Indian Institute of Technology Tirupati

Department of Electrical Engineering

M.TECH : MVLSI

Device Simulation Laboratory (EE5195)

Instructor: Dr. Bhuktare Swapnil Sopanro

Assignment: 8

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Roll No: ee22m308

Take cross sectional area, A=1 μm2 , hole mobility, μP = 450 cm2 V-1s -1 and electron mobility, μn = 1417 cm2V-1s -1 .

Q.1: Draw a simple n-type Si of dimensions 1 x 1 μm2 on the sentaurus structure editor with uniform doping of 1x1016 cm-3 (use proper meshing).

Q.2: Use *****.tdr file (which is generated after meshing), in the sdevice command-

(a) Calculate I-V characteristics for a voltage range from -1 V to 1 V

(b) Calculate resistance, R of the given sample using I-V plot and using formula. Compare both the results.

(c) Include doping dependent mobility in the sdevice **.cmd file and calculate resistance, R of the given sample using I-V plot and using formula. See the change in resistance.

(d) Change the mobility, μn to 200 cm2V-1s -1 (parameter file) as discussed in the class and again do (b). See the change in resistance with respect to change in mobility (1417 cm2V-1s -1 to 200 cm2V-1s -1 i.e. approximately 7 times).

(e) Draw energy band diagram in equilibrium (0V) and for 1V.

Q.1: Draw a simple n-type Si of dimensions 1 x 1 μm2 on the sentaurus structure editor with uniform doping of 1x1016 cm-3 (use proper meshing).

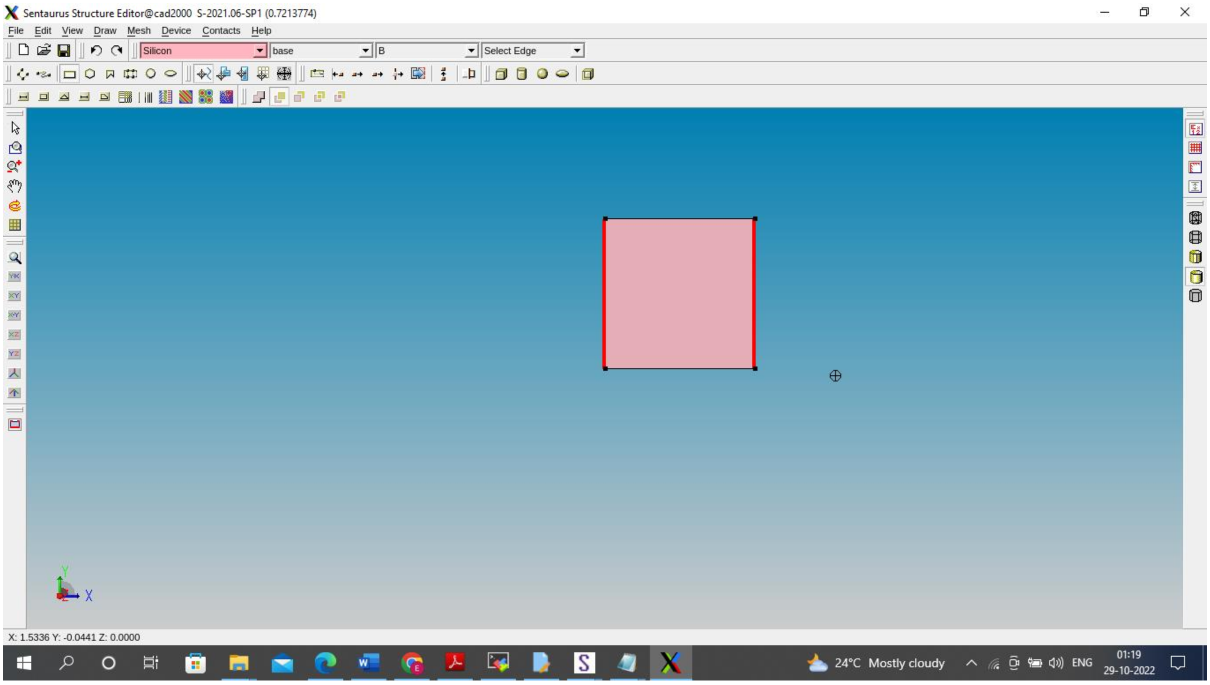
Ans :

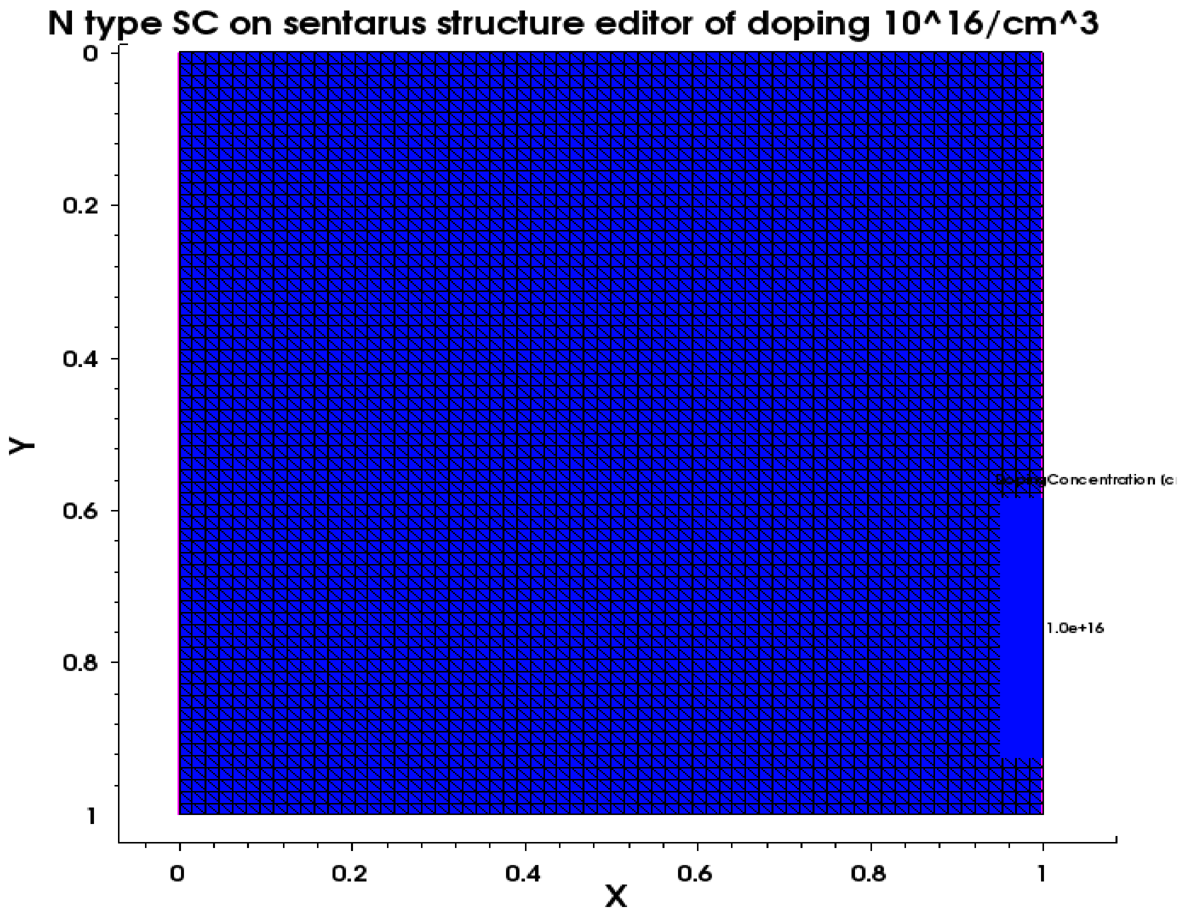
Jrl file:

```
;;
;; (journal:on "/home/students/MVLSI_2022/Group2/Praveen/assign86/m3d.jrl")
;; "/home/students/MVLSI_2022/Group2/Praveen/assign8 ...
(sdegeo:set-auto-region-naming OFF)
;; #t
(bound? 'region_1)
;; #f
(sdegeo:create-rectangle (position 0 0 0)  (position 1 1 0) "Silicon" "region_1")
;; #[body 5 1]
(sdegeo:define-contact-set "A" 4  (color:rgb 1 0 0 ) "##")
;; ()
(sdegeo:define-contact-set "B" 4  (color:rgb 1 0 0 ) "##")
;; ()

;; ()
(render:rebuild)
;; ()
(sdegeo:define-2d-contact (list (car (find-edge-id (position 0 0.5 0)))) "A")

;; ()
(render:rebuild)
;; ()
(sdegeo:define-2d-contact (list (car (find-edge-id (position 1 0.5 0)))) "B")

;; ()
(render:rebuild)
;; ()
(sdedr:define-constant-profile "ConstantProfileDefinition_N" "ArsenicActiveConcentration" 1e16)
;; #t
(sdedr:define-constant-profile-region "ConstantProfilePlacement_N" "ConstantProfileDefinition_N" "region_1")
;; #t
(sdedr:define-refinement-size "RefinementDefinition_N" 0.02 0.02 0 0.02 0.02 0 )
;; #t
(sdedr:define-refinement-placement "RefinementPlacement_N" "RefinementDefinition_N" (list "region" "region_1" ) )
```

```
;; #t
(sde:set-project-name "/home/students/MVLSI_2022/Group2/Praveen/assign86/NNEW")
;; ""
(sdesnmesh:iocontrols "outputFile" "/home/students/MVLSI_2022/Group2/Praveen/assign86/NNEW")
;; #t
(sde:set-meshing-command "snmesh")
;; #t
(sde:set-project-name "/home/students/MVLSI_2022/Group2/Praveen/assign86/NNEW")
;; "/home/students/MVLSI_2022/Group2/Praveen/assign8 ...
(sdesnmesh:iocontrols "outputFile" "/home/students/MVLSI_2022/Group2/Praveen/assign86/NNEW")
;; #t
(sde:build-mesh "" "/home/students/MVLSI_2022/Group2/Praveen/assign86/NNEW")
"Meshing successful"
;; #t
(system:command "svisual /home/students/MVLSI_2022/Group2/Praveen/assign86/NNEW_msh.tdr &")
;; 0
;; (journal:off)
```

Sde structure:





Q.2: Use *****.tdr file (which is generated after meshing), in the sdevice command-

(a) Calculate I-V characteristics for a voltage range from -1 V to 1 V

Ans

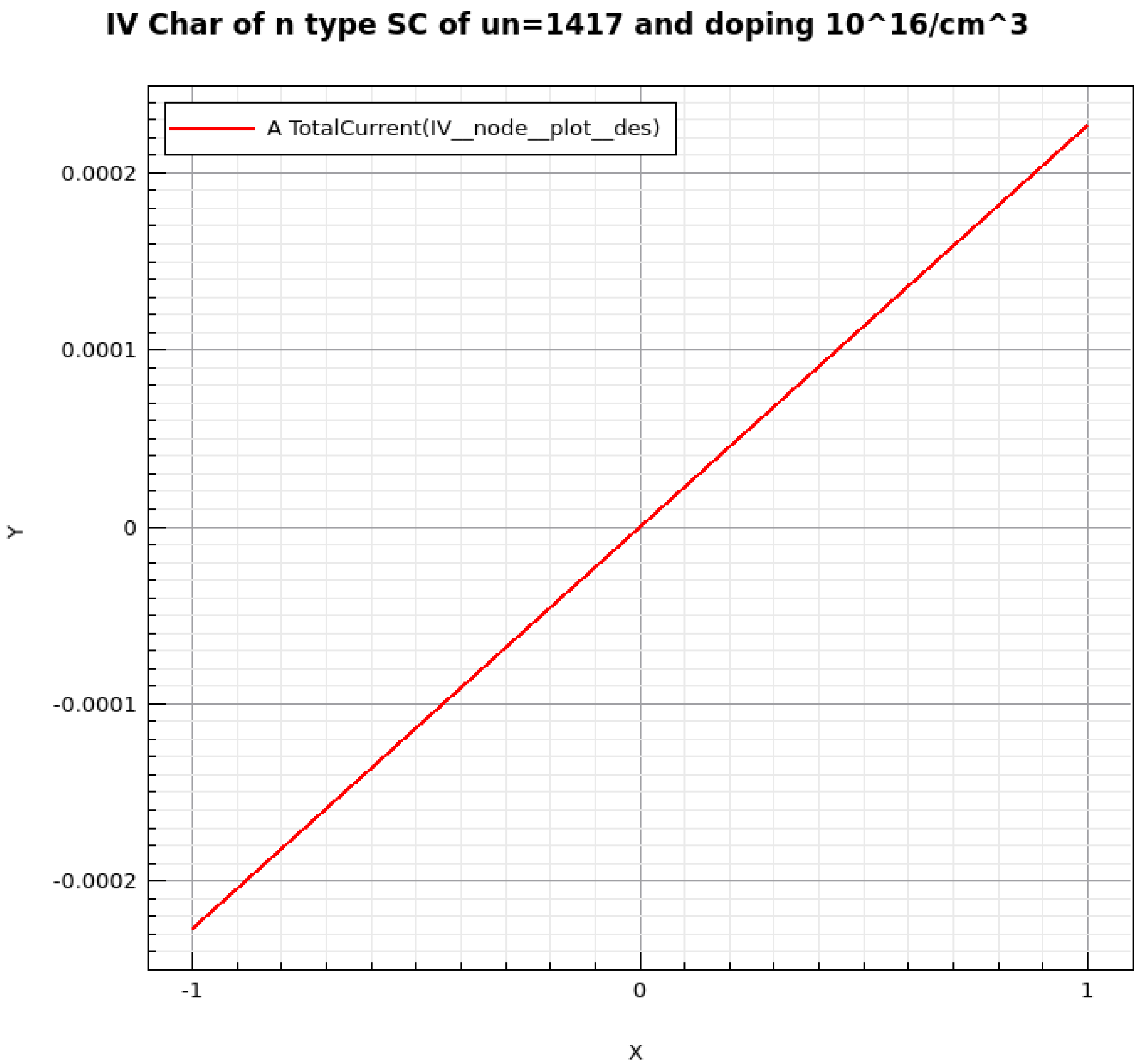
CMD FILE: Sdevice.cmd

```
File{
  Grid      = "NNEW_msh.tdr"
   Plot     = "@tdrdat@"
  Current   = "@plot@"
  Output    = "@log@"
}

Electrode{
  { Name="A"    Voltage=0.0 }
  { Name="B"    Voltage=0.0 }
}

Physics{
```

```
  Fermi
  EffectiveIntrinsicDensity( OldSlotboom )




}

Plot{

  eDensity hDensity
  TotalCurrent/Vector eCurrent/Vector hCurrent/Vector
  eQuasiFermi hQuasiFermi
  eMobility hMobility

  ElectricField/Vector Potential SpaceCharge

  Doping DonorConcentration AcceptorConcentration

  BandGap
  ConductionBand ValenceBand
}

Math {
  Extrapolate
  RelErrControl
  Digits = 5
  Iterations= 20
  Notdamped= 100
  Method= Pardiso

}

Solve {


  Coupled(Iterations=100){ Poisson }
  Coupled{ Poisson Electron Hole }

  NewCurrentPrefix="IV_@node@"
  Quasistationary(
```

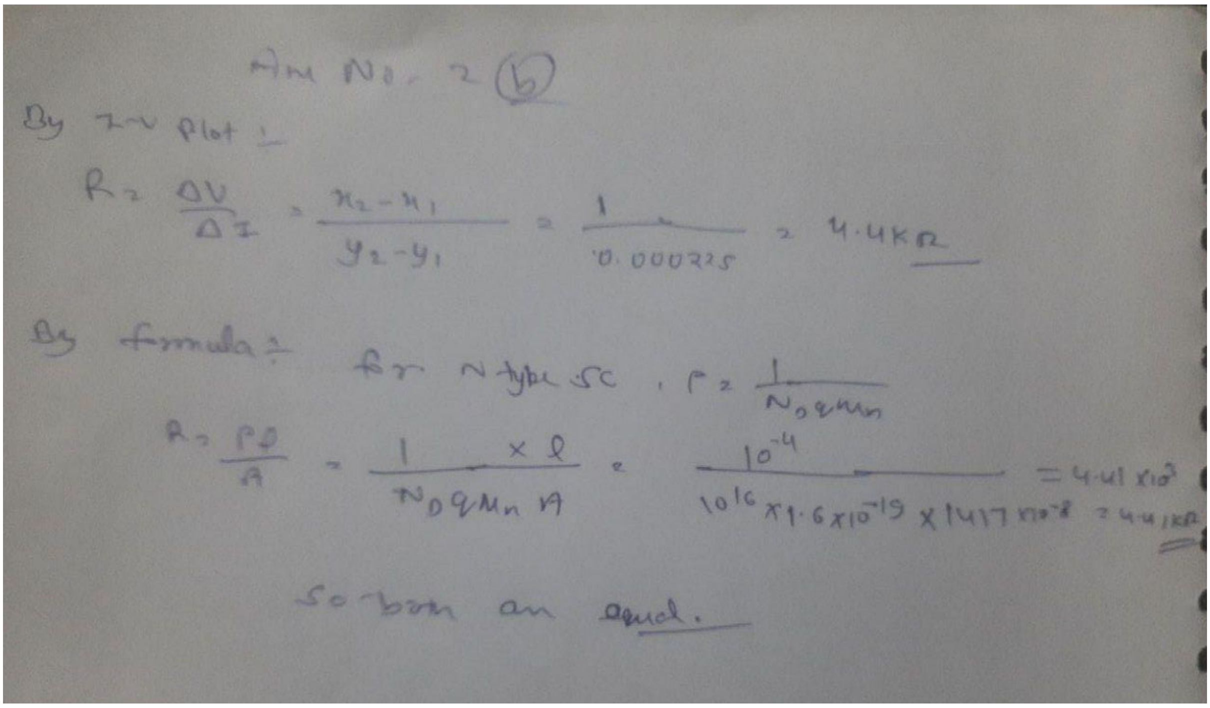
```
    InitialStep=1e-3 MinStep=1e-4 MaxStep=0.05
    Goal{ Name="A" Voltage= 1 }
  ) { Coupled { Poisson Electron Hole } }
   NewCurrentPrefix="IV_@node@"
  Quasistationary(
    InitialStep=1e-3 MinStep=1e-4 MaxStep=0.05
    Goal{ Name="A" Voltage= -1 }
  ) { Coupled { Poisson Electron Hole } }
}
```

I-V Char of N type SC:



(b) Calculate resistance, R of the given sample using I-V plot and using formula. Compare both the results.

Ans



Ans No. 2 (b)

By I-V plot :-

$$R = \frac{\Delta V}{\Delta I} = \frac{x_2 - x_1}{y_2 - y_1} = \frac{1}{0.000225} = 4.4\,k\Omega$$

By formula :- for N type SC, $\rho = \frac{1}{N_D q \mu_n}$

$$R = \frac{\rho l}{A} = \frac{1}{N_D q \mu_n A} \times l = \frac{10^{-4}}{10^{16} \times 1.6\times10^{-19} \times 1417 \times 10^{-8}} = 4.41\times10^{3} = 4.41\,k\Omega$$

So both are equal.

(c) Include doping dependent mobility in the sdevice **.cmd file and calculate resistance, R of the given sample using I-V plot and using formula. See the change in resistance.

Ans

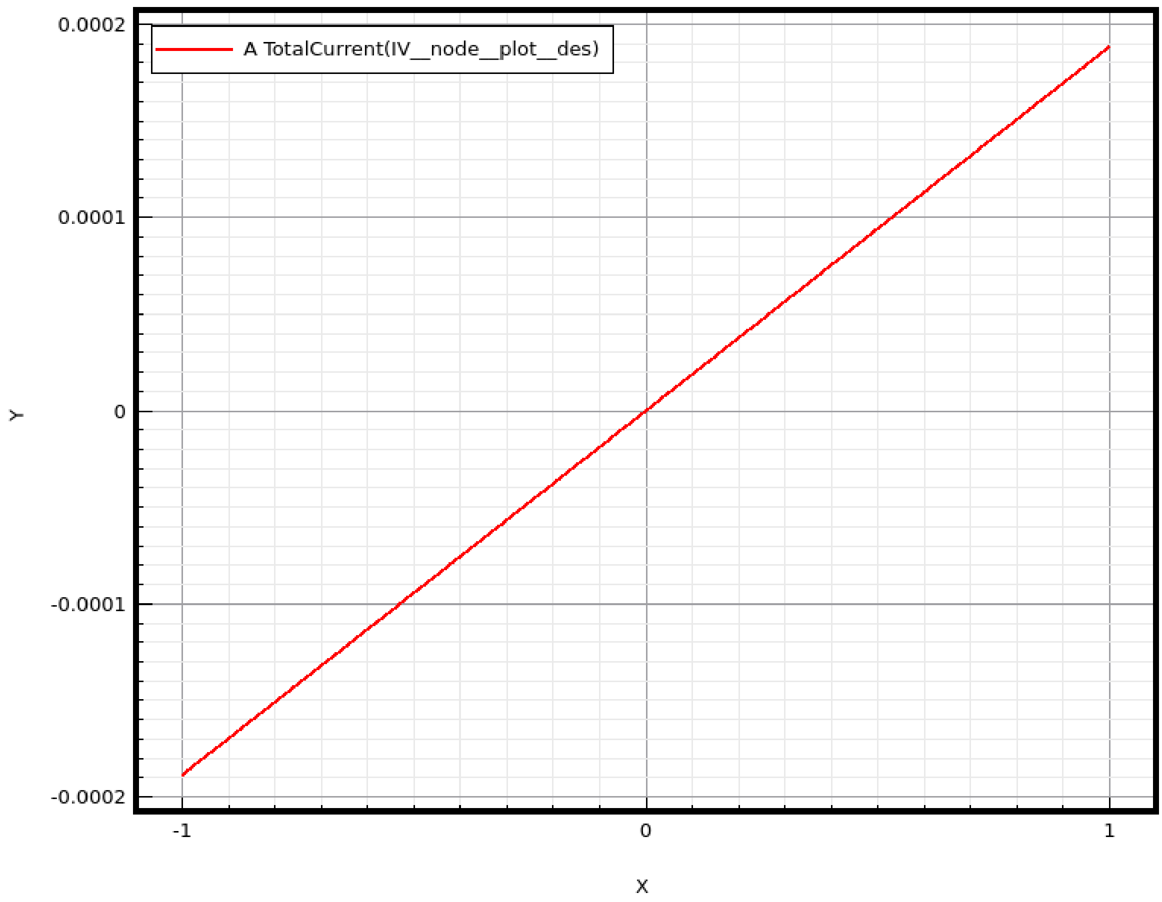
Cmd code:

```
File{
   Grid      = "NNEW_msh.tdr"
    Plot     = "@tdrdat@"
   Current   = "@plot@"
   Output    = "@log@"
}

Electrode{
   { Name="A"    Voltage=0.0 }
   { Name="B"    Voltage=0.0 }
}

Physics{
```

```
  Fermi
  EffectiveIntrinsicDensity( OldSlotboom )

  Mobility(
        DopingDep


  Recombination( SRH (DopingDependence) )

}

Plot{

  eDensity hDensity
  TotalCurrent/Vector eCurrent/Vector hCurrent/Vector
  eQuasiFermi hQuasiFermi
  eMobility hMobility

  ElectricField/Vector Potential SpaceCharge

  Doping DonorConcentration AcceptorConcentration

  BandGap
  ConductionBand ValenceBand
}

Math {
  Extrapolate
  RelErrControl
  Digits = 5
  Iterations= 20
  Notdamped= 100
  Method= Pardiso

}

Solve {


  Coupled(Iterations=100){ Poisson }
```

```
  Coupled{ Poisson Electron Hole }

  NewCurrentPrefix="IV_@node@"
  Quasistationary(
    InitialStep=1e-3 MinStep=1e-4 MaxStep=0.05
    Goal{ Name="A" Voltage= 1 }
  ) { Coupled { Poisson Electron Hole } }
   NewCurrentPrefix="IV_@node@"
  Quasistationary(
    InitialStep=1e-3 MinStep=1e-4 MaxStep=0.05
    Goal{ Name="A" Voltage= -1 }
  ) { Coupled { Poisson Electron Hole } }
}
```

inculding doping dependent I-V characteristics for a voltage range from -1 V to 1 V



Calculation:

So both are equal.

Ans No - 2(c)

include doping dependent mob. by Plot

$$R = \frac{\Delta V}{\Delta I} = \frac{x_2 - x_1}{y_2 - y_1} = \frac{1}{0.00019} = 5.263\ k\Omega$$

w/o include doping dep. mob.

$$R = \frac{\Delta V}{\Delta I} = \frac{x_2 - x_1}{y_2 - y_1} = \frac{1}{0.000225} = 4.4\ k\Omega$$

So by including doping dep. Resistance increased by around 0.8[illegible]9 kΩ.

(d) Change the mobility, µn to 200 cm2V-1s -1 (parameter file) as discussed in the class and again do (b). See the change in resistance with respect to change in mobility (1417 cm2V-1s -1 to 200 cm2V-1s -1 i.e. approximately 7 times).

Ans

Cmd file :

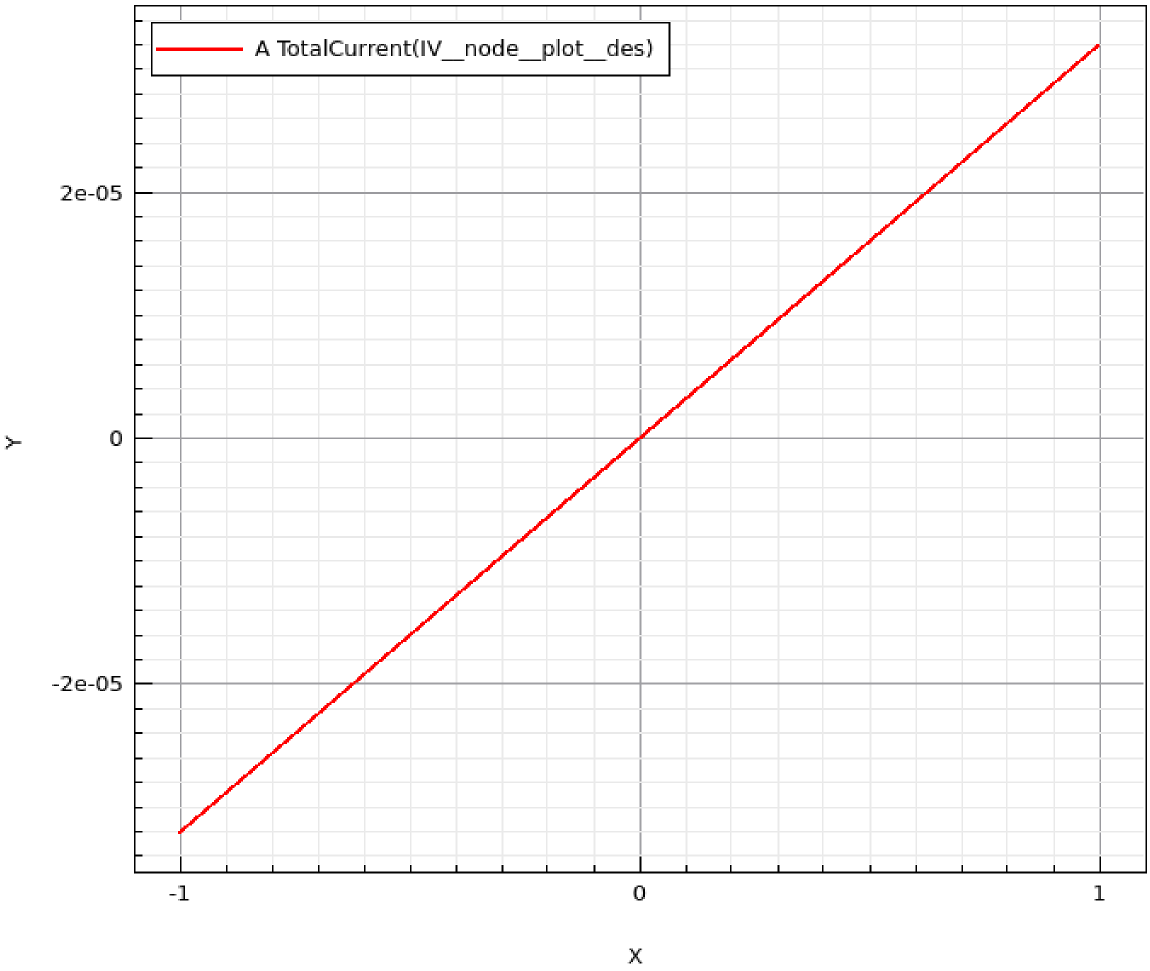
```
File{
  Grid      = "NNEW_msh.tdr"
   Plot     = "@tdrdat@"
  Current   = "@plot@"
  Output    = "@log@"
}

Electrode{
  { Name="A"    Voltage=0.0 }
  { Name="B"    Voltage=0.0 }
}
```

```
Physics{

  Fermi
  EffectiveIntrinsicDensity( OldSlotboom )

  Mobility(
          DopingDep


  Recombination( SRH (DopingDependence) )

}

Plot{

  eDensity hDensity
  TotalCurrent/Vector eCurrent/Vector hCurrent/Vector
  eQuasiFermi hQuasiFermi
  eMobility hMobility

  ElectricField/Vector Potential SpaceCharge

  Doping DonorConcentration AcceptorConcentration

  BandGap
  ConductionBand ValenceBand
}

Math {
  Extrapolate
  RelErrControl
  Digits = 5
  Iterations= 20
  Notdamped= 100
  Method= Pardiso

}

Solve {
```

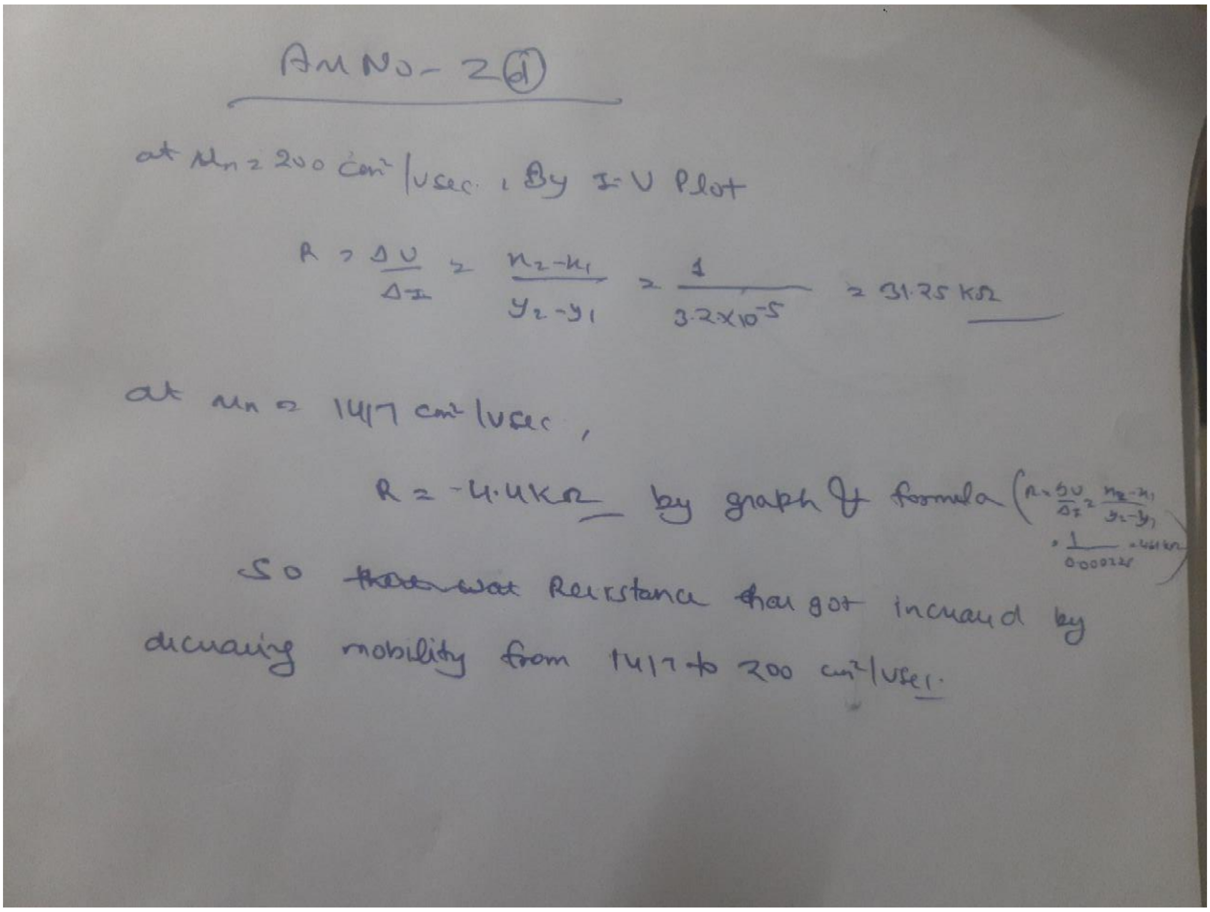
```
   Coupled(Iterations=100){ Poisson }
   Coupled{ Poisson Electron Hole }

   NewCurrentPrefix="IV_@node@"
   Quasistationary(
      InitialStep=1e-3 MinStep=1e-4 MaxStep=0.05
      Goal{ Name="A" Voltage= 1 }
   ) { Coupled { Poisson Electron Hole } }
    NewCurrentPrefix="IV_@node@"
   Quasistationary(
      InitialStep=1e-3 MinStep=1e-4 MaxStep=0.05
      Goal{ Name="A" Voltage= -1 }
   ) { Coupled { Poisson Electron Hole } }
}
```

I-V CHAR:

at mobility, µn to 200 cm2V-1s -1,I-V char. of N type SC for a voltage range from -1 V to 1 V



Calculation :


Ans No- 2(d)

at $\mu_n = 200\ cm^2/Vsec$, By I-V Plot

$R = \frac{\Delta V}{\Delta I} = \frac{x_2-x_1}{y_2-y_1} = \frac{1}{3.2\times10^{-5}} = 31.25\ k\Omega$

at $\mu_n = 1417\ cm^2/Vsec$,

$R = 4.4 k\Omega$ by graph & formula ($R = \frac{\Delta V}{\Delta I} = \frac{x_2-x_1}{y_2-y_1} = \frac{1}{0.000226} = 4.42\ k\Omega$)

So ~~that~~ Resistance has got increased by decreasing mobility from 1417 to 200 $cm^2/Vsec$.

(e) Draw energy band diagram in equilibrium (0V) and for 1V.

Ans

EBD for 0 Volt:

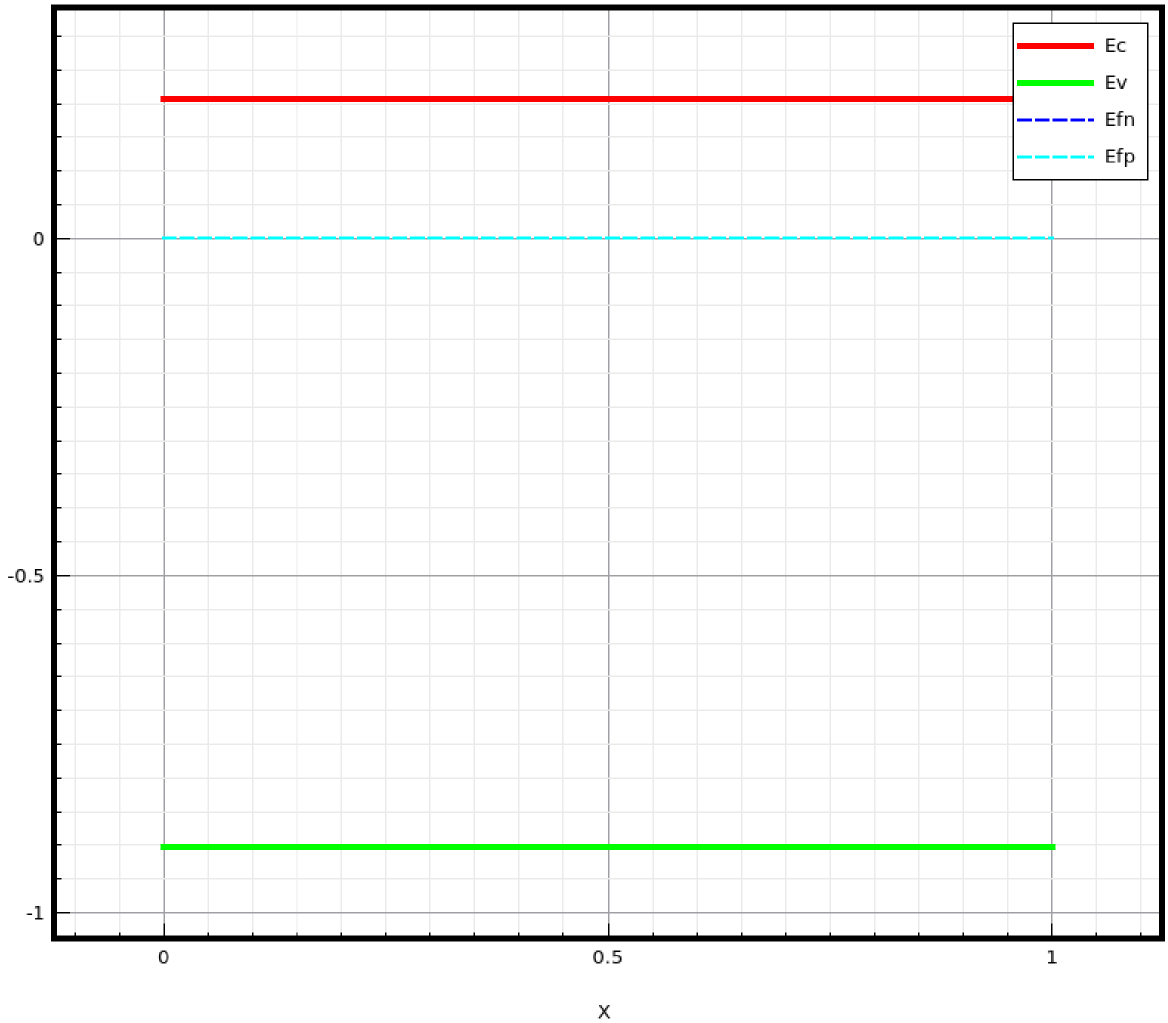
Cmd Code:

```
File{
  Grid      = "NNEW_msh.tdr"
   Plot    = "@tdrdat@"
  Current   = "@plot@"
  Output    = "@log@"
}

Electrode{
  { Name="A"    Voltage=0.0 }
```

```
  { Name="B"    Voltage=0.0 }
}

Physics{

  Fermi
  EffectiveIntrinsicDensity( OldSlotboom )




}

Plot{

  eDensity hDensity
  TotalCurrent/Vector eCurrent/Vector hCurrent/Vector
  eQuasiFermi hQuasiFermi
  eMobility hMobility

  ElectricField/Vector Potential SpaceCharge

  Doping DonorConcentration AcceptorConcentration

  BandGap
  ConductionBand ValenceBand
}

Math {
  Extrapolate
  RelErrControl
  Digits = 5
  Iterations= 20
  Notdamped= 100
  Method= Pardiso

}

Solve {
```

```
  Coupled(Iterations=100){ Poisson }
  Coupled{ Poisson Electron Hole }

  NewCurrentPrefix="IV_@node@"
  Quasistationary(
    InitialStep=1e-3 MinStep=1e-4 MaxStep=0.05
    Goal{ Name="A" Voltage= 0 }
  ) { Coupled { Poisson Electron Hole } }
}
```

Band Diagram of N type SC with doping of 1x1016 cm-3 at 0Volt



EBD at 1 Volt:

```
File{
  Grid     = "NNEW_msh.tdr"
```

```
   Plot     = "@tdrdat@"
  Current   = "@plot@"
  Output    = "@log@"
}

Electrode{
  { Name="A"    Voltage=0.0 }
  { Name="B"    Voltage=0.0 }
}

Physics{

  Fermi
  EffectiveIntrinsicDensity( OldSlotboom )



      }

Plot{

  eDensity hDensity
  TotalCurrent/Vector eCurrent/Vector hCurrent/Vector
  eQuasiFermi hQuasiFermi
  eMobility hMobility

  ElectricField/Vector Potential SpaceCharge

  Doping DonorConcentration AcceptorConcentration

  BandGap
  ConductionBand ValenceBand
}

Math {
  Extrapolate
  RelErrControl
  Digits = 5
  Iterations= 20
```

```
  Notdamped= 100
  Method= Pardiso

}

Solve {


  Coupled(Iterations=100){ Poisson }
  Coupled{ Poisson Electron Hole }

  NewCurrentPrefix="IV_@node@"
  Quasistationary(
    InitialStep=1e-3 MinStep=1e-4 MaxStep=0.05
    Goal{ Name="A" Voltage= 1 }
  ) { Coupled { Poisson Electron Hole } }
}
```

Band Diagram of N type SC of doping 1e16 at 1volt