[ESS09]

UNIVERSITY OF BOLTON

NATIONAL CENTRE FOR MOTORSPORT ENGINEERING

B.SC. (HONS) MOTORSPORT TECHNOLOGY

SEMESTER TWO EXAMINATION 2018/2019

ENGINEERING PRINCIPLES

MODULE NUMBER MSP4011

Date: Tuesday 21st May 2019 **Time: 14:00 – 16:00**

INSTRUCTIONS TO CANDIDATES:

This paper has SEVEN questions
The marks for each question are shown in brackets
Attempt FOUR questions

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination

Mobile telephones or cellular telephones may-not be used as calculators

Formula sheet attached

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Question 1

(a) During a race, a driver enters and leaves the pits at 22.2m/s and is moving, entering and leaving, at this speed for 12 seconds. The car is stationary for an additional 3.2 seconds.

The average speed of the car on the track is 80 m/s. The pit lane is the same length as the circuit outside the pit lane. Ignore effects due to accelerations.

Draw a diagram to illustrate the times and speeds travelled by a pitting car and a car on the circuit with a representation of the distances involved. **(3 marks)**

Calculate the distance lost by the car during the stop. What is the loss in race time?. **(6 marks)**

(b) During a straight-line test, a Formula Student car accelerates from zero velocity and travels 24.2 metres in 2.2 seconds. The car then travels 50.8 metres in 1.9 seconds. The car travels a total distance of 75 metres.

(i) Calculate a speed and an acceleration over the first 24.2 metres in 2.2 seconds. The car was stationary at the start. **(5 marks)**

(ii) Calculate a value for the acceleration from 24.2 metres to 75 metres in a time of 1.9 seconds. Calculate a value for the speed at 75 metres. Take the initial velocity from part (i). **(5 marks)**

(c) A brake test machine is to simulate braking a car with a flywheel slowing from 82 radians/second to a stop in 3.5 seconds.
What is the angular acceleration of the flywheel? How many revolutions does the flywheel travel through during the braking? **(6 marks)**

The 'suvat' equations are included in the formula sheet on the last page

Total marks 25

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Question 2

(a) Figure Q2.1 illustrates a section on the carbon fibre tub of figure Q2.2. Compare the weight and stiffness, using areas and second moments of area, of the section of figure Q2.1 with a solid section having the same outer dimensions.

Draw diagrams of the outside of the section and the cut-out from the section.

(5 marks)

Calculate the areas and second moment of areas of the solid section and the 'cut-out'. Hence, calculate the area and second moment of area for the section.

(8 marks)

Compare the values with the area and second moment of area for a solid section with the same outside dimensions. Comment on the significance in terms of weight and stiffness. **(8 marks)**

(b) Explain the terms stiffness and strength. Using the appropriate equations explain how the shape of a component influences the stiffness and the strength of the component. **(4 marks)**

The second moment of area of a solid section is $I = \frac{BD^3}{12}$

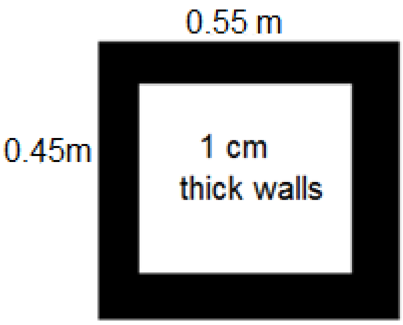

Figure Q2.1

Figure Q2.2

Total marks 25

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Question 3

(a) In figure Q3a the values of R_1 and R_2 are 50Ω and 150Ω. What is the current through R_1 and R_2? Calculate the value of the voltage at A. What is the power required at the power supply? **(6 marks)**

(b) In the Wheatstone bridge circuit of figure Q3b the resistance R_1=121Ω and the resistances of R_2, R_3 and R_4 are each 120Ω. The applied emf, E=6 volts. What is the potential difference, (v_a-v_b)? **(6 marks)**

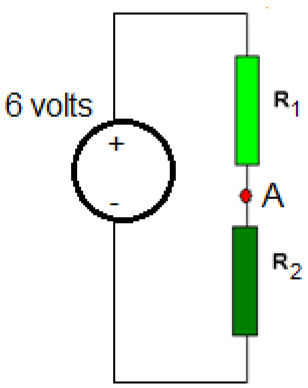

Figure Q3a

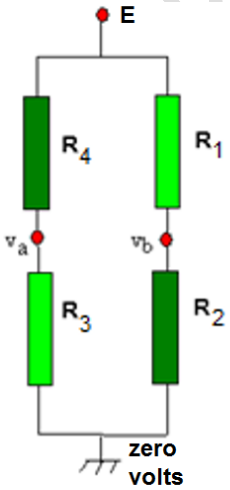

Figure Q3b

(c) Figure Q3c illustrates an inverting operational amplifier circuit. The resistors have values R_1=5.6kΩ and R_2=1kΩ respectively.

(i) What is the gain of the amplifier? **(2 marks)**

(ii) Annotate figure Q3c with the voltages and currents for the case where vin=1.5 volts. Figure Q3c is re-printed on the next page of the examination paper. **(6 marks)**

(iii) What is the operating range at the input voltage to avoid saturation at the output? Comment on the operating range in practice. **(5 marks)**

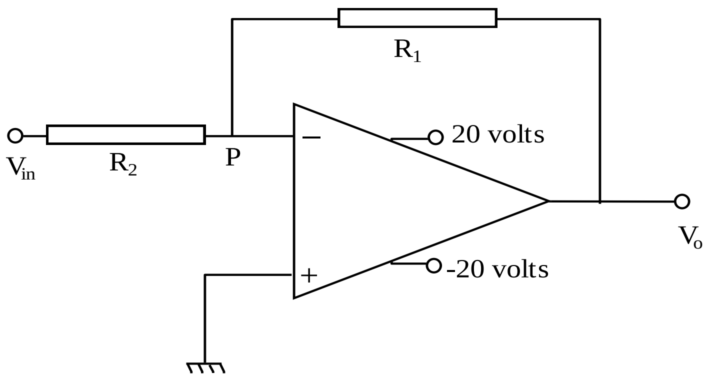

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Figure Q3c **Total marks 25**

Figure Q3c for annotation over the page….

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For use with Question 3 Part c
Mark on the voltages and currents

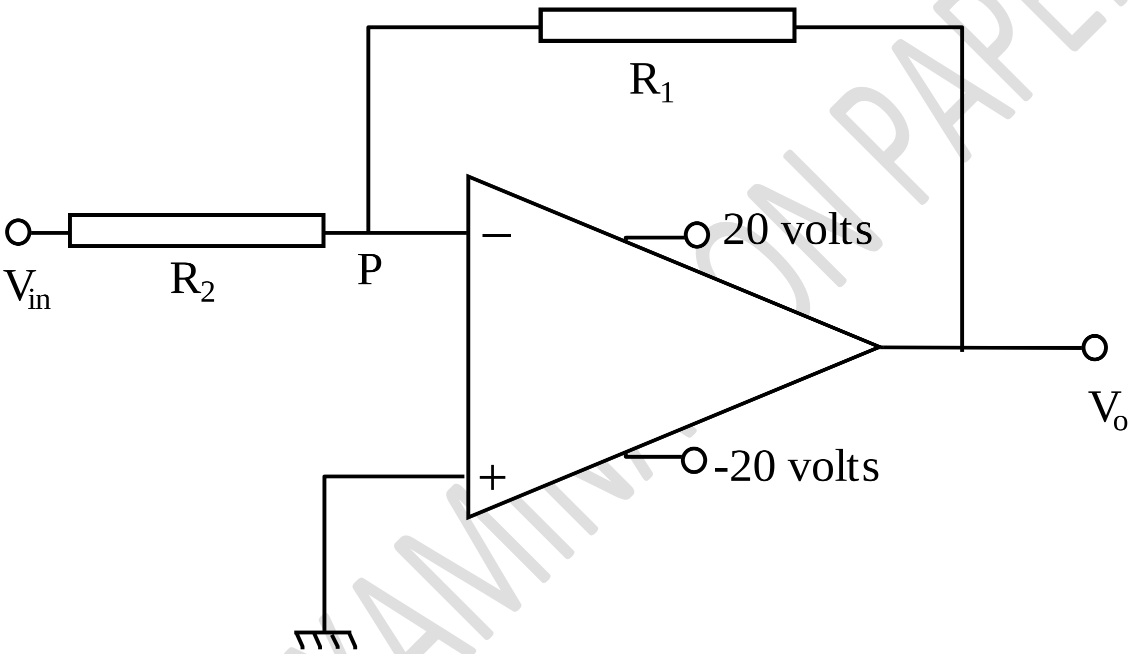

Figure Q3c ~ Circuit diagram for annotation

Student Number :

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Question 4

Figure Q4 represents part of a suspension system for a single seater race car. The pivot is fixed to the race car chassis between the upright and the spring-damper. The spring stiffness is 45kN/m.

(i) The wheel is moved through a displacement of 25mm. Draw a diagram of the rocker clearly showing the deflection at the wheel and the corresponding deflection at the spring. Use the diagram to estimate the deflection at the spring. **(5 marks)**

(ii) Calculate a value for the lever ratio and hence confirm the result for the deflection at the spring. **(2 marks)**

(iii) What is the force to compress the spring at the spring? What is the force at the wheel to produce the compression at the spring? **(5 marks)**

(iv) What is the effective stiffness of the spring at the wheel? **(5 marks)**

(v) Explain the relationship between the lever ratio, the stiffness of the spring and the effective stiffness of the spring at the wheel. Hence, confirm the installed stiffness calculated above. **(8 marks)**

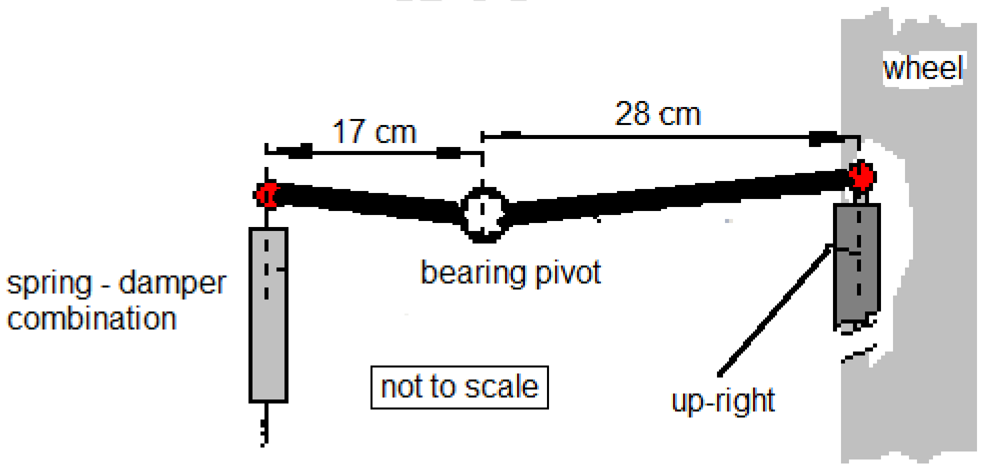

Figure Q4

Total marks 25

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Question 5

Figure Q5a illustrates a four-point bending test. Figure Q5b illustrates the cross section of the carbon fibre beam in Figure Q5a.

(i) Draw the shear force and bending moment diagrams for the beam. **(6 marks)**

(ii) Comment on the significance of the bending moment between the supports Q and R and the significance of the positioning of a strain gauge to indicate the bending strain. **(4 marks)**

(iii) Calculate the maximum bending stress for the loading of figure Q5a. **(8 marks)**

(iv) Calculate a value for the Young's modulus for the beam given that the strain on the upper surface was indicated as $503*10^{-6}$ **(7 marks)**

Total marks 25

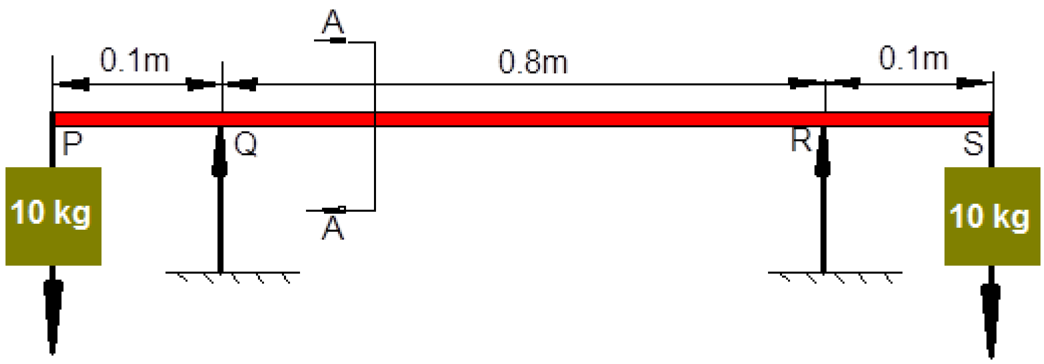

Figure Q5a

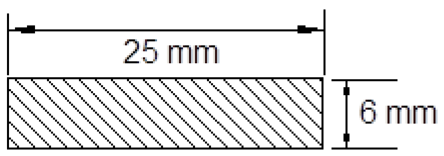

Figure Q5b

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Question 6

(a) Using appropriate diagrams explain the terms in the equations Q6a and Q6b.

(10 marks)

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L} \quad \text{…equation (Q6a)}$$

$$J = \frac{\pi d^4}{32} \quad \text{…equation (Q6b)}$$

(b) A solid half shaft has a length of 0.45 metres and diameter of 25mm. The maximum load on the half shaft in a test is 750Nm. Calculate the maximum shear stress on the half shaft and the resulting twist in degrees. Take G=80GPa.

(15 marks)

Total marks 25

Question 7

(a) For the circuit of figure Q7a, determine: -

(i) The overall resistance across Vs **(4 marks)**

(ii) The current supplied by the voltage source Vs **(2 marks)**

(iii) The voltage drops across each of the resistors with a check calculation **(4 marks)**

(iv) The energy supplied by Vs in 30 minutes in joules and Wh **(4 marks)**

(b) Use Kirchhoff's method of loops to find the currents, I_1 and I_2 in the circuit of figure Q7b. **(8 marks)**

Check your results using separate calculations **(3 marks)**

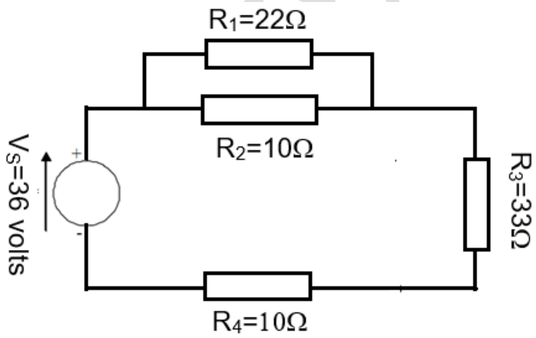

Figure Q7a

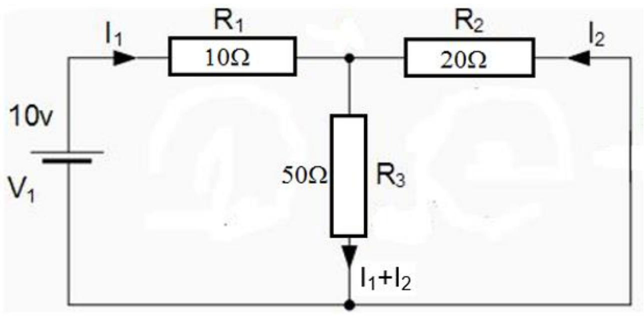

Figure Q7b

Total marks 25

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 — $F = ma$ & $T = I\alpha$ where a general expression for $I = mk^2$

Law of Friction: $F = \mu R$

Torque & Power Expressions $T = Fd$; $P = Fv$

Kinematic Equations

Linear Motion

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

Angular Motion

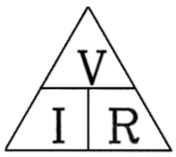
$$\omega_f = \omega_i + \alpha t$$
$$\theta = \tfrac{1}{2}(\omega_i + \omega_f)t$$
$$\theta = \omega_i t + \tfrac{1}{2}\alpha t^2$$
$$\theta = \omega_f t - \tfrac{1}{2}\alpha t^2$$
$$\omega_f^2 = \omega_i^2 + 2\alpha\theta$$

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
$P=I^2R$

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
$\sum I = 0$ & $\sum emf = 0$

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

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

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

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

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Conversion Factors

Time: 1 h = 60 min = 3600 s	Temperature difference: 1C = 1.8°F
Volume: $1 m^3 = 10^3 \, dm^3 = 10^3$ litre = $36.31 ft^3$ = 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: $1kW = 1kJs^{-1} = \frac{10^3}{9.80665 \times 75}$ metric hp ≈ 1.359 metric hp	Angle: 1 revolution = 360° = 2π

END OF FORMULA SHEETS

END OF PAPER