MAE 263F Fall 2025 Homework_4

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I. REPORT DELIVERABLES

A. Part (1): Single Load Level. Use F = Fchar. Run the simulation to steady state and record $\delta * z$ .In your report, include at least five snapshots of the helix centerline at different simulation times. Use axis equal (or its equivalent) and label the x, y, and z axes with units. On each snapshot, clearly indicate the simulation time by placing a text label directly on the figure. For example, if the snapshot corresponds to t = 5 s, then include a visible annotation such as "t = 5 s" on that snapshot.
Plot time t vs. displacement δz (t) starting from (0, 0). State clearly how you decide that the system has reached steady state. For example, you may choose a simple rule such as: the value of δz (t) changes by less than one percent over a one-second interval. Once you determine that the motion has settled according to your chosen rule, mark the corresponding steady value $\delta * z$ on your time displacement plot.

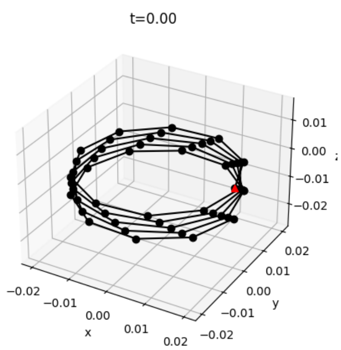


Fig. 1. Helix centerline at t = 0s

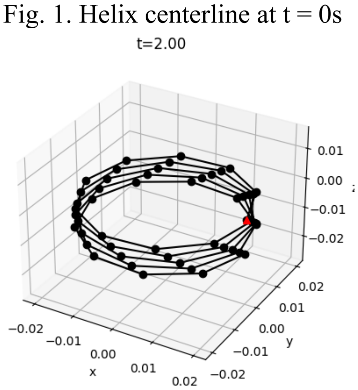


Fig. 2. Helix centerline at t = 2s

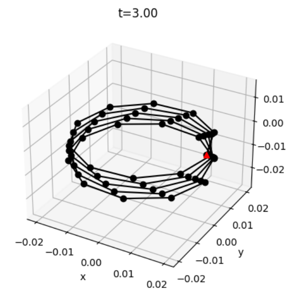


Fig. 3. Helix centerline at t = 3s

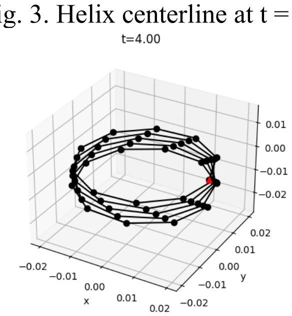


Fig. 4. Helix centerline at t = 4s

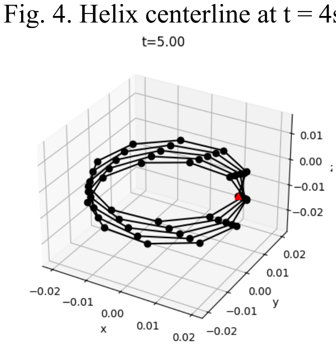


Fig. 5. Helix centerline at t = 5s

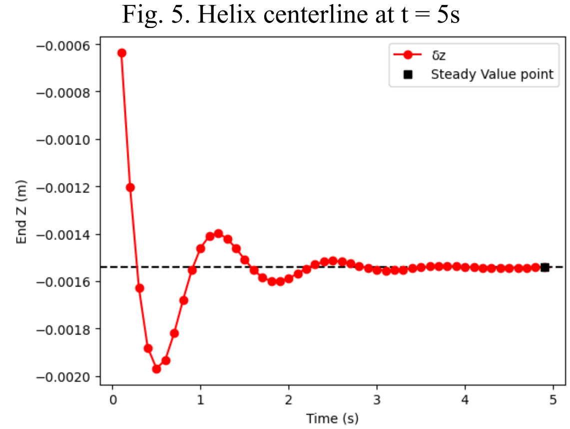


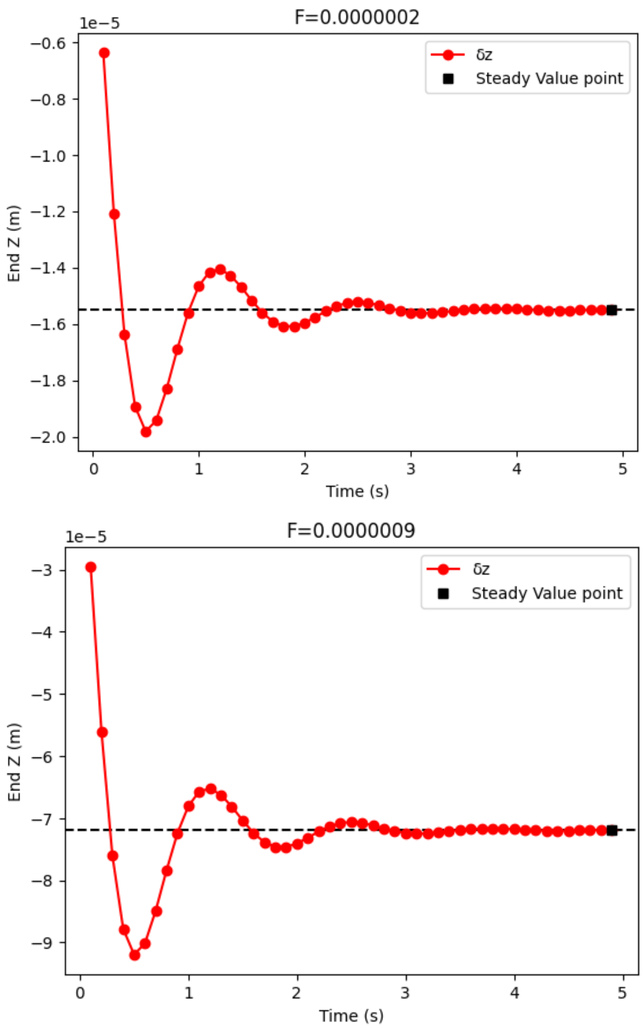
Fig. 6. δz displacement with time till steady state (steady state δz = -0.0013m)

1. The system is determined to be at steady state by evaluating whether the percentage difference RMS values of the current and previous endδz over 1 second intervals is less than .3%. This was chosen due to the sinusoidal basis of the displacement output and to mitigate problems with figuring steady state frequency problems.

```
if timeStep % window == 0:
  rms1 = np.sqrt(np.mean(endZ[timeStep]**2))
  rms2 = np.sqrt(np.mean(endZ[timeStep- window]**

  if abs(rms1 - rms2) / abs(rms1) < 0.003:
    finalT = timeStep
    break
```

B. Part (2): Force Sweep and Linear Fit. Vary the axial force F using logspace (for example, in NumPy) so that the sampled force values range from 0.01 Fchar to 10 Fchar on a logarithmic scale. For each force value, run the simulation to steady state and record the corresponding displacement $\delta{*}z$. Plot the applied force F versus the steady displacement $\delta{*}z$. To extract the linear stiffness k, fit the data in the small-displacement region using the model $F = k\,\delta{*}$



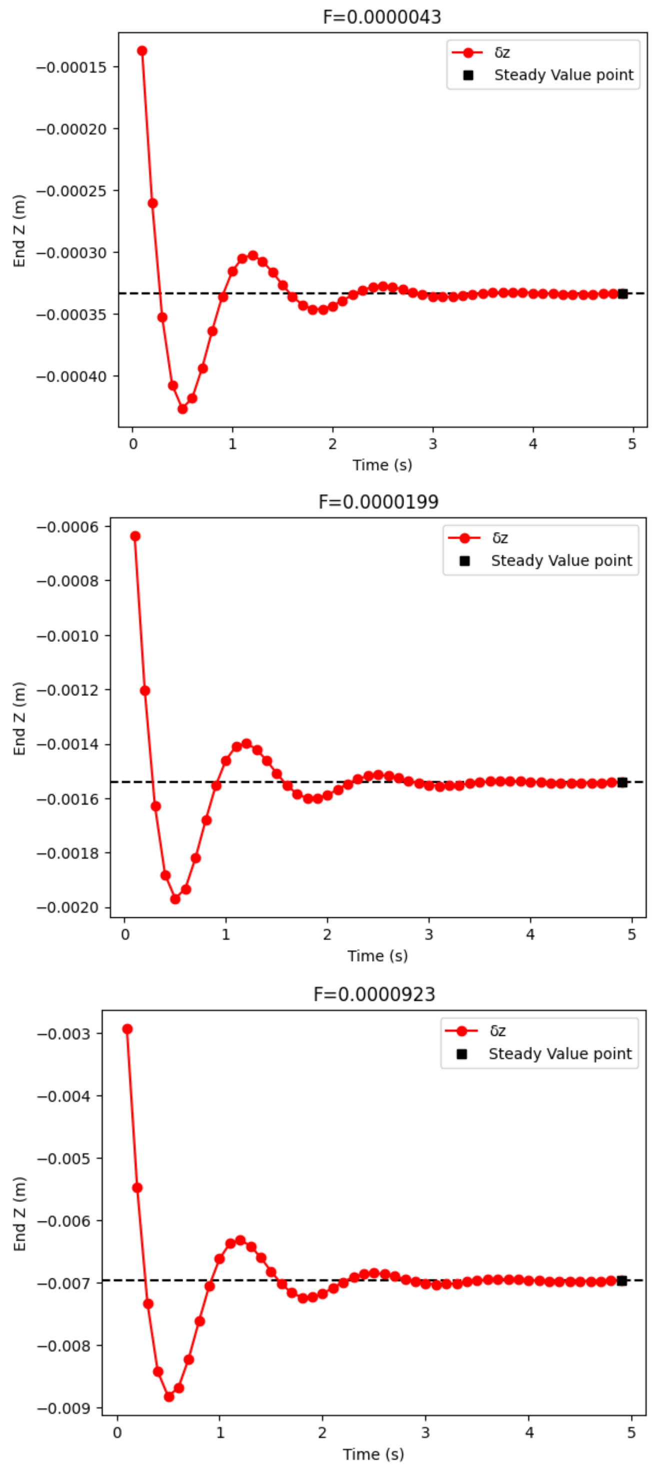


Fig. 7. δz displacement with time till steady state over Force Sweep

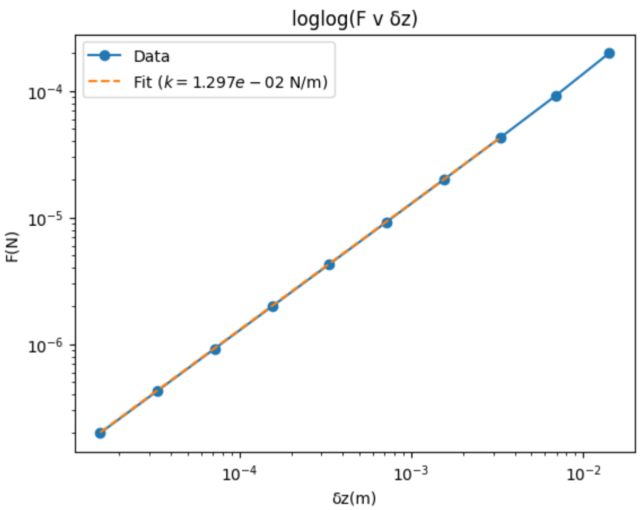


Fig. 7. Loglog plot of Force vs δz displacement to fit for stiffness in linear regime

C. Part (3): Diameter Sweep vs. Textbook Trend.

Textbooks often approximate the axial stiffness of a close-coiled helical spring using the formula $k_{text} = G d^4 / (8 N D^3)$, (1) which is valid only in the linear, small-deflection regime where the spring behaves like a torsion-dominated structure. In this part, you will examine how your DER-based numerical stiffness compares to this classical prediction. Vary the helix diameter D between 0.01 m and 0.05 m using at least ten values, and keep all other parameters (d, p, N, E, ν) fixed. For each chosen D, run your DER simulation as in Part (B) to obtain the linear stiffness k as a function of D. Make a plot with horizontal axis G d4/(8 N D3) and vertical axis k. On the same plot, draw the textbook relation in Eq. 1 (i.e., a straight line of slope 1 through the origin) for reference. Discuss the trends you observe in your results. The goal of this part is not to obtain exact numerical agreement with the textbook formula. You should not expect quantitative agreement between your DER simulations and the classical expression. Instead, focus on whether the qualitative behavior matches the expected trend. For example, as the helix diameter D increases, the spring becomes more flexible and the axial stiffness k decreases. Your discussion should compare this qualitative trend with the textbook prediction and comment on any deviations

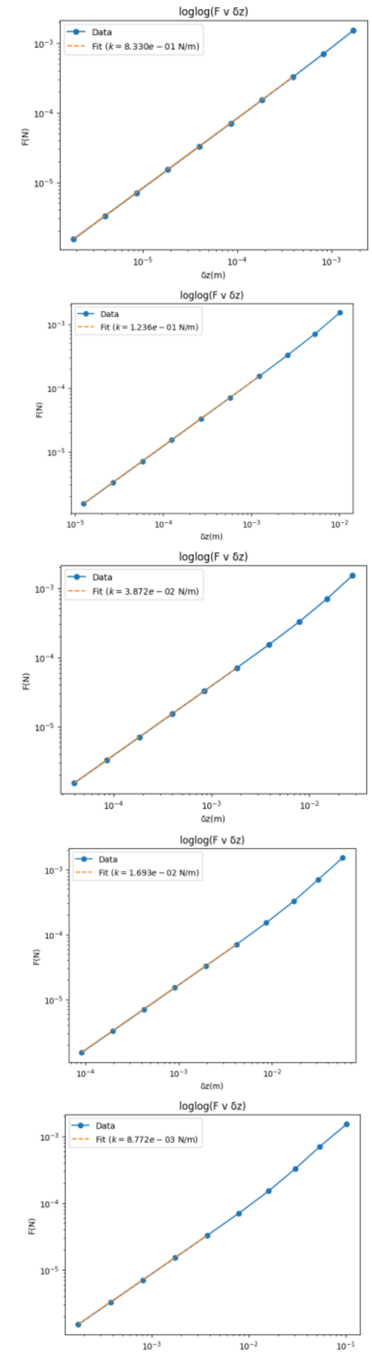


Fig. 12. Loglog plot of Force vs δz displacement to fit for stiffness in linear regime for 0.01D to 0.05D

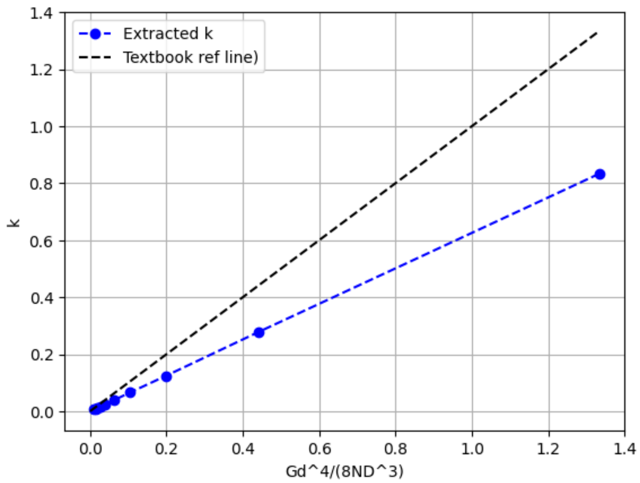


Fig. 13. k vs Gd^4/(8ND^3) with textbook reference line (x=y)

1. Through the above plot we do indeed not see agreement between the DER simulation and textbook formula, where as D increases, k is less than what the formula states. This makes sense though in that the stiffness decreases overall as the diameter gets wider which is in the right direction as the textbook formula is proportional to 1/D^3. The difference in simulation could arise from the fact that the spring itself is being approximated with line segmetns and are not perfectly circular. Additionally relatively large timesteps are utilized in the simulation as we sweep the diameter and forces so more accurate results aligning with the formula can probably be seen with more computational time.

REFERENCES

[1] K. J. Majeed, Colab notebook, MAE 263F: Mechanics of Flexible Structures and Soft Robots, University of California, Los Angeles, Fall 2025.