

# DIODE APPROXIMATIONS

SEMICONDUCTOR DIODE







## TOPIC OUTLINE

## **Diode Approximations**

- Ideal Diode
- 2<sup>nd</sup> Approximation
- 3<sup>rd</sup> Approximation

**Shockley's Equation** 

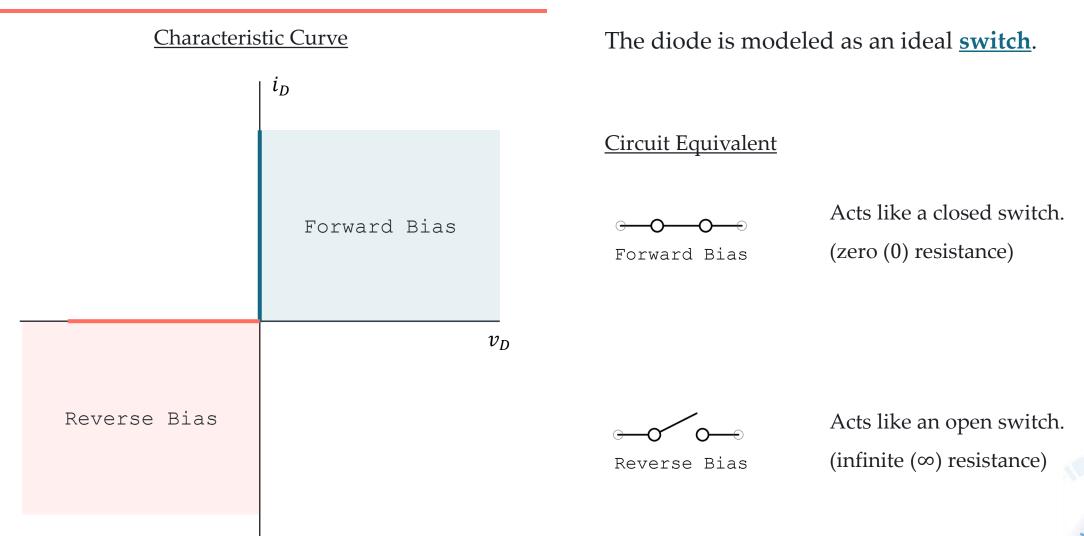
**Reading Datasheet** 



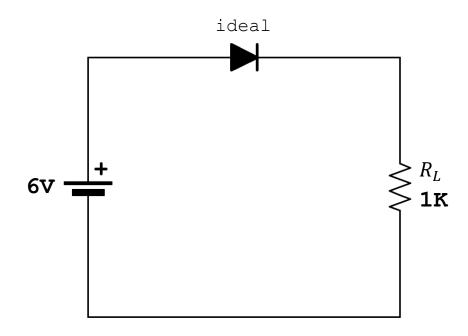
## **DIODE APPROXIMATIONS**



## **IDEAL DIODE**

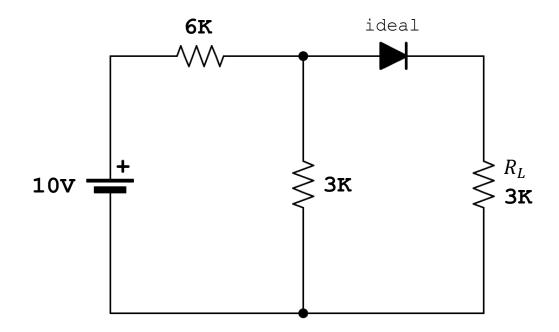


Using the ideal diode model, determine the load voltage, load current, and the power dissipated by the diode in the given circuit.



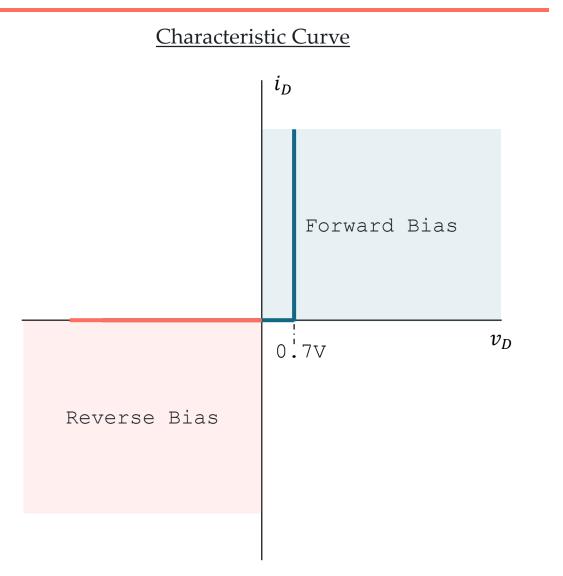


Using the ideal diode model, determine the load voltage, load current, and the power dissipated by the diode in the given circuit.



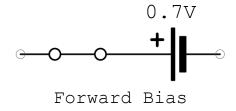


## 2<sup>ND</sup> APPROXIMATION

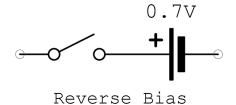


The diode is modeled as an ideal **switch** in series with a **barrier potential**.

#### Circuit Equivalent

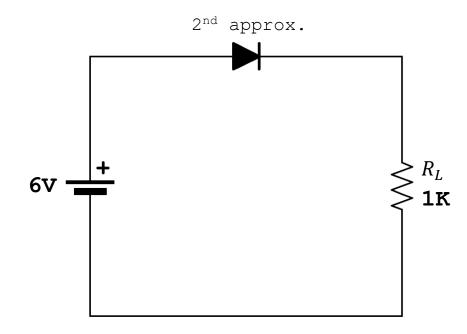


If  $v_D \ge 0.7$  V, the switch is closed, and the diode conducts.



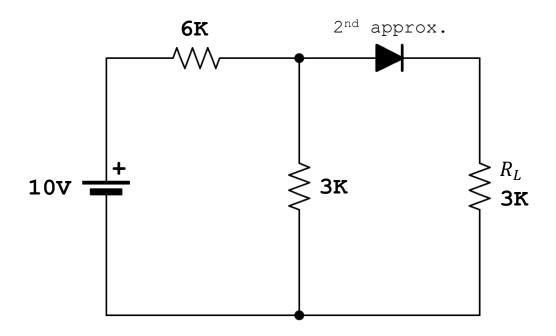
If  $v_D < 0.7$  V, the switch is open, and the diode does not conduct.

Apply the second approximation of the diode model to determine the load voltage, load current, and the power dissipated by the diode in the given circuit.





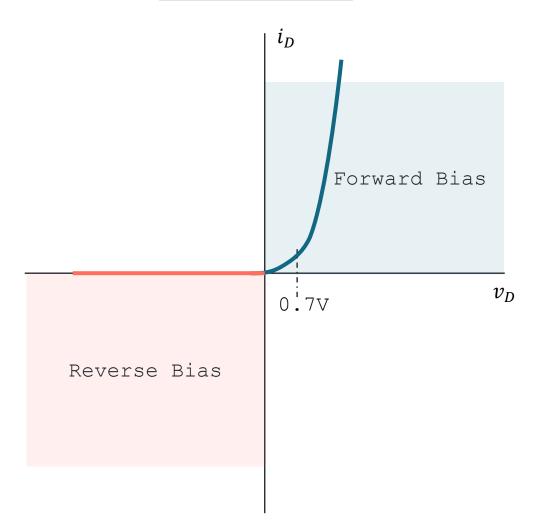
Apply the second approximation of the diode model to determine the load voltage, load current, and the power dissipated by the diode in the given circuit.





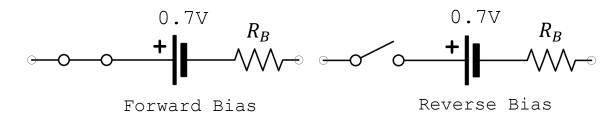
## 3<sup>RD</sup> APPROXIMATION

#### **Characteristic Curve**



The diode is modeled as an ideal <u>switch</u> in series with a <u>barrier potential</u> and a <u>bulk resistance</u>.

#### Circuit Equivalent

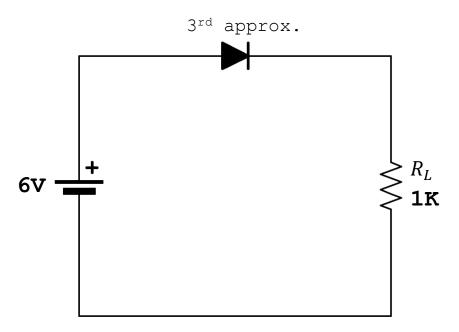


$$v_D = 0.7V + i_D R_B$$

Typical value of  $R_B < 1\Omega$ , and often ignored if  $R_B < 0.01R_{TH}$ 



The 1N4001 of the given network has a bulk resistance of 0.23  $\Omega$ . What is the load voltage, load current, and the power dissipated by the diode?





The 1N4001 of the given network has a bulk resistance of 0.23  $\Omega$ . What is the load voltage, load current, and the power dissipated by the diode?

 $\begin{array}{c|c}
\mathbf{6R} & 3^{\text{rd}} \text{ approx.} \\
\hline
\mathbf{10V} & \\
\end{array}$ 

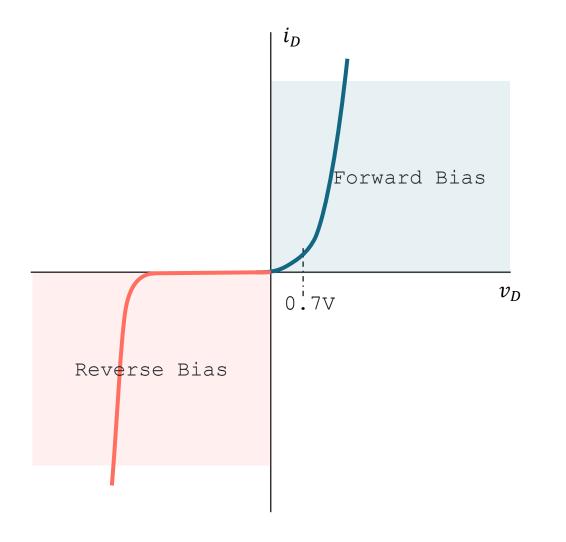


## SHOCKLEY'S EQUATION



## **SHOCKLEY'S EQUATION**

#### **Characteristic Curve**



#### **Shockley's Equation**

$$i_D = i_S \left( e^{\frac{v_D}{nv_T}} - 1 \right)$$

#### where:

 $i_D$  = diode current

 $i_S$  = reverse saturation current

 $v_D$  = voltage across the diode

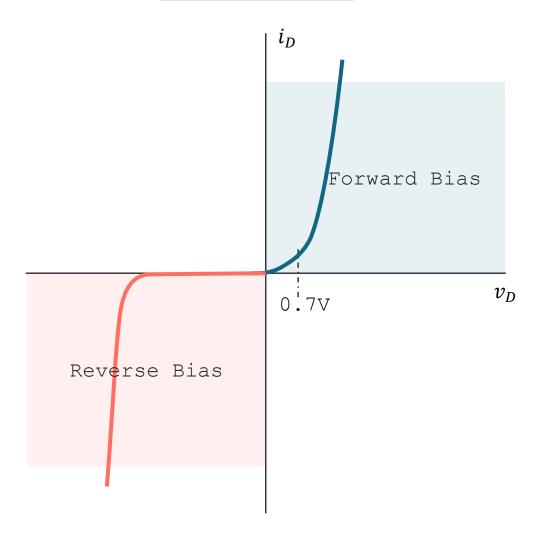
 $n = ideality factor (1 \le n \le 2)$ 

• n = 1 for ideal diode

 $v_T$  = thermal voltage ( $\approx 25.85 mV$  at room temperature)

## **THERMAL VOLTAGE**

#### Characteristic Curve



#### Thermal Voltage

$$v_T = \frac{kT}{q}$$

#### where:

 $k = \text{Boltzmann's constant } (1.38 \times 10^{-23} \text{ J/K})$ 

T = absolute temperature (°C + 273)

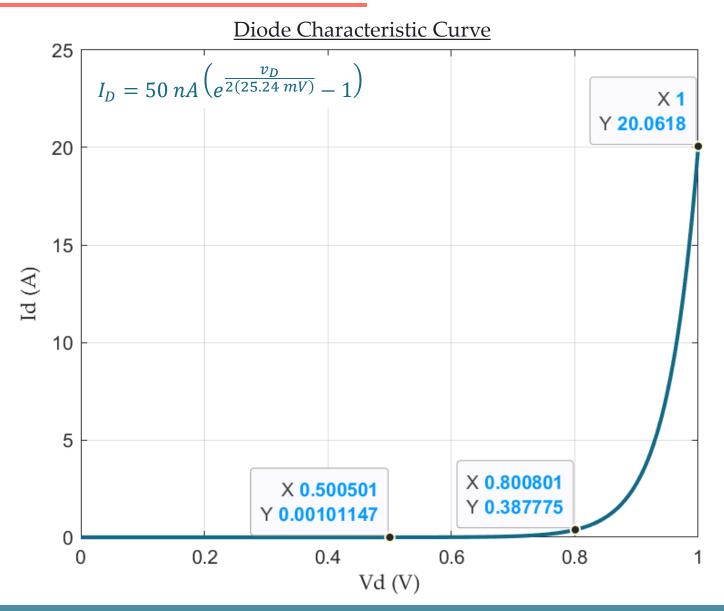
q =electron charge  $(1.602 \times 10^{-19} \text{ C})$ 



Determine the diode current at 20°C for silicon diode with a reverse saturation current of 50*n*A and an ideality factor of 2, under the following applied voltages:

- 0V
- 0.5V
- 0.7V
- 1V







## READING DATASHEET



## **REVERSE BREAKDOWN VOLTAGE**

#### **MAXIMUM RATINGS**

| Rating                                                                                                | Symbol                                                 | 1N4001 | 1N4002 | 1N4003 | 1N4004 | 1N4005 | 1N4006 | 1N4007 | Unit     |
|-------------------------------------------------------------------------------------------------------|--------------------------------------------------------|--------|--------|--------|--------|--------|--------|--------|----------|
| †Peak Repetitive Reverse Voltage<br>Working Peak Reverse Voltage<br>DC Blocking Voltage               | V <sub>RRM</sub><br>V <sub>RWM</sub><br>V <sub>R</sub> | 50     | 100    | 200    | 400    | 600    | 800    | 1000   | <b>V</b> |
| †Non-Repetitive Peak Reverse Voltage<br>(halfwave, single phase, 60 Hz)                               | V <sub>RSM</sub>                                       | 60     | 120    | 240    | 480    | 720    | 1000   | 1200   | ٧        |
| †RMS Reverse Voltage                                                                                  | V <sub>R(RMS)</sub>                                    | 35     | 70     | 140    | 280    | 420    | 560    | 700    | V        |
| †Average Rectified Forward Current<br>(single phase, resistive load,<br>60 Hz, T <sub>A</sub> = 75°C) | l <sub>O</sub>                                         |        |        |        | 1.0    |        |        |        | Α        |

**<u>Destructive level</u>** to avoid under all operating conditions.

Practice safety factor of 2.



## MAXIMUM FORWARD CURRENT

#### **MAXIMUM RATINGS**

| Rating                                                                                                | Symbol                                                 | 1N4001 | 1N4002 | 1N4003 | 1N4004 | 1N4005 | 1N4006 | 1N4007 | Unit |
|-------------------------------------------------------------------------------------------------------|--------------------------------------------------------|--------|--------|--------|--------|--------|--------|--------|------|
| †Peak Repetitive Reverse Voltage<br>Working Peak Reverse Voltage<br>DC Blocking Voltage               | V <sub>RRM</sub><br>V <sub>RWM</sub><br>V <sub>R</sub> | 50     | 100    | 200    | 400    | 600    | 800    | 1000   | >    |
| †Non-Repetitive Peak Reverse Voltage<br>(halfwave, single phase, 60 Hz)                               | V <sub>RSM</sub>                                       | 60     | 120    | 240    | 480    | 720    | 1000   | 1200   | ٧    |
| †RMS Reverse Voltage                                                                                  | V <sub>R(RMS)</sub>                                    | 35     | 70     | 140    | 280    | 420    | 560    | 700    | V    |
| †Average Rectified Forward Current<br>(single phase, resistive load,<br>60 Hz, T <sub>A</sub> = 75°C) | l <sub>O</sub>                                         |        |        |        | 1.0    |        |        |        | Α    |

Level of forward current before the **diode burns out** 

because of excessive power dissipation.



## **FORWARD VOLTAGE DROP**

#### **ELECTRICAL CHARACTERISTICS**†

| Rating                                                                                                           | Symbol             | Тур         | Max      | Unit |
|------------------------------------------------------------------------------------------------------------------|--------------------|-------------|----------|------|
| Maximum Instantaneous Forward Voltage Drop, (i <sub>F</sub> = 1.0 Amp, T <sub>J</sub> = 25°C)                    | v <sub>F</sub>     | 0.93        | 1.1      | V    |
| Maximum Full-Cycle Average Forward Voltage Drop, (I <sub>O</sub> = 1.0 Amp, T <sub>L</sub> = 75°C, 1 inch leads) | V <sub>F(AV)</sub> | -           | 0.8      | V    |
| Maximum Reverse Current (rated DC voltage) $ (T_J = 25^{\circ}C) $ $ (T_J = 100^{\circ}C) $                      | I <sub>R</sub>     | 0.05<br>1.0 | 10<br>50 | μА   |
| Maximum Full-Cycle Average Reverse Current, (I <sub>O</sub> = 1.0 Amp, T <sub>L</sub> = 75°C, 1 inch leads)      | I <sub>R(AV)</sub> | _           | 30       | μА   |

The typical voltage across the diode.



## **LABORATORY**

