Donald P. Shiley School of Engineering

ME 328 – Machine Design, Spring 2020

Assignment 1 – Review Questions

NOTE: Problems 3a and 5q have been re-phrased

Name: ________________________

This is assignment is in "workbook" format, meaning you may fill in the blanks (you do not need to follow the standard problem-solving format – **this assignment only!** If you need more space, attach separate sheets of paper (but refer to this in the space provided for the associated problems).

Educational Purpose: *all of the following are **review** questions. If you have difficulty with any of these, then please come see me! You need to have a **solid** foundation in stress analysis and basic material properties to learn well in this course!!!! It is fine if you have to look up terminology, etc., but strive to "memorize" much of what's in this assignment. These things to become part of your vocabulary – so deeply embedded you cannot imagine not knowing these things.*

1. Pedagogical Purpose: *Significant figures do matter! They communicate a level of precision. This question is meant to help you appreciate that. Analysis, whether conducted by hand or computer, **very rarely provides** **the answer** **to an engineering question.** It merely provides the engineer with "data" that helps him or her reach a conclusion. All engineering decisions require "judgment" – data helps the engineer make that judgment. That is why understanding assumptions is so **very critical** to engineering!*
   A round steel bar of 0.25000 inch diameter carries an axial load in the vertical direction. Determine the largest load that can be applied to the bar such that the maximum **shear stress** does not exceed 59.872 kpsi. Your answer should be to the nearest 0.001 pounds. **To receive credit, you must** discuss the critical assumptions that were required as well as discuss their impact. Draw Mohr's circle to help you remember the relationship between shear stress and normal stress for uniaxial loading.

2. *Your knowledge of unit prefixes is very important…*
   a) *How many mm in 1 cm?*___________
   b) *How many mm in 1 m?*___________
   c) *How many lb/in^2 in 1 ksi (aka 1 kpsi)?*___________
   d) *How many Pascal's in 1 MPa?*___________
   e) *How many Pascal's in 1 GPa?*___________
3. *Your knowledge of units is very important! If you don't know the units, then you do NOT understand the relevant concept sufficiently well!*
   a) Using units, show that $E=mc^3$ must be false and $E=mc^2$ may be true. In other words, show that $E=mc^3$ has inconsistent (left side are different that right side units) units and $E=mc^2$ are consistent.

   b) A "Newton" is a unit of force. What are the basic units of a "Newton?" (in terms of kg, m, and/or sec).

   c) What is stress, what is strain, and what are their units?

   d) Is stress a vector? Explain

   e) What are the units for energy? (in terms of N, m, and/or sec)

   f) What are the units for power? (in terms of N, m, and/or sec)

   g) What are the units of torque? (in terms of N, m, and/or sec)

h) What are the units of moments, such as bending moments? (in terms of N, m, and/or sec)

i) Show that strain energy (the area under a stress-strain diagram) has units of energy per unit volume.

j) Show that $1\ N/mm^2 = 1$ MPa (*this is one reason mechanical drawings express lengths in terms of millimeters rather than centimeters*). This is an IMPORTANT unit relationship to MEMORIZE.

k) Show that $1\ kN/mm^2 = 1$ GPa. This is an IMPORTANT unit relationship to MEMORIZE.

l) How many MPa in 1 ksi? (you don't need to memorize this precisely, but you should memorize that 1 ksi is approximately 7 MPa).

4. There are a few basic material properties that you should have memorized by now. Here are two: what is Young's modulus of steel? What is Young's modulus of aluminum alloys? Express your answers in both SI (GPa) and United States customary units (Mpsi).

Steel (SI)	Steel (US Customary)	Aluminum (SI)	Aluminum (US Customary)

5. As a review of material properties, concisely define the following (typically, one brief sentence each). You should **include sketches** and equations where appropriate to help with communication. Feel free to use various resources to help you answer these.

a) A general description of yield strength (a.k.a. yield stress, yield point). NOTE: from this point forward, we will use the nomenclature S_{ys} for yield strength.

b) Yield strength (S_{ys}) based on 0.2% offset (include what is meant by 0.2% offset).

c) Dislocation

d) Dislocation slip, dislocation glide, and dislocation motion are different ways of trying to describe the same phenomena. Concisely, describe the phenomena – what is "dislocation slip"? What type of stress causes dislocation slip (dislocation glide, dislocation motion)? Macroscopically, what does dislocation slip manifest itself as?

e) Tensile strength (also referred to as ultimate tensile strength)

f) Compressive strength (also referred to as ultimate compression strength)

g) Hardness

h) Show that Hooke's law for three dimensional stress (as shown in any strength of materials text and ME304 notes) becomes one dimensional for uniaxial loading (1D Hooke's law: $\sigma = \varepsilon E$)

i) Young's modulus. Hint: this is a material property, it is **not** the same as Hooke's law – Hooke's law is an equation. Hint #2, include a sketch of $\sigma-\varepsilon$ diagram.

j) Poisson's ratio. To help demonstrate this, show a sketch of a rectangle with strains caused by uniaxial tension.

k) Define toughness and explain how impact toughness is measured

l) Ductility (in words and two different equations)

m) Ductile fracture

n) Brittle fracture

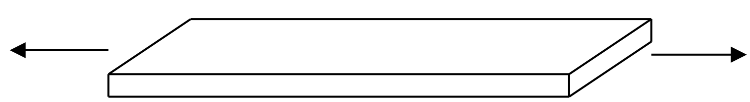
o) Describe (equations and words) the following failure criteria, and describe the general material classifications for which each is appropriate to use: von Mises (distortion energy), maximum shear stress (Tresca), maximum normal stress.

p) Explain why the maximum shear stress theory predicts the onset of yielding so well for ductile metals/alloys. In other words, what does the shear stress in a metal have to do with yielding?

q) Here's an "extra credit" problem for those of you wanting a challenge. Show the following relationships between the shear strength (τ_{ys}) and yield strength (S_{ys}). Maximum shear stress failure criterion $\tau_{ys} = 0.5S_{ys}$ and that for the von Mises criterion $\tau_{ys} = 0.577S_{ys}$. To do this, assume a material has a yield strength of 100ksi. Show that for pure shear loading (a shaft in torsion loading), the Maximum Shear Stress theory predicts yielding will occur when $\tau = Tr/J = 50$ksi, and the Distortion Energy theory predicts yielding will occur when $\tau = Tr/J = 57.7$ksi

Factor of safety in general is described as: FOS = "material strength"/"actual load"

6. Create Mohr's circle for the stress condition in a flat plate (3 inches wide, 0.250 inch thick, 10 inches long) with a 5000 pound load. State all assumptions. What are the maximum and minimum principal stresses and what is the maximum shear stress in the plate. What is the "von Mises stress" (aka "effective stress")? Briefly describe how the stress varies within the plate.

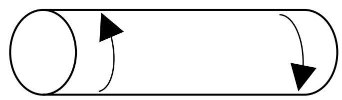


ATTACH WORK ON SEPARATE PAGE.

- If the part were made of a ductile alloy, what yield strength would be required for a factor safety of 2 against yielding?

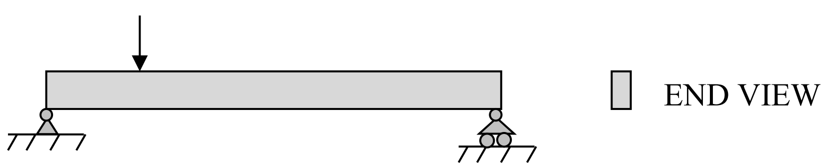
- If the part were made of a brittle material, what tensile strength is required for a factor of safety of 2 for fracture?

7. Create Mohr's circle for the stress condition in a round bar (2 inch diameter, 10 inches long) with a torsion load of 500 ft-lb. State all assumptions. What are the maximum and minimum principal stresses and what is the maximum shear stress in the bar? What is the "von Mises stress" (aka "effective stress") at the surface? Briefly describe how the stress varies within the bar. ATTACH WORK ON SEPARATE PAGE.



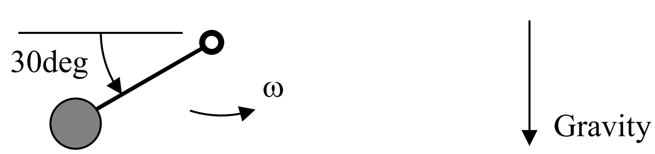
- If the part were made of a ductile alloy, what yield strength would be required for a factor safety of 2 against yielding?
- If the part were made of a brittle material, what tensile strength is required for a factor of safety of 2 for fracture?

8. For the simply supported beam shown below, precisely where (what point on the beam) is the bending stress maximum? Determine the maximum bending stress at that point. At that point, what are the maximum and minimum principal stresses, what is the maximum shear stress, and what is the "von Mises stress"? Briefly describe how the stress varies in the bar. Draw a complete free body diagram and create the shear and moment diagrams. The beam is 1000 mm long and a 2kN load is applied 200 mm from the left end. The beam's height is 20mm and it is 10mm wide. State all assumptions. ATTACH WORK ON SEPARATE PAGE.



- If the part were made of a ductile alloy, what yield strength would be required for a factor safety of 2 against yielding?
- If the part were made of a brittle material, what tensile strength is required for a factor of safety of 2 for fracture?

9. Determine the reaction on the hub of the following system when the 10kg mass is located at a point as shown. The link is 10 cm long and the angular speed about the hub is constant at 500 rpm. State all assumptions and include a free body diagram of the mass. Assume acceleration due to gravity is $10 m/sec^2$



10. Pedagogical Purpose: *good engineers have good observing skills. They observe things they encounter noticing what works well and what doesn't. This is a skill that can be developed by practice.* Task: Observe designs of various things you use. Describe something "well" designed and something "poorly" designed – and why you think they are good or not so good designs. Include photographs if possible.
11. If you have not done so in the past, complete the online safety training for the maker-space (SH110) https://sites.up.edu/pilotspace/ . You will want to have access to SH110 this semester. For this assignment, circle this sentence once it is true: **YES – I have completed the online training.**