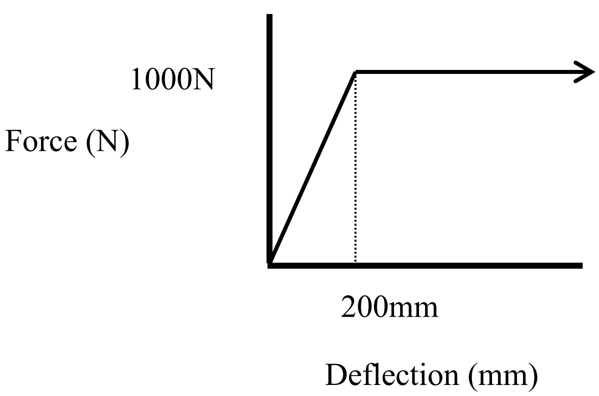
ME328 – Machine Design
Assignment 5, Spring 2020

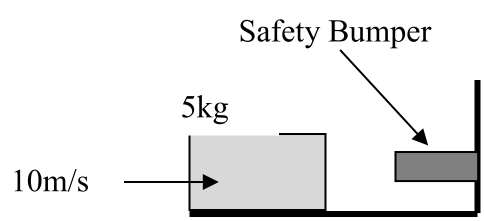
Educational purpose: *we are now moving away from quasi-static loads and entering the realm of dynamics and energy dissipation. Stress is still proportional to force (so what we have learned about quasi-static stress analysis is still valid), but what forces are acting on the structure is the thing we now must learn how to determine.*

1. *5 pts Note: this is a simple hand calculation that will be utilized on a future assignment.* How much deflection will occur when a 100 kg object moving horizontally at a velocity of 4.4m/s strikes a coil spring with a stiffness of 13kN/m? Assume no friction.

2. 5 pts Redo problem 1 (determine deflection), but this time the 100kg object is moving downward (rather than horizontally) at 4.4m/s when it strikes the top of a 13kN/m spring. Before starting the analysis, answer for yourself, *should the deflection be greater in this problem compared with problem 1*?

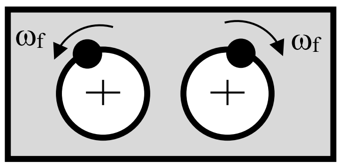
3. *10 pts Educational Purpose: It is very important to understand that impact analysis is an* ***energy based*** *analysis. This problem is intended to reveal that.* If a 5 kg object is moving horizontally at 10m/s (without friction) strikes a "safety bumper". The safety bumper has a force deflection curve as shown below. How much will the bumper deform (deflect)? What is the peak impact force? STATE ALL CRITICAL ASSUMPTIONS. *(ask yourself: what do force and deflection have to do with energy?)*





4. ***15 pts DESIGN PROBLEM Educational purpose****: to refresh your ability to analyze dynamic problems and to apply this ability in machine design. You* ***will see this problem again*** *on a future assignment – this is the first rung in a ladder –* ***so it is HIGHLY advisable to do it correctly now****.* Two gas turbine engines are attached side-by-side and spin in

opposite directions (one spins clockwise, the other counterclockwise). The total mass is 700kg (both engines, and the entire structure combined). The mass of each turbine disk is 100kg, and the masses are eccentric (not centered on the axis of rotation). The effective eccentricity is 20mm in each disk (in other words, the center of mass is 20mm offset from the center of rotation). This will result in a serious "wobble force". Since they are spinning in opposite directions, the horizontal component of force produced by one disk is equal and opposite to the horizontal component of force produced by the other disk. The vertical components, however, are additive (each disk produces equal force in the same direction as the other at the same time). Using Excel, create a plot of vertical force amplitude as a function rotation rate from zero to 3000RPM. Solution check: at 1000RPM, the vertical force has a magnitude of +/- 43.8kN; {$P(t) = 43.8kN \sin(\omega_f t)$}.



5. **Educational purpose**: *Due to low density and high strength and stiffness, composite materials are widely used in aerospace, automotive, sporting goods, biomechanics, etc. They are highly anisotropic and inhomogeneous. The study of composites is typically at the graduate level and not typically discussed much at the undergraduate level. This assignment is meant to help you become slightly more aware the manufacturing and usage of composite materials.* Common 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. Watch the following videos on composites:
"Pre-pregs" (3.5min) https://www.youtube.com/watch?v=5A0phymRYTo
Skateboard layup (4.5min) https://www.youtube.com/watch?v=scvXKij1hQ0

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.

6. No homework "credit" will be given for this part of the assignment – nothing to turn in. It is not "due" this week, but we be discussing it in a few weeks or so – watch it this week or next (or split it up). 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."** Boeing bets the whole project on thermoplastic composites to save weight, but how can thermoplastic composites save weight? We'll discuss that later, because it isn't clear how from the video. Don't forget the popcorn: https://www.youtube.com/watch?v=Y_WPLeDmU6o

   Also pay attention to a meeting of a few dozen engineers trying to determine which of two different design they should pursue. **There are two important lessons demonstrated**: 1) the fact that engineers must often make decisions without having all the facts and data needed and 2) engineers need to have confidence in their professional opinions in order to make significant contributions to engineering decisions.