1. Assuming an offset ideal model, what is the current, \( I \), if the diode has the turn on voltage \( V_{on} = 3 \, V \)?

   a. 15 mA  
   b. 30 mA  
   c. 45 mA  
   d. 60 mA  
   e. 75 mA  

   Since \( 4.5 \, V > V_{on} \), assume diode is ON.

   \[ I = \frac{4.5 - 3}{100} = 15 \, mA \]

2. What is the current, \( I \), supplied by the voltage source, assuming offset ideal model with \( V_{on} = 0.3 \, V \) for both diodes?

   a. 0 mA  
   b. 7 mA  
   c. 8.5 mA  
   d. 14 mA  
   e. 17 mA  

   For \( D1 \) to be ON need \( 0.3 \, V \).

3. How many of the light-emitting diodes are ON (emitting light) in the diagram below, assuming an offset ideal model with \( V_{on} = 2 \, V \) for all diodes?

   a. 3  
   b. 4  
   c. 5  
   d. 6  
   e. 7  

   \( V_{on} = 2 \, V \) is not TRUE.
4. What are the minimum and maximum values of $V_{out}$ assuming the offset ideal model for the diodes with $V_{on} = 0.7\, V$ and the input signal given by $V_{in} = 5\cos(120\pi t)$?

a. minimum -5 V, maximum 5 V  
b. minimum -5 V, maximum 3.7 V  
c. minimum -5 V, maximum 3 V  
d. minimum 2.3 V, maximum 5 V  
e. minimum 3.7 V, maximum 5 V

5. What are the minimum and maximum values of $V_{in}$ assuming the offset ideal model for the diodes with $V_{on} = 0.7\, V$ and the input signal given by $V_{out} = 2\cos(120\pi t)$?

a. minimum -2 V, maximum 2 V  
b. minimum -2 V, maximum 1.4 V  
c. minimum 0.3 V, maximum 1.4 V  
d. minimum 1.7 V, maximum 1.4 V  
e. minimum 1.7 V, maximum 2 V

Neither path 1 nor 2 are part of the circuit $V_{out} = V_{in}$  
Path 1 - both diodes are conducting (D1 and D2)  
$V_{out} = 1.4V = 2V_{on}$  
$V_{in} > 1.4\, V$  
Path 2 - diode D3 is conducting  
$V_{out} = 0.3V = 1\, \times V_{on}$  
$V_{in} < 0.3\, V$
Transistor with parameters

\[ \beta = 100 \]
\[ V_{CESAT} = 0.2V \]
\[ V_{BEON} = 0.74 \]

Transfer Curve

In the active region, \( V_{out} = -\frac{R_c}{R_B} V_{in} + V_{cc} + \frac{R_c}{R_B} V_{BEON} \)

in general.

When \( V_{out} = V_{CESAT} \), we can solve for \( V_{in} \) that puts the transistor into saturation:

\[ 0.2 = -\frac{R_c}{R_B} V_{in} + V_{cc} + \frac{R_c}{R_B} V_{BEON} \quad \Rightarrow \quad V_{in} = (V_{cc} - 0.2) \frac{R_B}{R_c} + V_{BEON} \]
6. The model below is applicable to
   a. BJT in the active regime
   b. BJT in saturation
   c. nMOS in the active regime
   d. nMOS in saturation
   e. nMOS in the ohmic regime

7. If we bias the transistor below with \( R_B = 20 \, \text{kΩ} \) and \( R_C = 300 \, \Omega \) what is the output voltage, \( V_{CE} \), when the input voltage, \( V_{IN} = 2.7 \, \text{V} \)?
   a. 6.2 \, \text{V}
   b. 5.1 \, \text{V}
   c. 3.2 \, \text{V}
   d. 1.1 \, \text{V}
   e. 0.2 \, \text{V}

Since \( V_{IN} > 0.7 \, \text{V} \) the transistor is ON.

Algebraically:
Assume Active and find \( I_C \)
\[
I_C = \beta I_B = 100 \times \frac{2.7 - 0.7}{20,000} = 10 \, \text{mA}
\]
Assume Saturation
\[
I_C = \frac{V_{CC} - V_{CE, sat}}{R_C} = \frac{6.2 - 0.2}{300} = 20 \, \text{mA}
\]

\( I_C \) is minimum if transistor is in the Active region.
\[
V_{CE} < R_C I_C \quad V_{CE} = 300 \times 10^{3} \times 20 \times 10^{-3} = 6.2 \quad \text{V}
\]

From formula
\[
V_{il} = (0.2 - 0.2) \times \frac{20000 - 0.7}{300 \times 100} = 3.4 \, \text{V}
\]
\( V_{in} < 3.4 \, \text{V} \Rightarrow \) in Active state
\[
V_{out} = \frac{-R_C V_{IN} + V_{CC} + R_C \beta V_{BE, on}}{4R_C} = \frac{3.2}{300} \, \text{V}
\]

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8. If we bias the transistor below with \( R_B = 20 \, k\Omega \) and \( R_C = 200 \, \Omega \) what is the input voltage, \( V_{IN} \), needed to set the output \( V_{CE} \) to 2.2 \( V \)?

a. 5.7 \( V \)
b. 4.7 \( V \)
c. 3.7 \( V \)
d. 2.7 \( V \)
e. 1.7 \( V \)

\[
\beta = 100 \\
V_{CE,sat} = 0.2 \, V \\
V_{BE,on} = 0.7 \, V
\]

\[
\begin{aligned}
V_{IN} &\quad + \\
I_B &\quad \text{(from diagram)} \\
&\quad \text{(from diagram)} \\
I_C &\quad \text{(from diagram)} \\
&\quad \text{(from diagram)} \\
&\quad \text{(from diagram)} \\
&\quad 6.2 \, V
\end{aligned}
\]

\[
\text{For } \quad V_{CE} = 2.2 \, V \\
I_C = \frac{6.2 - 2.2}{200} = 20 \, mA \\
\text{So } \quad I_B = 0.2 \, mA \\
V_{IN} = R_B I_B + V_{BE,on} = 4.7 \, V
\]

9. If \( R_B = 1 \, k\Omega \) and \( R_C = 300 \, \Omega \) what is the maximum possible value of \( I_C \)?

a. 60 mA
b. 20 mA
c. 10 mA
d. 6 mA
e. 0.2 mA

\[
\begin{aligned}
\beta = 100 \\
V_{CE,sat} = 0.2 \, V \\
V_{BE,on} = 0.7 \, V
\end{aligned}
\]

\[
\begin{aligned}
V_{IN} &\quad + \\
I_B &\quad \text{(from diagram)} \\
&\quad \text{(from diagram)} \\
I_C &\quad \text{(from diagram)} \\
&\quad \text{(from diagram)} \\
&\quad \text{(from diagram)} \\
&\quad 6.2 \, V
\end{aligned}
\]

\[
I_C = \frac{6.2 - 0.2}{300} = 20 \, mA
\]

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10. Dani has just connected the circuit below, but cannot read the resistor code and does not
know what value she used for either resistor. She measures $V_{CE}$ to be 6.2 V. What will $V_{CE}$
become if she adds a resistor identical to $R_B$ in parallel to $R_B$ (thereby reducing $R_B$ by a
factor of two)? Note: You don’t need $V_{IN}$ to solve this.

a. 0.2 V  

b. 3.1 V  

c. 4.2 V  

d. 5.5 V  

e. 7.2 V  

Adding a resistor in parallel with $R_B$ reduces the resulting $R_{B_{eq}} = \frac{R_B}{2}$
So $I_{B2} = 2I_{B1}$ since $I_B = \frac{V_{IN} - 0.7}{R_B}$

The transistor is clearly operating in ACTIVE region.
So $I_C = I_B$  
At first $V_{CE} = 6.2 = 8.2 - R_C I_C$
So $R_C I_C = 2$

$V_{CE_{new}} = 8.2 - 2(R_C I_C) = 4.2 V$

11. If we double the base current to 2 mA, the power dissipated by the transistor approximately

a. goes up by a factor of 3  

b. goes up by a factor of 2  

c. goes up by a factor of 4/3  

d. remains the same  

e. goes down by a factor of 2
12. Consider the transistor circuit below where a diode with $V_{ON} = 0.7 \, V$ is added to raise the input voltage for turning on the BJT. If we bias the circuit with $V_{CC} = 6 \, V$, $R_B = 20 \, k\Omega$ and $R_C = 400 \, \Omega$, what is the output voltage, $V_{out}$, when the input voltage is $V_{in} = 2 \, V$?

**HINT:** Remember the voltage drop across the diode.

\[ a. \quad 6.0 \, V \]
\[ b. \quad 4.8 \, V \]
\[ c. \quad 3.4 \, V \]
\[ d. \quad 2.6 \, V \]
\[ e. \quad 1.3 \, V \]

For the transistor to turn on BOTH the diode and the base-to-emitter diode, the input voltage must be:

\[ V_{IN} > 1.4 \, V \quad \checkmark \quad V_{IN}=2 \, V \]

13. Given the BJT below biased with $V_{CC} = 3.2 \, V$, $R_C = 400 \, \Omega$, $R_B = 4 \, k\Omega$, what is the value of the $v_I$ transition point of the BJT voltage transfer function graphed below?

\[ a. \quad 0.3 \, V \]
\[ b. \quad 0.7 \, V \]
\[ c. \quad 1.0 \, V \]
\[ d. \quad 1.3 \, V \]
\[ e. \quad 1.7 \, V \]

\[ V_{i2} = (V_{CC} - V_{CESAT}) \frac{R_B}{\beta R_C} + V_{BEon} \]
\[ = (3.2 - 0.2) \cdot \frac{4000}{100 \cdot 400} + 0.7 \]
\[ = 1 \, V \]
14. Given the BJT below biased with $V_{CC} = 3.2 \, V$, $R_C = 200 \, \Omega$, $R_B = 10 \, k\Omega$, what is/are the regime(s) of operation of the BJT if the input voltage is given by $V_i(t) = 1.6 + 0.8 \cos(200\pi t)$?

a. Active only  

b. Cut-off (Off) and Active  

c. Cut-off (Off) and Saturation  

d. Active and Saturation  

e. Cut-off (Off), Active, and Saturation

15. If the BJT below is biased with $V_{CC} = 12 \, V$ and $R_C = 200 \, \Omega$, what should be the value of $R_B$ in order to set the magnitude of amplifier “gain” to ten, i.e. $G = \frac{V_{o2}-V_{o1}}{V_{i2}-V_{i1}} = -10$?

a. 500 $\Omega$  

b. 1 k$\Omega$  

c. 1.5 k$\Omega$  

d. 2 k$\Omega$  

e. 5 k$\Omega$
16. Correctly complete the following statement about a **p-channel MOSFET** transistor in a cMOS circuit? When the gate-to-source (also gate-to-body) voltage is...

a. **low**, a conductive channel forms between **source** and **drain**.
b. **high**, a conductive channel forms between **gate** and **drain**.
c. **high**, a conductive channel forms between **source** and **drain**.
d. **low**, a conductive channel forms between **gate** and **drain**.
e. **low**, a conductive channel forms between **gate** and **body**.

17. Consider the graph and the nMOS circuit below.

If $I_t = 5 \ mA$, $V_{GS} = 4 \ V$, $V_{TH} = 2 \ V$, and, as the load line shows, $V_{DD} = 9 \ V$ and $R_D = 150 \ \Omega$, what is $V_{DS}$?

- a. 2 V
- b. 3 V
- c. 4 V
- d. 6 V
- e. 9 V

Find the operating point

- $V_{DS} = 4I_1$
- $I_t = 5 \ mA \Rightarrow I_D = 20mA$ and $V_D = 6V$

**operating pt. (6, 20)**
18. Consider the graph and the nMOS circuit below.

If $I_I = 5 \, mA$, $V_{TH} = 3 \, V$ and $V_{GS} = V_{DD} = 5 \, V$, what is the value of $R_D$ which would result in $V_{DS} = 4 \, V$?

- a. 125 $\Omega$
- b. 100 $\Omega$
- c. 75 $\Omega$
- d. 50 $\Omega$
- e. 25 $\Omega$

Know that $V_{GS} = 5\, V$ and $V_{TH} = 3\, V$

$\Rightarrow V_{GS} - V_{TH} = 2\, V$

Slope of load line $m = \frac{1}{R_D}$

$m = \frac{4.5\, mA}{1\, V} = 20 \times 10^{-3}$

$\Rightarrow R_D = \frac{1}{20 \times 10^{-3}}$

19. The gate-source junction of an nMOS with a grounded source is best modeled by a

- a. voltage source
- b. current source
- c. resistor
- d. diode
- e. capacitor

modelled by a capacitor
20. Which of the following output columns correctly represents the output of the logic gate circuit below for inputs A and B?

- a. \( Z_1 \)
- b. \( Z_2 \)
- c. \( Z_3 \)
- d. \( Z_4 \)
- e. \( Z_5 \)

21. For the cMOS circuit to the right below, how can we describe all of the inputs for which \( Z = 1 \)?

- a. \( A = 0 \) or \( B = C = 0 \)
- b. \( A = B = C = 0 \)
- c. \( A = 1 \) or \( B = C = 1 \)
- d. \( A = B = C = 0 \)
- e. \( A = 1 \) and \( B = C = 0 \)
22. Why might this cMOS circuit cause a problem?

   a. The pMOS and nMOS transistors are switched.
   b. The output Z is independent of inputs A and B.
   c. The output Z is undefined when A=0 and B=0.
   d. The output Z is undefined when A=0 and B=1.
   e. The power source can be mistakenly shorted to ground.

23. Consider the truth table of the logic circuit, LC, below, with the current output given by Z. If an inverter is placed after the original output, what will be the new output?

   a. Z_1
   b. Z_2
   c. Z_3
   d. Z_4
   e. Z_5

24. If a computer chip with a switching rate of 1 GHz and $V_{DD}$ of 5 V is dissipating 50 W, what will be the power dissipation if we lower $V_{DD}$ to 3 V and increase the switching rate to 1.5 GHz, while keeping the activity factor the same?

   a. 27 W
   b. 45 W
   c. 68 W
   d. 75 W
   e. 100 W

$$P = a + \frac{C}{V^2} \cdot V^2 \cdot \frac{1}{2} \cdot \frac{f}{f_s} \cdot \frac{1}{f_s}$$

$$P = 1.5 \cdot 3^2 \cdot 2 \times 10^{-9} = 27 \text{ W}$$