Types of Diode Breakdown, Diode Approximations

13 September 2023 10:50

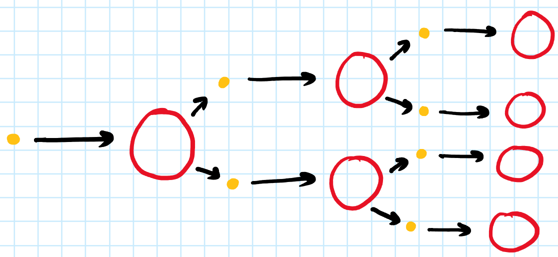
TYPES OF DIODE BREAKDOWN

Avalanche breakdown

Under reverse bias,

Voltage increases → Depletion region widens → Accumulation of more immobile ions → Electric field is generated → Kinetic energy is provided to charge carriers → Collision with other atomic structures → Releases more charge carriers; covalent bonds broken, electron-hole generating

- Happens due to impact ionisation / avalanche multiplication

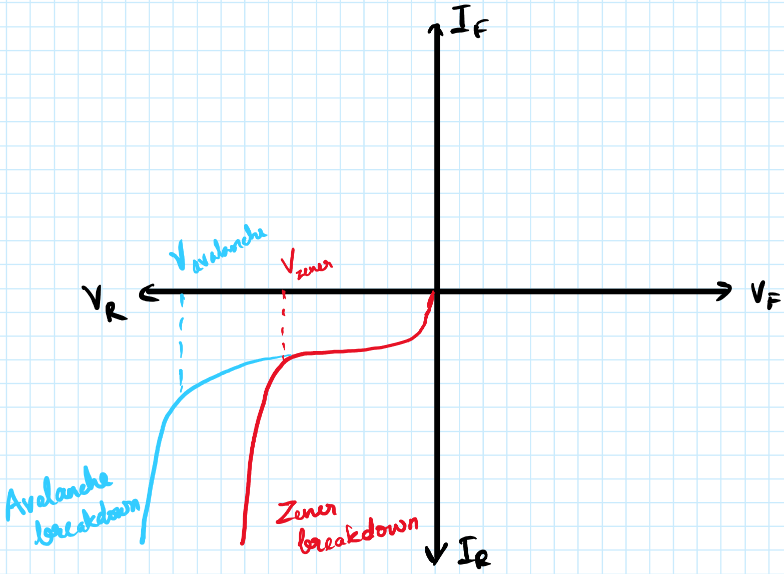


- Motion of these charge carriers creates a sudden jump in current, often damaging the diode itself

Zener Breakdown

- Occurs in Zener diode → Both p and n heavily doped
- Due to more charge carriers, depletion region is narrower in normal state
- Smaller reverse bias voltage → stronger electric field → more charge carriers liberated

↓
breakdown occurs for a lower voltage



Diode Approximations / Equivalent Diagrams

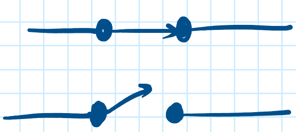
Mathematical method to approximate non-linear behaviour of real diodes

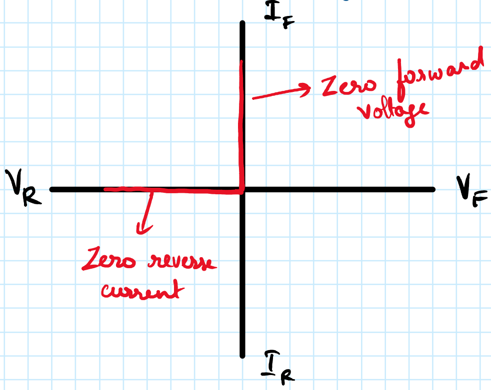
three types
- First Approximation (Ideal Diode Characteristics)
- Second Approximation (Simplified Diode Characteristics)
- Third Approximation (Linear Piece-wise Diode Characteristics)

First Approximation (Ideal Diode Characteristics)

FORWARD BIAS: Closed switch, no voltage drop

REVERSE BIAS: Open switch, infinite resistance

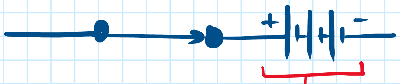




Second Approximation (Simplified Diode Characteristics)

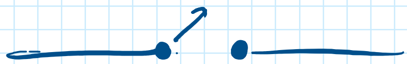
Second Approximation (Simplified Diode Characteristics)

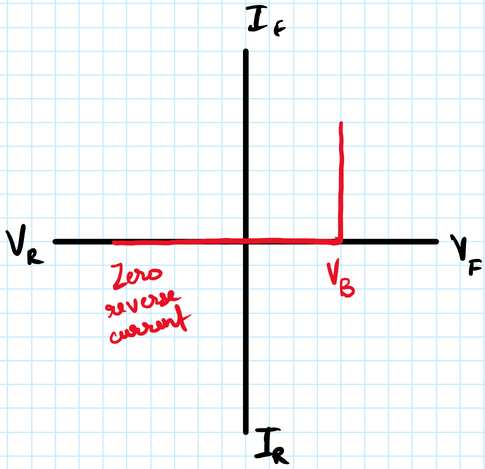
FORWARD BIAS: In series with a battery to turn on, specific knee voltage is given



0.7 V or greater for Si

REVERSE BIAS: Open switch



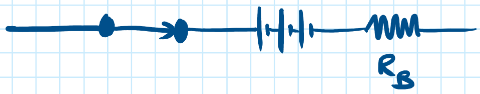


Third Approximation (Linear Piece-wise Diode Characteristics)

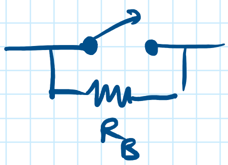
FORWARD: Includes knee voltage as well as voltage across bulk resistance R_B

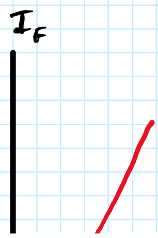
Voltage drop V_D

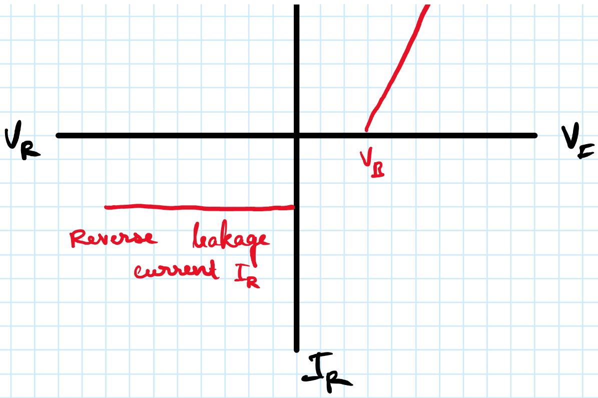
$$\boxed{V_D = \underbrace{0.7\,V}_{\text{knee voltage}} + \underbrace{(I_D)(R_B)}_{\text{voltage across bulk resistance}}}$$



REVERSE: Open switch with R_B in parallel

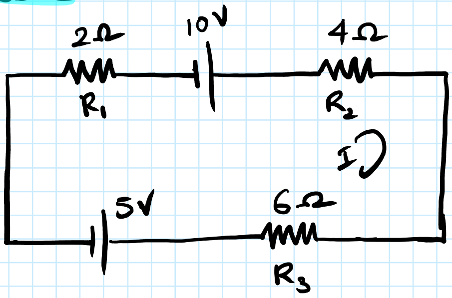






PROBLEMS

①



Soln: Using KVL, → REVISE

$$10 - 4I - 6I - 5 - 2I = 0$$

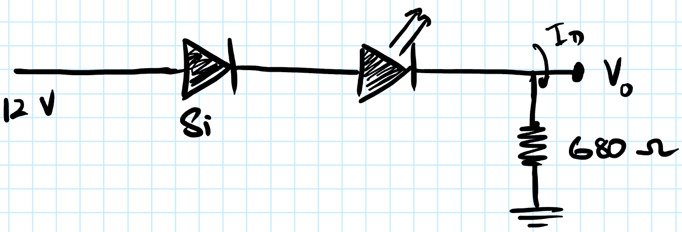
$$5 - 12I$$

② A Si diode and Ge diode are connected in series with a 2kΩ resistor. If each diode has an internal resistance of 5 Ω, find the diode current for both piece-wise linear circuit and simplified circuit if applied voltage is

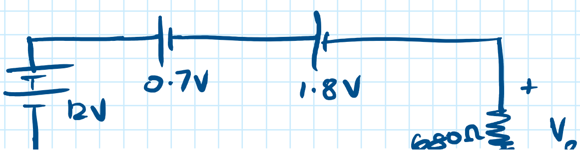
(a) $V_D = 1\,V$

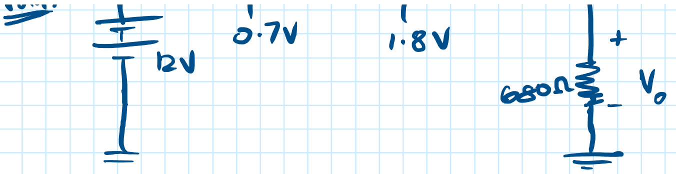
(b) $V = 5\,V$

③ Determine V_o, I_D for given series diode circuit. Assume LED voltage as 1.8 V



Soln:

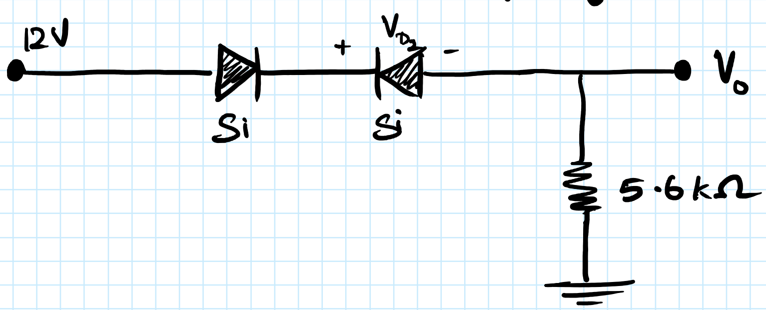




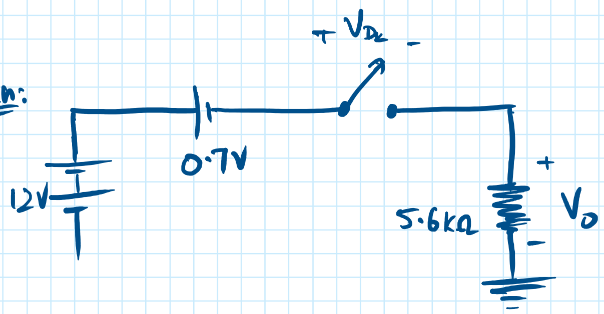
$$V_o = 12 - 0.7 - 1.8$$
$$= \underline{\underline{9.5\,V}}$$

$$9.5 - 680 I_D = 0$$
$$I_D = \frac{-9.5}{-680}$$
$$= \underline{\underline{0.013\ A}}$$

④ Determine I_D, V_{D_2} & V_o for given circuit

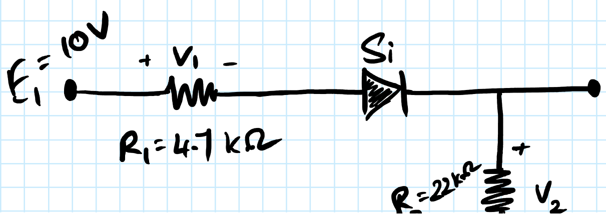


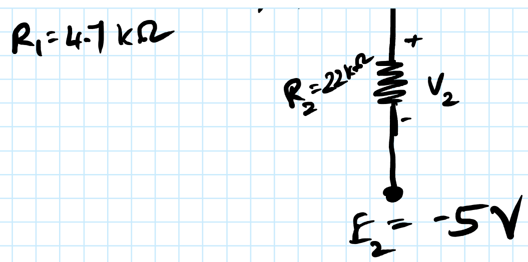
Soln:



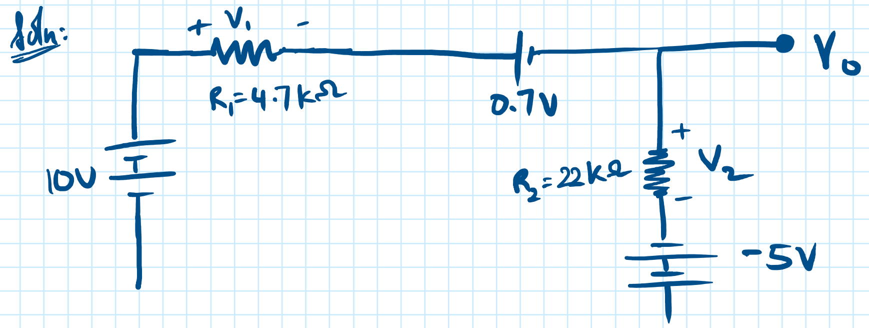
$$I_D = 0$$
$$V_o = 5.6\,k\Omega \times I_D$$
$$V_o = 0$$

⑤ Determine V_1, V_2, V_o, I in the given circuit





Soln:



Using KVL,

$$10 - 4.7kI - 0.7 - 22kI + 5 = 0$$

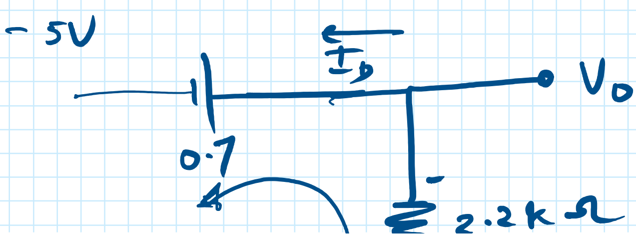
$$14.3 - 26.7kI = 0$$

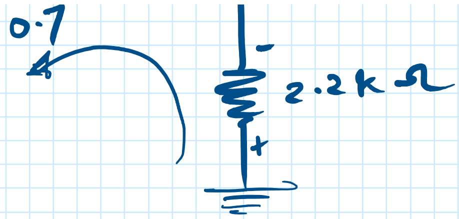
$$I = \frac{-14.3}{-26.7 \times 10^3} = 5.35 \times 10^{-4}\ A$$

$$V_1 = IR_1$$
$$= 5.35 \times 10^{-4} \times 4.7 \times 10^3$$
$$= 2.51V$$

$$V_2 = IR_2$$
$$= 5.35 \times 10^{-4} \times 22 \times 10^3$$
$$= 11.77V$$

$$-5 + V_2 - V_0 = 0$$





$$-2.2kI - 0.7 + 5 = 0$$

$$I = \frac{-4.3}{-2.2 \times 10^3} = 1.95 \times 10^3 \, A$$

$$V_0 = I(2.2k)$$

$$= 4.3\,V$$