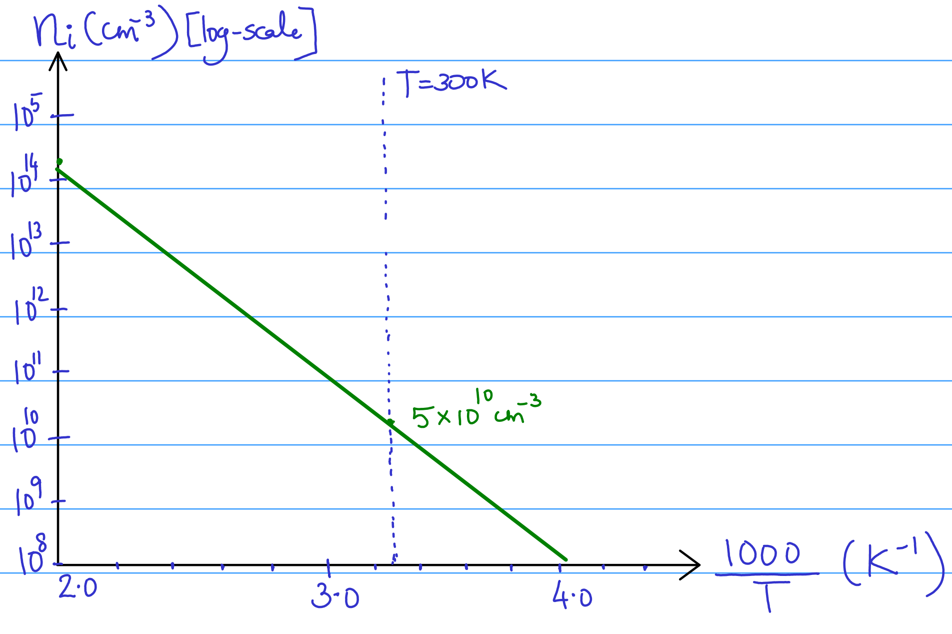
Assignment - 03

[A] Semiconductors : Charge - Carrier density

Q1. A silicon sample is doped with 10^{17} As atoms cm^{-3}. What is the equilibrium hole density at 300 K? Where is E_F relative to E_c? [Assume: $n_i = 1.5 \times 10^{10}\ cm^{-3}$ and $N_c = 1 \times 10^{19}\ cm^{-3}$]

Q2. A silicon bar 0.1 cm long and $100\ \mu m^2$ in cross-sectional area is doped with $10^{17}\ cm^{-3}$ phosphorus atoms. Calculate the electron density at 300K. Find the current at 300K with 10V applied. [Assume: Mobility of electrons at 300K = $100\ cm^2 V^{-1} s^{-1}$.

Q3. The following figure shows variation of intrinsic charge-carrier density n_i with the temperature. Use the data to estimate the band-gap of the semiconductor.



Q4. Justify why holes are found at the top of the valance band, whereas electrons are found at the bottom of the conduction band.

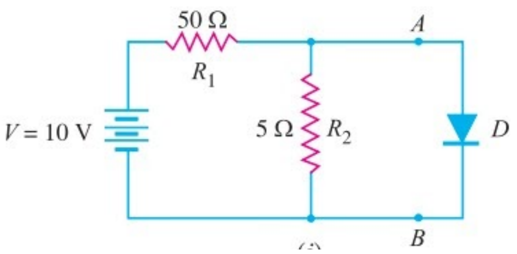
Q5. A silicon sample is doped with $6 \times 10^{15}\ cm^{-3}$ donor atoms from one end and with $2 \times 10^{15}\ cm^{-3}$ acceptor atoms from other end. Find the position of Fermi energy level w.r.t. corresponding band edge (E_c or E_v) at 300K.

[Assume: $N_c = N_v = 1 \times 10^{19}\ cm^{-3}$ at 300K]

[B] p-n Homojunction Diodes : Circuit Problems

1. An a.c. voltage of peak value 20 V is connected in series with a silicon diode and load resistance of 500 Ω. If the forward resistance of the diode is 10 Ω, find : (i) peak current through diode (ii) peak output voltage across the load. What will be these values if the diode is assumed to be ideal ?

2. Find the current through the diode in the circuit shown in Fig. 1. Assume the diode to be ideal.

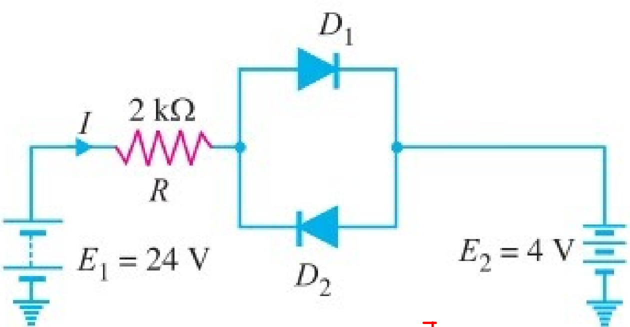


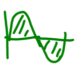
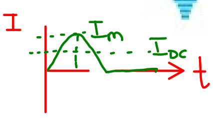
$V_{AB} > 0$; diode ≡ short

$V_{AB} < 0$; diode ≡ open

Fig. 1

3. Determine the current I in the circuit shown in Fig. 2. Assume the diodes to be of silicon (turn-On voltage = 0.7V) and forward resistance of diodes to be zero.



$I_{RMS} = \frac{1}{\sqrt{2}} I_m$ Full wave  $V_{DC} = \frac{V_m}{\pi} = V_{avr.}$ **Fig. 2** 

I_m = peak current

$I_{DC} = I_m / \pi$

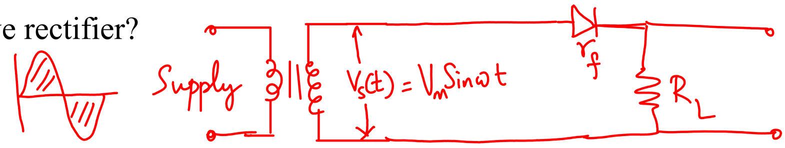
$I_{RMS} = \frac{1}{2} I_m$ Half wave

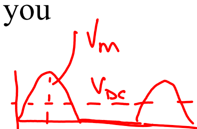
4. A crystal diode having internal resistance $r_f = 20$ Ω is used for half-wave rectification. If the applied a.c. voltage is $v(t) = 50$ Sin(ωt) and load resistance $R_L = 800$ Ω, find: (*i*) I_m, I_{dc}, I_{rms} (*ii*) a.c. power input and d.c. power output (*iii*) d.c. output voltage (*iv*) efficiency of rectification.

$(I_{rms})^2 (r_f + R_L)$ $\quad I_{DC}^2 \cdot R_L \quad I_{DC} R_L \quad \eta = \frac{\text{DC power output}}{\text{ac power input}} \times 100$

5. A half-wave rectifier is used to supply 50V d.c. to a resistive load of 800 Ω. The diode has a resistance of 25 Ω. Calculate a.c. voltage required.

6. Consider a half-wave rectifier designed connecting a diode and a load resistance across the secondary winding of a step-down transformer. Let $v_s(t) = V_m\text{Sin}\omega t$ be the alternating voltage that appears across the secondary winding. Let r_f and R_L be the diode resistance and load resistance, respectively. Show that the maximum rectifier efficiency $\eta_{max.} = 40.6\%$. What do you expect if you design a full wave rectifier?

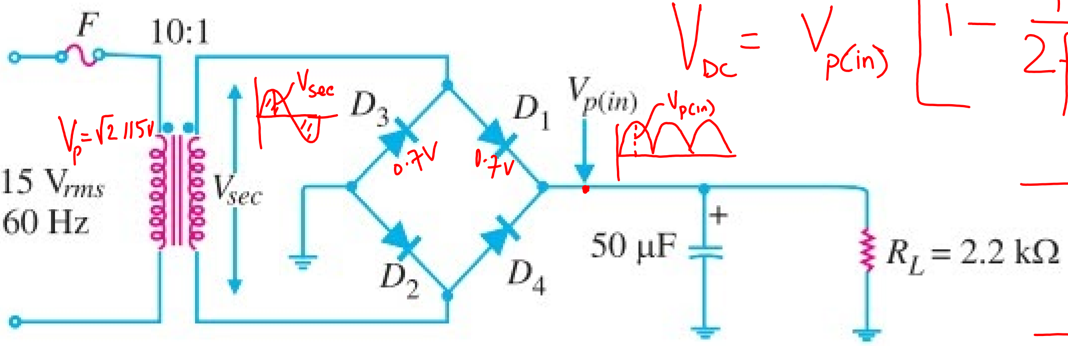




7. A full-wave rectifier uses two diodes, the internal resistance of each diode may be assumed constant at 20 Ω. The transformer r.m.s. secondary voltage from centre tap to each end of secondary is 50 V and load resistance is 980 Ω. Find : (i) the average load current (ii) the r.m.s. value of load current.

8. For the circuit shown in Fig. 3, find the output d.c. voltage.

$V_{DC} = V_{p(in)}\left[1 - \frac{1}{2fR_L C}\right]$



$V_{DC} = ?$

Fig. 3

9. The zener diode shown in Fig. 4 has V_Z = 18 V. The voltage across the load stays at 18 V as long as I_Z is maintained between 200 mA and 2 A. Find the value of series resistance R so that E_O remains 18 V while input voltage V_i is free to vary between 22 V to 28V.

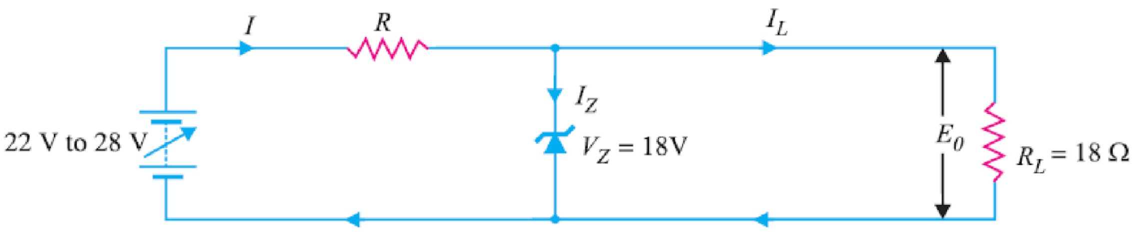


Fig. 4

10. A 10-V zener diode is used to regulate the voltage across a variable load resistor [see Fig. 5]. The input voltage varies between 13 V and 16 V and the load current varies between 10 mA and 85 mA. The minimum zener current is 15 mA. Calculate the value of series resistance R.

$V_R = 3V$ $\quad R = \frac{3V}{100mA} = 30\Omega$

$I_{min} = 100mA$

$I = I_Z + I_L$

$I_{min} = I_{Z,min} + I_{L,max}$

$\Rightarrow V_{in} = V_{min} = 13V$

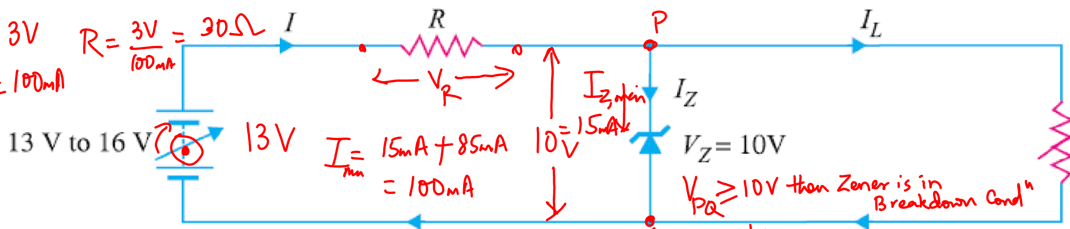


Fig. 5 & $V_{PQ} = 10V$

11. The circuit of Fig. 6 uses two zener diodes, each rated at $\underbrace{15\ V}_{V_Z}$, $\underbrace{200\ mA}_{I_Z}$. If the circuit is connected to a 45-volt unregulated supply, determine :(*i*) The regulated output voltage (*ii*) The value of series resistance *R*.

$V_{in} = 45V$; $V_{PQ} = 30V$; $V_R = 45V - 30V = 15V$

$I = I_Z + I_L$

$\checkmark R = \dfrac{15V}{200mA + 30mA}$ $\qquad R \uparrow\downarrow \dfrac{V_{in} - V_{PQ}}{\uparrow I_Z \downarrow + I_L}$ $\qquad R = \dfrac{15V}{200mA} = 75\Omega$

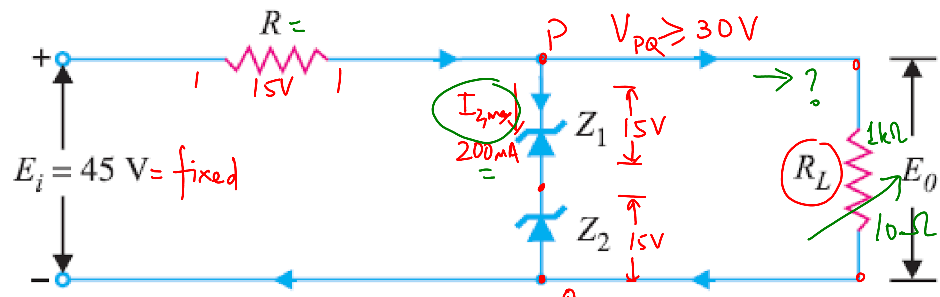


Fig. 6

$I_L = \dfrac{30V}{1k\Omega} = 30mA$

12. What value of series resistance R is required when three 10-watt, 10-volt, 1000 mA zener diodes are connected in series to obtain a 30-volt regulated output from a 45 volt d.c. power source? [See Fig.7]

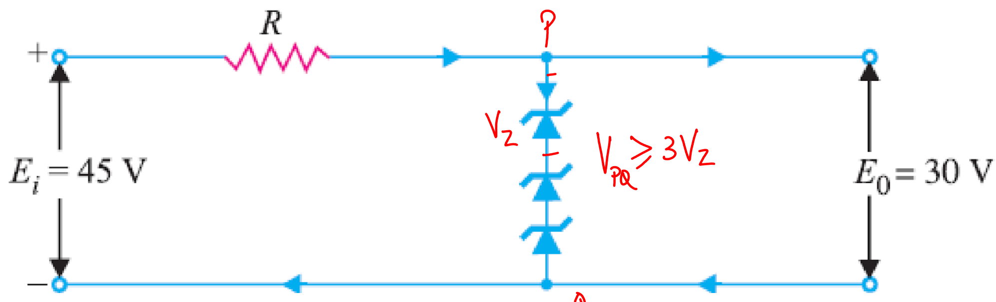


Fig. 7

13. Over what range of input voltage will the zener circuit shown in Fig. 8 maintain 30 V across 2000 Ω load, assuming that series resistance R = 200 Ω and zener current rating is 25 mA?

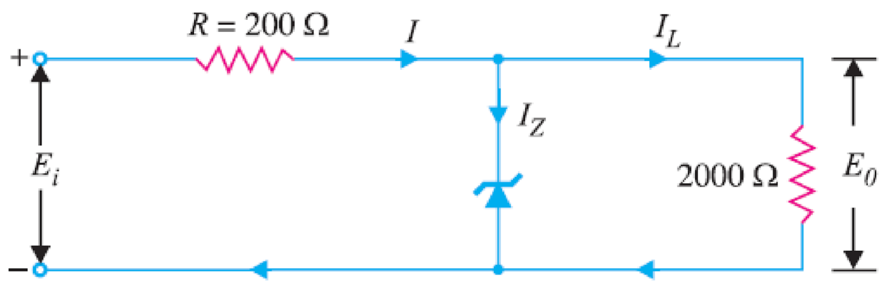


Fig. 8

14. In the circuit shown in Fig. 9, the voltage across the load is to be maintained at 12 V as load current varies from 0 to 200 mA. Design the regulator. Also find the maximum wattage rating of the zener diode.

$R = \dfrac{16V - 12V}{I_{z,min} + I_{L,max}}$

$R = \dfrac{4V}{\mu A + 200mA} \approx \dfrac{4V}{200mA}$

$\approx 20\Omega$

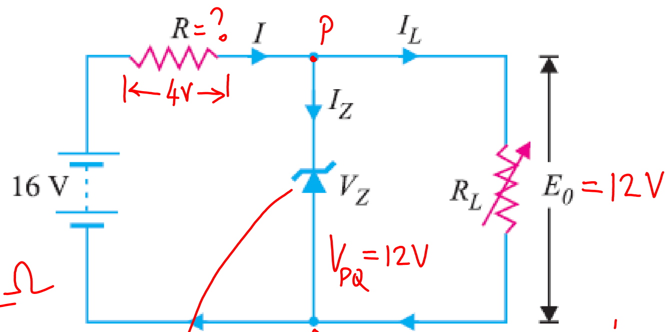


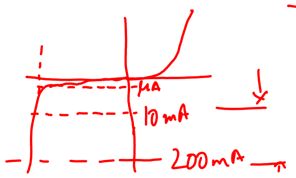
Fig. 9

$I_{L,min} = 0mA = R_L = \text{open}$

$I_{L,max} = 200mA$

$R_{L,min} = \dfrac{12V}{200mA}$

$I = I_{z,min} + I_{L,max}$



$P_{z,M} = 12V(200mA) =$

15. In the circuit shown in Fig. 10, determine the range of R_L that will result in a constant voltage of 10 V across R_L.

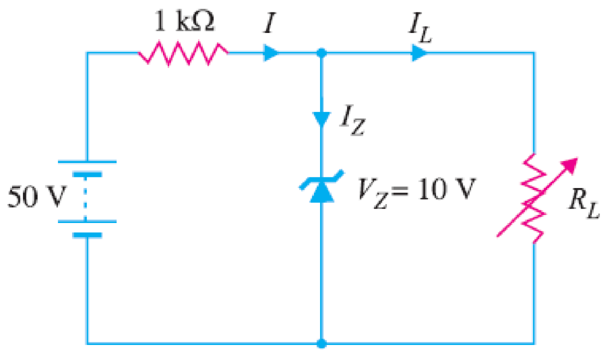


Fig. 10