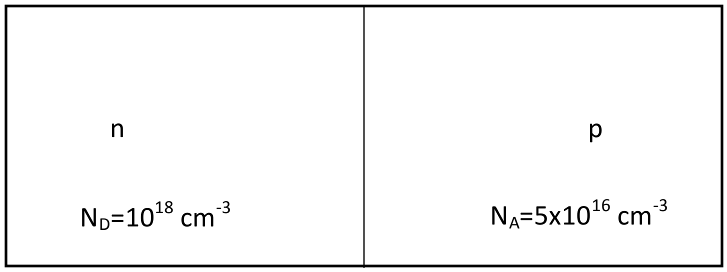
1) A pn junction diode is shown below with the doping levels on each side indicated in the figure. What is the majority and minority carrier densities in the n and p sides of the diode? Assume $n_i = 10^{10}$ cm^{-3}

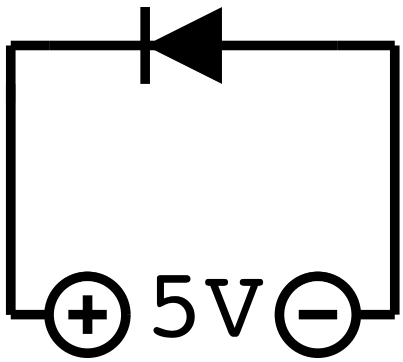


1) N-side (n=10^{18}, p= $5\text{x}10^{16}$) P-side (n=2000, p= $5\text{x}10^{16}$)
2) N-side (n=10^{18}, p= 100) P-side (n=2000, p= $5\text{x}10^{16}$)
3) N-side (n=100, p= $5\text{x}10^{16}$) P-side (n=10^{18}, p= $5\text{x}10^{16}$)
4) N-side (n=10^{18}, p= 10^{10}) P-side (n=2000, p= $5\text{x}10^{16}$)
5) N-side (n=10^{18}, p= 100) P-side (n=2000, p= 10^{10})
6) None of the above

$$n\text{-side} \quad n = N_D = 10^{18}\ \text{cm}^{-3} \qquad p = \frac{n_i^2}{N_D} = \frac{10^{20}}{10^{18}} = 100\ \text{cm}^{-3}$$

$$p\text{-side} \quad p = N_A = 5\times 10^{16}\ \text{cm}^{-3} \qquad n = \frac{n_i^2}{N_A} = \frac{10^{20}}{5\times 10^{16}} = 2000\ \text{cm}^{-3}$$

2) Assuming a reverse bias voltage of 5 V is applied to the above diode, what is the depletion layer width? On which side of the junction is the depletion layer penetrating more? Dielectric constant of silicon is 11.7 and $\epsilon_o = 8.85\times10^{-14}$ F/cm, thermal voltage at room temperature is 25 mV.



1) W=40µm and mostly in the p region
2) W=0.4µm and mostly in the n region
3) W=0.4µm and mostly in the p region
4) W= 0.2µm and mostly in the p region
5) W=40µm and mostly in the n region
6) None of the above

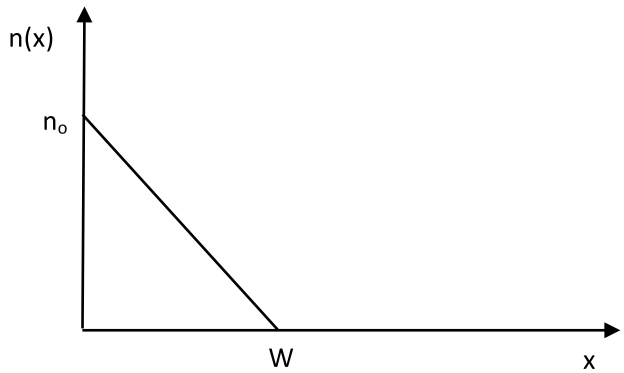
$$V_0 = V_T \ln\left(\frac{N_D N_A}{n_i^2}\right) = 0.025\ln\left(\frac{10^{18}\times 5\times 10^{16}}{10^{20}}\right) = 0.846(141)V$$

$$W = \sqrt{\frac{2\times\varepsilon_0\times\varepsilon}{q}\left(\frac{1}{N_D}+\frac{1}{N_A}\right)} = \sqrt{\frac{2\times 11.7\times 8.85\times 10^{-14}}{1.6\times 10^{-19}}\left(\frac{1}{10^{18}}+\frac{1}{5\times 10^{-16}}\right)} = 0.0000399(075)\ \text{cm} = 0.4\ \mu\text{m}$$

Since $N_D > N_A \Rightarrow$ mostly in p-region

$W = 0.4\ \mu$m and mostly in p-region

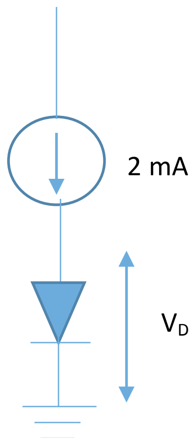
3) The linear electron concentration profile shown in figure below has been established in a piece of silicon, if $n_o = 10^{17}$ cm^{-3} and W=1 µm, what is the electron current density? Assume room temperature operation (V_T = 25 mV) and an electron mobility of 1250 cm^2/V.s. (q = 1.6×10^{-19} C)

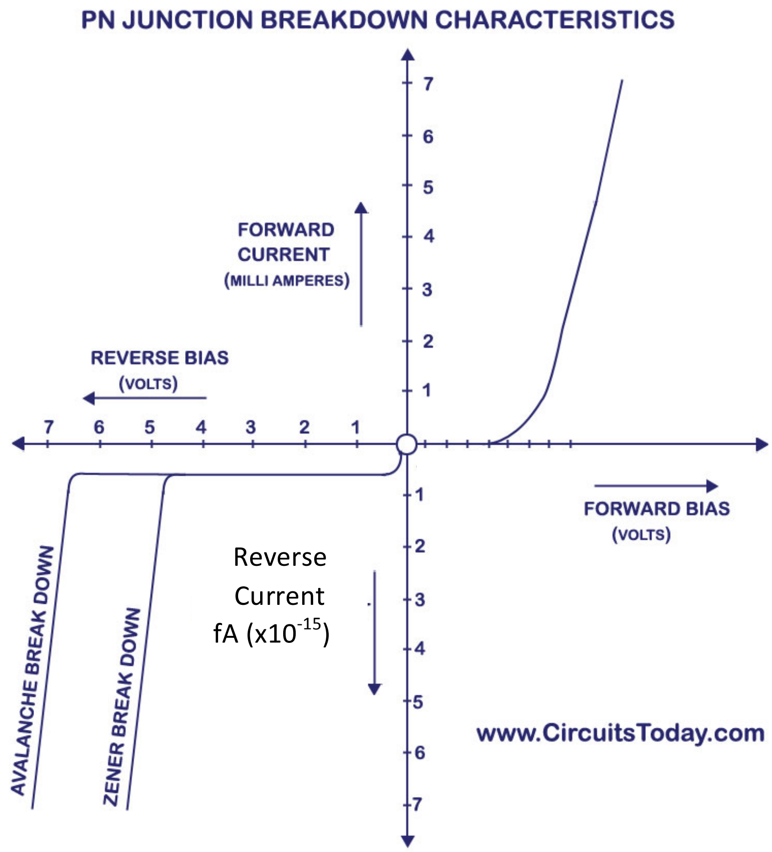


1) J_n=-5000 A/cm^2
2) J_n=500,000 A/cm^2
3) J_n=5000 A/cm^2
4) J_n=-200,000 A/cm^2
5) J_n=-250 A/cm^2
6) None of the above

$$J_n = q \underbrace{D_n}_{\mu_n V_T} \frac{dn}{dx} = 1.6\times10^{-19}[C](1250\left[\mathrm{cm}^2/(\mathrm{Vs})\right]\times 0.025\left[\mathrm{V}\right])\times\left(\frac{-10^{17}\left[\mathrm{cm}^{-3}\right]}{10^{-4}\left[\mathrm{cm}\right]}\right) = -5000\ \left[\mathrm{A/cm^2}\right]$$

4) The circuit below shows a diode forward biased using a current source of 2 mA in magnitude what is the voltage drop across the diode (V_D)? The iv characteristics of the diode is also shown below. Assume room temperature operation V_T = 25 mV



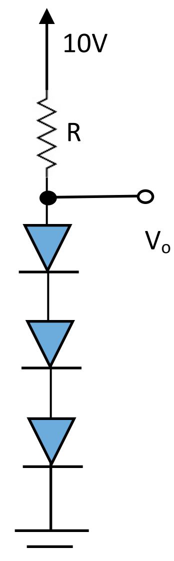


1) Vo=0.725V
2) Vo=0.710V
3) Vo=0.825V
4) Vo=0.65V
5) Vo=0.8V
6) None of the above

$$V_D = V_T \ln\left(\frac{I}{I_S}\right) = 0.025 \ln\left(\frac{2\times10^{-3}}{0.5\times10^{-15}}\right) = 0.725\left(433\right)\ \text{V}$$

$$V_D = 0.725\ \text{V}$$

5) Find the value of R such that the output voltage will be 2.4 V. Assume that all diodes are the same and have 0.7 voltage drop at 1mA. V_T=0.025V

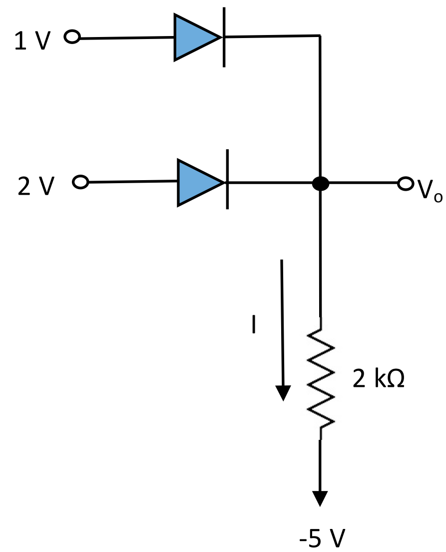


1) R=7.6kΩ
2) R=1.4kΩ
3) R=7.9kΩ
4) R=140Ω
5) R=44Ω
6) None of the above

$$\text{Individual Diode } \mathrm{V}_D = 0.8\left[V\right]$$
$$I_D = I_S \exp\left(V_D / V_T\right)$$
$$\begin{cases} I_D = I_S \exp\left(0.8/0.025\right) \\ \dfrac{10^{-3}}{\exp\left(0.7/0.025\right)} = I_S \end{cases} \Rightarrow I_D = \frac{10^{-3}\exp\left(0.8/0.025\right)}{\exp\left(0.7/0.025\right)} = 0.0545\left(982\right) = 54.6\left[\mathrm{mA}\right]$$

$$R = \frac{10\left[V\right] - V_O}{I_D} = \frac{\left(10 - 2.4\right)\left[V\right]}{0.0546\left[A\right]} = 139.\left(19\right)\left[\Omega\right]$$
$$R = 139\left[\Omega\right]$$

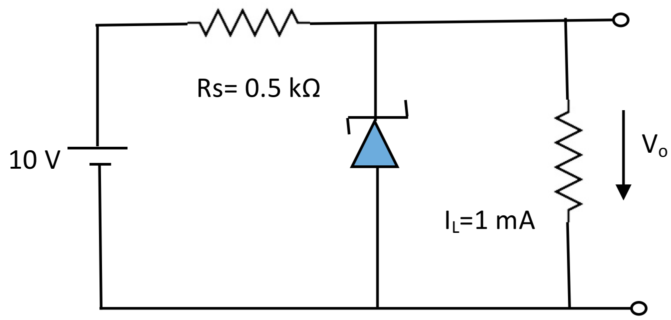
6) In figure shown below what is the current I assuming both diodes are ideal?



1) I=3mA
2) I=3.5mA
3) I=0
4) I=2.5mA
5) I=2mA
6) None of the above

$$I = \frac{(V_O - (-5))[V]}{2 \times 10^3 [\Omega]} = \frac{2+5}{2}[mA] = 3.5[mA]$$

7) The figure below shows a Zener shunt voltage regulator. From Zener data sheet we have (V_Z=6.8V at I_Z=5mA and r_Z=20Ω), what is the voltage across the load (V_o) it I_L=1mA?

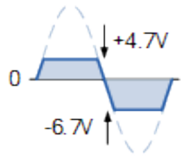


1) V_o=6.83V
2) V_o=6.7V
3) V_o=6.8V
4) V_o=3.2V
5) V_o=6.807V
6) None of the above

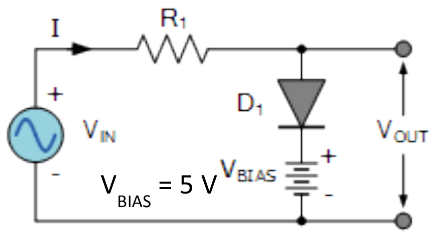
First find V_{zo}

$$V_Z = V_{ZO} + r_Z I_Z$$
$$V_Z - r_Z I_Z = V_{ZO} = 6.8[V] - 20[\Omega]5\times10^{-3}[A] = 6.7[V]$$
$$V_{ZO} = 6.7[V]$$
$$I_{OC} = \frac{(10[V] - V_{ZO})}{R_S + r_Z} = \frac{(10-6.7)[V]}{520[\Omega]} = 6.34(615)[mA] = 6.35[mA]$$
$$I_L = 1[mA] \Rightarrow I_Z = 5.35[mA]$$
$$V_O = 6.7[V] + 20[\Omega]5.35\times10^{-3}[A] = 6.807[V]$$

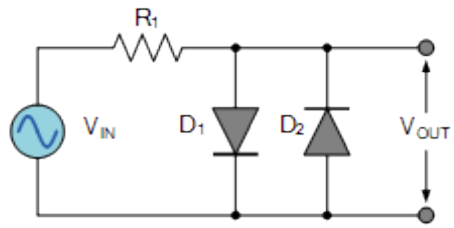
8) Which one of the clipping circuits below produce the following output



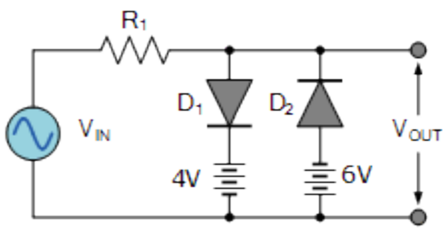
in response to the input signal, V_{in} = (10V)sinωt ? Assume V_{ON} = 0.7 V for all diodes.



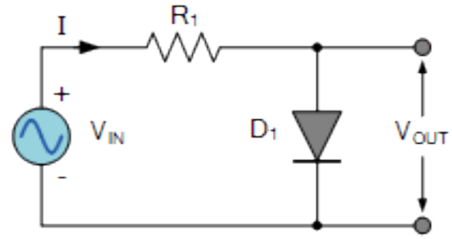
(#1)



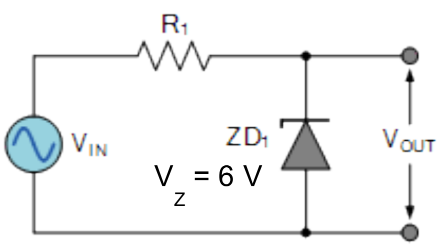
(#4)



(#2)

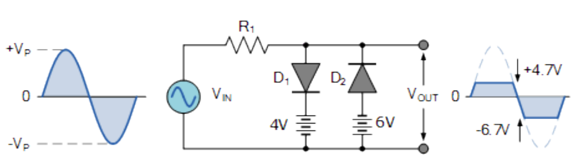


(#5)

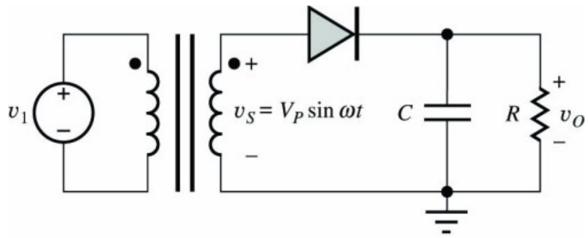


(#3)

1) Clipping circuit #1
2) Clipping circuit #2
3) Clipping circuit #3
4) Clipping circuit #4
5) Clipping circuit #5
6) None of the above



9) Find the value of the conduction angle for a half-wave rectifier driven from a transformer having a secondary voltage of 12.6 Vrms (60 Hz) with R = 15 Ω and C = 25,000 µF.
Assume the diode on-voltage V_{on} = 0 V, and that for small Δt $\cos(\omega\Delta t) \approx 1 - \frac{1}{2}(\omega\Delta t)^2$.



1) 1.0 rad
2) 0.7 rad
3) 0.1 rad
4) 0.3 rad
5) 0.6 rad
6) None of the above

$$V_P = 12.6\sqrt{2}[V] = 17.8[V]$$

$$V_r = \frac{V_P}{fCR} =$$

$$\frac{17.8[V]}{60[Hz]\times 15[\Omega]\times 25\times 10^{-3}[F]} =$$

$$0.791(111)[V]$$

$$V_P \cos\left(\underbrace{\omega\Delta t}_{\theta}\right) = V_P - V_r$$

$$\cos\theta \approx 1 - \tfrac{1}{2}\theta^2$$

$$\theta = \sqrt{\frac{2V_r}{V_P}} = \sqrt{\frac{2\times 0.791}{17.8}} =$$

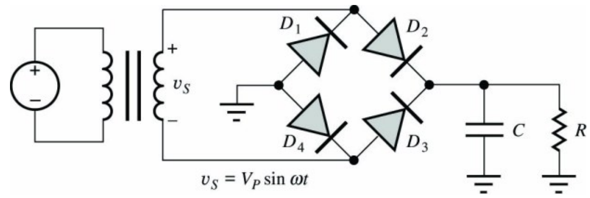
$$0.298(142) \approx 0.3\ [rad] = 17°$$

$$\text{ExactValue } \theta = \arccos\frac{V_P - V_r}{V_P}$$

$$= 0.299237 \approx 0.3\ [rad] = 17°$$

10) Select a minimal capacitor sufficient for a bridge rectifier (60 Hz) with given specifications, V_{dc} = 15 V, V_r < 0.15 V, I_{dc} = 2 A.

Assume V_{on} = 1 V.



1) 0.111 F
2) 3.62 μF
3) 0.412 F
4) 19.1 pF
5) 0.337 F
6) None of the above

$$C = I_{dc}\left(\frac{T/2}{V_r}\right) = 2A\left(\frac{1}{120}s\right)\left(\frac{1}{0.15V}\right) = 0.111\ F$$