Examination Period 3: 2018/19

Module Title: Mechanical Principles
Level: Four
Time Allowed: Two hours

Instructions to students:

• Enter your student number not your name on all answer books.
• Answer four out of five questions. Please note: you will only be marked on the first four questions answered.
• All questions are equally weighted. Where a question has more than one part the division of marks is clearly stated.
• Begin each question on a separate answer page; label each answer page clearly with the number of the question you are answering.
• The use of a calculator is permitted.
• Students are permitted to take rule and protractor stationery into the examination room.
• Graph paper can be located at the back of each answer book.
• Engineering formulae can be found at the back of this exam paper.
• Neither books nor notes can be taken into the examination.

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Answer four out of five questions.

**Question 1**

a. How would you calculate the following? Give a standard formula.
   
   i. Stress
   ii. Strain
   iii. Young’s Modulus of Elasticity

   (5 marks)

b. A mild steel specimen of cross-sectional area 250 mm$^2$ and gauge length 100 mm was subjected to a tensile test and the following data obtained:

   Load at Yield Point = 80 kN
   Maximum load on specimen = 120 kN
   Final cross-sectional area of waist at fracture = 90 mm$^2$
   Final gauge length at fracture = 135 mm

   **Determine:**
   
   i. the Yield Stress
   ii. the Tensile Strength
   iii. the percentage elongation
   iv. the percentage reduction in area

   (8 marks)

c. A component is machined from a length of solid square bar to form a circular shaft of diameter 30 mm with a square flange of side 30 mm at one end, see **Figure Q1**.

   Determine the stress in each of the sections if an axial compressive load of 50 kN is applied to the component.

   ![Figure Q1](image)

   (6 marks)
d. A simple riveted lap joint connecting two plates is formed from four rivets arranged in two rows, see Figure Q2. If the rivet diameter is 8 mm and the maximum shear stress (i.e. the shear strength) of the rivet material is 350 N/mm² determine the maximum safe working load \( F \) for the joint if a Factor of Safety of 5 is used.

![Figure Q2](image)

(6 marks)

Total: 25 marks

Question 2

A hollow square beam of outside dimension 25mm and 1.2mm gauge was subjected to a loading experiment to determine the rigidity characteristics.

![Beam setup](image)

Test data: Beam length = 600mm;
Beam loading = 35N;
Deflection = 0.06mm.

**Determine the following:**

a. Maximum bending moment (4 marks)
b. 2\(^{nd}\) moment of area (5 marks)
c. Maximum stress (4 marks)
d. Modulus of elasticity (4 marks)
e. Radius of curvature (4 marks)
f. Stiffness value (4 marks)

Total: 25 marks
Question 3

String is wound around the central drum of a wheel of mass 0.6 kg as illustrated in Figure Q3. The drum is of radius 0.012 m and the wheel has a radius of gyration of 0.025 m. As the wheel is released it descends and rotates.

a. Calculate the moment of inertia.  
   (8 marks)

b. Calculate the linear and angular velocity of the wheel after it falls 0.8 m.  
   (17 marks)

Figure Q3

Total: 25 marks

Question 4

Three masses A, B and C are placed on a balanced disc as shown in Figure Q4 at radii of 120 mm, 100 mm and 80 mm respectively. The masses are 1 kg, 0.5 kg and 0.7 kg respectively.

a. Draw up a table to calculate the value of M r for each mass.  
   (8 marks)

b. Draw the M r polygon to find the value of M r for the 4th mass.  
   (12 marks)

c. Find the Resultant and the 4th mass which should be added at a radius of 60 mm in order to statically balance the system.  
   (5 marks)

Figure Q4

Total: 25 marks
Question 5

A steel cylinder 0.5 m outer diameter, 0.45 m inner diameter and 1.5 m long is filled with concrete and used as a vertical column to support a weight of 30 kN. Determine the compression and the stresses in both the steel and concrete. $E$ is 205 GPa for the steel and 10 GPa for concrete. (25 marks)

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End of Questions
Formulae follows overleaf
Formulae List

Composite Bars

\[ F = \sigma_1 A_1 + \sigma_2 A_2 \quad \frac{\sigma_1}{E_1} = \frac{\sigma_2}{E_2} \quad (\alpha_1 - \alpha_2) \Delta \theta = \frac{\sigma_1}{E_1} + \frac{\sigma_2}{E_2} \quad \sigma_1 A_1 = \sigma_2 A_2 \]

Shear

\[ \tau = \frac{F}{A} \quad \gamma = \frac{x}{L} \quad G = \frac{\tau}{\gamma} \]

Bending

\[ \frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R} \]

\[ I = \frac{\pi D^4}{64} \quad \text{For solid round bar} \]

\[ I = \frac{\pi}{64} \left( D_o^4 - D_i^4 \right) \quad \text{For hollow round bar} \]

\[ I = \frac{bd^3}{12} \quad \text{For rectangular section bar} \]

\[ I = \frac{BD^3 - bd^3}{12} \quad \text{For hollow rectangular section} \]

Torsion

\[ \frac{T}{J} = \frac{\tau}{r} = \frac{G \theta}{L} \]

\[ J = \frac{\pi D^4}{32} \quad \text{For solid round bar} \]

\[ J = \frac{\pi}{32} \left( D_o^4 - D_i^4 \right) \quad \text{For hollow round bar} \]

Linear Motion

\[ v + u = at \quad v^2 = u^2 + 2as \quad s = ut + \frac{1}{2}at^2 \quad s = \frac{(v + u)t}{2} \]

Formulae continues overleaf
Angular Motion

\[ \omega_2 = \omega_1 + at \]
\[ \theta = \omega_1 t + \frac{1}{2} \alpha t^2 \]
\[ \omega_2^2 = \omega_1^2 + 2 \alpha \theta \]
\[ v = \omega r \]
\[ a = \alpha r \]
\[ a = \omega^2 r = \frac{v^2}{r} \]
\[ F = m \omega^2 r = m \frac{v^2}{r} \]

Acceleration due to gravity
\[ g = 9.81 \text{ m/s}^2 \]

Rotating Masses

\[ \sum mr = 0 \quad \text{(for static balance)} \]
\[ \sum mr \times x = 0 \quad \text{(for dynamic balance)} \]

\[ F = m \omega^2 r \]

Flywheels

\[ T = I \alpha \quad K.E. = \frac{1}{2} I \omega^2 \]
\[ I = mk^2 \]
\[ P = T \omega \]

\[ k^2 = \frac{d^2}{8} \quad \text{For a solid, circular disc} \]

Mechanics of Fluids

\[ 1 \text{ bar} = 10^5 \text{ N/m}^2 \quad g = 9.81 \text{ m/s}^2 \]
\[ \text{For water } \rho = 10^3 \text{ kg/m}^3 \]

Steady Fluid Flow

For unit mass
\[ \frac{p_1}{\rho} + \frac{v_1^2}{2} + gh_1 = \frac{p_2}{\rho} + \frac{v_2^2}{2} + gh_2 + \text{(losses)} \]

Mass Continuity
\[ A_1 v_1 = A_2 v_2 \]

Pressure
\[ p = \rho gh \]

\[ Q = \frac{m}{\rho} \quad v_1 = Q/A_1 \]

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End of Formulae
End of Paper