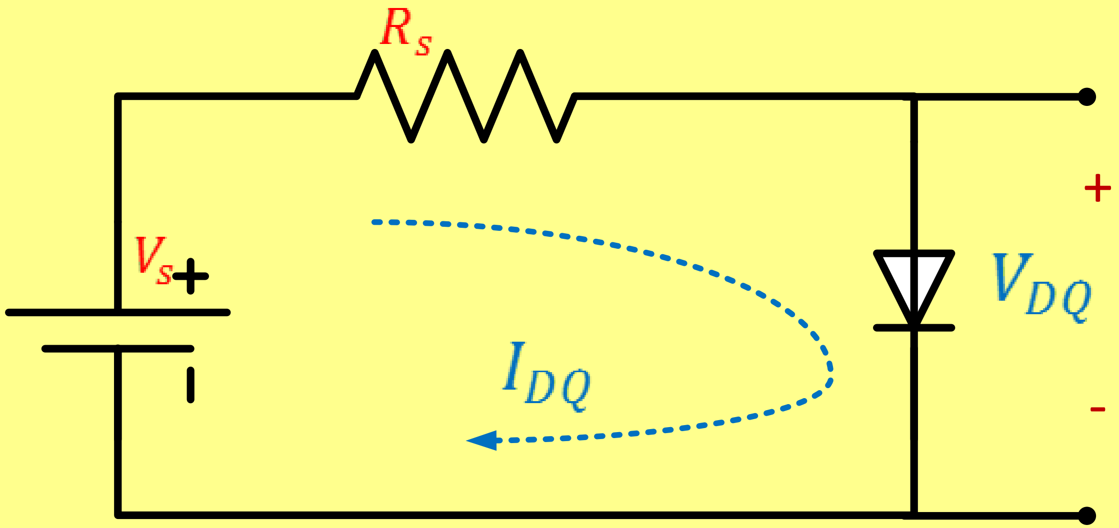
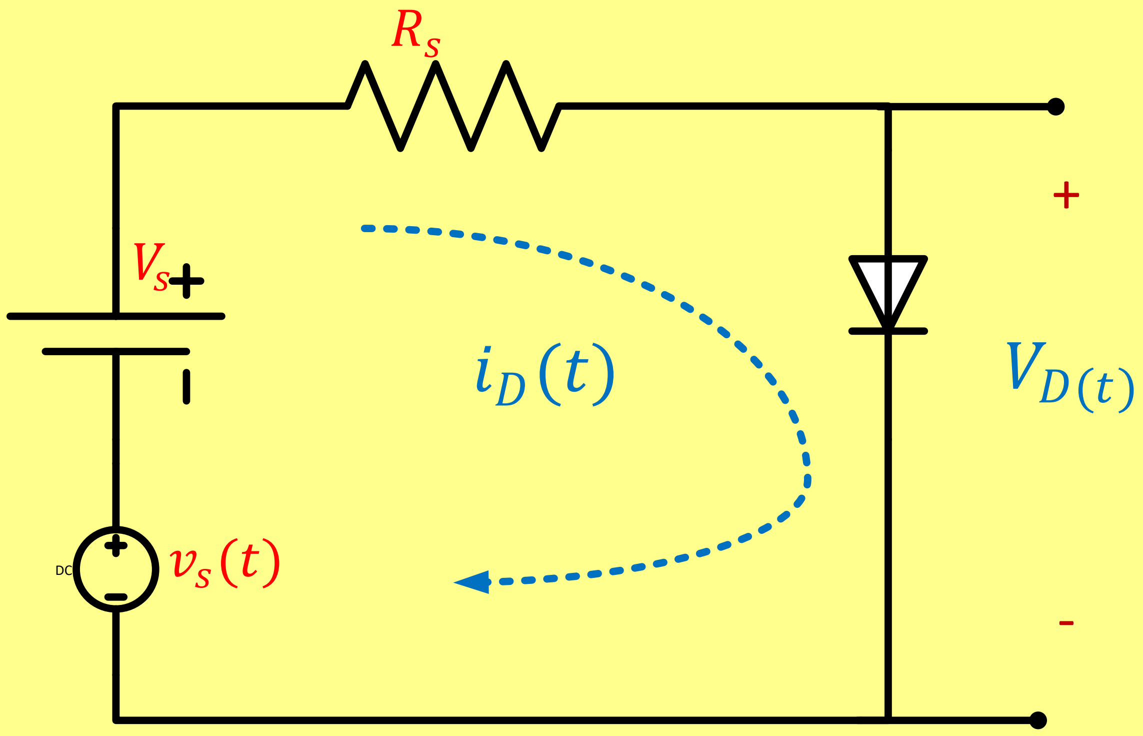
Ac Small Signal Analysis

- $I_{DQ} = I_S\left(e^{\frac{V_{DQ}}{\eta V_T}} - 1\right)$
- $I_{DQ} = I_S(e^{\frac{V_{DQ}}{\eta V_T}})$



now

- $i_D(t) = I_{DQ+}\, i_d(\mathrm{t})$
- $V_D(t)$ $=V_{DQ}$ + $v_d(\mathrm{t})$
- $i_D(t) = I_S(e^{\frac{V_D(t)}{\eta V_T}} - 1)$



- And since the diode is forward biased
- $i_D(t) = I_S(e^{\frac{V_D(t)}{\eta V_T}})$
- $i_D(t) = I_S(e^{\frac{V_{DQ} + v_d}{\eta V_T}})$
- $i_D(t) = I_S e^{\frac{V_{DQ}}{\eta V_T}} . e^{\frac{V_d}{\eta V_T}}$
- $i_D(t) = I_{DQ}(e^{\frac{v_d}{\eta V_T}})$
- using $e^x = 1+x$; x is very small

but $i_D(t) = I_{DQ+}\, i_d(\text{t})$

$\therefore\ i_d(\text{t}) = \frac{v_d(t)}{\eta V_{T/I_{DQ}}} = \frac{v_d}{r_d}$

where $r_d = \frac{\eta V_T}{I_{DQ}} = \frac{V_T}{I_{DQ}}$

$$i_D(t) = I_{DQ}\,(1 + \frac{v_d(t)}{\eta V_T}) = I_{DQ+} \frac{v_d(t)}{\eta V_{T/I_{DQ}}}$$

$\therefore$ If V_S(t) = V_S+ vs(t)

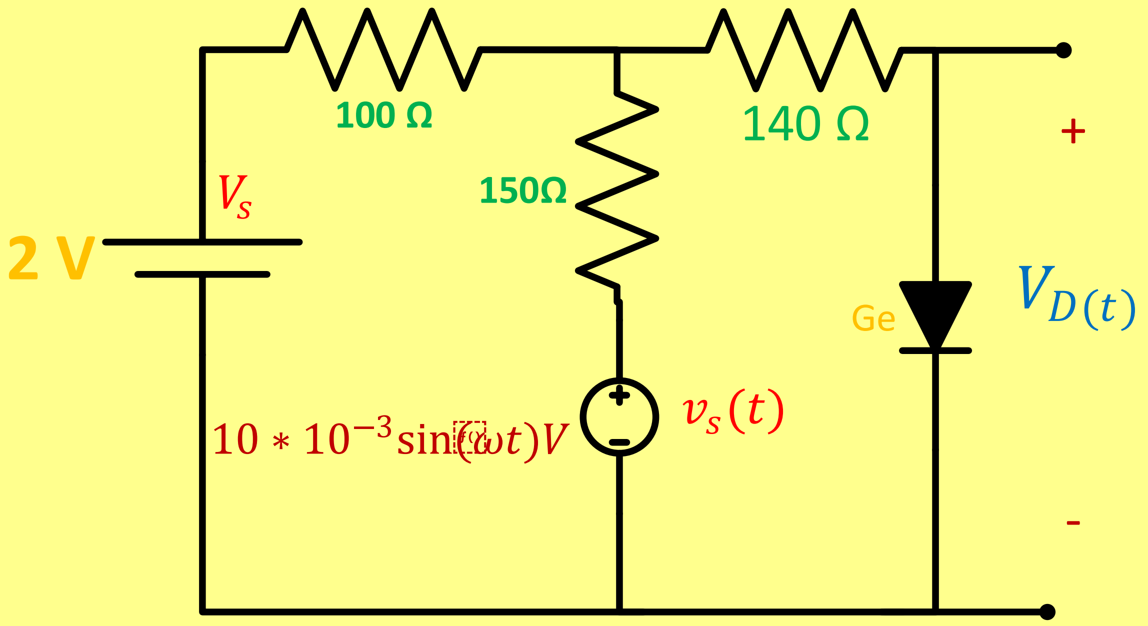
V_S= Dc component

vs(t)= ac component

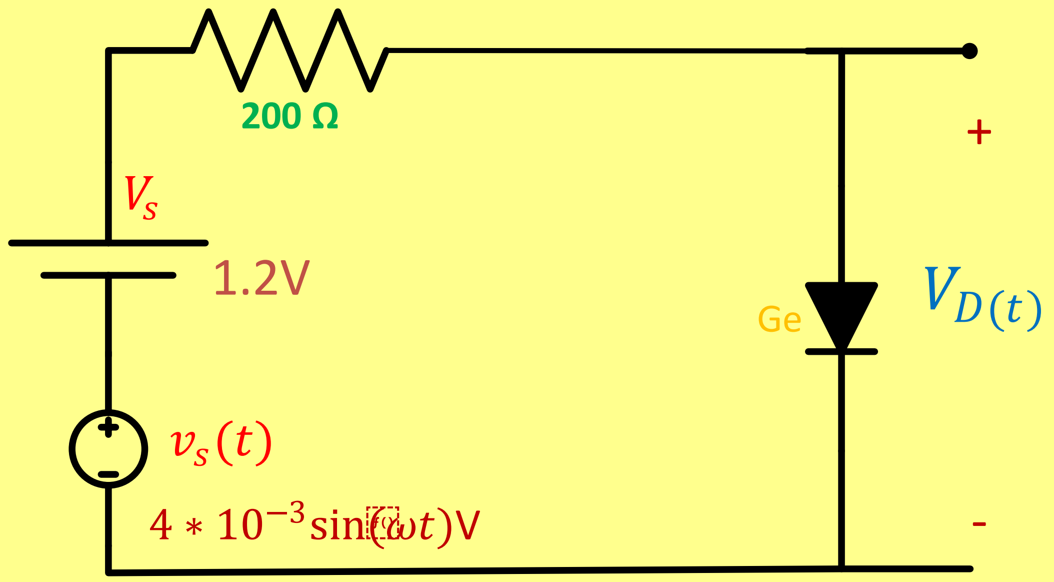
and the amplitude of vs(t) is small and the diode is always on ; we could use the superposition theorem to find the response ($V_{D(t)}$, $i_D(t)$) .

Example

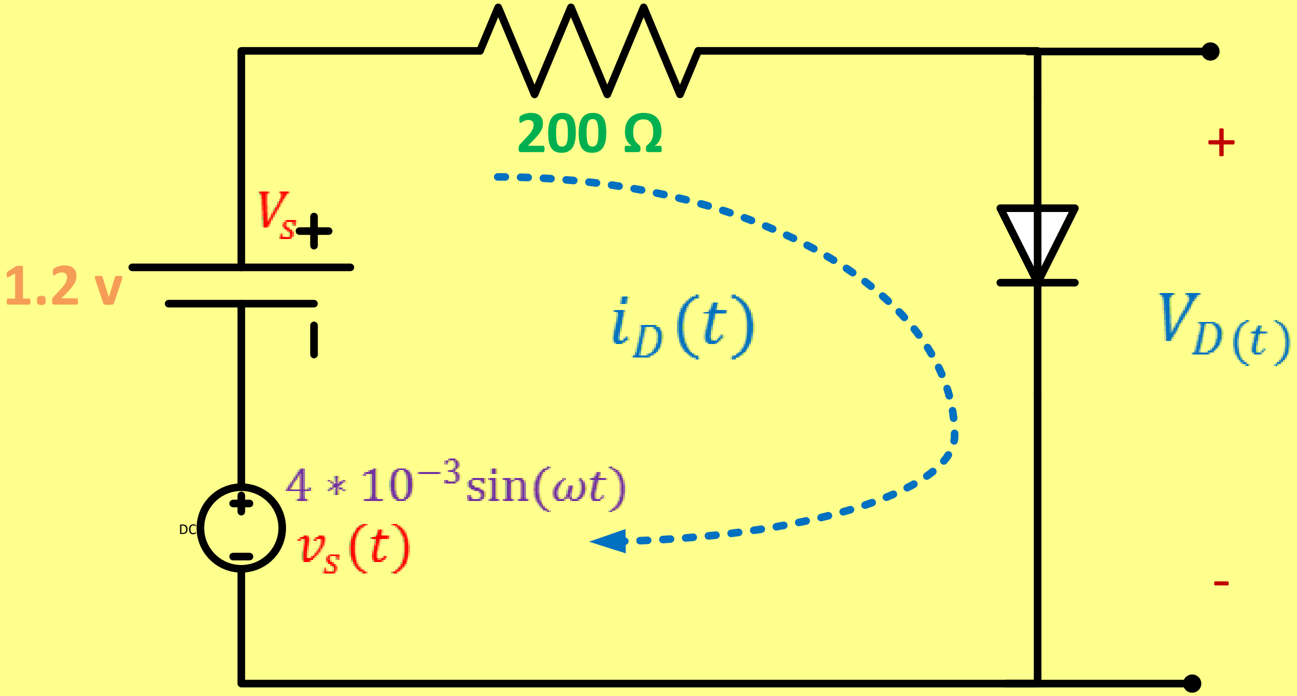
Find $V_D(t)$



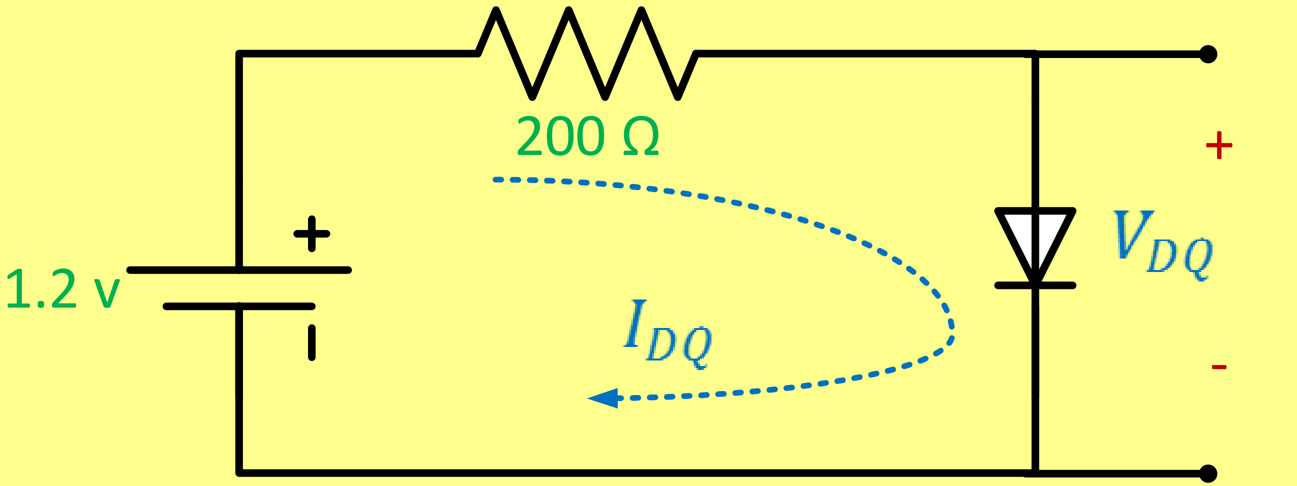
Using Thevenin's Theorem



Since we have a dc source (1.2 V) and an ac signal ($4x10^{-3}$ sinωt V) and the diode is always on ; we use superposition theorem to find $V_D(t)$



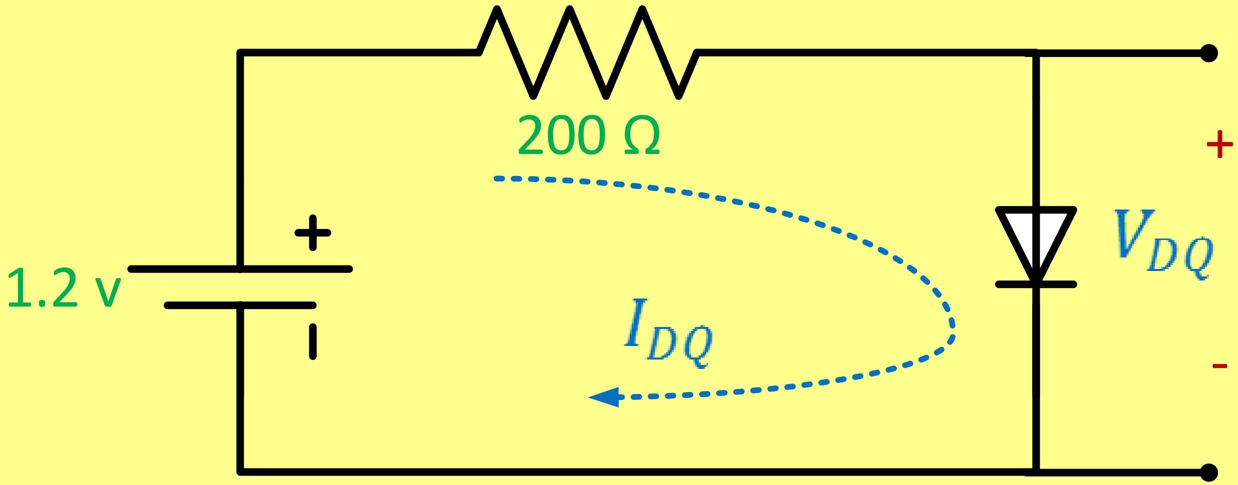
1) to find V_{DQ} (DC Analysis)

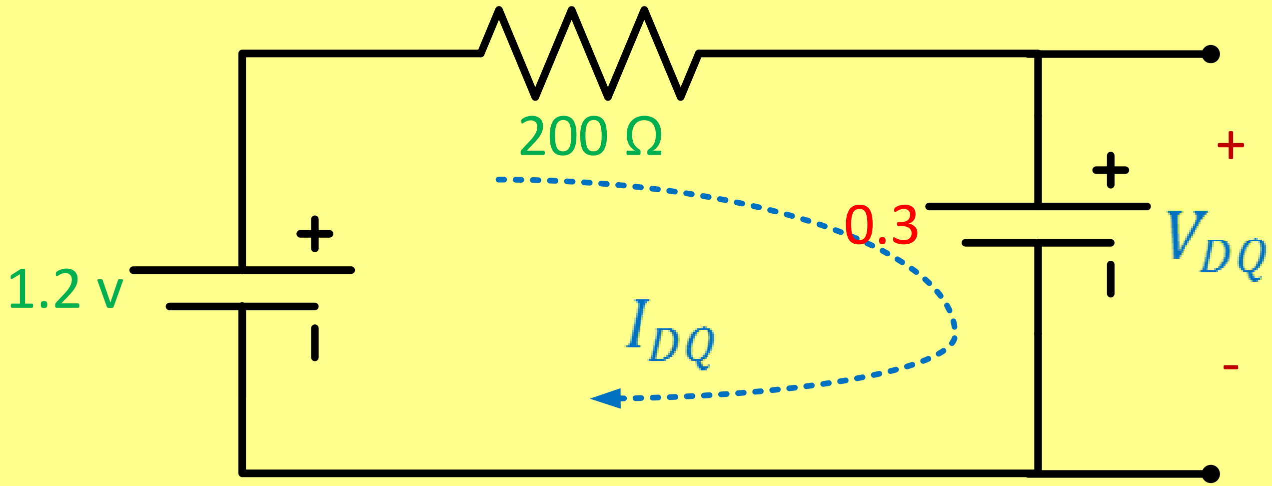


$$\therefore V_{DQ} = 0.3 \text{ v}$$

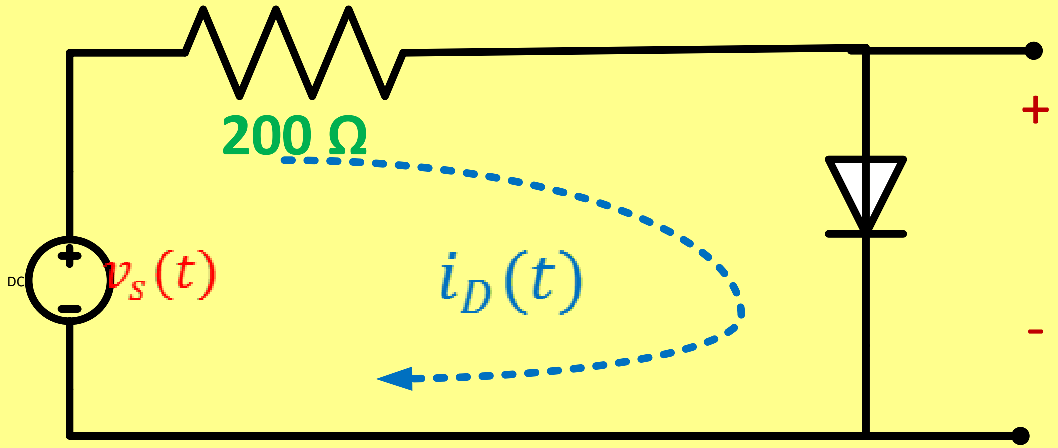
$$\text{and } I_{DQ} = \frac{1.2v - 0.3v}{200} = 4.5 \text{ mA}$$

$$\therefore r_d = \frac{V_T}{I_{DQ}} = \frac{25.69mv}{4.5mA} = 5.69\ \Omega$$





2) To find $V_d(t)$ (ac small signal)

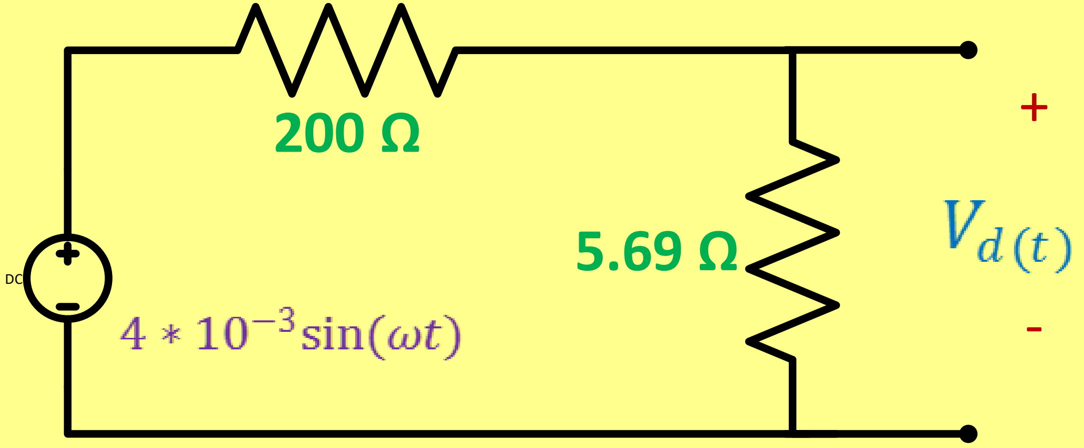


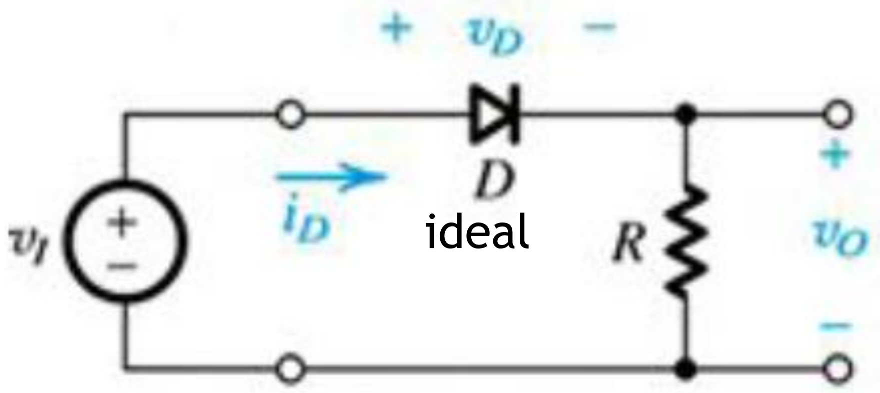
$$v_d(\text{t}) = \frac{5.69}{200+5.69} \cdot 4\text{x}10^{-3} \sin\omega t \text{ v}$$

$$v_d(\text{t}) = 0.1165 \text{ x}10^{-3} \sin\omega t \text{ v}$$

$$\therefore V_D(t) = V_{DQ} + v_d(\text{t})$$

$$V_D(t) = (0.3 + 0.1165 \text{ x}10^{-3} \sin\omega t \text{) v}$$





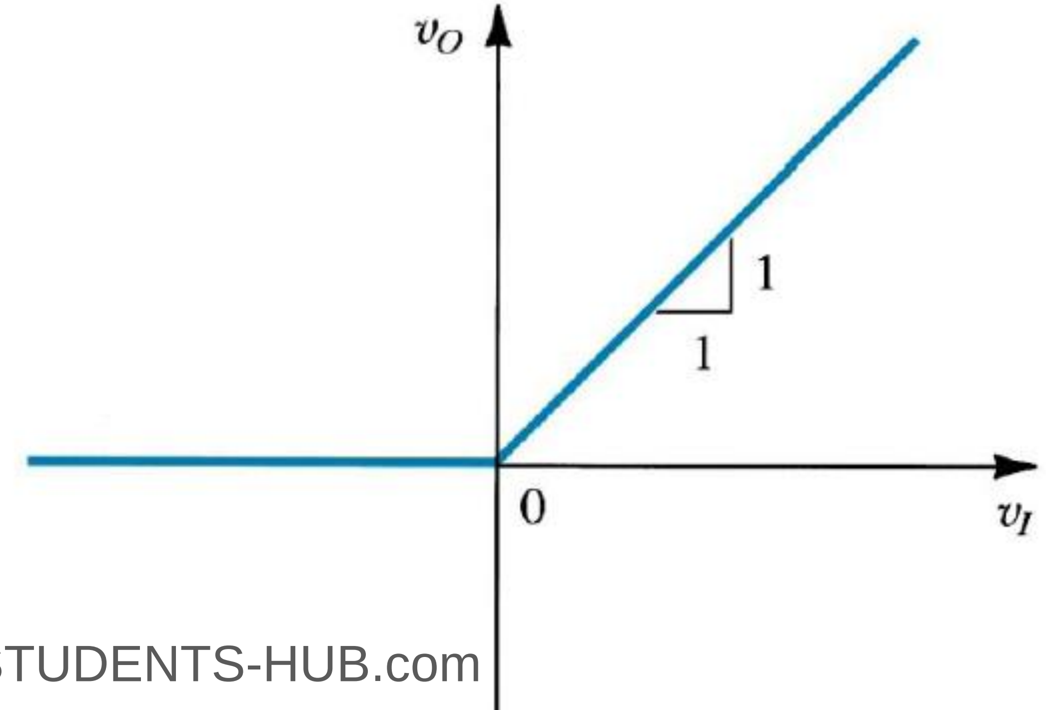
A) when $V_i(t) > 0$, Diode is on (short circuit)

$$\therefore V_o(t) = V_i(t)$$

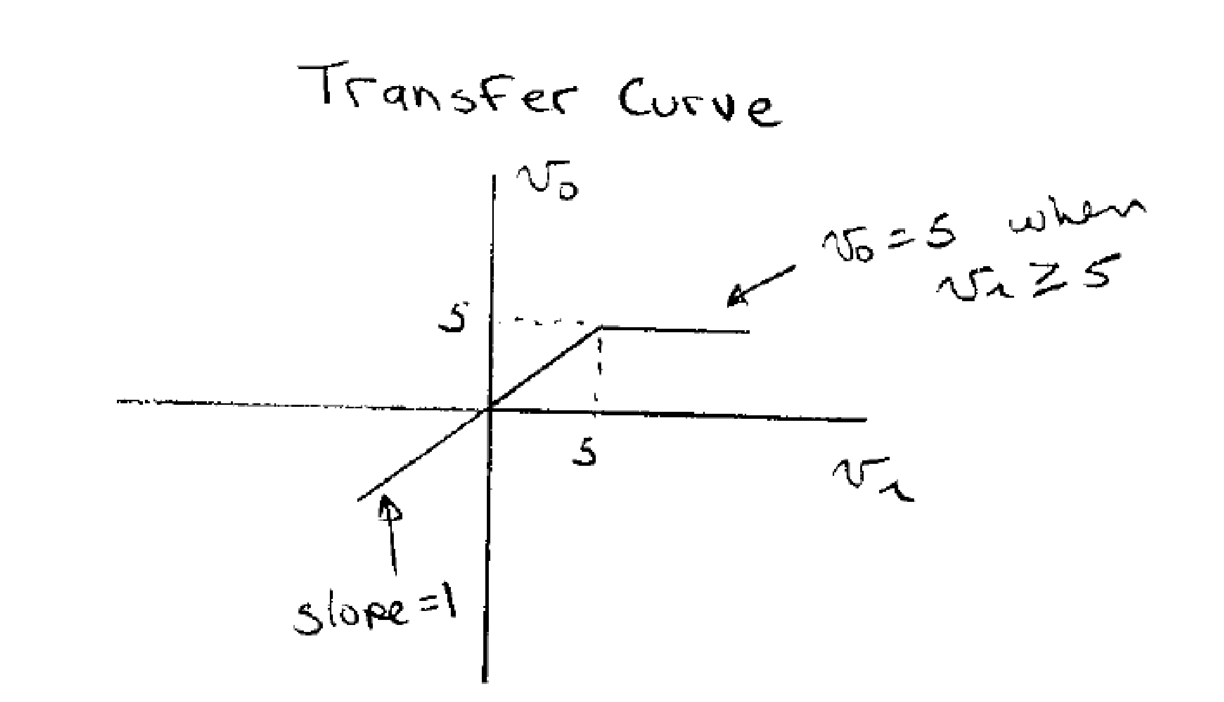
B) when $V_i(t) < 0$, Diode is off (open circuit)

$$\therefore V_o(t) = 0$$

Transfer characteristic curve



Design a diode circuit that have the given characteristic curve



Solution