

Block C: Diode

Q1. Problem P9.7 (modified)

Consider the circuit of Figure P9.7. Determine whether the diode is conducting or not. Assume that the diode is an ideal diode.

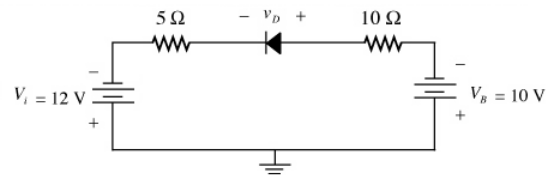


Figure P9.7

Answer: it is conducting

Solution:

Known quantities:

The circuit of Figure P9.7.

Find:

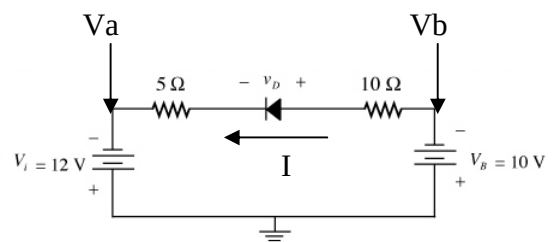
Determine the diode is conducting or not.

Analysis:

Assuming the diode is conducting, the current is found to be

$$I = \frac{V_b - V_a}{10 + 5} = \frac{(-10) - (-12)}{10 + 5} = \frac{2}{15} = 0.133\text{A}$$

Since the current I is positive to the diode turn on direction, the result is agreed with the assumption. Thus the diode must be conducting.



Q2. Problem P9.14

For the circuit of Figure P9.14, find the range of V_{in} for which D_1 is forward-biased. Assume an ideal diode.

Answer: the range of V_{in} is: $V_{in} \geq -2V$.

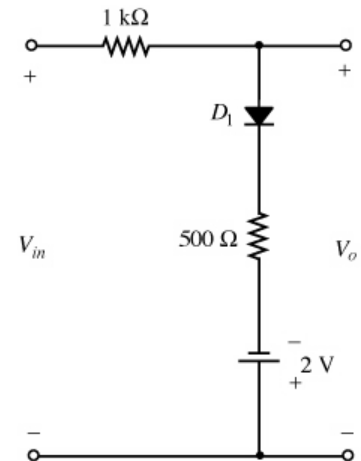


Figure P9.14

Solution:**Known quantities:**

The circuit of figure of P9.14.

Find:

The range of V_{in} for a forward-biased D_1 .

Analysis:

Assume diode D_1 is conducting; the diode current is

$$I = \frac{V_{in} + 2}{1500} \geq 0$$

Since the current is positive, the initial assumption was correct. Therefore, the range of V_{in} is:

$$V_{in} \geq -2V.$$

Q3. Problem P9.16

Find voltage v_L in the circuit of Figure P9.16 where D is an ideal diode, for positive and negative values of v_S . Sketch a plot of v_L versus v_S .

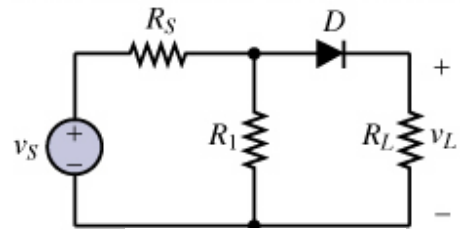


Figure P9.16

Answer:

For $v_S < 0$, $v_L = 0$.

For $v_S \geq 0$, $v_L = v_S \left(\frac{R_L \parallel R_1}{R_S + R_L \parallel R_1} \right)$.

Solution:

Known quantities:

The circuit of Figure P9.16.

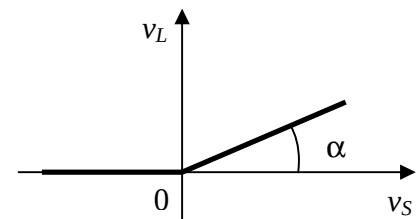
Find:

A plot of v_L versus v_S .

Analysis:

For $v_S < 0$, the diode is reverse biased, and $v_L = 0$.

For $v_S \geq 0$, the diode is forward biased, and $v_L = v_S \left(\frac{R_L \parallel R_1}{R_S + R_L \parallel R_1} \right)$. (slope)



where $\alpha = \tan^{-1} \left(\frac{R_L \parallel R_1}{R_S + R_L \parallel R_1} \right)$

*** degree = arctan(slope)**

Q4. Problem P9.19 (modified)

Assume that the diode in Figure P9.19 requires a minimum current of 1 mA to be above the knee of its i - v characteristic. Use $V_\gamma = 0.7$ V.

- What should be the value of R to establish 10 mA in the circuit?
- With the value of R determined in part a, what is the minimum value to which the voltage E could be reduced and still maintain diode current above the knee?

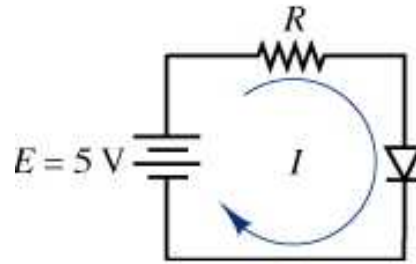


Figure P9.19

Answer:

- 430 Ω
- 1.13 V

Solution:

Known quantities:

The current $I = 1$ mA, that make the diode to be above the knee of its $i - v$ characteristic.

Find:

- The value of R to establish a 10 mA current in the circuit.
- With the value of R established in the preceding part, what is the minimum value to which the voltage E could be reduced and still maintain diode current above the knee.

Assumptions:

$V_\gamma = 0.7$ V.

Analysis:

$$\text{a) } R = \frac{5 - 0.7}{10 \times 10^{-3}} = 430 \Omega$$

$$\text{b) } I = \frac{E_{\min} - 0.7}{430} = 10^{-3}$$

$$\Rightarrow E_{\min} = 0.43 + 0.7 = 1.13 \text{ V}$$

Q5. Problem P9.20

In Figure P9.20, a sinusoidal source of 50 V rms drives the circuit. Use the offset diode model for a silicon diode.

- What is the maximum forward current?
- What is the peak inverse voltage across the diode?

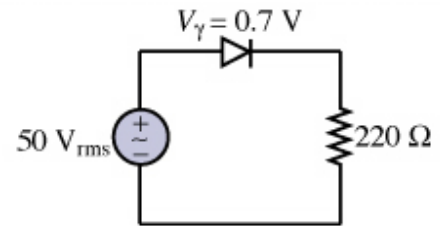


Figure P9.20

Answer:

- 318mA
- 70.7V

Solution:

Known quantities:

The circuit of Figure P9.20 driven by a sinusoidal source of 50 V rms, $V_\gamma = 0.7 \text{ V}$, $R = 220 \Omega$.

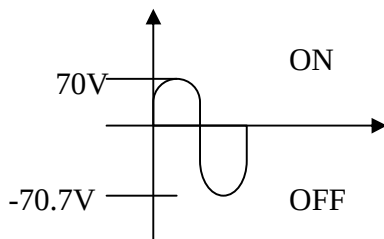
Find:

- The maximum forward current. $\rightarrow$ peak current
- The peak inverse voltage across the diode.

Analysis:

$$\text{a) } I_{F_{\max}} = \frac{50\sqrt{2} - 0.7}{220} = 318 \text{ mA}$$

$$\text{b) } V_{rev_{\max}} = 50\sqrt{2} = 70.7 \text{ V}$$



Q6. Problem P9.22

In the circuit of Figure P9.22, find the range of V_{in} for which D_1 is forward-biased. Assume ideal diodes.

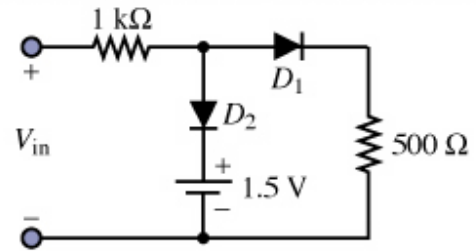


Figure P9.22

Answer: $V_{in} > 0$

Solution:**Known quantities:**

The configuration shown in Figure P9.22.

Find:

The range of V_{in} for which D_1 is forward-biased.

Analysis:

The diode D_1 is clearly forward-biased for any $V_{in} > 0$.

For better analysis,
Can separate in 3 case,
a) $V_{in} < 0$
b) $0 \leq V_{in} < 1.5V$
c) $V_{in} > 1.5V$

It is easy to observe that D_1 should be **OFF in case a) and ON in case c)**
For case b, we can prove the correct situation by assuming the diode is on or off.

D1	D2	Ture/False
ON	ON	False
OFF	OFF	False
OFF	ON	False
ON	OFF	True

So, D_1 must be ON.

As a result, D_1 is ON for both case b) and c), that implies D_1 is ON when $V_{in} \geq 0$

Q7. Problem P9.25

Sketch the output waveform and the voltage transfer characteristic for the circuit of Figure P9.25. Assume offset diode model with $V_\gamma = 0.6\text{ V}$, $v_S(t) = 10 \sin(2,000\pi t)$.

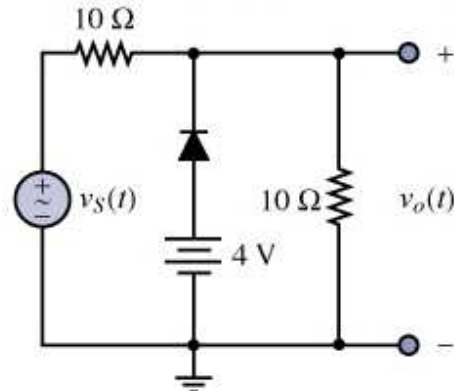


Figure P9.25

Solution:**Known quantities:**

The circuit of Figure P9.25; $v_S(t) = 10 \sin(2,000\pi t)$.

Find:

The output waveform and the voltage transfer characteristic.

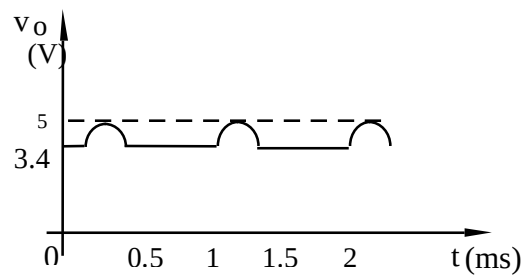
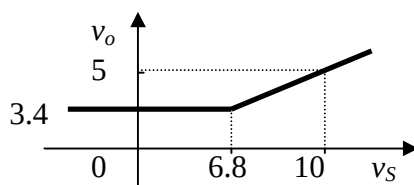
Assumptions:

$V_\gamma = 0.6\text{ V}$.

Analysis:

For $v_S < 6.8\text{ V}$, $v_o = 3.4\text{ V}$. For $v_S \geq 6.8\text{ V}$, $v_o = 0.5 v_S / 2$.

The voltage transfer characteristic is



Q8. Problem P9.33

Find the average value of the output voltage for the circuit of Figure P9.33 if the input voltage is sinusoidal with an amplitude of 5 V. Let $V_\gamma = 0.7$ V.

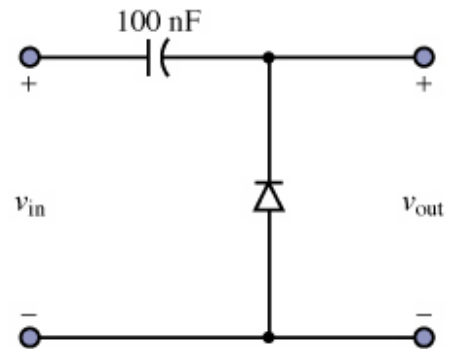


Figure P9.33

Answer: 4.3V

Solution:**Known quantities:**

The circuit of Figure P9.33. The input voltage is sinusoidal with an amplitude of 5 V.

Find:

The average value of the output voltage.

Assumptions:

$V_\gamma = 0.7$ V .

Analysis:

The capacitor will charge to $5\text{ V} - 0.7\text{ V} = 4.3\text{ V}$ and, therefore, the input sine wave will be shifted up 4.3 V to produce the output. As a result, after the cycle (the capacitor builds up its stored charge during the third quarter cycle), the average value of the output will be 4.3 V.

Q9. Problem P9.34

In the rectifier circuit shown in Figure P9.34, $v(t) = A \sin(2\pi 100)t$ V. Assume a forward voltage drop of 0.7 V across the diode when it is conducting. If conduction must begin during each positive half-cycle at an angle no greater than 5° , what is the minimum peak value A that the AC source must produce?

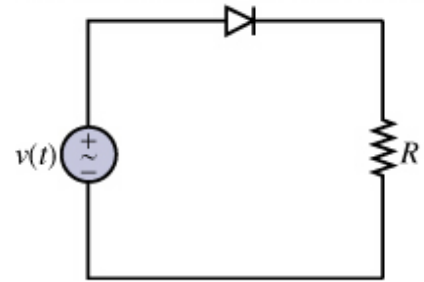


Figure P9.34

Answer: 8.03V

Solution:**Known quantities:**

The rectifier circuit of Figure P9.34; $v(t) = A \sin(2\pi 100t)$ V. The conduction must begin during each positive half-cycle at an angle no greater than 5° .

Find:

The minimum peak value A that the AC source must produce.

Assumptions:

$V_f = 0.7$ V .

Analysis:

Diode on, $V(t) > 0.7$

Therefore, minimum peak voltage for the circuit is being conducted:

$$A_{\min} \sin(5^\circ) = 0.7 \Rightarrow A_{\min} = \frac{0.7}{\sin(5^\circ)} = \frac{0.7}{0.0872} = 8.03V$$

Q10. Problem P9.35

A half-wave rectifier is to provide an average voltage of 50 V at its output.

- Draw a schematic diagram of the circuit.
- Sketch the output voltage waveshape.
- Determine the peak value of the output voltage.
- Sketch the input voltage waveshape.
- What is the rms voltage at the input?

Answer:

- 157.2V
- 111.2V

Solution:**Known quantities:**

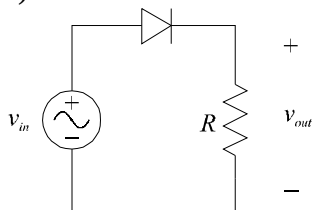
A half-wave rectifier is to provide an average voltage of 50 V at its output.

Find:

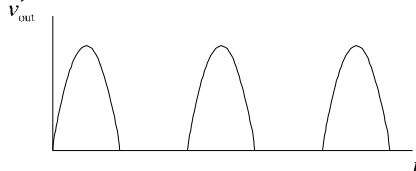
- Draw a schematic diagram of the circuit.
- Sketch the output voltage waveshape.
- Determine the peak value of the input voltage.
- Sketch the input voltage waveshape.
- The rms voltage at the input.

Analysis:

a)



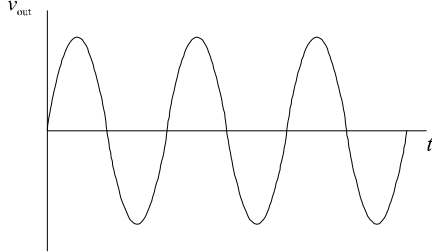
b)



c)

$$V_{\text{ave}} = \frac{1}{\pi} V_{\text{peak}} = 0.318 V_{\text{peak}} = 50 \Rightarrow V_{\text{peak}} = 157.2 \text{ V}$$

d)



e)

$$V_{in_{rms}} = \frac{157.2}{\sqrt{2}} = 111.2 \text{ V}$$

Q12. Problem P9.42

The diodes in the full-wave DC power supply shown in Figure P9.42 are silicon. If $I_L = 5 \text{ mA}$, $V_L = 10 \text{ V}$, $V_r = 20\%$, $v_{line} = 170 \cos(\omega t) \text{ V}$, $\omega = 377 \frac{\text{rad}}{\text{s}}$.

Determine the

- Turns ratio $n = V_{line}/V_{s1}$
- The values of the capacitor C .

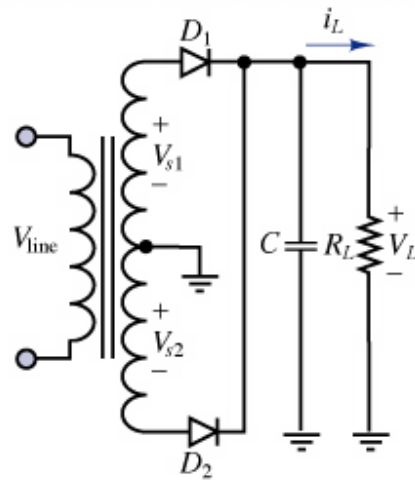


Figure P9.42

Answer:

- 14.53**
- $16.84 \mu\text{F}$

Solution:

Known quantities:

The full-wave DC power supply of Figure P9.38; $I_L = 5 \text{ mA}$, $V_L = 10 \text{ V}$, $V_r = 20\%$, $v_{line} = 170 \cos(\omega t) \text{ V}$, $\omega = 377 \frac{\text{rad}}{\text{s}}$.

Find:

- The turns ratio $n = V_{line}/V_{s1}$.
- The capacitor C .

Analysis:

$$a) V_m = V_L + \frac{1}{2}V_r = 10 + 1 = 11 \text{ V}, V_{L-\min} = V_L - \frac{1}{2}V_r = 10 - 1 = 9 \text{ V},$$

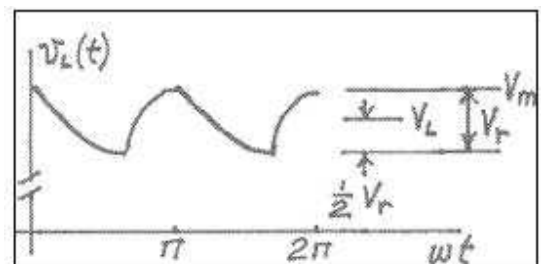
$$V_{s1} = V_{s2} = V_{s0} \cos(\omega t).$$

$$\text{KVL: } -v_{s1}(t) + v_{D1} + v_L(t) = 0$$

At $\omega t = 0$,

$$-V_{s0} + V_{D-\text{on}} + V_L = 0 \Rightarrow V_{s0} = V_{D-\text{on}} + V_m = 0.7 + 11 = 11.7 \text{ V}$$

$$n = \frac{V_{io}}{V_{so}} = 14.53$$



a) KVL: $-V_{S2}(t) + V_{D2} + V_L(t) = 0$
 Because $V_{S2}(t) = -V_{so} \cos(\omega t_2)$

So, at $t = t_2$, $V_{so} \cos(\omega t_2) = -V_{D2-on} - V_{L-min}$. $t_2 = \frac{1}{\omega} \cos^{-1} \left(-\frac{V_{D2-on} + V_{L-min}}{V_{so}} \right) = 6.76 \text{ ms}$.

The exponential discharge of the capacitor can be expressed:

$$v_L(t) = v_L(\infty) + (v_L(0) - v_L(\infty))e^{-\frac{t}{TC}} = 0 + (V_m - 0)e^{-\frac{t}{R_L C}} = V_m e^{-\frac{I_L t}{V_L C}}$$

$$v_L(t_2) = V_{L-min} = V_m e^{-\frac{I_L t_2}{V_L C}}, \quad C = -\frac{I_L t_2}{V_L \ln \left(\frac{V_{L-min}}{V_m} \right)} = 16.84 \text{ } \mu\text{F}$$

Note: An approximate but conservative value of C can be obtained by using the approximation:

$$\omega t_2 \approx \pi. \text{ Then } C \approx -\frac{I_L (\omega t_2)}{\omega V_L \ln \left(\frac{V_{L-min}}{V_m} \right)} = 20.76 \text{ } \mu\text{F}.$$

This value is conservative because it gives a smaller ripple voltage than that specified.