July 19, 2022

INSTRUCTIONS

Begin each problem in the space provided.

If your solution does not follow a logical thought process, it will be assumed to be in error.

GUIDELINES FOR ZOOM PROCTORING

- Mute yourself but your audio should remain on for the duration of the exam in order to hear any instructions or announcements of clarifications.
- Your webcam and audio should remain on for the duration of the exam. Webcams should be located off to one side so that your hands and desk materials are visible in the frame. Your face does not need to be visible in the frame.
- Open a chat window at the start of the exam and keep it visible throughout the exam. The chat window will allow you to correspond with the proctor, but you will not be allowed to correspond with your peers.
- The proctor may ask you to show the room in which you are working as well as other materials in order to ensure academic integrity of the assessment.
- The exam will be e-mailed to you at the beginning of the exam.
- You may print the exam and work on those pages, view the exam on your computer and work problems on blank pages, or work the exam on a tablet.
- Questions for the proctor should be asked during the exam using the chat window.
- Clarifications made by the proctor during the exam will be made vocally and in the chat window.
- When you have completed the exam, you should scan/save your work as a single PDF file and upload the exam to Gradescope.
- If you lose your connection during the exam, be patient, continue working, and wait for the connection to return. If the connection does not recover within a couple of minutes, then you may be asked to take a make-up oral exam (via Zoom) in place of the written exam.
- The exam will be recorded, with only the course instructor having preliminary access to the recording. The video recording will only be reviewed for the purpose of identifying potential cheating incidents and will be deleted after one week from when the exam was completed if no cheating allegations have been made. If a cheating allegation has been made, then the recording will be retained until the cheating incident has been resolved. Any student accused of cheating will be allowed to review the video recording as part of their due process. All incidents of academic misconduct will be referred to the Office of the Dean of Students who will be provided access to recordings, as well as other supporting documentation to utilize in their process of determining potential violations of University policies on academic dishonesty.

EQUATIONS

Small angle ($\theta \approx 0$) approximations

$$\sin(\theta) \approx \theta \qquad \cos(\theta) \approx 1 \qquad \tan(\theta) \approx \theta$$

Average stress

$$(\sigma)_{ave} = \frac{P}{A} \qquad (\tau)_{ave} = \frac{V}{A}$$

Generalized Hooke's Law

$$\epsilon_x = \frac{1}{E}[\sigma_x - \nu(\sigma_y + \sigma_z)] + \alpha\Delta T$$

$$\epsilon_y = \frac{1}{E}[\sigma_y - \nu(\sigma_x + \sigma_z)] + \alpha\Delta T$$

$$\epsilon_z = \frac{1}{E}[\sigma_z - \nu(\sigma_x + \sigma_y)] + \alpha\Delta T$$

$$\sigma_x = \frac{E}{(1+\nu)(1-2\nu)}[(1-\nu)\epsilon_x + \nu(\epsilon_y + \epsilon_z) - (1+\nu)\alpha\Delta T]$$

$$\sigma_y = \frac{E}{(1+\nu)(1-2\nu)}[(1-\nu)\epsilon_y + \nu(\epsilon_x + \epsilon_z) - (1+\nu)\alpha\Delta T]$$

$$\sigma_z = \frac{E}{(1+\nu)(1-2\nu)}[(1-\nu)\epsilon_z + \nu(\epsilon_x + \epsilon_y) - (1+\nu)\alpha\Delta T]$$

$$\gamma_{xy} = \frac{1}{G}\tau_{xy}$$

$$\gamma_{yz} = \frac{1}{G}\tau_{yz}$$

$$\gamma_{xz} = \frac{1}{G}\tau_{xz}$$

$$G = \frac{E}{2(1+\nu)}$$

Axial deformations

$$e_{AB} = u_B - u_A$$

$$e = \int_0^L \frac{F}{AE}\,dx + \int_0^L \alpha\Delta T\,dx$$

$$e = \frac{FL}{AE} + \alpha\Delta T L$$

$$e = u\cos\theta + v\sin\theta$$

EQUATIONS (continued)

Torsional deformations

$$\phi_{AB} = \phi_B - \phi_A$$

$$\phi = \int_0^L \frac{T(x)}{G(x)I_p(x)} dx$$

$$\phi = \frac{TL}{GI_p}$$

$$\gamma = \rho \frac{d\phi}{dx}$$

$$\gamma = \frac{\rho T}{GI_p}$$

$$\tau = G\rho \frac{d\phi}{dx}$$

$$\tau = \frac{\rho T}{I_p}$$

$I_p = \frac{\pi}{2} r^4$ (solid) $\qquad$ $I_p = \frac{\pi}{2}(r_o^4 - r_i^4)$ (hollow)

Bending deformations

$$\frac{dV}{dx} = w(x)$$

$$\frac{dM}{dx} = V(x)$$

$$M = EIv''$$

$$\Delta V = P$$

$$\Delta M = -M_0$$

$$\sigma(x, y) = \frac{-Ey}{\rho} = \frac{-M_{zz} y}{I_{zz}}$$

$I_{zz} = \frac{bh^3}{12}$ (rectangle) $\qquad$ $I_{zz} = \frac{\pi r^4}{4}$ (circle)

$$\tau(x, y) = \frac{VQ}{I_{zz} t} = \frac{VA^* y^*}{I_{zz} t}$$

$\tau_{max} = \frac{3V}{2A}$ (rectangle) $\qquad$ $\tau_{max} = \frac{4V}{3A}$ (circle)

EQUATIONS (continued)

Transformation of stress

$$\sigma_n = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \left(\frac{\sigma_x + \sigma_y}{2}\right)\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\tau_{nt} = -\left(\frac{\sigma_x + \sigma_y}{2}\right)\sin 2\theta + \tau_{xy}\cos 2\theta$$

$$\sigma_{P1}, \sigma_{P2} = \sigma_{ave} \pm R$$

$$\sigma_{ave} = \frac{\sigma_x + \sigma_y}{2}$$

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\tau_{max,abs} = \frac{\sigma_1 - \sigma_3}{2}$$

Thin-wall pressure vessels

Cylindrical: $\sigma_h = \frac{pR}{t}$ $\sigma_a = \frac{pR}{2t}$

Spherical: $\sigma_s = \frac{pR}{2t}$