hw01

Dan White

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1 Book problem 2.6

In [1]:

```
phys_con = {
    'kB': 8.62e-5, # eV/K
    }

semi_con = {
    'Si':   {'Eg': 1.12, 'B': 1.08e31},
    'Ge':   {'Eg': 0.66, 'B': 2.31e30},
    'GaAs': {'Eg': 1.42, 'B': 1.27e29},
    }


def ni(T, semi='Si'):
    k = phys_con['kB']
    Eg = semi_con[semi]['Eg']
    B = semi_con[semi]['B']

    return sqrt(B * T**3 * exp(-Eg / (k * T)))
```

In [2]:

```
names = ('Temp K', 'n_Si', 'n_Ge')
fmt = '{:>10} ' * (len(names))

print '*** Intrinsic carrier densities, n=p (cm^-3)***'
print fmt.format(*names)
print fmt.format(*['-'*10]*len(names))

for temp in (77, 300, 500):
    n_Si = ni(temp, 'Si')
    n_Ge = ni(temp, 'Ge')

    print fmt.format(temp, '%.3e'%n_Si, '%.3e'%n_Ge)
```

```
*** Intrinsic carrier densities, n=p (cm^-3)***
    Temp K        n_Si        n_Ge
---------- ---------- ----------
        77  5.068e-19  2.625e-04
       300  6.725e+09  2.267e+13
       500  8.363e+13  8.036e+15
```

2 Book problem 2.7

Find the temperature at which the carrier density is as given. The first is 10^{13}, this will be somewhere around 500K according to the last problem. Therefore, give the function root solver an initial guess `x0` of 500. Pay attention to the output message to make sure the solver actually thinks it found a solution (converged), otherwise the output number is garbage.

In [3]:
```
from scipy.optimize import root

# we need a function which is zero at the requested density
def ni_solve(T, n_goal):
    return ni(T, 'Si') - n_goal
```

2.1 Part (a)

In [4]:
```
n = 1e13

out = root(ni_solve, args=n, x0=500)
print out
print
print 'Solution:'
print 'n = %.2e at %.3f K' % (n, out['x'][0])
```

```
  status: 1
 success: True
     qtf: array([-3181.13085938])
    nfev: 11
       r: array([ -3.76640856e+11])
     fun: array([-0.02539062])
       x: array([ 435.70424751])
 message: 'The solution converged.'
    fjac: array([[-1.]])

Solution:
n = 1.00e+13 at 435.704 K
```

2.2 Part (b)

In [5]:
```
n = 1e15

out = root(ni_solve, args=n, x0=500)
print out
print
print 'Solution:'
```

```
print 'n = %.2e at %.3f K' % (n, out['x'][0])
```

```
  status: 1
 success: True
     qtf: array([ 96245.5])
    nfev: 16
       r: array([ -2.04135098e+13])
     fun: array([ 0.625])
       x: array([ 602.06866113])
 message: 'The solution converged.'
    fjac: array([[-1.]])

Solution:
n = 1.00e+15 at 602.069 K
```

3 Thinking

Hspice, a commercial version of SPICE, uses a default temperature of 25°C Most other SPICE versions use a default temperature of 27°C. How does the intrinsic carrier density n_i of pure silicon change when the temperature is changed from 25 to 27°C? Report this as a percent change.

In [6]:

```
n25 = ni(25 + 272.15)   # temp in kelvin
n27 = ni(27 + 272.15)

print '25 C: %.2e' % n25
print '27 C: %.2e' % n27
print '%+.1f %% change' % ((n27 - n25) / n25 * 100)
```

```
25 C: 5.39e+09
27 C: 6.30e+09
+16.9 % change
```

In [6]:

```

```