[ENG12]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

B.ENG (HONS) MECHANICAL ENGINEERING

SEMESTER 1 EXAMINATION - 2022/2023

ENGINEERING PRINCIPLES 1

MODULE NO: AME4062

Date: Tuesday 10th January 2023 **Time: 10:00 – 12:00**

INSTRUCTIONS TO CANDIDATES:

There are THREE questions 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
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Section 1: Mathematics

Question 1

a) **Figure Q1a** shows the symmetrical roof truss. Span BC is of length 6m. Rafter AB is inclined at angle 60°. Find the lengths of the Rafter AB, AC and AD.

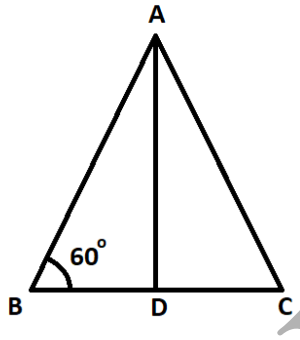

Figure Q1a: Truss. **10 Marks]**

b) **Figure Q1b** shows a part of a bicycle frame which is simplified into a triangle. Top tube, AC is 3m and down tube, BC is 2m. if angle, B=120°, find the other two angles, A and C, and the length of the seat tube, AB.

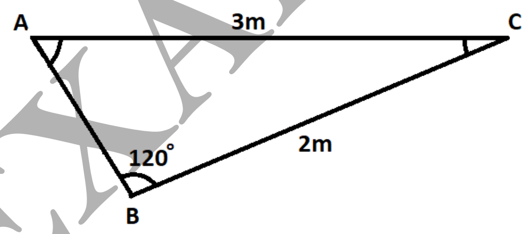

Figure Q1b: Bicycle frame. **[10 Marks]**

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

i. $x = 20 + 10\sin(60^{\circ})$

[2.5 Marks]

ii. $y = 10 + 20\cos(45^{\circ})$

[2.5 Marks]

Total 25 Marks

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Question 2

a) The pressure, P, of a gas at an altitude, Z, and temperature, T, is given by

$$P = Ae^{-\left(\frac{g}{RT}\right)Z}$$

i. Find P given that A=20x10^{3}N/m^2, R=287J/(kg.K), Z=4x10^{3}m, T=200K and g=9.81m/s^2.

[5 Marks]

i. If altitude is changed into 6x10^{3}m, then what will be the pressure, P?

[2 Marks]

b) The velocity, v, of a car during the application of brakes according to time t is given by

$$v = 9e^{-kt}$$

where k is a friction constant of the brakes and its 0.046 and elapsed time, t is in sec.

i. At velocity, v= 2m/s, determine the elapsed time, t.

[5 Marks]

ii. If velocity, v is changed into 1m/s, then what will be the elapsed time, t?

[2 Marks]

c) A gas in a piston has an initial volume of 0.02m^3 at a pressure of 240kPa. The gas is then compressed to a pressure of 700kPa according to the law, $P(V)^{1.2} = C$, where, P is pressure, V is volume and C is a constant. Find the final volume.

[6 Marks]

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

i. $\mathrm{x} = 5 + 6\mathrm{e}^3$

[2.5 Marks]

ii. $\mathrm{y} = 8 + 3\ln(5)$

[2.5 Marks]

Total 25 Marks

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Question 3

a) By analysing the motion of a robot we obtain the following equations:

$$6u + 8a = 3$$
$$4u + 6a = 1$$

where, u is velocity in m/s and a is acceleration in m/s^2. Find the values of u and a using Matrices.

[10 Marks]

b) **Figure Q3b** shows marble O subject to forces. Find the resultant force $\boldsymbol{R}$ in terms of magnitude and angle.

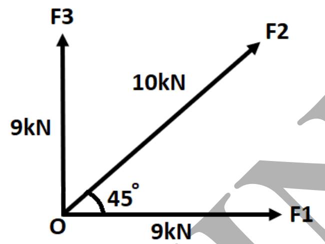

Figure Q3b: Marble O subject to forces.

[5 Marks]

c) A force, $\boldsymbol{F}$(N) moves an object through a displacement, $\boldsymbol{s}$(m). Find the work done, w by the force $\boldsymbol{F}$. Here,

$$\boldsymbol{F} = 10\boldsymbol{i} - 5\boldsymbol{j} + 2\boldsymbol{k}$$

$$\boldsymbol{s} = 5\boldsymbol{i} + 2\boldsymbol{j} + 1\boldsymbol{k}$$
$$w = \boldsymbol{F}.\boldsymbol{s}$$

[5 Marks]

d) Determine the moment vector, $\boldsymbol{M}$, about the origin, O, of a force, $\boldsymbol{F} = 9\boldsymbol{i} - \boldsymbol{j} + 3\boldsymbol{k}$ passing through the point with position vector, $\boldsymbol{r} = 3\boldsymbol{i} - 4\boldsymbol{j} + 7\boldsymbol{k}$. Here,

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

[5 Marks]

Total 25 Marks

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Section 2: Mechanics

Question 4

a) Assume that you are working in a car manufacturing industry. You have to select a new material for its chassis. Hence, you need to perform a tensile test to verify its mechanical properties. You conducted the test under a tensile load of 50kN below material's elastic limit and got data.

Before the test, the length, width and thickness were 1.25m, 25mm and 5mm, respectively, and after the test, the length became 1.30m.

Determine:

i. Normal Stress. **[4 marks]**

ii. Strain. **[4 marks]**

iii. Stiffness. **[4 marks]**

iv. Elastic Modulus. **[4 marks]**

b) You are, furthermore, required to verify a rectangular plastic block under given dimension:400mm long by 30mm wide by 250mm high, has its lower face glued to a bench and a force of 150N is applied to the upper face and in line with it. The upper face moves 10mm relative to the lower face.

Determine:

i. Shear Stress. **[4 marks]**

ii. Shear Strain. **[5 marks]**

Total 25 marks

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Question 5

a) An internal aircraft frame can be assumed as a truss, which is given in **Figure Q5**. Assume that the frame is at static state and ignore its weight.

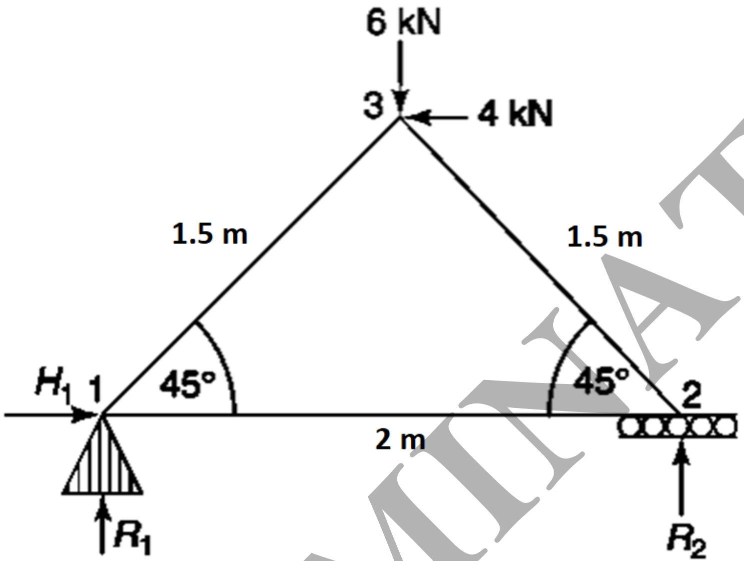

Figure Q5: Truss structure.

Figure out the following:

i. Make a free body diagram (FDM).

[**5 marks**]

ii. The support reactions at points 1 and 2.

[**5 marks**]

iii. Internal forces in all members of the truss.

[**5 marks**]

iv. Nature of the internal forces.

[**5 marks**]

b) If the horizontal concentrated load of 4kN is taken off from the truss at point 2, determine the support reactions at points 1 and 2.

[**5 marks**]

Total 25 marks

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Question 6

a) A bridge can be assumed as a simply supported beam, which is given in **Figure Q6.** Assume that the beam is at steady state and ignore its weight.

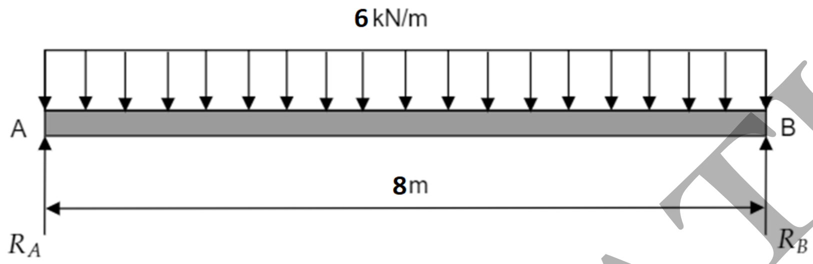

Figure Q6: Simply Supported Beam with uniformly distributed load (UDL).

Figure out the following:

i. Make a Free-body diagram. [**4 marks**]

ii. The support reactions at points A and B. [**4 marks**]

iii. Draw the Shear Force diagram. [**4 marks**]

iv. Draw the Bending Moment diagram. [**4 marks**]

v. Locate the positions in the beam for maximum and minimum bending Moment values. [**4 marks**]

b) If the UDL of 6kN/m is replaced by a point load of 10kN on the beam at 4 m apart from point A which is acting vertically downwards, determine the Moment.

[**5 marks**]

Total 25 marks

END OF QUESTIONS

FORMULA SHEET FOLLOWS ON NEXT PAGES

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FORMULA SHEET

Mathematics Equations

Trigonometry:

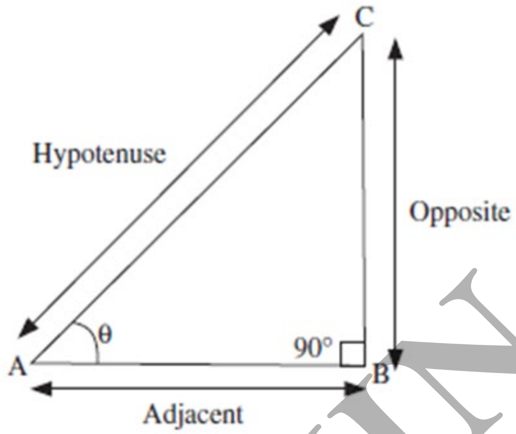

Figure 7

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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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:

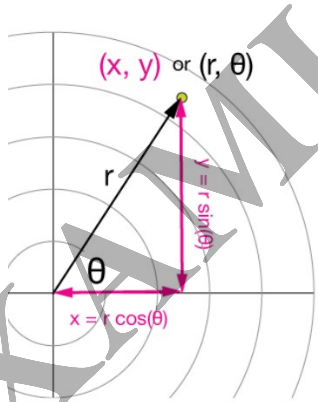

Figure 8

In Figure 8

$$x = rcos\theta$$

$$y = rsin\theta$$

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

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

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

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

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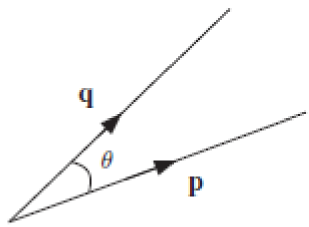

Figure 9

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

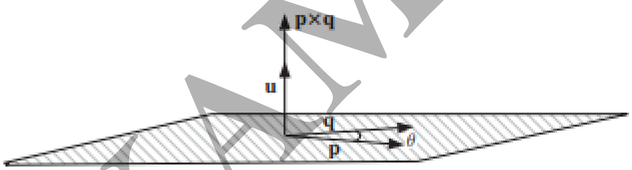

Figure 10

In Figure 7, 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,

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

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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.

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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.

End of Formula Sheet

<u>END OF PAPER</u>