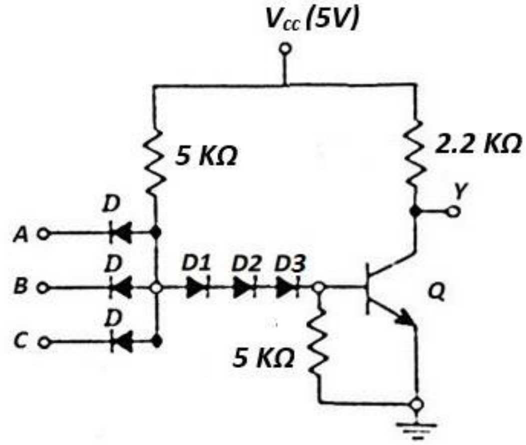
1. For the following circuit, assume that $V_{BE(sat)} = 0.8$ V, $V_\gamma = 0.5$ V and $V_{CE(Sat)} = 0.2$ V. The drop across a conducting diode is 0.7 V and $V_{\gamma(diode)}$= 0.6 V and h_{FE}=30. Here Y is the output of the given circuit.



a) Prove that the circuit works like a NOR gate and also find the minimum value of h_{FE} so that the circuit will properly operate as a negative logic NOR gate. **5**

b) Calculate NM(0) and NM(1). **3**

c) Find the average power P dissipated by the gate. **2**

Solution:

Case-1:

A= 0.2 V= V(1)
B= 5 V= V(0)

V_p= 0.2+0.7= 0.9 V

Minimum amount of voltage required to turn on the transistor, Q is:

D1+D2+D3+Q
= 0.6+0.6+0.6+0.5 [Taking the cut-in voltages of diodes and transistor]
= 2.3 V

As, V_p << 2.3 V so the transistor will operate in cut-off region.

So, Y = V_o = 5.0 V = V(0)

The same case will happen for the case A=5V, B=0.2V and A=0.2V, B=0.2V

Case-2:

A = B = 5 V = V(0)

V_p = D1+D2+D3+Q
= 0.7+0.7+0.7+0.8
= 2.9 V

I_1 = (5-2.9)/5 K = 0.42 mA
I_2 = (0.8-0)/5 K = 0.16 mA
$I_B = I_1 - I_2$ = 0.42-0.16 = 0.26 mA
I_C = (5-0.2)/2.2 K = 2.182 mA

$h_{FE} = I_C/I_B$ = 2.182/0.26 = 8.392

In order to turn the transistor in saturation the value h_{FE} should be more than 8.392.

A	B	V_o
V(1)	V(1)	V(0)
V(1)	V(0)	V(0)
V(0)	V(1)	V(0)
V(0)	V(0)	V(1)

Here, V(1) = 0.2 V, V(0) = 5 V

Conclusion: The circuit is acting as a **negative logic** NOR gate.

NM(0):

When at least one input is V(1)= 0.2 V then output V_0 = 5 V = V(0)

V_p= 0.2+0.7= 0.9 V

Minimum amount of voltage required to turn on the transistor, Q is:

D1+D2+D3+Q
= 0.6+0.6+0.6+0.5 [Taking the cut-in voltages of diodes and transistor]
= 2.3 V

NM(0) = 2.3-0.9 = + 1.4 V ['+' because the voltage might increase up to 1.4 V]

NM(1):

When all the inputs are V(0)= 5 V then output V_0 = 0.2 V = V(1)

V_p= D1+D2+D3+Q = 0.7+0.7+0.7+0.8 = 2.9 V

Reverse bias by: (5-2.9) = 2.1 V
Forward bias by: 0.6 V [cut-in voltage of diode is 0.6 V]

NM(1) = 2.1+0.6 = - 2.7 V ['-' because the voltage might decrease up to 2.7 V]

Power(P):

$I(1) = I_1+I_C = 0.42+2.182 = 2.602$ mA
$I(0) = (5-0.9)/5$ K $= 0.82$ mA

$P(1) = V.I(1) = 5*2.602 = 13.01$ W
$P(0) = V.I(0) = 5*0.82 = 4.1$ W

Power, $P = (P(1)+P(0))/2 = (13.01+4.1)/2 = 8.555$ W