ENG79

UNIVERSITY OF GREATER MANCHESTER

SCHOOL OF ENGINEERING

B.Eng (Hons) MECHANICAL ENGINEERING

SEMESTER 2 EXAMINATION 2024/25

ENGINEERING PRINCIPLES 2

MODULE No: AME4063

Date: Monday 12th May 2025 **Time: 10:00 – 12:00pm**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

Question 1

(a) Torsion vs. Torque in Mechanical Engineering

- (i) Define Torque and Torsion, and explain their differences in the context of mechanical engineering.
- (ii) State the SI unit of Torque and describe how it is measured in rotating machinery.
- (iii) Provide two real-world mechanical engineering applications where Torque and Torsion are critical, explaining their effects on system performance.

[2+2+2=6 Marks]

(b) A wind turbine is designed to operate under varying wind conditions. The turbine's main drive shaft, which transmits rotational power from the blades to the generator, is hollow with an outer diameter of 70 mm and an inner diameter of 45 mm. The turbine experiences a torque of 1.76 kN·m, and the shaft material has a modulus of rigidity of 90 GPa. The rotor speed is 100 rpm.

- (i) Calculate the power transferred from the wind turbine rotor to the generator in kilowatts.

[4 Marks]

- (ii) Determine the polar moment of inertia for the hollow shaft.

[4 Marks]

- (iii) Compute the shear stress at both the inner and outer surfaces of the shaft, and discuss its role in preventing mechanical fatigue and failure in wind turbines.

[7 Marks]

- (iv) If the length of the drive shaft is 2 m, determine the angle of twist, and explain how excessive torsional deformation could affect the efficiency of power transmission in the wind turbine system.

[4 Marks]

TOTAL: 25 marks

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Question 2

A commercial aircraft is preparing for take-off on a runway. The aircraft starts from rest with an initial speed of 2 m/s and accelerates uniformly to reach its take-off speed of 74 m/s in 20 seconds. As an engineer, you are tasked with analysing the aircraft's take-off performance and ensuring the runway length is sufficient for a safe take-off.

a) Define the following terms and explain the difference between them:

   i) Distance and Displacement

   ii) Speed and Velocity

[5 Marks]

b) Calculate the acceleration of the aircraft during its motion on the runway.

[5 Marks]

c) Determine the distance covered by the aircraft on the runway.

[5 Marks]

d) Confirm your answer for the distance by using all five equations of motion.

[10 Marks]

TOTAL: 25 marks

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Question 3

You are a structural engineer tasked with analysing the cross-sectional properties of a beam used in the construction of a bridge. The beam is subjected to bending loads, and its performance depends on its geometric properties. The cross-section of the beam is shown in Figure Q3:

a) Define the term "Second Moment of Area" (Area Moment of Inertia) and explain its significance in the design of beams and structural members.

[5 Marks]

b) Calculate the total cross-sectional area of the beam

[4 Marks]

c) Determine the centroid of the cross-section (dx, dy) relative to a reference axis.

[8 Marks]

d) Calculate the second moment of area about the horizontal axis passing through the centroid.

[8 Marks]

TOTAL: 25 marks

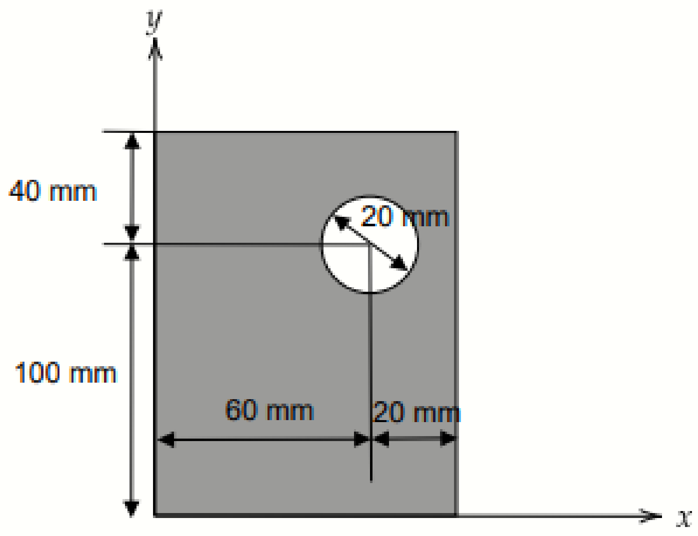

Figure Q3: cross-section

School of Engineering
BEng (Hons) Mechanical Engineering
Semester 2 Exam 2024-2025
Engineering Principles 2
Module No. AME4063

Question 4

a) A simply supported beam with a symmetrical I-section is used to support a factory floor. The beam is subjected to a point load of 120 kN at a distance of 2 meters from the left support, as shown in Figure Q4a. The dimensions of the I-section are provided in Figure Q4b. The factory floor is designed to carry heavy machinery, and the beam must be analysed to ensure it can safely support the load. For this beam, answer the following:

b) Find the reactions at the supports R1 and R2

[6 marks]

c) Draw the shear Force diagram and the bending moment diagram, then find the location and the value of the maximum bending moment.

[6 marks]

d) Calculate the second moment of area of **I** cross-section with respect to horizontal axis passing through the centroid.

[6 marks]

e) Calculate the maximum tensile and compressive stresses in the beam and draw the distribution of stress along the thickness of the beam.

[7 marks]

TOTAL: 25 marks

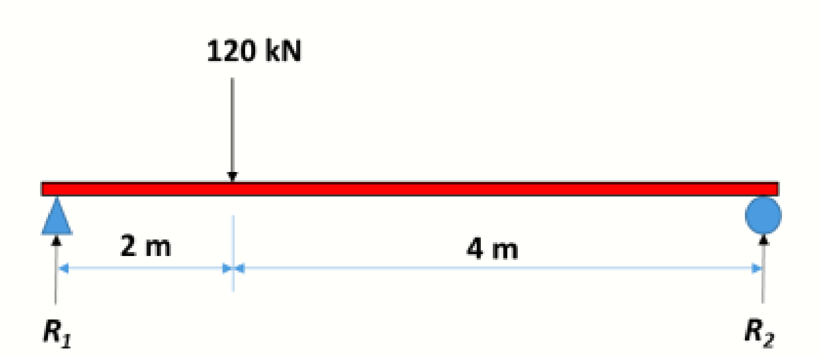

Figure Q4a - Simply supported beam

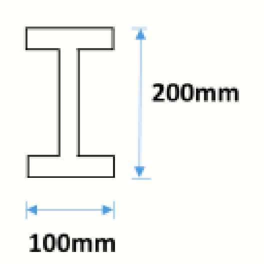

Figure Q4b cross-section

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Question 5

a) Apply the general rule of the differentiation to the following design scenarios, differentiate the functions with respect to x and interpret the results,

i. $\boldsymbol{f(x) = \ln 2x + 2 \sin 3x}$

ii. $\boldsymbol{f(x) = 8 \cos 2x - 9 \sin 3x}$

iii. $\boldsymbol{f(x) = 4 \cos x - 2 \ln (x + 4)}$

[5+5+5=15 marks]

b) Determine the **second** derivative of the function:

$$f(x) = -2x^3 + 4x + 7$$

Then determine the gradient of the curve at $x = -1.5$

[10 marks]

TOTAL: 25 marks

Question 6

Integration plays a crucial role in engineering applications such as calculating areas, volumes, and accumulated quantities.

a) Compute the following integrals using both definite and indefinite integration rules:

$$\text{i. } \int_{1}^{2} 3x \, dx$$

$$\text{ii. } \int 4 \cos 3x \, dx$$

$$\text{iii. } \int_{-2}^{3} (4 - x^2) \, dx$$

[5+5+5=15 marks]

b) Using integration, determine the area enclosed between the curve y = x(x − 3) and the ordinates x = 0 and x =5 in Figure Q6.

[10 marks]

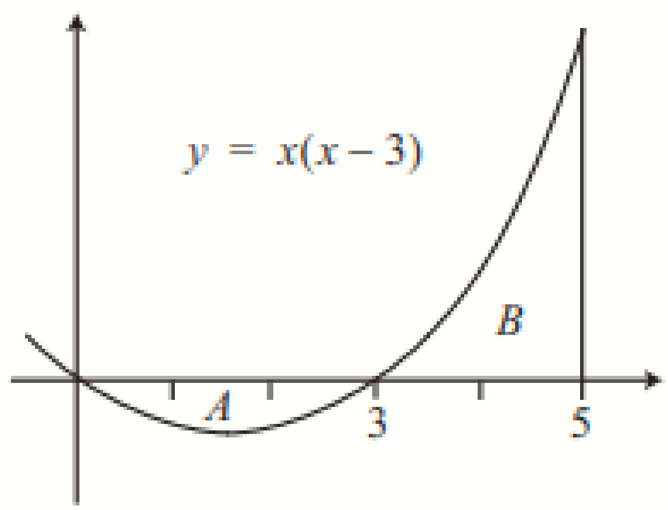

Figure Q6 - Area under the curve.

TOTAL: 25 marks

END OF QUESTIONS

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School of Engineering
BEng (Hons) Mechanical Engineering
Semester 2 Exam 2024-2025
Engineering Principles 2
Module No. AME4063

FORMULAE SHEET

Table of derivatives

function $f(x)$	derivative $\frac{df}{dx}$ or $f'(x)$	
c	0	c is any constant
x	1	
$2x$	2	
x^n	nx^{n-1}	n is any real number
$\sin x$	$\cos x$	
$\cos x$	$-\sin x$	
e^x	e^x	
$\ln x$	$\frac{1}{x}$	
$cf(x)$	$cf'(x)$	c constant
$f(x) \pm g(x)$	$f'(x) \pm g'(x)$	
$\sin mx$	$m \cos mx$	m is a constant
$\cos mx$	$-m \sin mx$	m is a constant
e^{mx}	me^{mx}	m is a constant
$\ln mx$	$\frac{1}{x}$	
$\ln(ax+b)$	$\frac{a}{ax+b}$	

Table of integrals

$f(x)$	$\int f\,dx$
1	$x + C$
k	$kx + C$
x	$\frac{x^2}{2} + C$
x^2	$\frac{x^3}{3} + C$
$x^n, n \neq -1$	$\frac{x^{n+1}}{n+1} + C$
$\frac{1}{x}$	$\ln(x) + C$

Note: C and k are constants.

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Torsion formula

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\,\theta}{L}$$

$$J = \frac{\pi}{32}(d_o^4 - d_i^4)$$

$$P = T\,\omega$$

ω = $2\pi n$ rad/s = 2πN 60 rad/s

τ – Shear stress (Pa or MPa)
T – Torque (N m)
J – Polar moment of inertia (m$^{4)}$
r – Distance from centre (m)
G – Shear modulus (Pa or GPa)
θ – Angle or twist (radians)
L – Length of the shaft (m)
d_o - Outer diameter
d_i - Inner diameter

Flexure formula

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

σ – Bending stress
M – Bending moment
I – Second moment or area
y – Distance from neutral axis
E – Young's modulus
R – Radius of curvature

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SUVAT equations for linear motion

$$v = u + at$$
$$s = \frac{1}{2}\,(u + v)t$$
$$s = ut + \frac{1}{2}at^2$$
$$s = vt - \frac{1}{2}at^2$$

$$v^2 - u^2 = 2as$$

s - displacement,
u - initial velocity,
v - final velocity,
t - time,
a - acceleration.

Angular Motion Equations

$$\omega_f = \omega_i + \alpha t$$
$$\theta = \frac{1}{2}(\omega_i + \omega_f)t$$
$$\theta = \omega_i t + \frac{1}{2}\alpha t^2$$
$$\theta = \omega_f t - \frac{1}{2}\alpha t^2$$
$${\omega_f}^2 = {\omega_i}^2 + 2\alpha\theta$$

θ - Angular displacement
ω_i- Initial angular velocity
ω_{f-} Final angular velocity
α - Angular acceleration
t - Time

Solid shaft

Polar moment of inertia

$$J = \frac{\pi}{32} D^4 = \frac{\pi}{2} R^4$$

D is the diameter of the circle
R is the radius of the circle

Hollow shaft

Polar moment of inertia

$$J = J_{outer\ circle} - J_{inner\ circle}$$

$$J = \frac{\pi}{32}\left(D_0^4 - D_i^4\right)$$

$$J = \frac{\pi}{2}\left(R_0^4 - R_i^4\right)$$

D_o is the diameter of the outer circle
D_i is the diameter of the inner circle

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