ENG63

UNIVERSITY OF GREATER MANCHESTER

NATIONAL CENTRE FOR MOTORSPORT ENGINEERING

B.SC. (HONS) MOTORSPORT TECHNOLOGY

SEMESTER 2 2024/2025

WRITTEN EXAM

ENGINEERING PRINCIPLES

MODULE MSP4025

Date: Tuesday 13 May 2025 **Time: 14:00 – 16:00**

INSTRUCTIONS TO CANDIDATES:

The paper has **SEVEN** questions

Attempt **FOUR** questions

The marks for each question are shown in brackets

Marks are awarded mainly for the development of an answer; using four significant figures for numbers and including units as appropriate with the numbers

Electronic calculators October be used

There is a formula sheet at the end of the paper

This is a closed book examination

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Question 1.

(a) The effects of a pit-stop can be assessed by comparing a car on a pit-stop with a car staying out on a circuit. Carry out a comparison for a car doing a pit stop where it is stationary for 6 seconds and travelling along a pit lane at 22 m/s. The total length of the pit lane between the entry and the exit is 550 metres.
The distance between the pit entrance and the exit for a car staying on the track is also 550 metres. The average speed of a car staying on the track is 80 m/s.
Ignore effects due to accelerations.

i. Draw a diagram to illustrate the problem and the information given above. **(5 marks)**

ii. Calculate the time and distance lost by a car during a stop-go penalty using the details above. **(7 marks)**

(b) A Formula Student car completes a 75-metre straight line acceleration test. The car is timed over two sections of 25 metres and 50 metres.
It completes the first section of 25 metres in 2.5 seconds from zero initial velocity.
It completes the second section of 50 metres in 2 seconds.

i. Calculate a value for the speed at the end of the first 25 metres.
Calculate the average acceleration over the first 25 metres. **(6 marks)**

ii. Calculate the average acceleration from 25 metres to 75 metres in a time of 2 seconds. Calculate the velocity at s=75 metres. **(7 marks)**

(Total marks 25)

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Question 2.

(a) Explain the terms and reasoning in equation Q2a for the second moment of area for the section of the space frame chassis illustrated by figure Q2. (5 marks)

$$I = 4 * \left\{\frac{\pi}{64}(d_o^4 - d_i^4)\right\} + 4Ah^2$$

Equation (Q2a)

(b) Figure Q2 illustrates a section on a space frame chassis. The four tubes each have an outside diameter of 28mm and a 2mm wall thickness.

i. Calculate the 2nd moment of area of the chassis section about the neutral axis. **(9 marks)**

ii. Compare the contribution from the $4Ah^2$ compared to the $4 * \left\{\frac{\pi}{64}(d_o^4 - d_i^4)\right\}$. **(3 marks)**

(c) One loading causes a bending moment of 1500 Nm on the section in figure Q2. What is the corresponding bending stress? **(5 marks)**

(d) Consideration is being given to increasing the stiffness of the chassis section of figure Q2. One proposal uses the same tubes as above, OD 28 mm and a wall thickness of 2mm, but with an increased, h, i.e. the spacing of the tubes. Comment on the benefits of such an approach. Use sample calculations as appropriate. **(3 marks)**

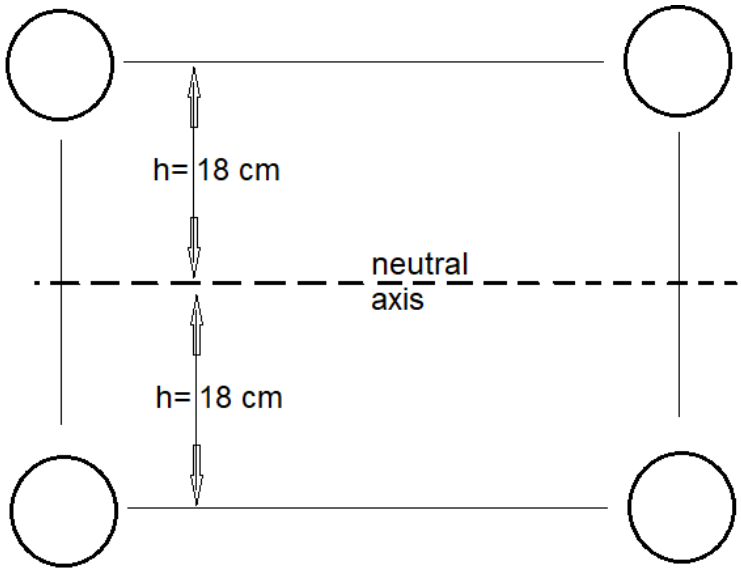

Figure Q2

(Total marks 25)

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Question 3.

(a) Figure Q3a shows a connection for a linear suspension potentiometer with a total movement of 150mm. The resistance across A and B is 25 kΩ.

i. What is the current supplied by the 12 volt emf? **(3 marks)**

ii. What is the sensitivity of the potentiometer with this connection? What is the signal voltage when the wiper is at 100mm from B **(6 marks)**

(b) Determine the unknown currents, I_1, I_2 & I_3, in figure Q3b using Ohm's law and Kirchhoff's rules as appropriate. What is the potential drop across each resistor? **(12 marks)**

What is the energy consumed by the circuit on two hours? **(4 marks)**

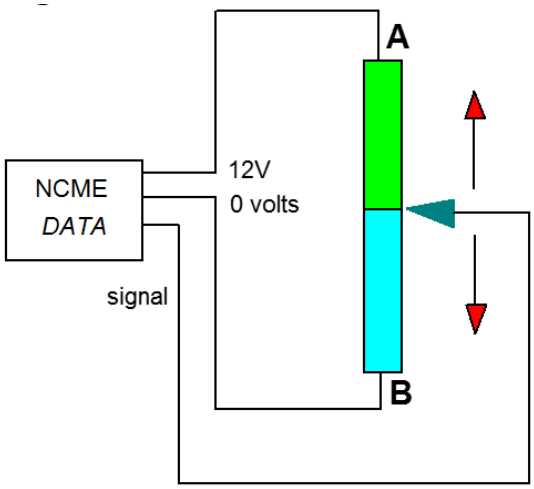

Figure Q3a

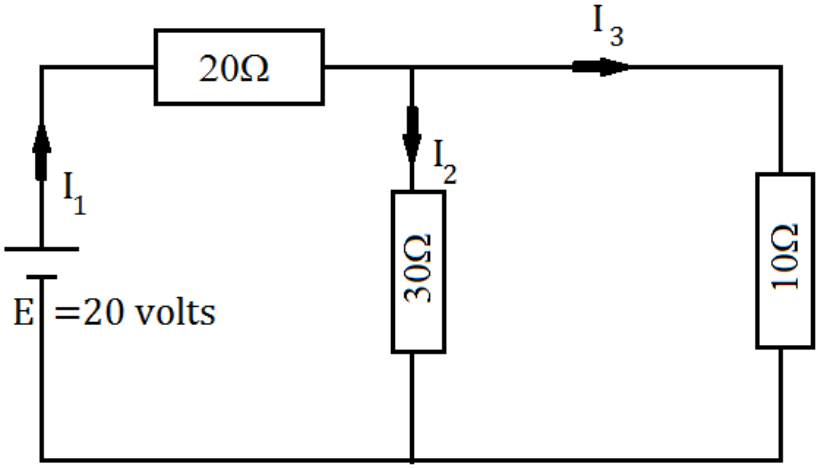

Figure Q3b

(Total marks 25)

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Question 4.

Figure Q4a shows a suspension rocker for an open-wheel race car. The spring stiffness coefficient k_s=50 N/mm. The bearing housing, B, is fixed to the race car chassis and can be considered fixed for this question. Using a 25mm deflection at the wheel:-

i. Calculate the corresponding compression of the spring and the force to compress the spring. **(5 marks)**

ii. Use equilibrium of moments to find the force at the wheel to produce the compression at the spring. What is the effective stiffness at the wheel? **(5 marks)**

iii. Use 'equilibrium of forces' or 'equilibrium of moments' find the force at the bearing housing, B. **(5 marks)**

iv. Draw the shear force diagram and the bending moment diagram for the rocker loaded as above. You can use figure Q4c and remove it from the exam question book. **(10 marks)**

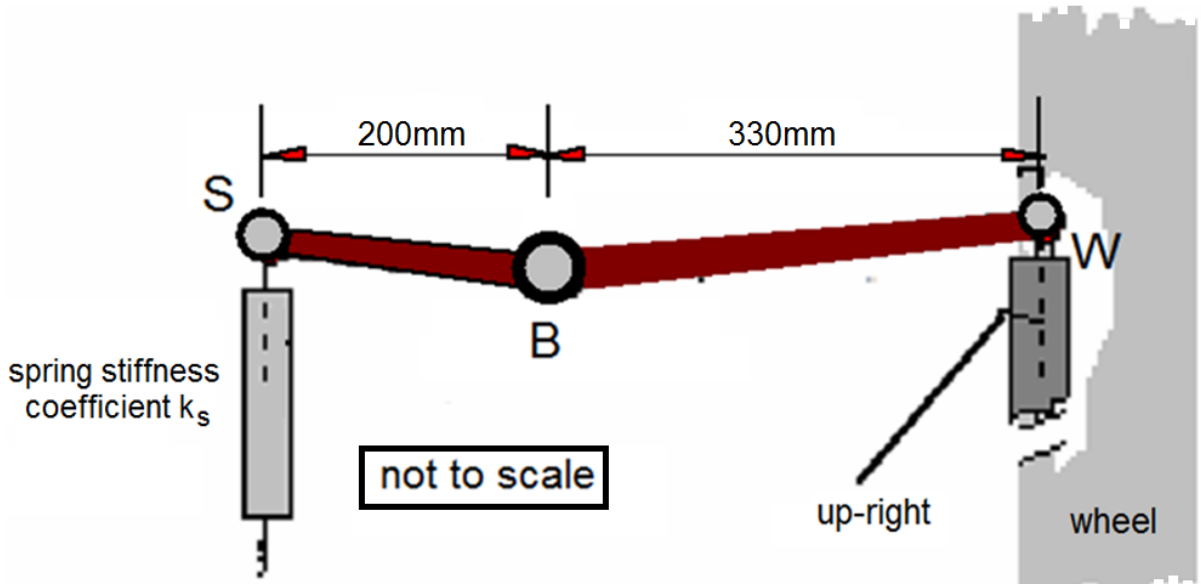

Figure Q4a

(Total marks 25)

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and/or
Student Number:

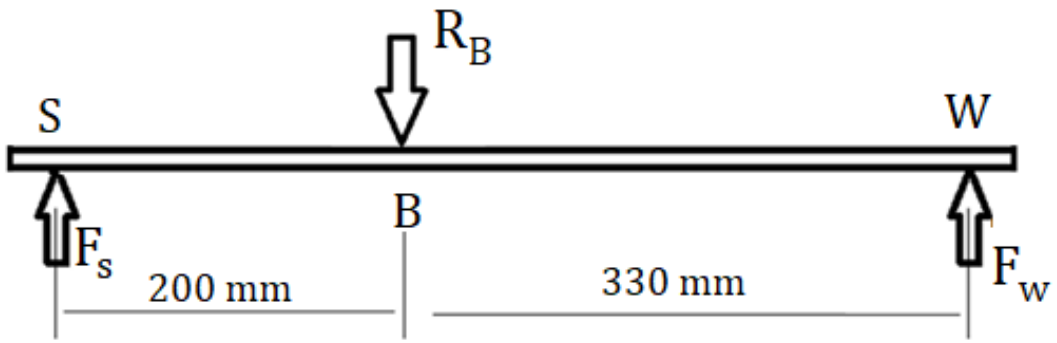

Figure Q4b

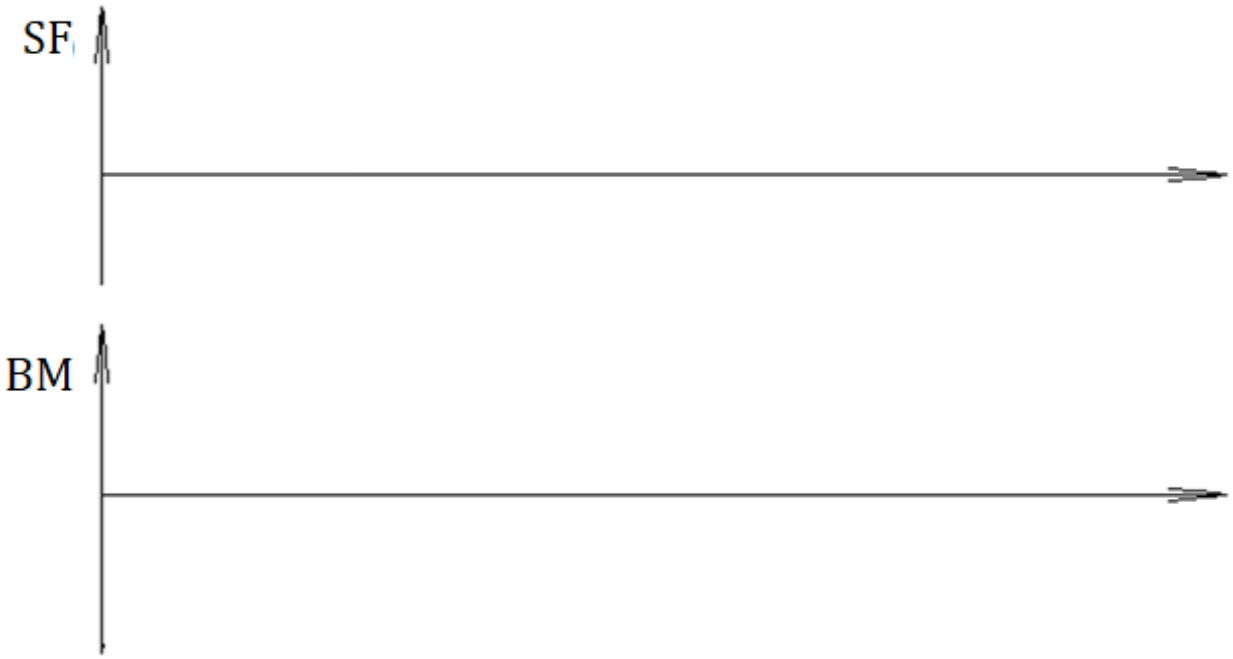

Figure Q4c

(Total marks 25)

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Question 5.

(a) Figure Q5a illustrates a load cell body for vehicle testing. It has a cross section that is 25mm by 10mm. The load cell is to be used with loads up-to 18kN.
The material specified for the load cell body is medium strength mild steel with a Young's modulus of 200 GPa , a Poisson's ratio ν=0.28 and a yield point of 280MPa.

i. Calculate the direct stress at a load of 18kN. **(4 marks)**

ii. Calculate the corresponding direct strain and lateral strain. **(6 marks)**

iii. Calculate the change in width on the 25mm dimension. State the nature of the change in width. **(3 marks)**

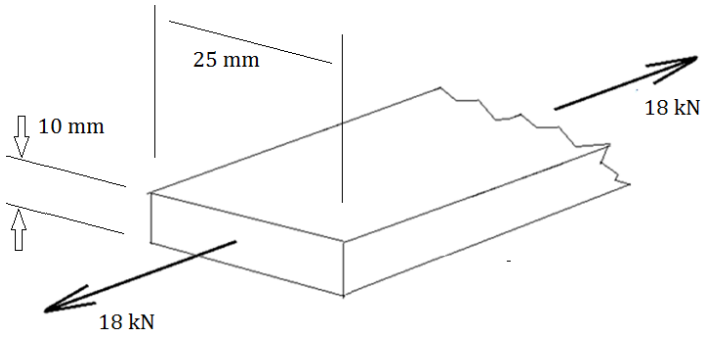

Figure Q5a

(b) Figure Q7 illustrates a bonded joint. The load on the bonding is a maximum of F=3.5kN. The maximum shear strength for the bonding is 5 MPa.

i. Calculate the shear stress with the load F=3.5kN **(7 marks)**

ii. Calculate a factor of safety for the loading F=3.5kN **(5 marks)**

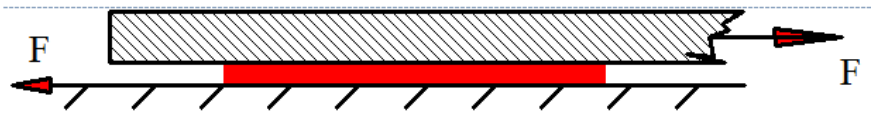

Figure Q5b

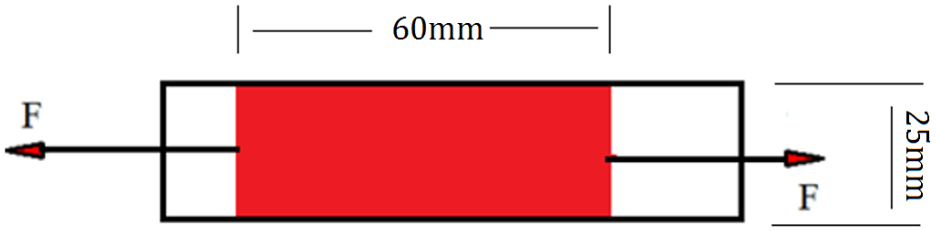

Figure Q7b

(Total marks 25)

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Question 6.

A battery is to be made with cells each having a maximum storage capacity of 0.8Ah and an emf of 3.6 volts. The maximum continuous discharge current from each cell is 0.25A. The maximum short-term or 'pulse' discharge current is 2A. The mass of each cell is 0.08kg.

i. Calculate the number of cells to provide a battery with a potential difference between the terminals of 72 volts and a capacity of 25 kWh. **(6 marks)**

ii. Draw a diagram to illustrate the connections required to form the battery. **(6 marks)**

iii. What is the maximum continuous power from the battery? **(5 marks)**

iv. What is the maximum short-term or 'pulse' power that the battery can provide? **(4 marks)**

v. What is the mass of the battery? **(4 marks)**

(Total marks 25)

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Question 7.

Figure Q7 illustrates a transmission in which an engine at 5800 revolutions per minute (rpm) and full throttle produces a torque of 100 Nm. The block 'm_1' in figure Q7 represents the gear selected by a driver. First gear is a speed reduction gear with a ratio 35:17. The differential, m_2, has a speed reduction in the ratio 31:9. The road wheels are 0.6 metres in diameter.

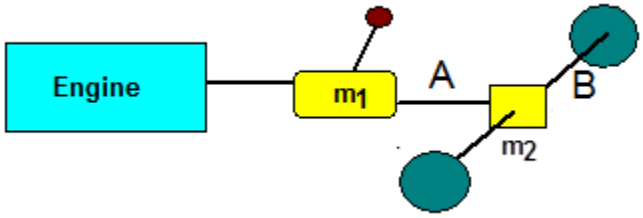

Figure Q7

Using the information above: -

i. Calculate the overall gear ratio in 1st gear **(3 marks)**

ii. Calculate the rotational speed of the wheels in 1st gear and the speed of the car in 1st gear both at an engine speed of 5800 rpm. **(5 marks)**

iii. Calculate the torque at the wheels in 1st gear and the tractive force at the wheels in 1st gear both at full throttle and at an engine speed of 5800 rpm. **(6 marks)**

iv. Calculate the power at the engine at full throttle with a torque of 100 Nm at 5800 rpm. Use the force at the wheels and the car speed from your results above to calculate the power at the wheels at full throttle at 5800 rpm. **(6 marks)**

v. The gear change from 1st to 2nd gear is taken at 5800 rpm. Assume that the car has a constant speed during the gear change. Second gear has a ratio 32:20 and is a speed reduction gear. Calculate the speed of the engine in 2nd gear just after the gear change. **(5 marks)**

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End of Questions

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FORMULA SHEET

Newton's Second Law: F = ma & T = I α where a general expression for I = mk²

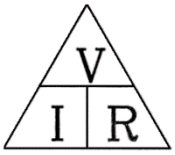
Law of Friction: F = μR Torque & Power Expressions: T = Fr; P = Fv=Tω

Kinematic Equations

Linear Motion	Angular Motion	Linear to Angular
$v = u + at$	$\omega_f = \omega_i + \alpha t$	$s = r\theta$
$s = ½(u + v)t$	$\theta = ½(\omega_i + \omega_f)t$	$v = r\omega$
$s = ut + ½at^2$	$\theta = \omega_i t + ½\alpha t^2$	$a = r\alpha$
$s = vt - ½at^2$	$\theta = \omega_f t - ½\alpha t^2$	
$v^2 = u^2 + 2as$	$\omega_f^2 = \omega_i^2 + 2\alpha\theta$	$\omega = \frac{\theta}{t}$

Centripetal Acceleration = $\frac{v^2}{R}$ & $\omega^2 R$

Ohm's Law
V=IR



Power supplied by a voltage source
P=V I

Power dissipated by a resistor
$P=I^2R$

Resistance of a wire
$R = \frac{\rho L}{A}$

Resistors in series
$R_T = R_1 + R_2 + R_3 + \cdots$

Resistors in parallel
$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{etc}$

Ohm's law V=IR

Power & Energy
P=VI & E=VIt

Kirchhoff's Laws
$\sum I = 0$ & $\sum \text{emf} = 0$

Stress equations

Direct
$\sigma = \frac{F}{A}$ & $E = \frac{\sigma}{\epsilon}$ & $\varepsilon = \frac{\delta L}{L}$
$A = \frac{\pi D^2}{4}$ etc

Bending
$\frac{\sigma}{y} = \frac{M}{I} = \frac{E}{R}$
$I = \frac{\pi D^4}{64}$ or $\frac{BD^3}{12}$

Torsion
$\frac{\tau}{r} = \frac{T}{J} = \frac{G\theta}{L}$
$J = \frac{\pi D^4}{32}$ $q = \frac{GJ}{L}$ $\phi = \frac{r\theta}{L}$

E = Young's modulus: σ=stress: ε=strain: G=modulus of rigidity

Stress in the walls of a thin walled sphere
$\sigma = \frac{pr}{2t}$

Stresses in the walls of a thin walled cylinder
$\sigma_a = \frac{pr}{2t}$ & $\sigma_b = \frac{pr}{t}$

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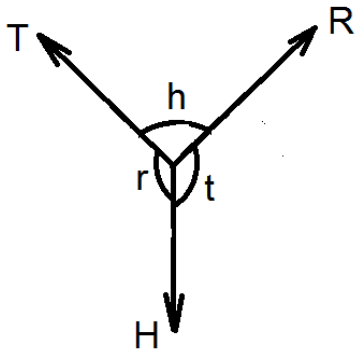
Conversion Factors

Time: 1 h = 60 min = 3600 s	Temperature difference: 1C = 1.8°F
Volume: $1m^3 = 10^3\ dm^3 = 10^3$ litre = $36.31ft^3$ = 220 UKgal	
Energy: 1 kJ = 10^3 Nm	Force: 1 N = 0.2248 lbf
Pressure: 1 bar = 10^5 Pa (Nm^{-2}) = 14.50 lbf in^{-2} = 750 mmHg = 10.2 mH_2O	
Density 1 kg m^{-3} = 0.062 43 lb ft^{-3}	Mass: $1kg=\frac{1}{0.45359237}lb\approx 2.205\ lb=\frac{1}{14.5939}slug$
1 mile=1760 yd≈1609m : 1 yd=3 ft=36 inches=0.914 m : 1 m=$\frac{1}{0.3048}$ft=3.281 ft	
Power: $1kW=1kJs^{-1}=\frac{10^3}{9.80665x75}$ metric hp≈1.359 metric hp	Angle: 1revolution= 360°=2π

Lami's theorem

$$\frac{T}{\sin(t)}=\frac{H}{\sin(h)}=\frac{R}{\sin(r)}$$



End of Examination Paper