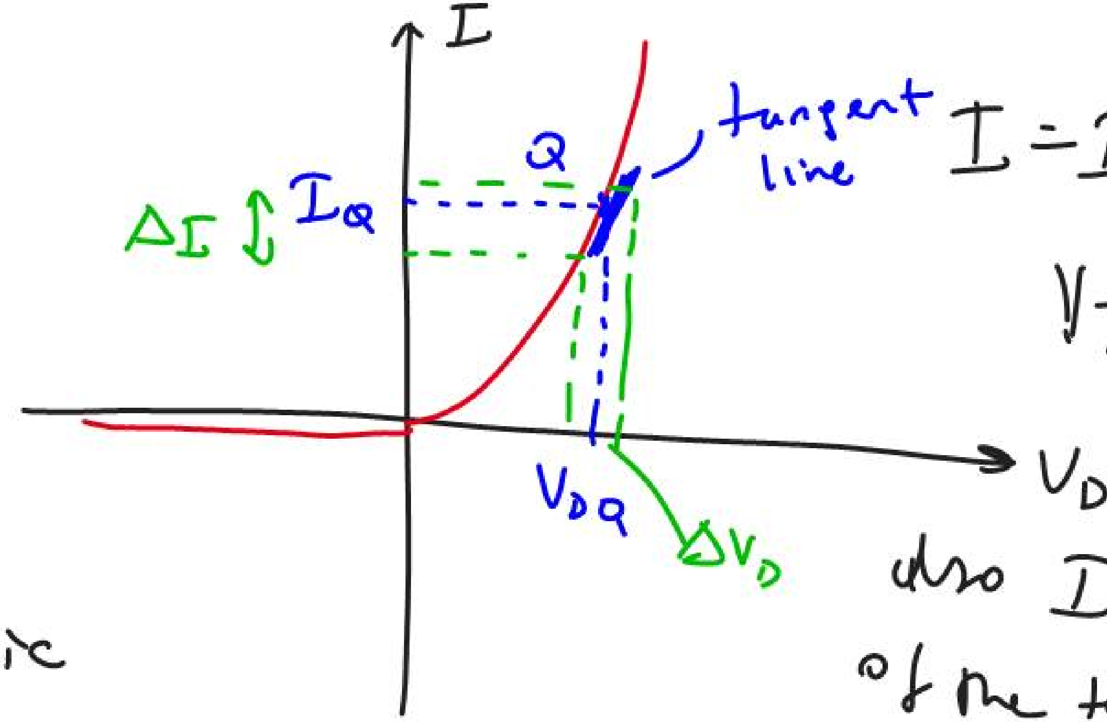
DIODE EQUATION

22.02.2011 ©



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

$V_T = 26\,mV$ at $300K$

also I_s is a function of the temperature.

Dynamic resistance of a diode: r_d

Slope of the tangent $\cong \left.\frac{\Delta I}{\Delta V_D}\right|_Q = \frac{dI}{dV_D}$

Q = quiescent

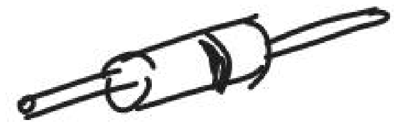
$$\frac{dI}{dV_D} = \frac{d}{dV_D}\left[\underbrace{I_s \left(e^{V_D/V_T} - 1 \right)}_{} \right] = \frac{I_s}{V_T} e^{V_D/V_T} = \frac{1}{V_T}\left(\underbrace{I_s e^{V_D/V_T}}_{\approx I} \right)$$

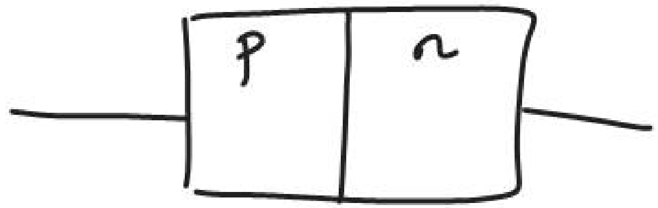
$$\frac{dI}{dV_D} \simeq \frac{I}{V_T}$$

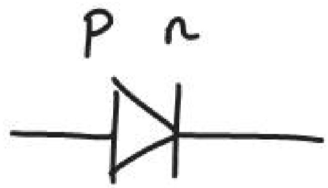
$$r_d = \frac{dV_D}{dI} \simeq \frac{V_T}{I}$$

$$\boxed{r_d \simeq \frac{V_T}{I}}$$

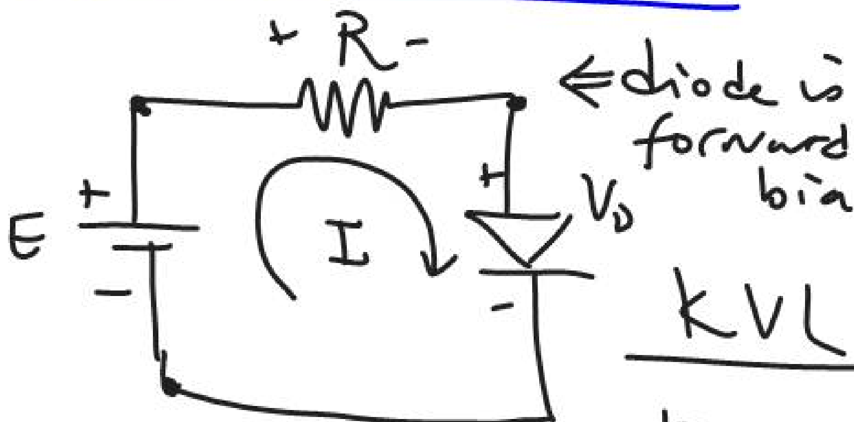
A pn Junction diode







A diode circuit:

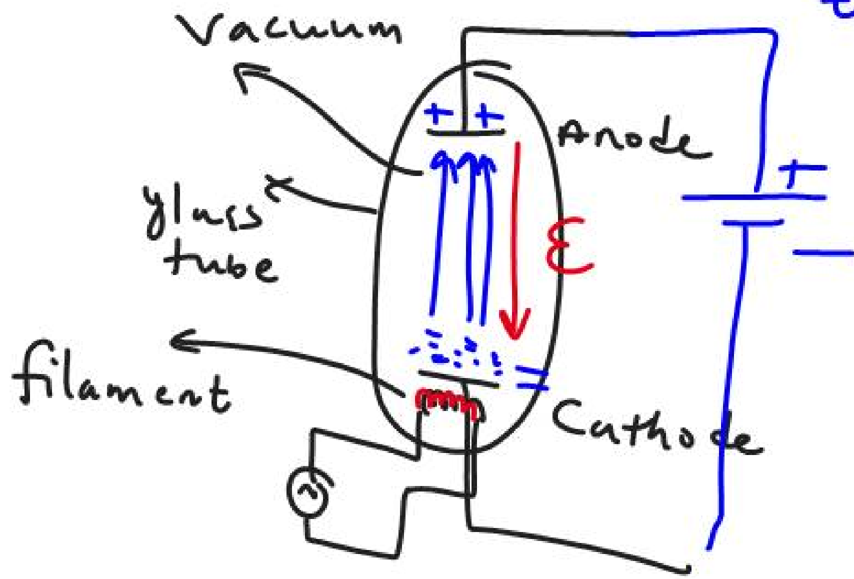


KVL

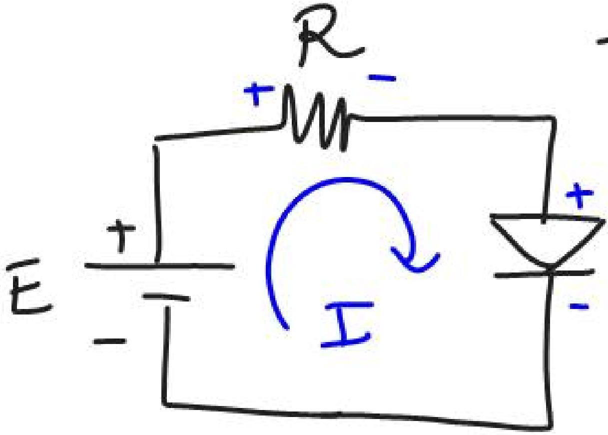
$$E - I \cdot R - V_D = 0$$

historical

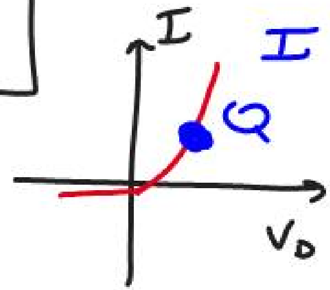
a diode tube



DIODE BIAS



Forward biased



KVL

$$E - I \cdot R - V_D = 0$$

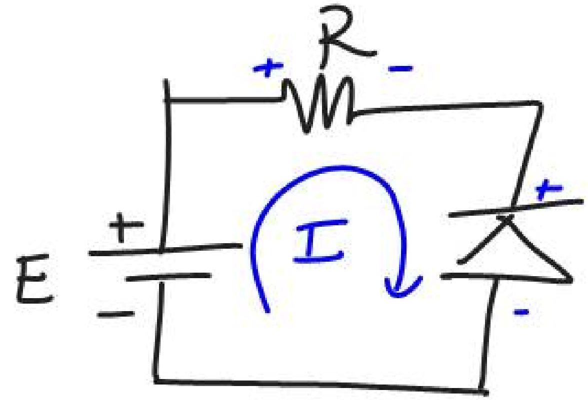
2 unknowns: I, V_D

We need another equation.

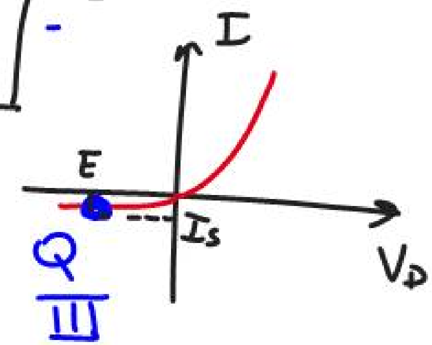
① The curve (The diode characteristics) ⇒ Graphical solution

② Use the diode equation $\left(I = I_S\left(e^{V_D/V_T} - 1\right)\right)$

③ Approx. Take $V_D = 0.7V$ for Si



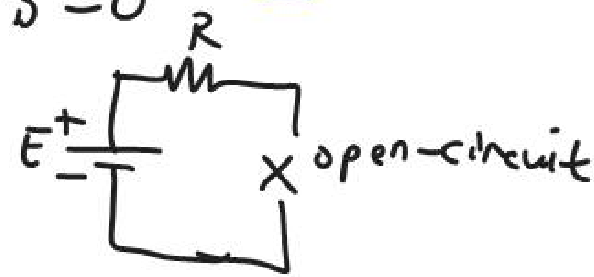
Reverse biased



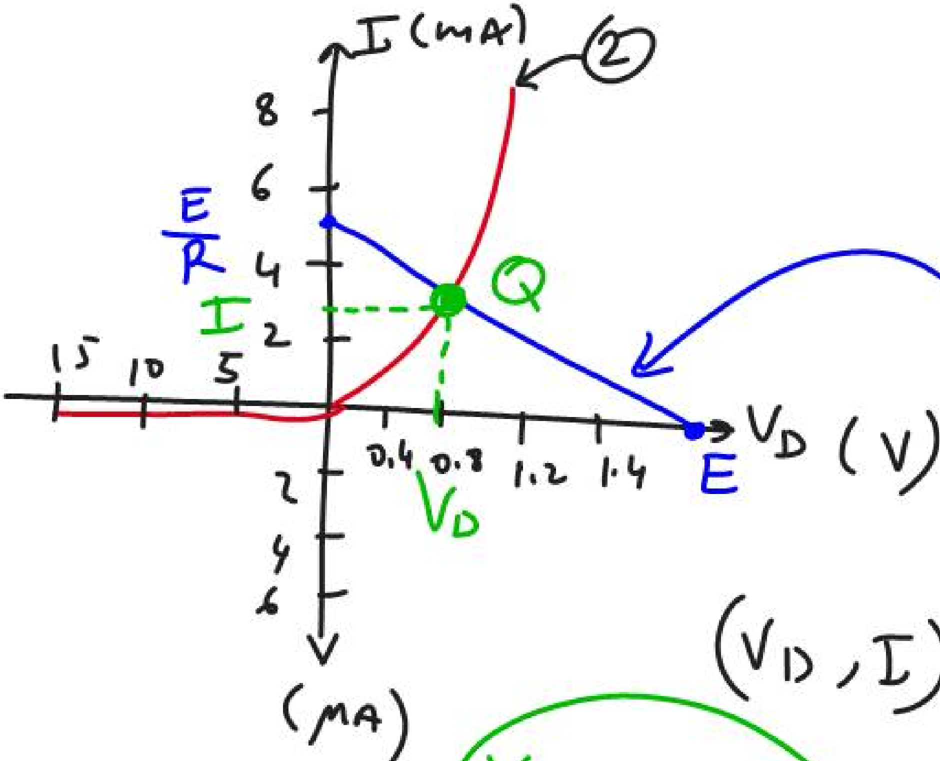
$$I \approx I_s \approx 0$$

$$E - I \cdot R - V_D = 0$$

$$\boxed{V_D \approx E}$$



① Graphical Solution



KVL:

$$E - I \cdot R - V_D = 0 \quad (1)$$

Line equation $y = ax + b$

LOAD LINE: $y \to I$, $x \to V_D$

$I = 0 \qquad V_D = E$

$V_D = 0 \qquad I = \frac{E}{R}$

$$(V_D, I) \Rightarrow \left(0, \frac{E}{R}\right), (E, 0)$$

$V_D \approx 0.8V$

$I \approx 3mA$

② DIODE EQUATION SOLUTION

Our objective is to find I, V_D

$$E - I \cdot R - V_D = 0 \qquad ①$$

$$I = I_S\left(e^{V_D/V_T} - 1\right) \qquad ②$$ → This is NOT a linear equation!

2 unknowns, 2 equations ✓

$$I = \frac{E - V_D}{R}$$ substitute this into ②

$$\frac{E - V_D}{R} = I_S\left(e^{V_D/V_T} - 1\right)$$

$V_T = 26\,mV$

$I_S = 1\,\mu A$

$E = 1.5\,V$

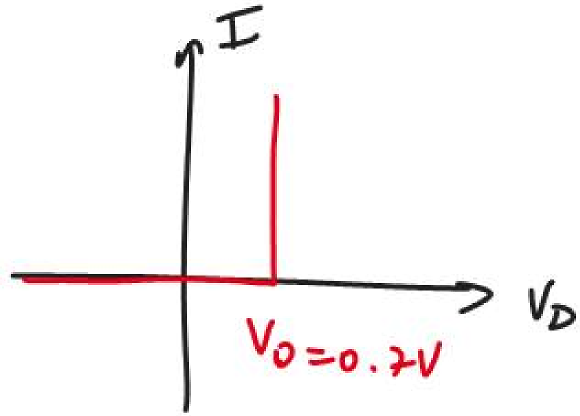
$R = 500\,\Omega$

③ Approximation

① $V_D \cong 0.7V$ (Si) $V_D \cong 0.3V$ (for Ge), $V_D \cong 1.2V$ (for GaAs)

② $E - I.R - V_D = 0$

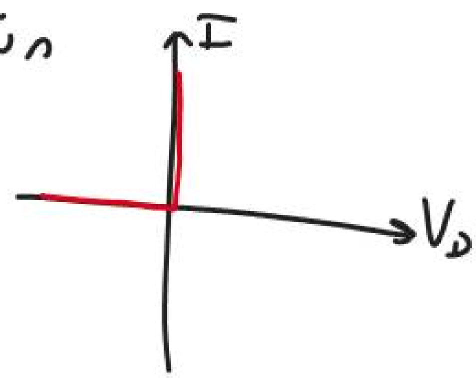
$$\boxed{I = \frac{E - V_D}{R}}, \quad V_D = 0.7V.$$



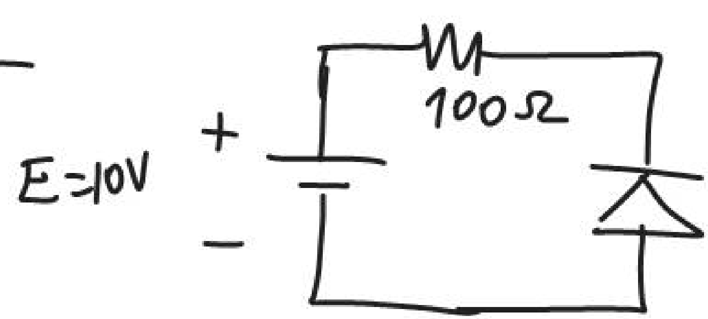
④ Very big approximation

$V_D \cong 0V.$

$$I = \frac{E}{R}$$



ex

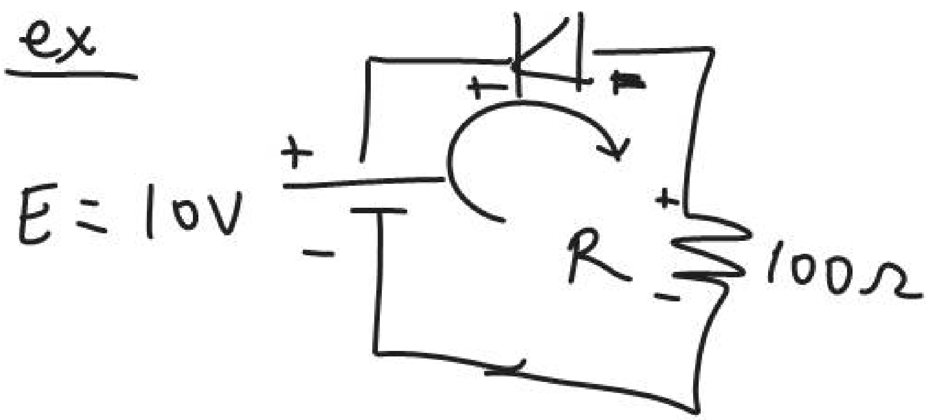


$V_D = ?$ $\approx 10V$

$I = ?$ ≈ 0

Diode is reverse biased.

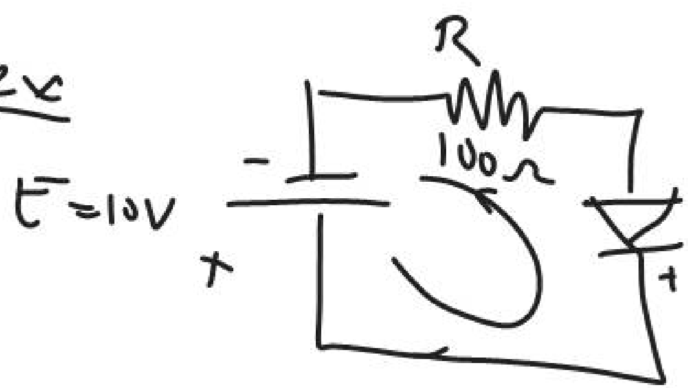
ex



$V_D = ?$ $V_D \approx E \approx 10V$ Reverse biased

$I = ?$ $I \approx 0$

ex

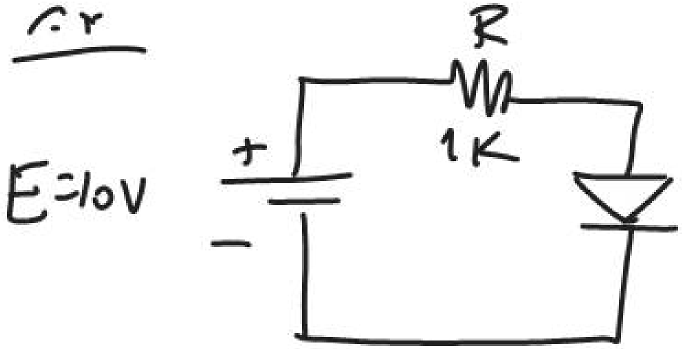


$V_D = ?$ $V_D \approx E \approx 10V$

$I = ?$ $I = 0$

Reverse biased

ex



$V_D = ?$

$I = ?$

Forward biased.

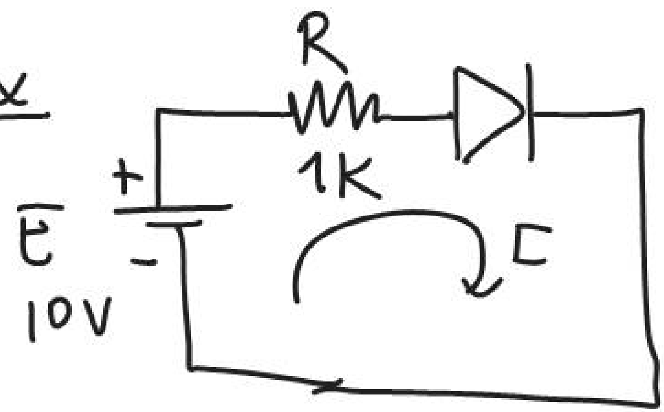
assume $V_D \simeq 0.7V$
when forward biased

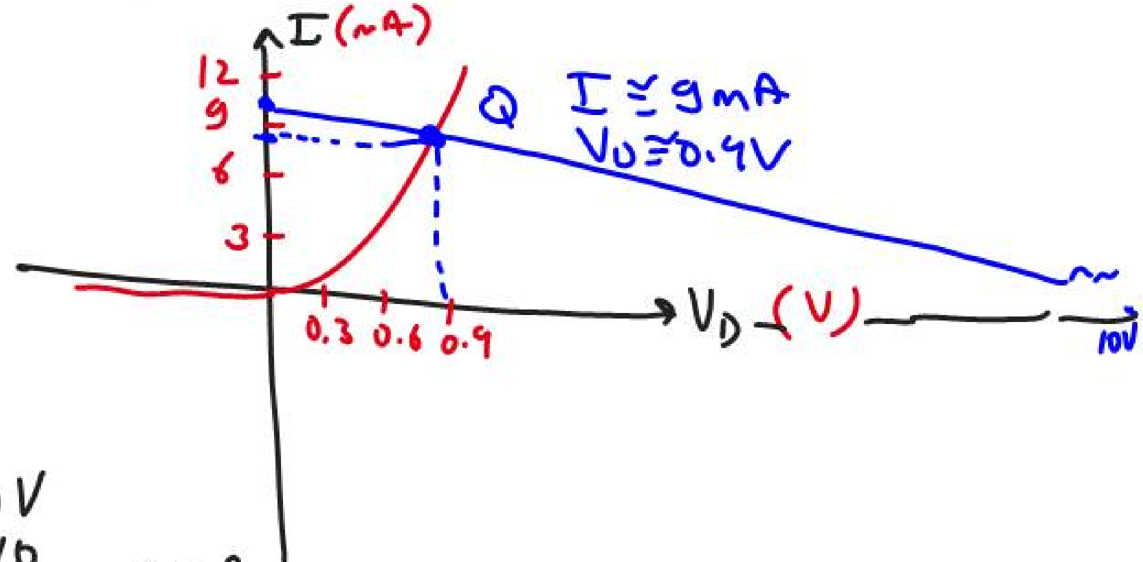
$V_D \cong 0.7V$

$I = \frac{E - V_D}{R} = \frac{10-0.7}{10^3} = 9.3\,mA$

$1K\Omega = 1000\Omega = 10^3\Omega$

ex



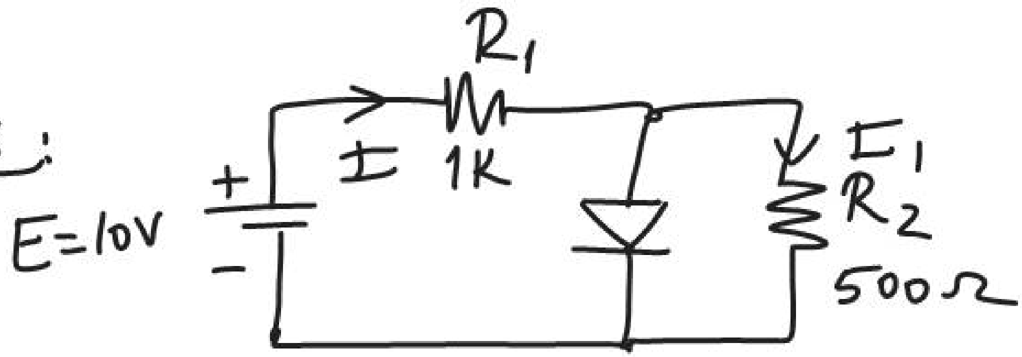


$I = ?$ $\quad E - V_D - IR = 0$

$V_D = ?$ $\quad I = 0 \quad V_D = E = 10V$

$V_D = 0 \quad I = E/R = \frac{10}{103} = 10\,mA$

Ex:



$I = ?$, $I_1 = ?$

$V_D = ?$ (Si)

$V_D \approx 0.7V.$

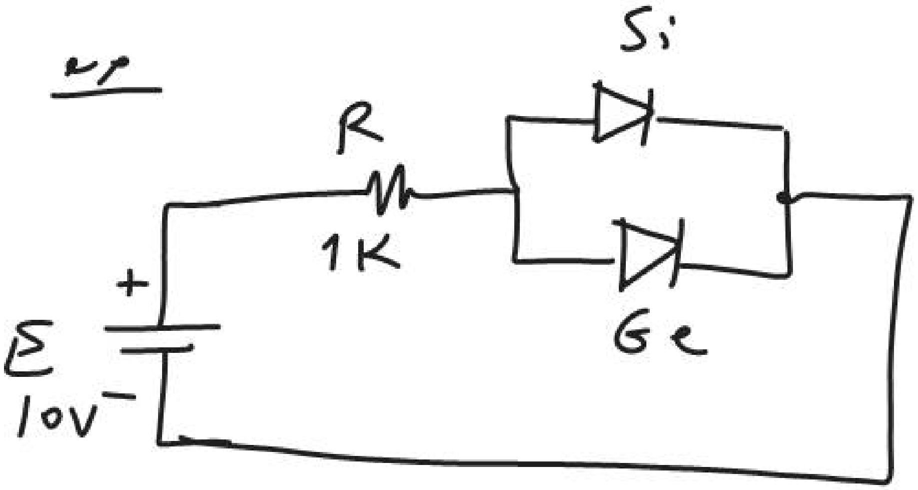
KVL

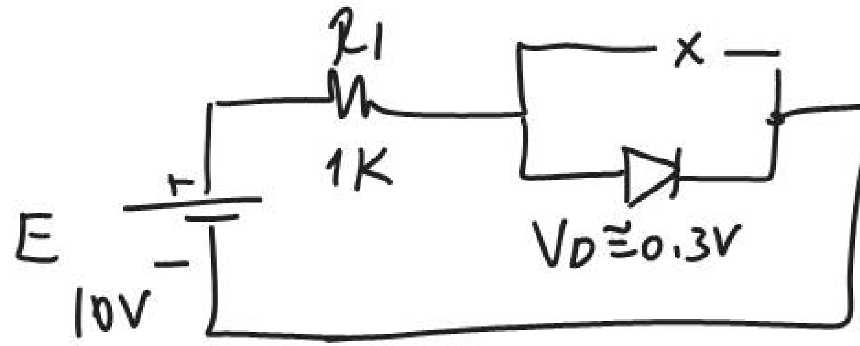
$E - I \cdot R_1 - V_D = 0$

$$I = \frac{E - V_D}{R_1} = \frac{10 - 0.7}{10^3} = 9.3\,mA$$

$$I_1 = \frac{V_D}{R_2} = \frac{0.7V}{500\Omega}$$

$$I_1 = \frac{1.4}{1000} = 1.4\,mA$$

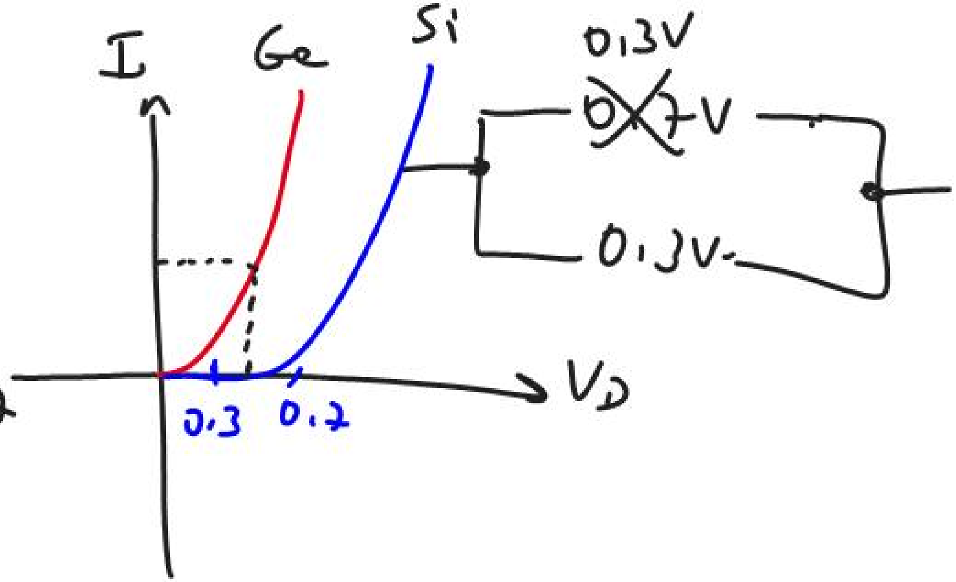




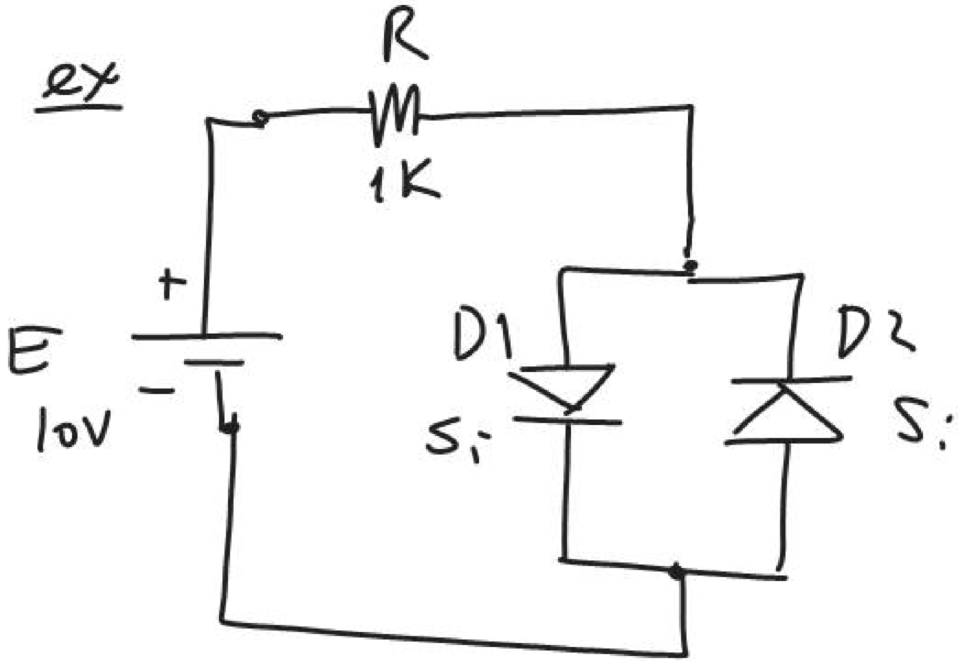
$$I = \frac{E - 0.3V}{R}$$

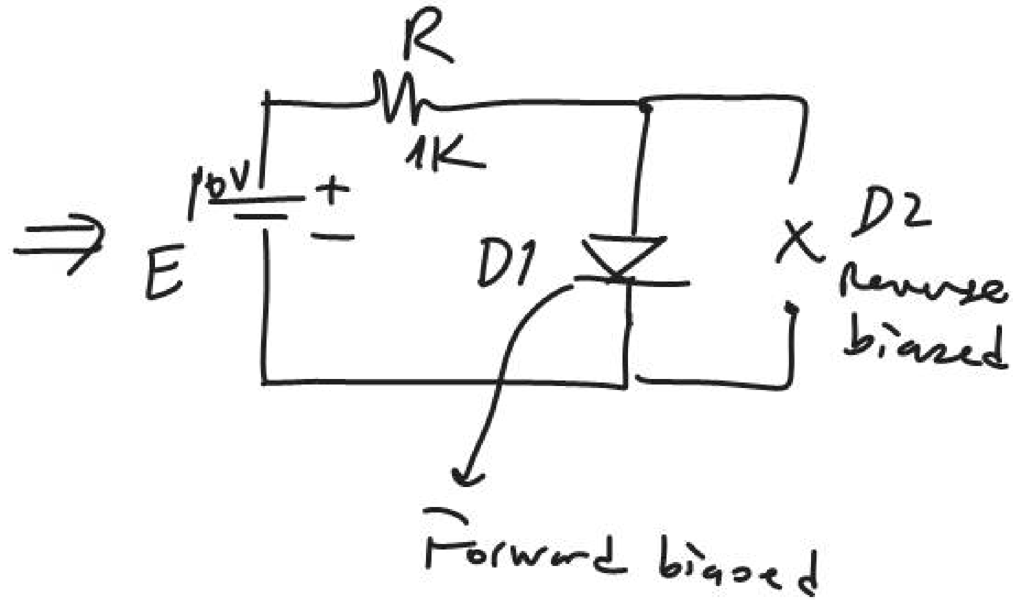
$$\cong \frac{10 - 0.3}{10^3} \cong 9.7mA$$

$$V_D \cong 0.3V$$



ex

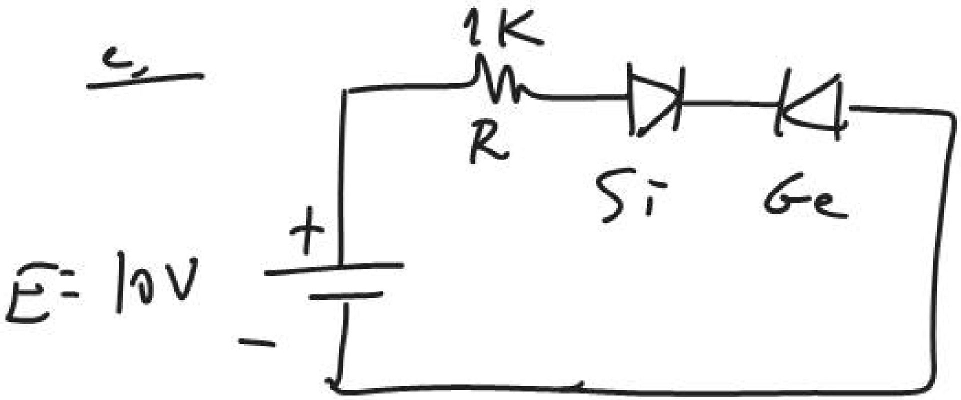




$$I = \frac{E - V_D}{R} = \frac{10 - 0.7}{10^3} = 9.3\,mA$$

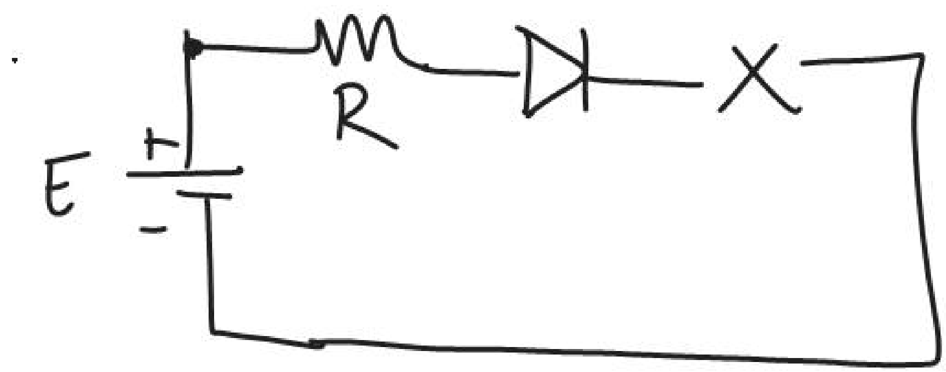
$$V_D \cong 0.7V$$

c.



Si is forward biased

Ge is reverse biased



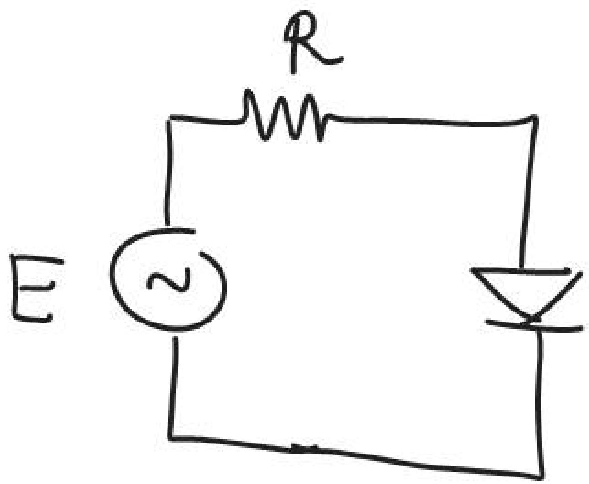
$I = 0$

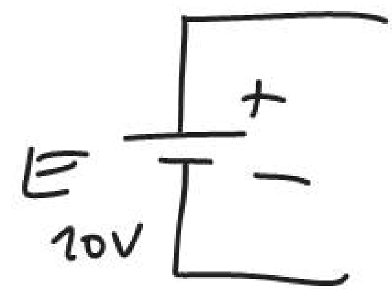
$V_D = ?$

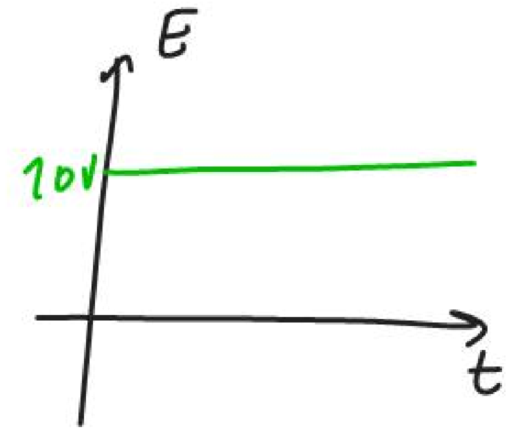
$V_D = V_{D1} + V_{D2} \cong E \cong 10V$

CLIPPERS & CLAMPERS

CLIPPERS

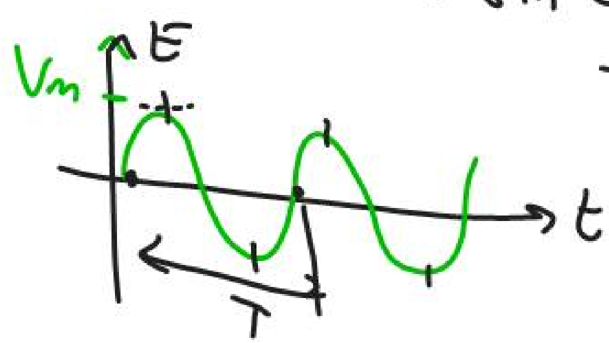






Direct Current (DC) Voltage

$$E = V_m \sin \omega t = V_m \sin 2\pi f t$$



T = period (second)

$f = \frac{1}{T}$ (1/second = Hertz = Hz)