

Exercise 1

Enter the height of the tower (in m) : 100

The time that the ball takes to reach the ground is (in sec) : 4.516

Exercise 2

1 day (86400 sec) : The altitude of the satellite is 35862994.1977 meters
90 minutes (5400 sec) : The altitude of the satellite is 274455.4688 meters
45 minutes (2700 sec) : This time period is not physically possible!

Thus the trend that we observe here is time period increases with height and there exists a lower bound on T_{\min} such that values of $T < T_{\min}$ are not physically realisable as it implies that h is negative which is against our initial assumption. Thus 45 minutes is one such example of $T < T_{\min}$

The sidereal day is the time required for the Earth to rotate once relative to the background of the stars (which remains fixed) i.e., the time between two observed passages of a star over the same meridian of longitude. This is 23.94 hours long. However a solar day is when the Earth completes one full rotation with respect to Sun, but it is longer than sidereal day as the Earth also revolves around the Sun so we have to consider the extra rotation for the Earth to reach the initial position. This is 24 hours long. Hence a sidereal day is the true time period of rotation of the Earth

1 sidereal day (86184 sec) : The altitude of the satellite is 35792563.0073 meters
1 solar day (86400 sec) : The altitude of the satellite is 35862994.1977 meters

Thus there is a difference of 70,431.1904 meters

Hence a geosynchronous satellite is placed at a height of 35792563.0073 meters

Exercise 4

Enter the value of distance in light years:10

Enter the value of speed as a fraction of the speed of light c :0.99

Time observed by an observer at rest on Earth is 10.1010 years

Time observed by an observer on ship is 1.4249 years

Exercise 5

For the given Energy and Step potential the transmission probability is 0.73013 and the reflection probability is 0.26987

Exercise 6

Earth:

Enter the perihelion distance (in m): $1.471\text{e}+11$

Enter the perihelion velocity at perihelion (in m/s): $3.0287\text{e}+4$

The Aphelion distance: 152111350728.5926 m

The Aphelion velocity: 29289.1864 m/s

The Orbital period: 1.0001 year

The Eccentricity: 0.0167

Halley's Comet:

Enter the perihelion distance (in m): $8.783\text{e}+10$

Enter the perihelion velocity at perihelion (in m/s): $5.4529\text{e}+4$

The Aphelion distance: 5371566481143.3535 m

The Aphelion velocity: 891.5988 m/s

The Orbital period: 77.9457 year

The Eccentricity: 0.9678

Exercise 7

1
2.0
5.0
14.0
42.0
132.0
429.0
1430.0
4862.0
16796.0
58786.0
208012.0
742900.0
2674440.0
9694845.0
35357670.0
129644790.0
477638700.0

Exercise 8

Computed value:

The value of Madelung constant for NaCl is: -1.7418198158396654

Literature value of Madelung constant for NaCl: ± 1.747565

Exercise 9

Enter the Atomic Number: 28

Enter the Mass Number: 58

The binding energy of an atom with $A = 58.0$ and $Z = 28$ is
493.93560680136824 MeV

The binding energy per nucleon of an atom with $A = 58.0$ and $Z = 28$ is
8.516131151747729 MeV

The most stable mass number for $Z = 28$ is $A = 58$ and the corresponding
binding energy per nucleon is 8.51613 MeV

The maximum binding energy per nucleon for $Z = 1$ is -2.5457 with
corresponding $A = 2$

The maximum binding energy per nucleon for $Z = 2$ is 5.8433 with
corresponding $A = 4$

The maximum binding energy per nucleon for $Z = 3$ is 4.7524 with
corresponding $A = 6$

The maximum binding energy per nucleon for $Z = 4$ is 6.8353 with
corresponding $A = 8$

The maximum binding energy per nucleon for $Z = 5$ is 6.4228 with
corresponding $A = 10$

The maximum binding energy per nucleon for $Z = 6$ is 7.4500 with
corresponding $A = 12$

The maximum binding energy per nucleon for $Z = 7$ is 7.2759 with
corresponding $A = 15$

The maximum binding energy per nucleon for $Z = 8$ is 7.8292 with
corresponding $A = 16$

The maximum binding energy per nucleon for $Z = 9$ is 7.7565 with
corresponding $A = 19$

The maximum binding energy per nucleon for $Z = 10$ is 8.0751 with
corresponding $A = 20$

The maximum binding energy per nucleon for $Z = 11$ is 8.0477 with
corresponding $A = 23$

The maximum binding energy per nucleon for $Z = 12$ is 8.2387 with
corresponding $A = 24$

The maximum binding energy per nucleon for $Z = 13$ is 8.2340 with
corresponding $A = 27$

The maximum binding energy per nucleon for $Z = 14$ is 8.3479 with
corresponding $A = 28$

The maximum binding energy per nucleon for $Z = 15$ is 8.3553 with
corresponding $A = 31$

The maximum binding energy per nucleon for $Z = 16$ is 8.4193 with
corresponding $A = 32$

The maximum binding energy per nucleon for $Z = 17$ is 8.4333 with
corresponding $A = 35$

The maximum binding energy per nucleon for $Z = 18$ is 8.4631 with
corresponding $A = 36$

The maximum binding energy per nucleon for $Z = 19$ is 8.4808 with
corresponding $A = 39$

The maximum binding energy per nucleon for $Z = 20$ is 8.4958 with
corresponding $A = 41$

The maximum binding energy per nucleon for $Z = 21$ is 8.5060 with
corresponding $A = 43$

The maximum binding energy per nucleon for $Z = 22$ is 8.5211 with
corresponding $A = 46$

The maximum binding energy per nucleon for $Z = 23$ is 8.5143 with
corresponding $A = 47$

The maximum binding energy per nucleon for $Z = 24$ is 8.5326 with
corresponding $A = 50$

The maximum binding energy per nucleon for $Z = 25$ is 8.5095 with
corresponding $A = 51$

The maximum binding energy per nucleon for $Z = 26$ is 8.5299 with corresponding $A = 54$
The maximum binding energy per nucleon for $Z = 27$ is 8.4945 with corresponding $A = 55$
The maximum binding energy per nucleon for $Z = 28$ is 8.5161 with corresponding $A = 58$
The maximum binding energy per nucleon for $Z = 29$ is 8.4712 with corresponding $A = 59$
The maximum binding energy per nucleon for $Z = 30$ is 8.4935 with corresponding $A = 62$
The maximum binding energy per nucleon for $Z = 31$ is 8.4412 with corresponding $A = 63$
The maximum binding energy per nucleon for $Z = 32$ is 8.4639 with corresponding $A = 66$
The maximum binding energy per nucleon for $Z = 33$ is 8.4070 with corresponding $A = 69$
The maximum binding energy per nucleon for $Z = 34$ is 8.4284 with corresponding $A = 70$
The maximum binding energy per nucleon for $Z = 35$ is 8.3785 with corresponding $A = 73$
The maximum binding energy per nucleon for $Z = 36$ is 8.3881 with corresponding $A = 74$
The maximum binding energy per nucleon for $Z = 37$ is 8.3442 with corresponding $A = 77$
The maximum binding energy per nucleon for $Z = 38$ is 8.3439 with corresponding $A = 78$
The maximum binding energy per nucleon for $Z = 39$ is 8.3050 with corresponding $A = 81$
The maximum binding energy per nucleon for $Z = 40$ is 8.2963 with corresponding $A = 82$
The maximum binding energy per nucleon for $Z = 41$ is 8.2618 with corresponding $A = 85$
The maximum binding energy per nucleon for $Z = 42$ is 8.2459 with corresponding $A = 86$
The maximum binding energy per nucleon for $Z = 43$ is 8.2151 with corresponding $A = 89$
The maximum binding energy per nucleon for $Z = 44$ is 8.1946 with corresponding $A = 92$
The maximum binding energy per nucleon for $Z = 45$ is 8.1656 with corresponding $A = 93$
The maximum binding energy per nucleon for $Z = 46$ is 8.1477 with corresponding $A = 96$
The maximum binding energy per nucleon for $Z = 47$ is 8.1136 with corresponding $A = 97$
The maximum binding energy per nucleon for $Z = 48$ is 8.0979 with corresponding $A = 100$
The maximum binding energy per nucleon for $Z = 49$ is 8.0595 with corresponding $A = 101$
The maximum binding energy per nucleon for $Z = 50$ is 8.0458 with corresponding $A = 104$
The maximum binding energy per nucleon for $Z = 51$ is 8.0036 with corresponding $A = 105$
The maximum binding energy per nucleon for $Z = 52$ is 7.9917 with corresponding $A = 108$
The maximum binding energy per nucleon for $Z = 53$ is 7.9465 with corresponding $A = 111$
The maximum binding energy per nucleon for $Z = 54$ is 7.9358 with corresponding $A = 112$
The maximum binding energy per nucleon for $Z = 55$ is 7.8938 with corresponding $A = 115$

The maximum binding energy per nucleon for $Z = 56$ is 7.8784 with corresponding $A = 116$
The maximum binding energy per nucleon for $Z = 57$ is 7.8394 with corresponding $A = 119$
The maximum binding energy per nucleon for $Z = 58$ is 7.8198 with corresponding $A = 120$
The maximum binding energy per nucleon for $Z = 59$ is 7.7834 with corresponding $A = 123$
The maximum binding energy per nucleon for $Z = 60$ is 7.7600 with corresponding $A = 124$
The maximum binding energy per nucleon for $Z = 61$ is 7.7260 with corresponding $A = 127$
The maximum binding energy per nucleon for $Z = 62$ is 7.7005 with corresponding $A = 130$
The maximum binding energy per nucleon for $Z = 63$ is 7.6675 with corresponding $A = 131$
The maximum binding energy per nucleon for $Z = 64$ is 7.6438 with corresponding $A = 134$
The maximum binding energy per nucleon for $Z = 65$ is 7.6079 with corresponding $A = 135$
The maximum binding energy per nucleon for $Z = 66$ is 7.5858 with corresponding $A = 138$
The maximum binding energy per nucleon for $Z = 67$ is 7.5474 with corresponding $A = 139$
The maximum binding energy per nucleon for $Z = 68$ is 7.5269 with corresponding $A = 142$
The maximum binding energy per nucleon for $Z = 69$ is 7.4861 with corresponding $A = 143$
The maximum binding energy per nucleon for $Z = 70$ is 7.4670 with corresponding $A = 146$
The maximum binding energy per nucleon for $Z = 71$ is 7.4280 with corresponding $A = 149$
The maximum binding energy per nucleon for $Z = 72$ is 7.4063 with corresponding $A = 150$
The maximum binding energy per nucleon for $Z = 73$ is 7.3693 with corresponding $A = 153$
The maximum binding energy per nucleon for $Z = 74$ is 7.3449 with corresponding $A = 154$
The maximum binding energy per nucleon for $Z = 75$ is 7.3098 with corresponding $A = 157$
The maximum binding energy per nucleon for $Z = 76$ is 7.2829 with corresponding $A = 158$
The maximum binding energy per nucleon for $Z = 77$ is 7.2496 with corresponding $A = 161$
The maximum binding energy per nucleon for $Z = 78$ is 7.2231 with corresponding $A = 164$
The maximum binding energy per nucleon for $Z = 79$ is 7.1887 with corresponding $A = 165$
The maximum binding energy per nucleon for $Z = 80$ is 7.1636 with corresponding $A = 168$
The maximum binding energy per nucleon for $Z = 81$ is 7.1273 with corresponding $A = 169$
The maximum binding energy per nucleon for $Z = 82$ is 7.1034 with corresponding $A = 172$
The maximum binding energy per nucleon for $Z = 83$ is 7.0653 with corresponding $A = 173$
The maximum binding energy per nucleon for $Z = 84$ is 7.0426 with corresponding $A = 176$
The maximum binding energy per nucleon for $Z = 85$ is 7.0056 with corresponding $A = 179$

The maximum binding energy per nucleon for $Z = 86$ is 6.9813 with corresponding $A = 180$
The maximum binding energy per nucleon for $Z = 87$ is 6.9459 with corresponding $A = 183$
The maximum binding energy per nucleon for $Z = 88$ is 6.9196 with corresponding $A = 184$
The maximum binding energy per nucleon for $Z = 89$ is 6.8856 with corresponding $A = 187$
The maximum binding energy per nucleon for $Z = 90$ is 6.8576 with corresponding $A = 190$
The maximum binding energy per nucleon for $Z = 91$ is 6.8249 with corresponding $A = 191$
The maximum binding energy per nucleon for $Z = 92$ is 6.7980 with corresponding $A = 194$
The maximum binding energy per nucleon for $Z = 93$ is 6.7637 with corresponding $A = 195$
The maximum binding energy per nucleon for $Z = 94$ is 6.7380 with corresponding $A = 198$
The maximum binding energy per nucleon for $Z = 95$ is 6.7021 with corresponding $A = 199$
The maximum binding energy per nucleon for $Z = 96$ is 6.6774 with corresponding $A = 202$
The maximum binding energy per nucleon for $Z = 97$ is 6.6415 with corresponding $A = 205$
The maximum binding energy per nucleon for $Z = 98$ is 6.6165 with corresponding $A = 206$
The maximum binding energy per nucleon for $Z = 99$ is 6.5819 with corresponding $A = 209$
The maximum binding energy per nucleon for $Z = 100$ is 6.5553 with corresponding $A = 210$
The element with the maximum binding energy per nucleon is $Z = 26$ with $A = 56$ and corresponding binding energy per nucleon is 8.78 MeV

Exercise 10

1 1

1 2 1

1 3 3 1

1 4 6 4 1

1 5 10 10 5 1

1 6 15 20 15 6 1

1 7 21 35 35 21 7 1

1 8 28 56 70 56 28 8 1

1 9 36 84 126 126 84 36 9 1

1 10 45 120 210 252 210 120 45 10 1

1 11 55 165 330 461 461 329 164 54 10 0

1 12 66 220 495 792 924 792 495 220 66 12 1

1 13 78 286 715 1287 1716 1716 1287 715 286 78 13 1

1 14 91 364 1001 2002 3003 3432 3003 2002 1001 364 91 14 1

1 15 105 454 1364 3002 5004 6434 6434 5004 3002 1364 454 104 14 0

1 16 120 560 1820 4368 8008 11440 12870 11440 8007 4367 1819 560 120 16 1

1 17 136 680 2380 6188 12376 19448 24310 24310 19448 12376 6188 2380 680
136 17 1

1 18 153 816 3060 8568 18564 31824 43758 48620 43758 31824 18564 8568
3060 816 153 18 1

1 19 171 969 3876 11628 27132 50388 75582 92378 92378 75582 50388 27132
11628 3876 969 171 19 1

1 20 190 1140 4845 15504 38760 77520 125970 167960 184756 167960 125970
77520 38760 15504 4845 1140 190 20 1

The probability that an unbiased coin, tossed 100 times, will come up
heads exactly 60 times is 0.0108439

The probability that it comes up heads 60 or more times is 0.0284440

Exercise 11

[2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97, 101, 103, 107, 109, 113, 127, 131, 137, 139, 149, 151, 157, 163, 167, 173, 179, 181, 191, 193, 197, 199, 211, 223, 227, 229, 233, 239, 241, 251, 257, 263, 269, 271, 277, 281, 283, 293, 307, 311, 313, 317, 331, 337, 347, 349, 353, 359, 367, 373, 379, 383, 389, 397, 401, 409, 419, 421, 431, 433, 439, 443, 449, 457, 461, 463, 467, 479, 487, 491, 499, 503, 509, 521, 523, 541, 547, 557, 563, 569, 571, 577, 587, 593, 599, 601, 607, 613, 617, 619, 631, 641, 643, 647, 653, 659, 661, 673, 677, 683, 691, 701, 709, 719, 727, 733, 739, 743, 751, 757, 761, 769, 773, 787, 797, 809, 811, 821, 823, 827, 829, 839, 853, 857, 859, 863, 877, 881, 883, 887, 907, 911, 919, 929, 937, 941, 947, 953, 967, 971, 977, 983, 991, 997, 1009, 1013, 1019, 1021, 1031, 1033, 1039, 1049, 1051, 1061, 1063, 1069, 1087, 1091, 1093, 1097, 1103, 1109, 1117, 1123, 1129, 1151, 1153, 1163, 1171, 1181, 1187, 1193, 1201, 1213, 1217, 1223, 1229, 1231, 1237, 1249, 1259, 1277, 1279, 1283, 1289, 1291, 1297, 1301, 1303, 1307, 1319, 1321, 1327, 1361, 1367, 1373, 1381, 1399, 1409, 1423, 1427, 1429, 1433, 1439, 1447, 1451, 1453, 1459, 1471, 1481, 1483, 1487, 1489, 1493, 1499, 1511, 1523, 1531, 1543, 1549, 1553, 1559, 1567, 1571, 1579, 1583, 1597, 1601, 1607, 1609, 1613, 1619, 1621, 1627, 1637, 1657, 1663, 1667, 1669, 1693, 1697, 1699, 1709, 1721, 1723, 1733, 1741, 1747, 1753, 1759, 1777, 1783, 1787, 1789, 1801, 1811, 1823, 1831, 1847, 1861, 1867, 1871, 1873, 1877, 1879, 1889, 1901, 1907, 1913, 1931, 1933, 1949, 1951, 1973, 1979, 1987, 1993, 1997, 1999, 2003, 2011, 2017, 2027, 2029, 2039, 2053, 2063, 2069, 2081, 2083, 2087, 2089, 2099, 2111, 2113, 2129, 2131, 2137, 2141, 2143, 2153, 2161, 2179, 2203, 2207, 2213, 2221, 2237, 2239, 2243, 2251, 2267, 2269, 2273, 2281, 2287, 2293, 2297, 2309, 2311, 2333, 2339, 2341, 2347, 2351, 2357, 2371, 2377, 2381, 2383, 2389, 2393, 2399, 2411, 2417, 2423, 2437, 2441, 2447, 2459, 2467, 2473, 2477, 2503, 2521, 2531, 2539, 2543, 2549, 2551, 2557, 2579, 2591, 2593, 2609, 2617, 2621, 2633, 2647, 2657, 2659, 2663, 2671, 2677, 2683, 2687, 2689, 2693, 2699, 2707, 2711, 2713, 2719, 2729, 2731, 2741, 2749, 2753, 2767, 2777, 2789, 2791, 2797, 2801, 2803, 2819, 2833, 2837, 2843, 2851, 2857, 2861, 2879, 2887, 2897, 2903, 2909, 2917, 2927, 2939, 2953, 2957, 2963, 2969, 2971, 2999, 3001, 3011, 3019, 3023, 3037, 3041, 3049, 3061, 3067, 3079, 3083, 3089, 3109, 3119, 3121, 3137, 3163, 3167, 3169, 3181, 3187, 3191, 3203, 3209, 3217, 3221, 3229, 3251, 3253, 3257, 3259, 3271, 3299, 3301, 3307, 3313, 3319, 3323, 3329, 3331, 3343, 3347, 3359, 3361, 3371, 3373, 3389, 3391, 3407, 3413, 3433, 3449, 3457, 3461, 3463, 3467, 3469, 3491, 3499, 3511, 3517, 3527, 3529, 3533, 3539, 3541, 3547, 3557, 3559, 3571, 3581, 3583, 3593, 3607, 3613, 3617, 3623, 3631, 3637, 3643, 3659, 3671, 3673, 3677, 3691, 3697, 3701, 3709, 3719, 3727, 3733, 3739, 3761, 3767, 3769, 3779, 3793, 3797, 3803, 3821, 3823, 3833, 3847, 3851, 3853, 3863, 3877, 3881, 3889, 3907, 3911, 3917, 3919, 3923, 3929, 3931, 3943, 3947, 3967, 3989, 4001, 4003, 4007, 4013, 4019, 4021, 4027, 4049, 4051, 4057, 4073, 4079, 4091, 4093, 4099, 4111, 4127, 4129, 4133, 4139, 4153, 4157, 4159, 4177, 4201, 4211, 4217, 4219, 4229, 4231, 4241, 4243, 4253, 4259, 4261, 4271, 4273, 4283, 4289, 4297, 4327, 4337, 4339, 4349, 4357, 4363, 4373, 4391, 4397, 4409, 4421, 4423, 4441, 4447, 4451, 4457, 4463, 4481, 4483, 4493, 4507, 4513, 4517, 4519, 4523, 4547, 4549, 4561, 4567, 4583, 4591, 4597, 4603, 4621, 4637, 4639, 4643, 4649, 4651, 4657, 4663, 4673, 4679, 4691, 4703, 4721, 4723, 4729, 4733, 4751, 4759, 4783, 4787, 4789, 4793, 4799, 4801, 4813, 4817, 4831, 4861, 4871, 4877, 4889, 4903, 4909, 4919, 4931, 4933, 4937, 4943, 4951, 4957, 4967, 4969, 4973, 4987, 4993, 4999, 5003, 5009, 5011, 5021, 5023, 5039, 5051, 5059, 5077, 5081, 5087, 5099, 5101, 5107, 5113, 5119, 5147, 5153, 5167, 5171, 5179, 5189, 5197, 5209, 5227, 5231, 5233, 5237, 5261, 5273, 5279,

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9883, 9887, 9901, 9907, 9923, 9929, 9931, 9941, 9949, 9967, 9973]

Exercise 12

The 100th Catalan Number is:

896519947090131678185430741499021921911623568450622849024

The GCD of 108 and 192 is 12

Exercise 16

Part A

Fixed Points:

In the Feigenbaum plot the points at which for a given value of r there is a single value of x are called fixed points, the range of values of r which produces fixed point is approximately $r = 1$ to $r = 3$.

Limit cycles:

In the Feigenbaum plot the points at which for a given value of r the value of x oscillates between two values for r in the range 3 to 3.5 (approximately), similarly for values of r slightly above 3.5, x oscillates between 4 points, and again for greater values of r x oscillates between 8, 16, 32, ... points.

Chaos:

After a certain threshold of r , x now takes seemingly infinite values at each point, but we can always algorithmically obtain any point in the Feigenbaum plot using the logistic equation. Thus we call it deterministic chaos.

Part B

The value at which the system moves from orderly behavior (fixed points or limit cycles) to chaotic behavior is (approximately) $r = 3.57$

Exercise 13
Part a

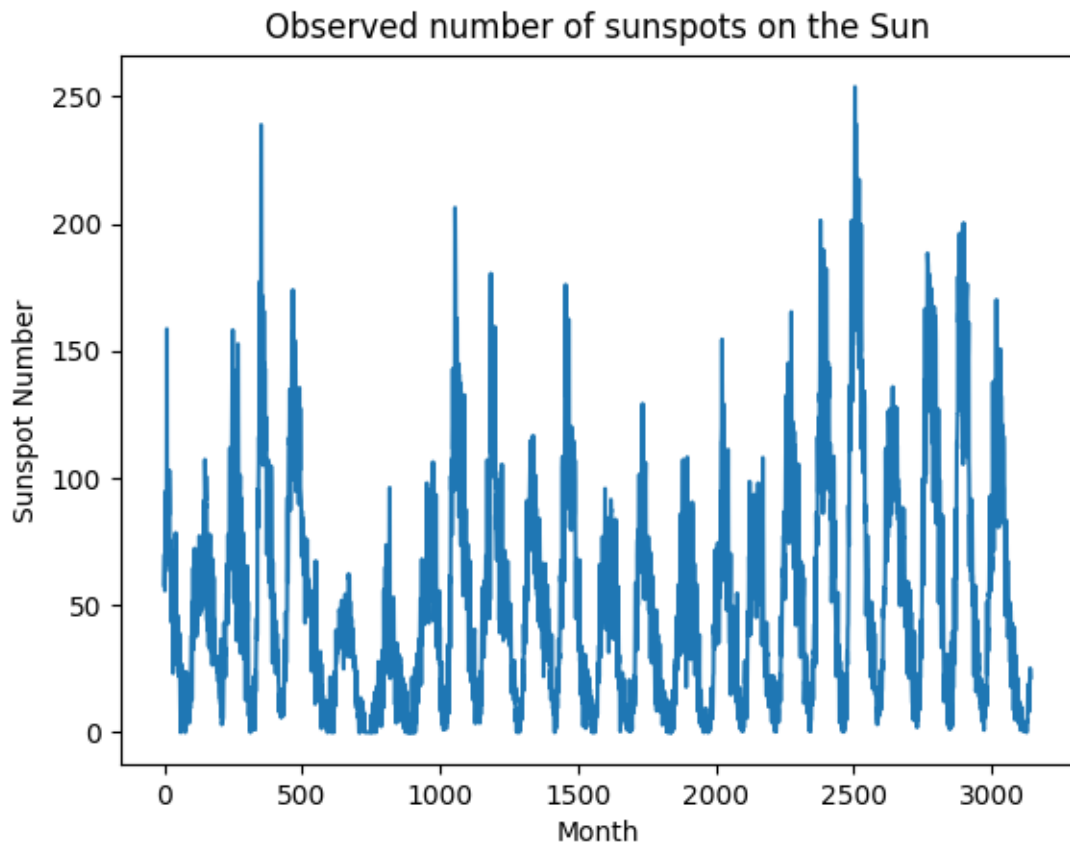


Figure 1: Part a

Part b

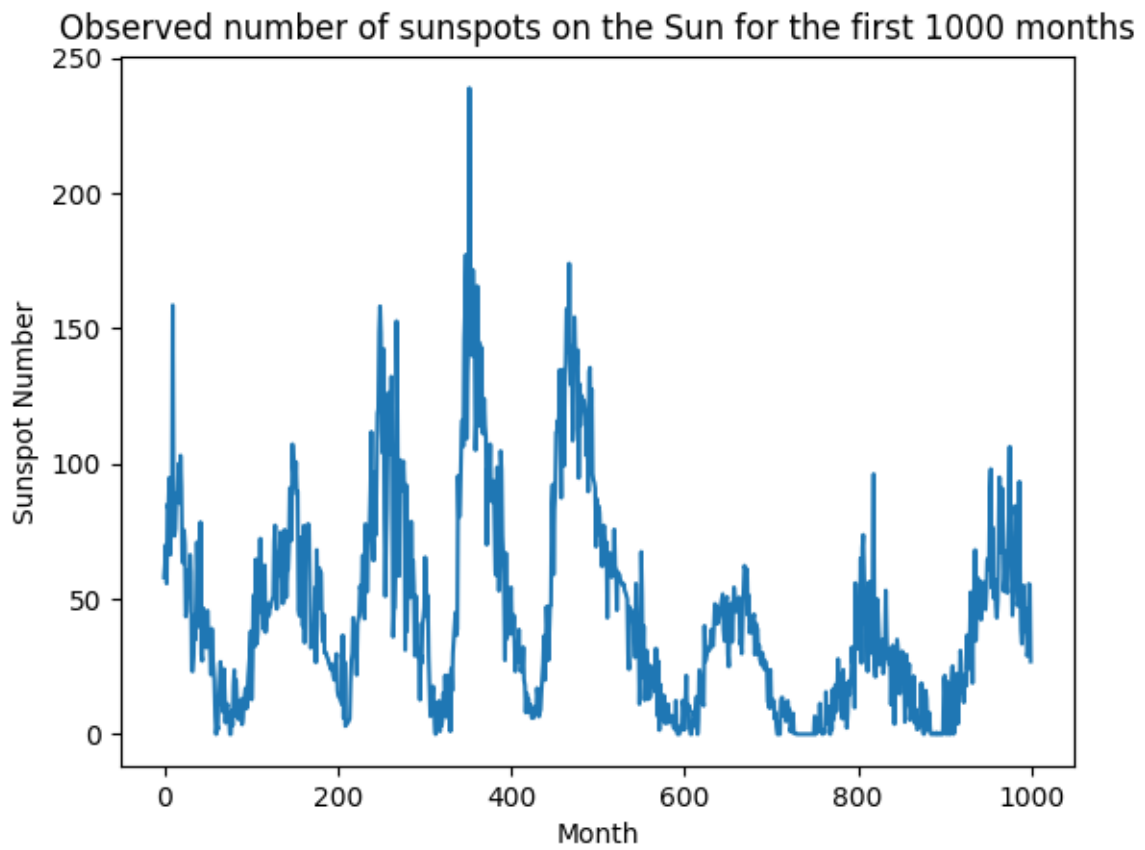


Figure 2: Part b

Part c

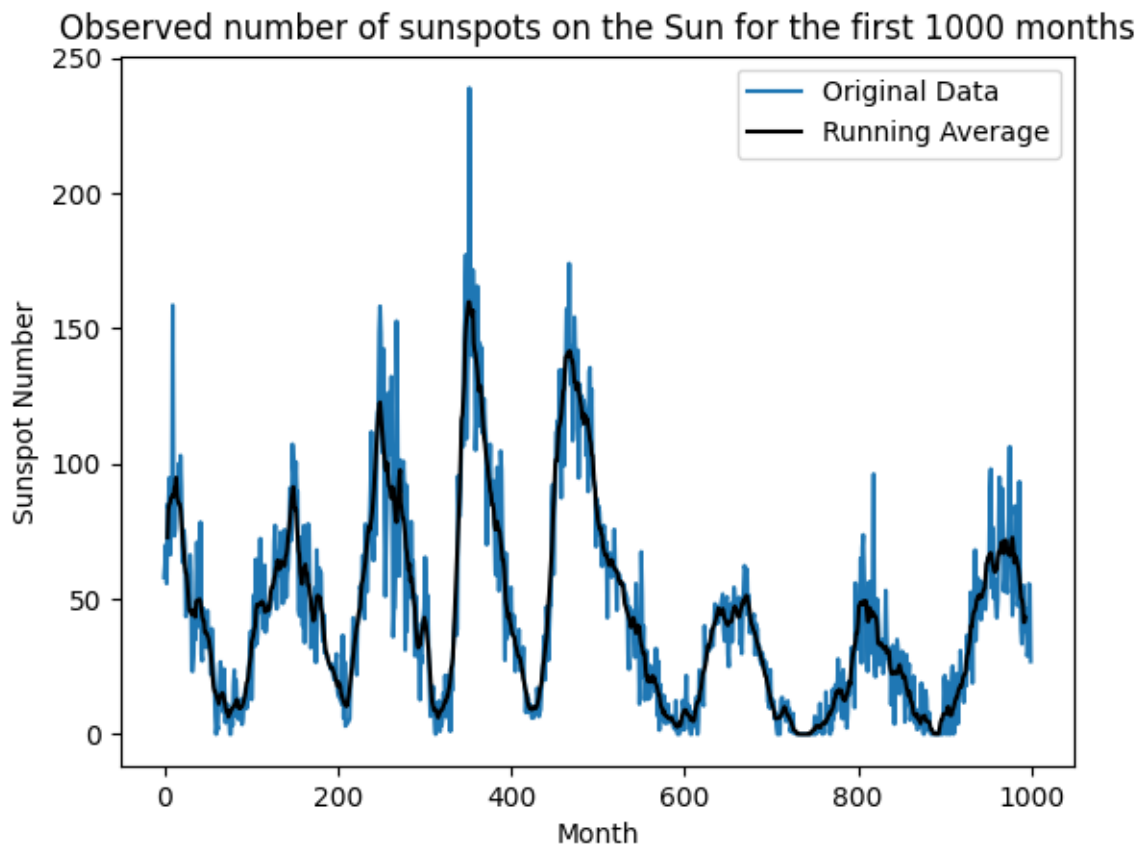


Figure 3: Part c

Exercise 14
Part a

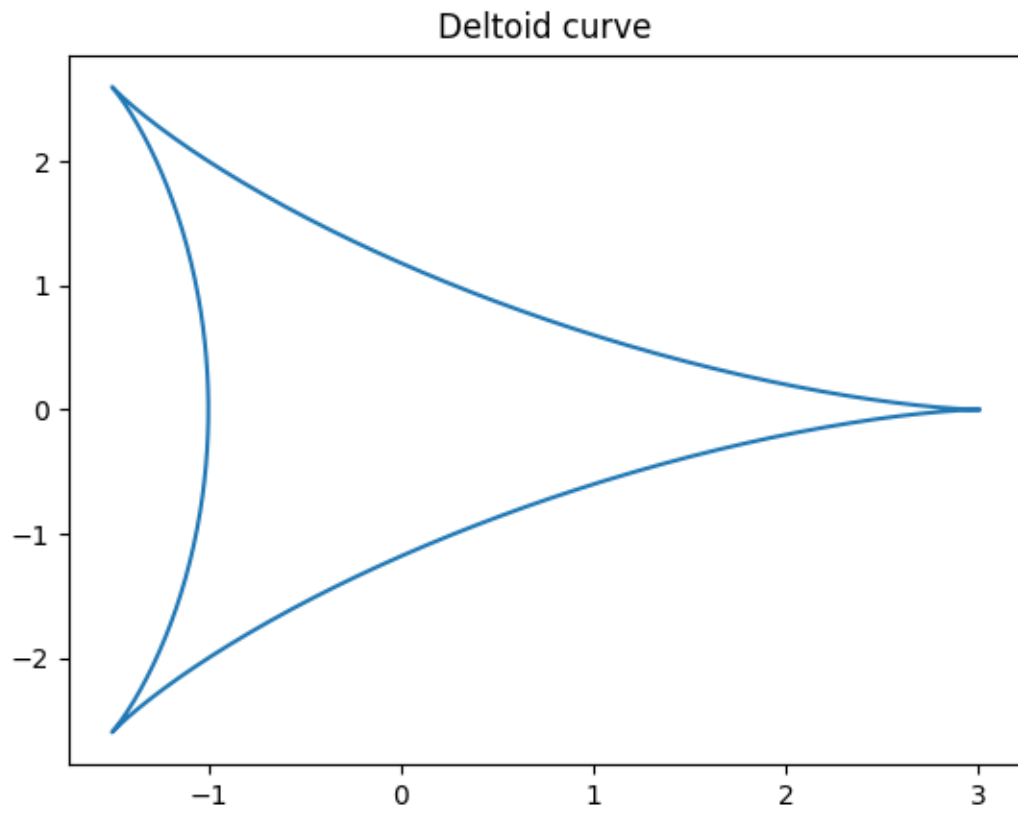


Figure 4: Part a

Part b

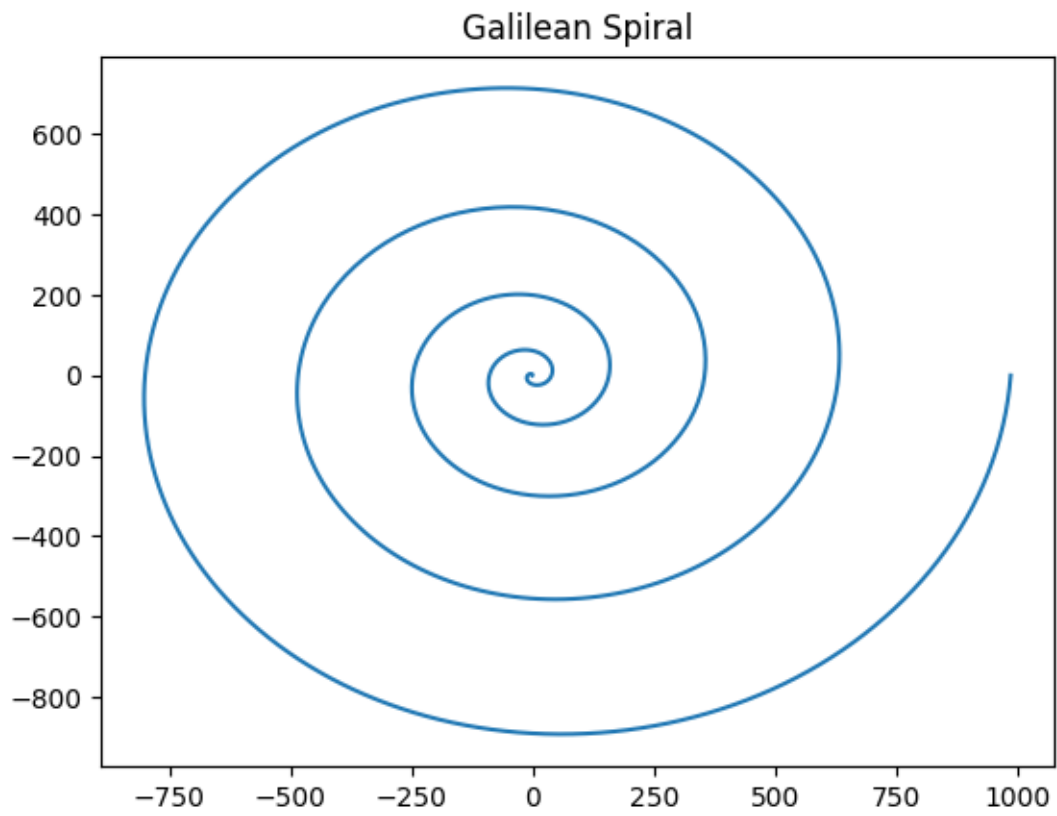


Figure 5: Part b

Part c

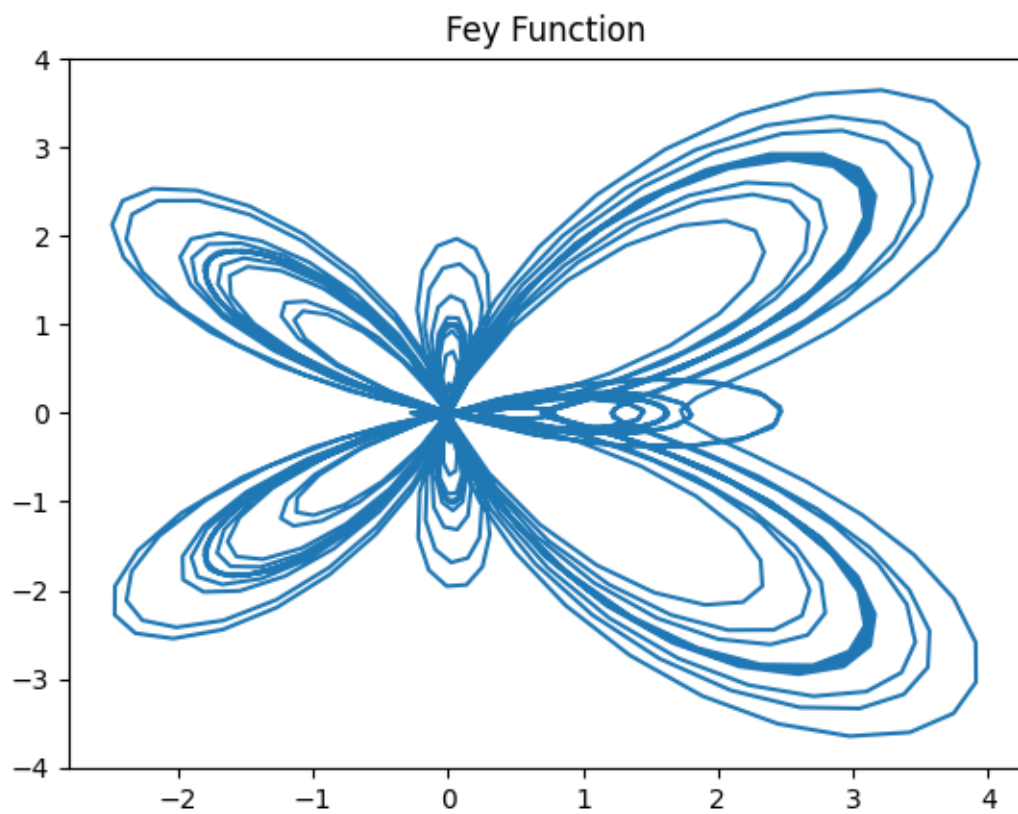


Figure 6: Part c

Exercise 15

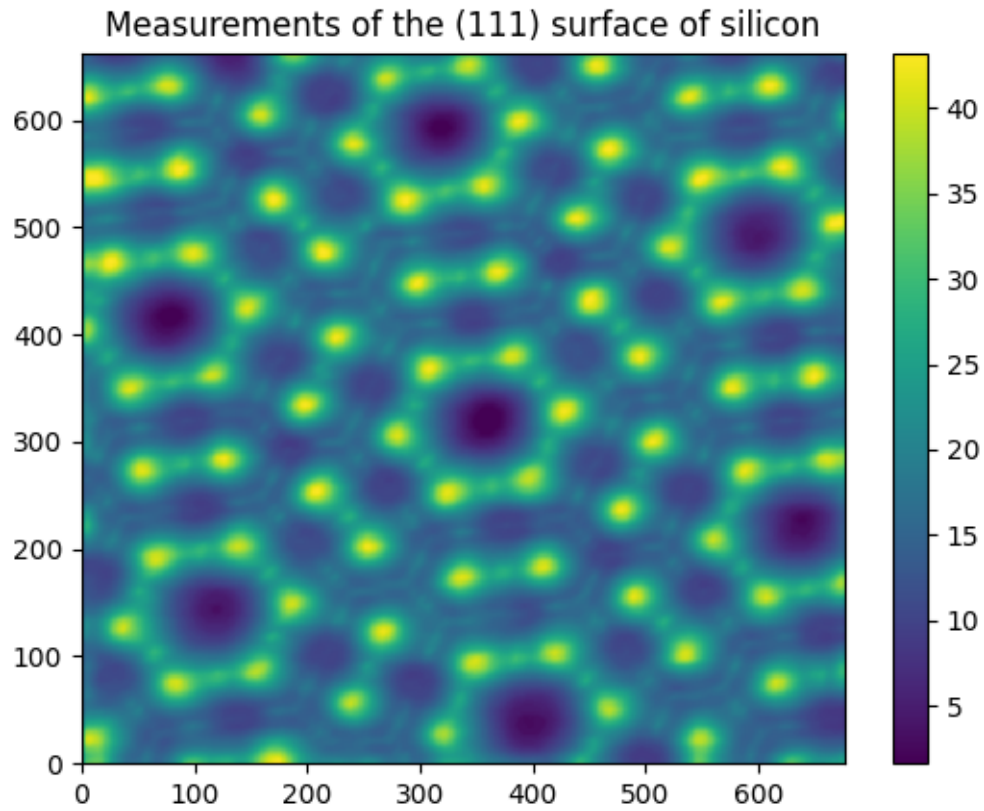


Figure 7:

Exercise 16

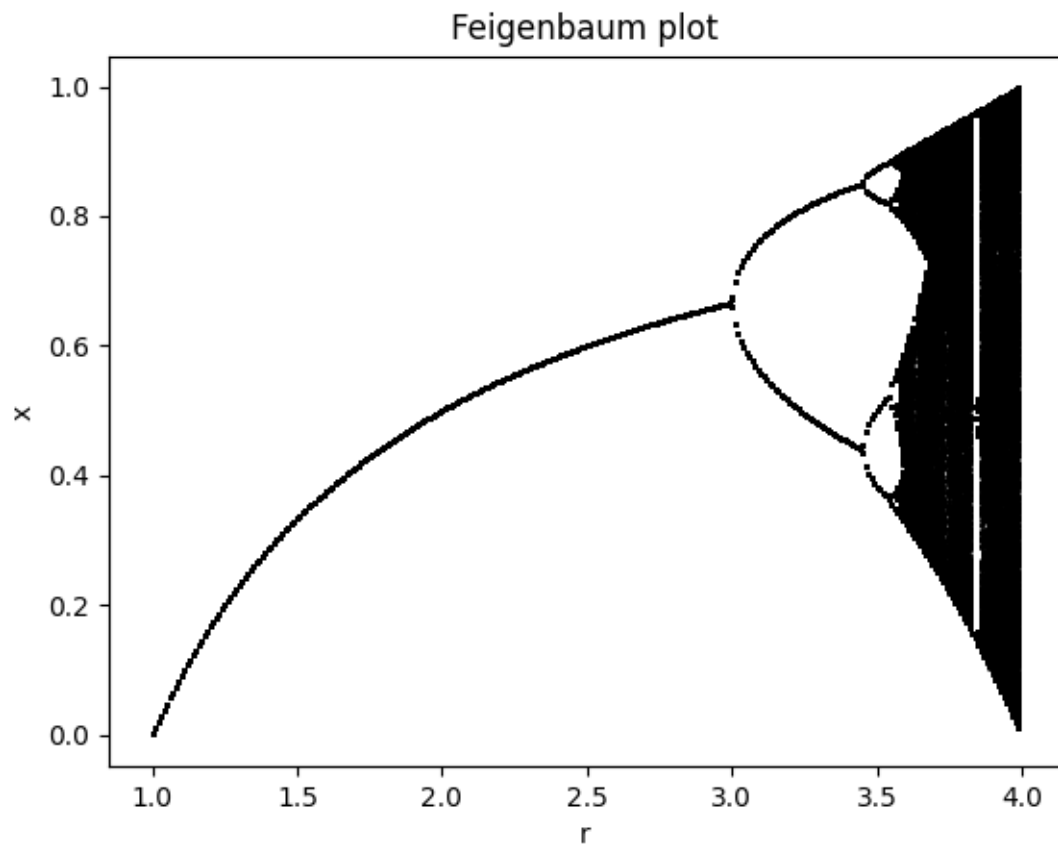


Figure 8:

Exercise 17

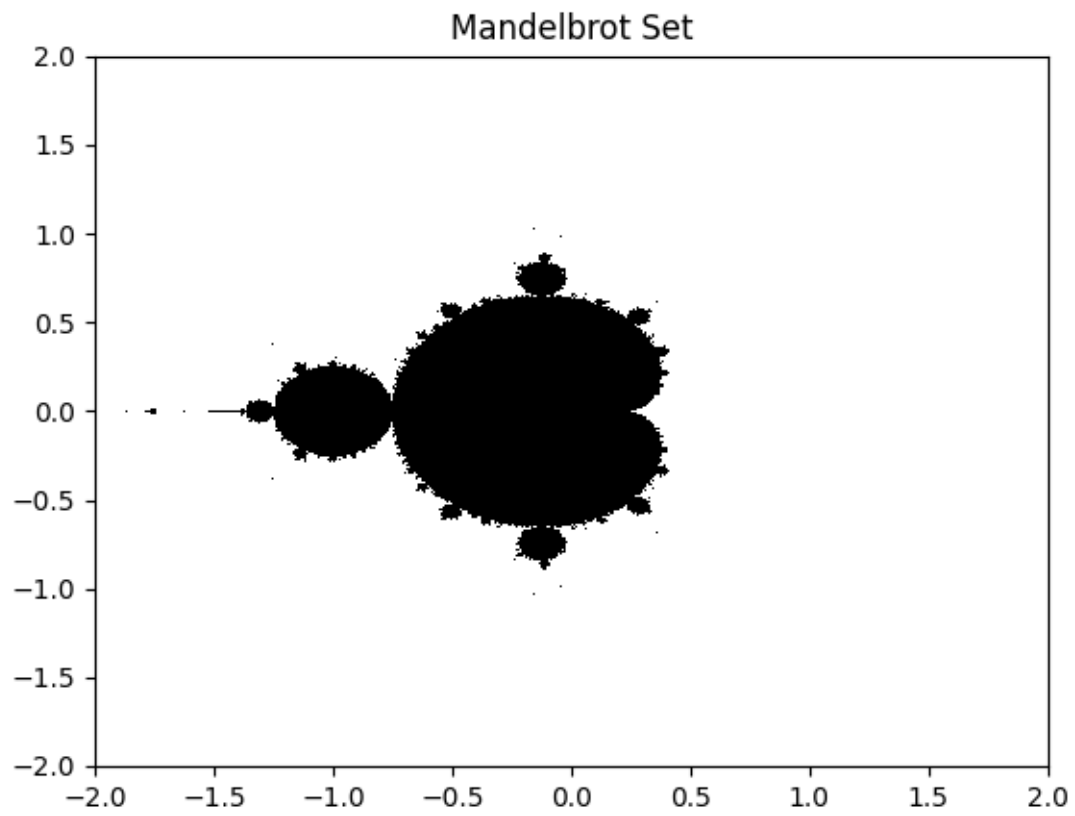


Figure 9: Black and White plot scheme



Figure 10: Hot plot scheme

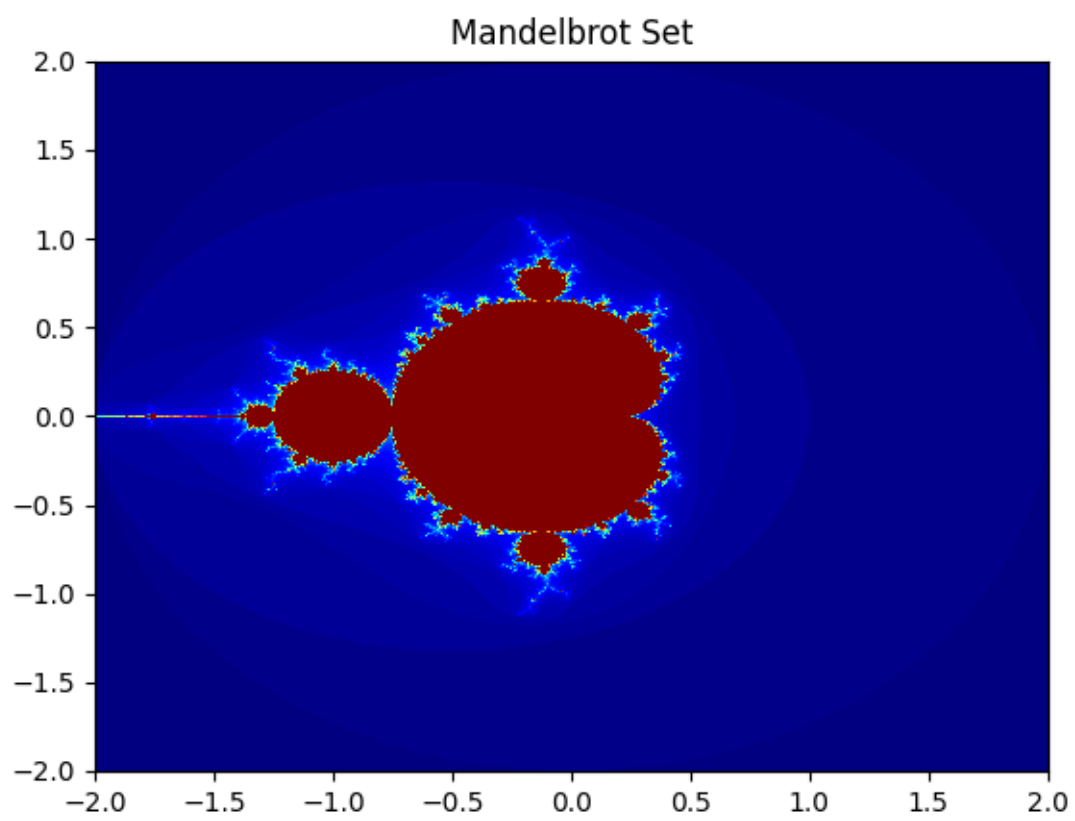


Figure 11: Jet plot scheme

Exercise 18
Part a

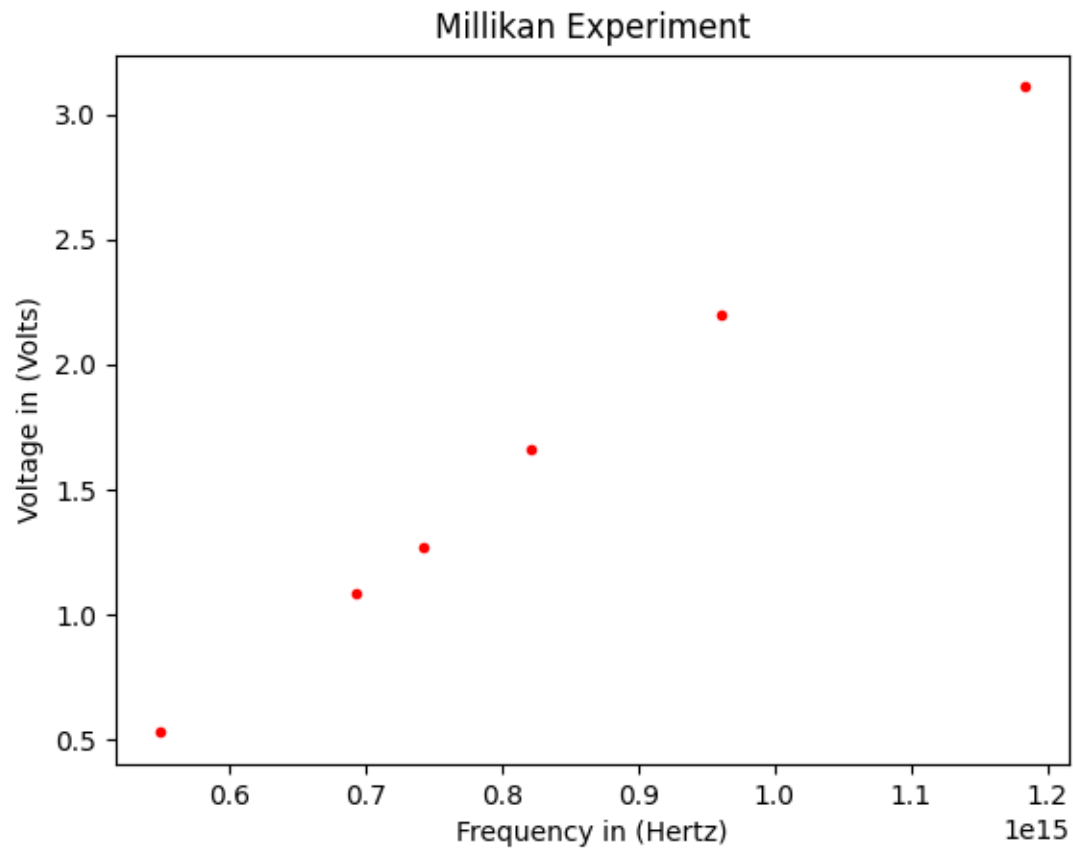


Figure 12: Part a

Part b

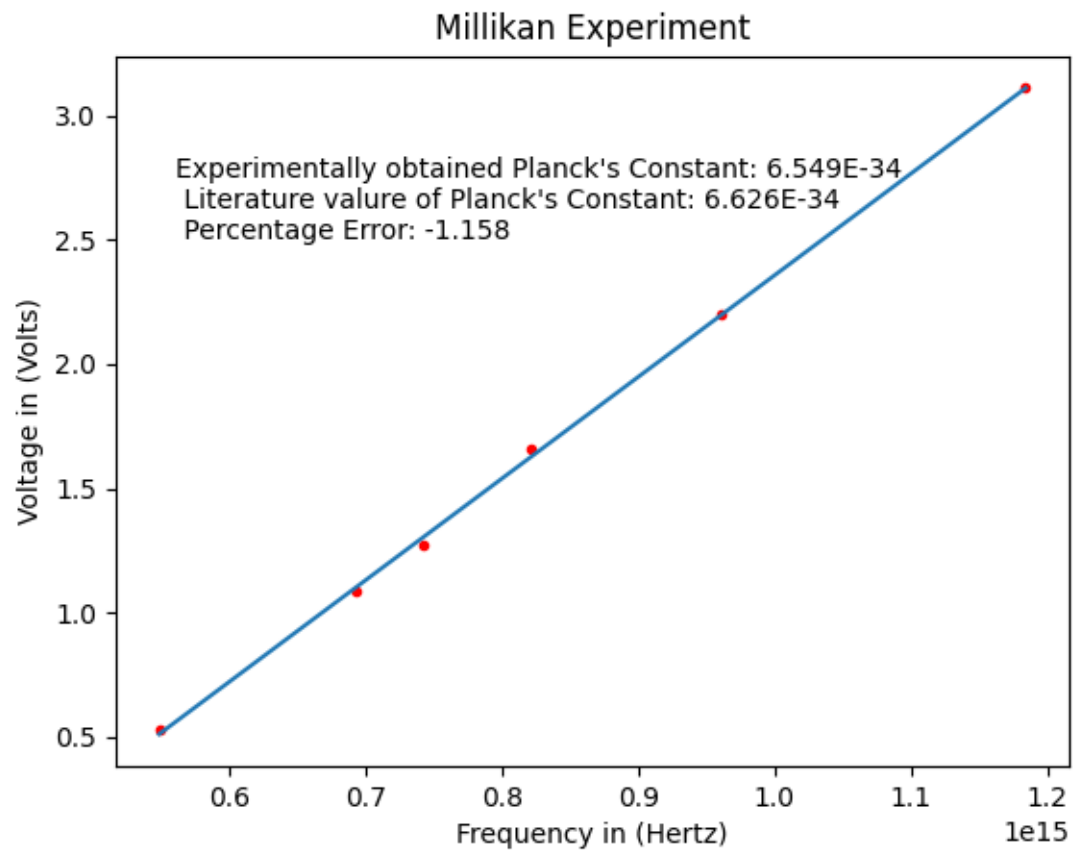


Figure 13: Part b