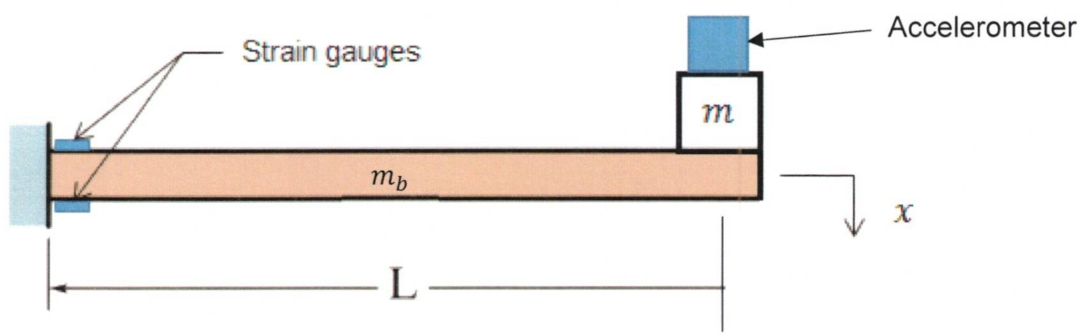
# MAE 3724 Systems Analysis
# Fall 2019

## Laboratory Experiment 3
## Cantilever Beam

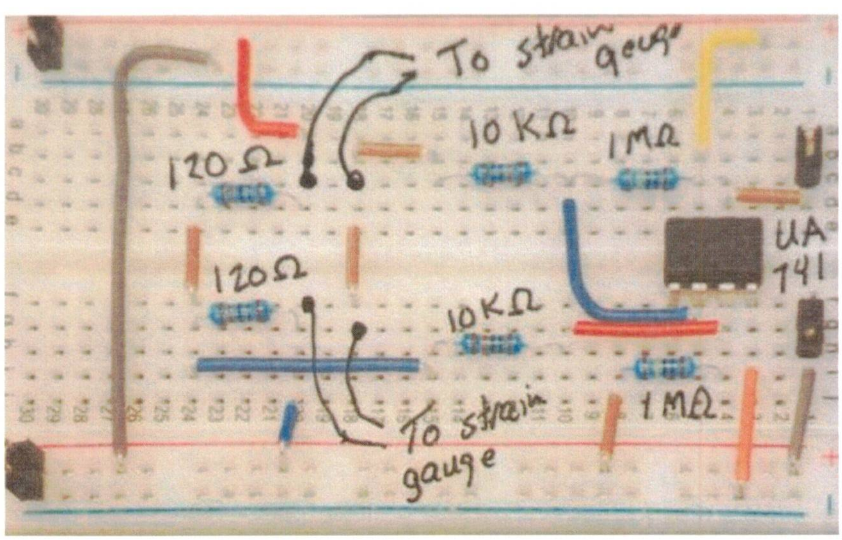
**Background for Laboratory Experiment 3**

You will study a mass-spring-damper system comprising a cantilever beam with a mass $m$ on the end as shown in the schematic below. A two-arm strain gage bridge will be used to measure the free response of the system, i.e., the motion $x(t)$ following an initial condition $x_0$ imposed on the system. An accelerometer mounted on the top of the mass will be used to measure $\ddot{x}(t)$.




**Setup:**

Start by checking the connections. Connect the strain gauges on the beam to the strain gauge bridge and amplifier (UA 741) as shown in the figure below.



The output of amplifier should be connected to the LabPro and the LabPro to the computer (ask the Lab Instructor for assistance). Connect the accelerometer at the end of the beam directly to the LabPro. Launch Logger Pro on the computer. The program should automatically recognize the sensors.

On the menu bar, under EXPERIMENT, go to CALIBRATE, Select "Voltage (+/-10V)". Click CALIBRATE NOW. Then change the units from "volts" to "cm" under reading 1, input "0", while the beam is at rest under the point load. Click KEEP. Under reading 2, while deflecting the end of the beam down 10 cm (4 inches), input "10", then click KEEP. Finally, click DONE.

Then under EXPERIMENT, go to DATA COLLECTION. Change the Duration to 30 seconds, and the Sampling Rate to 100 samples/second. Then click DONE.

## Experiment:

1) **WITHOUT ADDITIONAL MASS.** Push the bar downwards so the output on Logger Pro is about 10 cm. Release the bar, then immediately start collecting data (green button).

2) Copy time, displacement, and acceleration data to an Excel sheet.

3) **WITH ADDITIONAL MASS.** Repeat steps 1) & 2) with the additional mass on the beam. (Make sure to zero the sensors after adding the mass).

4) You should have four sets of data: deflection (position) and acceleration without the additional mass, and with the additional mass.

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## FINAL REPORT: (Each individual must submit a Final Report)

**SHOW ALL YOUR WORK ON THIS AND THE FOLLOWING PAGES. Scan these pages and all requested plots and upload them into the Brightspace Dropbox for Lab 3**

1) [4 pts] Use the Logarithmic decrement method (equation 8.4.14 and equation 8.4.13) to find the damping ratio ($\zeta$) from the displacement vs time data with and without the additional mass. That is calculate $\zeta_{mass}$ and $\zeta_{no\ mass}$ .

$B_1 = 7.339$
$B_{n+1} = 1.475$
$n = 29$
$\zeta_{no\ mass} = 0.0088$

$B_1 = 8.37$
$B_{n+1} = 3.872$
$n = 29$
$\zeta_{mass} = 0.0042$

2) [2 pts] How do these two calculated damping ratios compare? Explain any difference.

$\zeta_{no\ mass} > \zeta_{mass}$ because $\zeta = \frac{c}{2\sqrt{mk}}$ & the mass is less $\therefore$ $\zeta$ is greater

3) [2 pts] Now repeat Part 1) using the acceleration data.

$B_1 = 47.24$
$B_{n+1} = 9.342$
$n = 29$
$\zeta_{no\ mass} = 0.0088$

$B_1 = 21.49$
$B_{n+1} = 8.873$
$n = 29$
$\zeta_{mass} = 0.0048$

4) [2 pts] Are the damping ratios using the displacement data the same as those using the acceleration data? If not, why not?

Yes, except $\zeta_{mass}$ is off by 0.0006.

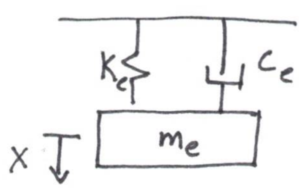
5) [2 pts] In the Pre-Lab, you calculated a damping ratio for the system with the additional mass using an assumed value of the damping constant. How does the damping ratio for the real system (with the additional mass) obtained using the experimental data, compare with the damping ratio determined in the Pre-Lab? What does this mean about the assumption for the damping coefficient in the Pre-Lab? What would be a better assumption for the damping coefficient? *(From Pre-Lab: $\zeta_{mass} = 3.46 \times 10^{-3}$)*

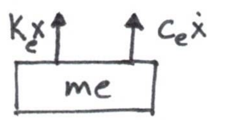
$(\zeta_{mass})_{exp} = 4.2\text{E-}3$ % diff = 19.3%

$(\zeta_{mass})_{pre} = 3.46\text{E-}3$

The better assumption for $\zeta$ & c would be $(\zeta_{mass})_{exp}$ because it is measured from the actual system and consequently a c

6) [4 pts] Repeat Parts e) and f) in the Pre-Lab with the improved assumption from Part 5) above.




$m_e\ddot{x} = -c_e\dot{x} - k_e x$

$$X(s) = \frac{m_e s + c_e}{m_e s^2 + c_e s + k_e}$$

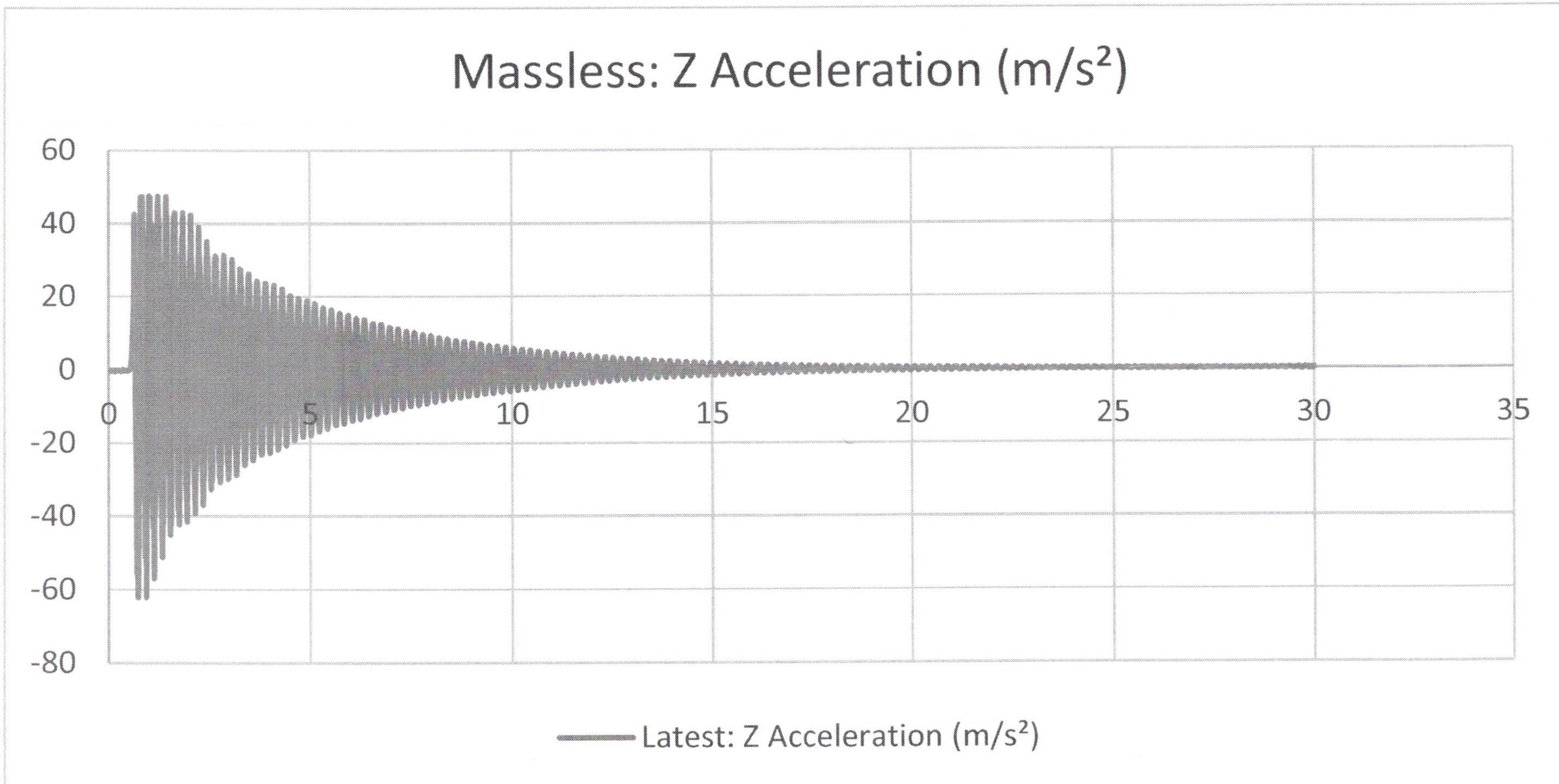
7) [4 pts] Include the four plots from the experiment in your final report.

**Final Evaluation (for feedback purposes, will not affect grade)**

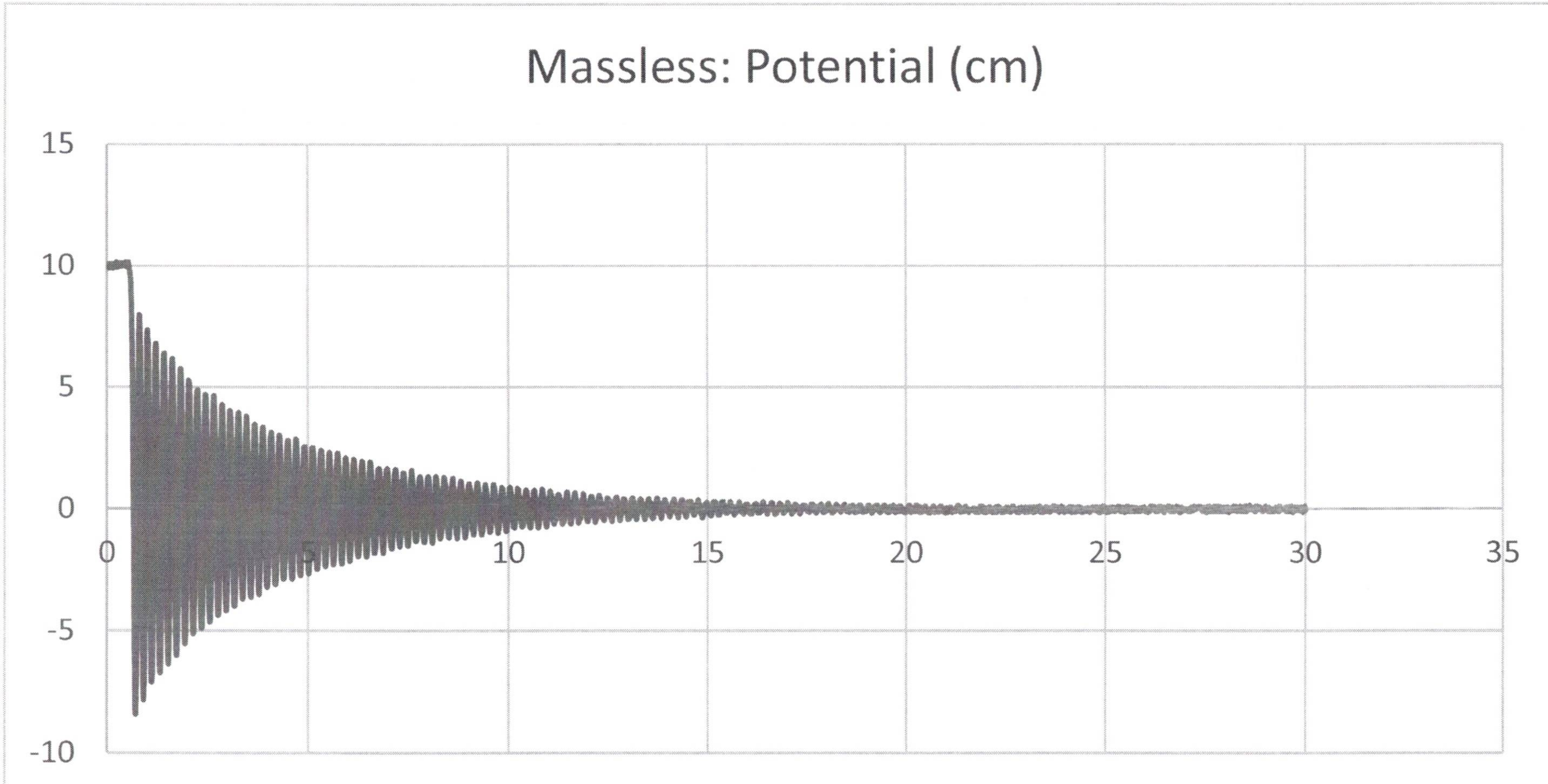
8) What did you learn from this experiment?

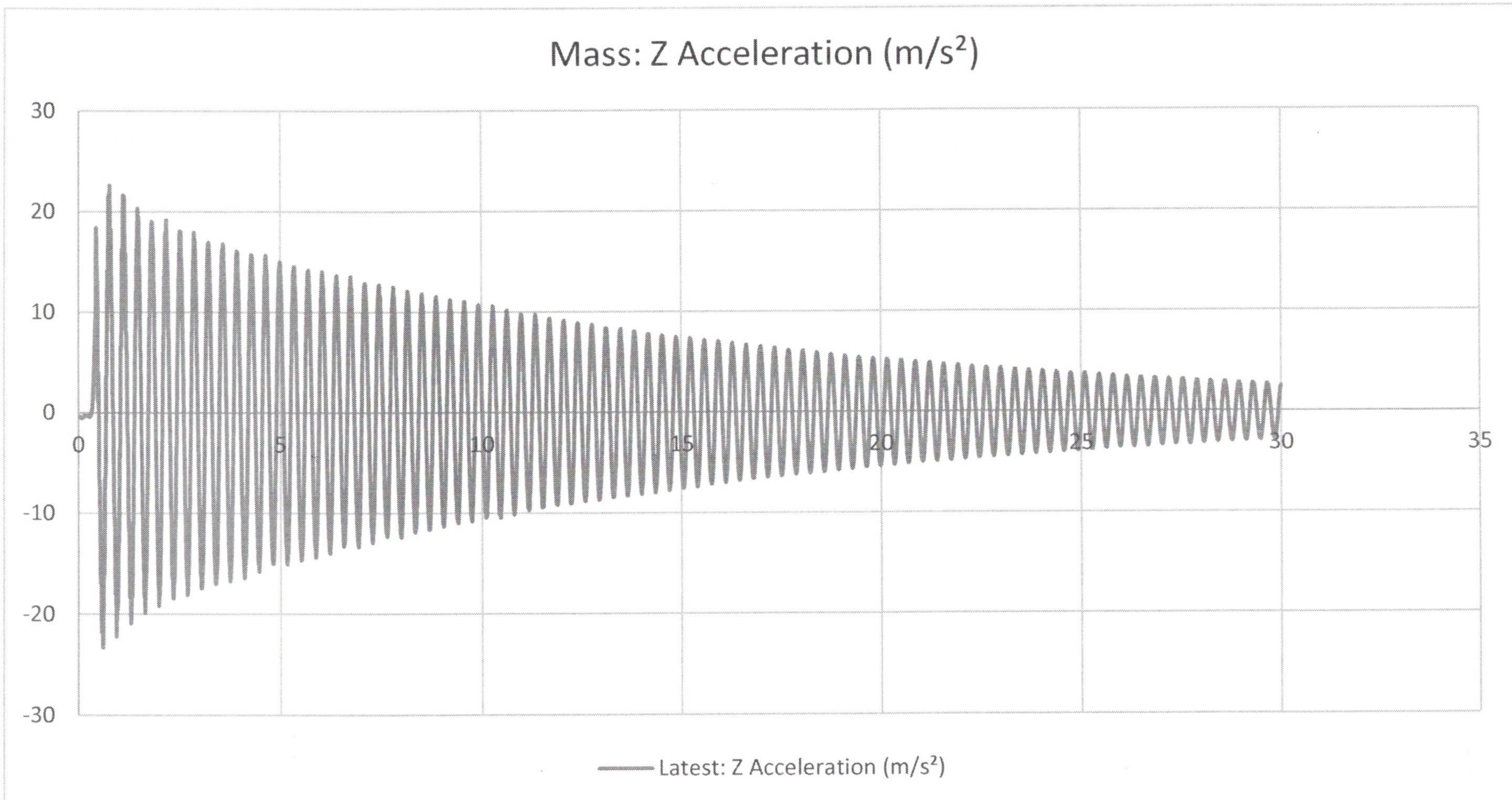
9) What could we do to make the experience more beneficial?

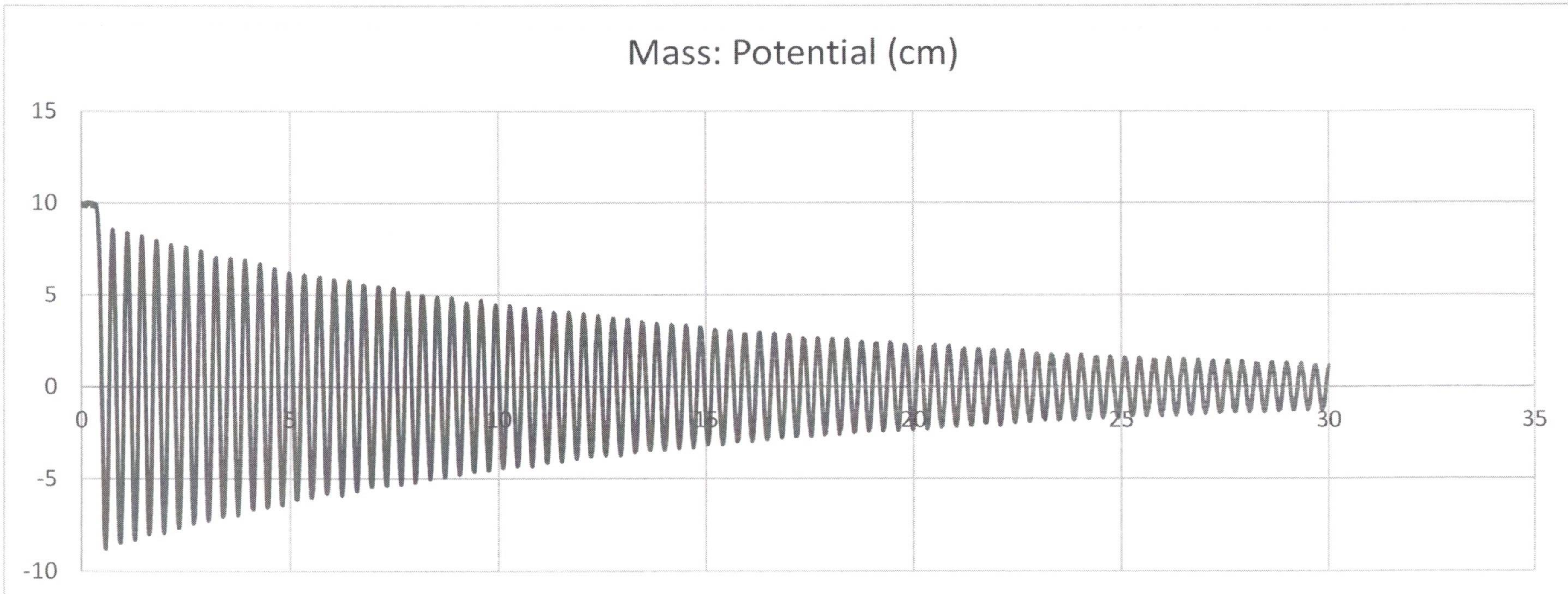
10) Which parts of the Prelab, Lab, and Post Lab were confusing, if any? If so, why?



Massless: Z Acceleration (m/s²)
60
40
20
0
-20
-40
-60
-80
0
5
10
15
20
25
30
35
Latest: Z Acceleration (m/s²)


Massless: Potential (cm)
15
10
5
0
-5
-10
0
5
10
15
20
25
30
35


Mass: Z Acceleration (m/s²)
30
20
10
0
-10
-20
-30
0
5
10
15
20
25
30
35
Latest: Z Acceleration (m/s²)


Mass: Potential (cm)
15
10
5
0
-5
-10
0
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30
35