UNIVERSITY OF BOLTON

NATIONAL CENTRE FOR MOTORSPORT ENGINEERING

B.Eng. (HONS) AUTOMOTIVE PERFORMANCE ENGINEERING

SEMESTER 2 EXAMINATION 2022/2023

ENGINEERING SCIENCE

MODULE NUMBER MSP4016

Date Friday 12th May 2023 **Time: 10:00am – 12:00pm**

INSTRUCTIONS TO CANDIDATES

The paper has SEVEN questions

Attempt ANY 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

Electronic calculators may be used

There is a formula sheet and a table of conversion factors at the end of the paper

This is a closed book examination

Question 1

(a) A corner of a vehicle has a stiffness from the suspension of 60 N/mm. The tyres are inflated to a pressure of 225 kPa.

Using figure Q1a write down the stiffness of a tyre. (2 marks)

Using the reciprocal rule calculate a value for the overall stiffness of the corner of the vehicle. (5 marks)

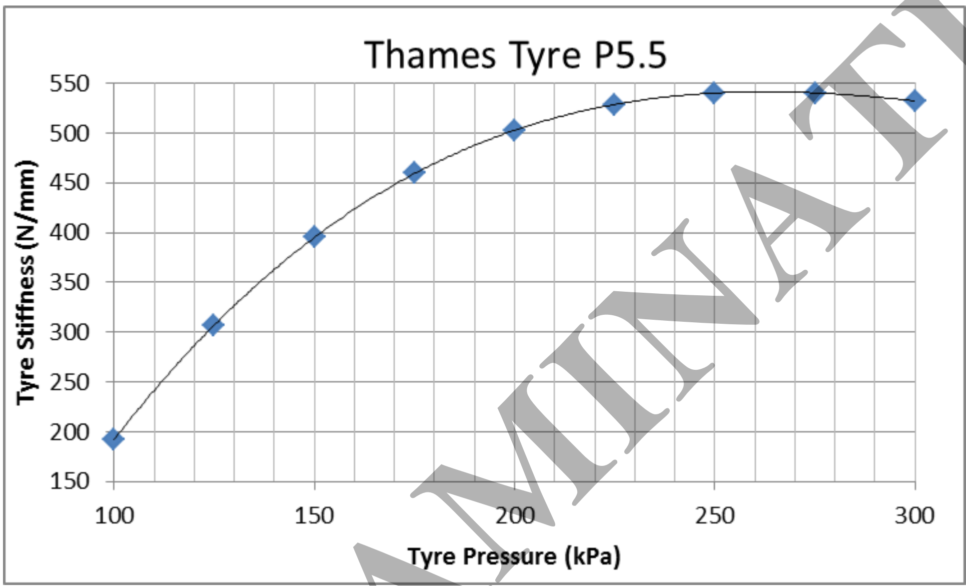

Figure Q1a

(b) The un-sprung mass of a vehicle freely vibrates at 5 Hz. Convert this natural frequency into units of radians/second. (3 marks)

Using an overall stiffness coefficient of 30 kN/m determine a value for the effective moving mass during the vibrations. (3 marks)

The displacement amplitude of vibrations is 15mm. What is the amplitude of the accelerations? (5 marks)

What is the periodic time of the vibrations? Sketch a graph of the variation of displacement and acceleration against time for 1.5 oscillations. (7 marks)

(Total marks 25)

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Question 2

Figure Q2 illustrates a transmission in which an engine at full throttle produces 122 Nm at 6000 revolutions per minute (rpm). Fourth gear is a speed reduction gear, m_1, with a ratio 26:24. The differential, m_2, has a speed reduction in the ratio 32:9. The road wheels are 0.6 metres in diameter. The car has a mass of 500kg.

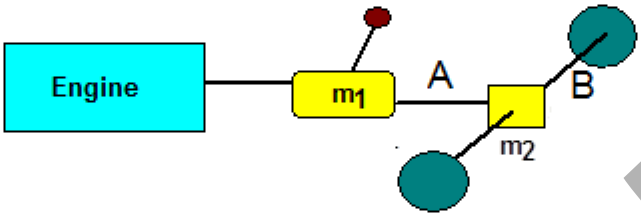

Figure Q2

Calculate the rotational speed of the wheels in 4th gear and the corresponding linear speed of the car in 4th gear at an engine speed of 6000 rpm. (6 marks)

Calculate the torque at the wheels in 4th gear and the corresponding tractive force at the wheels in 4th gear at full throttle at an engine speed of 6000 rpm. (6 marks)

Calculate the power at the engine at full throttle with a torque of 122Nm at 6000 rpm? What is the power at the wheels at full throttle at 6000rpm? (6 marks)

A gear change from 3rd to 4th gear is taken at 6000 rpm in 3rd gear. Assume that the car has a constant speed during the gear change. Third gear has a ratio 30:22 and is a speed reduction gear. Calculate the speed of the engine immediately after a gear change from third to fourth gear. What is the change in engine speed during the gear change? (7 marks)

(Total marks 25)

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Question 3

(a) A mild steel tube has a diameter of 12.7 mm, a maximum operating pressure of 5 bar and is limited to a maximum wall stress of 2 MPa.

Using the expression for the hoop stress calculate the minimum wall thickness to produce the limiting stress at the maximum pressure. (5 marks)

Draw a diagram of the stresses acting on the tube. Identify the value of each of the stresses. (5 marks)

(b) A load cell has a rectangular cross-section that is 9mm by 16mm with a length between the loading points of 100mm. During a test the load cell indicated a direct strain of $300*10^{-6}$. The load cell is manufactured from a material with a Poisson's ratio ν=0.3 and a Young's modulus E=200GPa.

For the case where the direct strain on the load cell is $300*10^{-6}$ calculate the following:-

(i) The direct stress (4 marks)

(ii) The change in length (4 marks)

(iii) The change in the 16mm dimension (3 marks)

(iv) The direct force acting on the load cell (4 marks)

In (ii) & (iii) state whether the changes in dimensions are increases or decreases

(Total marks 25)

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Question 4

(a) The effects of a pit-stop can be analysed by comparing a pitting car with a car staying out on a circuit.
One such case has a car making a pit stop travelling at 22 m/s along a pit lane that is 520 metres long between entry and exit. The car remains stationary for 2.8 seconds.
The speed of a car on the circuit is 78 m/s. The distance between the pit lane entrance and the pit lane exit for a car on the circuit is 560m.

Using the details above calculate the time and distance lost by the pitting car during the pit stop. Ignore effects due to accelerations. (7 marks)

(b) At one point in a race a leading car has a speed 35 m/s and an acceleration of 4.5 m/s^2. A following car has a speed of 40 m/s with an acceleration 4.5 m/s^2. The following car is 12 metres behind the leading car. The accelerations are constant throughout.

Draw a diagram of the two cars containing the information given above. (5 marks)

Find the time taken for the following car to catch the lead car (7 marks)

Calculate the distance travelled by the following car in catching the lead car (3 marks)

What is the speed of each car when they are side by side? (3 marks)

The 'suvat' equations are included in the formula sheet

(Total marks 25)

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Question 5

Figure Q5a illustrates a hollow shaft with external and internal diameters 88mm and 55 mm respectively. The shaft transmits 7500Nm at 1500 rev/min. The shaft is 0.8 metres long and is manufactured from a material with modulus of rigidity of 77GPa.

Calculate the polar second moment of area. (3 marks)

Calculate the maximum shear stress in the shaft with the applied torque above. (5 marks)

Draw a diagram of the shear stress in the shaft (4 marks)

Calculate the angular deflection of the shaft in degrees (6 marks)

Figure Q5b illustrates a flanged coupling with eight bolts on a pitch circle diameter of 180 mm. Calculate the minimum diameter of the bolts so that the shear stress is a maximum 50 MPa when transmitting the 7500Nm. (7 marks)

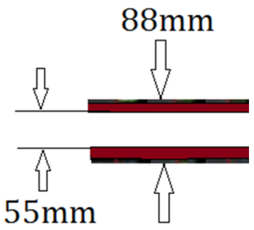

Figure Q5a

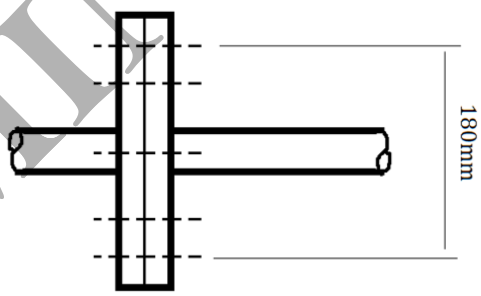

Figure Q5b

(Total marks 25)

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Question 6

(a) Use Kirchhoff's methods to find two loop equations for the circuit of figure Q6a. (6 marks)

Hence find the currents I_1 and I_2 in the circuit of figure Q6a. (6 marks)

Check your calculations by finding the potential at 'B' in two different ways. (4 marks)

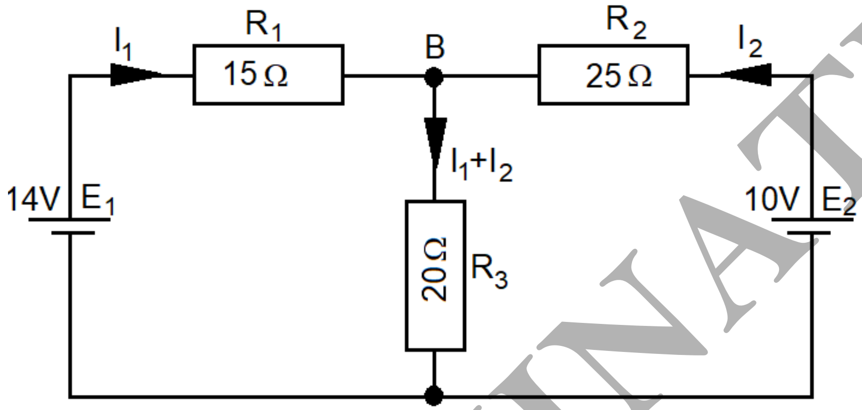

Figure Q6a

(b) Figure Q6b shows a connection for a linear suspension potentiometer. The resistance across A and B is 1.8 kΩ. The total movement for the potentiometer is 180mm.

What is the current supplied by the 12 volt emf? (2 marks)

What is the sensitivity of the potentiometer with this connection? (2 marks)

What is the energy used by the device during a 40 minute race? Express your answer in joules, amp-hours & watt-hours. (5 marks)

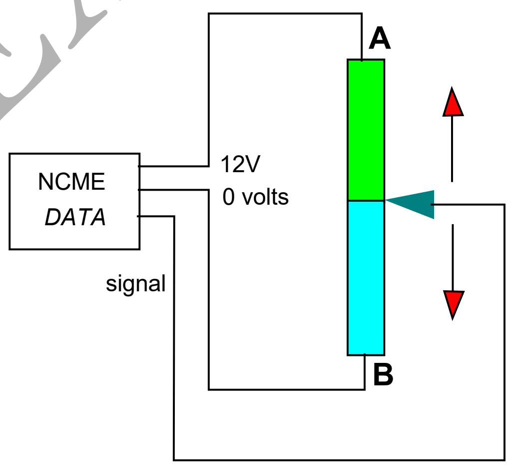

Figure Q6b

(Total marks 25)

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Question 7

Figure Q7a shows a prototype automotive door beam, AC, with a test load, F, located at distances a=0.3 metres and b=0.5 metres from the rigid supports. Figure Q7b illustrates the cross section of the beam. It is a box section with 20mm sides and a wall thickness of 3mm.

a) Calculate the second moment of area for the beam cross-section (5 marks)

b) Draw the shear force diagram for the case where the applied load F=1000N (5 marks)

c) Draw the bending moment diagram for the case where the applied load F=1000N (5 marks)

d) Calculate the maximum bending stress, with F=1000N, for the beam. (2 marks)

Draw a diagram to illustrate the stress distribution in the beam. (5 marks)

e) The beam is an energy absorbing device. Calculate the value of the load, F, at which the beam will start to yield. The yield point for the material is 350MPa. You can extend your existing calculations to do this. (3 marks)

Figure Q7c can be detached from the examination paper to draw the shear force & bending moment diagrams. Attach the page to your Examination Answer Book using a treasury tag. A treasury tag will be provided by an invigilator if one is not already on your desk. A treasury tag is the short piece of cord with a metal bar at each end.

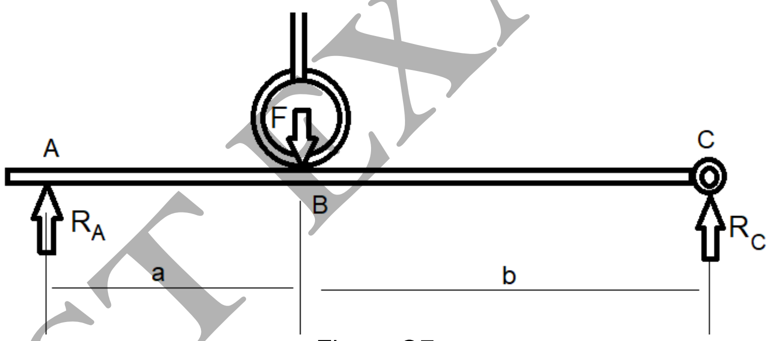

Figure Q7a

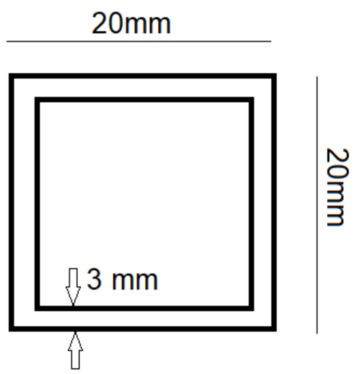

Figure Q7b

(Total marks 25)

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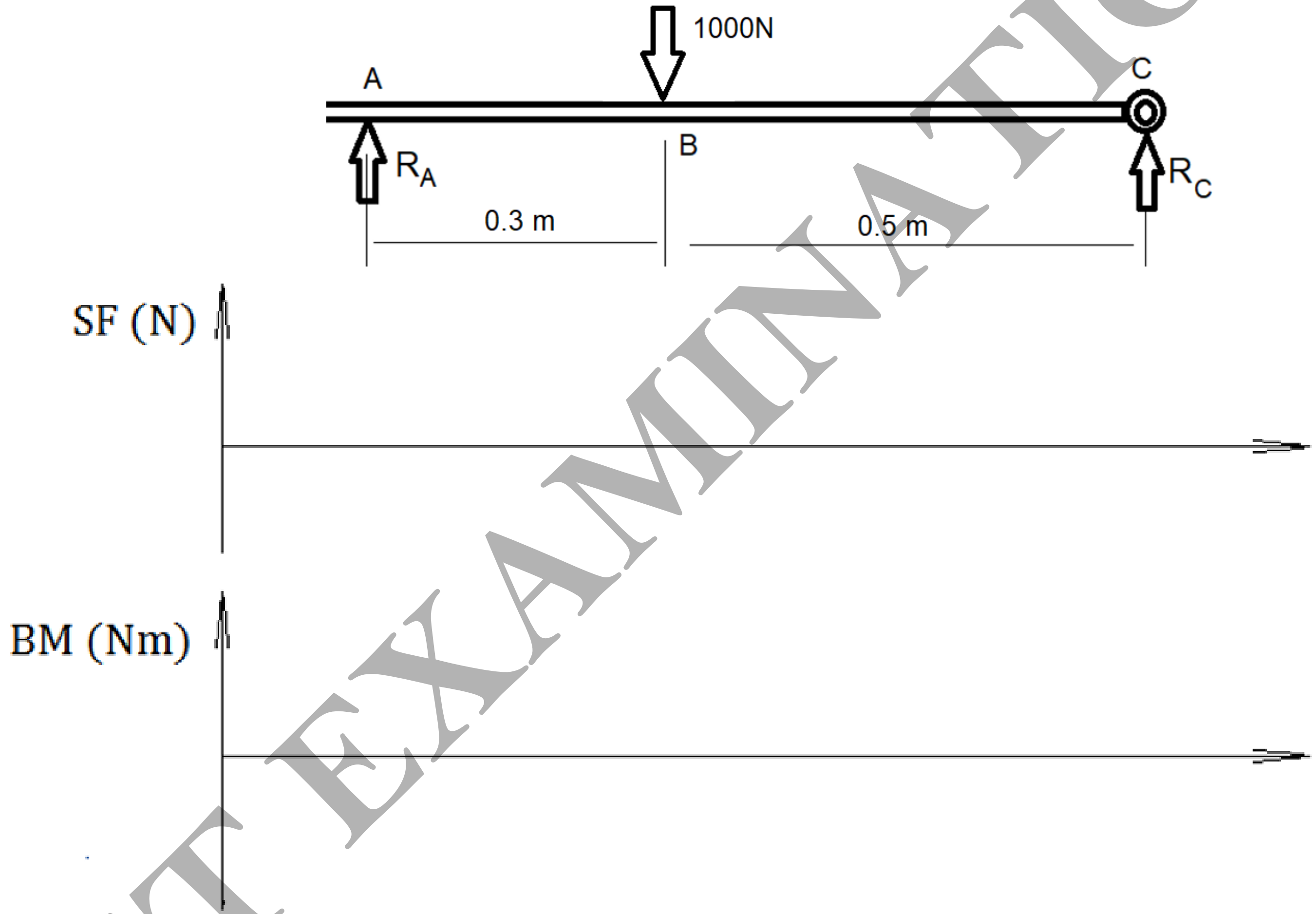

Figure Q7c

END OF QUESTIONS

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National Centre for Motorsport Engineering
BEng (Hons) Automotive Performance Engineering
Semester Two Examination 2022/23
Engineering Science   Module MSP4016

Information for Candidates

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 = Fd; P = Fv

Kinematic Equations

Linear Motion

$$v = u + at$$
$$s = ½(u + v)t$$
$$s = ut + ½at^2$$
$$s = vt - ½at^2$$
$$v^2 = u^2 + 2as$$

Angular Motion

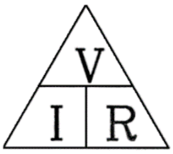
$$\omega_f = \omega_i + \alpha t$$
$$\theta = ½(\omega_i + \omega_f)t$$
$$\theta = \omega_i t + ½\alpha t^2$$
$$\theta = \omega_f t - ½\alpha t^2$$
$$\omega_f^2 = \omega_i^2 + 2\alpha\theta$$

Linear to Angular

$$s = r\theta$$
$$v = r\omega$$
$$a = r\alpha$$
$$\omega = \frac{\theta}{t}$$

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=I²R

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

$$\sigma = \frac{F}{A} \;\&\; E = \frac{\sigma}{\epsilon} \;\&\; \varepsilon = \frac{\delta L}{L}$$

$$A = \frac{\pi D^2}{4} \text{ etc}$$

Bending

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

$$I = \frac{\pi D^4}{64} \text{ or } \frac{BD^3}{12}$$

Torsion

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

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

$$q = \frac{GJ}{L}$$

Thin Walls

$$\sigma_a = \frac{pr}{t}$$

$$\sigma_b = \frac{pr}{2t}$$

E = Young's modulus: σ=stress: ε=strain

Undamped natural frequency $\omega_n = \sqrt{\frac{k}{m}}$ Periodic time of vibrations $= \frac{2\pi}{\omega}$

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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 N.m	Force: 1 N = 0.2248 lbf
Pressure: 1 bar = 10^5 Pa ($N.m^{-2}$) = 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: $1kW=1kJ.s^{-1}=\frac{10^3}{9.80665x75}$ metric hp≈1.359 metric hp	Angle: 1revolution =360°=2π

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