Name: ____

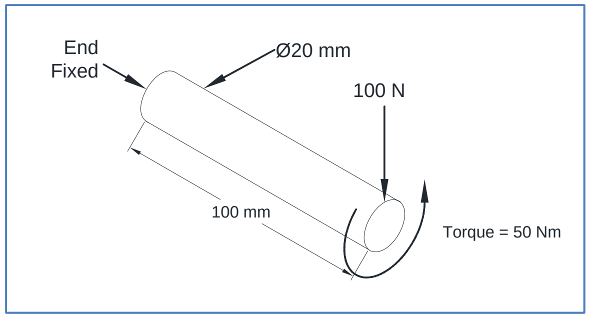
Exam II – ME 360 – Spring 2012

IMPORTANT NOTICES:

- **Open book.** You may use your textbook and a single one sided page of notes during the exam. Notes that you took in class and homework problems may NOT be referenced during the exam.
- **Use your calculator** Use your calculator where necessary to compute values.
- **Use your paper for exam answers.** Start a new page for each problem. Staple your pages together behind this sheet at the end of the exam.
- **Box your answers.** Draw a box around each answer.
- **Write neatly and legibly.** Illegible work will not be considered. If you are of the opinion that insufficient information was provided to solve a specific problem, make realistic assumptions, motivate these and continue solving the problem based on your assumptions made.
- **Write each equation you are solving on the exam.** Write the equation followed by your calculations using that equation. Organize your work so that the steps are sequentially organized moving down the page. Numbers without an associated equation will not be considered.
- **Use F.B.D's and illustrative diagrams where needed.**
- **Where useful, clearly show the reference Cartesian axes system used for each question.**
- **Pay attention to units and show the relevant unit in each calculated answer.**
- **No points will be awarded for answers only.** Calculations must contain a minimum number of logically sequenced steps illustrated with equations followed by an answer.
- **Answer *all* questions.** If you do not have sufficient time to complete the test, write the equations you will solve in the order in which they should be solved.

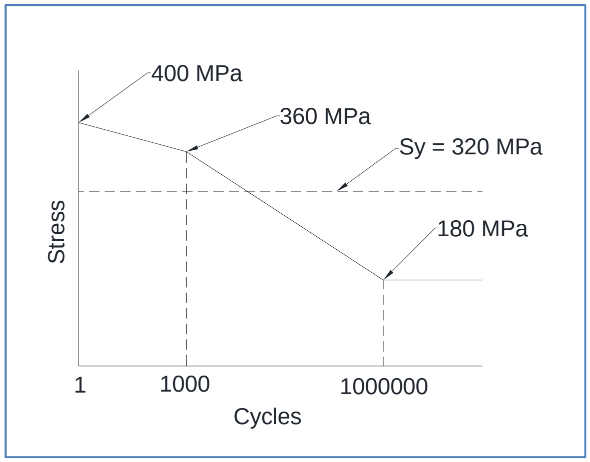
Name: ____

1. **(40 Points)** The cantilever rod shown in the diagram on the right has a diameter of 20 mm and a length of 100 mm. The rod is statically loaded as shown in the diagram. What is the safety factor for this loading condition? Show all work.



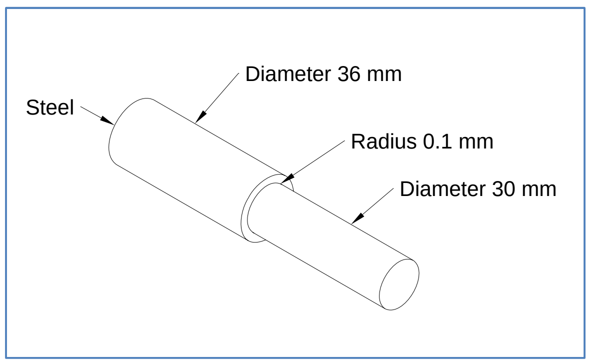
Material:	Steel
	S_y = 320 MPa
	S_u = 450 MPa

2. **(20 Points)** You are working with steel which has the S-N curve shown on the right. You want the part to last at least 100,000 cycles. What is the maximum allowable stress you can use? Show all work.



Material:	Steel
Tensile Strength:	S_{ut} = 400 MPa
Finish:	Cold rolled
Temperature:	300°C
Loading:	Fully reversed
Reliability:	99%

3. **(40 Points)** A steel shaft is shown in the diagram on the right. It has a step that increases the diameter from 30 to 36 mm. The radius of the fillet at the step is 0.1 mm. The alternating torque and axial loads are 50% of the mean torque and axial loads. Assume that the alternating and mean stresses occur in a fixed ratio. What are the Gerber and modified Goodman safety factors for the shaft? Show all work.



Material:	Steel	Temperature:	350°C
Finish:	Machined	Reliability:	99.9%
S_{ut}:	600 MPa	S_y:	480 MPa
S_e:	200 MPa	$K_{t(axial)}$:	4.1
$K_{t(bending)}$:	3.4	$K_{ts(torsion)}$:	2.9
Mean Torque:	100 N-m (applied force)	Mean Axial Load:	1000 N (applied force)
Rotational Rate:	2,000 RPM		

EXAM II

1)

$$\sigma_x = \frac{Mc}{I} \qquad I = \frac{\pi D^4}{64} = \frac{\pi (20)^4}{64} = 7854$$

$$M = 100 \cdot 100 = 10{,}000 \text{ N mm}$$

$$c = D/2 = 10$$

$$\sigma_x = \frac{10{,}000(10)}{7854} = \underline{12.7 \text{ MPa}}$$

$$\tau_{xy} = \frac{Tr}{J} = \qquad T = 50(1000) = 50{,}000 \text{ Nmm}$$

$$\tau_{xy} = \frac{50{,}000(10)}{7854(2)} = \underline{31.83 \text{ MPa}}$$

$$\sigma' = \sqrt{12.7^2 + 3(31.83)^2} = 56.58 \text{ MPa}$$

$$S_y = 320 \text{ MPa}$$

$$N = S_y/\sigma' = \frac{320}{56.58} = 5.66$$

$$\boxed{N = 5.66}$$

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2) Interpolate S-N Curve at 100,000 cycles.

$S_m = 360\ MPa \qquad S_e = 180\ MPa$

* $b = -\frac{1}{3} Log\left(\frac{S_m}{S_e}\right) = -\frac{1}{3} Log\left(\frac{360}{180}\right) = -.1003$

$S(N) = a N^b$

$a = \frac{S(N)}{N^b} = \frac{360}{1000^{-.1003}} = 719.8$

$S(100{,}000) = 719.8\,(100{,}000)^{-.1003}$

$$\boxed{S(100{,}000) = 226.6\ MPa}$$

* Formula

$S(N) = a N^b$

$Log(S(N)) = Log(a N^b) = Log(a) + b\,Log(N)$

@ $N = 10^3$ $S(N) = S_m$

$Log(S_m) = Log(a) + b(Log(10^3))$

@ $N = 10^4$, $S(N) = S_e$ $\quad Log(S_e) = Log(a) + b(Log(10^6))$

subtracting

$Log(S_m) - Log(S_e) = b(Log(10^3) - Log(10^6))$

$Log\left(\frac{S_m}{S_e}\right) = b(3-6) = b(-3)$

$b = -\frac{1}{3} Log\left(\frac{S_m}{S_e}\right)$

3) $\tau_{mean} = \frac{Tr}{J}$ $J = \frac{\pi D^4}{32} = \frac{\pi (30)^4}{32}$

$T = 100(1000) = 100{,}000$ N mm $J = 79{,}521$

$\tau_{mean} = \frac{100{,}000(15)}{79{,}521} = 18.86$ MPa

$\tau_{alt} = 0.5\,\tau_{mean} = \underline{9.43 \text{ MPa}}$

Axial Load

$\sigma_{mean} = \frac{\text{Load}}{\text{Area}} =$ $\text{Area} = \frac{\pi D^2}{4} = \frac{\pi (30)^2}{4}$

Area = 706.86

$\sigma_{mean} = \frac{1000}{706.86} = \underline{1.14 \text{ MPa}}$

$\sigma_{alt} = 0.5\,\sigma_{mean} = .707$ MPa

Compute Neuber Constant

$q = \frac{1}{1 + \frac{\sqrt{a}}{\sqrt{r}}}$

Torsion

$\sqrt{a} = 0.190 - 2.51(10^{-3})S_{ut} + 1.35(10^{-5})S_{ut} - 2.67(10^{-8})S_{ut}$

$S_{ut} = 600 \text{ MPa} = \frac{600}{6.895E-3} = 87{,}019$ psi

$S_{ut} = 87.$ KPSI

$\sqrt{a} = 0.190 - 2.51E-3(87) + 1.35E-5(87)^2 - 2.67E-8(87)^3$

$\sqrt{a} = .0562$

$r = 0.1$ mm $r = \frac{0.1}{25.4} = 3.94E-3$ in $\sqrt{r} = .0627$

$$q = \frac{1}{1 + \frac{.0562}{.0627}} = .527$$

$$K_{fs} = 1 + q(K_t - 1) = 1 + .527(2.9 - 1)$$

$$\underline{K_{fs} = 2.00}$$

AXIAL

$$\sqrt{a} = .246 - 3.08E{-3}\,S_{ut} + 1.51E{-5}\,S_{ut}^2 - 2.67E{-8}\,S_{ut}^3$$

$$\sqrt{a} = .246 - 3.08E{-3}(87) + 1.51E{-5}(87)^2 - 2.67E{-8}(87)^3$$

$$\sqrt{a} = .0747$$

$$q = \frac{1}{1 + \frac{.0747}{.0627}} = .456$$

$$K_f = 1 + q(K_t - 1) = 1 + .456(4.1 - 1)$$

$$K_f = 2.41$$

CHECK FOR LOCAL YIELDING

$$\sigma_{max} = (\sigma_{mean} \cdot \sigma_{alt})K_f = 2.41(1.14 + .707)$$

$$\sigma_{max} = 4.45$$

$$\tau_{max} = K_{fs}(\tau_{mean} + \tau_{alt}) = 2(18.86 + 9.43)$$

$$\tau_{max} = 56.58$$

$$\sigma' = \sqrt{\sigma^2 + 3\tau^2} = \sqrt{4.45^2 + 3(56.58)^2}$$

$$\sigma' = 98.1$$

$$\sigma' < S_y \Rightarrow 98.1 < 486$$

No Correction for Local Yielding

von Mises Stresses

$$\sigma_a' = \sqrt{\left(K_f \frac{\sigma_a}{.189}\right)^2 + 3\left(K_{fs}(\tau_a)\right)^2}$$

$$\sigma_a' = \sqrt{\left(2.41\left(\frac{.707}{.189}\right)\right)^2 + 3\left(2(9.43)\right)^2}$$

$$\sigma_a' = \underline{32.73}$$

$$\sigma_m' = \sqrt{\left(K_f \sigma_m\right)^2 + 3\left(K_{fs}(\tau_m)\right)^2}$$

$$\sigma_m' = \sqrt{\left(2.41(1.14)\right)^2 + 3\left(2(18.86)\right)^2}$$

$$\sigma_m' = \underline{65.39}$$

<u>GOODMAN</u>

$$N_f = \frac{1}{\frac{\sigma_a'}{S_e} + \frac{\sigma_m'}{S_{ut}}} = \frac{1}{\frac{32.73}{200} + \frac{65.39}{600}}$$

$$\boxed{N_f = 3.66}$$

GERBER

$$N_f = \frac{1}{2}\left(\frac{S_{ut}}{\sigma_m}\right)^2 \frac{\sigma_a}{S_e}\left[-1+\sqrt{1+\left(\frac{2\sigma_m S_e}{S_{ut}\sigma_a}\right)^2}\right]$$

$$N_f = \frac{1}{2}\left(\frac{600}{65.39}\right)^2 \frac{32.73}{200}\left[-1+\sqrt{1+\left(\frac{2(65.39)(200)}{600(32.73)}\right)^2}\right]$$

$$\boxed{N_f = 4.6}$$

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