Solutions to Exercise: Intrinsic Carrier Density

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Constants

In[44]:=
```
Nicm3 = 1.01 × 10^10 (* carriers per cm^3 *);
μe = 1400; μh = 480  (* cm^2/Vs *);
q = 1.6 × 10^-19 (* elementary charge in C *);
```

1. Carrier density in carriers per um^3

In[47]:=
```
Niμm3 = Nicm3 / (10^4)^3 (* divide by 10^4 (cm → μm) for each space dimension *)
```

Out[47]=
```
0.0101
```

2. Current in a 200 × 200 μm^2 pixel at a bias of 100V

In[48]:=
```
σ = q Nicm3 (μe + μh) (* Conductivity in As cm^-3 cm^2/Vs = S/cm *)
```

Out[48]=
```
3.03808 × 10^-6
```

In[49]:=
```
ρ = 1/σ 10^4 (* Resistivity in Ω μm *)
```

Out[49]=
```
3.29155 × 10^9
```

In[50]:=
```
R = ρ L/A /. {L → 300, A → 200^2} (* everything is in μm, result is in Ohm *)
```

Out[50]=
```
2.46866 × 10^7
```

In[51]:=
```
Curr = V/R /. V → 100 (* current result in in Ampere *)
```

Out[51]=
```
4.05077 × 10^-6
```

3. Electrons / holes per nanosecond ?

In[52]:=
```
Q = Curr 10^-9 (* just multiply with 1 ns. Result is in Coulomb *)
```

Out[52]=
```
4.05077 × 10^-15
```

In[53]:=
```
Neh = Q / q (* Convert Charge to number of electrons per ns *)
```

Out[53]=
```
25317.3
```

Additional: Temperature Dependence of Carrier Density

In[54]:=
```
Ni[TC_] = 9.39 × 10^19 ((TC + 273)/300)^2 Exp[-6884/(TC + 273)]
  (* Formula from Literature, temperature in Celsius *);
```

In[55]:=
```
{Ni[17], Ni[27]} (* Compare 17°C and 27°C *)
```

Out[55]=
```
{4.30494 × 10^9, 1.01638 × 10^10}
```

In[56]:=
```
Show[(*Plot the temperature dependence,
  also plot the same without the ()^2 term to show that it is small *)
 LogPlot[Ni[TC]/10^10 * {1, 1/((TC+273)/300)^2}, {TC, -40, 30},
  PlotRange → Automatic, Frame → True, GridLines → Automatic
  , PlotLabel → Style["Carrier Density / 10^10 vs. Temperature [C]",
    14, FontFamily → "Arial"]]
 , Graphics[{PointSize[Large], Red, Point[{27, Log[Ni[27]/10^10]}]}]
 (* Show a point at 27°C *)
]
```

Out[56]=