Problem:

Consider a PN junction of length 3µm (1.5µm on each side) with an abruppt doping concentration (for Na, Nd) of $1*10^{15}cm^{-3}$ (similar to assignment 3). Consider that a voltage of 1V (across the diode terminals) in forward bias is applied for a long time and a voltage of 1V is applied in reverse bias at time, t=0. Let $ni=1.5*10^{10}\ cm^{-3}$, $\mu_p=450cm^2/s$, $\tau_p=20\ \mu s$, $J_R = 2KA/cm^2$.

Plot the decay profile of stored hole charge in the PN junction diode as a function of time from 0<t<ts from the edge of depletion region (of N-side) to the end of diode.

Also Find the value of approximate "ts" value

Where, ts is time where diode remains in the forward bias even after switching from FB to RB

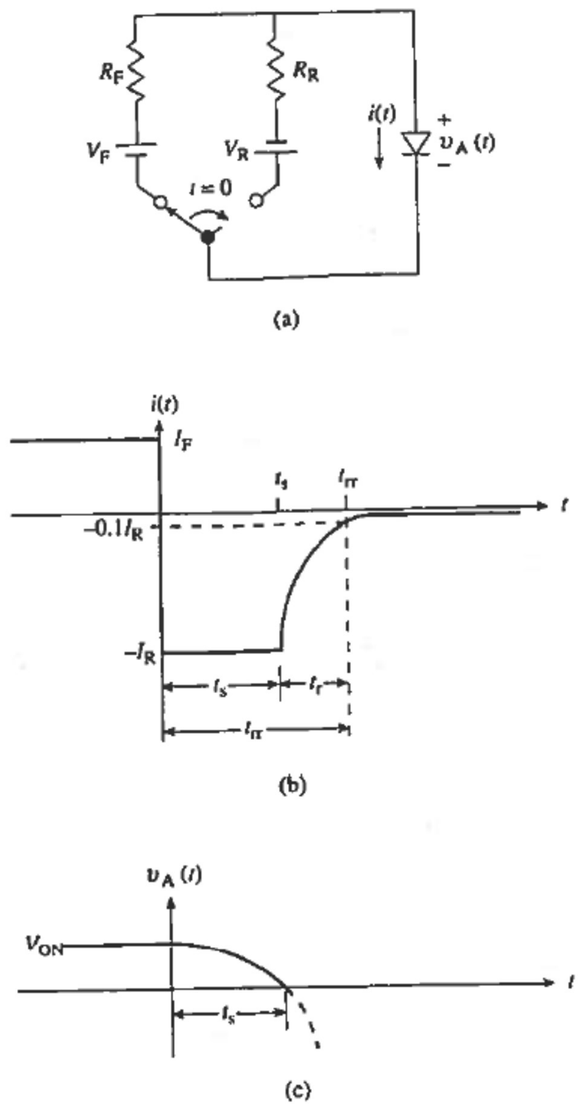

Figure 8.1 The turn-off transient. (a) Idealized representation of the switching circuit. (b) Sketch and characterization of the current-time transient. (c) Voltage-time transient.

Theory:

The minority carrier diffusion equation for holes in the n-region of a PN junction diode is a partial differential equation that describes how the concentration of minority carriers (holes in this case) changes with time and position within the semiconductor. It can be written as follows:

$p(x,t) = p_o + \Delta p(x,t)$ ……………………………………………(1)

$\frac{\partial \Delta p(x,t)}{\partial t} = D_p \frac{\partial^2 \Delta p(x,t)}{\partial x^2} - \frac{\Delta p(x,t)}{\tau_p}$ ……………………………..(2)

Where

- $\Delta p(x,t)$ is the excess concentration of minority carriers (holes) as a function of position (x) and time (t)
- $p(x,t)$ is the concentration of minority carriers as a function of position (x), and time (t)
- p_o is the minority carrier concentration in n-side ($=\frac{n_i^2}{N_d}$ $at\ equilibrium$)
- D_p is the diffusion coefficient for holes in n-region
- τ_p is the carrier lifetime for holes

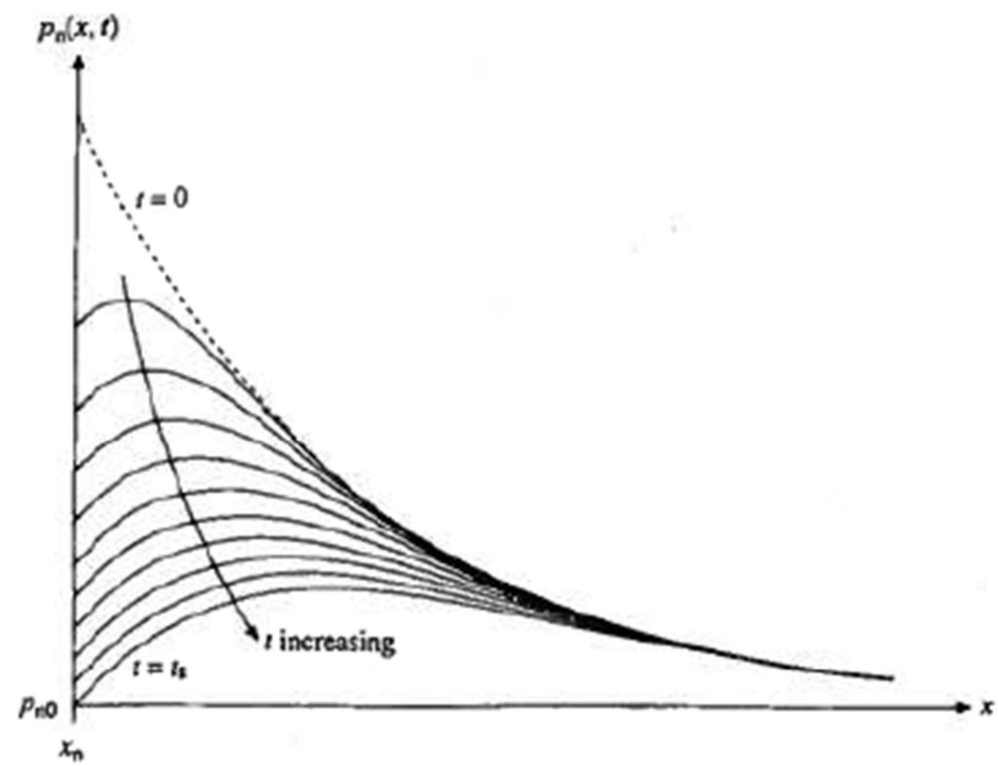

Figure 8.3 Decay of the stored hole charge inside a p^+-n diode as a function of time for $0 \le t \le t_s$.

Boundary Condition:

Slope of $p(x,t)$ at x=w_n is always constant.

$\frac{d\Delta p}{dx}$ $(at\ x = w_n) = slope\ of\ p(x,t) = slope\ of\ \Delta p(x,t) = \frac{|J_R|}{qD_p}$ ....(3)

Procedure:

1. Determine holes concentration profiles at equilibrium for PN Diode with depletion approximation**.**
2. Determine the position of edge of Depletion region (wn) on n-side.
3. Apply variation of voltage on hole concentration profile. (p(at V=Va) = p(at equilibrium)*exp(Va/Vt)) and store these values in j=1.
4. In finite equations, equation 2, will become as follows (for i=wn+h to Ln and j=2 onwards)
$$\frac{\Delta p(i,j) - \Delta p(i,j-1)}{dt} = D_p\frac{\Delta p(i+1,j) + \Delta p(i-1,j) - 2\Delta p(i,j)}{h^2} - \frac{\Delta p(i,j) - \Delta p(i,j-1)}{\tau_p}$$
5. Iteratively solve for $\Delta p(i,j)$ where, dt is the time interval, and h is step size.
6. For $\Delta p(i,j)$ at w_n, use boundary conditions stated in equation 3.
7. Find excess charge density (Q/A) from x= w_n to L_n at each interval of time. Given by Q/A (at time t) = q * (summation of excess hole concentration (at time t) from x = w_n to L_n)
8. At time, t=t_s excess charge density will become 0. Find the approximate time taken for it.
9. Plot $p(i,j)$ from time t=0^- to t= t_s
10. You may get a plot similar to the following figure