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GATE Electronics (ECE) and GATE Electrical (EE) Coaching By IITians GATE CLASSES

Analog Electronics

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Diode

Diode is unilateral device, which converts the bi-directional current into uni-directional current.

Application:

It is used in the rectifier, clipper and clamper, which will be discussed in more details later

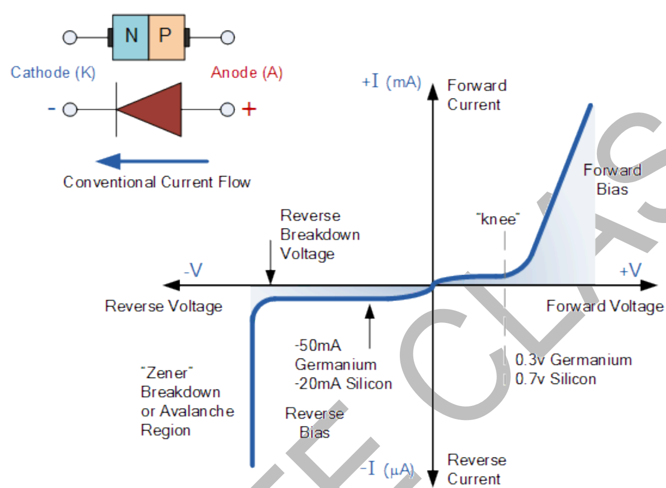

Fig. 1 Diode and its I-V response

Diode's Shockley equation:

$I_D = I_S\,(e^{VD}-1)$ eq. 1

I_D is the diode current

V_D is the voltage across diode

I_S is the reverse bias current

V_{diode} is the cut-in voltage of the diode, which is generally 0.7V for Si, and 0.4V for Ge.

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Diode in DC circuit (DC analysis):

In DC circuits, diode behaves like a battery in series with a resistor (R_D) as shown in fig. 2

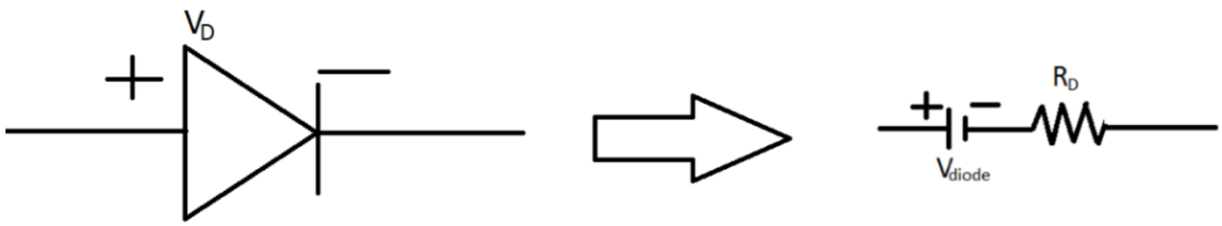

Fig. 2 Diode and its DC equivalent model

V_{diode} is considered as the cut-in voltage of the diode, which is generally 0.7V for Si and 0.4V for Ge.

In any question, R_D is considered as zero, until and unless it is given.

How to solve for the DC circuits consisting of diodes?

Step-1 Assume all the diodes are forward-biased

Step-2 Apply KVL/KCL to get the answer

Step-3 Verify, that if your assumption (that all diodes are forward-biased) is correct.

If assumption is correct, then your calculated answer in step-2 is correct

If assumption is incorrect, then your calculated answer in step-2 is false, and again you have to start from the step-1, with the new assumption, and then proceed to step-2

These things will be more clear in the below example.

Ques. Calculate Vo in the below circuit.

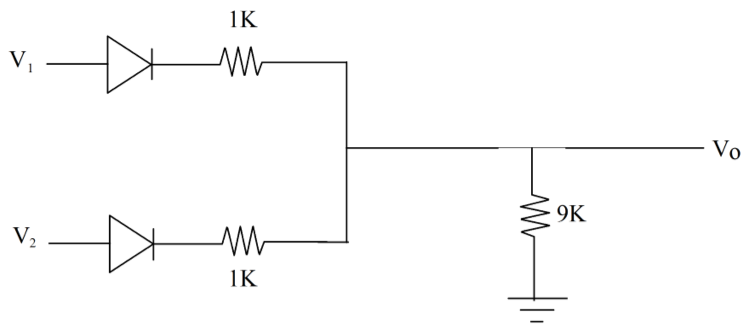

Fig. 3

Cut-in voltage of the diodes (V_{diode}) = 0

DC resistance of the diodes (R_D) = 0

So the diode can be replaced with a wire.

Sol.

Step-1) Assume all the diodes are forward-biased, so the equivalent circuit will be as shown below in fig. 4

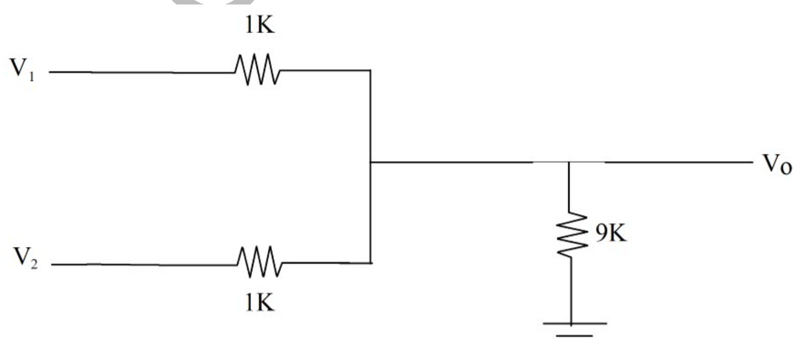

Fig. 4

Step-2) Apply KCL at node Vo

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$\frac{V1-Vo}{1k} + \frac{V2-Vo}{1k} = \frac{Vo}{9k}$

$V_o = 7.1$ V

Step-3 Verify the assumption (i.e. every diode is ON)

	Condition	
About D1 (to be ON)	V1 > Vo	V1=10 V & Vo = 7.1V (V1 > Vo)
About D2 (to be ON)	V2 > Vo	V2 = 5V & Vo = 7.2V (V2 < Vo), it is violating the condition, and so it has to be in reverse-biased

Our assumption is wrong, and so our answer is also wrong. Now again we have to start from the step-1, with the new assumption (D1 is ON and D2 is OFF).

Step-1 Assume D1 is ON and D2 is OFF, and so equivalent circuit will be as shown below in fig. 5

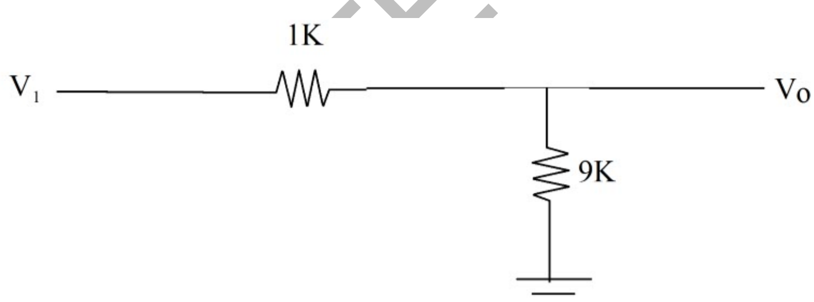

Fig. 5

Step-2 Apply KCL at node Vo

$\frac{V1-Vo}{1k} = \frac{Vo}{9k}$

$V_o = 9$ V

Step-3 Verify the assumption (D1 is ON and D2 is OFF)

	Condition	

About D1 (to be ON)	V1 > Vo	V1=10 V & Vo = 9V (V1 > Vo)
About D2 (to be OFF)	V2 < Vo	V2 = 5V & Vo = 9V (V2 < Vo)

Conditions for both (D_1 and D_2) are favorable, which concludes that our assumptions is write and hence our answer is also correct.

Diode in AC circuit (AC analysis):

In AC circuits, diode behaves like a resistor (R_{ac}), as shown in fig. 6

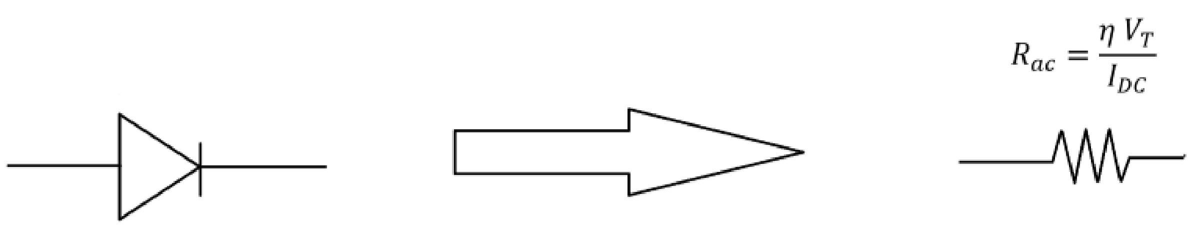

Fig. 6 Diode and its ac equivalent model

$R_{ac} = \frac{\eta V_T}{I_{DC}}$

η is the emission constant or the ideality factor, whose value is considered to be 1, until and unless it is given

I_{DC} is the DC current, which was calculated in the DC analysis

V_T is the thermal equivalent voltage, whose value is 25 mV at room temperature (27C).

Note: Circuits are not pure AC, instead there are both DC and AC voltage sources present in the circuit.

In this kind of question, first do the DC analysis and then do the AC analysis

DC analysis:

Rules for the DC analysis

1) Short all the AC-voltage sources and open all the AC current sources
2) Replace the diode, with a battery in series with resistor as shown in the fig. 2

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3) Solve the circuit, to calculate the DC current (I_{DC}), which will be used to calculate the R_{ac} in the AC analysis

AC analysis:

1) Short all the DC voltage sources, open all the DC current sources
2) Replace the diode with a small signal ac equivalent model as shown in fig. 6
3) Then solve the resultant circuit to get the desired answer.

Ques: Calculate the total current passing through the diodes as shown in fig. 7

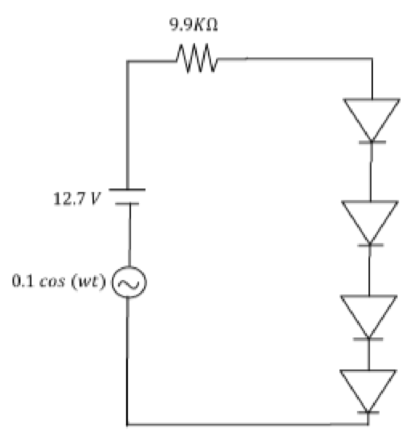

Fig. 7

In this circuit, dc and ac sources are present, so first DC analysis and then AC analysis has to be done.

Total current = $I_{DC} + i_{ac}$

DC analysis:

$\boldsymbol{I_{DC}}$

Apply first two rules of the DC analysis mentioned above, and then the equivalent circuit will look like

fig. 8 shown below

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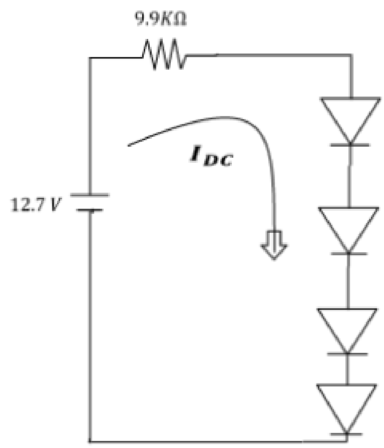

Fig. 8

Note: R_D is not given, hence is considered to be zero, hence not shown in the fig. 8

And now apply the 3rd rule, i.e. apply the KVL, and calculate the current (I_{DC})

$12.7 – 9.9k*I_{DC} -4*0.7 = 0$

$I_{DC} = 1mA$

AC analysis:

Apply the first two rules for the AC analysis and so the equivalent circuit will look like in fig. 9

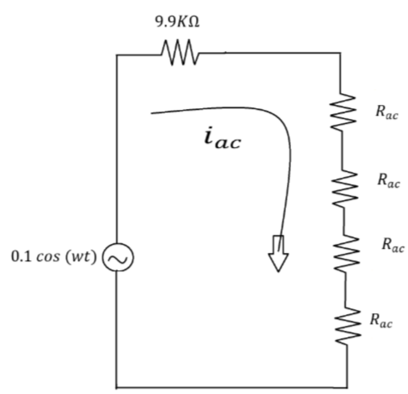

Fig. 9

$R_{ac} = \frac{\eta V_T}{I_{DC}}$ = 25 Ω

Now use the 3rd rule and apply the KVL

$0.1\cos(\omega t) - 9.9k*i_{ac} - 4*R_{ac}*i_{ac} = 0$

$I_{ac} = 10^{-5}\cos(\omega t)$

Total current = $I_{DC} + i_{ac}$

= $(1m + 10^{-5}\cos(\omega t))$ A