ENG62

# UNIVERSITY OF GREATER MANCHESTER

# NATIONAL CENTRE FOR MOTORSPORT ENGINEERING

# B.ENG. (HONS) AUTOMOTIVE PERFORMANCE ENGINEERING

# SEMESTER 2 EXAMINATION 2024/2025

# ENGINEERING SCIENCE

# MODULE MSP4024

**Date: Monday 12 May 2024** **Time: 14:00 – 16:00**

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**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**

**Question 1.**

For the air standard Otto cycle in tables Q1a and Q1b calculate

(i) Sketch a p-V diagram for the cycle. Clearly label the end states and the values for the pressure and the volumes at the end states. Explain the function each process performs. Shade in the area for the nett work from the cycle. **(8 marks)**

(ii) the mass of air in the cycle **(4 marks)**

(iii) the compression ratio **(3 marks)**

(iv) air standard thermodynamic efficiency **(5 marks)**

(v) mean effective pressure for comparison with a four-stroke engine **(5 marks)**

| State | p(bar) | V(litres) | T/(degC) | State | p(Pa) | V(m^3) | T/(K) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1.778 | 27 | 1 | 1.000E+05 | 1.778E-03 | 300 |
| 2 | 28.69 | 0.1616 | 509.3 | 2 | 2.869E+06 | 1.616E-04 | 782.3 |
| 3 | 44.09 | 0.1616 | 929.5 | 3 | 4.409E+06 | 1.616E-04 | 1202 |
| 4 | 1.537 | 1.778 | 188.1 | 4 | 1.537E+05 | 1.778E-03 | 461.1 |

**Table Q1a**

| Process | Q (J) | W (Nm) | dU (J) | dT (K) |
|---|---|---|---|---|
| 1 to 2 | 0 | -715.145659 | 715.1 | 482.3 |
| 2 to 3 | 622.9 | 0 | 622.9 | 420.1 |
| 3 to 4 | 0 | 1099 | -1099 | -741.3 |
| 4 to 1 | -238.9 | 0 | -238.9 | -161.1 |
| cycle | 384.0 | 384.0 | 0 | 0 |

**Table Q1b**

**(Total marks 25)**

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**Question 2.**

Figure Q2 illustrates a transmission in which first gear, $m_1$, is a speed reduction ratio, 35:17. The differential, $m_2$, is a speed reduction ratio 31:9. The road wheels are 0.6 metres in diameter. The engine produces 105 Nm at full throttle at an engine speed of 6200 revolutions per minute (rpm). The car has a mass of 500kg.

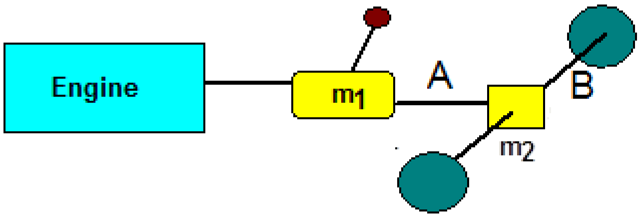


Figure Q2

Using the information above:-

Calculate the rotational speed of the wheels in 1st gear at an engine speed of 6200rpm. Calculate the corresponding speed of the car in metres/second and miles per hour.

**(8 marks)**

Calculate the torque at the wheels in 1st gear at full throttle with an engine speed of 6200 rpm. Calculate the corresponding tractive force at the wheels. **(6 marks)**

Check your results by calculating the power at the engine using (i) the product of the engine torque and the engine speed in radians/second and (ii) the product of the calculated tractive force at the wheels and the calculated car speed in m/s.

**(6 marks)**

The gear change from 1st to 2nd gear is taken at 6200 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.
What is the speed of the engine immediately after the gear change from 1st to 2nd gear? What is the change in speed of the engine across the gear change?

**(5 marks)**

**(Total marks 25)**

**Please turn the page**

**Question 3.**

**(a)** A piezo-static force transducer has a static sensitivity of 15 pC/kN and is connected to a charge amplifier with a gain set at 400 mV/pC and to a pen recorder with a sensitivity of 2mm/V. The force transducer has an accuracy of ±0.5% and the pen recorder an accuracy of ±0.8%. The system is to be used to indicate forces up to 20 kN. The pen recorder has a maximum travel of 40 cm.

Draw a block diagram of the system. Include the information given above **(5 marks)**

Determine the overall sensitivity of the system. **(4 marks)**

Determine the pen travel for a change in input of 15 kN. Comment on whether the force causes the pen to hit the end stops. **(4 marks)**

The overall accuracy is to be within ±2.5%. Determine the allowable tolerance on the charge amplifier. **(4 marks)**

**(b)** Figure Q3 shows three forces acting at a point. Using either a scale drawing or calculations determine the resultant force equivalent to the combined 7kN, the 5kN and the 6kN force. Draw a diagram of the action of the resultant force clearly marking the magnitude and the angle to the positive x-axis **(8 marks)**

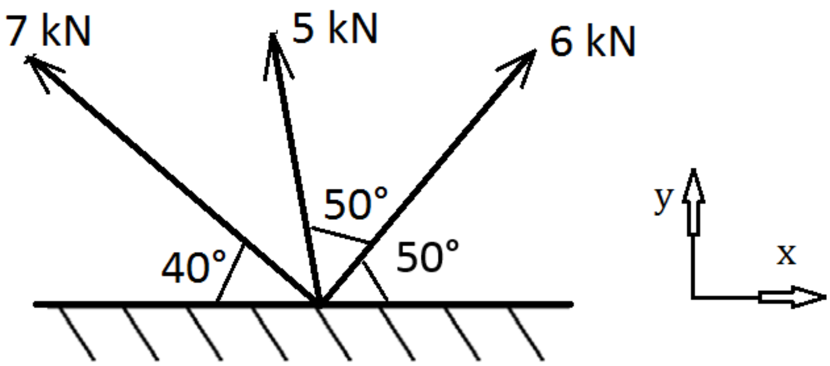


Figure Q3

**(Total marks 25)**

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**Question 4.**

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 cars are at the pit lane entrance at the same time. The stop-go penalty requires a car to return to pits and remain stationary for 5 seconds.

The total length of the pit lane from the entry to the exit is 400 metres with a speed limit of 22m/s.

The distance from the pit entrance to the pit exit for a car staying on the track is 450 metres. The car staying on the track has an average speed of 85 m/s.

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

Calculate the distance travelled beyond the exit of the pit lane by the car that stays on the circuit when the pitting car is at the pit lane exit. What is the time lost by the car that is exiting the pits and is at the pit lane exit? **(7 marks)**

Ignore effects due to accelerations. Assume cars travel at average speeds and speed limits.

b. A Formula Student car completes a 75 metres long acceleration test. It is timed over two sections of 30 metres and 45metres. It completes the first section of 30 metres in 3 seconds from standstill. It travels the remaining 45 metres in 2 seconds.

(i) Calculate a value for the speed at the end of the first 30 metres.
Calculate the average acceleration over the first 30 metres. **(6 marks)**

(ii) Calculate the average acceleration from 30 metres to 75 metres. Calculate the velocity at s=75 metres. **(7 marks)**

The ‘suvat’ equations are included in the formula sheet

**(Total marks 25)**

**Please turn the page**

**Question 5.**

(a) A tube has a mean diameter of 18 mm with a wall thickness 0.4mm. The tube is subjected to a test pressure of 100 bar. Calculate and identify the hoop and axial stresses in the tube using the expressions for the stresses in a thin-walled tube. **(5 marks)**

(b) Figure Q5 shows a load cell with a rectangular cross-section that is 9mm by 17mm. The length between the loading points is 90mm. During a test the load cell indicated a direct strain of $650*10^{-6}$ in the direction of the applied load. The load cell is manufactured from a material with a Poisson's ratio $\nu$=0.28 and a Young's modulus E=190 GPa.

For the case where the direct strain on the load cell is $650*10^{-6}$ calculate the following:-

(i) the direct stress **(5 marks)**

(ii) the change in the length between the loading points **(5 marks)**

(iii) the change in the 9 mm dimension **(5 marks)**

(iv) the direct force or applied load acting on the load cell **(5 marks)**

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

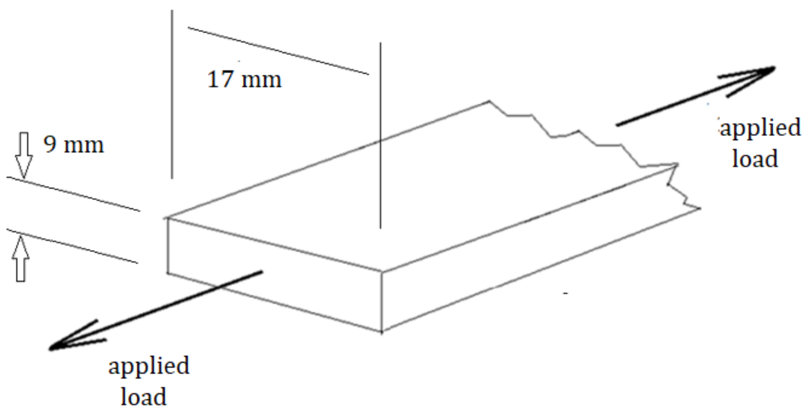


**Figure Q5**

**(Total marks 25)**

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**Question 6.**

(a) Using Kirchhoff's methods determine the two loop equations for the circuit of figure Q6a **(6 marks)**

Find the currents $I_1$ and $I_2$ in the circuit of figure Q6a **(6 marks)**

Use either a third loop equation or finding the potential at 'B' in two different ways to check your calculations. **(4 marks)**

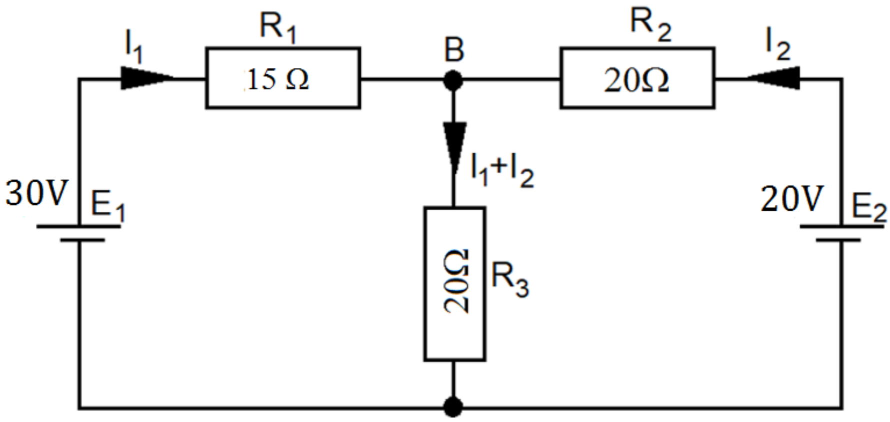


**Figure Q6a**

(b) Calculate the currents through each resistor and the potential difference ($v_b$-$v_a$) in the circuit of figure Q6b

**(6 marks)**

What is the energy consumed during 5 hours of operation of the circuit?

**(3 marks)**

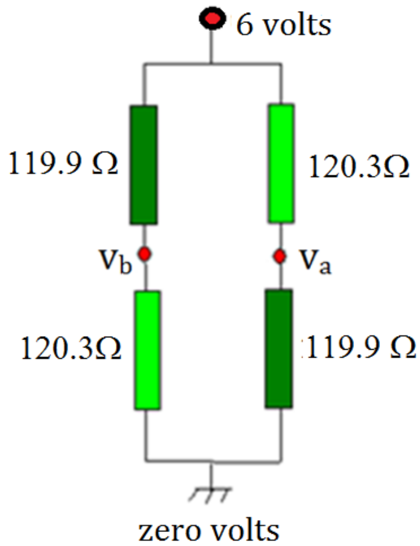


**Figure Q6b**

**(Total marks 25)**

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**Question 7.**

Figure Q7a shows a beam, AC, with a 12 kN test load located at distances a=0.3 metres and b=0.5 metres from the supports. Figure Q7b illustrates the beam cross section. It has a breadth of 50mm, a depth of 100mm and a wall thickness of 3mm.

a) Use equilibrium of moments to find the reactions at A and C. **(4 marks)**

b) Calculate the second moment of area for the beam cross-section **(4 marks)**

c) Draw the shear force diagram with the 12 kN applied load **(3 marks)**

d) Draw the bending moment diagram with the 12 kN applied load **(5 marks)**

e) Calculate the maximum bending stress, with the 12 kN load, for the beam. Draw a diagram to illustrate the stress distribution in the beam. **(6 marks)**

f) Calculate the value of the load, F, at which the beam will start to yield. The yield point for the material is 350 MPa. 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.

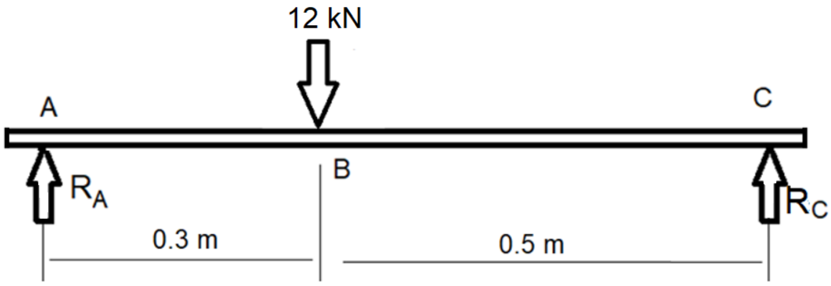


**Figure Q7a**

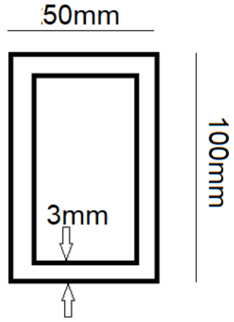


**Figure Q7b**

**(Total marks 25)**

**Please turn the page Q7 Continues…**

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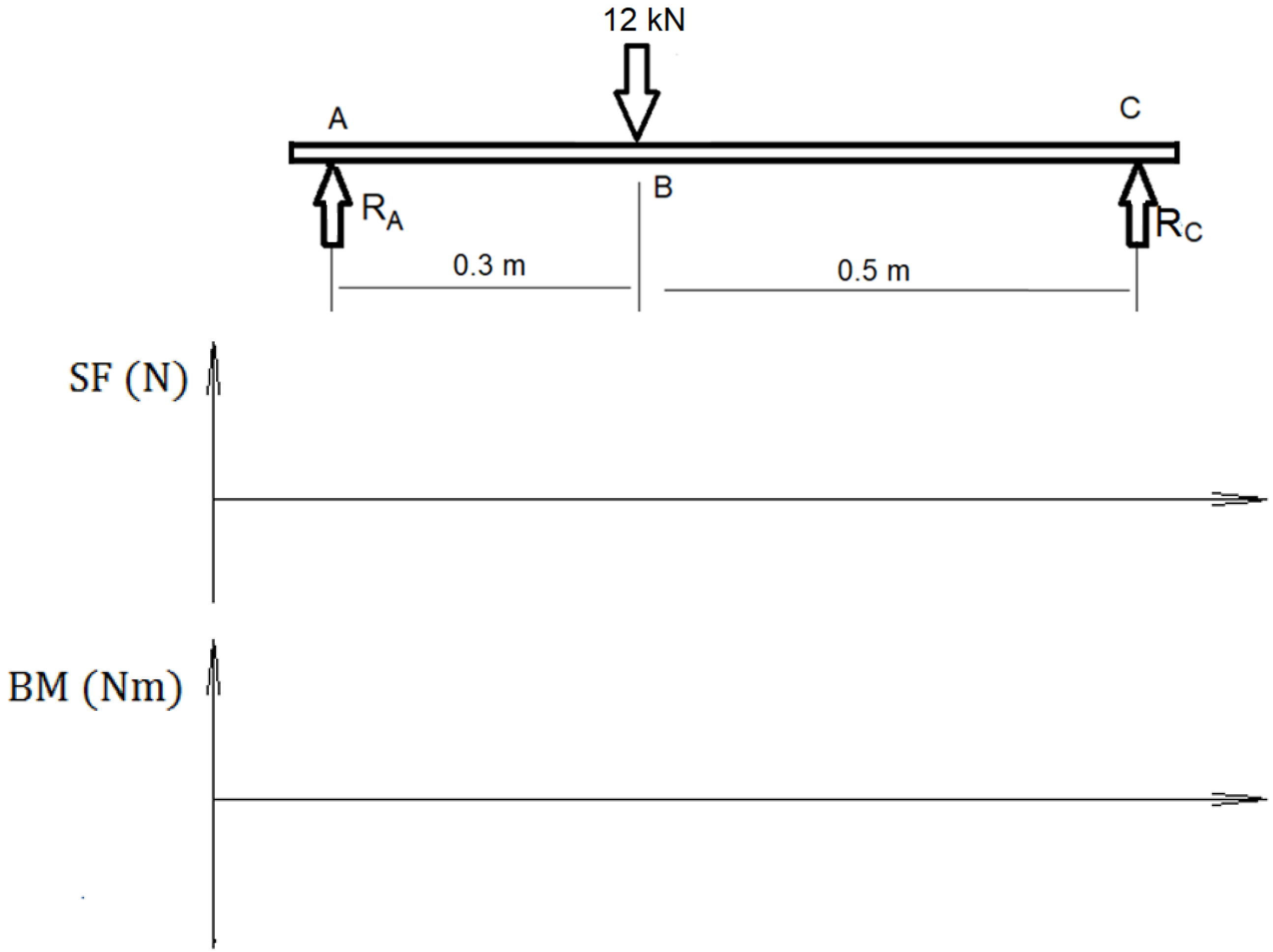


**Figure Q7c**

**End of Questions. Please turn over for formula sheet.**

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## FORMULA SHEET

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

Law of Friction: F=μR

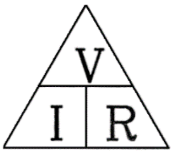
Torque & Power Expressions T=Fr; P=Fv=Tω

### Kinematic Equations

| Linear Motion | Angular Motion | Linear to Angular |
|---|---|---|
| $v = u + at$ | $\omega_f = \omega_i + \alpha t$ | $s = r\theta$ |
| $s = \frac{1}{2}(u+v)t$ | $\theta = \frac{1}{2}(\omega_i + \omega_f)t$ | $v = r\omega$ |
| $s = ut + \frac{1}{2}at^2$ | $\theta = \omega_i t + \frac{1}{2}\alpha t^2$ | $a = r\alpha$ |
| $s = vt - \frac{1}{2}at^2$ | $\theta = \omega_f t - \frac{1}{2}\alpha t^2$ | |
| $v^2 = u^2 + 2as$ | $\omega_f^2 = \omega_i^2 + 2\alpha\theta$ | $\omega = \frac{\theta}{t}$ |

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

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

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

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

### Thermodynamics

Ideal gas law
pV=mRT
$p = \rho RT$ & $pv = RT$

Internal energy $U=m\,c_v\,T$
NFEE Q-W=ΔU

Polytropic process equation $pV^n$=constant

$$\text{1st law} \quad \sum \begin{matrix}\text{sum of heat energy} \\ \text{transfers around a cycle}\end{matrix} = \sum \begin{matrix}\text{sum of work transfers} \\ \text{around a cycle}\end{matrix}$$

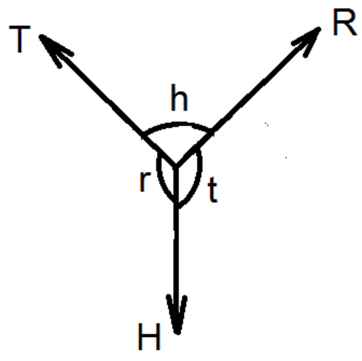
**Please turn the page**

## 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 | kelvin=celcius+273 |
| 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<br>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$^{-1}$=$\frac{10^3}{9.80665\text{x}75}$metric hp≈1.359 metric hp | Angle:1revolution= 360°=2$\pi$ |

**Lami's theorem**

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

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