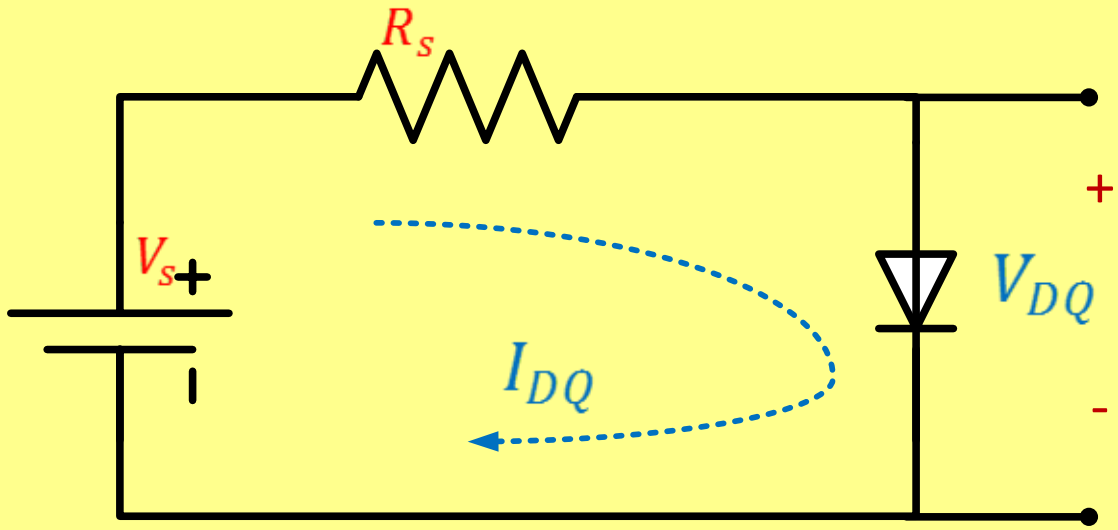
Ac Small Signal Analysis

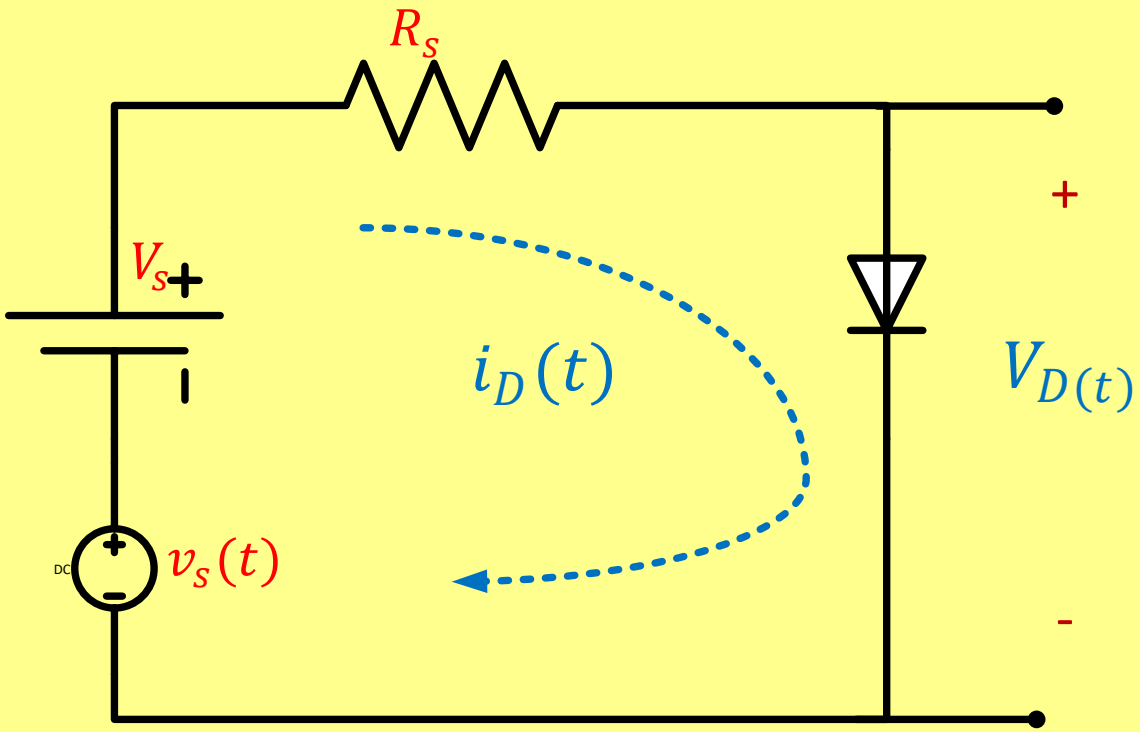
- $I_{DQ} = I_S\left(e^{\frac{V_{DQ}}{\eta V_T}} - 1\right)$
- $I_{DQ} = I_S\left(e^{\frac{V_{DQ}}{\eta V_T}}\right)$



now

- $\boldsymbol{i_D(t) = I_{DQ+}\, i_d(\mathrm{t})}$
- $\boldsymbol{V_D(t) = V_{DQ} + v_d(\mathrm{t})}$

- $\boldsymbol{i_D(t) = I_S(e^{\frac{V_D(t)}{\eta V_T}} - 1)}$



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

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

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

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

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

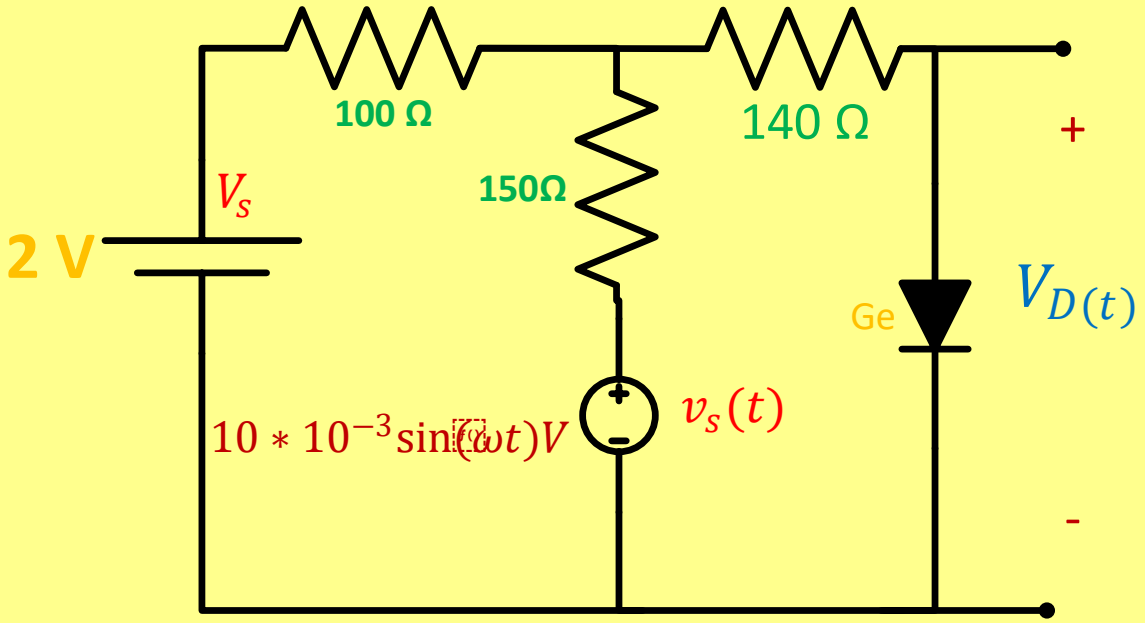
V_S= Dc component

vs(t)= ac component

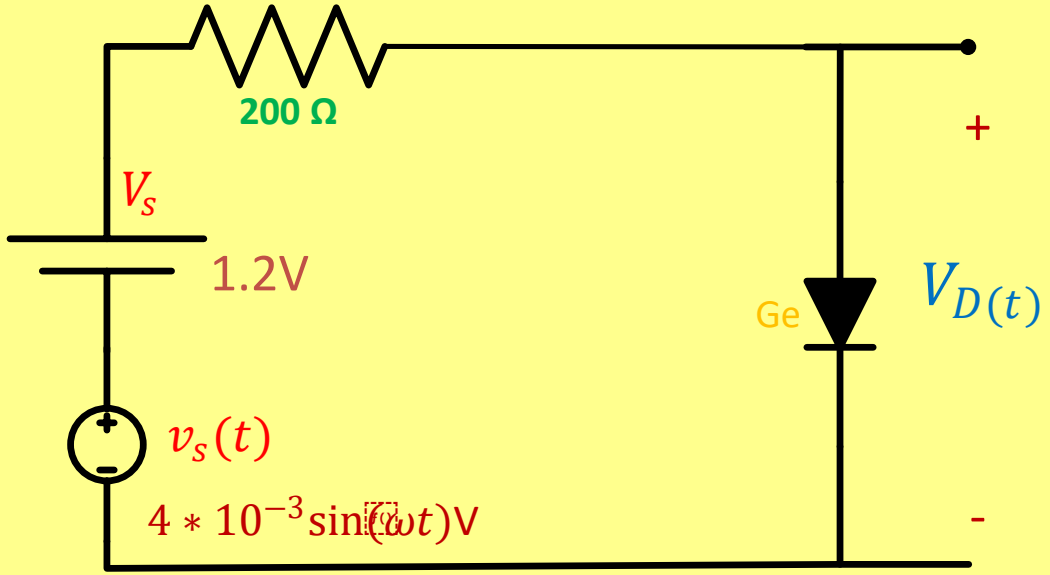
and the amplitude of vs(t) is small and the diode is always on ; we could use the superposition theorem to find the response ($V_{D(t)}$, $i_D(t)$) .

Example

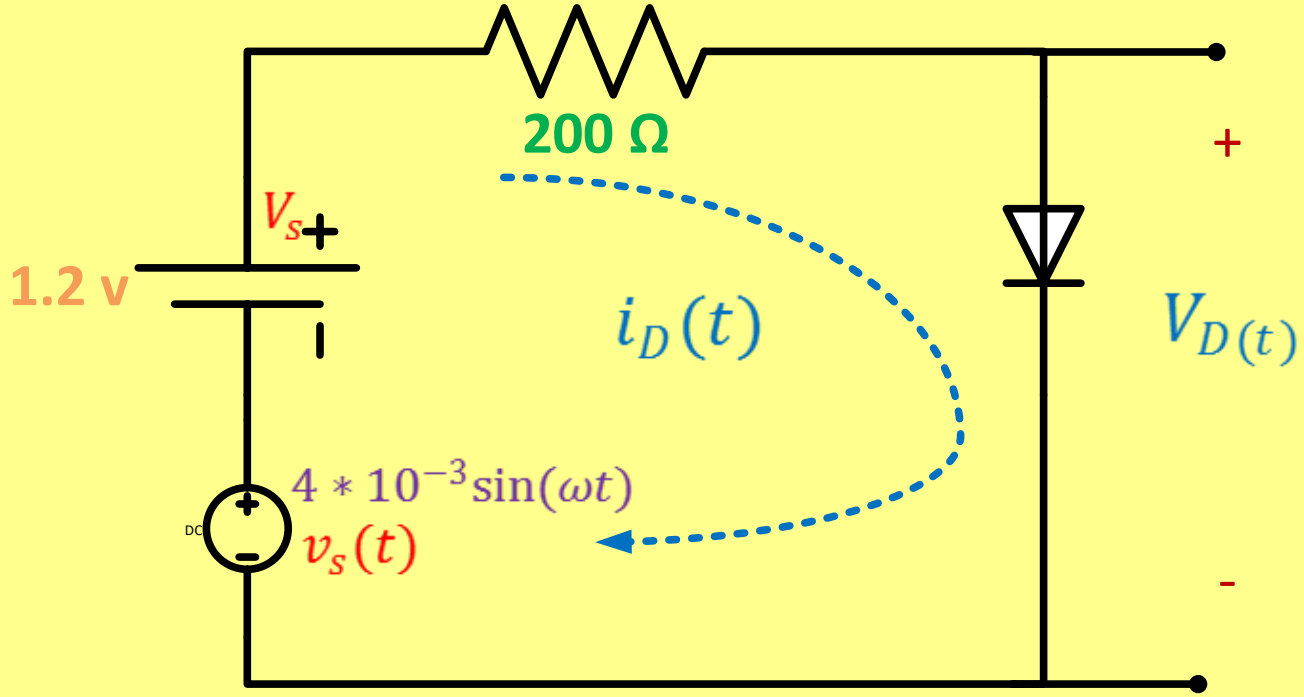
Find $V_D(t)$



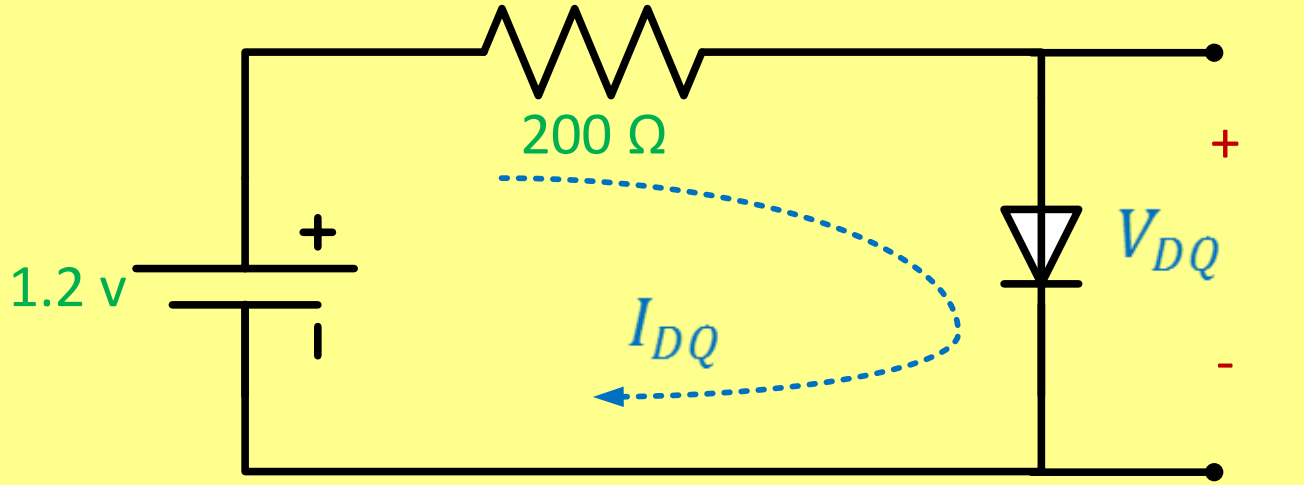
Using Thevenin's Theorem



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 $V_D(t)$



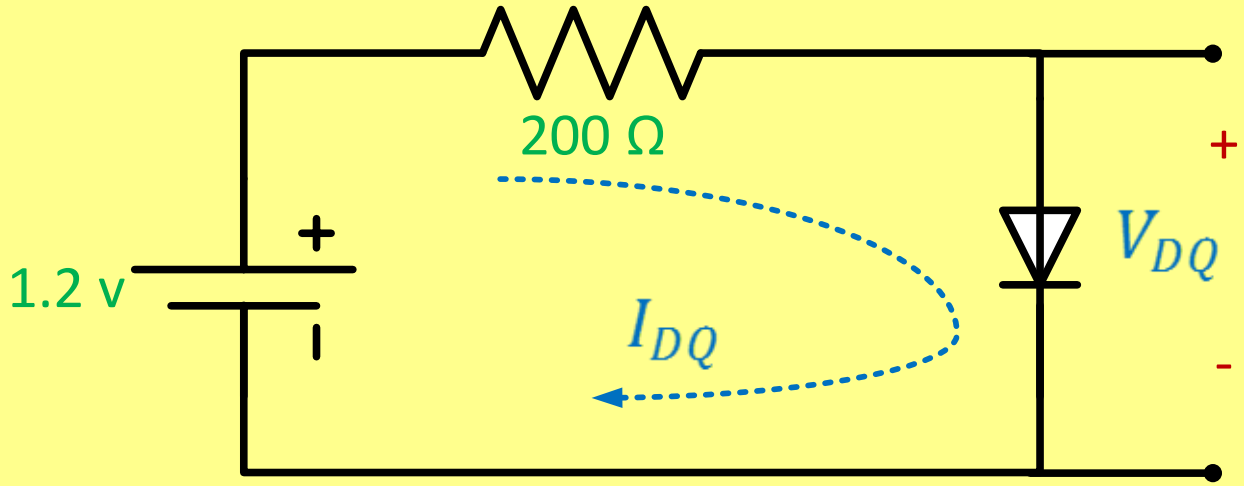
1) to find V_{DQ} (DC Analysis)

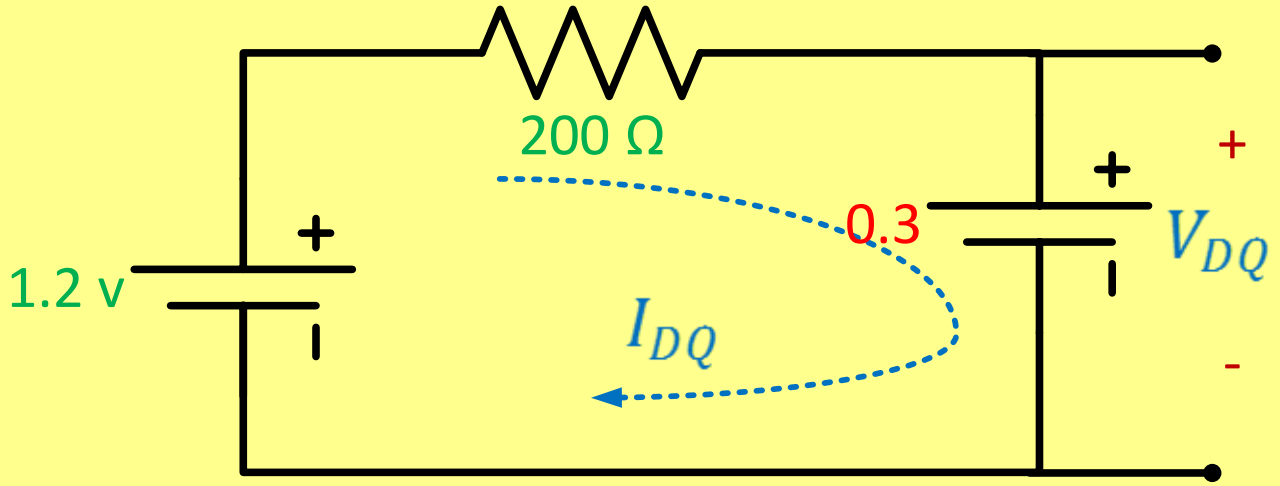


$\therefore V_{DQ}$ = 0.3 v

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

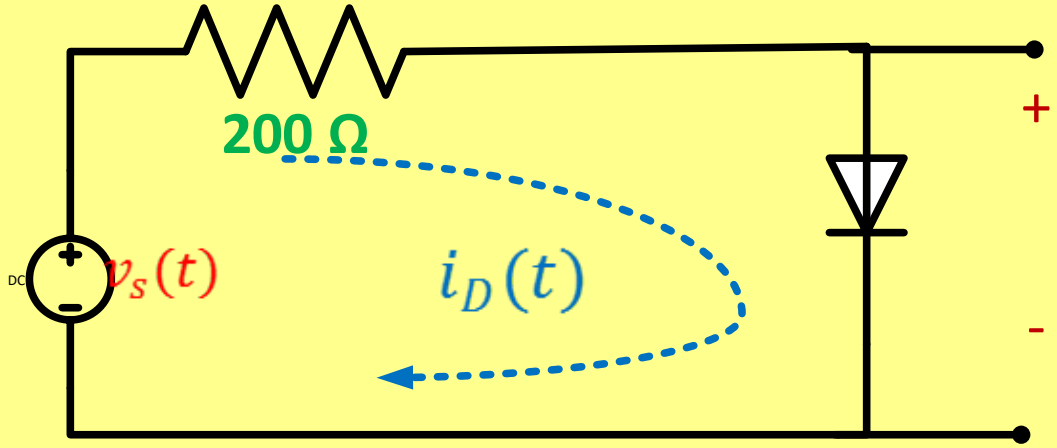
$\therefore r_d = \frac{V_T}{I_{DQ}} = \frac{25.69mv}{4.5mA}$ = 5.69 Ω





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

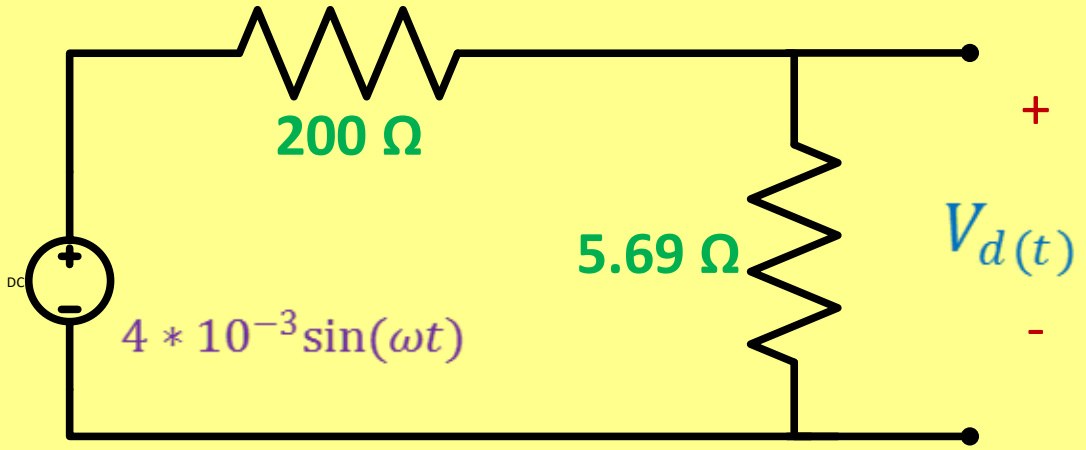
$$v_d(t) = \frac{5.69}{200+5.69} \cdot 4x10^{-3} \sin\omega t \text{ v}$$

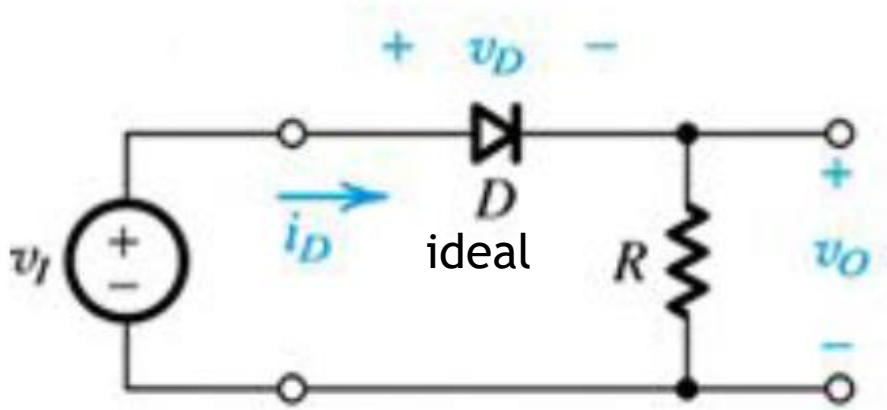


$$v_d(t) = 0.1165\ x10^{-3} \sin\omega t \text{ v}$$

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

$$V_D(t) = (0.3 + 0.1165\ x10^{-3} \sin\omega t\ ) \text{ v}$$





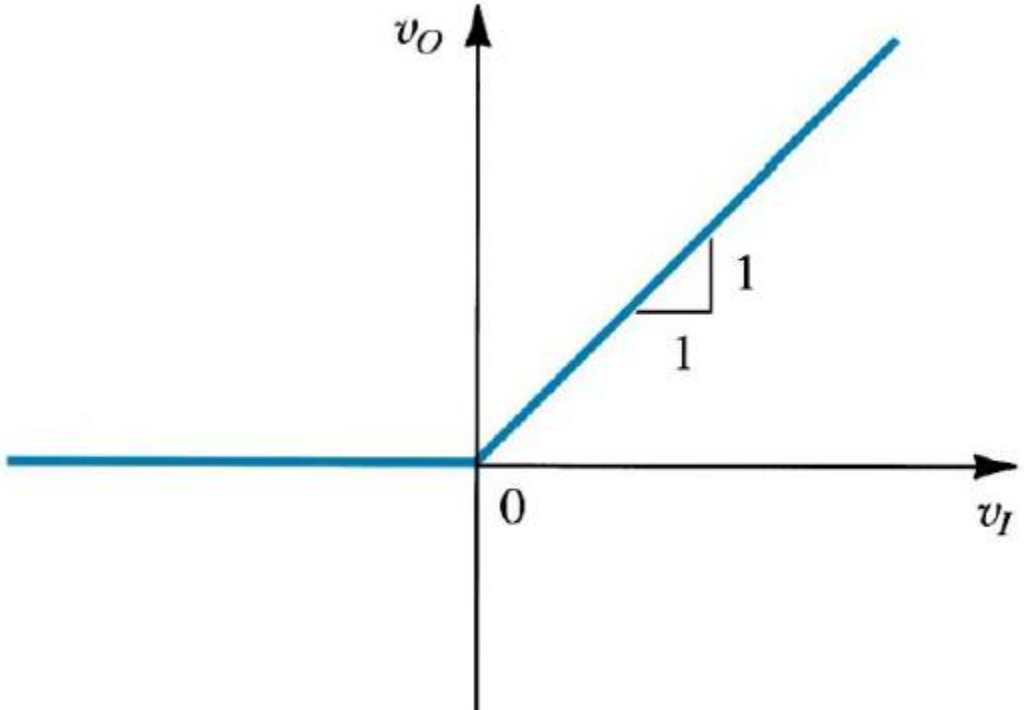
A) when $V_i(t) > 0$, Diode is on (short circuit)

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

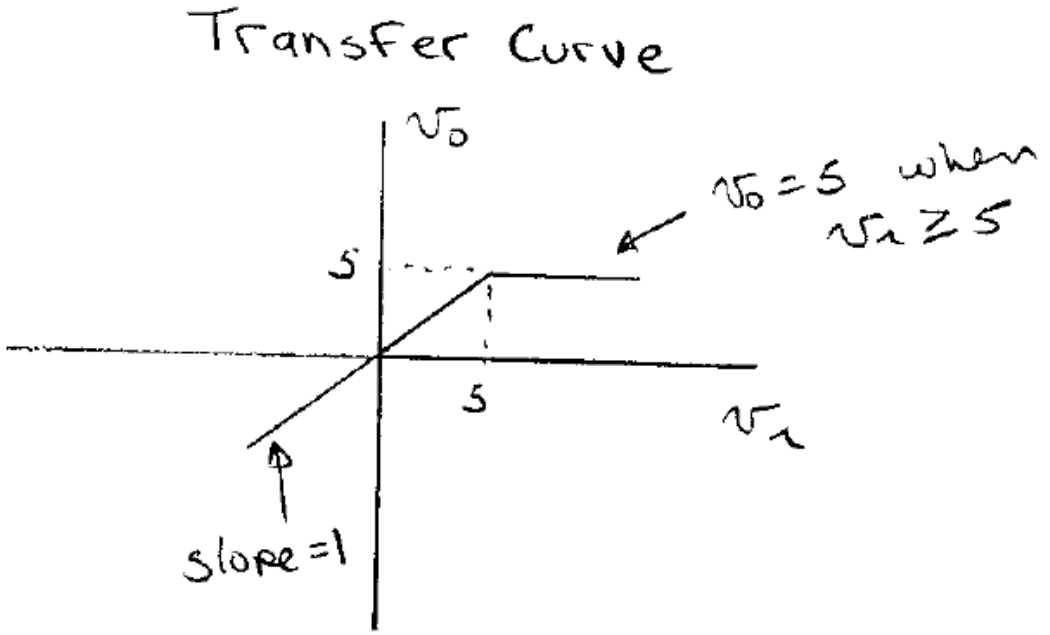
B) when $V_i(t) < 0$, Diode is off (open circuit)

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

Transfer characteristic curve



Design a diode circuit that have the given characteristic curve



Solution