Problem 1_d

```
import numpy as np
from matplotlib import pyplot as plt


t = np.arange(0, 17520)
S_0 = 1361
gamma = np.radians(23.5)
P = 17520
phi = np.radians(90)


x_dot_n = []

for i in t:
    lamb = (np.pi * (.5 * i - 12))/12
    delta = gamma * np.cos((2 * np.pi * i) / P)
    x_dot_n.append(max(S_0 * (np.cos(phi)*np.cos(lamb)*np.cos(delta) +
np.sin(phi)*np.sin(delta)), 0))

print len(x_dot_n)

plt.plot(t, x_dot_n, label = 'latitude = %s' % (np.degrees(phi)))
plt.legend()
plt.xlabel('Time (half-hours)')
plt.ylabel('Insolation (Watts/m^2)')
plt.title('Insolation over a Year at Various Latitudes')
```

Problem 2_a

```
import scipy
import numpy as np
from matplotlib import pyplot as plt

matdata = scipy.io.loadmat('HarvardForest.mat')
q_s = matdata['HarvardForest'][0, 0]['Solar_Rad'][0]

t = np.arange(0, 48*7)
year_data = q_s[:48*7]
```

```
plt.plot(t, year_data, label = 'Harvard Forest Data' )
plt.legend()
plt.xlabel('Time (half-hours)')
plt.ylabel('Insolation (Watts/m^2)')
plt.title('Insolation in a week in 1993 at the Harvard Forest')
```

Problem 2_b

```
import scipy
import numpy as np
from matplotlib import pyplot as plt

matdata = scipy.io.loadmat('HarvardForest.mat')
q_s = matdata['HarvardForest'][0, 0]['Solar_Rad'][0]

t = np.arange(0, 17520)
S_0 = 1361
gamma = np.radians(23.5)
P = 17520
phi = np.radians(42.5)


x_dot_n = []
shift = np.radians((194.5/365) * 360)

for i in t:
    lamb = (np.pi * (.5 * i - 12))/12
    delta = gamma * np.cos((2 * np.pi * i) / P)
    x_dot_n.append(max(S_0 * (np.cos(phi)*np.cos(lamb + shift)*np.cos(delta + shift) +
np.sin(phi)*np.sin(delta + shift)), 0))

year_data = q_s[:(17520)]

plt.scatter(x_dot_n, year_data)
plt.xlabel('Theoretical I')
plt.ylabel('Harvard Forest Data')
plt.title('Comparison of Theoretical and Observed Insolation at the Harvard Forest')
plt.gca().set_xlim(left=0)
plt.gca().set_ylim(bottom=0)
```

Problem 2_c

```
import numpy as np
import scipy.io.wavfile as siw
import scipy

matdata = scipy.io.loadmat('HarvardForest.mat')
q_s = matdata['HarvardForest'][0, 0]['Solar_Rad'][0]

t = np.arange(0, 17520)
S_0 = 1361
gamma = np.radians(23.5)
P = 17520
phi = np.radians(42.5)

x_dot_n = []
shift = np.radians((194.5/365) * 360)

for i in t:
    lamb = (np.pi * (.5 * i - 12))/12
    delta = gamma * np.cos((2 * np.pi * i) / P)
    x_dot_n.append(max(S_0 * (np.cos(phi)*np.cos(lamb + shift)*np.cos(delta + shift) +
np.sin(phi)*np.sin(delta + shift)), 0))


year_data = q_s[:(17520)]

'''
maxx = max(year_data)
minx = min(year_data)

sound_dat = []

for i in xrange(0, len(year_data)-1):
    x = year_data[i]
    newx = 2*((x - minx)/(maxx - minx)) - 1
    sound_dat.append(float(newx))

siw.write('forest.wav', 8192, np.array(sound_dat))

'''

sound_dat = []
```

```
maxx = max(x_dot_n)
minx = min(x_dot_n)

for i in xrange(0, len(x_dot_n)-1):
    x = x_dot_n[i]
    newx = 2*((x - minx)/(maxx - minx)) - 1
    sound_dat.append(float(newx))


siw.write('theoretical.wav', 8192, np.array(sound_dat))
```