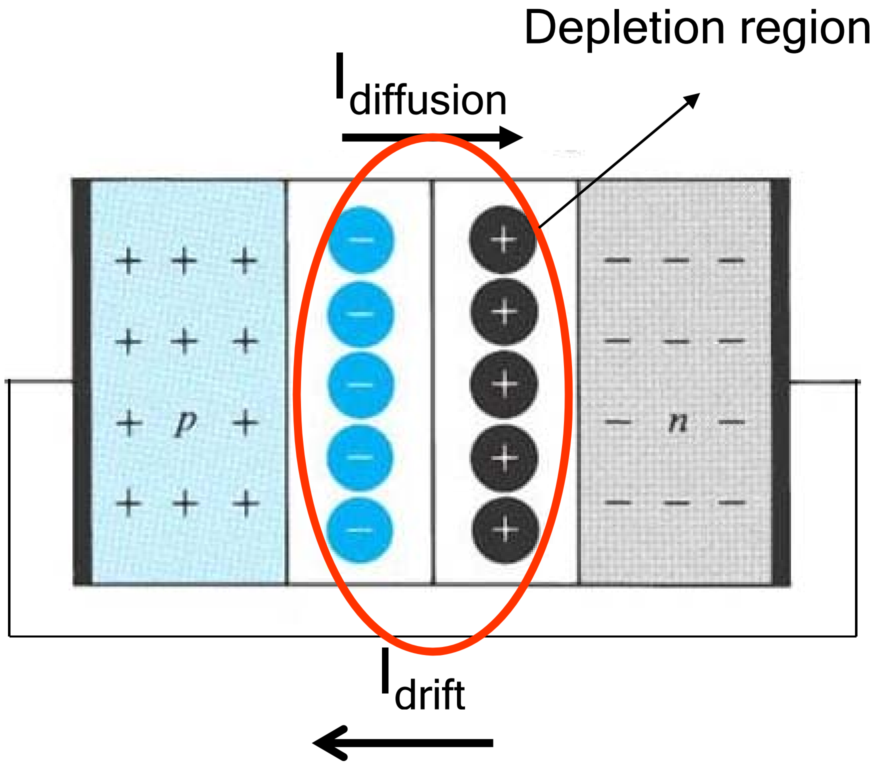

Diffusion causes depletion of carriers
➔ depletion region

Depletion layer provides built-in E-field

Built-in E-field produces drift current

$$I_{total} = I_{diffusion} + I_{drift} = 0$$

No currents due to balance between diffusion and drift currents

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With bias voltage,

Balance between diffusion and drift currents is broken.

V>0: Forward Bias

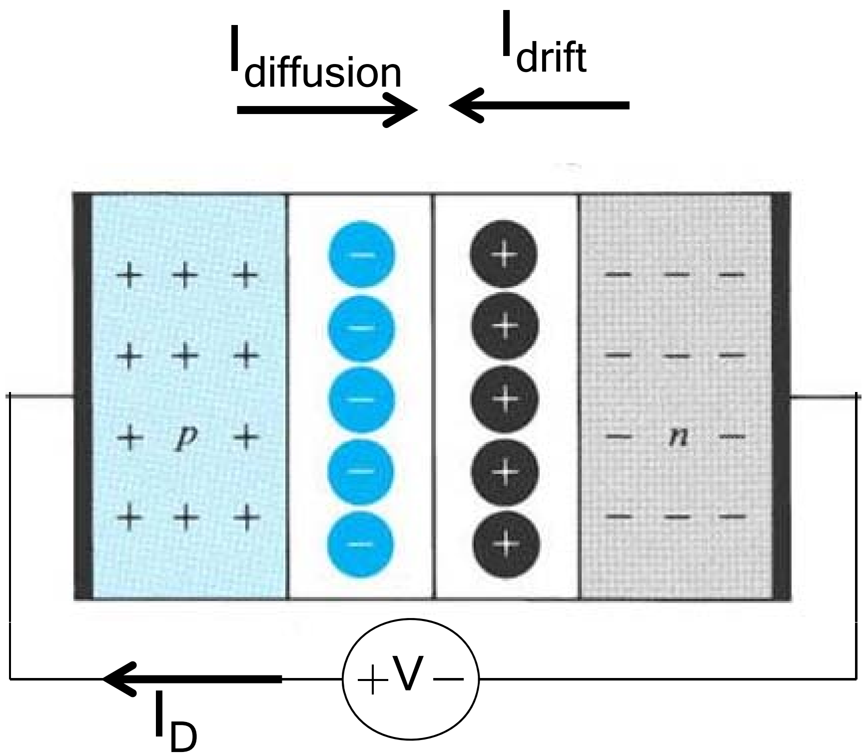
$I_{diffusion}$ >> I_{drift},

➔ I_D>0, very large currents if V is sufficiently large

V<0: Reverse Bias

$I_{diffusion}$ < I_{drift},

➔ I_D<0, but very little currents until breakdow



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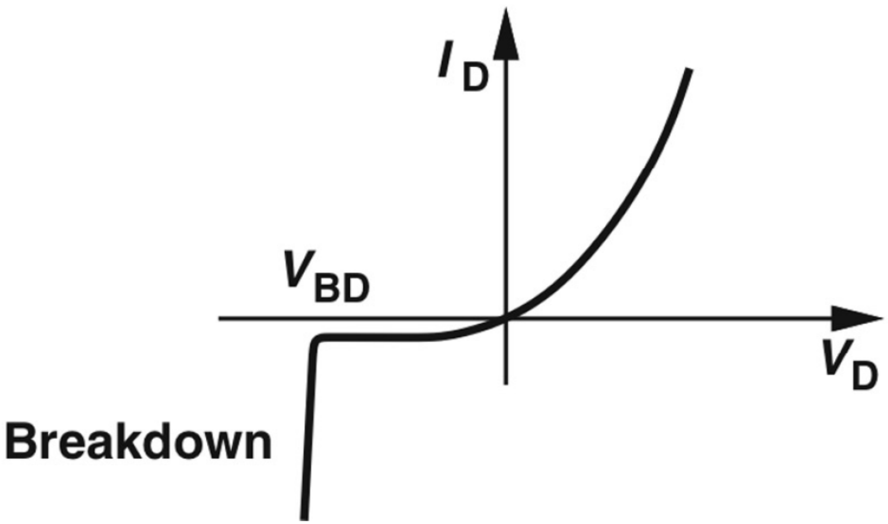
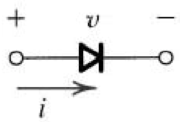
With more detailed analyses





$$i = I_S[\exp(v/V_T) - 1]$$

$$(v > -V_{BD})$$

I_S : saturation current

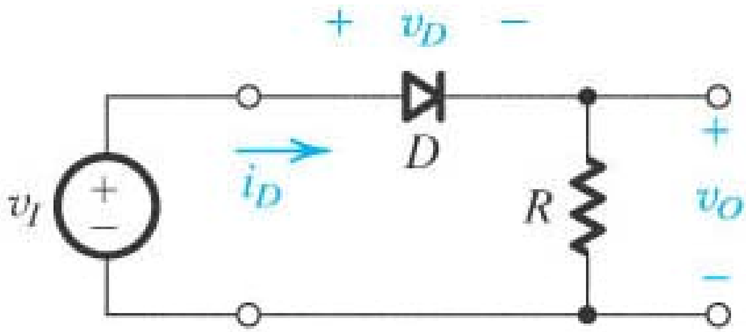
usually very small

V_T : thermal voltage

$$(= \frac{kT}{q} \sim 25\text{mV at Room Temp.})$$

V_{BD}: Breakdown voltage

Diode circuit analysis



(a)

What are v_D, $i_{D,}$, v_O as function of v_I?

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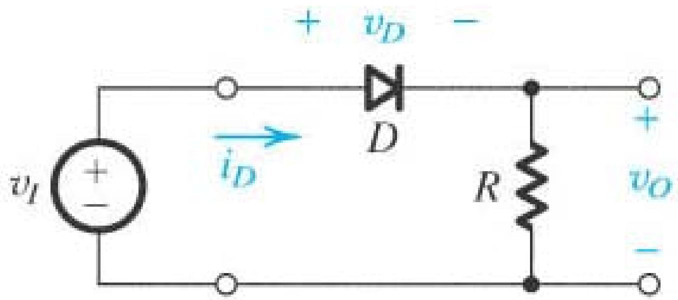

(a)

Node analysis: 3 unknows

$$v_I - v_D - v_O = 0$$

$$v_O = i_D \cdot R$$

$$i_D = I_S[\exp(v_D / V_T) - 1]$$

(Assume V_{BD} is very large)

Can we solve it?

Computers can ➔ SPICE

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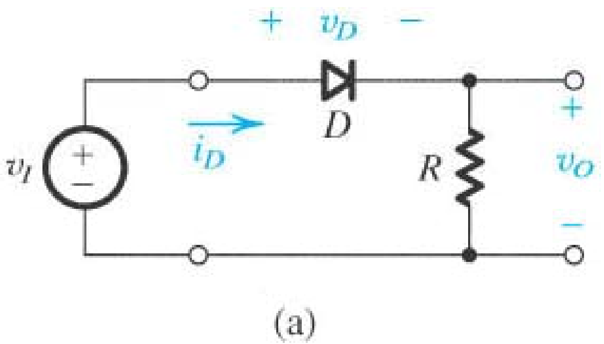
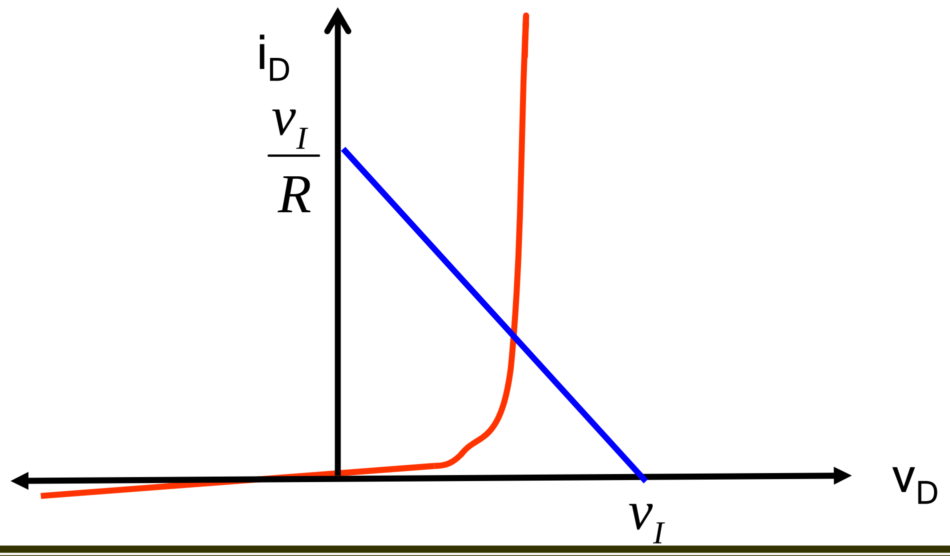
Graphical analysis (load line analysis)

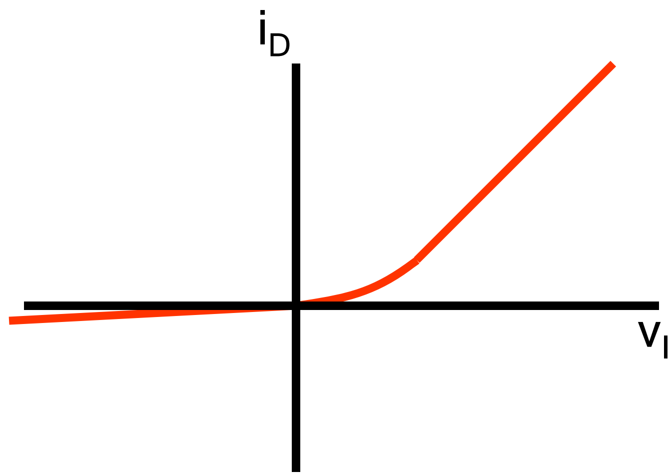


(a)

$$i_D = \frac{v_O}{R} = \frac{v_I - v_D}{R}$$

$$i_D = I_S[\exp(v_D/V_T) - 1]$$





Graph for every circuit problem?

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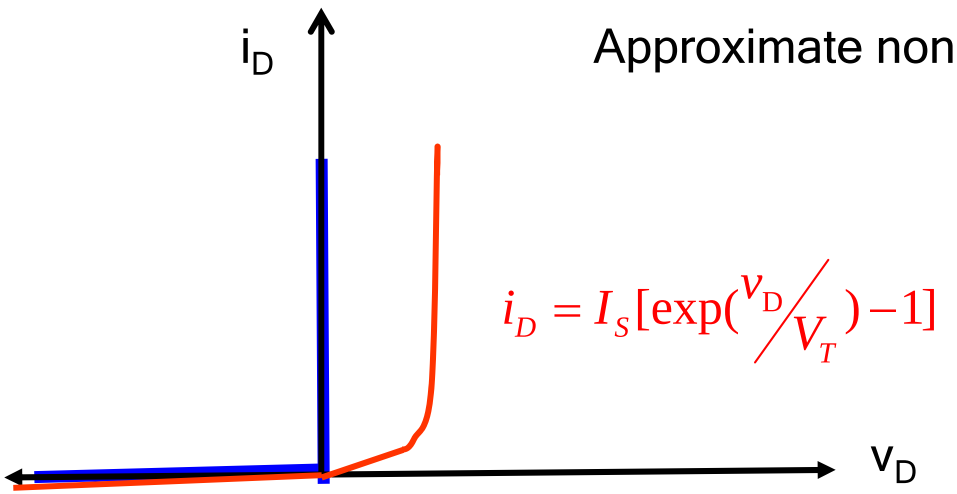
Approximate non-linear diode by linear circuit elements



Diode is either On (Short) or Off (Open)

$$\text{If } i_D > 0 \text{ (Diode On)},\ v_D = 0 \text{ (short)}$$
$$\text{If } v_D < 0 \text{ (Diode Off)},\ i_D = 0 \text{ (open)}$$

➔ Ideal diode model

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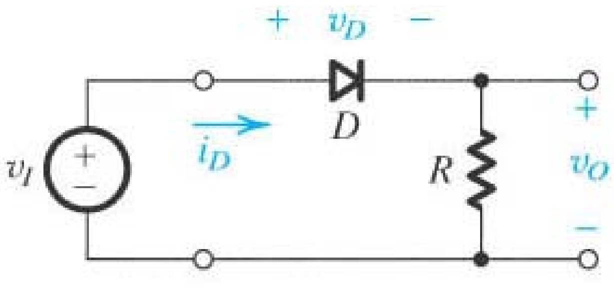


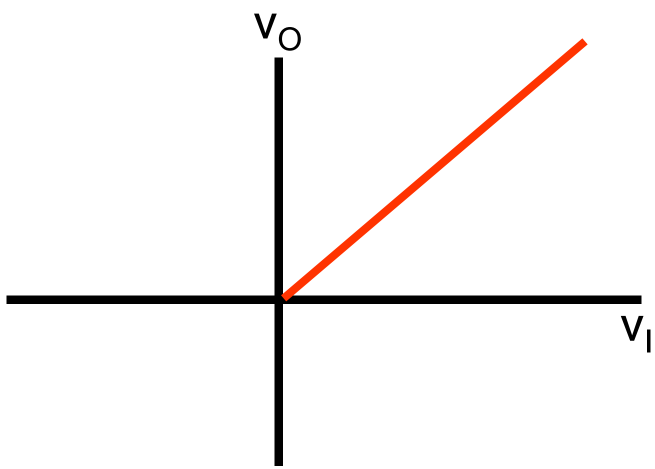
(a)

If $i_D > 0$ (Diode On), $v_D = 0$ (short)

If $v_D < 0$ (Diode Off), $i_D = 0$ (open)

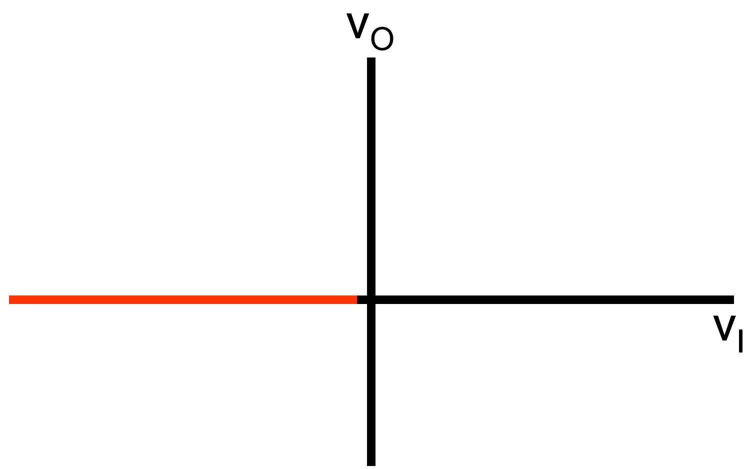
Assume diode on, $v_D = 0$, $v_O = v_I$

$$i_D = \frac{v_I}{R} > 0 \quad \therefore v_I > 0$$



Assume diode off, $i_D = 0$ (open) and $v_D < 0$

$$v_D = v_I - v_O < 0 \quad \therefore v_I < 0$$



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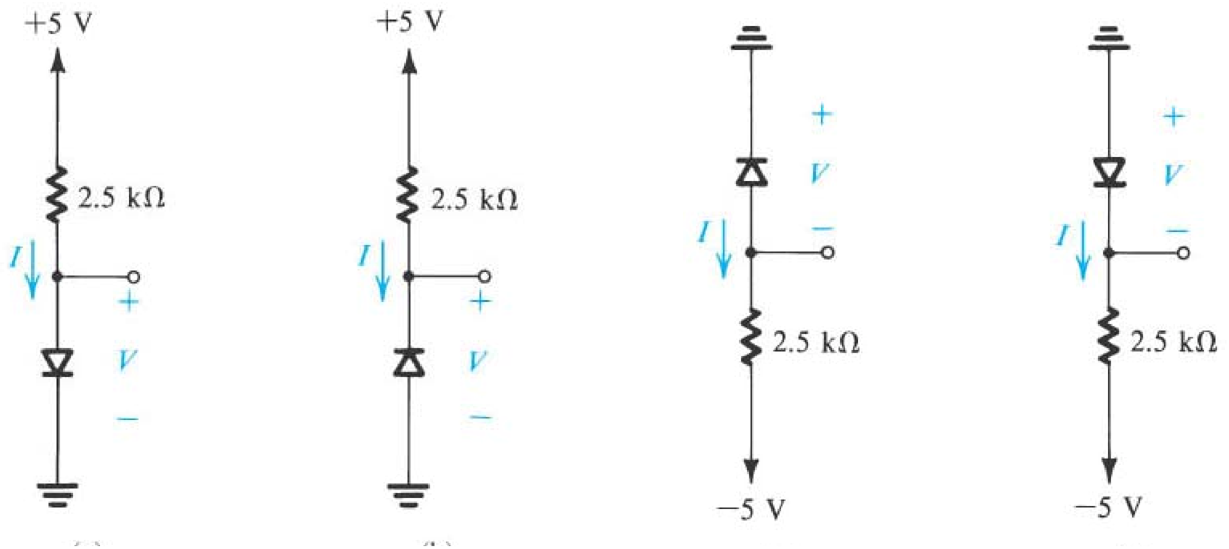
If $i_D > 0$ (Diode On), $v_D = 0$ (short)

If $v_D < 0$ (Diode Off), $i_D = 0$ (open)

Determine I, V using the ideal diode model



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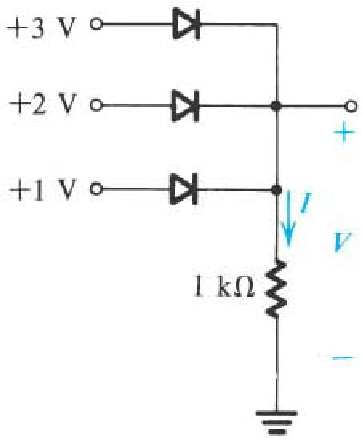

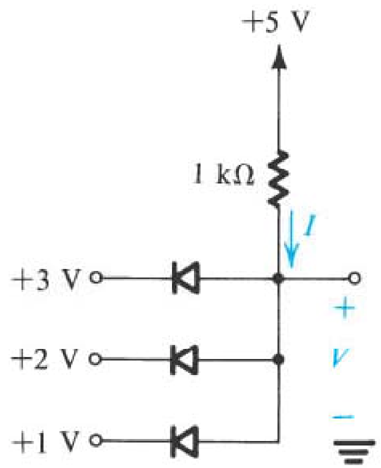

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Homework (Due on 9/14 before tutorial):

- Prob. 3.9 in Razabi