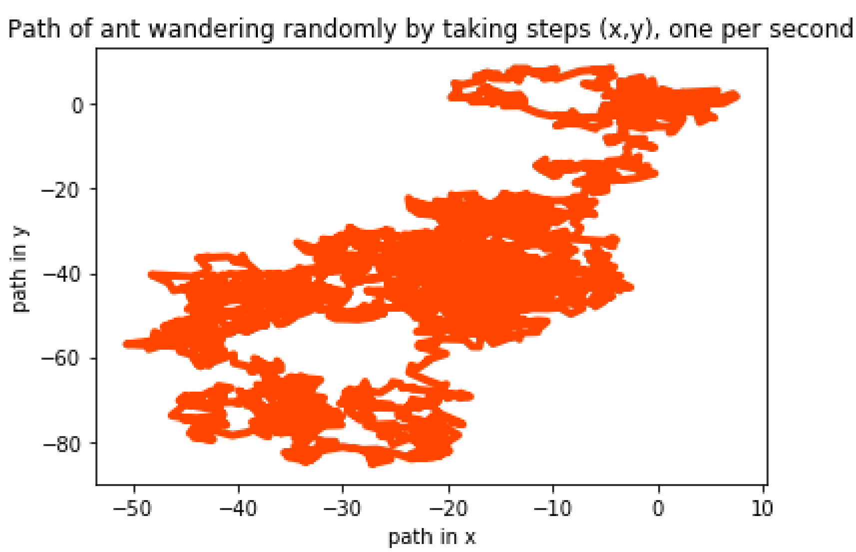
1a

In [2]:

```
import matplotlib.pyplot as plt
import numpy as np
import random

def path_finder(time_in_s, initial_x=0, initial_y=0):

    curr_pos_x = initial_x
    curr_pos_y = initial_y

    global path_x
    global path_y
    path_x = [curr_pos_x]
    path_y = [curr_pos_y]

    for n in range(0, time_in_s):
        curr_pos_x = curr_pos_x + np.random.normal()
        curr_pos_y = curr_pos_y + np.random.normal()
        path_x.append(curr_pos_x)
        path_y.append(curr_pos_y)

path_finder(3600)

x = path_x
y = path_y

fig = plt.figure()
ax = plt.axes()

#plt.axis([-50, 50, -50, 50])
plt.plot(x, y, color='orangered', linewidth=4)
plt.xlabel('path in x')
plt.ylabel('path in y')
plt.title('Path of ant wandering randomly by taking steps (x,y), one per second')
#plt.scatter(x, y, color='orange', marker='^')
#ax.xaxis.set(ticks=range(0,21),)
plt.savefig('foo.png')
plt.show()
```



1b

In [9]:
```python
import matplotlib.pyplot as plt
import numpy as np
import random
from math import sqrt


def path_finder(time_in_s, initial_x=0, initial_y=0):
    curr_pos_x = initial_x
    curr_pos_y = initial_y

    global path_x
    global path_y
    path_x = [curr_pos_x]
    path_y = [curr_pos_y]

    for n in range(0, time_in_s):
        curr_pos_x = curr_pos_x + np.random.normal()
        curr_pos_y = curr_pos_y + np.random.normal()
        path_x.append(curr_pos_x)
        path_y.append(curr_pos_y)





def nest_finder(time_in_s, nest_dist, nest_pos_x=0, nest_pos_y=0):
    path_finder(time_in_s)

    food_pos_x = path_x[-1]
    food_pos_y = path_y[-1]

    curr_pos_x = food_pos_x
    curr_pos_y = food_pos_y

    found_nest = False

    for n in range(0, time_in_s):
        curr_pos_x = curr_pos_x + np.random.normal()
        curr_pos_y = curr_pos_y + np.random.normal()
        dist_from_nest = sqrt(curr_pos_x ** 2 + curr_pos_y ** 2)

        if dist_from_nest <= nest_dist:
            found_nest = True
            break

    if found_nest:
        return True

    return False


def prob_finder(time_in_s, num_trials, nest_dist):
    found = 0
    n = 0
    while n < num_trials:
        if nest_finder(time_in_s, nest_dist) == True:
```

```
            found += 1
        n += 1
    return found / num_trials


prob = prob_finder(3600, 1000, 10)
print(prob)
```

0.219

In [4]:
```
### The probability I get is 0.2x with 1000 trials. Obviously, this is not a good strategy because the ant is solely relying on a random steps to find its way back to its nest. With 1000 trials, the probablility of finding the nest is 0.2, which is certainly not a good number. Close to 80% of the time, the ant will end up wandering around unable to find its way back to the nest, therefore, this is not a good strategy.
```

1c

In [10]:
```python
def avg_closest(time_in_s, nest_pos_x=0, nest_pos_y=0):

    path_finder(time_in_s)

    food_pos_x = path_x[-1]
    food_pos_y = path_y[-1]

    curr_pos_x = food_pos_x
    curr_pos_y = food_pos_y

    closest_dist = sqrt(food_pos_x ** 2 + food_pos_y ** 2)

    for n in range(0, time_in_s):
        curr_pos_x = curr_pos_x + np.random.normal()
        curr_pos_y = curr_pos_y + np.random.normal()

        curr_dist = sqrt(curr_pos_x ** 2 + curr_pos_y ** 2)

        if curr_dist < closest_dist:
            closest_dist = curr_dist

    return closest_dist

def prob_finder(time_in_s, num_trials):

    n = 0
    closest_dist_sum = 0

    while n < num_trials:

        closest_dist_sum += avg_closest(time_in_s)
        n += 1
    return closest_dist_sum / num_trials

closest_avg = prob_finder(3600, 1000)
print(closest_avg)
```

```
47.558947560537014
```

In [6]:
```python
### Average closest distance would be 45 based on 1000 trial runs.
```

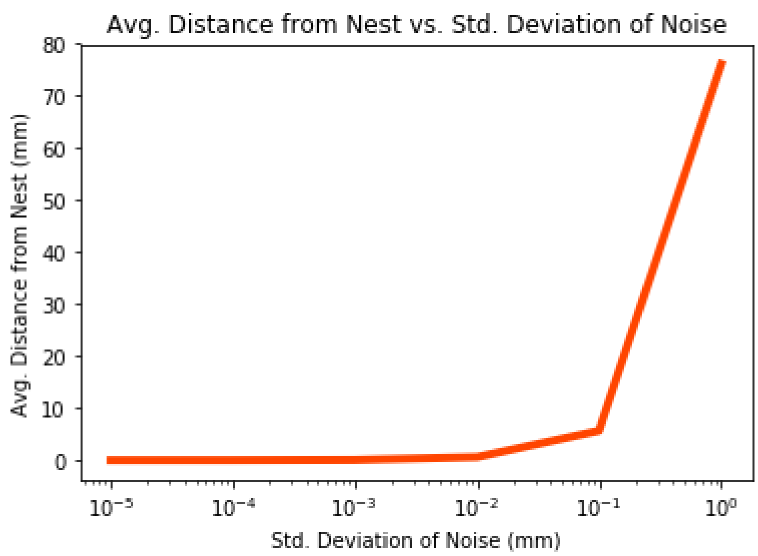
2

In [11]:

```python
import matplotlib.pyplot as plt
import numpy as np
import random
from math import sqrt

def memory_vector_finder(time_in_s, std_dev, initial_x=0, initial_y=0):
    curr_pos_x = initial_x
    curr_pos_y = initial_y
    memory_x = initial_x
    memory_y = initial_y

    for n in range(0, time_in_s):

        x_step = np.random.normal()
        y_step = np.random.normal()
        curr_pos_x = curr_pos_x + x_step
        curr_pos_y = curr_pos_y + y_step
        memory_x =  (memory_x + x_step + np.random.normal(scale=std_dev
))
        memory_y =  (memory_y + y_step + np.random.normal(scale=std_dev
))

    dist_x = curr_pos_x - memory_x
    dist_y = curr_pos_y - memory_y
    dist = sqrt(dist_x**2 + dist_y**2)
    return dist

def avg_distance_finder(time_in_s, std_dev, num_trials):
    memory_vector_sum = 0
    for n in range(0, num_trials):
        memory_vector_sum += memory_vector_finder(time_in_s, std_dev)
    return memory_vector_sum / num_trials

t_1 = avg_distance_finder(3600, 1, 10)
t_2 = avg_distance_finder(3600, 0.1, 10)
t_3 = avg_distance_finder(3600, 0.01, 10)
t_4 = avg_distance_finder(3600, 0.001, 10)
t_5 = avg_distance_finder(3600, 0.0001, 10)
t_6 = avg_distance_finder(3600, 0.00001, 10)


print(t_1)
print(t_2)
print(t_3)
print(t_4)
print(t_5)
print(t_6)

y = [t_6, t_5, t_4, t_3, t_2, t_1]
x = [0.00001, 0.0001, 0.001, 0.01, 0.1, 1]

#y = y[::-1]
#x = x[::-1]

fig = plt.figure()
ax = plt.axes()
```

```
ax.set_xscale('log')

plt.plot(x, y, color='orangered', linewidth=4)
plt.xlabel('Std. Deviation of Noise (mm)')
plt.ylabel('Avg. Distance from Nest (mm)')
plt.title('Avg. Distance from Nest vs. Std. Deviation of Noise')
plt.savefig('foo.png')
plt.show()
```

```
76.04009028314289
5.655185290515554
0.6183116161855854
0.06224101096903323
0.007462066447808923
0.0007538861241587004
```



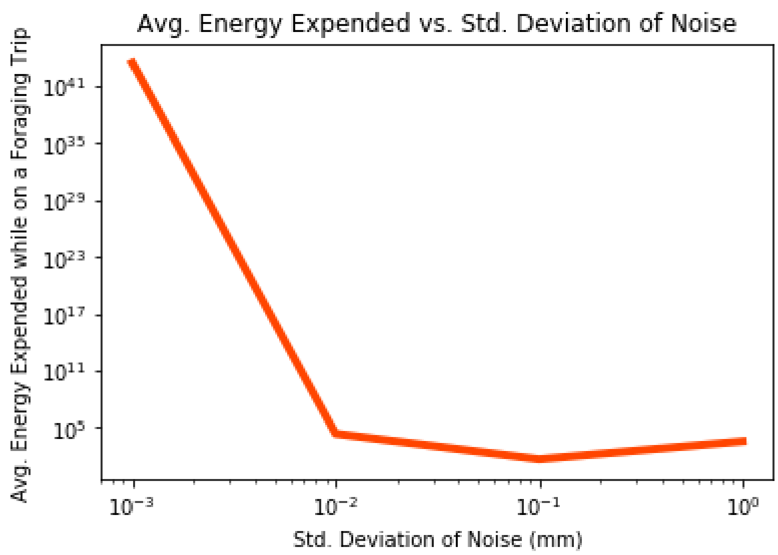
3a

In [12]:

```
import matplotlib.pyplot as plt
import numpy as np
import random
from math import sqrt

def memory_vector_finder(time_in_s, std_dev, initial_x=0, initial_y=0):
    curr_pos_x = initial_x
    curr_pos_y = initial_y
    memory_x = initial_x
    memory_y = initial_y

    for n in range(0, time_in_s):

        x_step = np.random.normal()
        y_step = np.random.normal()
        curr_pos_x = curr_pos_x + x_step
        curr_pos_y = curr_pos_y + y_step
        memory_x =  (memory_x + x_step + np.random.normal(scale=std_dev
))
        memory_y =  (memory_y + y_step + np.random.normal(scale=std_dev
))

    dist_x = curr_pos_x - memory_x
    dist_y = curr_pos_y - memory_y
    dist = sqrt(dist_x**2 + dist_y**2)
    return dist

def avg_distance_finder(time_in_s, std_dev, num_trials):
    memory_vector_sum = 0
    for n in range(0, num_trials):
        memory_vector_sum += memory_vector_finder(time_in_s, std_dev)
    return memory_vector_sum / num_trials

t_1 = avg_distance_finder(3600, 1, 10)
t_2 = avg_distance_finder(3600, 0.1, 10)
t_3 = avg_distance_finder(3600, 0.01, 10)
t_4 = avg_distance_finder(3600, 0.001, 10)
t_5 = avg_distance_finder(3600, 0.0001, 10)
t_6 = avg_distance_finder(3600, 0.00001, 10)

t1_std = (t_1, 1)
t2_std = (t_2, 0.1)
t3_std = (t_3, 0.01)
t4_std = (t_4, 0.001)
t5_std = (t_5, 0.0001)
t6_std = (t_6, 0.00001)

def energy_finder(t_std_dev):
    return (np.exp(0.1 / t_std_dev[1]) + (t_std_dev[0] ** 2))

e1 = energy_finder(t1_std)
e2 = energy_finder(t2_std)
e3 = energy_finder(t3_std)
e4 = energy_finder(t4_std)
e5 = energy_finder(t5_std)
e6 = energy_finder(t6_std)
```

```
y = [e1, e2, e3, e4, e5, e6]
x = [1, 0.1, 0.01, 0.001, 0.0001, 0.00001]
#y.reverse()
#x.reverse()

fig = plt.figure()
ax = plt.axes()
ax.set_xscale('log')
ax.set_yscale('log')

plt.plot(x, y, color='orangered', linewidth=4)
plt.xlabel('Std. Deviation of Noise (mm)')
plt.ylabel('Avg. Energy Expended while on a Foraging Trip')
plt.title('Avg. Energy Expended vs. Std. Deviation of Noise')
plt.savefig('foo.png')
plt.show()
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-pa
ckages/ipykernel_launcher.py:47: RuntimeWarning: overflow encountered i
n exp
```



3b

In [ ]:

```
### The minimum energy is spent when the std. deviation is 0.1. From the
 evolutionary point of view, it makes perfect sense for ants to adapt to
 0.1 std to spend least amount of energy because this is the point where
 there is optimal balance between the avg closest distance from a nest a
nts end up at & the energy spent. If I compare the graph from 2 and 3a,
 when std=1.0, the distance from nest is significantly larger than when
 std=1.0 and energy expenditure is also farily larger, so it is unfeasib
le for an ant to have evolved to adapt to std=1.0. When std=0.01, there
 is tiny gain to reduce distance from distance, but its advantage is ver
y minimal compared to the significantly larger energy expenditure. There
fore, std of 0.1 is the perfect number for an ant to have evolved to ada
pt to balance the energy and the probabiltiy of finding the food and fin
ding its way back to the nest.
```