PHYS 304 HW2 Xiyue Shen

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Required (graded) Exercises
All Python scripts are located in the same folder. Check the script for specific lines.

1. **Exercise 2.2: Altitude of a satellite**

   (a) For a satellite with mass m orbiting around the Earth with mass M, the motion can be described as a circular motion. The centripetal force is,

   $$F_c = \frac{mv^2}{r} \tag{1}$$

   where v is the tangential velocity, and r is the radius. We can write r as $R+h$, where R is the earth's radius, and h is the satellite altitude. The source of the centripetal force comes from the gravity of the earth. As Newton described, the gravitational force is,

   $$F_g = G\frac{Mm}{r^2} \tag{2}$$

   where the r is the same distance in equation 1.G is the gravitational constant, $6.674 \times 10^{-11} m^3 kg^{-1} s^{-2}$.
   Let $F_g = F_c$, then we have,

   $$G\frac{Mm}{r^2} = \frac{mv^2}{r}$$
   $$v = \sqrt{\frac{GM}{r}} \tag{3}$$

   We have $v = \frac{2\pi r}{T}$ as defined. Then, we can substitute the velocity term in equation 3 so that we can derive a relation in between period and altitude.

$$
\begin{aligned}
\frac{2\pi r}{T} &= \sqrt{\frac{GM}{r}} \\
r &= (\frac{GMT^2}{4\pi^2})^{1/3} \\
h + R &= (\frac{GMT^2}{4\pi^2})^{1/3} \\
h &= (\frac{GMT^2}{4\pi^2})^{1/3} - R \qquad (4)
\end{aligned}
$$

From the second line, r was substituted by $h + R$. Equation 4 is what's given in part a.

(b) Figure 1 shows my script. Here, I import all the necessary packages. Then, I assign several constants. "height" is the equation part a gives. Through "rcParams", we import LaTex font for plotting.

```
#Exercise 2.2 part b
import matplotlib.pyplot as plt
import numpy as np
plt.rcParams['text.usetex'] = True
plt.rcParams['text.latex.preamble'] = r'\usepackage{bm}'
plt.rcParams['pgf.texsystem'] = 'pdflatex'  # or 'latex'

T=input("what period T you would like to?")
T=float(T)
G=6.67e-11
M=5.97e24
R=6.371e6
pi=np.pi
height=(G*M*T**2/(4*pi**2))**(1/3)-R
print("the altitude of the satellite is", height)
```

Figure 1: Programming for calculating the height given a period

(c) For one day (86400 seconds), the altitude is 35855910.176174976 meters; for 90 minutes (5400 seconds), the altitude is 279321.6253728606 meters; for 45 minutes (2700 seconds), the altitude is -2181559.8978108233 meters, as indicated by figure 2.

(d) For a sidereal day, as the code indicates, I calculated the heights for $Ta = 24$ hours and $Tb = 23.93$ hours. Then, I subtracted the heights ha and hb to get the difference. The discrepancy is 82147.84627933055 meters, as shown by figure 3

2. **Exercise 2.5: Quantum potential step**

Firstly, I input several parameters used as constants, such as electron mass m, Planck constant h, and the joules and electron-volt converting constant j.

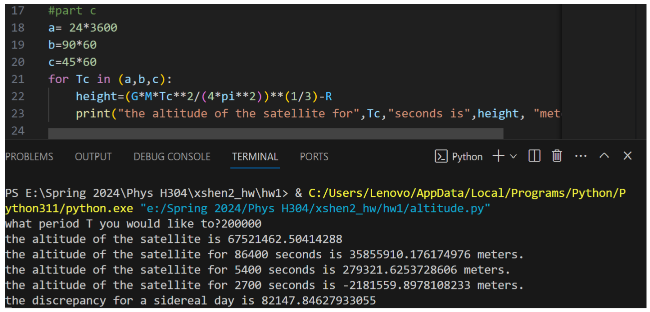


Figure 2: Attached is my code and result after running.

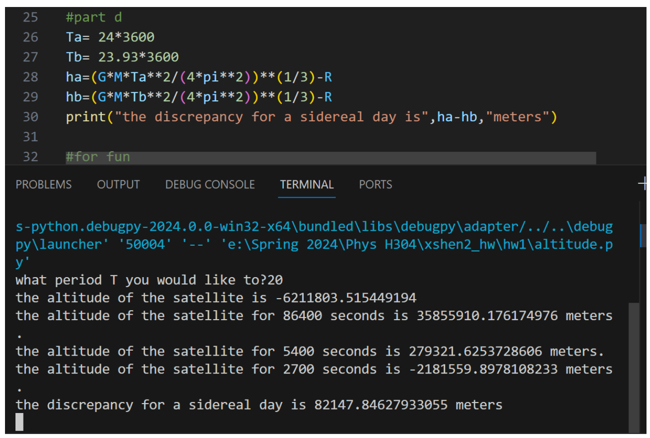


Figure 3: Height difference of a sidereal day.

Then, I assign values to energy E and potential V. k_1 and k_2 are equations given for wavevectors. T and R are the probability for transmission and reflection.

After all equations and constants are set, I print out the probabilities. For transmission probability, I get 0.730; for reflection probability, I get 0.270 as shown in figure 4.

3. **Exercise 3.3: STM density plot**

   Coding structure: Firstly, I import all packages that I need, such as "numpy", "matplotlib", and some LaTex rendering. After downloading the data and saving it in the same folder as my python script, I use "loadtxt" to read and get the data. Then, I use inshow to plot the data. I got three different plots with gray, rainbow, and Viridis color bars. To make the color contrast more obvious, I set vmin and vmax values, which employ the extremes in the data to make the color distribution.

   Figure 5d is a $3D$ plot, which shows the height distribution more obviously.

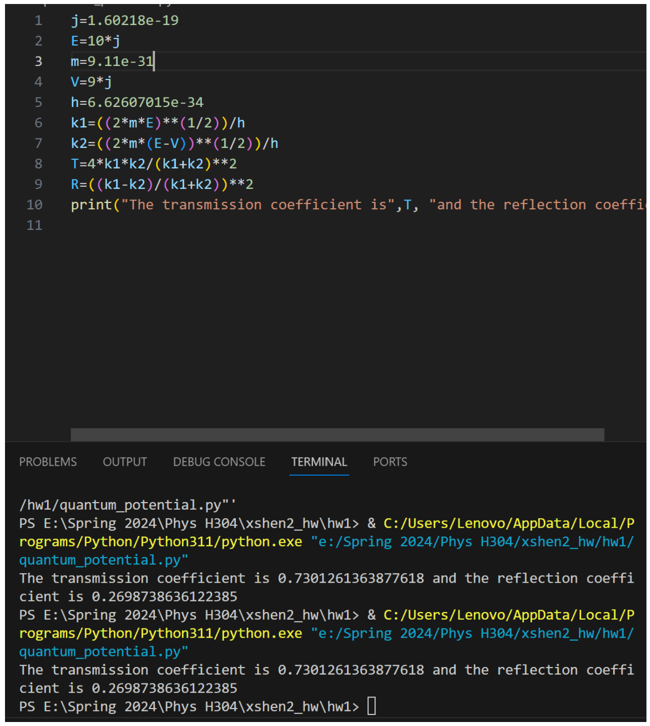


Figure 4: Quantum potential probability code

4. **Exercise 3.2: Curve plotting**

   I assigned θ with evenly distributed values using "linspace". Then, set x and y as functions of θ given in the problem.

   (a) We have $x = 2\cos(\theta) + \cos(2\theta)$ and $y = 2\sin(\theta)\sin(2\theta)$

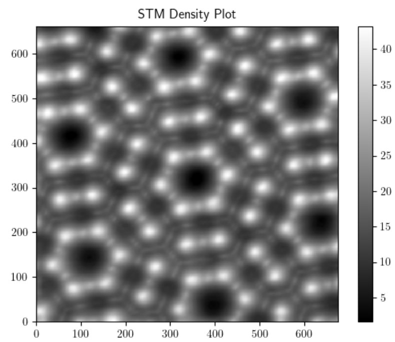
   (b) We have $r = \theta^2$; then, $x = \theta^2\cos(\theta)$ and $y = \theta^2\sin(\theta)$. In the coding, I used ϕ instead of θ to avoid confusion with part a.

   (c) We have $r = e^{cos\theta} - 2\cos(4\theta) + \sin^5(\frac{\theta}{12})$; then, $x = [e^{cos\theta} - 2\cos(4\theta) + \sin^5(\frac{\theta}{12})]\cos(\theta)$ and $y = [e^{cos\theta} - 2\cos(4\theta) + \sin^5(\frac{\theta}{12})]\sin(\theta)$. I used α instead of θ to avoid confusion with part a in the coding.

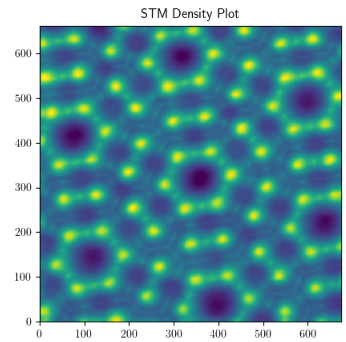
Survey Questions

I spent roughly 3 hours on this week's homework, but I spent another 3 hours figuring out how to apply LaTex rendering and adding the path to the terminal. I learned to make plots, define equations, arrange, linspace, etc. I think the problem set is about the right length.

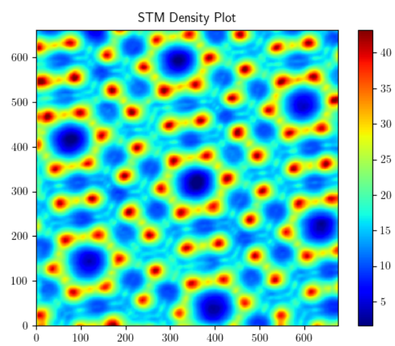
Required (ungraded) work



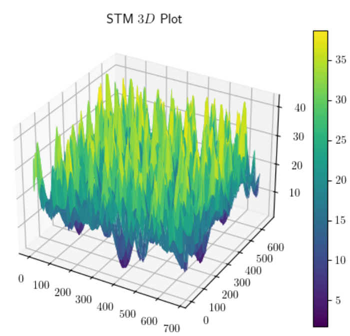
(a) STM plot in gray colorbar



(b) STM plot in Viridis colorbar



(c) STM plot in Rainbow colorbar



(d) 3D STM Plot

Figure 5: STM Density Plot

- I have downloaded the repository
- I followed along with class notes and understood every code
- I tried some examples.

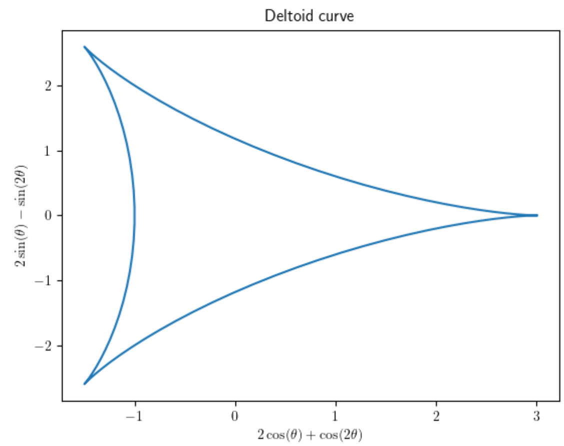


Figure 6: Deltoid curve

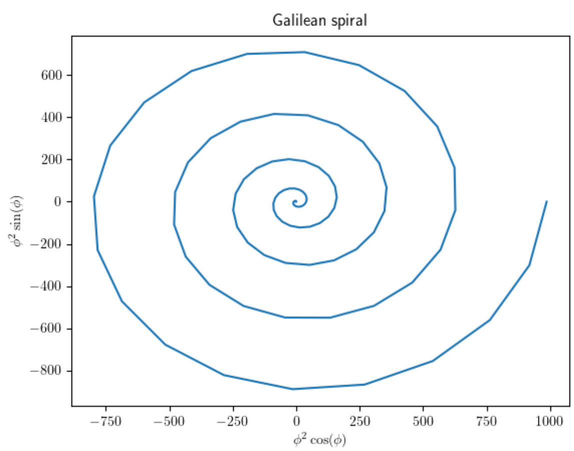


Figure 7: Galilean spiral

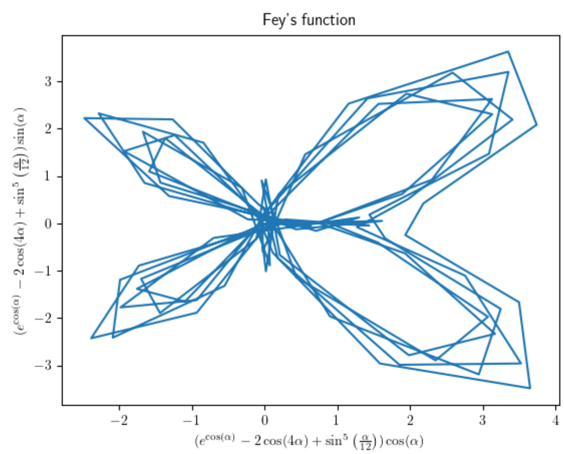


Figure 8: Fey's function