

Expression for the Dynamic Resistance of a Diode

The dynamic resistance is defined as under:-

$$r_F = \frac{1}{\text{slope of the V-I characteristics}}$$

$$\text{or, } r_F = \frac{1}{\left[\frac{dI}{dV}\right]}$$

Now, the forward current, I_F is given as

$$I_F = I_0 \left[e^{V_F/nV_T} - 1 \right] \quad \text{--- (1)}$$

Differentiating equation (1) with respect to V_F , we get

$$\frac{dI_F}{dV_F} = \frac{d}{dV_F} \left[I_0 e^{V_F/nV_T} - I_0 \right]$$

$$\text{or, } \frac{dI_F}{dV_F} = \left[I_0 \frac{d[e^{V_F/nV_T}]}{dV_F} - \frac{d(I_0)}{dV_F} \right]$$

$$\text{or, } \frac{dI_F}{dV_F} = I_0 \frac{e^{V_F/nV_T}}{nV_T} \times 1 - 0$$

$$\text{or, } \frac{dI_F}{dV_F} = \frac{I_0 e^{V_F/nV_T}}{nV_T}$$

$$\text{So, } r_F = \frac{1}{\frac{dI_F}{dV_F}} = \frac{nV_T}{I_0 e^{V_F/nV_T}} \quad \text{--- (11)}$$

$$\text{From (1), } I_F = I_0 e^{V_F/nV_T} - I_0$$

$$\text{or, } I_F + I_0 = I_0 e^{V_F/nV_T} \quad \text{--- (111)}$$

using (ii) and (iii), we get

$$r = \frac{nV_T}{I + I_0}$$

Q:- The reverse saturation current for a Ge diode is $1\mu A$ at a reverse voltage of -0.52 Volts. Calculate the values of the forward and reverse dynamic resistance. Assume the forward voltage to be $+0.52V$ at room temperature.

sol:- Given that,

$$I_0 = 1\mu A = 1 \times 10^{-6} A$$

$$V_F = 0.52V \text{ for the forward biased condition.}$$

$$V_R = -0.52V \text{ for the reverse biased condition.}$$

$$n = 1 \text{ for Ge Diode}$$

$$V_T = \frac{T}{11,600} V = \frac{300}{11,600} = 25.86mV \approx 26mV.$$

① Dynamic resistance in forward biased condition

$$\text{We know, } r_F = \frac{nV_T}{I_F + I_0} = \frac{nV_T}{I_0 e^{V_F/nV_T}}$$

$$\text{or, } r_F = \frac{1 \times 26 \times 10^{-3}}{1 \times 10^{-6} \times e^{0.52/1 \times 26 \times 10^{-3}}} = \frac{26 \times 10^3}{e^{20}}$$

$$\text{or, } r_F = \frac{26 \times 10^3}{485165195.40} = 5.358 \times 10^{-5} \Omega$$

$$\text{or, } \boxed{r_F = 0.0536 \times 10^{-3} \Omega}$$

② Dynamic resistance in the reverse biased condition

$$\text{We know, } r_R = \frac{nV_T}{I_0 e^{-V_R/nV_T}} = \frac{1 \times 26 \times 10^{-3}}{1 \times 10^{-6} \times e^{-0.52/1 \times 26 \times 10^{-3}}}$$

$$\text{or, } r_R = \frac{26 \times 10^3}{e^{-20}} = 26 \times 10^3 \times e^{20} = 1.26 \times 10^{13} \Omega$$

Q:- A p-n junction diode has a temperature of 125°C and a reverse saturation current of 30μA. At a temperature of 125°C, find the dynamic resistance for 0.2 volt bias in the forward and reverse direction.

Sol:- Given that,

$$I_0(125^\circ\text{C}) = 30\mu\text{A} = 30 \times 10^{-6}\text{A}$$

$$V_F = \pm 0.2\text{V}$$

$$T = 125^\circ\text{C} \text{ or } 398\text{K.}$$

$$[K = 273 + ^\circ\text{C}]$$

$$V_T = \frac{T}{11,600} \text{ V} = \frac{398}{11,600} = 0.0343\text{V.}$$

$$\begin{aligned} \text{Temp. in K} \\ &= 273 + 125 \\ &= 398 \end{aligned}$$

$$\text{or, } V_T = 34.3\text{mV}$$

① Dynamic resistance in the forward biased condition

$$r_F = \frac{nV_T}{I_0 e^{V_F/nV_T}}$$

$$\text{or, } r_F = \frac{1 \times 34.3 \times 10^{-3}}{30 \times 10^{-6} \times e^{0.2/1 \times 34.3 \times 10^{-3}}} = \frac{34.3 \times 10^{-3}}{30 \times 10^{-6} \times e^{5.830}}$$

$$\text{or, } r_F = \frac{1143.333}{340.3586} = 3.36\Omega$$

② Dynamic resistance in the reverse biased condition

$$r_R = \frac{nV_T}{I_0 e^{-V_F/nV_T}} = \frac{1 \times 34.3 \times 10^{-3}}{30 \times 10^{-6} e^{-0.2/34.3 \times 10^{-3} \times 1}}$$

$$\text{or, } r_R = \frac{1143.333}{e^{-5.830}} = 1143.333 \times e^{5.830}$$

$$\text{or, } r_R = 1143.333 \times 340.3586.$$

$$\text{or, } \boxed{r_R = 389.14\text{K}\Omega}$$

Q:- Determine the dynamic resistance of a P-N junction diode at a forward current of 2mA. Assume that

$$\frac{KT}{e} = 25\text{mV.}$$

sol:- Given that $I_F = 2\text{mA} = 2 \times 10^{-3}\text{A}$

and $V_T = \text{voltage-equivalent of temperature} = \frac{KT}{e} = 25\text{mV.}$

Dynamic resistance r_F is given as

$$r_F = \frac{nV_T}{I_F + I_0}$$

But $I_F \gg I_0$, so

$$r_F \approx \frac{nV_T}{I_F}^*$$

$$\text{Therefore, } r_F = \frac{1 \times 25 \times 10^{-3}}{2 \times 10^{-3}}$$

$$\text{or, } r_F = 12.5 \Omega$$

Q:- Find ac resistance for a semiconductor diode having a forward bias of 200mV and reverse saturation current of 1 μ A at room temperature.

sol:- Given, $V_F = 200\text{mV} = 200 \times 10^{-3}\text{V}$

$$I_0 = 1\mu\text{A} = 10^{-6}\text{A}$$

$$V_T = \frac{T}{11,600} \text{ V} \Rightarrow V_T \Big|_{\text{room temperature}} = 26\text{mV} = 26 \times 10^{-3}\text{V.}$$

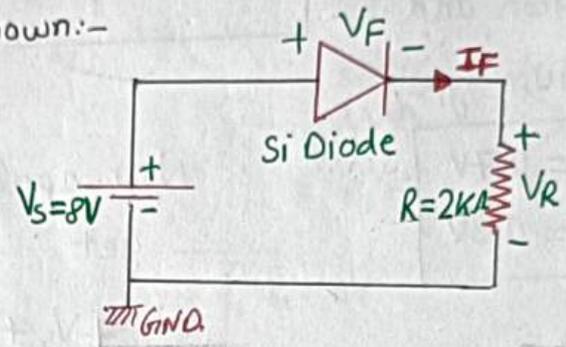
$$\therefore \text{ ac resistance, } r_F = \frac{nV_T}{I_0 e^{V_F/nV_T}} = \frac{1 \times 26 \times 10^{-3}}{10^{-6} e^{\frac{200 \times 10^{-3}}{1 \times 26 \times 10^{-3}}}}$$

$$\text{or, } r_F = \frac{26 \times 10^{-3}}{e^{7.6923}} = \frac{26 \times 10^{-3}}{2191.4090}$$

$$\text{or, } r_F = 0.01186 \times 10^{-3}$$

$$\text{or, } r_F = 11.86 \Omega$$

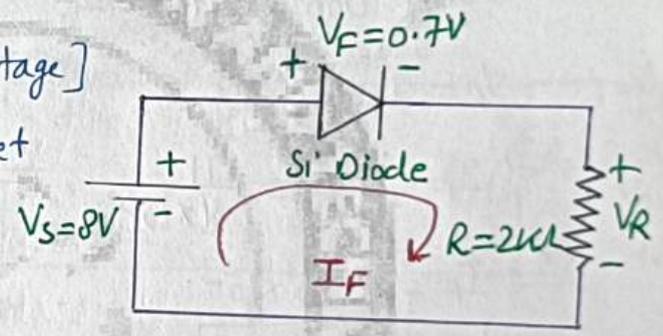
Q1:- Find the value of V_F , V_R and I_F for the series diode configuration circuit shown:-



Sol:- Given, diode used is Silicon

So, $V_F = V_0 = 0.7V$ [cut-in voltage]

Applying KVL in the circuit, we get



$$+V_s - V_F - V_R = 0$$

$$\Rightarrow V_R = V_s - V_F = 8 - 0.7 = 7.3V$$

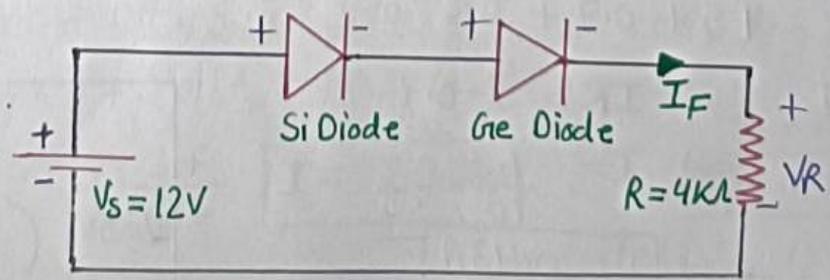
$$\Rightarrow V_R = 7.3V$$

Now, using Ohm's law, $V_R = I_F R$

$$\Rightarrow I_F = \frac{V_R}{R} = \frac{7.3}{2 \times 10^3} = 3.65 \times 10^{-3}$$

$$\Rightarrow I_F = 3.65mA$$

Q2:- Find the value of V_R and I_F for the series diode configuration shown:-



Sol:-

Given, diodes used are Silicon and Germanium type.

So, $V_{F1} = 0.7V$
 and, $V_{F2} = 0.3V$

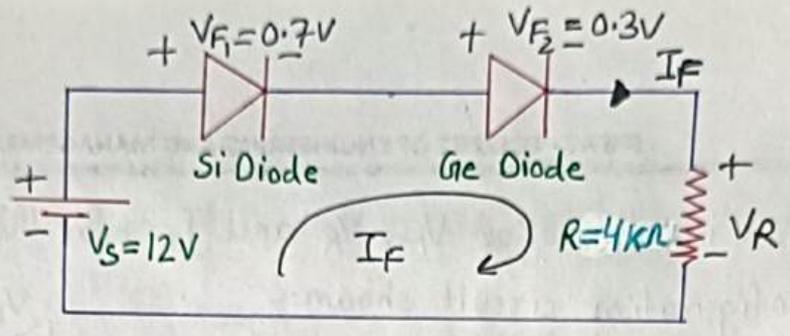
Now, using Ohm's law

$$V_R = I_F R$$

$$\Rightarrow I_F = \frac{V_R}{R} = \frac{11}{4 \times 10^3}$$

$$\Rightarrow I_F = 2.75 \times 10^{-3}$$

$$\Rightarrow \boxed{I_F = 2.75 \text{ mA}}$$



Now, applying KVL in the circuit, we get

$$+V_S + V_{F1} - V_{F2} + V_R = 0$$

$$\Rightarrow V_R = V_S - V_{F1} - V_{F2}$$

$$\Rightarrow V_R = 12 - 0.7 - 0.3$$

$$\Rightarrow V_R = 11$$

$$\Rightarrow \boxed{V_R = 11V}$$

Q3:- What is the current in the following circuit shown:-

Sol:- Given, Silicon diode is used,

So, $V_F = 0.7V$.

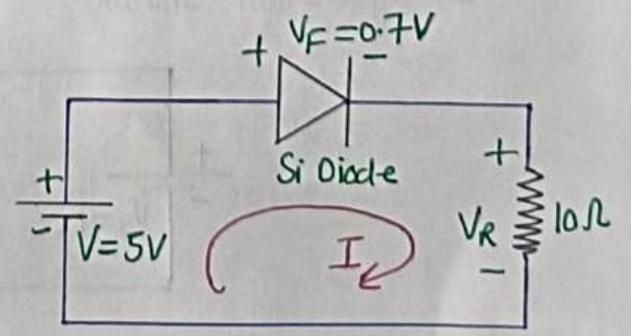
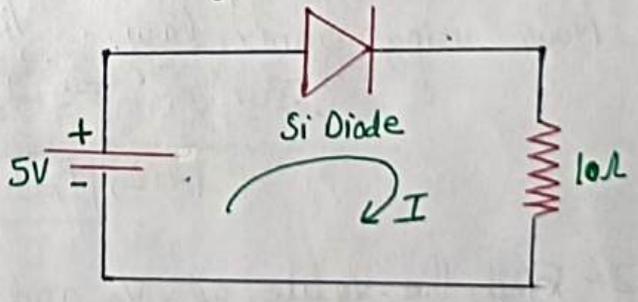
On applying KVL, we get

$$+5 + 0.7 - IR = 0$$

$$\Rightarrow IR = 5 - 0.7$$

$$\Rightarrow I = \frac{4.3}{10}$$

$$\Rightarrow \boxed{I = 0.43A}$$



Q4:- Figure shows the circuit of series diode configuration. Find the value of I , V_{R_1} , V_{R_2} and V_o .

Sol:- Given, $R_1 = 4k\Omega$
 $R_2 = 2k\Omega$
 $V_{S_1} = 10V$
 $V_{S_2} = 5V$

$$V_F |_{\text{Si Diode}} = 0.7V$$

On applying KVL, we get

$$+V_{S_1} - V_{R_1} - V_F - V_{R_2} + V_{S_2} = 0$$

$$\Rightarrow V_{R_1} + V_{R_2} = V_{S_1} + V_{S_2} - V_F$$

$$\Rightarrow V_{R_1} + V_{R_2} = 10 + 5 - 0.7$$

$$\Rightarrow V_{R_1} + V_{R_2} = 14.3 \quad \text{--- (I)}$$

Now, using Ohm's law, we get

$$V_{R_1} = IR_1 \Rightarrow V_{R_1} = I \times 4 \times 10^3$$

$$V_{R_2} = IR_2 \Rightarrow V_{R_2} = I \times 2 \times 10^3$$

Using (I) and (II), we get

$$I \times 4 \times 10^3 + I \times 2 \times 10^3 = 14.3$$

$$\Rightarrow I [4 \times 10^3 + 2 \times 10^3] = 14.3$$

$$\Rightarrow I = \frac{14.3}{6 \times 10^3} \Rightarrow \boxed{I = 2.38 \text{ mA}}$$

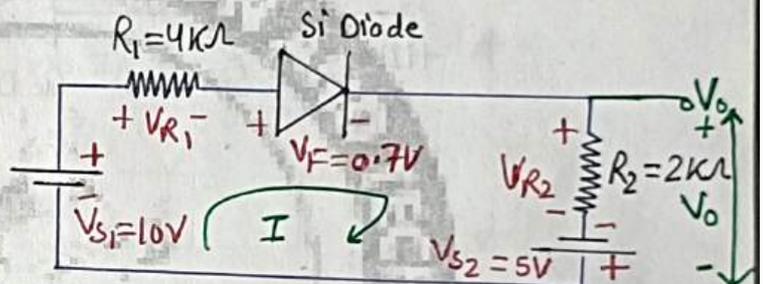
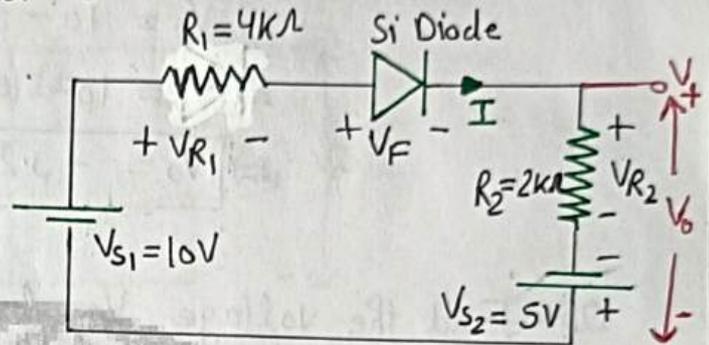
Using (II), we get

$$V_{R_1} = 2.38 \times 10^{-3} \times 4 \times 10^3$$

$$\Rightarrow \boxed{V_{R_1} = 9.52 \text{ V}}$$

$$\text{And, } V_{R_2} = 2.38 \times 10^{-3} \times 2 \times 10^3$$

$$\text{or, } \boxed{V_{R_2} = 4.76 \text{ V}}$$



To find V_o , applying KVL again, we get

(54)

$$+V_{s1} - V_{R1} - V_F - V_o = 0$$

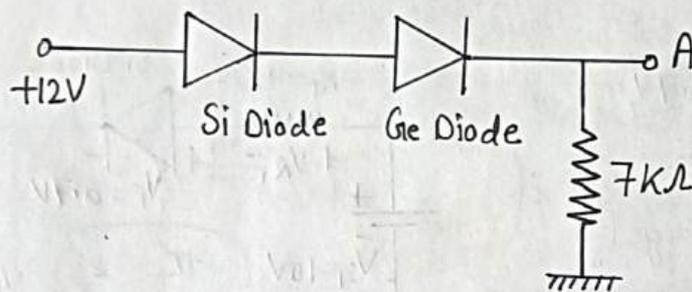
$$\Rightarrow V_o = V_{s1} - V_{R1} - V_F$$

$$\Rightarrow V_o = 10 - 9.52 - 0.7$$

$$\Rightarrow V_o = 10 - 10.22$$

$$\Rightarrow \boxed{V_o = -0.22V}$$

Q5:- Find the voltage V_A for the given circuit



Sol:- The given circuit can be redrawn as:-

On applying KVL, we get

$$+12 + 0.7 + 0.3 + V_A = 0$$

$$\Rightarrow V_A = 12 - 1$$

$$\Rightarrow \boxed{V_A = 11V}$$

or

On applying KVL, we get

$$+12 - 0.7 - 0.3 + V_R = 0$$

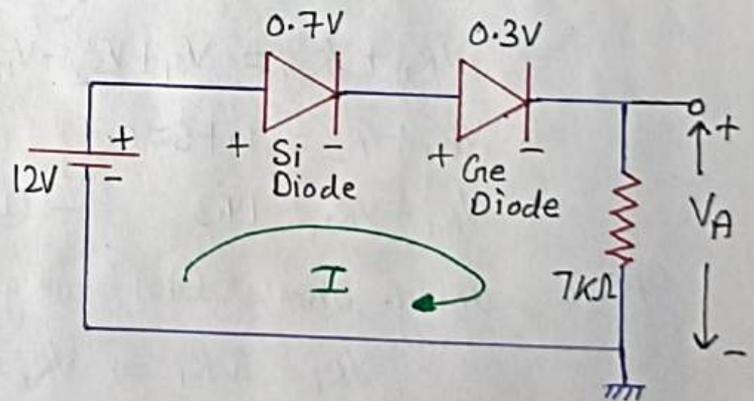
$$\Rightarrow V_R = 12 - 1$$

$$\Rightarrow I \times R = 11$$

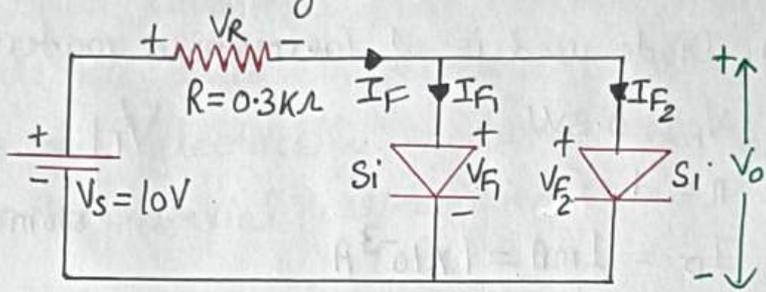
$$\Rightarrow I = \frac{11}{7 \times 10^3} = 1.57 \text{ mA}$$

$\therefore V_A = V_R =$ Voltage drop in resistor $7 \text{ k}\Omega = 1.57 \times 10^{-3} \times 7 \times 10^3$

$$\Rightarrow \boxed{V_A = 11V}$$

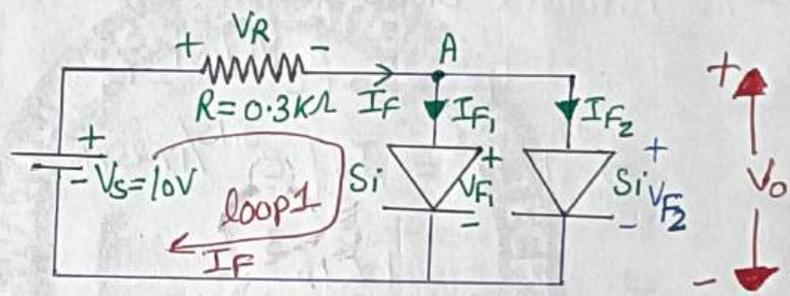


Q6:- Find the values of V_o , I , I_{F1} and I_{F2} for the circuit of parallel diode configuration.



Sol:-

Assuming the silicon diode used is identical i.e.



made having same characteristics and properties.

So, $V_{F1} = V_{F2} = 0.7V$ (say)

Also, $I_{F1} = I_{F2}$

Applying KCL at node A, we get

$$I_F = I_{F1} + I_{F2}$$

$$\Rightarrow I_F = I_{F1} + I_{F1}$$

$$\Rightarrow I_F = 2I_{F1}$$

$$\Rightarrow \boxed{I_{F1} = I_{F2} = \frac{I_F}{2}}$$

Also, the voltage drop across the parallel elements are always same.

Therefore, $\boxed{V_{F1} = V_{F2} = V_o = 0.7V}$

Now, applying KVL in loop 1, we get

$$+V_s - V_R - V_{F1} = 0$$

$$\Rightarrow V_R = V_s - V_{F1}$$

$$\Rightarrow V_R = 10 - 0.7$$

$$\Rightarrow I_F \times R = 9.3$$

$$\Rightarrow I_F = \frac{9.3}{0.3 \times 10^3}$$

$$\Rightarrow I_F = 31mA$$

So, $\boxed{I_{F1} = I_{F2} = \frac{I_F}{2} = 15.5mA}$

(56)

Q7:- A Germanium diode carries a current of 1mA at room temperature when forward bias applied is 0.15V. Calculate the reverse saturation current.

Sol:- Given, Diode used is of Germanium material

$$V_F = 0.15V$$

$$n = 1$$

$$I_F = 1mA = 1 \times 10^{-3}A$$

$$V_T \Big|_{\text{room temperature}} = 26mV$$

Now, Forward Diode current equation is given as

$$I_F = I_0 \left[e^{V_F/nV_T} - 1 \right]$$

$$\Rightarrow 1 \times 10^{-3} = I_0 \left[e^{0.15/1 \times 26 \times 10^{-3}} - 1 \right]$$

$$\Rightarrow I_0 = \frac{1 \times 10^{-3}}{e^{5.769} - 1}$$

$$\Rightarrow I_0 = \frac{10^{-3}}{320.217 - 1}$$

$$\Rightarrow I_0 = \frac{1 \times 10^{-3}}{319.217}$$

$$\Rightarrow I_0 = 3.13 \mu A = 3.13 \times 10^{-6} A$$

Diode Capacitance

In P-N junction diode, two types of capacitance take place.

They are:-

(I) Transition Capacitance (C_T)

(II) Diffusion Capacitance (C_D)