Physics -1 Lab SM203P

Experiment - 2

Understanding behaviour of simple and double pendulums

Group: 24

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Aim :

Understanding behaviour of simple and double pendulums.

Apparatus Used :

1. A string and a mount for your phone.
2. A meter scale/measuring tape.
3. PhyPhox application on a mobile device.
4. myPhysicsLab.

Procedure :

1. Attach your mobile device to the mount (A simple mount can be made from a small paper roll and rubber band).
2. Suspend your mounted mobile with the help of a string. This will serve as our pendulum.
3. Under the “Mechanics” section of the PhyPhox application, open “Pendulum”.
4. Click on the option to do Timed Runs. Set Start delay(s) as 3s and Experiment duration(s) as 10s.
5. Measure the length of the string from the center of mass of your mobile and input it on PhyPhox.
6. Click the start button, then set your pendulum in motion. After the 10s timer runs out, the application will give the period, frequency, and the value of g.
7. Repeat the process 3-5 times.
8. Using the “Inclination” option under “Tools" in PhyPhox, do a similar timed run to obtain a ($\theta \; vs \; t$) graph for your pendulum. For ($d\,\theta \; / \, dt \; vs \; \theta$) graph, export the data in an excel sheet and plot values in Python.
9. Next, we will run simulations at myPhysicsLab .
10. Run the simulation for a simple pendulum without dissipation and plot the phase portrait (dΘ/dt vs t) for 3 different initial amplitudes.
11. Now run the simulation for a simple pendulum with any non-zero value of damping. Plot the phase portrait.
12. Next, run simulations for a double pendulum. For L1/L2 = 1, fix n different values of m = m2/(m1+m2). Plot ($d\,\theta_1/dt \; vs \; \theta_1$), ($d\,\theta_2/dt \; vs \; \theta_2$) and the time graphs for each case.
13. Now, keep m as constant at some value. Plot ($d\,\theta_1/dt \; vs \; \theta_1$), ($d\,\theta_2/dt \; vs \; \theta_2$) and the time graphs for n different values of L such that values of L < 1, L = 1, L > 1 are covered.

Theory and Equations used :

For a single, simple pendulum :

We are using the well-known time period equation for a simple pendulum. Using the value of l, and using a stopwatch, we can cross-check the value of g obtained from the PhyPhox application.

$$T = 2\pi\sqrt{\frac{l}{g}}$$

The omega-theta relation for a simple pendulum is: -

$$\frac{d\Theta}{dt} = \sqrt{\frac{2gl(\cos\Theta - \cos A)}{l}}$$

Where A is the amplitude (maximum angle) of oscillation

Now in non-ideal cases, there will be dissipation of energy. This will result in imperfect graphs, like a non-uniform ellipse for omega vs theta. We can enter a value of damping in a simulation to obtain such graphs, then to cross-check we can compare the value of areas of the diagram obtained.

So, for an ideal case, the ellipse area would be πab. Now to calculate for a damped oscillation, we obtain a and b for each quadrant, the area would be $\frac{\pi a' b'}{4}$. Then we sum up the 4 quadrants and find their ratio to cross-check with the damped ratio we put in the simulation.

For double pendulum :

Let the bob on top have mass m_1, bob in the bottom have mass m_2.

Lengths are L_1 and L_2

Their angles are Θ_1 and Θ_2

Equations of motions obtained is: -

Equation 1: -

$$(m_1 + m_2)\, L_1^2 \Theta_1'' + m_2 L_1 L_2 \Theta_2'' \cos(\Theta_1 - \Theta_2) + m_2 L_1 L_2 \Theta_1' \Theta_2' \sin(\Theta_1 - \Theta_2) + g L_1 \sin\Theta_1 (m_1 + m_2) = 0$$

Equation 2: -

$$m_2 L_2^2 \Theta_2'' + m_2 L_1 L_2 \Theta_1'' \cos(\Theta_1 - \Theta_2) - m_2 L_1 L_2 \Theta_1'^2 \sin(\Theta_1 - \Theta_2) + g m_2 L_2 \sin\Theta_2 = 0$$

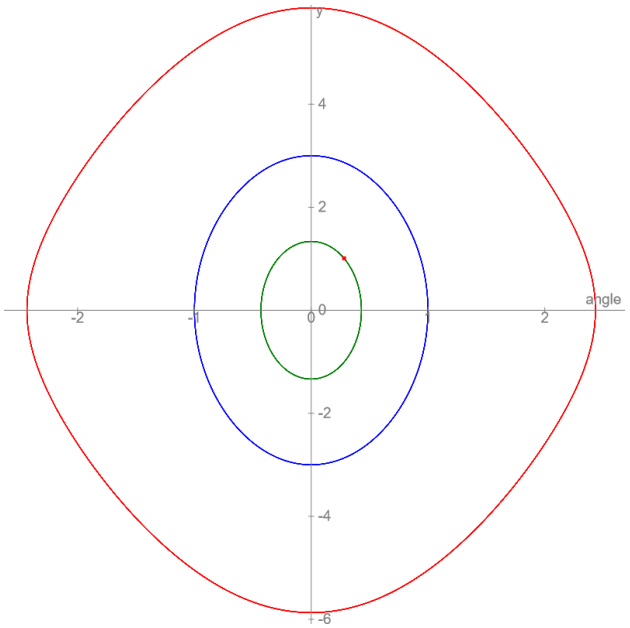
Observation Tables and Graphs :

Question 1: Finding g using phone as a simple pendulum

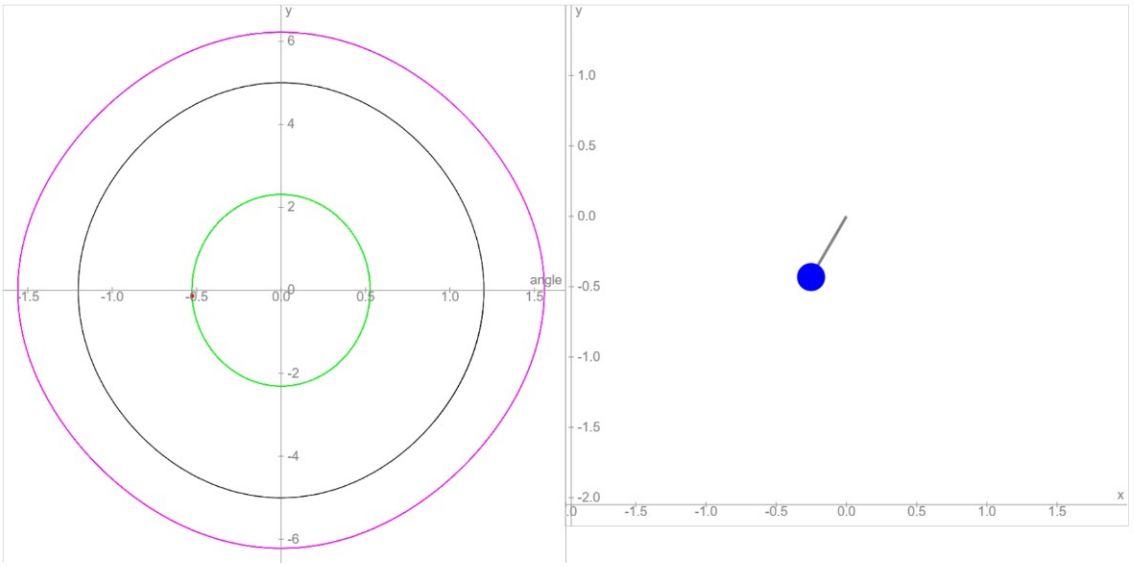
Name Readings	Shridhar Sharma	Abhinav Mahajan	Shaurya Agrawal	Harshadeep Donapati	Ayushmaan Singh	Vishnutha Sheela
1	9.79 ± 0.01	9.71 ± 0.01	9.62 ± 0.01	9.97 ± 0.01	9.56 ± 0.01	9.74±0.01
2	9.59 ± 0.01	9.91 ± 0.01	9.53 ± 0.01	9.43 ± 0.01	9.89 ± 0.01	9.82±0.01
3	9.68 ± 0.01	9.92 ± 0.01	9.72 ± 0.01	9.26 ± 0.01	9.61 ± 0.01	9.68±0.01
4	9.89 ± 0.01	-	-	9.18 ± 0.01	-	
5	9.43 ± 0.01	-	-	9.55 ± 0.01	-	
Average	9.67 ± 0.02	9.85 ± 0.01	9.62 ± 0.01	9.478 ± 0.01	9.686 ± 0.01	9.74±0.01

Note: Readings are reported in m/s².

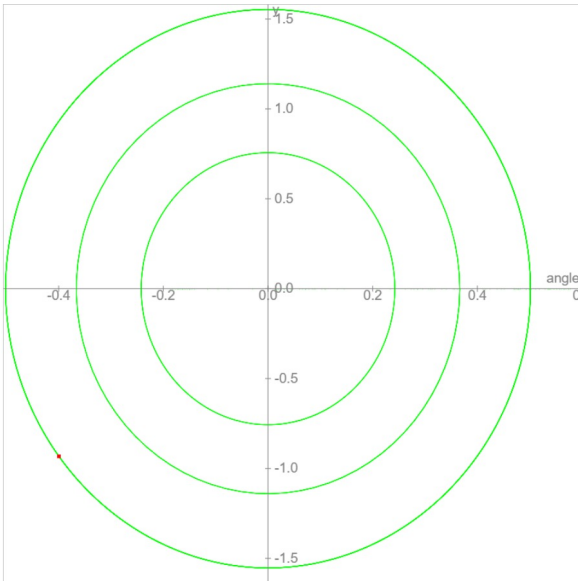
Question 2(a): Running simulation for a simple pendulum (without dissipation) and plotting the phase portrait for 3 different amplitudes.



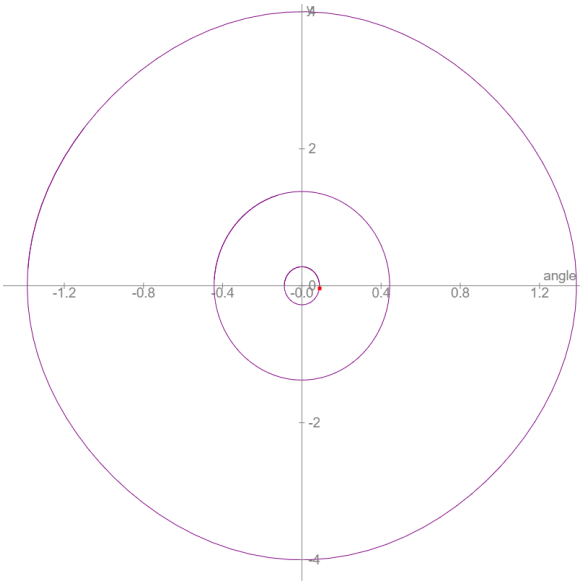
IMT2020065 Shridhar Sharma



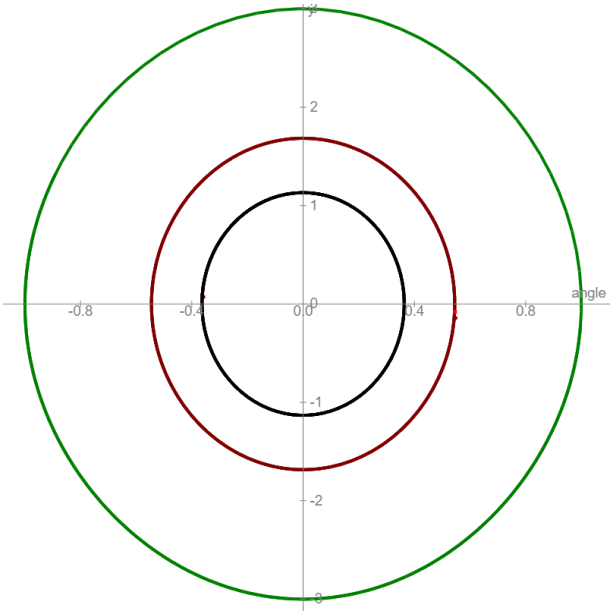
IMT2020553 Abhinav Mahajan

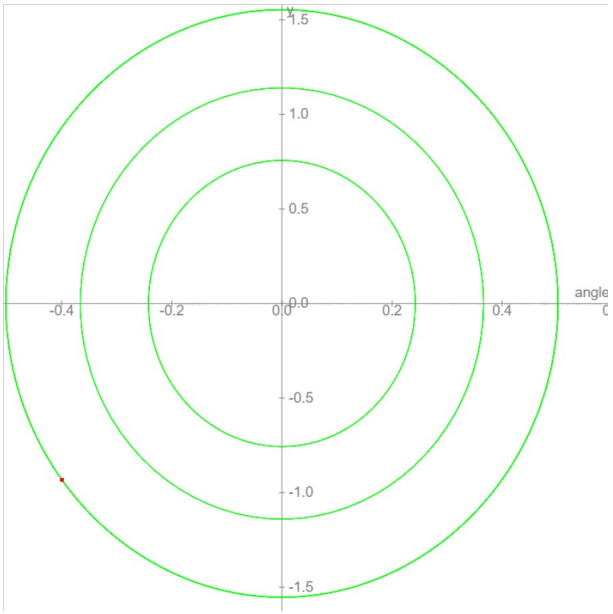


IMT2020539 Shaurya Agarwal



IMT2020085 Harshadeep Donapati

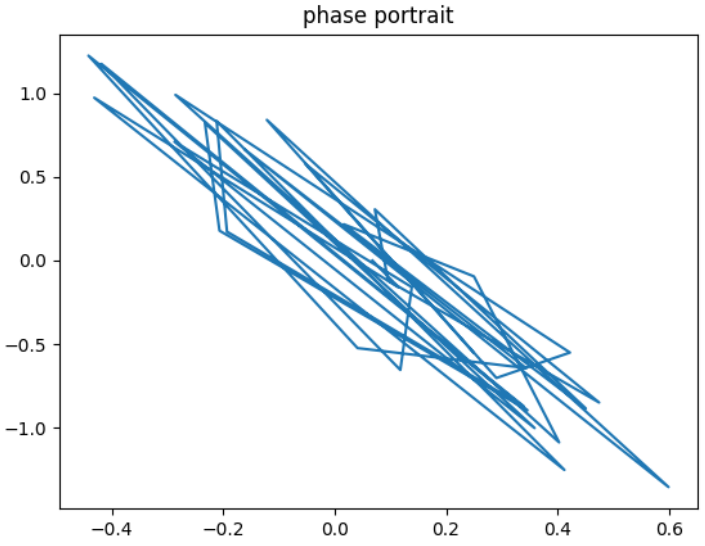




IMT2020126 Ayushmaan Singh

IMT2020057 Vishnutha Sheela

Question 2(b) : Plotting ($d\,\theta \;\; vs\;\theta$) for our Smartphone Pendulum.



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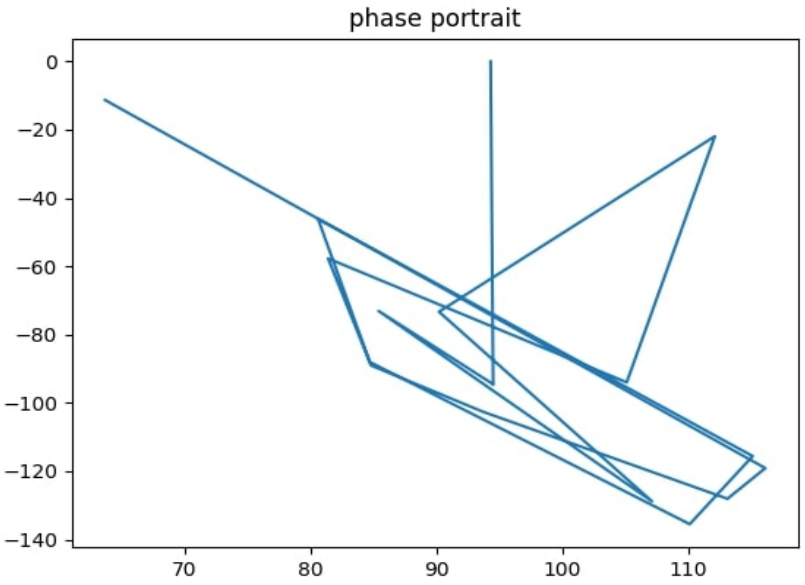
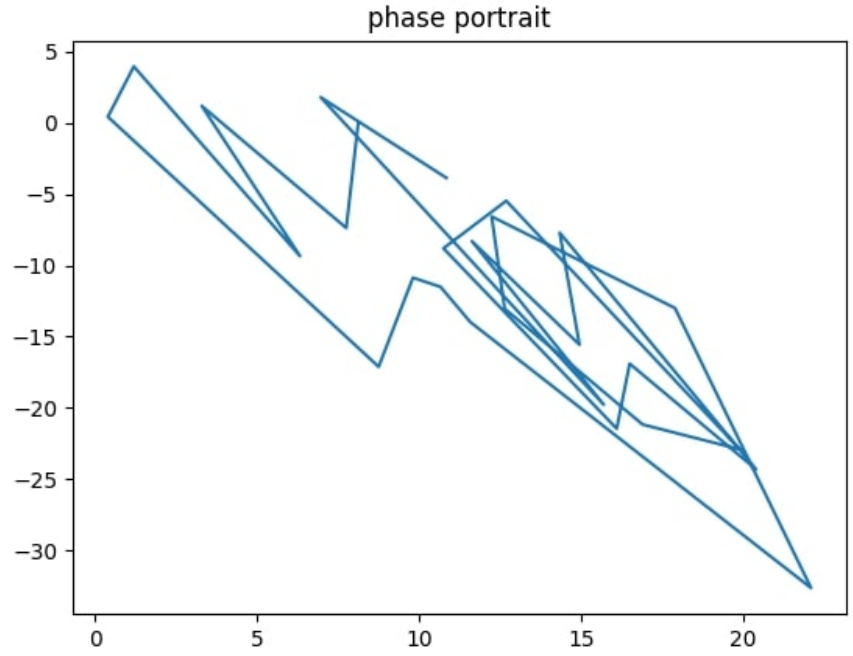
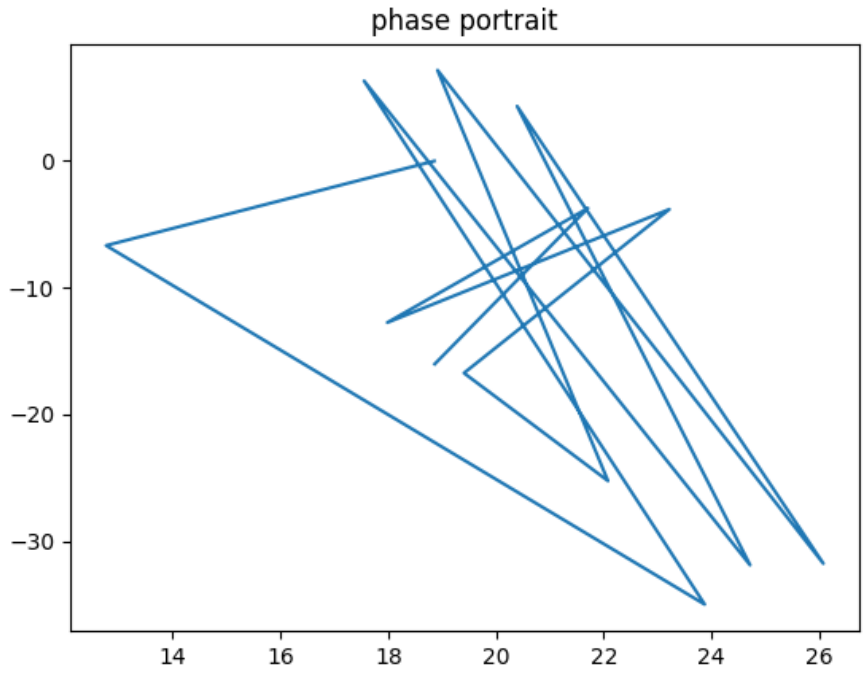


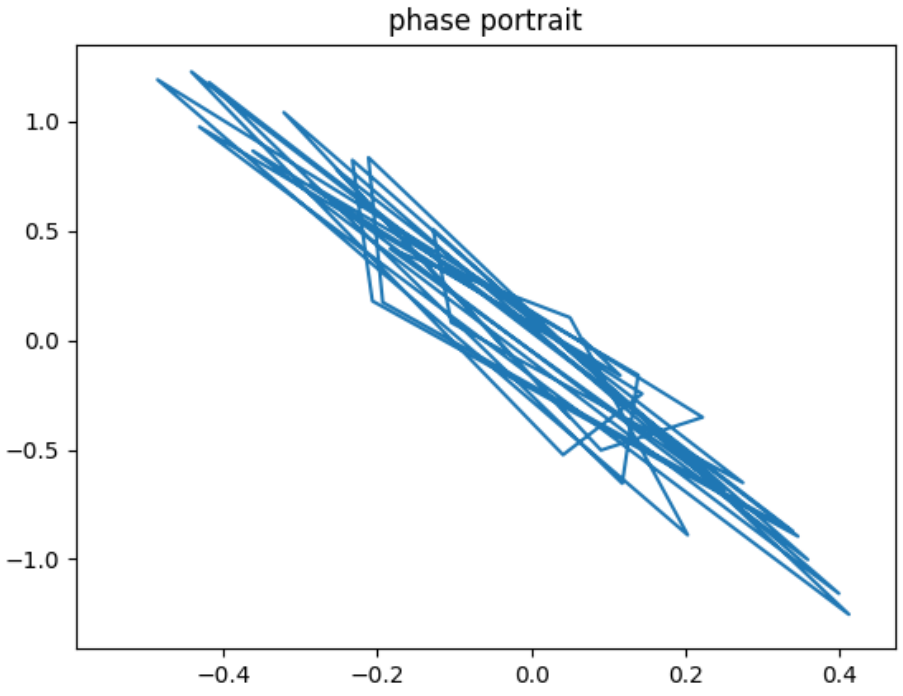
IMT2020553 Abhinav Mahajan



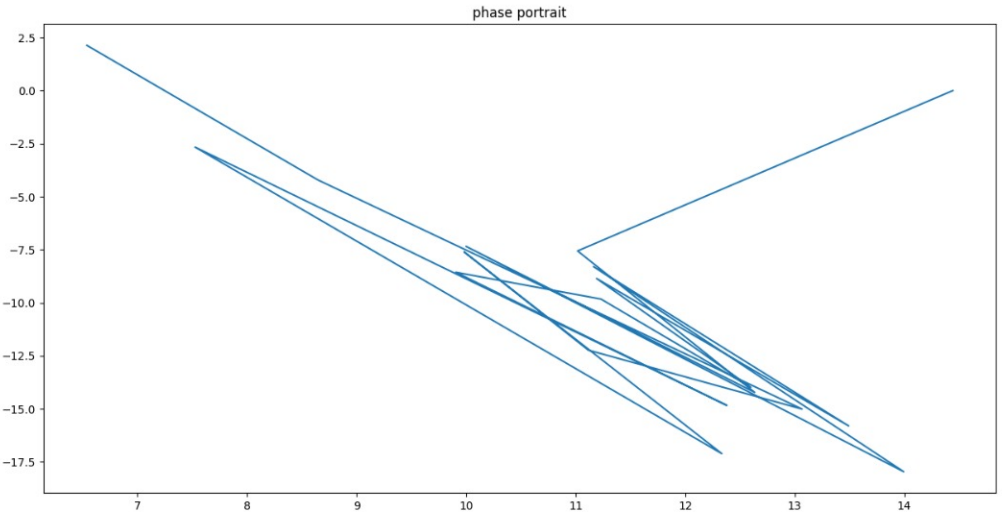
IMT2020539 Shaurya Agarwal



IMT2020085 Harshadeep Donapati

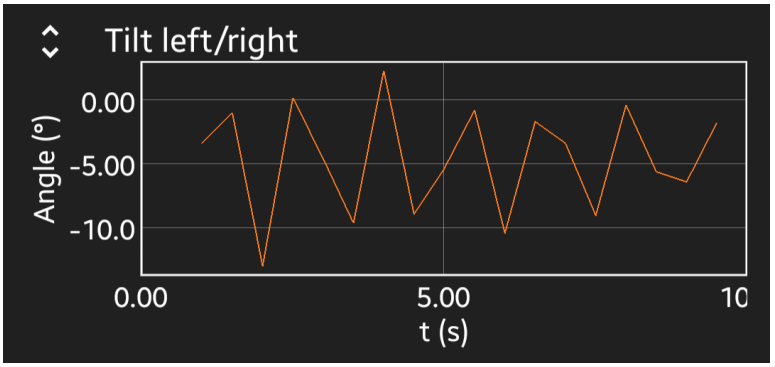


IMT2020126 Ayushmaan Singh

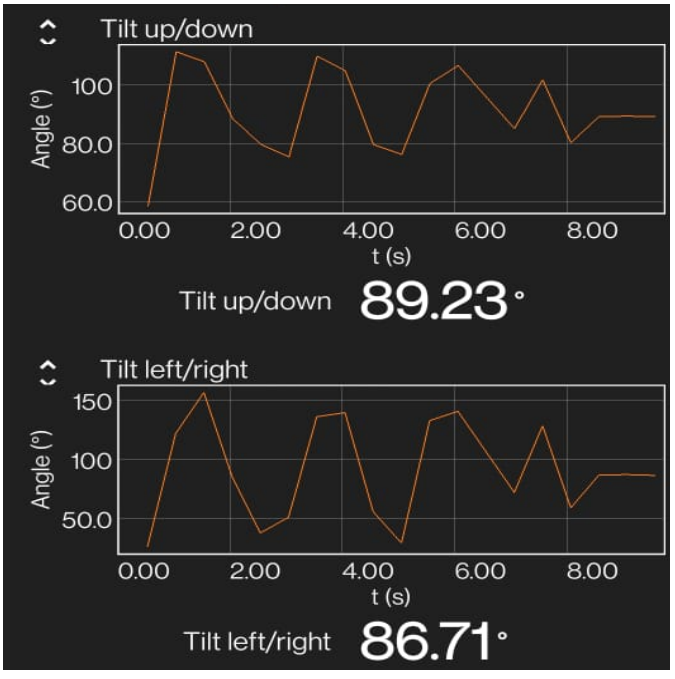


IMT2020057 Vishnutha Sheela

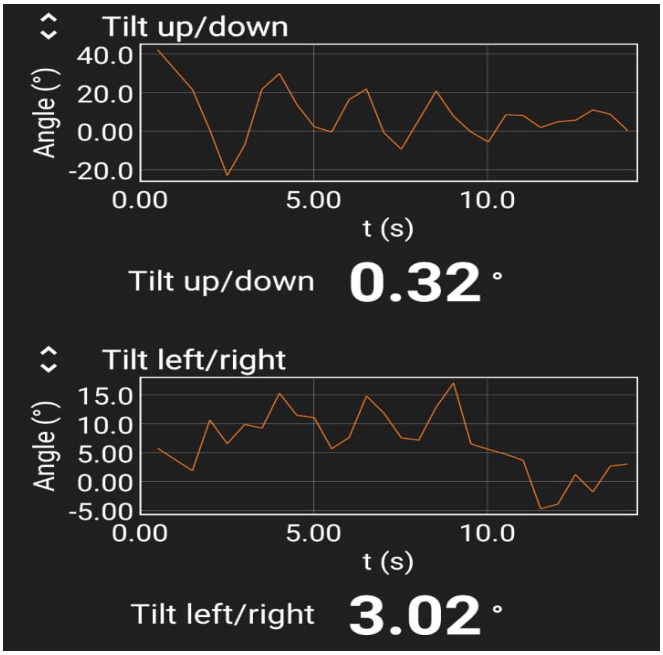
Question 2(c): Plotting the (θ vs t) graph for our Smartphone pendulum.



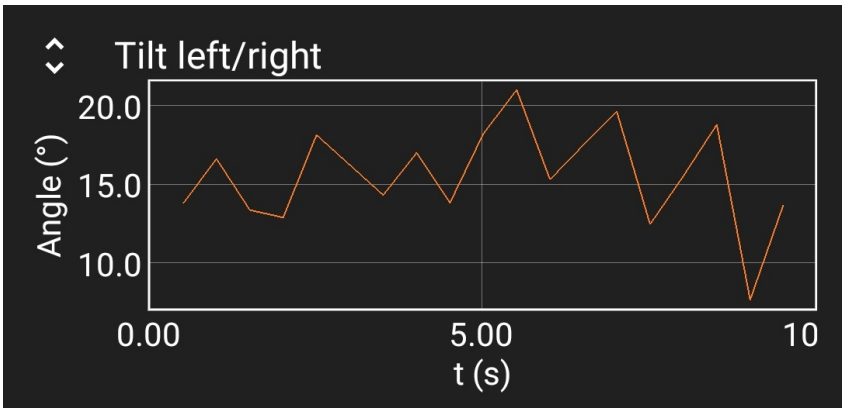
IMT2020065 Shridhar Sharma



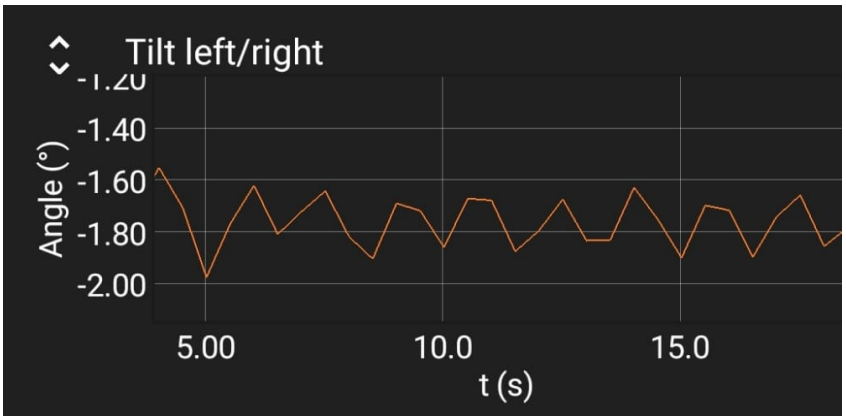
IMT2020553 Abhinav Mahajan



IMT2020539 Shaurya Agarwal



IMT2020085
Harshadeep Donapati



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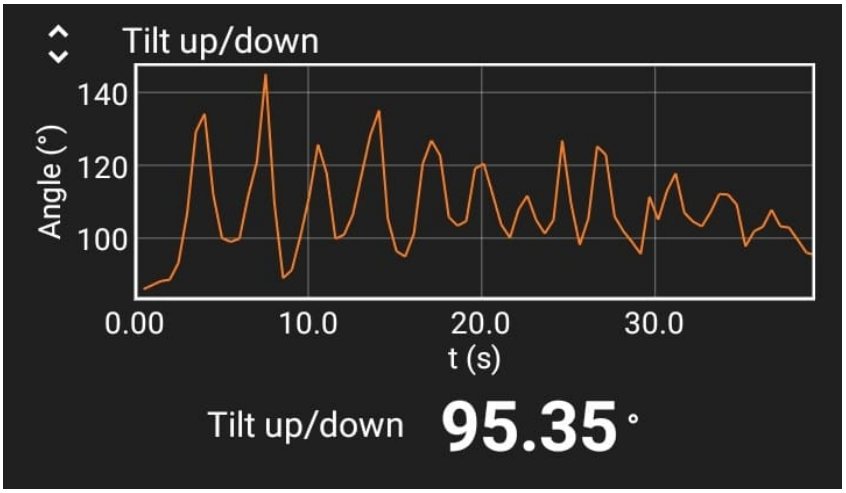
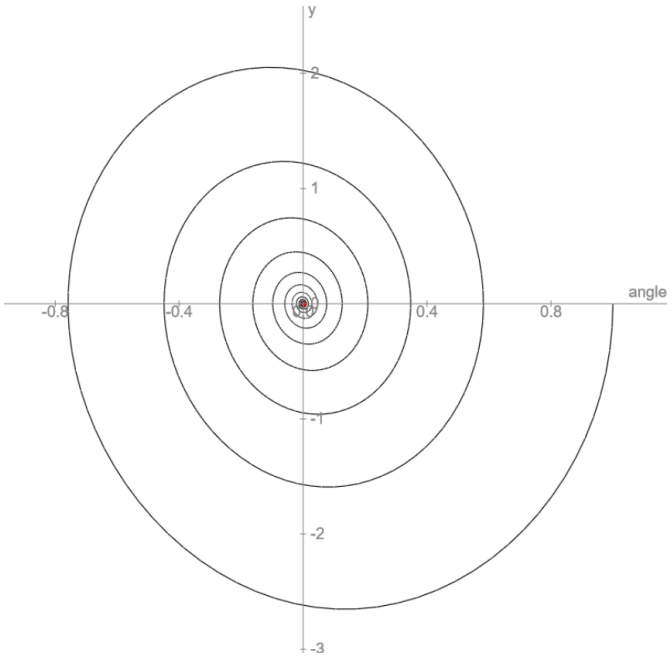
Ayushmaan Singh

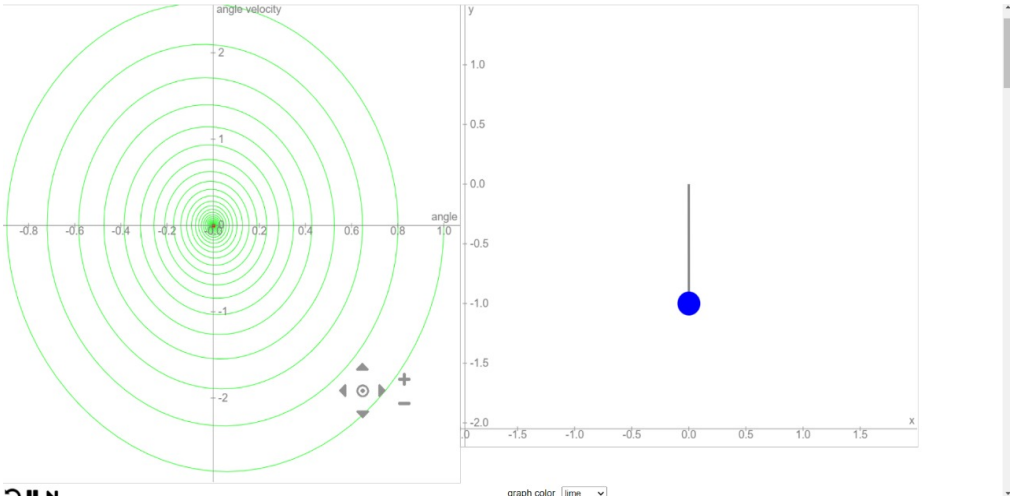


IMT2020057 Vishnutha
Sheela

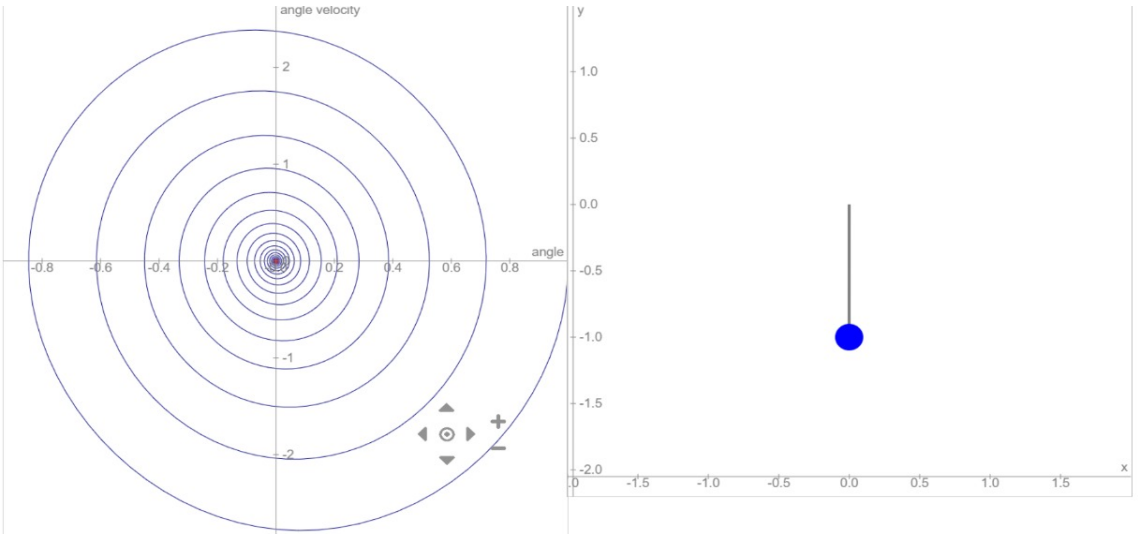
Question 3 : Plotting $d\,\theta\ /\ dt\ vs\ \theta$ for a Simple Pendulum (with Dissipation).



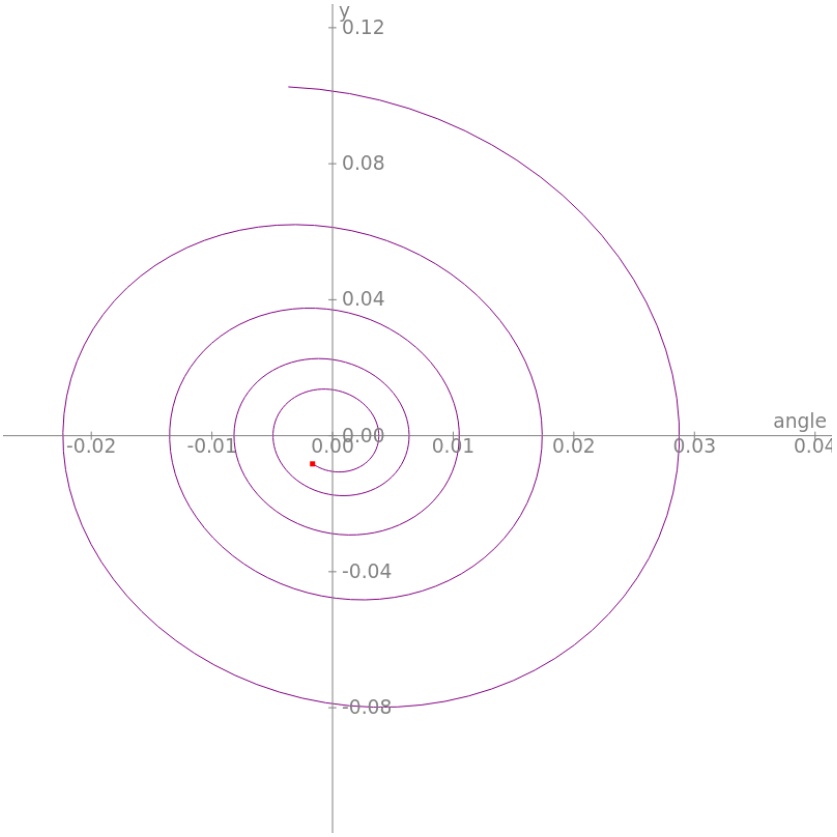
IMT2020065 Shridhar Sharma (damping = 0.5)



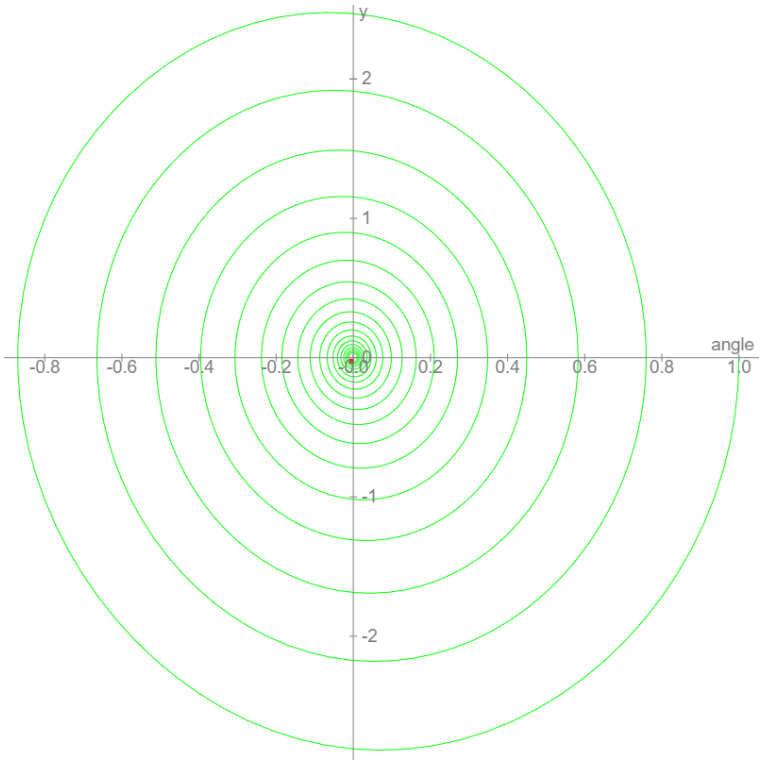
IMT2020553 Abhinav Mahajan



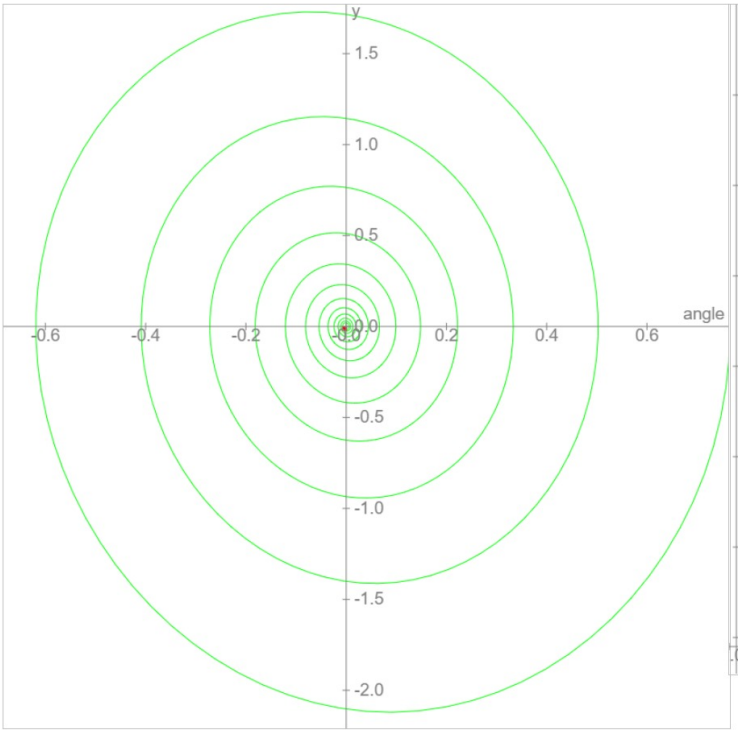
IMT2020539 Shaurya Agarwal



IMT2020085
Harshadeep Donapati
(damping = 0.5)



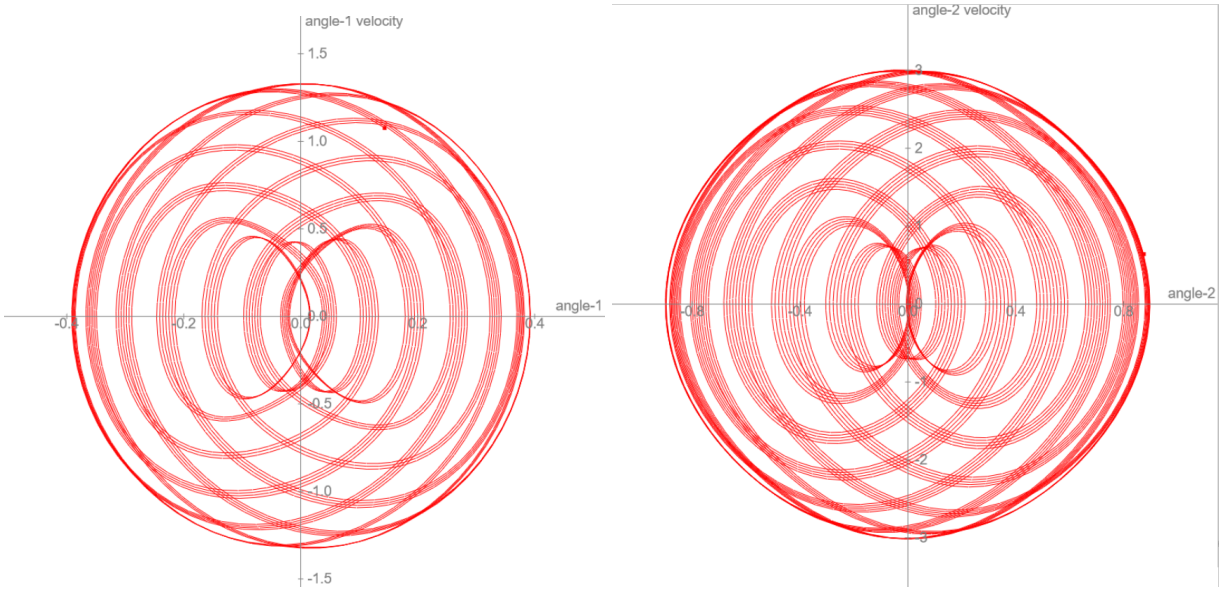
IMT2020126 Ayushmaan Singh (Damping = 0.25)



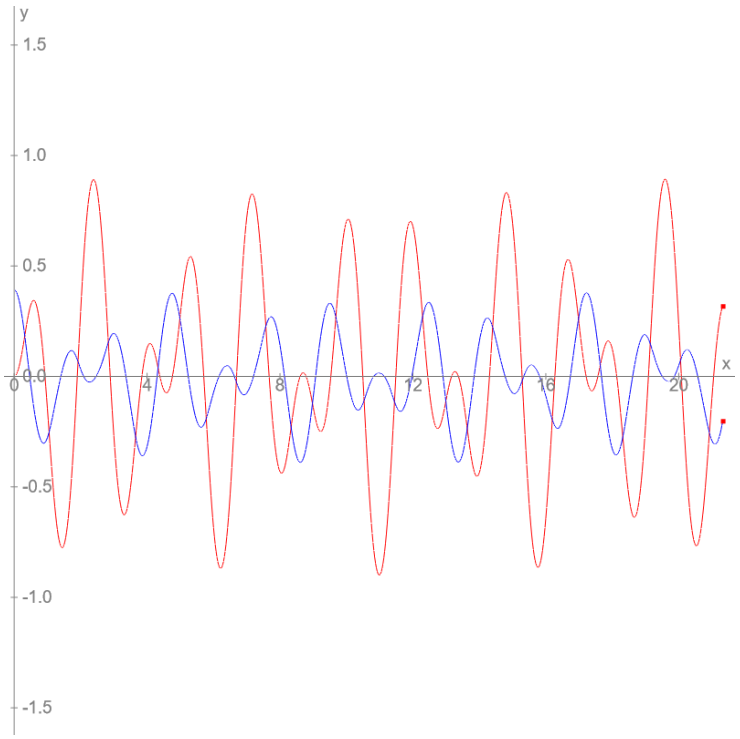
IMT2020057 Vishnutha Sheela

Question 4(a): Plotting phase portraits and time series for a double pendulum.

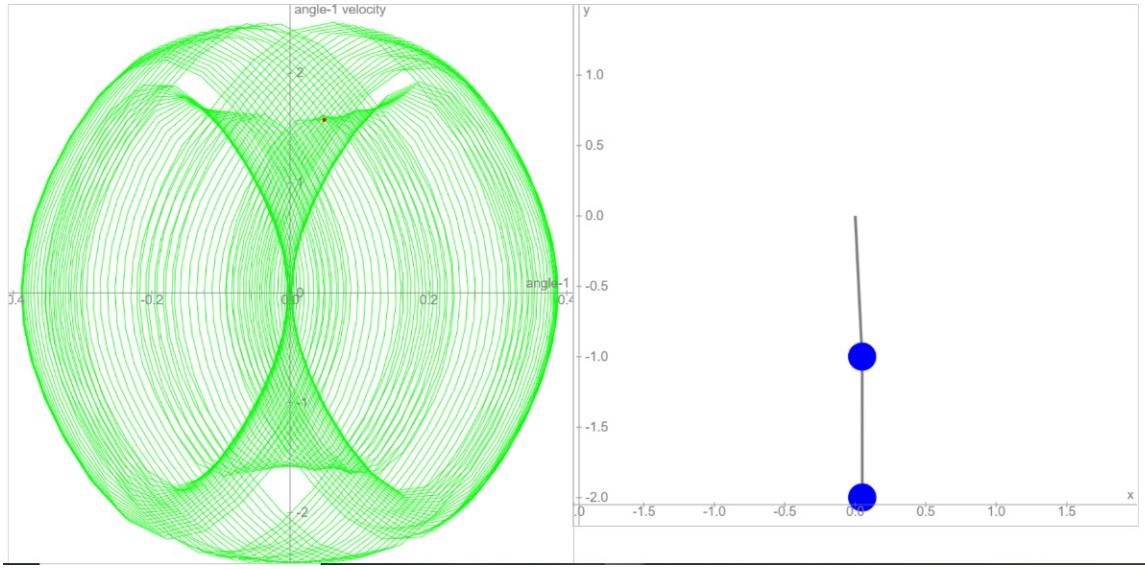
IMT2020065 Shridhar Sharma

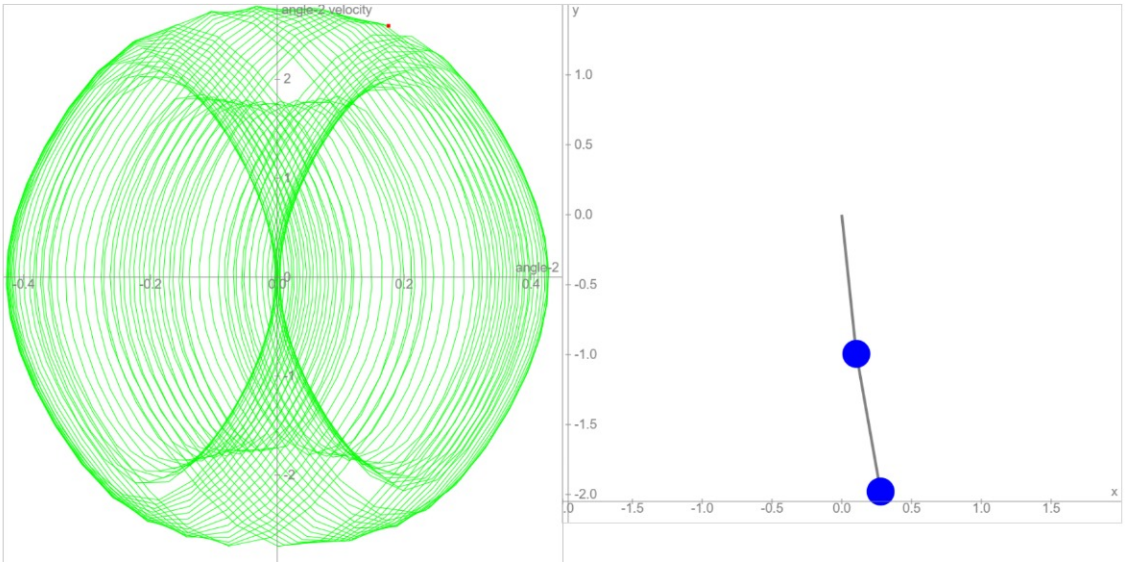


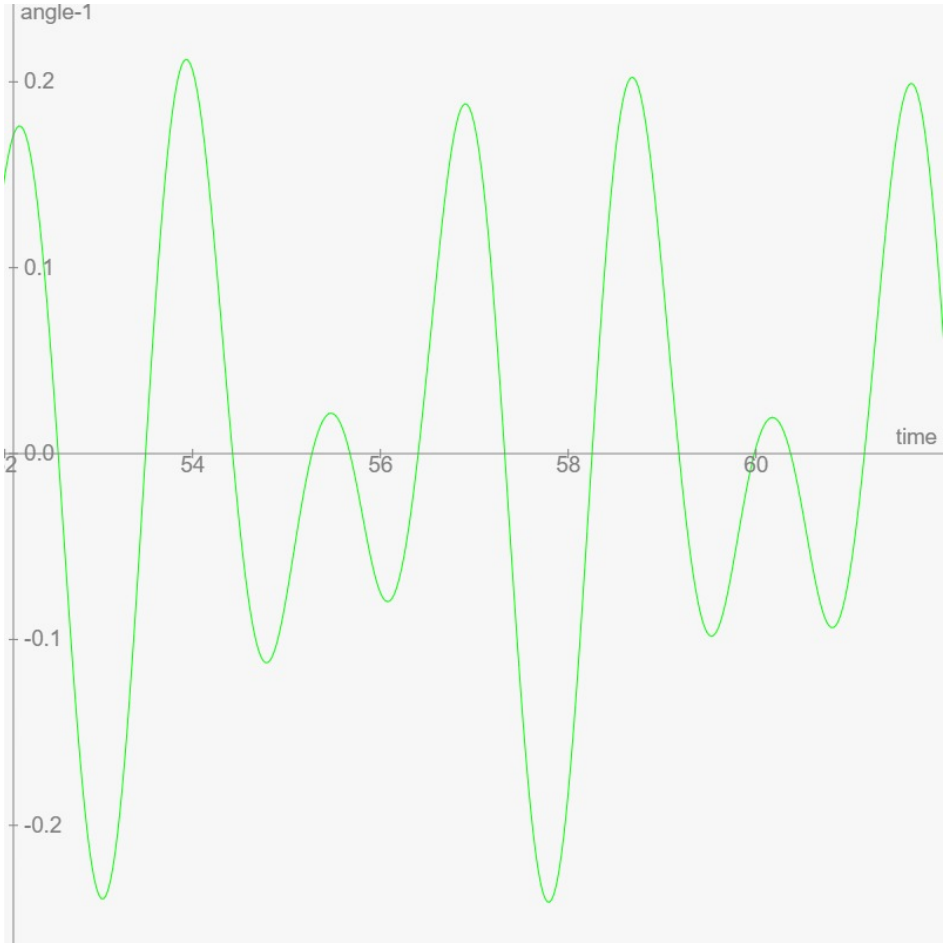
IMT2020065 Shridhar Sharma - ($d\,\theta_1/dt\ vs\ \theta_1$) and ($d\,\theta_2/dt\ vs\ \theta_2$)



IMT2020553 Abhinav Mahajan



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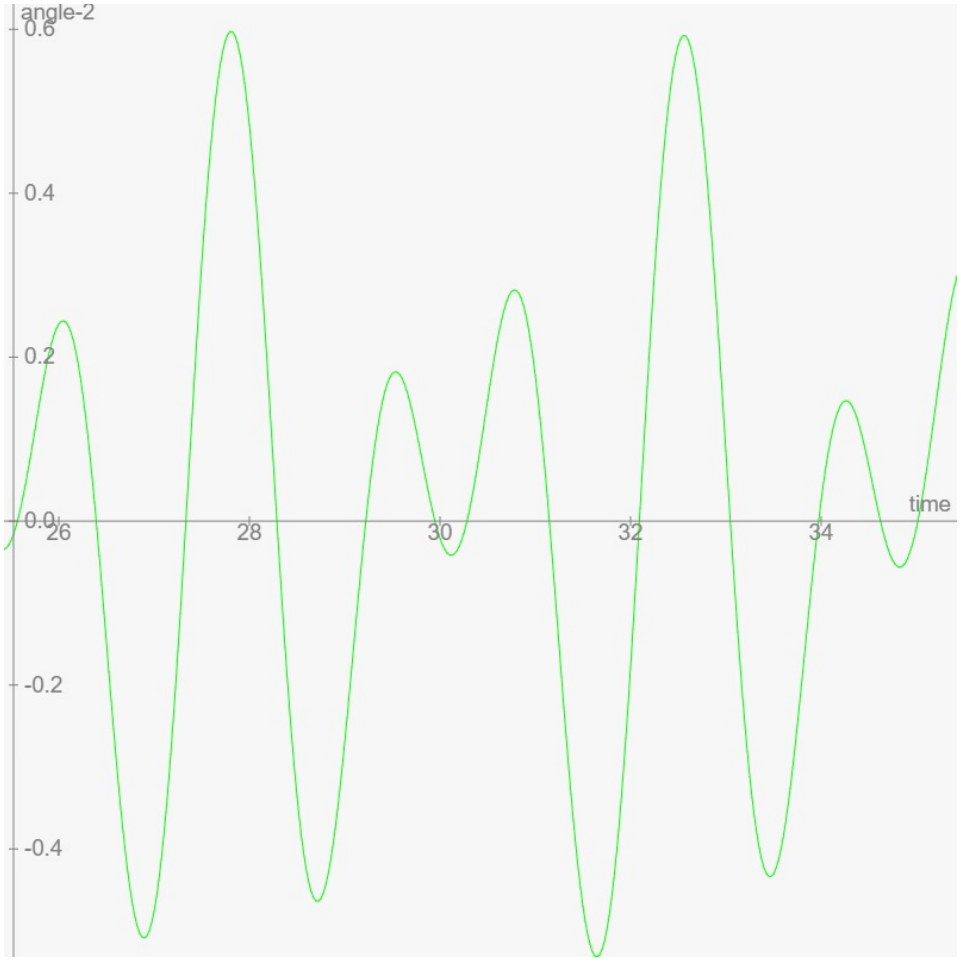
56
58
60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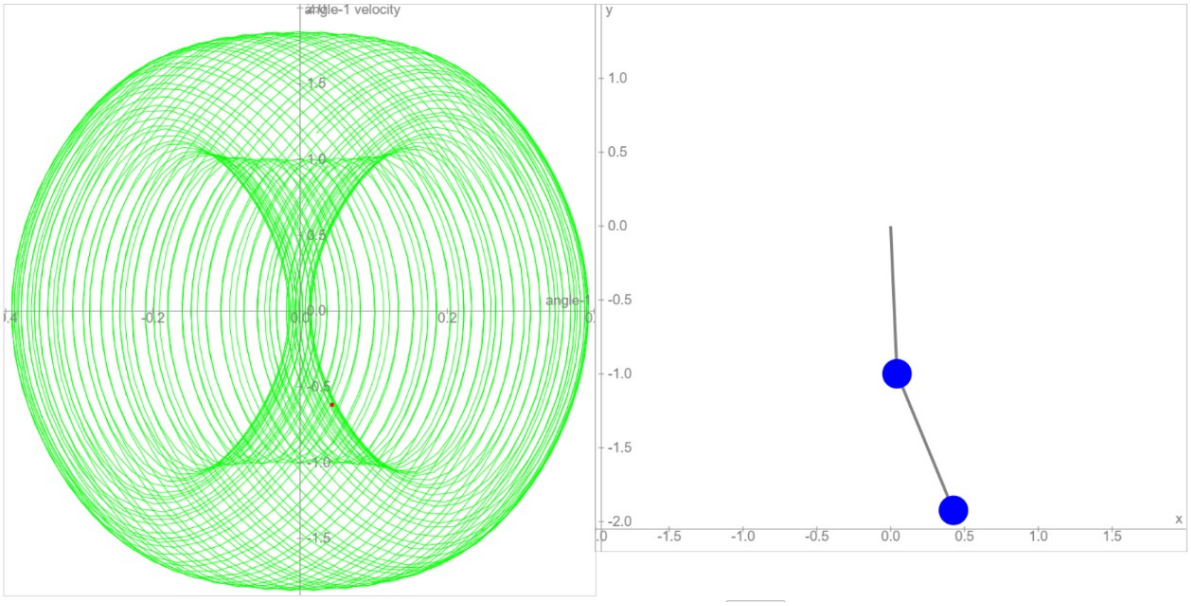
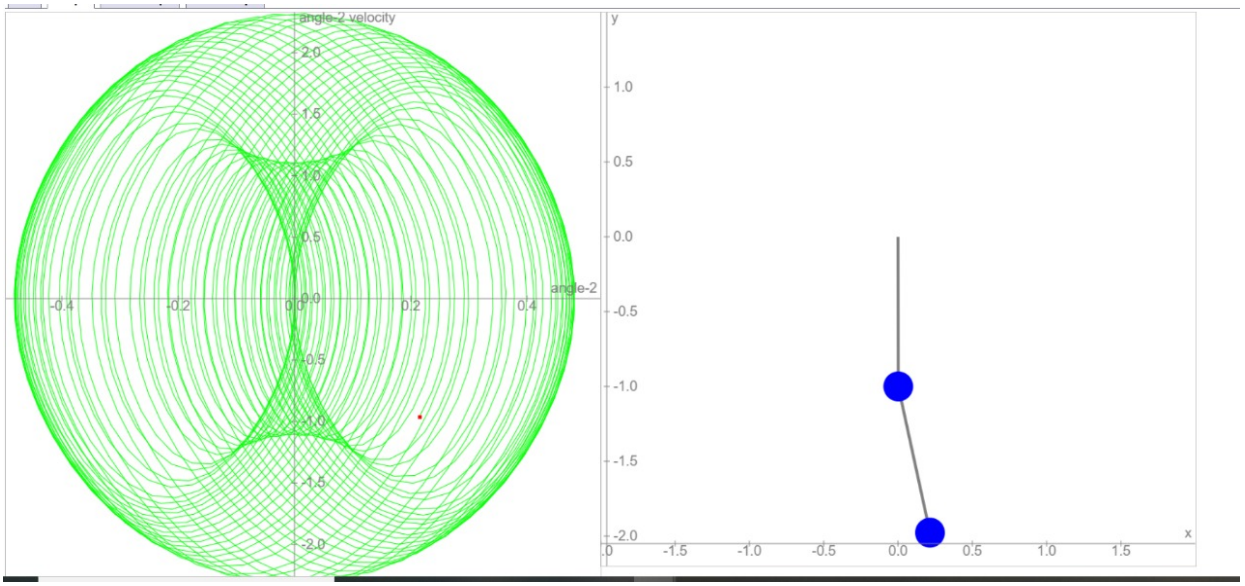
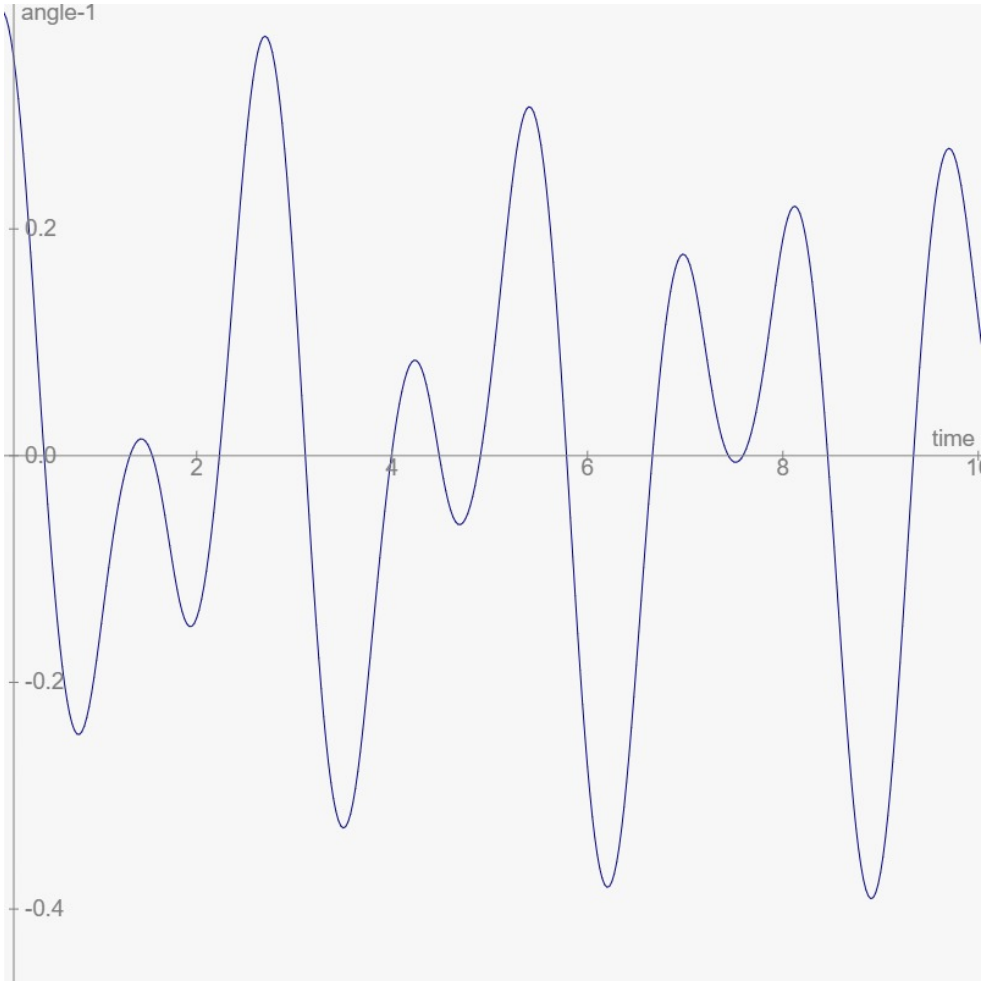
IMT2020539 Shaurya Agrawal



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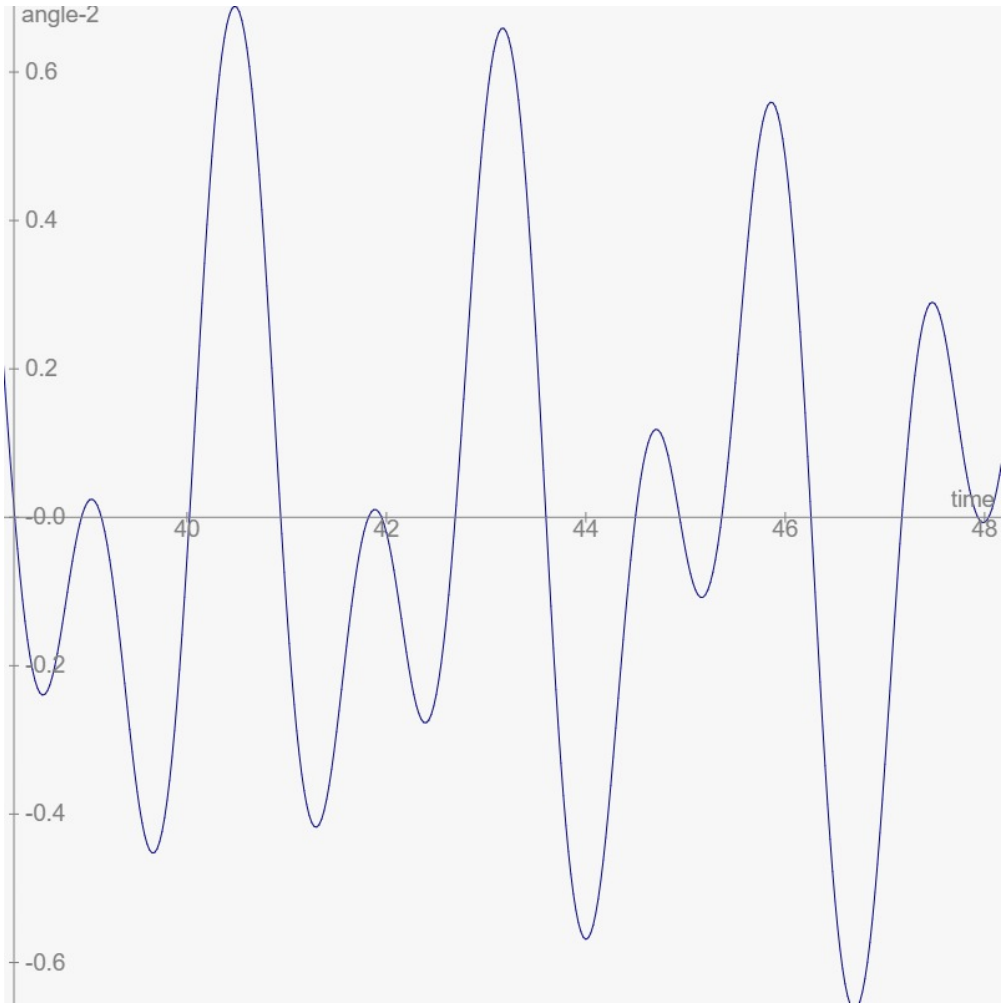
time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-0.4
-0.6
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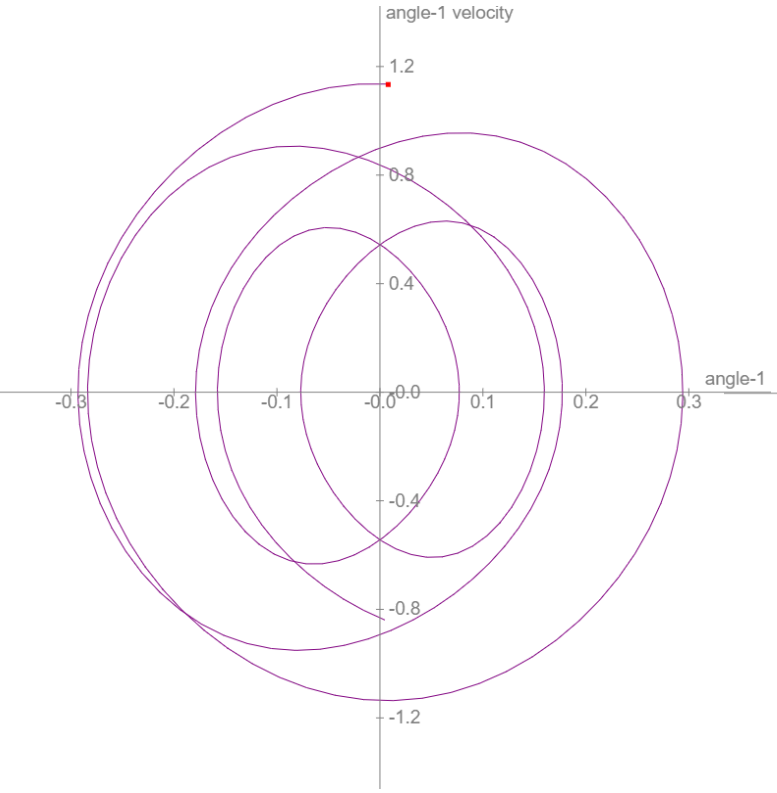
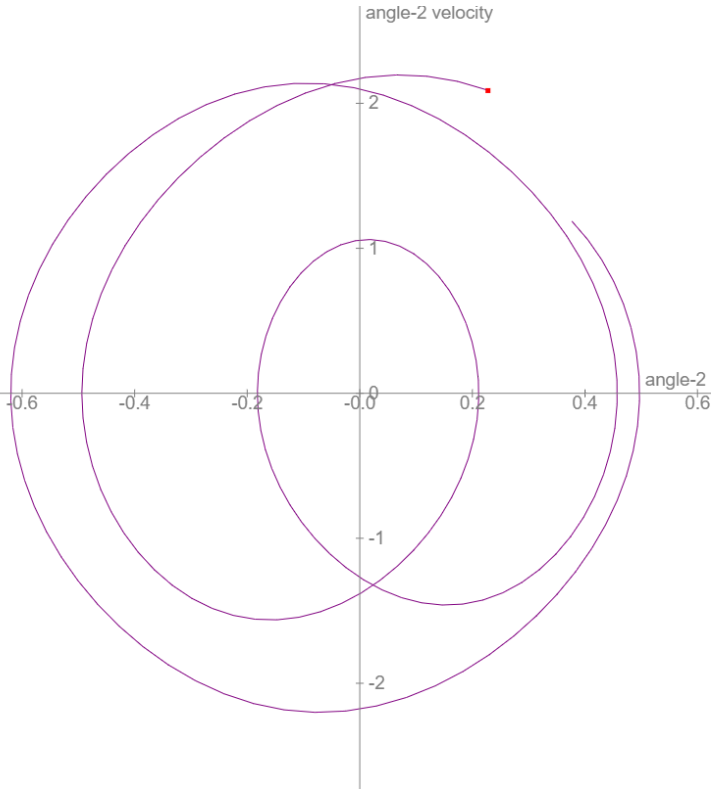
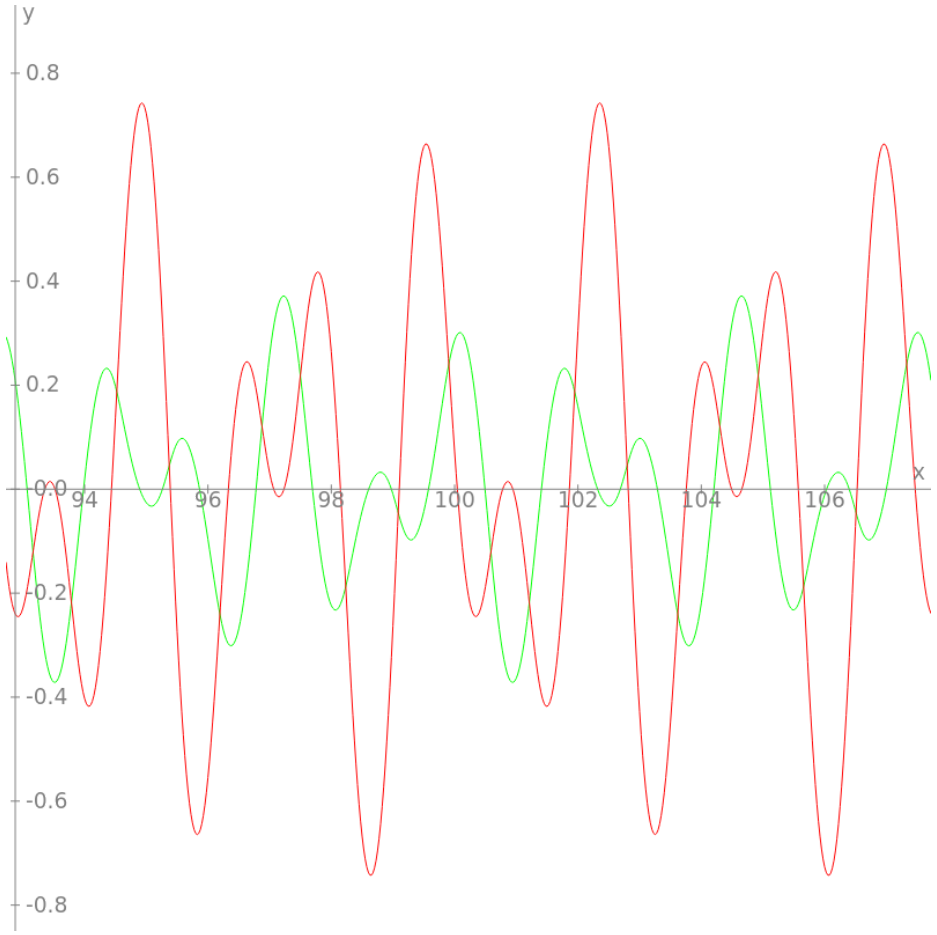
48
time

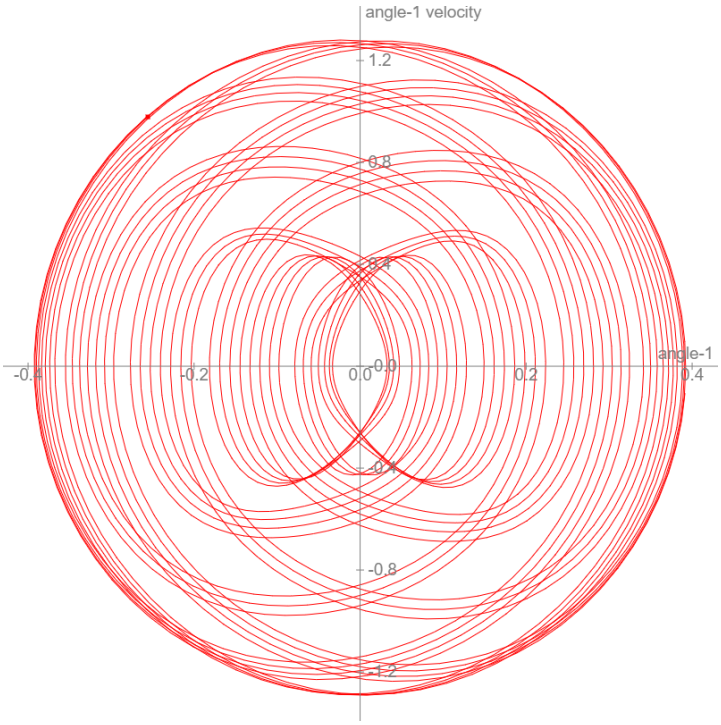
IMT2020085 Harshadeep Donapati (m = 0.25 , Green - m_1, Red - m_2)

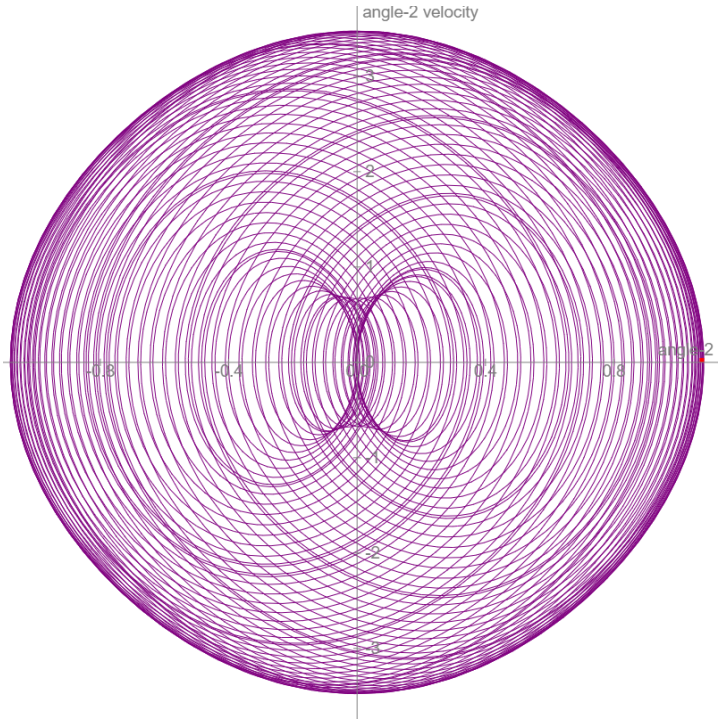


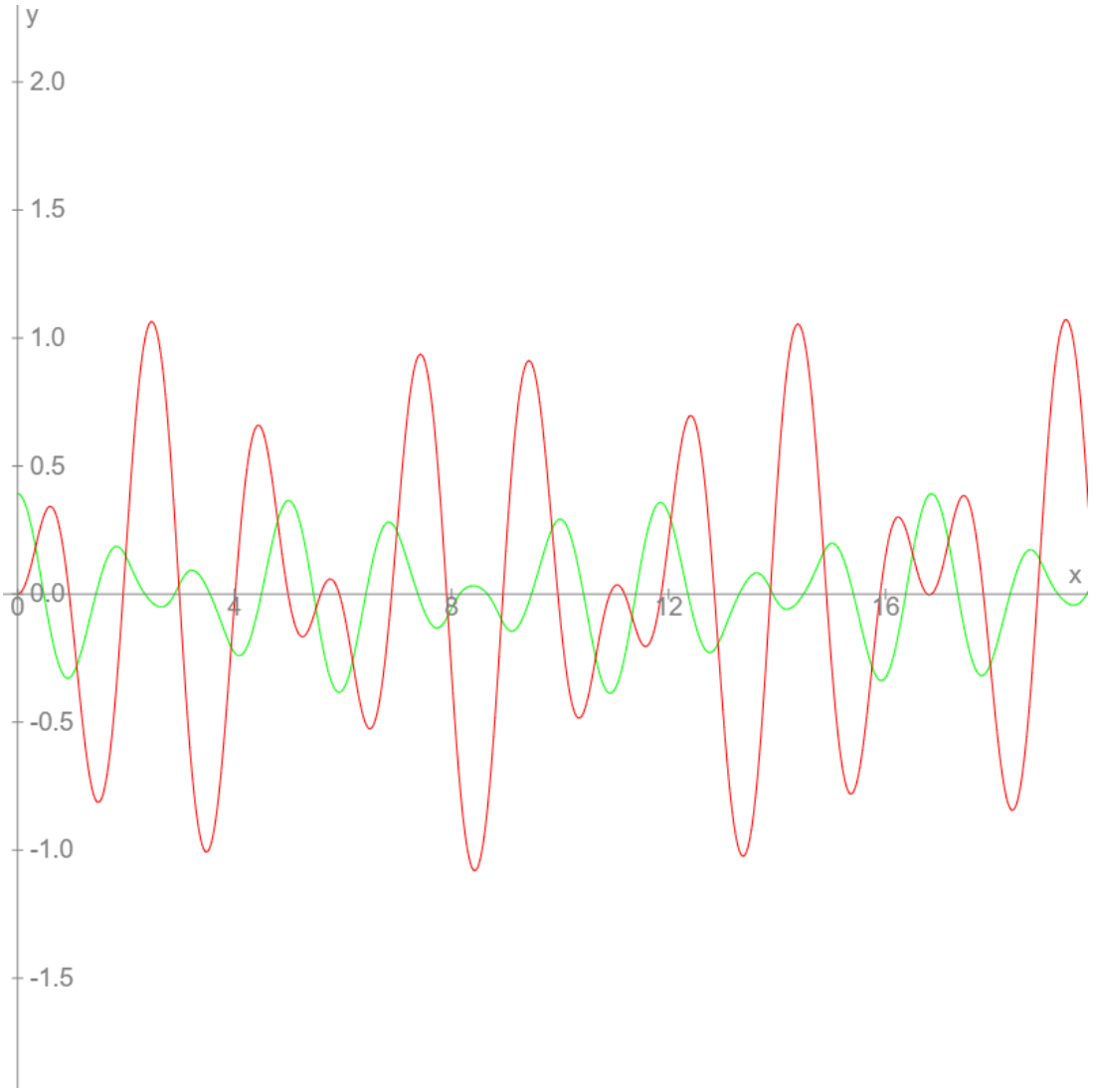




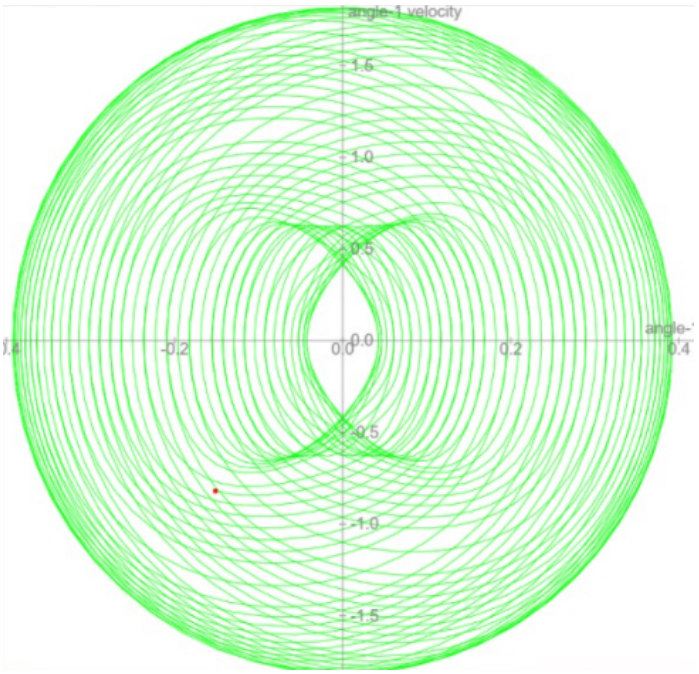
IMT2020126 Ayushmaan Singh

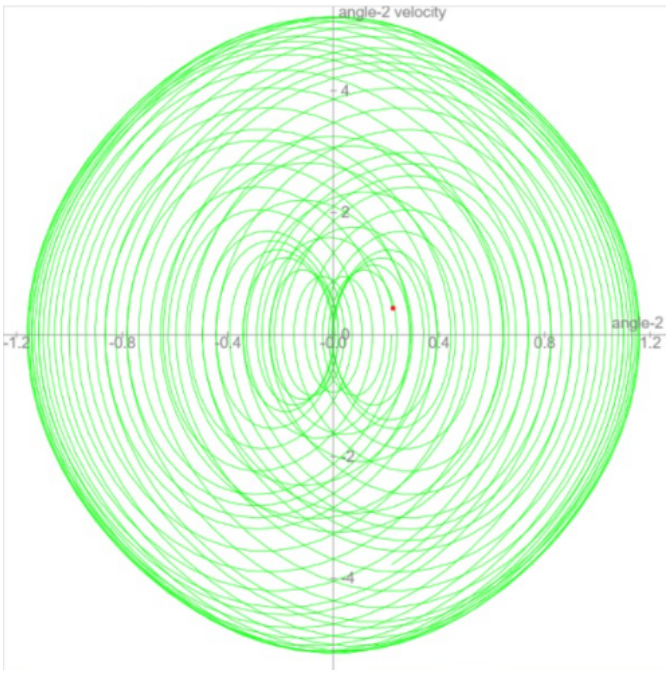


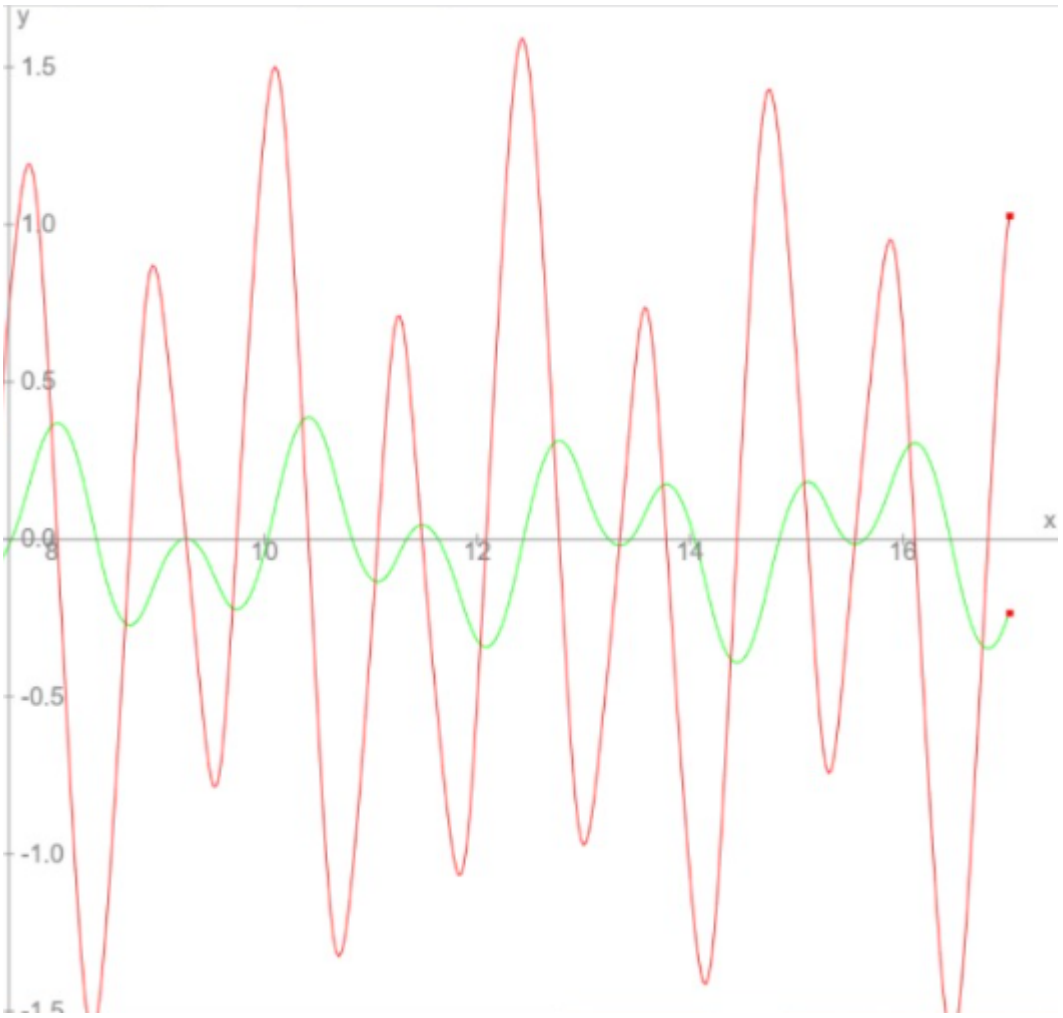




IMT2020057 Vishnutha Sheela

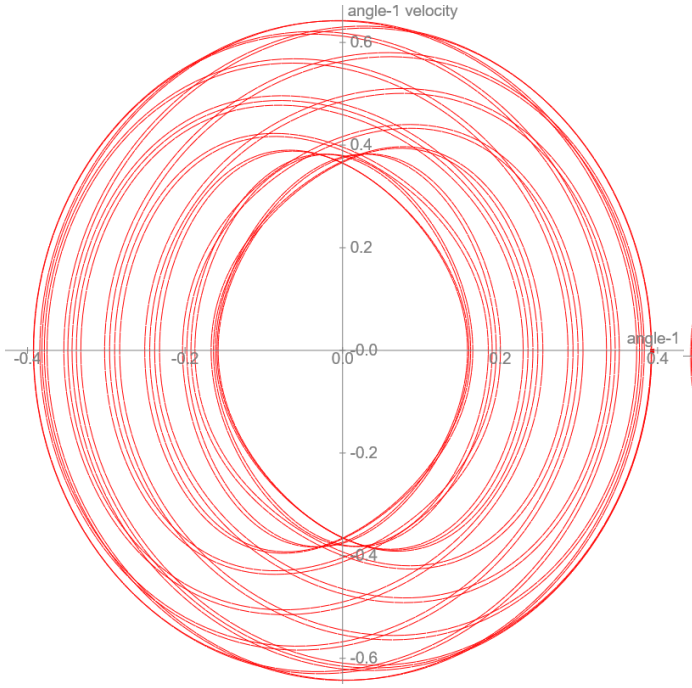


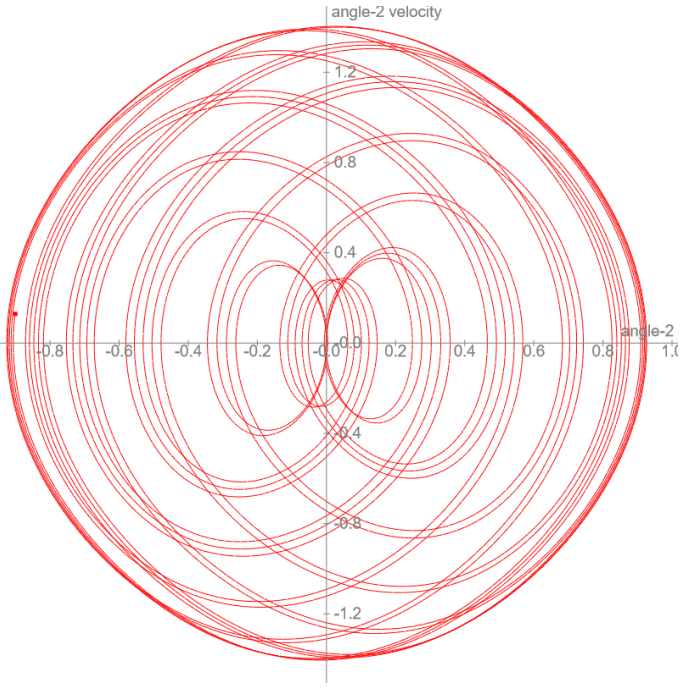


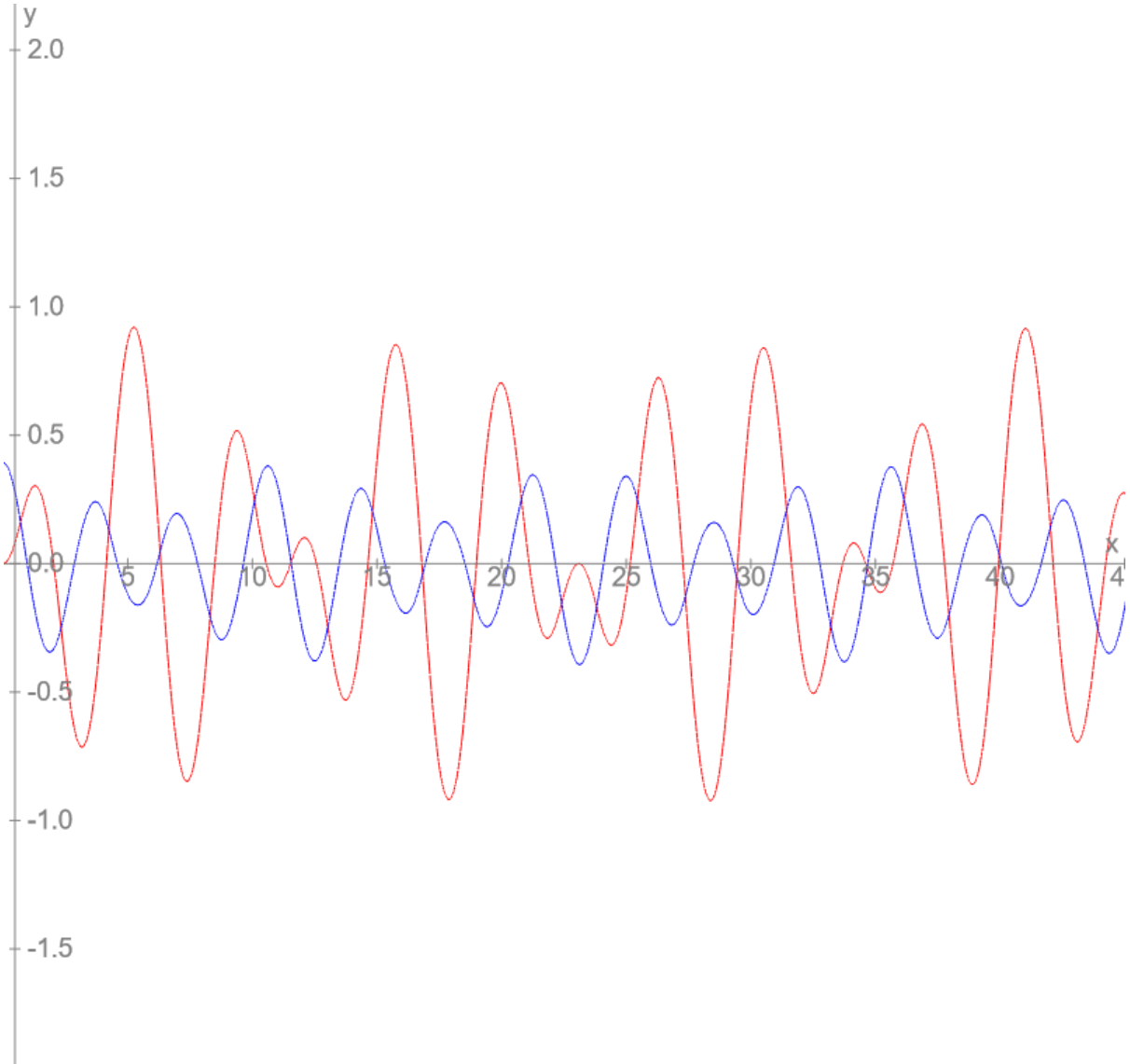


4b) (m = 0.125)

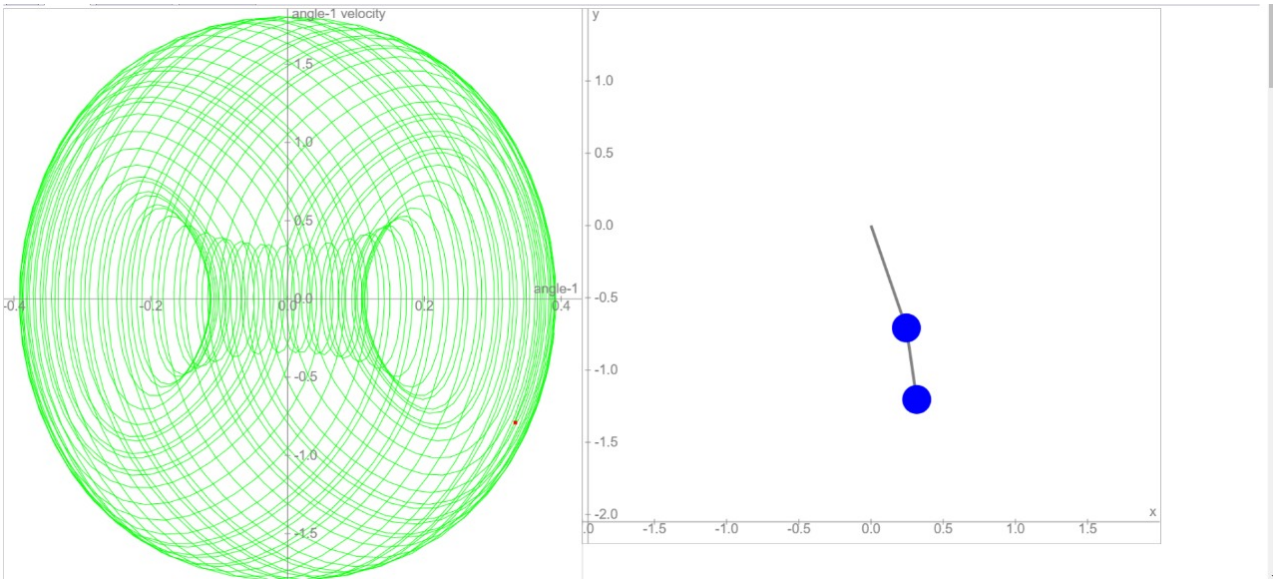
IMT2020065 Shridhar Sharma (I = 1.25)

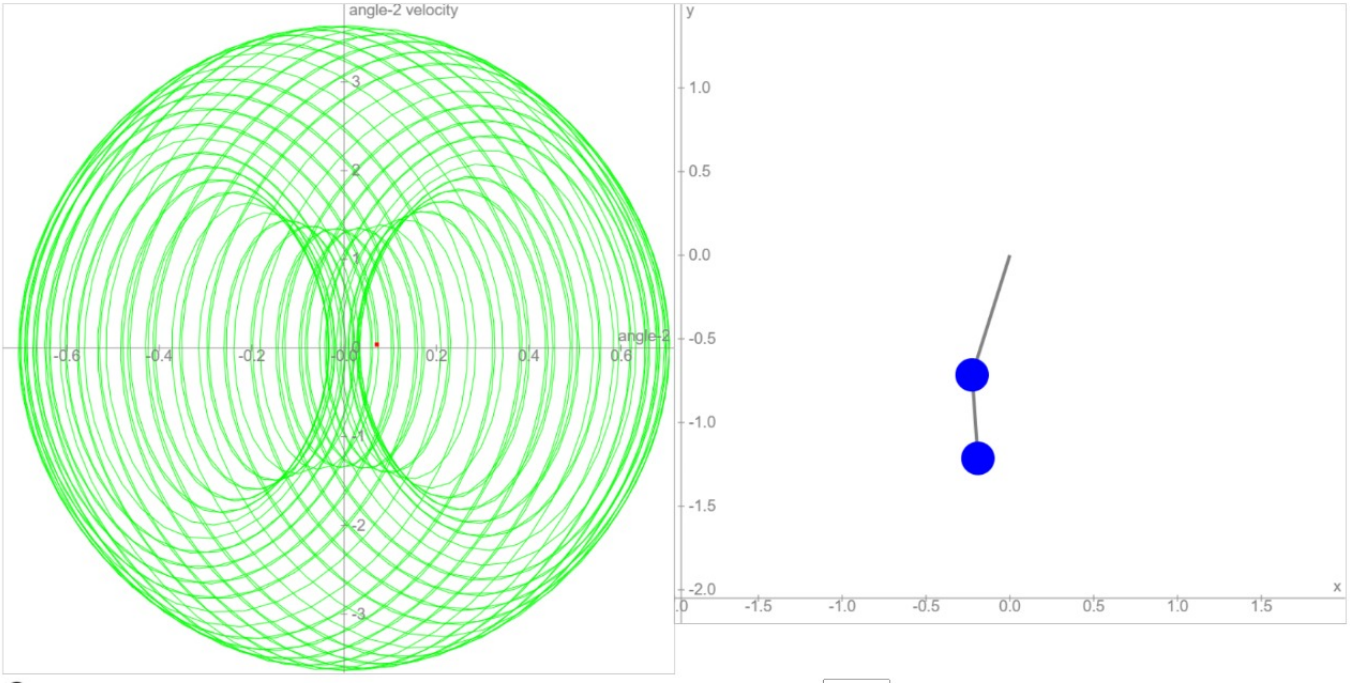


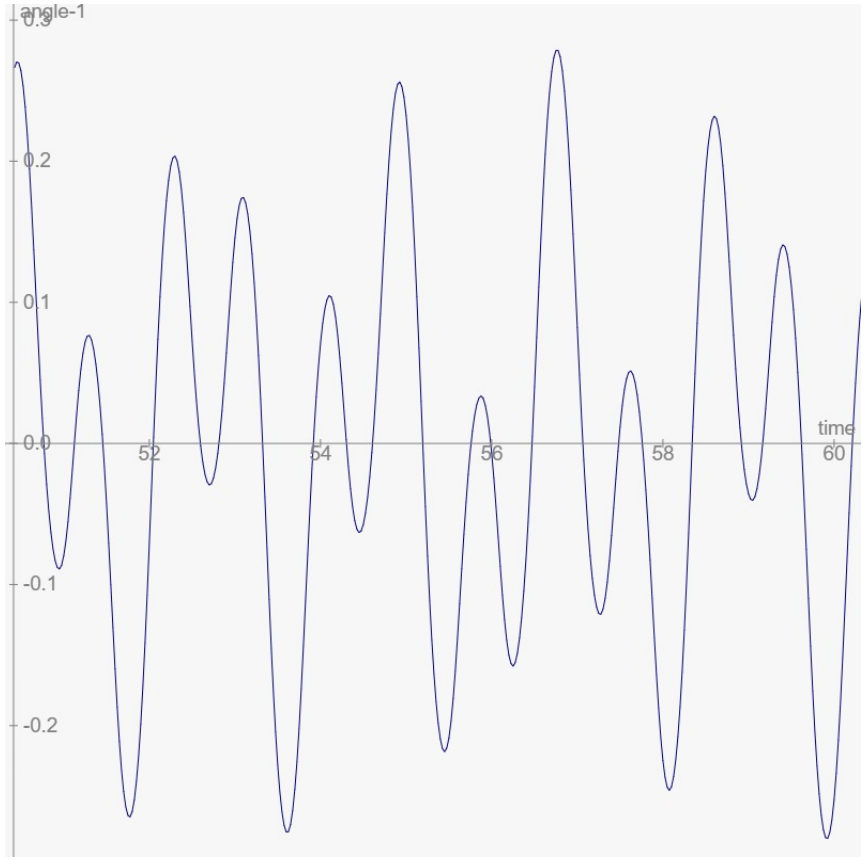


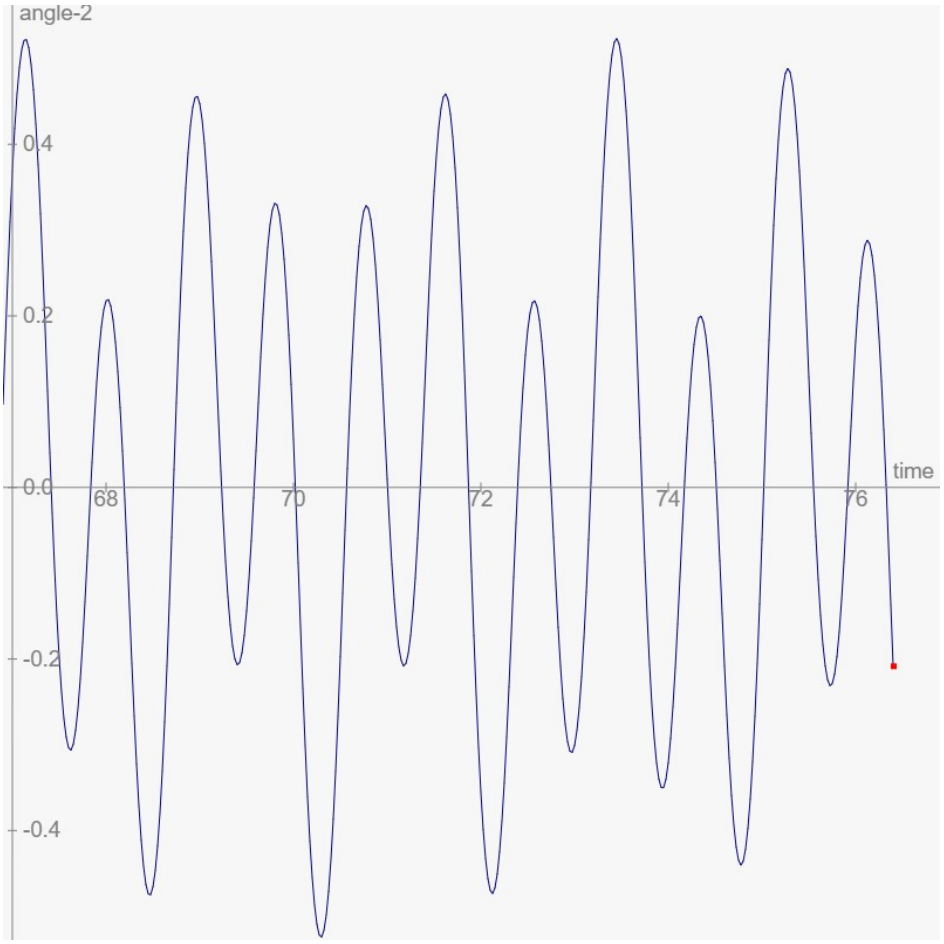


IMT2020553 Abhinav Mahajan (l = 1.5)

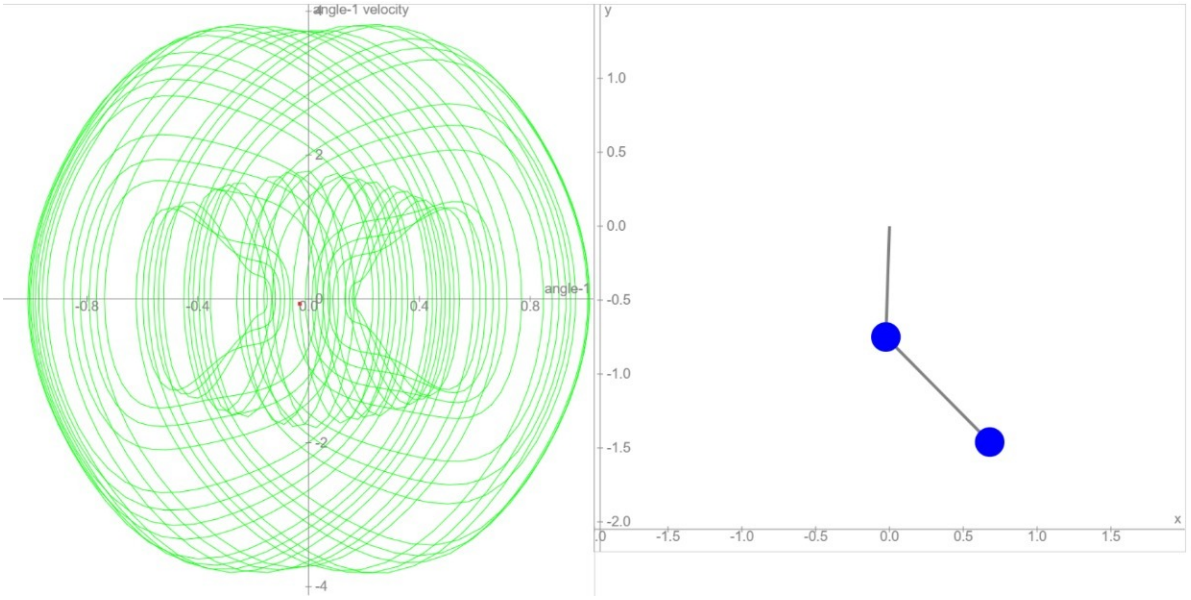


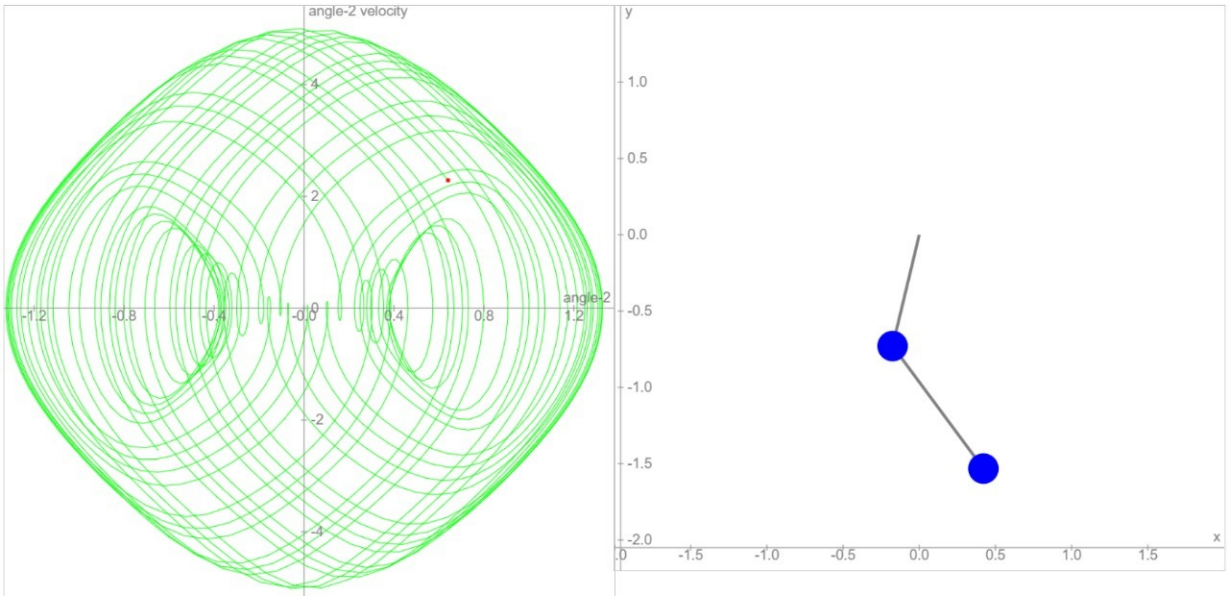


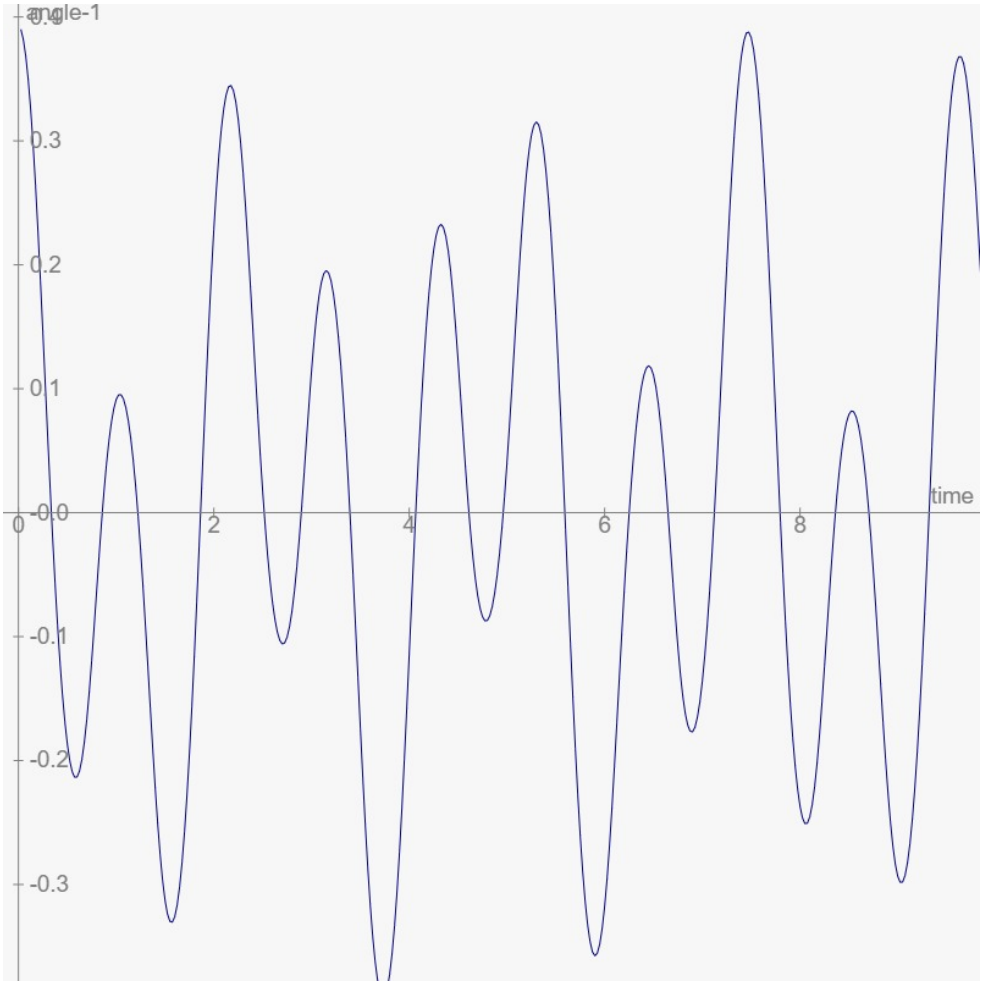

angle-1
0.3
0.2
0.1
0.0
-0.1
-0.2
52
54
56
58
60
time

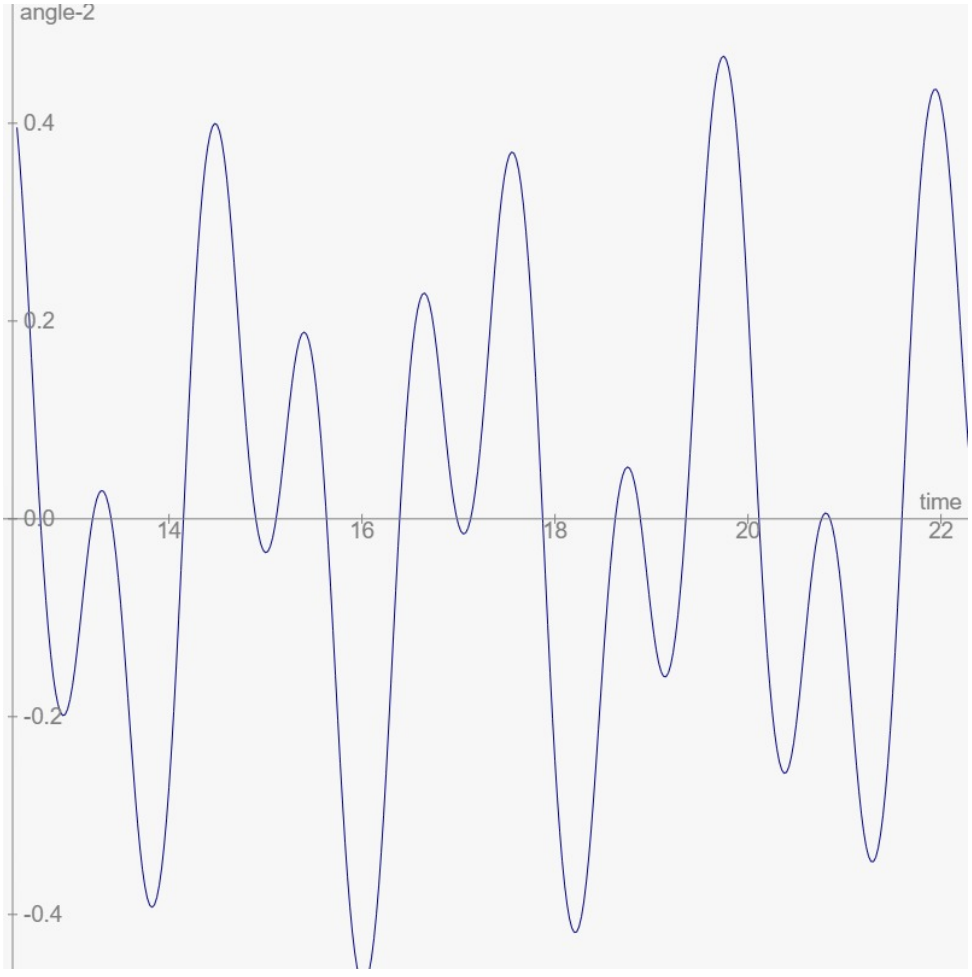

angle-2
0.4
0.2
0.0
-0.2
-0.4
68
70
72
74
76
time

IMT2020539 Shaurya Agrawal (I = 0.75)

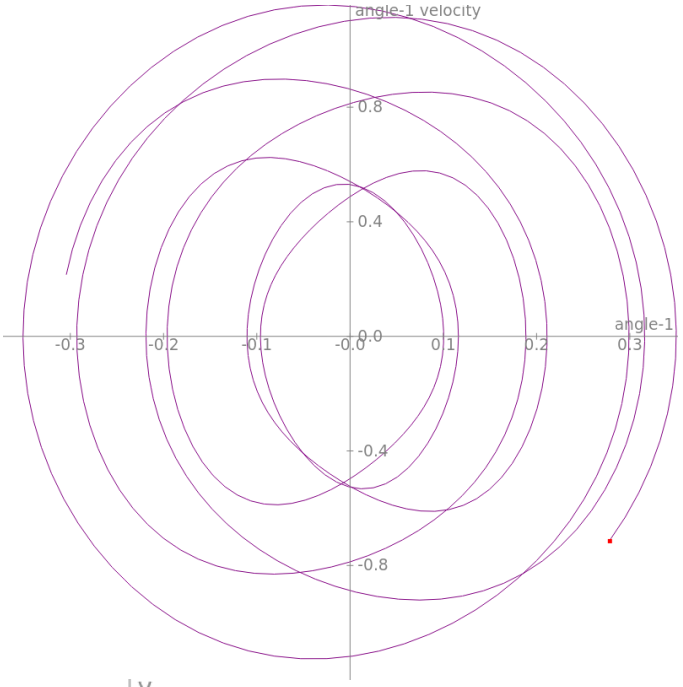


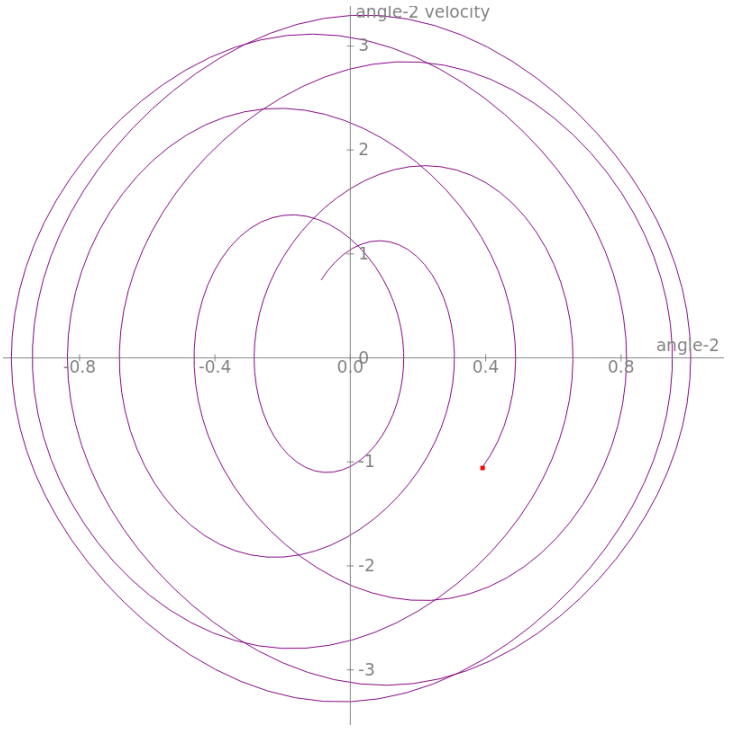


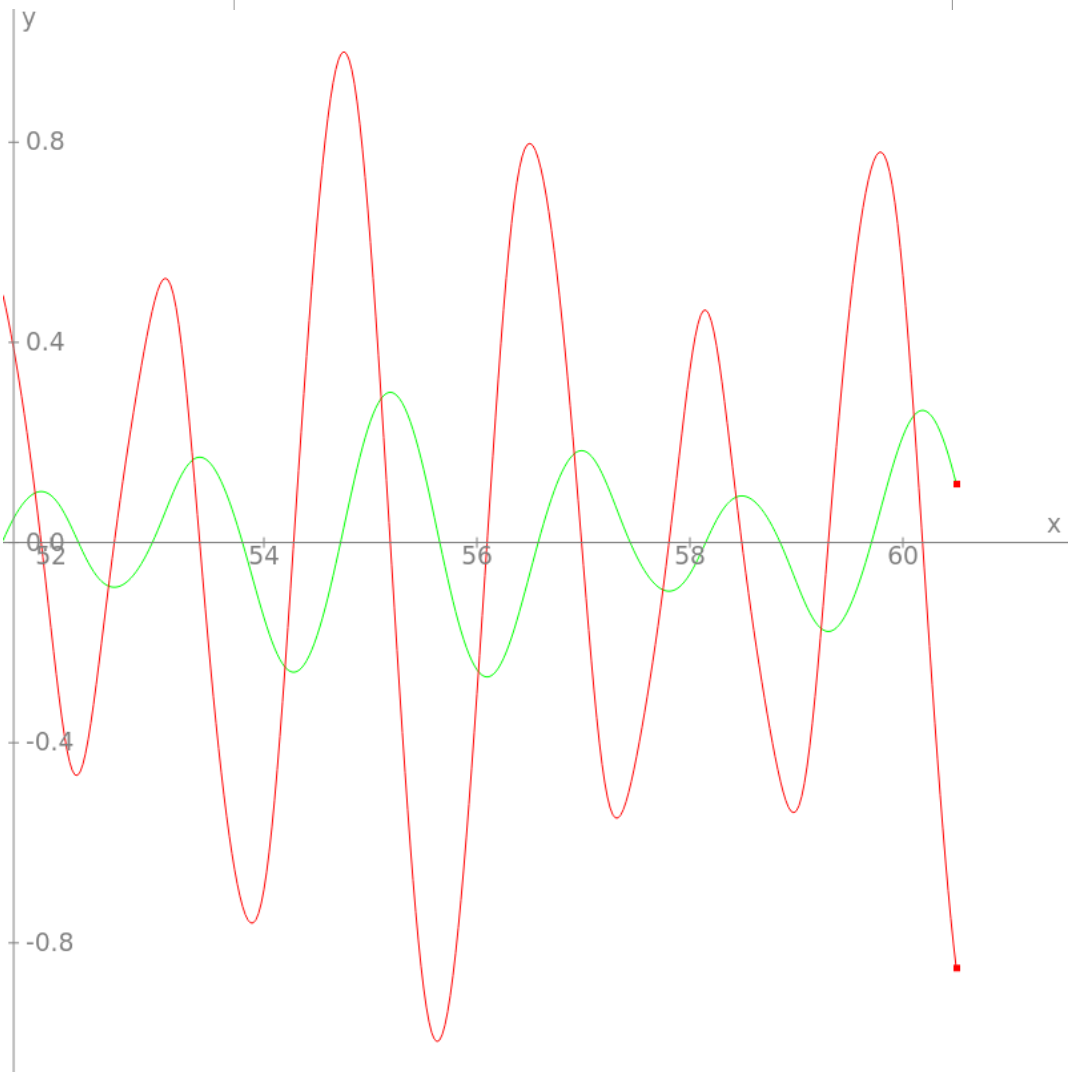

angle-1
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
0
2
4
6
8
time


angle-2
0.4
0.2
0.0
-0.2
-0.4
14
16
18
20
22
time

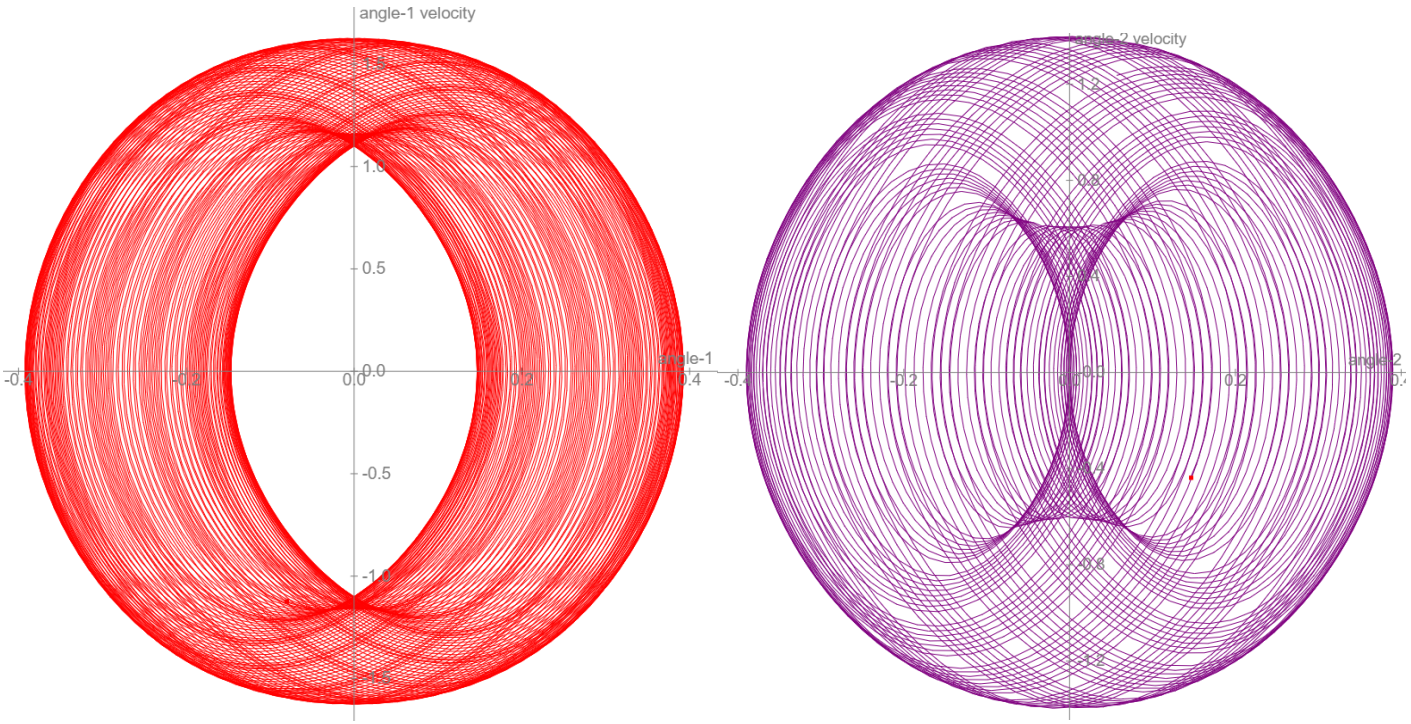
IMT2020085 Harshadeep Donapati (l = 1, Green - m_1, Red - m_2)

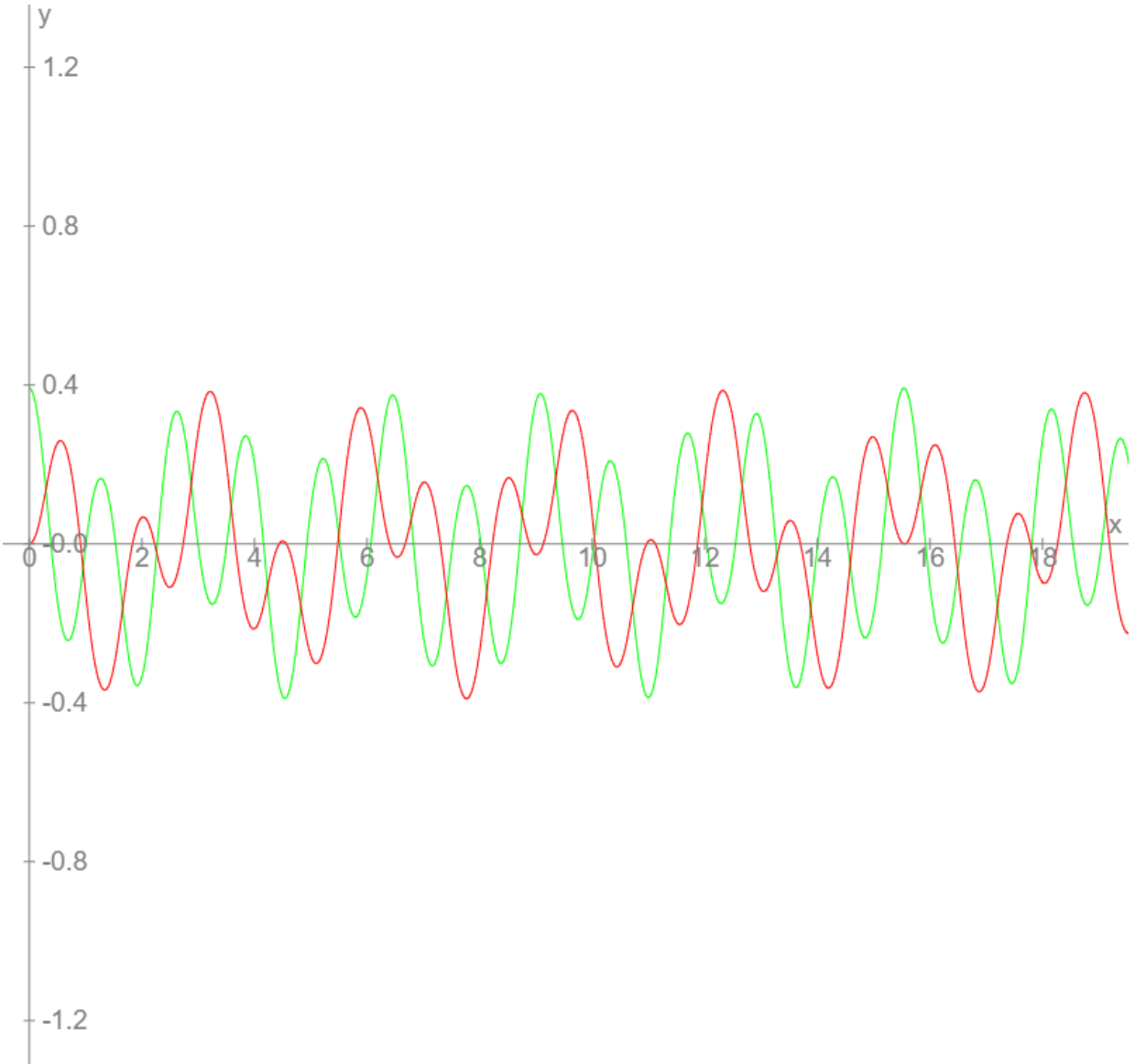




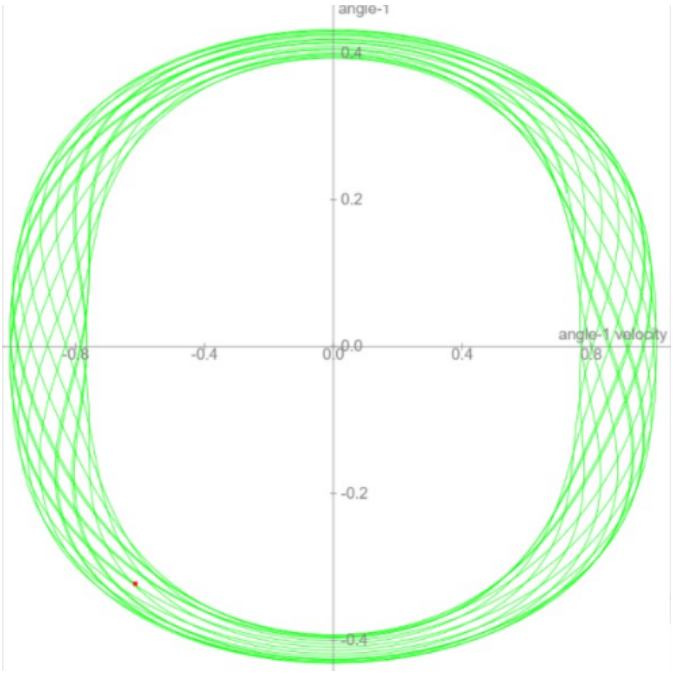


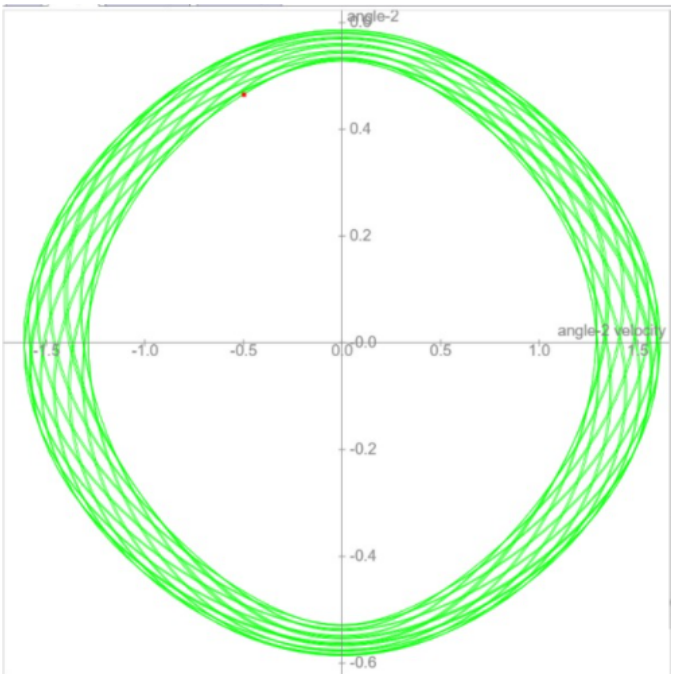
IMT2020126 Ayushmaan Singh (l = 1.75)

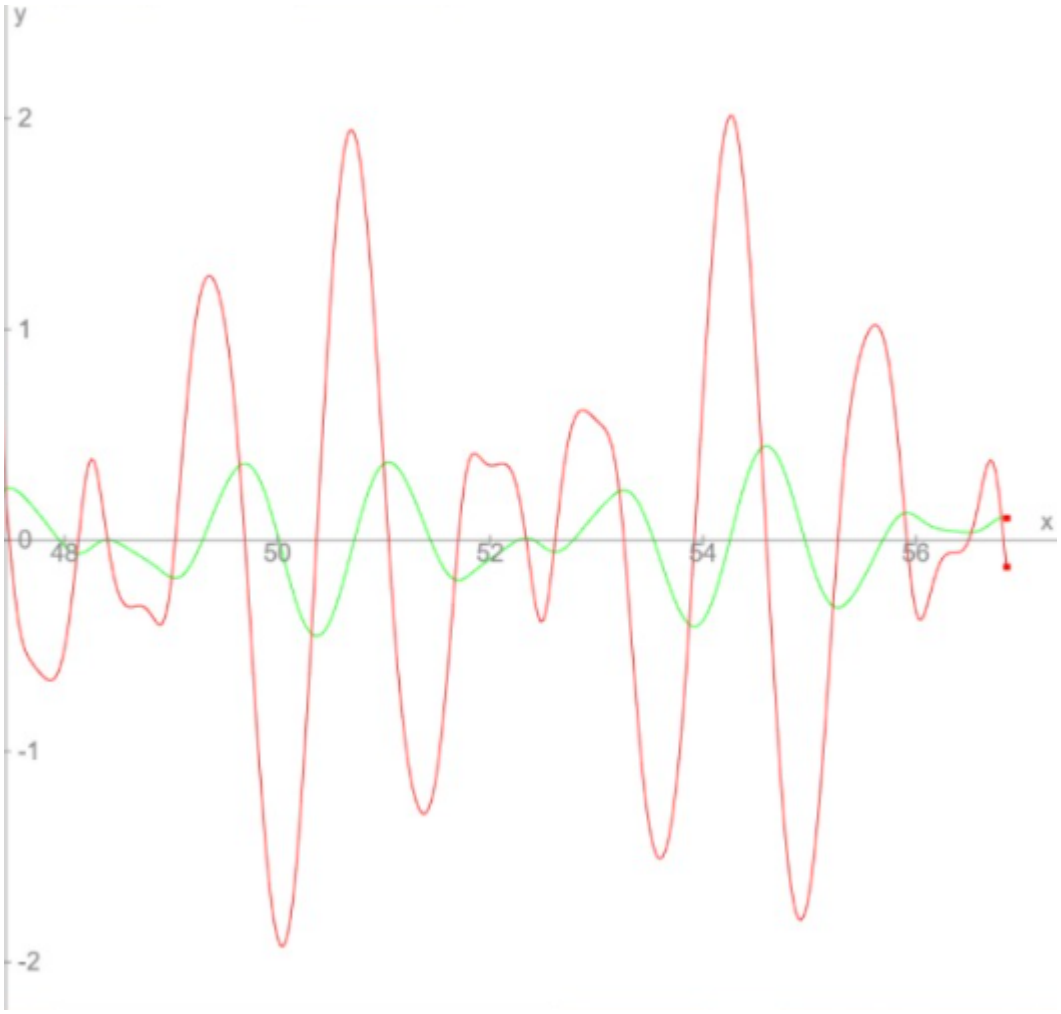




IMT2020057 Vishnutha Sheela (l = 0.5)

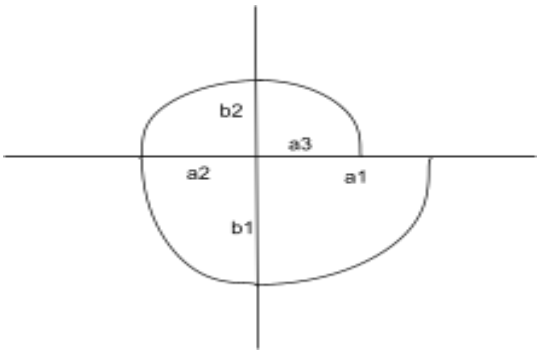






Calculations and Results :

Question 3 :



Percentage decrease in area per cycle = $\frac{4\,a1\,b1 - (\,a1\,b1 + a2\,b1 + a2\,b2 + a3\,b2)}{4\,a1\,b1} \times 100$

1. Shridhar Sharma (Damping = 0.500) -

$$\% \text{ decrease} = \frac{4\,(2.6) - (\,2.6 + 0.76 + 1.52 + 1.14)}{4\,(2.6)}$$

$$= 42.115\ \%$$

2. Abhinav Mahajan (Damping = 0.200) -

$$\% \text{ decrease} = \frac{4\,(3) - (\,2.8 + 2.52 + 2.34 + 2.08)}{4\,(3)}$$

$$= 18.834\ \%$$

3. Shaurya Agrawal (Damping = 0.300) -

$$\% \text{ decrease} = \frac{4\,(3) - (\,2.8 + 2.5 + 2.16 + 1.68)}{4\,(3)}$$

$$= 23.834\ \%$$

4. Harshadeep Donapati (Damping = 0.500) -

$$\% \text{ decrease} = \frac{4\,(0.029) - (\,0.0029377 + 0.000638 + 0.001738 + 0.001422)}{4\,(0.029)} \times 100$$

$$= 42.679\ \%$$

5. Ayushmaan Singh (Damping = 0.250) -

$$\% \text{ decrease} = \frac{4\,(2.8) - (\,2.8 + 2.464 + 2.156 + 1.862)}{4\,(2.8)}$$

$$= 17.125\ \%$$

6. Vishnutha Sheela (Damping = 0.50) -

$$\% \text{ decrease} = \frac{4\,(0.7*2.23) - ((0.7+0.65)*2.23 + (0.65+0.53)*1.86)}{4\,(2.6)}$$

$$= 40.535\%$$

Sources of errors :

Environmental errors
Inconsistencies in the surroundings may affect the workings of the experiment, resulting in errors in the readings. We have performed the procedures in a setup where the effects of such external causes is minimised. Effects of the windy atmosphere have been avoided to the best of our abilities. The resulting outcomes can be considered fairly independent of such changes in the environment.

Instrumental errors
This occurs when the instruments used have faulty scaling and the measurements taken get distorted by the equipment. In this experiment, care has been taken to avoid these errors and while recording measurements. For the measurement of angles with respect to time, we have relied wholly on the PhyPhox application, so the accuracy is limited. This limited accuracy is carried over to the phase portraits since they are based on the same measurements.

Estimation errors
These occur in reading recorded values, like on a scale. Efforts have been made to keep the measurements consistent between all recordings. Most of the avoidable sources of errors have been considered to reduce the final amount of error in the calculations. Least count errors stemming from the resolution of the scale and application measurements have been accounted for in the calculations too.