Title: Sinkage of heavy objects in a soft soil.
Theme: Non-linear and linear systems of equations

Background:

Consider a soft and homogenous soil lying above a hard base soil. The soft soil thickness is D. Experiments found out that the amount of pressure *p* needed to sink a circular plate of radius *r* a distance *d* in the soft soil can be approximated by the following equation:

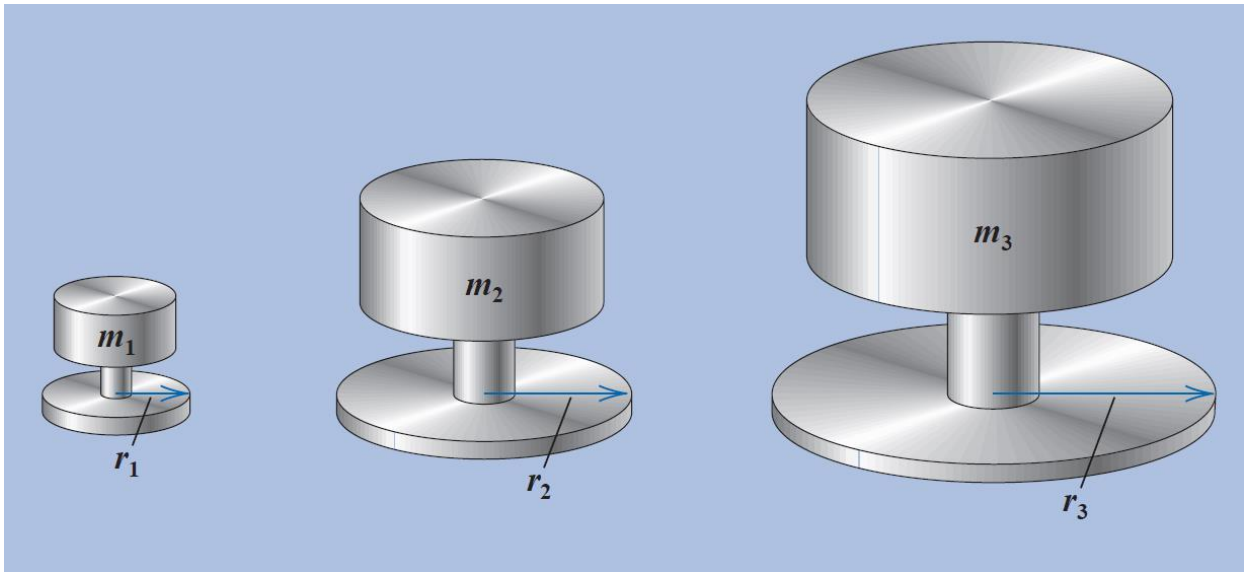
$$p = k_1 e^{k_2 r} + k_3 r,$$

where k_1, k_2 and k_3 are constants depending on *d* and the composition of the soil , but do not depend on the radius of the plate. It should be noted the distance *d* has to be less than the thickness of the soft soil D.

To find the constants k_1, k_2 and k_3 we need to conduct three experiments. In each experiment, we use three different circular plates as shown in the figure below, press on each plate until it sinks a distance *d* inside the soft soil, and measure the amount of pressure needed to achieve this. These three experiments result in three non-linear equations

$$p_1 = k_1 e^{k_2 r_1} + k_3 r_1 ,$$
$$p_2 = k_1 e^{k_2 r_2} + k_3 r_2 ,$$
$$p_3 = k_1 e^{k_2 r_3} + k_3 r_3 ,$$

in three unknowns k_1, k_2 and k_3. We would like to develop a MATLAB software to solve these non-linear equations using Newton-Raphson method.



Problem Statement:

You are required to develop a software package that determines the constant k_1, k_2 and k_3 for a given set of radii (r_1, r_2, r_3) and pressures (p_1, p_2, p_3). In particular, your package should be able to perform the following:

1- Prompts the user to enter the radii (r_1, r_2, r_3) and the pressures (p_1, p_2, p_3). It also asks the user about the stopping criterion for Newton-Raphson iterations.
2- Offers the user the flexibility between using Gauss-elimination with partial pivoting or Naïve Gauss-Jordan to solve the linear systems that arise during the iterations of Newton Raphson.
3- Calculates and plots (on the same graph) the three approximate relative error in estimating the constants k_1, k_2 and k_3 as a function of the number of iterations.

4- Reports to the user (in a friendly way!) the final values of the constants k_1, k_2 and k_3 using the correct units for these constants.
5- Plots the pressure as a function of the radius r.
6- [**BONUS**] Prompts the user again to ask if they are interested in predicting the lowest size of a circular plate that would be required to sustain a load F (in units of kN (kilo newton) on this soil with a sinkage less than or equal d. Then, your code gets the value of F from the user and it should calculate the radius *r* using the bisection method. [Hint1: Think about getting good initial guesses!] [Hint 2: F = p/A and $A = \pi r^2$]

A test case that you need to discuss in the project report is based on the following data from experiments in which three plates were sinked to a distance 0.305 m in a muddy soil.

Experiment	Pressure (kPa)	Plate radius (m)
#1	68.948	0.0254
#2	82.737	0.0508
#3	103.421	0.0762

If you will do the **BONUS** part, test your code with the load 2.224 kN.
You are **not allowed to use MATLAB built-in functions** for finding roots or solving linear systems. If in doubt consult with your instructors.

Deliverables:
On the due date, you are required to submit **a PDF copy of the project report and your MATLAB package in a single compressed .zip folder on blackboard.**

The code has to be
1- modular which means that every function is separate in a single .m file. We expect from you a main file , Gauss file, Gauss-Jordan file, Newton-Raphson iterations file, … and so on.
2- There should be rich comments in every part of the code to explain what is every function, loop, if-statement is doing.
3- The plots generated by the code need to be of high quality, axes labeled, and legends present when needed.

The report has to be written in single-spaced lines format, font 12, and Times New Roman. The report should not exceed 15 pages by any means and it should include:

a) A cover page [1 page]
b) List of contributors and their photos and clearly explain the contribution of each team member. [1 page].
c) Abstract [½ page].
d) Background review of the problem we are trying to address here using your own words. [1 page max].
e) Background on the numerical methods employed in the project. Use your own words. Write the equations using your word processor. Include citations in text and cite every figure you use from outside sources. [3 pages max]
f) Validation for the functions separately, where you show that you applied the function to a problem of known solutions (e.g. from class example) and that the function gave you the correct output. [3 pages max].
g) A graphical flow chart for the code. [1page max]
h) A manual for using your code. Explain how the user can use your code. **Clearly present a case study that validates the code (the one suggested abote)**. Take snapshots from your screen. [3 pages max].
i) Discuss any difficulties or sources of error you may have faced in the programming. [maximum ½ page]

j) Conclusion: Summarize your work and discuss any future improvements. [maximum ½ page]
k) References. Make sure to cite all sources in the text itself. Make sure not to plagiarize a figure, a whole sentence or a whole paragraph. [max 1 page]

Grade distribution and rubrics:

- The report is graded out of 3.
- The package is graded out of 6.
- The BONUS is graded out of 2. So you can possibly get 11/9 in the project.

Your final grade is your team's grade in both the report and the package multiplied by a fraction. The fraction depends in your performance in an oral discussion scheduled by your instructor. Tentatively each group will have 15-20 minutes for the oral discussion.

If you did not participate in the coding, your grade will be your team's report grade multiplied by the fraction related to your performance in the oral discussion.

ChatGPT/Bard

We do not mind if you use ChatGPT or Bard in generating or debugging your code. However, please note that you will be asked about all items in the code. So, if ChatGPT/Bart provided you with a running code and you do not know how it works, ChatGPT/Bard will receive the grade, not you. You also have to acknowledge this usage of GPT/Bard in the references.

Rubrics for the report

Rubrics for the report

	Aspect in the report	Grade reduction
1	Coverage of all 11 sections discussed above (a-k)	(-0.25 for each missing section of a,b,c,i,j,k). (-0.5 for each missing section of d,e,f,g) (-2 if section h missing)
2	No plagiarism of paragraphs or sentences	(Up to -3).
3	English can be understood and coherent	(Up to -0.5 for unclear English)
4	Format (25 pages max, font 12, Times New Roman, single spaced)	(-0.25 if format is different)
5	In-text citation	(-0.25 if references not cited in text)
6	Figures have captions and cited	(-0.25 for problematic figures)
7	Equations written by word-processor (not scanned, or copied as images)	(-0.25 for problematic equations).
8	References in-place	(-0.25 for missing references)
9	Plots labeled and with legends	(-0.25 for mislabeled figures)

Rubrics for the code

	Level of maturity of the code	Grade deserved
1	The code is only one file and is missing few functions and code does not work	0 / 6
2	The code is only one file contains all numerical methods functions but no coherent output and functions do not work separately.	Up to 1.5 / 6
3	Modular code that contains all functions. Some functions work separately but the code overall does not work	Up to 2.5/ 6
4	Modular code that contains all functions. All functions work separately but the code overall does not work	Up to 4/ 6
5	Modular code that contains all functions. All functions work separately, the code work overall and produces some output. The output is wrong or incomplete.	Up to 5/6
6	Modular code that contains all functions. All functions work separately and the code works collectively. It produces all outputs in neat format.	Up to 6 /6
Note 1: For every usage of MATLAB built-in functions for the numerical techniques, you lose 1.5 points if you are at level 3, 4, 5, or 6.		
Note 2: Subtract 1 point from any level if the code does not have comments throughout.		

Rubrics for the Oral discussion

	Aspect for the student	Grade
0	Cannot write a simple MATLB code	0%
1	Can run the project code (or one of its functions.)	Up to 30%
2	Can run the code (or one of its functions.) and explain the code logic correctly. [You will be asked about which function depends on which , where does the output of function go next?, or where is the input of a function coming from?,… etc..]	Up to 50 %
3	Can run the project code (or one of its functions.), explain its logic correctly, and explain certain loops or if-statement whether coded by her/himself or by another team member.	Up to 80 %
4	Can run the project code (or one of its functions.), explain its logic correctly, and explain certain loops or if-statement whether coded by her/himself or by another team member. Additionally, can answer a question about the numerical techniques employed.	Up to 100 %