

UNIVERSITY OF GREATER MANCHESTER

**SCHOOL OF ENGINEERING AND BUILT
ENVIRONMENT**

BENG (HONS) MECHANICAL ENGINEERING

SEMESTER ONE EXAMINATION 2025/2026

ENGINEERING PRINCIPLES 1

MODULE NO: AME4062

Date: Wednesday 14th January 2026

Time:

10am – 12 noon

INSTRUCTIONS TO CANDIDATES:

There are **THREE** questions each in **TWO** sections.

Answer **ANY FOUR** questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.

Formula Sheets for reference follow after the questions.

Section 1: Mathematics

Question 1-Trigonometry

a) Support Frame of a Drone Launch Platform

A portable drone launch platform has a triangular support frame as shown in **Figure Q1a**.

The horizontal base $BC = 3.6\text{ m}$ supports two inclined beams AB and AC joined at the top apex A .

Beam AB is inclined at 40° and beam AC at 55° to the base.

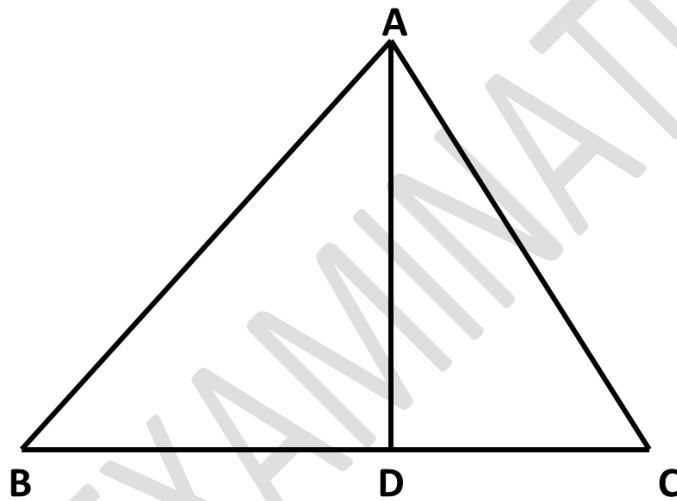


Figure Q1a: Support Frame.

Tasks:

- Determine the height AD of the apex above the base (where AD is perpendicular to BC).
- Find the lengths of the inclined beams AB and AC .
- If each beam carries a compression load of 8 kN , determine the vertical component of the total load supported at point A .

(Assume symmetry in load distribution and neglect beam weight.)

[10 marks]

Q1 continued over next page

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Q1 continued**b) Linkage in a Mechanical Lifting Arm**

In **Figure Q1b**, a lifting arm consists of two rigid links:

- $OA = 180 \text{ mm}$ and $AB = 300 \text{ mm}$,
- The included angle $\angle OAB = 65^\circ$.

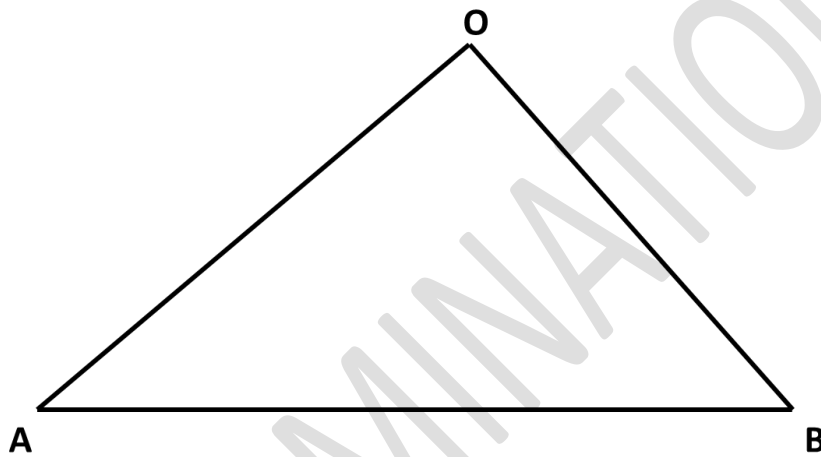


Figure Q1b: Lifting Arm

Tasks:

- Use the cosine rule to find the distance OB .
- If the linkage angle increases to 80° determine the new distance OB .
- Calculate the change in extension and discuss briefly how increasing linkage angle influences lifting reach and mechanical advantage.

[10 marks]

Q1 continued over next page

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Q1 continued**c) Trigonometric Identity Application**

Given that

$$x = \sin(45^\circ + \theta)$$

Tasks:

- i. Simplify the expression for x using trigonometric identities.
- ii. Find the value of x when $\theta = 30^\circ$.
- iii. Briefly explain what the term 45° represents in the context of **vibrating** or **rotating systems**.

[5 marks]

Total 25 marks

Question 2-Logarithmic and Exponential Functions**a) Cooling of a Turbine Blade**

After shutdown, the temperature T of a turbine blade made from a nickel alloy cools exponentially according to Newton's law of cooling:

$$T = T_{room} + (T_0 - T_{room})e^{-kt}$$

where:

- $T_0 = 950^\circ C$ is the initial temperature,
- $T_{room} = 25^\circ C$ is the ambient air temperature,
- k is a material cooling constant,
- t is the time in minutes.

Q2 continued over next page

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Q2 continued**Tasks:**

- i. If the blade temperature is 400°C after $t = 20 \text{ min}$, determine the value of k in min^{-1} . (Show all steps using logarithmic rearrangement.)
- ii. Using the calculated k , estimate the time required for the blade temperature to reach 100°C .
- iii. The cooling constant k depends on thermal conductivity. A nickel alloy has a conductivity of approximately $60 \text{ W m}^{-1} \text{ K}^{-1}$, whereas a titanium alloy of the same geometry has about $20 \text{ W m}^{-1} \text{ K}^{-1}$.

Based on these values, state and explain how the **cooling constant k** would differ for the titanium alloy blade.

[10 marks]**b) Pressure Decay in a Pneumatic Cylinder**

The air pressure P in a sealed pneumatic system decreases with time due to a micro-leak, according to the law:

$$P = P_0 e^{-ct}$$

where P_0 is the initial pressure (kPa), c is a leakage constant in s^{-1} , and t is the time in seconds.

Experimental data are as follows (**Table 2Qa**):

Table 2Qa: Time vs Pressure.

Time t (s)	Pressure P (kPa)
0	600
30	420
60	?

Q2 continued over next page**PLEASE TURN THE PAGE**

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Q2 continued

Tasks:

- i. Determine the leakage constant c using the data at $t = 30$ s.
- ii. Predict the pressure P after $t = 60$ s.
- iii. Hence, find the time taken for the pressure to fall below 150 kPa.

The leakage constant c depends on the air properties and seal condition. If the **seal temperature increases**, the air viscosity decreases and the rubber seal may expand slightly.

Explain qualitatively how this would affect the **value of c** , and justify physically.

[10 marks]

c) Material Strength Degradation

The tensile strength of a polymer composite exposed to UV radiation follows a logarithmic decay relationship:

$$S = S_0 - 12 \ln(t + 1)$$

where S is in MPa, $S_0 = 120$ MPa and t is the exposure time in hours.

Tasks:

- i. Determine the tensile strength after $t = 10$ hours.
- ii. Estimate the time when $S = 80$ MPa.
- iii. Explain what the logarithmic form implies about the **rate of degradation** over time.

[5 marks]

Total 25 marks

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Question 3 - Vectors and Matrices

a) Cable Tension Analysis using Matrix Method

Formula:

$$[A][T] = [B]$$

where:

- $[A]$ = coefficient matrix from equilibrium equations,
- $[T]$ = column matrix of unknown tensions T_1 and T_2 (kN),
- $[B]$ = load vector (kN).

Given equilibrium equations:

$$\begin{aligned} 6T_1 + 4T_2 &= 28 \\ 3T_1 + 5T_2 &= 19 \end{aligned}$$

Tasks:

- Represent the system in matrix form and determine the inverse of $[A]$.
- Find the cable tensions T_1 and T_2 in kN .

[10 marks]

b) Resultant Force on Drone Frame

Formula:

$$R = \sqrt{(R_x)^2 + (R_y)^2}, \quad \tan \theta = \frac{R_y}{R_x}$$

where:

- $R_x = \sum F_x, R_y = \sum F_y$
- θ = angle of resultant with horizontal.

Q3 continued over next page

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Q3 continued**Given:**

$F_1 = 20\text{ N}$ (horizontal),
 $F_2 = 15\text{ N}$ at 45°C ,
 $F_3 = 10\text{ N}$ vertically downward.

Tasks:

- Resolve each force into x and y components.
- Determine the resultant magnitude and direction.

[5 marks]**c) Work Done by Drone Manipulator****Formula:**

$$W = \vec{F} \cdot \vec{s}$$

where:

$$\vec{F} = 8\mathbf{i} - 4\mathbf{j} + 3\mathbf{k}\text{N},$$

$$\vec{s} = 2\mathbf{i} + 3\mathbf{j} + 6\mathbf{k}\text{m}.$$

Tasks:

- Calculate the scalar work done W in joules.
- Comment on the physical meaning of the sign of W .

[5 marks]**Q3 continued over next page****PLEASE TURN THE PAGE**

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Q3 continued

d) Torque on Wind-Turbine Bracket

Formula:

$$\vec{M} = \vec{r} \times \vec{F}$$

where:

$$\vec{F} = 4\mathbf{i} + 3\mathbf{j} + 2\mathbf{k} \text{ kN},$$

$$\vec{s} = 12\mathbf{i} + 6\mathbf{j} + 10\mathbf{k} \text{ kN}.$$

Tasks:

- i. Evaluate \vec{M} using the determinant method.
- ii. Explain the physical significance of each component of \vec{M} .

[5 marks]

Total 25 marks

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Section 2: Mechanics

Question 4

During a tensile test to determine the properties of a material, the following results were recorded: the specimen has a diameter of 15 mm and an original length of 40 mm. At the limit of proportionality, the applied load was 85 kN, and the material extended by 0.075 mm. The maximum load recorded before the material fractured was 120 kN, and the length of the specimen at the point of fracture was 55 mm. Based on this data, further calculations are required to analyse the material's properties.

- i. Calculate the Young's modulus of elasticity, [6 marks]
 - ii. Calculate the ultimate tensile strength, [3 marks]
 - iii. Calculate the stress at the limit of proportionality, [3 marks]
 - iv. Calculate the percentage elongation. [3 marks]
- b) A hollow cast iron cylinder of outside diameter D and wall thickness of 10 mm (**Figure Q4**) is to carry a compressive load of 100 kN. Compute the required outside diameter D , if the working stress in compression is 80 N/mm^2 .

[10 marks]

Total 25 marks

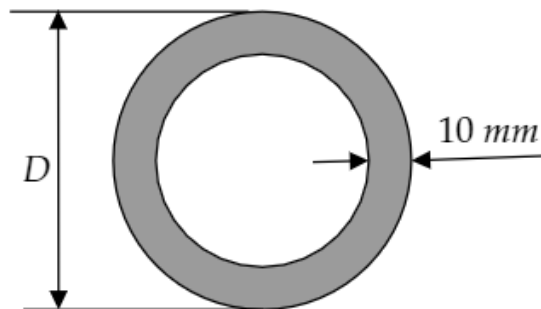


Figure Q4: Hollow circular cross-section.

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Question 5

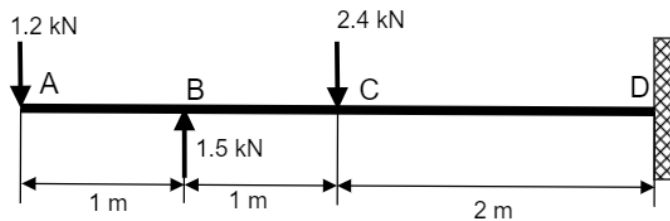
a) A cantilever beam supports three-point loads as shown in **Figure Q5a**. For this beam configuration

- i. Find the reaction forces and moments at the fixed end.

[4 marks]

- ii. Construct the shear force diagram.

[5 marks]

**Figure Q5a: Cantilever beam.**

b) A steel I-beam is used to support an industrial motor in a machining plant. The beam is simply supported, and the weight acting on the beam can be modelled as a uniformly distributed load (UDL), as shown in **Figure Q5b**. For this beam configuration:

- i. Determine the reactions at the supports A and B.

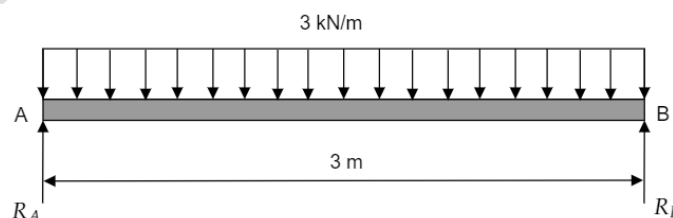
[4 marks]

- ii. Draw the shear force and bending moment diagrams with appropriate annotations.

[8 marks]

- iii. Find the maximum bending moment and the location on the beam that experiences maximum bending moment.

[4 marks]

Total 25 marks**Figure Q5b: Simply supported beam with UDL.****PLEASE TURN THE PAGE**

Question 6

- a) Describe the different types of structural supports (roller, pinned, and fixed supports). For each support type, explain the movement it allows or restricts and state the types of reaction forces and moments generated at the support.

[6 marks]

- b) A truss structure for a small bridge is shown in **Figure Q6**. For the given geometry and loads,

- i. Find the reactions at supports A and D.

[4 marks]

- ii. Calculate forces in all truss members using the Method of Joints. Consider the joints A, B, C and D only.

[12 marks]

- iii. Check your results by applying the method of joints at joint E.

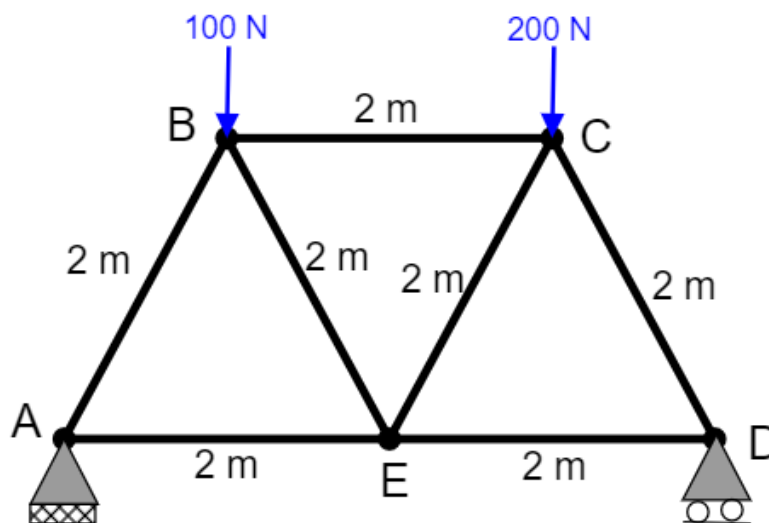
[3 marks]**Total 25 marks**

Figure Q6: Truss structure.

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FORMULA SHEET

Mathematics Equations

Trigonometry:

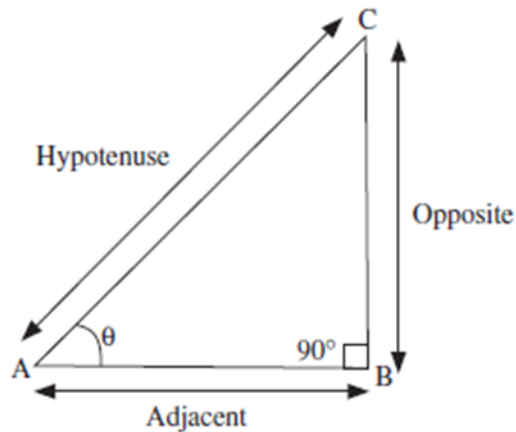


Figure 7

In Figure 7

$$\sin(\theta) = \frac{\text{opposite length}}{\text{hypotenuse length}}$$

$$\cos(\theta) = \frac{\text{adjacent length}}{\text{hypotenuse length}}$$

$$\tan(\theta) = \frac{\text{opposite length}}{\text{adjacent length}}$$

$$\operatorname{cosec}(\theta) = \frac{1}{\sin(\theta)}$$

$$\operatorname{sec}(\theta) = \frac{1}{\cos(\theta)}$$

$$\operatorname{cot}(\theta) = \frac{1}{\tan(\theta)}$$

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Pythagoras's theorem

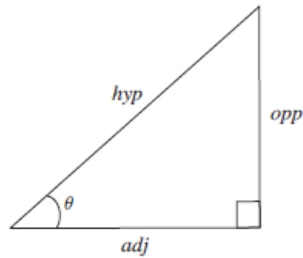


Figure 8

In Figure 8

$$hyp^2 = adj^2 + opp^2$$

Sin and cosine rule

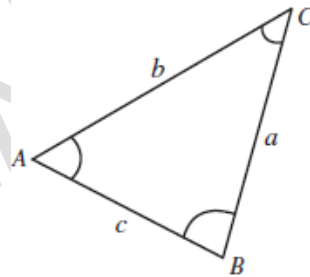


Figure 9

Sine rule:

In Figure 9

$$\frac{a}{\sin(A)} = \frac{b}{\sin(B)} = \frac{c}{\sin(C)}$$

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Cosine rule:

In Figure 9

$$a^2 = b^2 + c^2 - 2bc \cdot \cos(A)$$

Trigonometric identities

$$\sin(A + B) = \sin(A)\cos(B) + \cos(A)\sin(B)$$

$$\sin(A - B) = \sin(A)\cos(B) - \cos(A)\sin(B)$$

$$\cos(A + B) = \cos(A)\cos(B) - \sin(A)\sin(B)$$

$$\cos(A - B) = \cos(A)\cos(B) + \sin(A)\sin(B)$$

$$\tan(A + B) = \frac{\tan(A) + \tan(B)}{1 - \tan(A)\tan(B)}$$

$$\tan(A - B) = \frac{\tan(A) - \tan(B)}{1 - \tan(A)\tan(B)}$$

Exponential Functions:

List of Indices

$$a^m a^n = a^{m+n}$$

$$\frac{a^m}{a^n} = a^{m-n} \quad (a \neq 0)$$

$$(a^m)^n = a^{m \times n}$$

$$\frac{1}{a^n} = a^{-n} \quad (a \neq 0)$$

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$$a^{\frac{1}{n}} = \sqrt[n]{a}$$

$$a^{\frac{m}{n}} = \sqrt[n]{a^m}$$

$$a^0 = 1$$

$$a^1 = a$$

Laws of logarithms:

$$\ln(A) + \ln(B) = \ln(AB)$$

$$\ln(A) - \ln(B) = \ln\left(\frac{A}{B}\right)$$

$$\ln(A^n) = n\ln(A)$$

$$\ln(e) = 1$$

$$\ln(e^x) = x$$

$$e^{\ln(x)} = x$$

$$e^{x\ln(a)} = a^x$$

Matrix:

$$A^{-1} = \frac{1}{\det A} \times \text{adj}(A)$$

where,

$$A = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$$

$$\det A = ad - bc$$

$$\text{Adj}(A) = \begin{pmatrix} d & -b \\ -c & a \end{pmatrix}$$

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Vector:

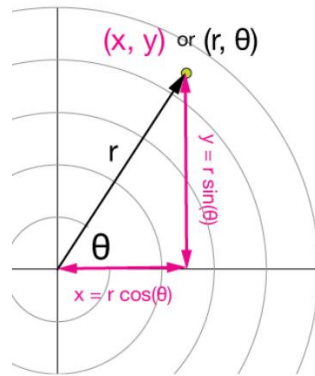


Figure 10

In Figure 10

$$x = r \cos \theta$$

$$y = r \sin \theta$$

$$\mathbf{r} = |r| \cos \theta \mathbf{i} + |r| \sin \theta \mathbf{j}$$

where \mathbf{i} and \mathbf{j} are unit vectors in the x (horizontal) and y (vertical) directions.

$$|r| = \sqrt{x^2 + y^2}$$

$$\theta = \tan^{-1} \left(\frac{y}{x} \right)$$

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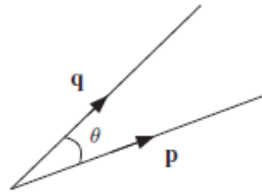


Figure 11

In Figure 11, scalar product can be defined as

$$\mathbf{p} \cdot \mathbf{q} = |\mathbf{p}||\mathbf{q}|\cos\theta$$

If $\mathbf{p} = ai + bj + ck$ and $\mathbf{q} = di + ej + fk$, then $\mathbf{p} \cdot \mathbf{q} = ad + be + cf$

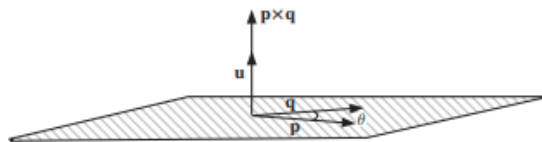


Figure 12

In Figure 12, vector product can be defined as

$$\mathbf{p} \times \mathbf{q} = |\mathbf{p}||\mathbf{q}|\sin(\theta)\mathbf{u}$$

If

$$\mathbf{p} = ai + bj + ck$$

$$\mathbf{q} = di + ej + fk$$

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Then,

$$\mathbf{p} \times \mathbf{q} = \det \begin{pmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ a & b & c \\ d & e & f \end{pmatrix} = (bf - ce)\mathbf{i} - (af - dc)\mathbf{j} + (ae - bd)\mathbf{k}$$

Mechanics Equations

Tensile Properties:

Normal Stress,

$$\sigma = \frac{F}{A}$$

where A is cross-sectional area and F is force normal to the A .

Strain,

$$\varepsilon = \frac{\Delta L}{L}$$

where L is initial length and ΔL is change in length.

Stiffness,

$$\frac{F}{\Delta L}$$

Elastic Modulus,

$$E = \frac{\sigma}{\varepsilon}$$

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Formula sheet continued**Shear Properties:**

Shear Stress,

$$\tau = \frac{F_1}{A_1}$$

where A_1 is cross-sectional area and F_1 is force parallel to the A_1 .

Shear Strain,

$$\gamma = \frac{x}{h}$$

where x is change in the movement of the face and h is height of the block.

Truss:

At any node of a truss,

Summation of all the vertical loads,

$$\Sigma F_y = 0$$

Summation of vertical reaction loads at 1 and 2,

$$R_1 + R_2 = 0$$

Summation of all the horizontal reaction loads,

$$H_1 = 0$$

Summation of all the horizontal loads,

$$\Sigma F_x = 0$$

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Formula sheet continued

Summation of Moments,

$$\Sigma M = \Sigma M_{clockwise} - \Sigma M_{anticlockwise} = 0$$

Moment,

$$M = r \times F$$

where, F is applied load and r is perpendicular distance to F

Beam:

Summation of reaction loads,

$$R_A + R_B = UDL \times L$$

where UDL is uniformly distributed load and L is length of the beam.

Summation of Moments,

$$\Sigma M_1 = \Sigma M_{1clockwise} - \Sigma M_{1anticlockwise} = 0$$

Moment,

$$M = r \times F$$

where F is applied load and r is perpendicular distance to F .

Hollow circular cross-section

Cross-sectional area, $A = \frac{\pi D_o^2}{4} - \frac{\pi D_i^2}{4}$

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