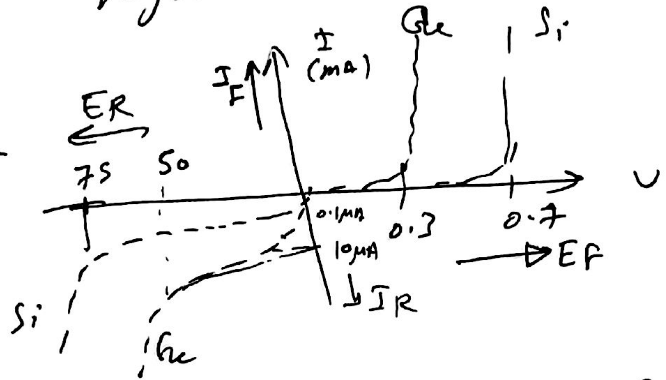
Semiconductor diodes

→ Diode is unipolar (one way device), with 2 terminals (anode, Kathode)

→ It has very low Resistance (at Forward Bias) & → S.C
  " high " (" Reverse "). → O.C

* diode ch/s



- I_R → minority charge carrier (reverse saturation current)
  It is unaffected By increase of Reverse Bias voltage.
- I_R < 1μA for Si & ≮ 10μA for Ge
- I_R may be neglected Compared to $\underline{I_F}$
  حيث تعتبر Reverse Biased diode كأنه open switch / insulator
- If ER (reverse voltage ↑) upto 75V (at Si) ∴ diode become in reverse **Breakdown** // diode destroyed unless there is a limiting Resistance for current Connected in series with diode

  الدايود يتدمر الا لو حطينا مقاومة توالي تحميه وتشيل الجهد الزيادة

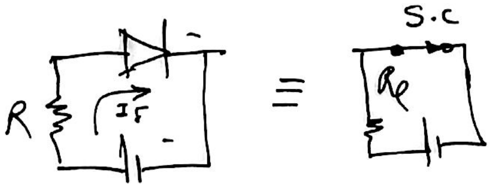
- ch/s of Ge ⟺(like) ch/s of Si

	Si	Ge
Forward Volt. V_F	0.7	0.3
I_R	< 1μA	10μA
V_{BB}	75V	50V

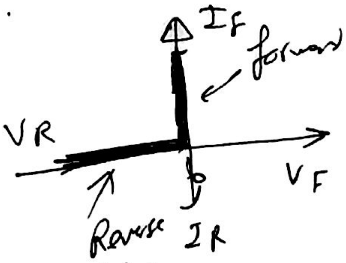
3 diode approximations (equivalent ckt)

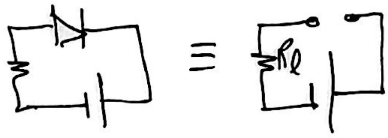
- ideal
- practical
- complete diode Model

1) ideal



Switch on $V_D=0$



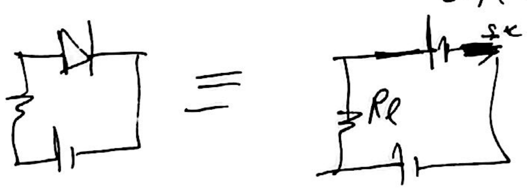


switch off $i_D=0$

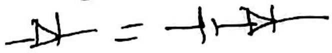
$$I_F=\frac{V_{Bias}}{R_{limit}} , \quad I_R=0$$

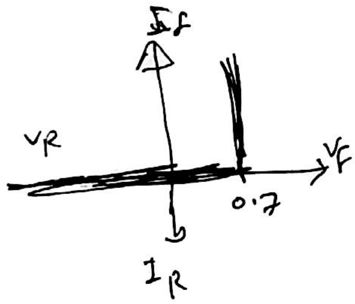
$V_R=V_{bias}$

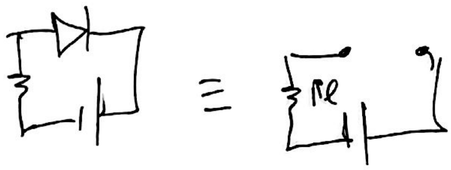
2) Practical



ال ideal + مصدر جهد عكسي ضد الدايود



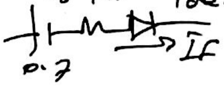


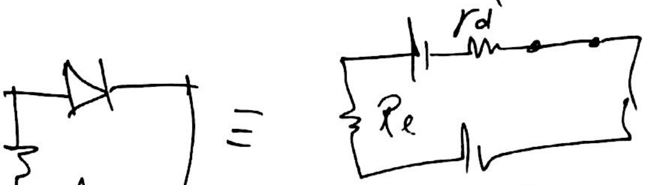


$$I_F=\frac{V_{bias}-V_F}{R_{limit}} \quad (0.7)$$

$I_R=0$, $V_R=V_{bias}$

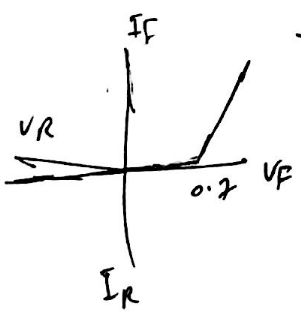
3) complete diode model

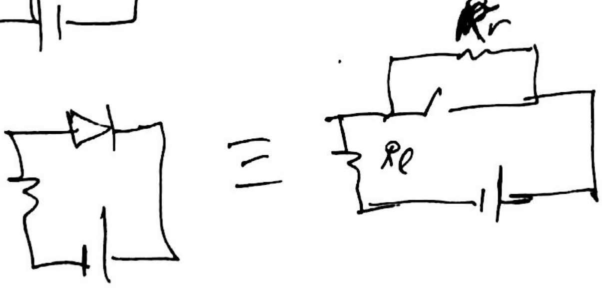




$$V_F=0.7+I_F R_F$$

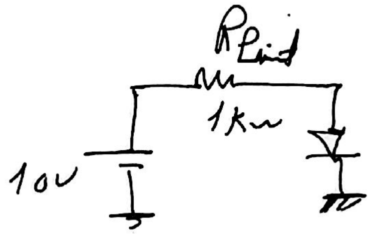
$$I_F=\frac{V_{bias}-0.7}{R_{limit}+r_d'}$$





3

Ex Determine forward voltage & forward current for diode in figure (a) for all diode models, Also voltage across limiting Resistor in each case assume $r_d' = 10\,\Omega$



sol/

[1] ideal $V_F = 0$

$i_F = \frac{10}{1K} = 10mA$

$V_{limit} = iR = 10mA \times 1k = 10V$

[2] Practical $V_F = 0.7V$

$I_F = \frac{V_{bias} - 0.7}{1K} = \frac{9.3}{1K} = 9.3mA$

$V_{limit} = iR_L = (9.3mA)(1K) = 9.3V$

[3] Compelete model $V_F = 0.7 + I_F r_d'$

$I_F = \frac{10 - 0.7}{R_L + r_d'} = \frac{9.3}{1010} = 9.21mA$ (R_L = 1K, r_d' = 10)

$\therefore V_F = 0.7 + (9.21) \times 10^{-3} \times 10 = 792mV$

$V_{Rlimit} = I_F R_L = (9.21mA)(1K) = 9.21V$

EX(2) for reverse diode connection of EX(1) determine Reverse voltage, Reverse current, V across R if $I_R = 1\mu A$

Sol

ideal

$I_R = 0A$

$V_R = V_{bias} = 10V$

$V_{Rlimit} = IR = 0V$

Practical

$I_R = 0$

$V_{Rlimit} = IR = 0$

$V_K = V_{bias} = 10V$

complete model

$I_R = 1\mu A$

$V_{RL} = (1\mu A)(1K) = 1mV$

$V_{Rr} = 10 - V_{Rlimit} = 9.999V$

معکوس الكترون 1.6×10^{-19} J/V = e (?)

I & V

i_d diode

$$i_d = I_o\left(e^{\frac{qV_d}{nKT}} - 1\right)$$

- i_d → diode current (Amp)
- I_o → reverse saturation current
- V_d → diode voltage
- n → const (bet 1, 2) Potential factor
- K → boltzmann's const 1.38×10^{-23} J/K°
- T → temp (absolute) = $C^\circ + 273^\circ$ K°

Simplifications

→ note $V_T = \frac{KT}{q}$ (thermal volt) ∴ $i_d = I_o\left(e^{\frac{V_d}{nV_T}} - 1\right)$ → I ...

→ at Forward Bias $i_d \approx I_o e^{\frac{V_d}{nV_T}}$

→ at Room temp (25°C) & $n=1$ → $nV_T = 26mV$

$n=2$ → $nV_T = 52mV$

→ $r_d = \frac{1}{di_d/dV_d} = \frac{1}{\text{Conductance of device}}$

→ Conductance $\frac{di_d}{dV_d} = \frac{1}{nV_T} I_o e^{\frac{V_d}{nV_T}}$

∴ $e^{\frac{V_d}{nV_T}} = \frac{i_d}{I_o} + 1$ → I

∴ $\frac{di_d}{dV_d} = \frac{I_o}{nV_T}\left(\frac{i_d}{I_o} + 1\right) = \frac{i_d + I_o}{nV_T}$

$r_d = \frac{1}{di_d/dV_d} = \frac{nV_T}{i_d + I_o}$

& ∵ $I_o \ll i_d$ ∴ neglected

$$\therefore r_d = \frac{nV_T}{I_d}$$

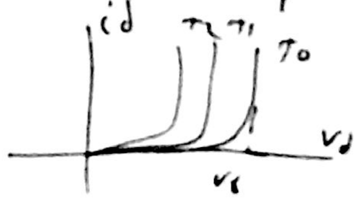
Example find the dynamic Resistance for diode at $i_d = 2mA$ & n (potential ideality factor) is 2 ∴ $r_d = \frac{2 \times 26mV}{2mA} = 26\Omega$

temperature effect

* As T ↑↑, V_γ (turn on voltage) ↓, & V_γ varies linearly with temp.

$$V_\gamma(T_1) - V_\gamma(T_0) = K_T\,(T_1 - T_0)$$

- $V_\gamma(T_1)$: diode voltage at new temp
- T_1: new temp (°C)
- $V_\gamma(T_0)$: diode voltage at room temp — 0.7 Si, 0.3 Ge
- T_0: room temp 25°C
- K_T: temp coeff — −2.5 mV/°C for Ge, −2 mV/°C for Si



كلما زادت درجة الحرارة 1°c تقل الفولت 2mV

مهم

* I_0 depends on temp

$\therefore$ $I_0(T_2) = I_0(T_1)\, e^{K_i (T_2 - T_1)}$ (K_i = 0.07/°C)

$\because$ $e^{0.07} = 2$ $\therefore$ $I_0(T_2) = I_0(T_1) * 2^{\left(\frac{T_2 - T_1}{10}\right)}$

Ex1 when Si conduct at Temp of 25°C & $V_\gamma = 0.7$ V, what V_γ across diode at 100°C

Sol

$V_\gamma(T_1) - V_\gamma(T_0) = K_T\,(T_1 - T_0)$

$V(100) - 0.7 = (-2\times10^{-3})[100 - 25]$ $\therefore V_\gamma = 0.55$ V

Ex2 If Si diode is cooled to −100°C, what voltage required across diode to establish a noticeable current at new temp

Sol

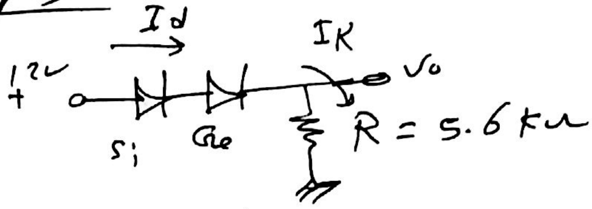
$V_\gamma(-100) - 0.7 = (-2\times10^{-3})[-100 - 25]$

$V_\gamma(-100) = 0.95$ V

6

Examples

① find I_d, V_o

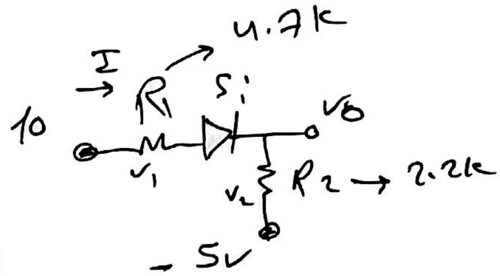


sol

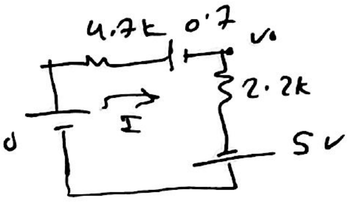
$V_o = 12 - V_{Si} - V_{Ge} = 12 - 0.7 - 0.3 = 11V$

$I_d = \frac{V_o}{R} = \frac{11}{5.6k} = 1.96\,mA$

② find I, V_1, V_2, V_o



$I = \frac{10 - 0.7 + 5}{(4.7+2.2)k} = \frac{14.3}{6.9k} = 2.07\,mA$



$V_1 = IR_1 = 2.07\,mA \times 4.7k = 8.78V$

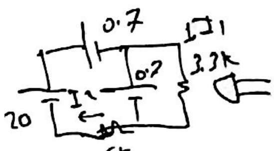
$V_2 = IR_2 = 2.07\,mA \times 2.2k = 4.55V$

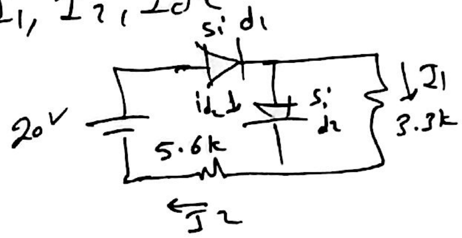
$V_o = ??$

$V_o - (-5) = V_2$

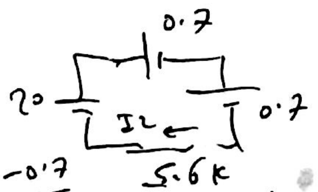
$V_o = V_2 - 5 = 4.55 - 5 = -0.45V$

③ find I_1, I_2, I_{d2}

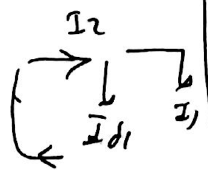




$\rightarrow V_{3.3k} = 0.7 = I_1 \times 3.3k \quad \therefore I_1 = \frac{0.7}{3.3k} = 0.212\,mA$



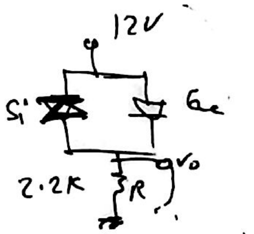
$I_2 = \frac{20 - 0.7 - 0.7}{5.6k} = 3.32\,mA$

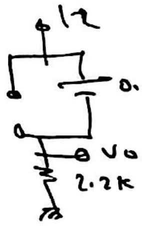


$I_2 = I_{d2} + I_1$

$\therefore I_{d2} = I_2 - I_1 = 3.108\,mA$

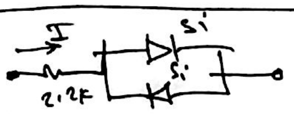
④ find V_o





$V_o = 12 - V_{Diode} = 12 - 0.3 = 11.7$

⑤ find I

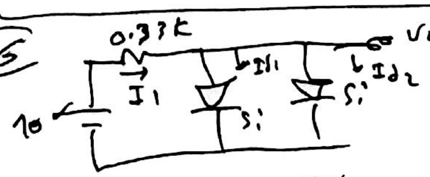


20v

$I = \frac{20 - 4 - 0.7}{2.2k}$

واحد شغال
و [illegible]

⑥ find V_o, I_1, I_{d2}, I_{d1}



$V_o = V_{\gamma1} = V_{\gamma2} = 0.7V$

$I_1 = \frac{10 - 0.7}{0.33k} = 28.18\,mA$

$I_{d1} = I_{d2} = \frac{1}{2} I_1 = 14.09\,mA$