Educational Purpose: the buckling problem below provides an opportunity to understand a few key characteristics of column buckling. It should help you develop an understanding of how to analyze both intermediate length and long columns and how they relate to each other. Although not part of this assignment, once you have created the spreadsheet – play around with changing different variables such as Young’s modulus, length, width, end conditions, etc. Learn a little beyond the assignment itself. This should be very easy to do if you construct your program (spreadsheet) properly. Hopefully, you will see that simple programs (spreadsheets) can be very helpful parametric design tools. Parametric design: alter various parameters (material properties, geometry, etc.) to determine the effect on the performance.

1. Given a column as shown (fixed-free ends). The column’s cross-section is 20mm by 50mm (hint, be sure to use the correct area moment of inertia). Using Excel, MatLab (or other program), make a single graph showing the critical stress ($P_{cr}/A$) as a function of length. Use equations for both “long columns” and “intermediate-length.” Consider (in other words, “use”) the following two materials: AISI 1020HR and 1080HR steels. Briefly comment on how the results are dependent (or not) on the material.

![Diagram of a column with applied load P]

2. Determine the critical load ($P_{cr}$) for the two columns described below. You may use your Excel (or MatLAB) program to determine the critical load, but if you do so, you should still use the standard hw format, but rather than include your analysis, explain that you used your work from problem 1 and describe any modifications to the program that was needed (if any). After calculating the critical load, go to SH 110 between 11AM and 3PM on Monday, Tuesday, Wednesday, or Friday and answer the same questions using the buckling test apparatus in SH 110. Compare your analytical and experimental answers (briefly discuss the results).

Column data: RG45 mild steel rods, 1/8” in diameter with “fixed” and “free” end conditions. Column “A” is 15 inches long. Column “B” is 21 inches long.

3. Educational Purpose: learn to apply Hertzian Contact stress equations and to understand that they are a local stress and diminish at some distance from contact. A railroad car wheel runs on a track. The rail and wheel are both steel. There is a normal force ($F_N$) between them. The wheel has a 20 inch diameter and is 2 inches wide. For plots, use Excel, MatLab, or other program. $S_y=120$ksi, $0<F_N<100,000$lb.
   a) Plot the maximum shear stress in the wheel as a function of $F_N$. 

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b) Plot the maximum compressive normal stress in the wheel as a function of $F_N$.

c) Normalize $\sigma_x$, $\sigma_y$, $\sigma_z$, and $\tau_{xy}$ by $P_{max}$ and using Excel create a graph showing these stresses as a function of distance along the $z$-axis (as those shown in section 3 of the text). In addition, include the von Mises stress (aka “effective stress”) on the same graph.

d) From part (b) discuss why the normal stress is not linearly proportional to the force, $F_N$.

e) Determine an appropriate yield strength for the wheel assuming a factor of safety of 2 against yielding with $F_N$ of 50,000 pounds.

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4. No homework “credit” will be given for this part of the assignment. However, it should be both very educational and interesting (it’s nice when those go together). If you do not watch the videos, you will be missing out on important lessons learned.

Traditional aerospace composite manufacturing process involves graphite/epoxy “pre-preg” material (fibers are pre-impregnated with non-cured epoxy resin). Sheets of non-cured composite are laid onto a mold (pre-preg is sticky stuff). The parts are made thicker by laying multiple sheets one on top of the other (called a layup). The stickiness of the pre-preg greatly helps each layer stay in place and helps ensure layers are properly cured to each other (rather than gaps in the layup). A plastic bag is then placed over the part, and a vacuum is pulled. The part is placed in an autoclave (pressurized oven) to cure the epoxy and bond layers together. If you want to learn more about that, I’m sure you can find many interesting videos on line.

Drive shaft video (5 min): https://www.youtube.com/watch?v=hjErH4_1fks

Drive shafts – both the steel and composites shafts are hollow “tubes”. A few things to take note of before and while watching:

- The failure in the steel is not “fracture” it is a structural buckling sort of failure. As ME’s, we generally don’t analyze structural failures such as this – the onset of yield (non-linear behavior) which occurred before “buckling” is failure enough.
- Graphite/epoxy composites (aka “carbon composite) are extremely strong in tension along the fiber direction and far less so in other directions. Notices the direction the fibers are laid in the shaft – at 45 degrees to the shaft-axis, that’s so they can carry the load effectively. Also notice the “spiral” fracture of the carbon shaft.

The video “Battle of the X-Planes” is a 2 hour documentary very well worth watching in regards to engineering design. Pay attention to any discussion about “thermosetting vs. thermoplastic composites.” How can thermoplastic composites save weight? We’ll discuss that later, because it isn’t clear how from the video. Watch Part 1 (about an hour) – don’t forget the popcorn: https://www.youtube.com/watch?v=cya1yA2tq3I

One important lesson from this first half is the fact that engineers must often make decisions without having all the facts and data needed. In fact, this is the norm. We have no crystal ball.

Part II will be assigned later.