THE UNIVERSITY OF MELBOURNE

Department of Mechanical Engineering

MCEN90026 SOLID MECHANICS

Semester 2, 2022 Supplementary Exam

Online open-book strict-time-limit exam and submission via Canvas Assignment

This paper has <u>11 pages</u> including this page.

Timing

- **Exam start time:** 3 pm Thursday 15th December 2022
- **Exam end time:** 5.45 pm Thursday 15th December 2022; you must **submit** all responses by 5.45 pm.
- **Exam duration:** 165 minutes in total composed of
  - **Reading time:** 15 minutes
  - **Writing time:** 120 minutes
  - **Submission time:** 30 minutes from 5.15 pm to 5.45 pm Thursday 15th December 2022

Alternative Exam Arrangements (AEAs) time settings may vary from the above.

Authorised materials

This exam will be conducted in an online open-book format and the following materials are permitted:

- Any material loaded onto Canvas as part of the subject content
- Notes (printed, hand-written, and digital/electronic)
- Textbooks
- Online books and materials
- Language dictionaries
- Calculators (any model), computers, electronic tablets, pens, rulers, etc.

Academic misconduct during exams

- **Collusion** is not allowed under any circumstances. Collusion includes, but is not limited to, talking to, phoning, emailing, texting or using the internet to communicate with other students. Similarly, you cannot communicate with any other person via any means about the content of this exam during the examination time. If another student contacts you during the examination period, please inform the subject coordinator immediately.
- **Plagiarism/copying** is not allowed under any circumstances. Your answers to the exam must be in your own words and not directly copied from lecture notes, tutorial

materials, the internet or study notes you have prepared with your friends. You may refer to sources, but answers should be written in your own words. This also applies to programming (code) related answers. Code must be written on your own displaying originality in the content.

- Any similarity detected between your answers, the answers from other students and/or from the internet or other sources will be investigated and may result in academic misconduct.

Instructions to students

- You will have **only one attempt** at completing this online exam.
- This paper consists of three questions. Question 1, Question 2 and Question 3.
- Attempt any two out of the three questions.
- **<u>YOU ARE REQUIRED TO ANSWER ONLY TWO QUESTIONS.</u>**
- The recommended browser for this exam is Google Chrome.
- Total marks for this paper are 100.
- For this remotely conducted exam, you may write answers during reading time.
- Do not write answers during submission time. This time is for submitting your work.
- **For file upload:**
    - Write legibly, preferably in blue or black pen
    - You may use an electronic tablet to write your answers, but all answers must be written using a stylus pen or similar.
    - Ensure your student number is written on each answer page that you upload
    - Start each question on a new page and write the question number in the top right-hand corner
    - Number each page prior to submission to indicate the order of the pages
    - Show all working for each question
    - Responses that span multiple images need be compiled into single PDF documents.
    - The Genius Scan phone app can be used to generate such PDFs.
    - PDFs of responses written on electronic tablets are also acceptable.

Communication and issues during the exam

- Any updates to the exam will be made by the Subject Coordinator via a Canvas Announcement during the exam.
- If you need to ask any exam content-related questions during the exam, please contact your Subject Coordinator via the dedicated Exam Support Chat tool in your Canvas subject immediately.
- If you run into any issues uploading your responses, please email your responses to pvlee@unimelb.edu.au prior to the end of your submission time. In your email, attach your responses and clearly state the subject code, your name and Student ID.
- For all technical and wellbeing enquiries, please contact Stop 1/13MELB via:
    - Phone: 13 6352 (inside Australia) and +61 3 9035 5511 (outside Australia)
    - Web chat: https://ask.unimelb.edu.au/app/ask?chat

INSTRUCTIONS

This paper consists of three questions. Question 1 (50 Marks), Question 2 (50 Marks) and Question 3 (50 Marks). **Attempt any two out of the three questions.**

QUESTION 1 (50 Marks)

Question 1a (20 Marks微信risepaper)

Consider an axisymmetric annular plate with an outer radius, *a* and an inner radius, *b* completely fixed at the inner radius and free at the outer radius. A positive bending moment per unit length, M_0, is applied at the outer radius.

Determine the equations for the maximum displacement and the reaction moments at the inner radius.

Note: State all your assumptions and boundary conditions clearly.

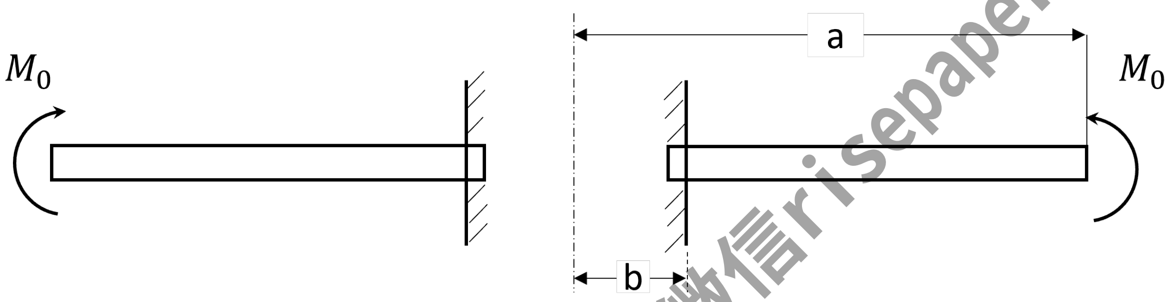

Figure 1a: Thin circular plate with a positive bending moment

(Question 1 continues on next page…)

Question 1b (15 Marks)

A homogenous steel disc with an outer diameter of 600mm and inner diameter of 300mm is shrunk fit onto a rotating steel shaft with an initial interference of 0.15mm.

Find:

- **The initial contact pressure.**
- **The speed at which the disc becomes loose on the shaft.**

Neglect shaft expansion. Assume the material properties of steel as follows:

Young's Modulus E = 207 GN/m^2

Poisson's ratio, $\nu = 0.3$

Density, $\rho = 7880\ kg/m^3$

(Question 1 continues on next page…)

Question 1c (15 Marks**)**

Figure 1c shows a water storage tank with 20mm uniform wall thickness. The tank is fixed at the top end (A-A). The tank is made up of cylindrical section joined to a spherical cap at B-B. The joint is reinforced by welding an angle-section ring with a cross-sectional area of $5000mm^2$. **Calculate,**

i. **the maximum stresses in the cylindrical section of the tank,**

ii. **the maximum stresses in the spherical cap of the tank,**

iii. **the hoop stress in the reinforcing ring,**

when the water is at the level shown in figure 1c.

Specific weight of water is $9.81kN/m^3$.

(Note: consider the radius of the tank and the wall thickness to determine if this is a thick or thin wall pressure vessel.)

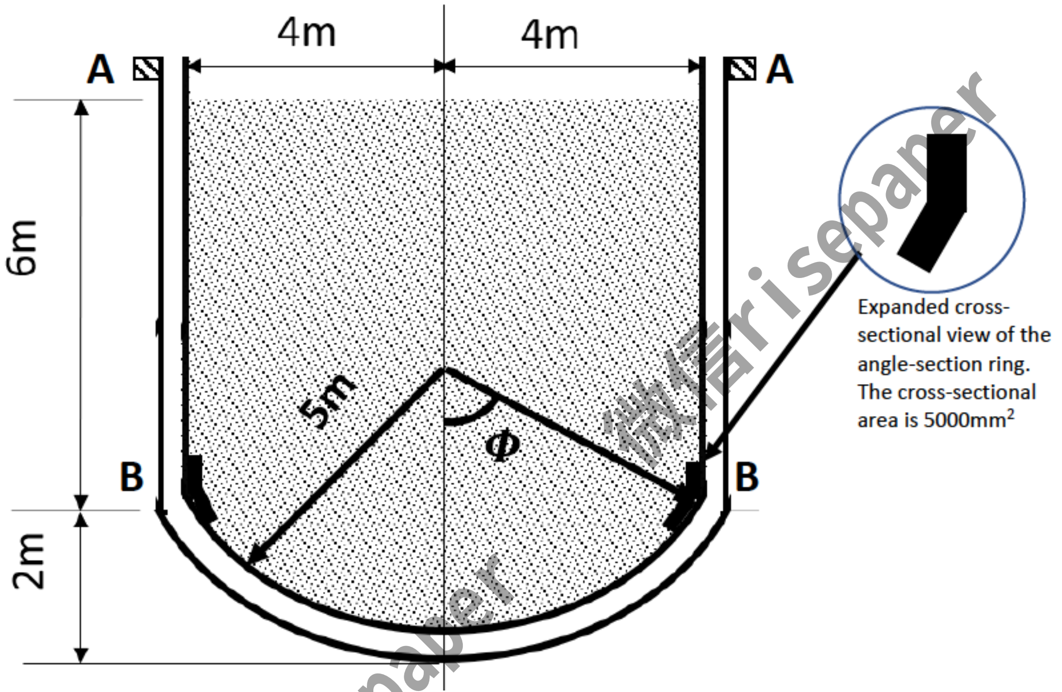

Figure 1c: A water storage tank with uniform thickness of 20mm.

---- End of Question 1 ----

QUESTION 2 (50 Marks)

Question 2a (20 Marks)

A high-strength steel disc 30mm thick with an outer diameter of 1200mm and inner diameter of 400mm is rotating at 120 Hz.

Young's Modulus, $E = 210\ GN/m^2$

Poisson's ratio, $\nu = 0.28$

Density, $\rho = 7880\ kg/m^3$

Yield Strength $S_y = 1200$ MN/m2

- **Determine the radial and tangential stress distributions as functions of radial position 'r'. Tabulate the values in 100mm increments of 'r' and plot the distribution neatly in your sketch. You do not need to use graph paper.**

- **Find the speed at which yielding starts.**

(Question 2 continues on next page…)

<u>Question 2b (15 Marks)</u>

A bronze bush of 25mm wall thickness is to be shrunk onto a steel shaft of 100mm in diameter. If an interface pressure of $69MN/m^2$ is required, **determine the interference between the bush and the shaft.**

Material properties are given as below:

Steel: E = $207GN/m^2$, $\nu = 0.28$

Bronze: E = $100GN/m^2$, $\nu = 0.29$

(Question 2 continues on next page…)

Question 2c (15 Marks)

A beam with T cross-section as shown in figure 2c below. The flange and web of the cross-section are each 12mm thick, the flange width is 100mm, and the overall depth of the section is 100mm. The centroid of the section is at 70.6mm from the bottom of the web and the second moment of area, I_{zz} of the section about a line through the centroid and parallel to the flange is $2.03 \times 10^6 mm^2$.

- **Determine the value of the shape factor.**

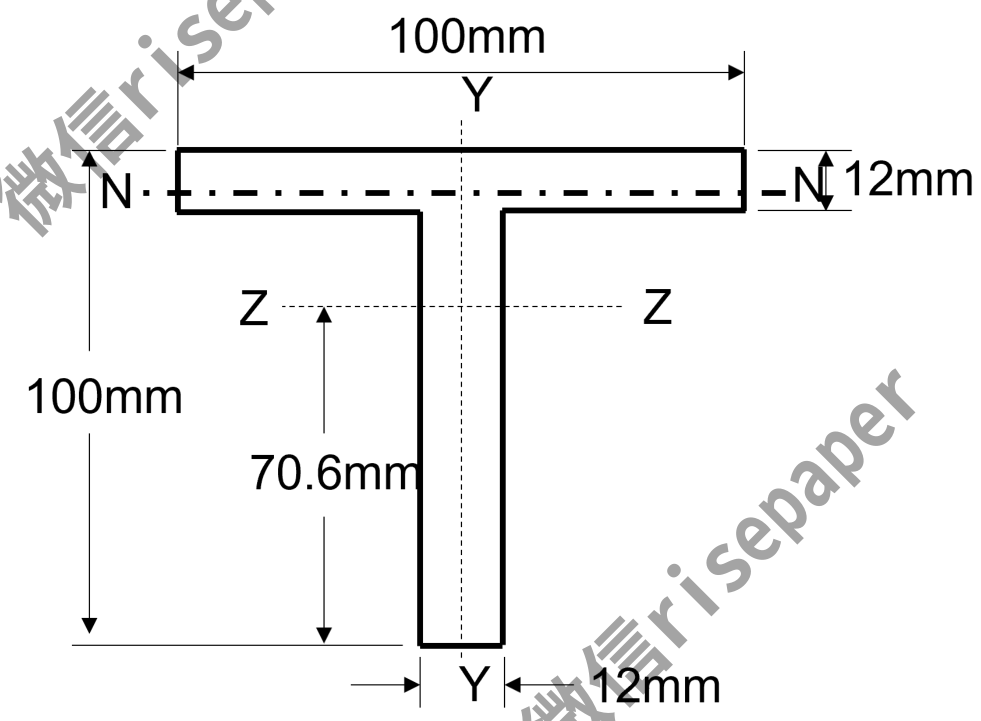

Figure 2c: A T-bar section in which YY is the only axis of symmetry

---- End of Question 2 ----

QUESTION 3 (50 Marks)

Question 3a (15 Marks)

A duplex thick-walled cylinder has an inner radius *a=100mm*, an outer radius *b=300mm*, and an interface radius *c=200mm*, as shown in figure 3a. Initially, the outer radius of the inner cylinder is larger than the inner radius of the outer cylinder by an amount of δ. For steel cylinder ($E = 200GPa$) and a shrinkage factor $\delta/_c = 0.001$, **determine the stresses in the cylinder at r = 100mm, r = 150mm and r =300mm.**

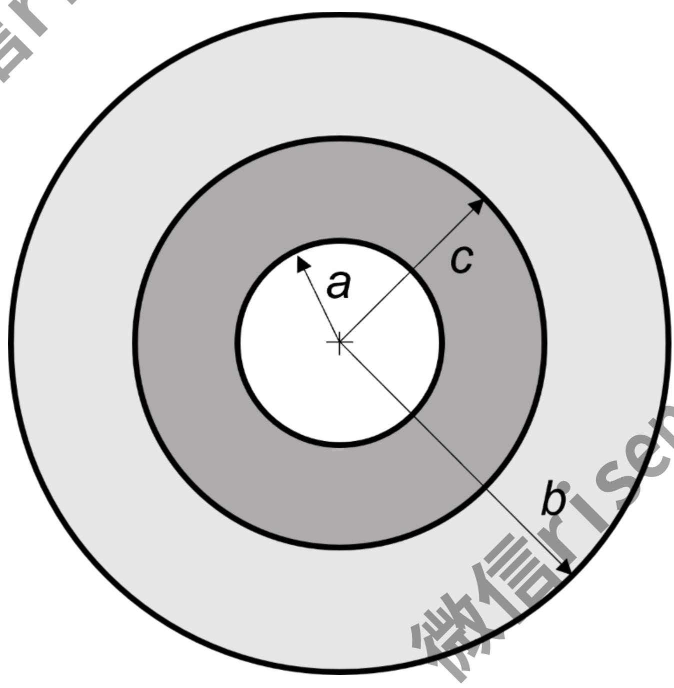

Figure 3a: A duplex thick-walled cylinder

(Question 3 continues on next page…)

Question 3b (20 Marks)

For the beam shown in Figure 3b, the bending moment capacity (i.e., plastic hinge moment) is M_p throughout.

- **There are two plausible collapse mechanisms. Consider both to determine the critical load (i.e., true collapse load, P_o) for plastic collapse.**

(Hint: Use the virtual work approach $M \times \theta$ or $P \times \delta$).

Your solution must include labelled sketches.

Check that the values of moment throughout the beam are less than or equal to the limiting plastic hinge moment M_p, when suggesting a value for P_o. Bending moment diagrams for both plausible collapse mechanisms should be sketched.

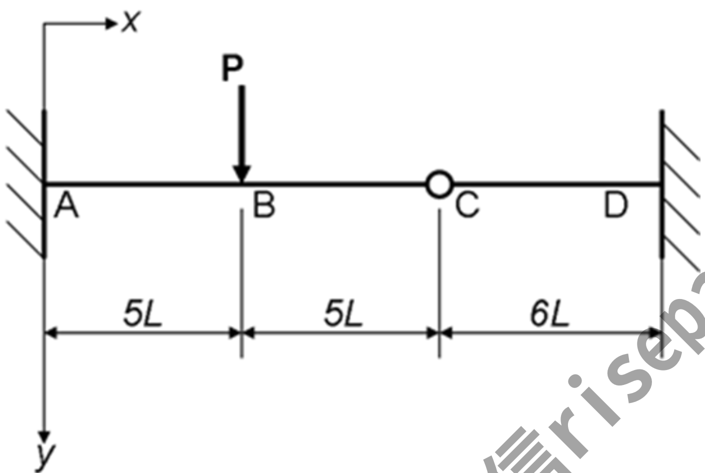

Figure 3b: Plastic collapse of the beam.

(Question 3 continues on next page…)

Question 3c (15 Marks**)**

A steel flywheel 25mm thick with an outer diameter if 1m and an inner diameter of 200mm is rotating at 100Hz as shown in figure 3c.

Material properties of steel are:

$$E = 210GPa, \rho = 7880\,kg/m^3\,, \nu = 0.28$$

- **Determine the radial and tangential stress distributions as functions of radial position, r and sketch the distribution neatly, you do not need to use graph paper.**
- **Determine the radial deflection of the outer radius of the flywheel**.

  Hint: You may need to use Hooke's law.

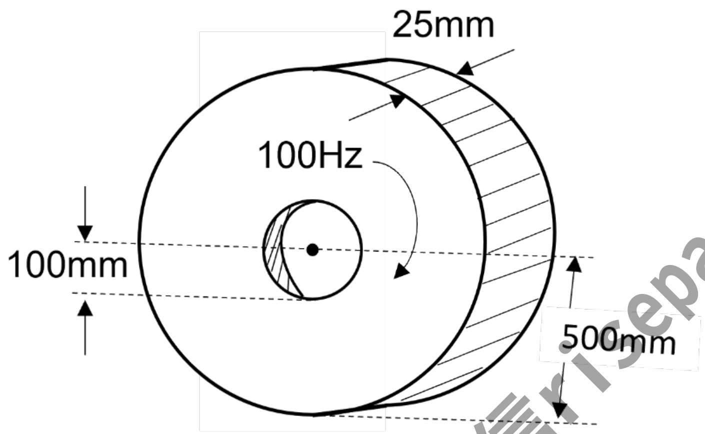

Figure 3c: A steel flywheel

---- End of Question 3 ----

End of exam