ENG19

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

B.ENG (HONS) MECHANICAL ENGINEERING

SEMESTER 1 EXAMINATION - 2024/2025

ENGINEERING PRINCIPLES 1

MODULE NO: AME4062

Date: Tuesday 7th January 2025 **Time: 10:00-12:00pm**

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.

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Engineering Principles 1
Module No. AME4062

Section 1: Mathematics

Question 1

a) **Figure Q1a** shows a model for the **symmetric** supports of a suspension bridge. The span BF= 15 m represents the deck of the bridge, and the inclined members AB and AC are support cables or beams, with angles of 30° and 60°. The vertical distance AD represents the height of the support towers from the deck. Calculate, AF and DE.

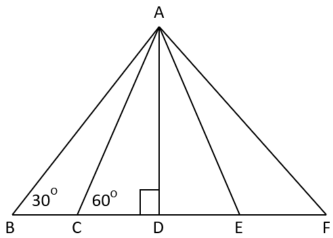

Figure Q1a: Support for a suspension bridge. **[10 Marks]**

In **Figure Q1b,** the crank arm OA=150 mm represents the first section of a robotic arm, rotating clockwise about a pivot point O. The connecting rod AB = 300 mm is the second segment of the arm, reaching out to a point B where it can pick up or manipulate objects. If the angle between OA and AB is 70°, calculate the length OB (the distance from the base to the object).

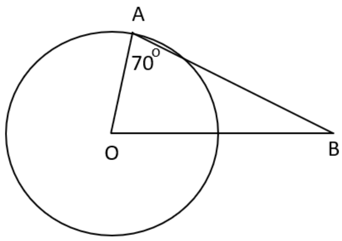

Figure Q1b: Part of a robotic arm. **[10 Marks]**

b) Find the solutions for x in m and y in cm, where

i. $x = 30 + 12\sin(30^{\circ}) - 2tan(45^{\circ})$ **[2.5 Marks]**

ii. $y = 20 + 10\cos(45^{\circ}) - 2cot(45^{\circ})$ **[2.5 Marks]**

Total 25 Marks

Please turn the page…

Question 2

a) The **sound intensity level**, L, at a distance r from a point source of sound is given by:

$$L = L_0 - 20\ln(r)$$

where L_0 is the reference sound intensity level at 1 meter from the source.

i. Given that $L_0 = 90\,dB$ and $r = 100$ m, find the sound intensity level L at a distance of $100\,m$.

[6 Marks]

ii. If the distance r is changed to $200\,m$, what will be the new sound intensity level?

[4 Marks]

b) The **temperature** T of an object as it cools down in a room over time t is modelled by the equation:

$$T = T_0 e^{-kt}$$

where T_0 is the initial temperature of the object, k is a cooling constant with a value of 0.05, and t is the time in s.

i. If the object's temperature has dropped to $25°\ C$ from an initial temperature of $100°\ C$, determine the elapsed time t.

[6 Marks]

ii. If the object's temperature further drops to $20°\ C$, what will be the new elapsed time t?

[4 Marks]

c) Determine x in km and y in m, where

i. $\mathrm{x} = 5 + 4\mathrm{e}^{-3}$

[2.5 Marks]

ii. $\mathrm{y} = 9 + 5\ln(4)$

[2.5 Marks]

Total 25 Marks

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Question 3

a) By analysing the forces acting on a beam, we derive the following system of linear equations:

$$5F_x + 8F_y = 10$$
$$3F_x + 4F_y = 5$$

where F_x is the horizontal force in N and F_y is the vertical force in N. Find the values of F_x and F_y using **matrices**.

[10 Marks]

b) **Figure Q3b** shows a block at point O is subject to three forces. The first force $\boldsymbol{F_1} = 10\,kN$, acts horizontally to the right, the second force $\boldsymbol{F_2} = 7kN$, acts at an angle of $30°$ above the horizontal, and the third force $\boldsymbol{F_3} = 8\,kN$, acts vertically upward. Find the resultant force $\boldsymbol{R}$ acting on the block in terms of its magnitude and direction.

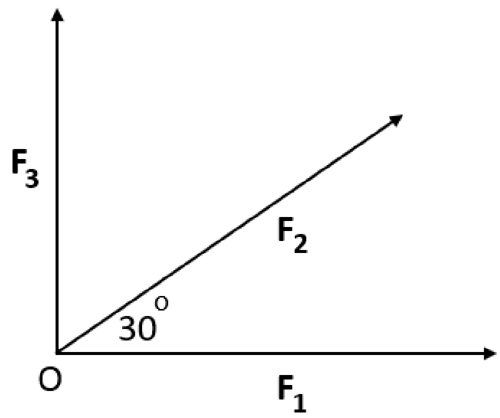

Figure Q3b: Block O subject to forces.

[5 Marks]

Question 3 continues in the next page…

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Question 3 continued

c) A drone is flying through a region with varying wind conditions. The drone's velocity $\boldsymbol{v}$ and the wind's force $\boldsymbol{F}$ acting on it are given by the following vectors. Calculate the power P exerted by the wind on the drone, which is the **dot product** of the wind force and the drone's velocity.
Given:

$$\boldsymbol{v} = 6\boldsymbol{i} + 4\boldsymbol{j} - 2\boldsymbol{k}\ \boldsymbol{m/s}$$

$$\boldsymbol{F} = 3\boldsymbol{i} - 5\boldsymbol{j} + 4\ \boldsymbol{kN}$$

Use the formula:

$$P = \boldsymbol{F}.\boldsymbol{v}$$

[5 Marks]

d) A crane is lifting a load, and a cable attached to the load exerts a tension force T at a certain point. The position of this point relative to the base of the crane is given by the position vector $\boldsymbol{r}$. Determine the torque T exerted by the tension in the cable about the base of the crane, which is a **cross product** of that position and tension vectors.
Given:

$$\boldsymbol{T} = 12\boldsymbol{i} - 4\boldsymbol{j} - 6\ \boldsymbol{kN}$$

$$\boldsymbol{r} = 7\boldsymbol{i} + 3\boldsymbol{j} + 2\ \boldsymbol{km}$$

Use the formula:

$$\boldsymbol{M} = \boldsymbol{r} \times \boldsymbol{T}$$

[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

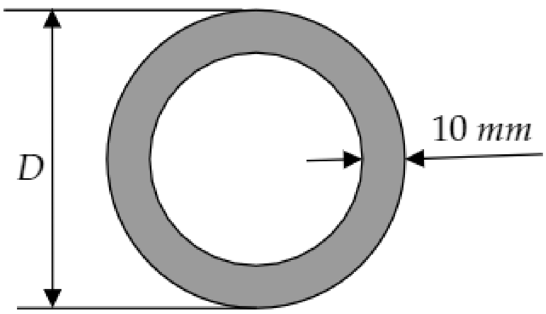

Figure Q4: Hollow circular cross-section.

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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]

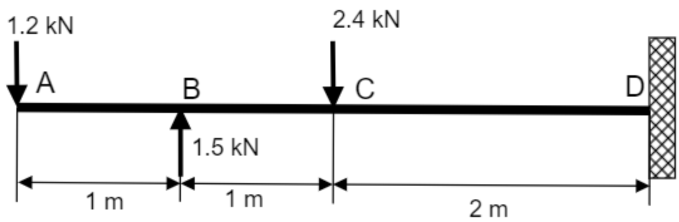

Figure 5a: Cantilever beam.

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 5b**. 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]

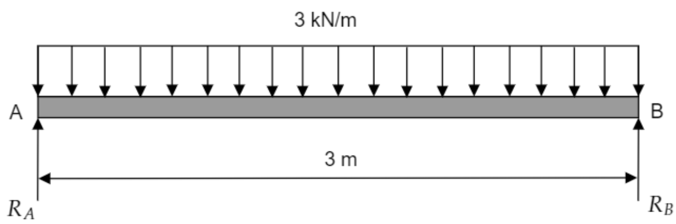

Figure 5b: Simply supported beam with UDL.

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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**]

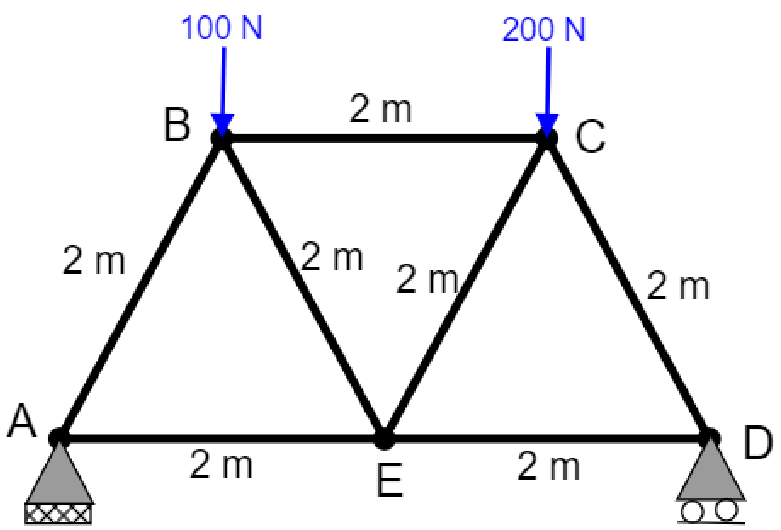

Figure Q6: Truss structure.

END OF QUESTIONS

FORMULA SHEET FOLLOWS ON NEXT PAGES

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FORMULA SHEET

Mathematics Equations

Trigonometry:

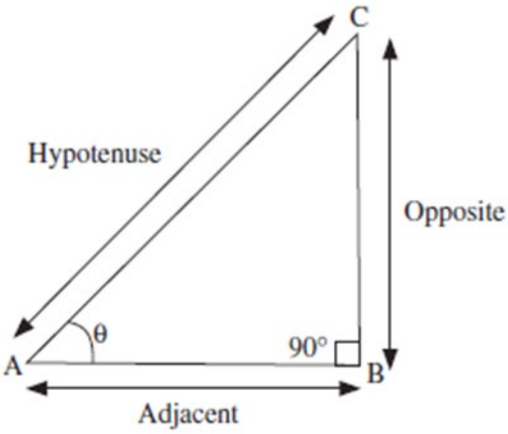

Figure 7

In Figure 7

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

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

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

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

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

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

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Pythagoras's theorem

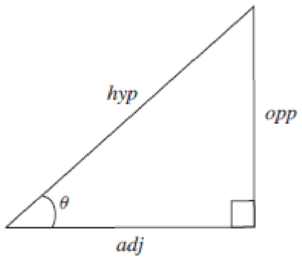

Figure 8

In Figure 8

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

Sin and cosine rule

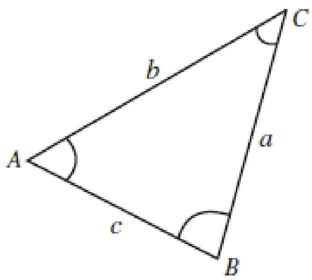

Figure 9

Sine rule:

In Figure 9

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

Cosine rule:

In Figure 9

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

Please turn the page…

Exponential Functions:

List of Indices

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

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

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

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

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

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

$$a^0 = 1$$

$$a^1 = a$$

Laws of logarithms:

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

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

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

$$\ln(e) = 1$$

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

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

$$e^{xln(a)} = a^x$$

Please turn the page…

Matrix:

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

where,

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

$$detA = ad - bc$$

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

Vector:

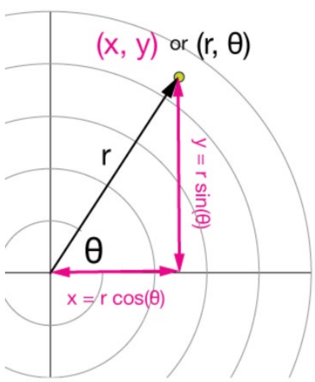

Figure 10

Please turn the page…

In Figure 10

$$x = rcos\theta$$

$$y = rsin\theta$$

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

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

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

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

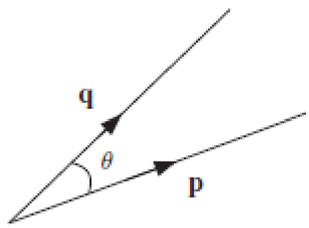

Figure 9

In Figure 9, scaler product can be defined as

$$\boldsymbol{p}.\boldsymbol{q} = |\boldsymbol{p}||\boldsymbol{q}|cos\theta$$

If $\boldsymbol{p}$ = $a\boldsymbol{i}$ + $b\boldsymbol{j}$ + $c\boldsymbol{k}$ and $\boldsymbol{q}$ = $d\boldsymbol{i}$ + $e\boldsymbol{j}$ + $f\boldsymbol{k}$, then $\boldsymbol{p}.\boldsymbol{q}$ = ad + be + cf

Please turn the page…

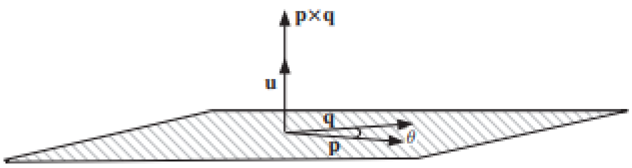

Figure 10

In Figure 10, vector product can be defined as

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

If

$$\boldsymbol{p} = a\boldsymbol{i} + b\boldsymbol{j} + c\boldsymbol{k}$$

$$\boldsymbol{q} = d\boldsymbol{i} + e\boldsymbol{j} + f\boldsymbol{k}$$

Then,

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

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,

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

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.

Please turn the page…

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,

$$\Sigma F_x = 0$$

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.

Please turn the page…

Hollow circular cross-section

Cross-sectional area, $A = \frac{\pi {D_0}^2}{4} - \frac{\pi {D_i}^2}{4}$

End of Formula Sheet

END OF PAPER