[ENG07]

UNIVERSITY OF BOLTON

NATIONAL CENTRE FOR MOTORSPORT ENGINEERING

B.SC. (HONS) MOTORSPORT TECHNOLOGY

SEMESTER TWO EXAMINATION 2021/2022

ENGINEERING PRINCIPLES

MODULE NO. MSP4011

Date: Thursday 19th May 2022 **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

Electronic calculators may 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 stop-go penalty are to be analysed by comparing a car on a stop-go penalty with a car staying out on a circuit. The stop-go penalty requires a car to return to pits and remain stationary for 5 seconds.

The total length of the pit lane for entry and exit is 300 metres with a maximum car speed of 22m/s. The distance travelled by the car staying on the track between the pit entry and pit exit is also 300 metres at an average speed of 80 m/s.

Draw a diagram to illustrate the problem in terms of the information provided. Include any speeds, distances and times that are known. **(5 marks)**

Calculate the time and distance lost by a car during a stop-go penalty using the details above. Ignore effects due to accelerations. **(7 marks)**

b. A Formula Student car completes a 75 metre long straight line acceleration test timed over two sections of 20m and 55m. It completes the first section of 20 metres in 2.2 seconds from zero initial velocity. It travels the remaining 55 metres in 2.5 seconds.

(i) Calculate a value for the speed at the end of the first 20 metres. Calculate the average acceleration over the first 20 metres. **(6 marks)**

(ii) Calculate the average acceleration from 20 metres to 75 metres in a time of 2.5 seconds. Calculate the velocity at 75 metres. **(7 marks)**

The 'suvat' equations are included in the formula sheet

Total marks 25

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Question 2

Figure Q2.1 illustrates a section of a race-car body or tub. The weight saving and retained stiffness are often factors in the selection of dimensions. The equation for the second moment of area of a hollow section is $I = \frac{BD^3 - bd^3}{12}$.

(i) Draw a diagram of section Q2.1 labelling and writing in the values for B, b, D and d.

(5 marks)

(ii) Calculate the areas of the sections in figures Q2.1 and Q2.2

(4 marks)

(iii) Using the areas of the sections Q2.1 and Q2.2 calculate the percentage of the weight of section Q2.1 compared to section of Q2.2.

(4 marks)

(iv) Calculate the second moments of area of sections Q2.1 and Q2.2

(7 marks)

(v) Use the second moments of area of sections Q2.1 and Q2.2 to indicate the percentage stiffness of section Q2.1 compared to the section of Q2.2.

(5 marks)

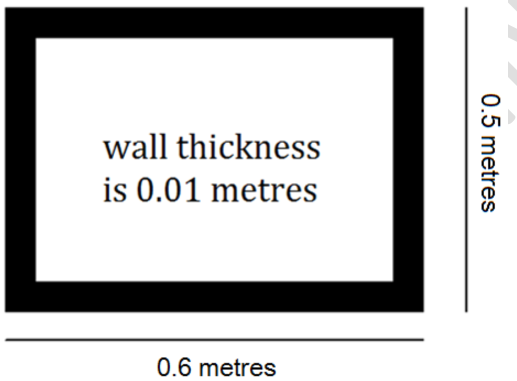

Figure Q2.1

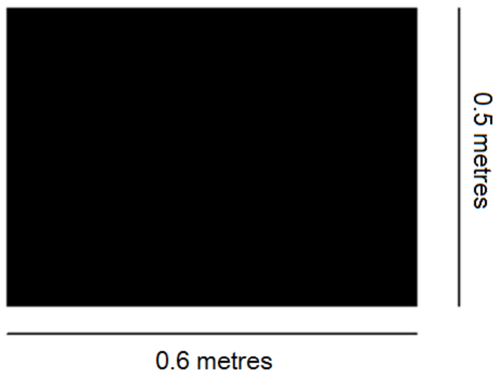

Figure Q2.2

Total marks 25

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Question 3

(a) Determine the unknown currents, I_1, I_2, I_3, I_4 & I_5 in figure Q3a. **(7 marks)**

(b) Using Kirchoff's laws and Ohm's law as appropriate determine the unknown emf, E, in figure Q3b. **(5 marks)**

(c) Calculate the potential, v_b, and the current through the two resistors in figure Q3c. **(5 marks)**

(d) Calculate the potential difference (v_b-v_a) in figure Q3d. **(8 marks)**

Total marks 25

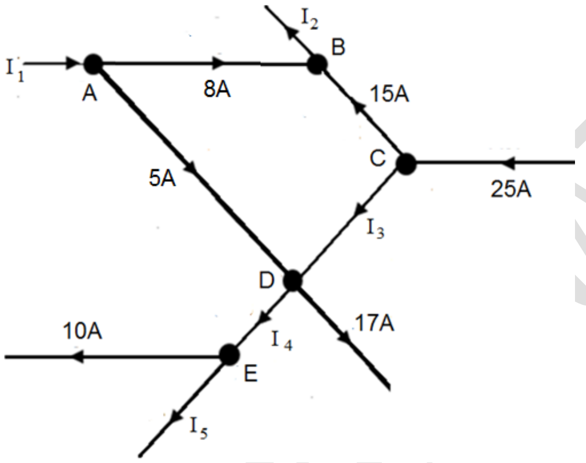

Figure Q3a

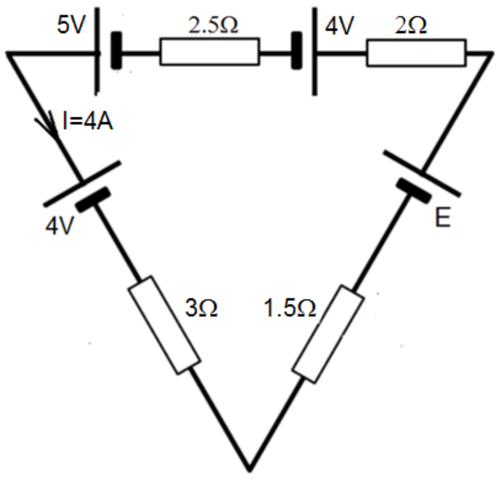

Figure Q3b

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Figure Q3c and Q3d over the page….

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Question 3 figures Q3c and Q3d….

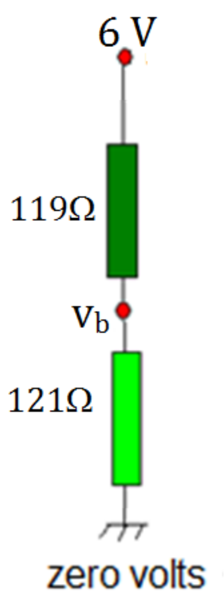

Figure Q3c

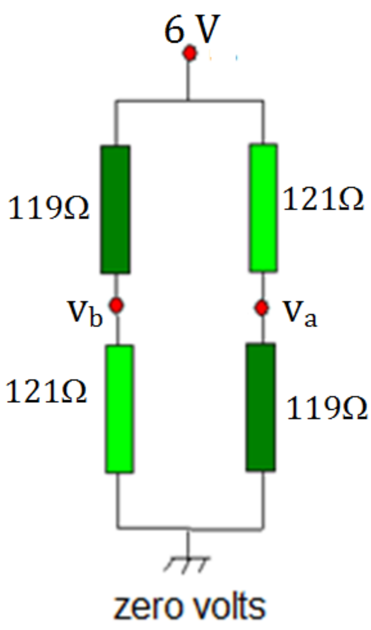

Figure Q3d

Total marks 25

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Question 4

Figure Q4a shows a brake pedal with a foot force F at 90° to the line of the brake pedal and the force or reaction, H, from the hydraulic braking system. H also acts at 90° to the line of the brake pedal.

Figure Q4b shows a free body diagram for the same brake pedal drawn horizontally. The foot force applied perpendicular to the pedal at C is F=2000N.

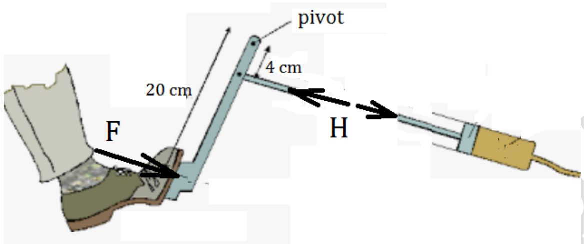

Figure Q4a

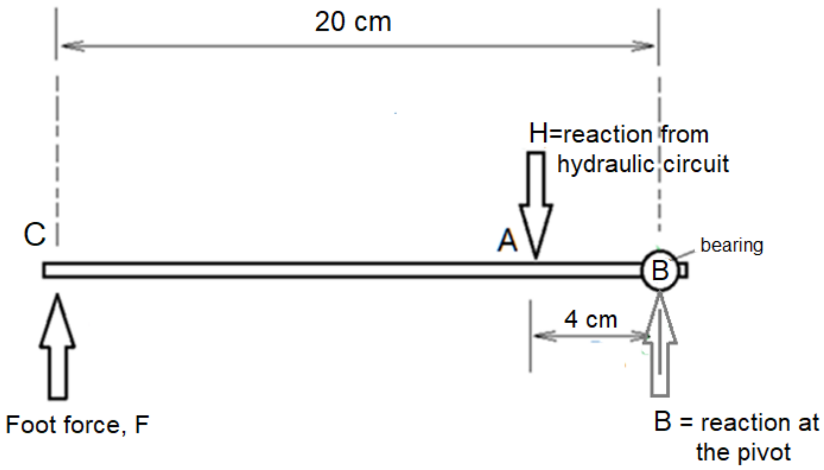

Figure Q4b

(a) Using equilibrium of moments find the reaction force, H, from the hydraulics and the reaction force from the bearing at B. **(10 marks)**

(b) Draw a free body diagram of the forces. Check the answers in (a) using equilibrium of forces. **(5 marks)**

(c) The piston in the brake master cylinder is 12mm in diameter. Using $p = \frac{H}{A}$ calculate the pressure of the fluid in the cylinder. The cross sectional area is $A = \frac{\pi d^2}{4}$. **(10 marks)**

Total marks 25

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Question 5

(a) Equations Q5a and Q5b relate the hoop and axial stresses in thin walled cylinders under pressure. A copper-nickel alloy tube has an outside diameter of 6mm with a wall thickness 0.5mm. The maximum allowable stress in the material is 250MPa. Calculate a value for the maximum allowable pressure in the tube.

(6 marks)

$$\sigma_a = \frac{pr}{t} \qquad \text{Equation (Q5a)}$$

$$\sigma_b = \frac{pr}{2t} \qquad \text{Equation (Q5b)}$$

It is suggested that a smaller diameter is used so that the working pressure can be increased? Explain whether using a smaller diameter with the same material and the same wall thickness will allow a higher working pressure? **(5 marks)**

(b) A solid suspension pull rod has an outside diameter of 11 mm and a length of 0.7m. It is tested with a direct tensile load of 4000 N. The material has a Poisson's ratio ν=0.28 and a Young's modulus E=200GPa.

Calculate

(i) the direct stress and strain on the pull rod; **(6 marks)**

(ii) the change in length of the pull rod and **(5 marks)**

(iii) the change in diameter of the pull rod. **(3 marks)**

State whether the changes in dimensions are increases or decreases in (ii) & (iii).

Total marks 25

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Question 6

Explain the meaning of the terms in equation Q6.1 in the context of the anti-roll bar illustrated by figure Q6.1 **(5 marks)**

$$k_t = \frac{GJ}{H}\frac{1}{A^2}$$ ...Equation Q6.1

Calculate a value for k_t given A=0.22 metres, H=0.78 metres, G=80GPa. The anti-roll bar has a solid circular section with diameter 0.028m. **(10 marks)**

Each end cantilever has an effective stiffness of 320 kN/m at E. Using the reciprocal rule calculate a value for the combined stiffness with k_t at E. **(5 marks)**

A spring is situated at each end E. Each spring has a stiffness, 42kN/m. Calculate a combined stiffness from the anti-roll bar and the 42kN/m when in roll. **(5 marks)**

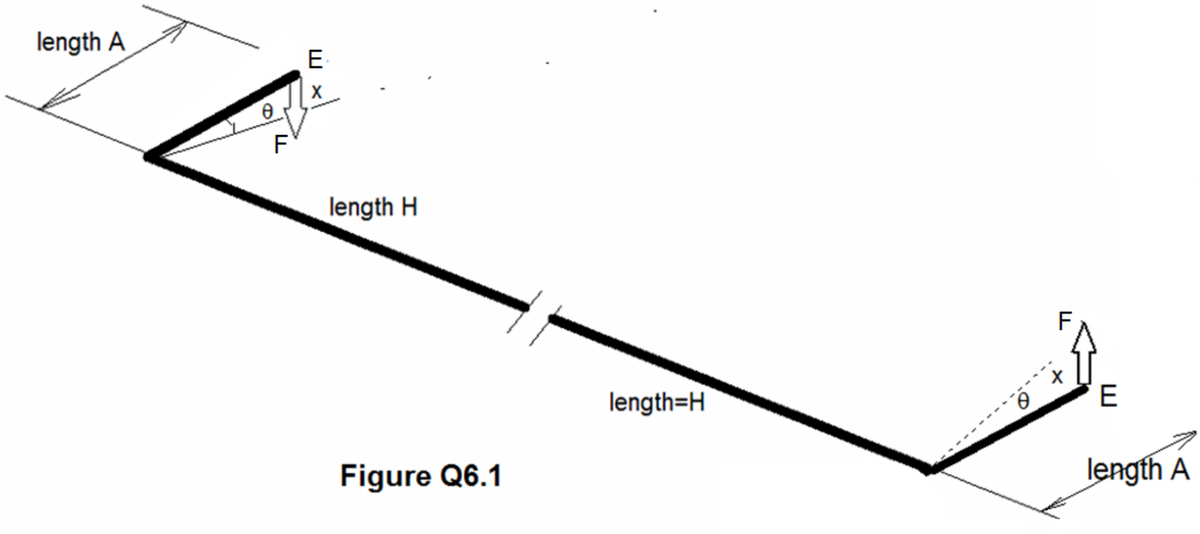

Figure Q6.1

Total marks 25

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Question 7

Figure Q7 illustrates the layout of a race car transmission. The engine produces a maximum torque of 108 Nm at 6100 revolutions/minute. Second gear is a speed reduction with the ratio 31:20. The differential, m_2, reduces the speed in the ratio 32:9. Third gear is a speed reduction gear with the ratio 30:23. The road wheels are 0.58 metres in diameter. The car has a mass of 500kg.

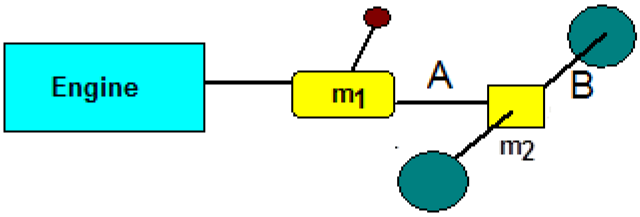

Figure Q7

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Using the information above calculate the following :-

The overall gear ratio, with second gear selected, relating the angular speed of the engine to the angular speed of the wheels. **(4 marks)**

The speed of the car in second gear at an engine speed of 6100rpm. **(6 marks)**

The acceleration in second gear at engine speed of 6100 rpm with an engine torque of 108 Nm. **(8 marks)**

Calculate the speed of the engine immediately after a gear change from second to third gear. What is the speed change of the engine during the gear change? The gear change from 2nd gear to 3rd gear is made at 6100 rpm in second gear. Assume that the car has a constant speed during the gear change. **(7 marks)**

Total marks 25

END OF QUESTIONS

Formulae Information on the following two pages….

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FORMULA SHEET

Newton's Second Law: $F = ma$ & $T = I\,\alpha$ where a general expression for $I = mk^2$

Law of Friction: $F=\mu R$ Torque $T=Fr$ Power $P=Fv=T\omega$

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

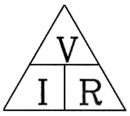
$$\omega_f = \omega_i + \alpha t$$
$$\theta = ½(\omega_i + \omega_f)t$$
$$\theta = \omega_i t + ½\alpha t^2$$
$$\theta = \omega_f t - ½\alpha t^2$$
$$\omega_f^2 = \omega_i^2 + 2\alpha\theta$$

Linear to Angular

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

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

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

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

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

Bending

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

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

Torsion

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

$$J = \frac{\pi D^4}{32} \qquad q = \frac{GJ}{L} \qquad \phi = \frac{r\theta}{L}$$

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

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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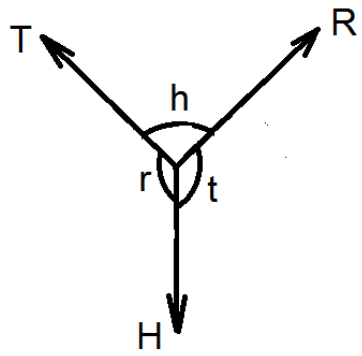
Conversion Factors

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≈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

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



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