[ENG01]

UNIVERSITY OF BOLTON

NATIONAL CENTRE FOR MOTORSPORT ENGINEERING

B.ENG. (HONS) AUTOMOTIVE PERFORMANCE ENGINEERING

SEMESTER 2 EXAMINATION 2023/2024

ENGINEERING SCIENCE

MODULE MSP4024

Date: Friday 17th May 2024 **Time: 10:00 – 12:00**

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.

Table Q1 has some of the properties for state 1 and state 2 for a compression process in an air standard cycle engine model. The process is closed and isentropic.

State	p/bar	V/litres	T/K
1	1	2.4	300
2		0.2	

Table Q1

(i) What is the compression ratio between states 1 and 2? (2 marks)
(ii) Use the ideal gas law to calculate the mass of air being compressed. (4 marks)
(iii) Use the process equation, pV^{γ}=constant, to calculate the pressure at state 2. (4 marks)
(iv) Use the ideal gas law to calculate the temperature at state 2. (4 marks)
(v) Calculate the work done from 1 to 2 and comment. (5 marks)
(vi) What is the heat energy transfer between state 1 and state 2? (3 marks)
(vii) The compression process is followed by a constant volume heat energy addition process to take the air to the next state. What are the effects on the temperature and the pressure from state 2 to state 3? (3 marks)

(Total marks 25)

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Question 2

Figure Q2 illustrates a transmission in which an engine produces 112 Nm at full throttle at 6000 revolutions per minute (rpm). Third gear has a ratio 30:22 and is a speed reduction gear. The differential, m_2, is a speed reduction in the ratio 33:10. The road wheels are 0.58 metres in diameter. The car has a mass of 500kg.

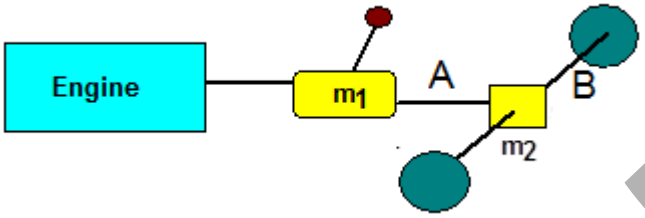

Figure Q2

Using the information above:-

Calculate the rotational speed of the wheels in 3rd gear and the speed of the car in 3rd gear both at an engine speed of 6000 rpm. (6 marks)

Calculate the torque at the wheels in 3rd gear and the tractive force at the wheels in 3rd gear both 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 112 Nm at 6000 rpm. Use the force at the wheels and the car speed, from your calculations above, to calculate the power at the wheels at full throttle at 6000rpm? (6 marks)

The gear change from 3rd to 4th gear is taken at 6000 rpm in 3rd gear. Fourth gear is a speed reduction gear with a ratio 26:24. Assume that the car has a constant speed during the gear change. Calculate: -

The speed of the engine immediately after a gear change from third to fourth gear (5 marks)

The change in speed of the engine during the gear change (2 marks)

(Total marks 25)

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Question 3.

Figure Q3a shows the force and displacement of a ram onto a structure that is being tested. The force and displacement are recorded on the y-axis and x-axis respectively on an x-y pen recorder. One test produced the force-displacement plot of figure Q3b.

The force measurement system on the y-axis has a force transducer and amplifier with a combined sensitivity of 1 V/kN. The y-axis of the chart recorder has a sensitivity of 100 mm/V.

Draw a block diagram to represent the y-axis of the measurement system. (3 marks)

Calculate the y-axis sensitivity. (2 marks)

The displacement measurement system on the x-axis uses a sensor with a sensitivity of 25 volts per metre of ram travel. The x-axis of the chart recorder has a sensitivity of 10 mm of pen travel per volt at the pen recorder input.

Draw a block diagram to represent the x-axis of the measurement system. (3 marks)

Calculate the x axis sensitivity. (2 marks)

What is the overall sensitivity of the measurement system? (5 marks)

The area under the curve is 38800 mm^2. Calculate the energy that the area represents (5 marks)

What is the average force exerted during the test? (5 marks)

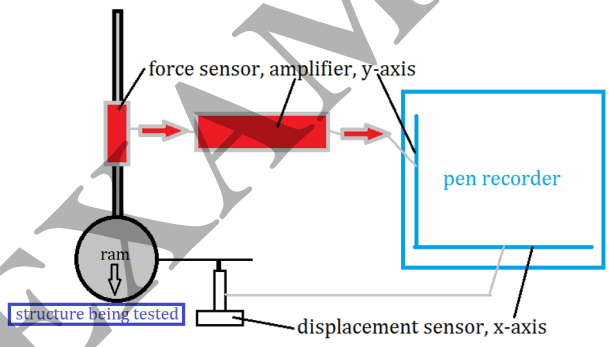

Figure Q3a

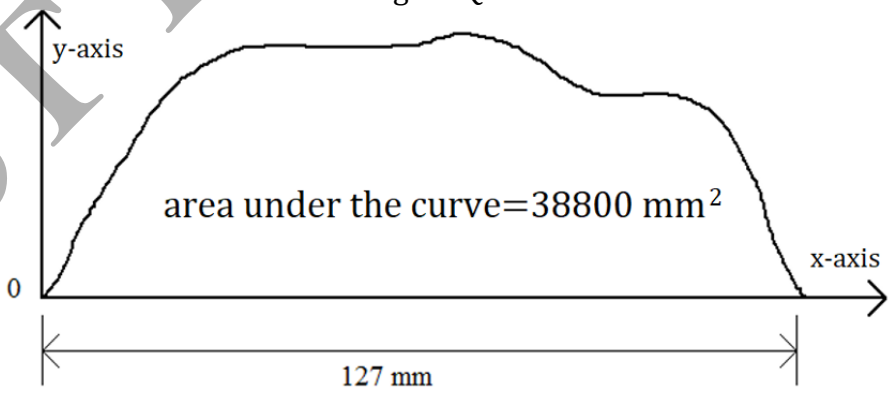

Figure Q3b

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Question 4. A duty cycle uses an overall distance from rest to rest as 400 metres. A vehicle has an average acceleration of 3 m/s/s from rest to a maximum speed of 27 m/s. At the end of the constant speed running the braking from 27 m/s to rest is achieved over a distance of 55 metres. Assume constant accelerations during acceleration and braking.

Determine the distance and time taken to accelerate from rest to 27m/s. (5 marks)

Determine the time taken to brake from 27m/s to rest. Determine the average acceleration during braking. (5 marks)

Determine the distance and time during the constant speed travel. (2 marks)

Using your results annotate figures Q4a and Q4b as appropriate with the 'suvat' information from your calculations. Figures Q4 are on the next page and both have velocity on the y-axis and either distance or time on the x-axis. (8 marks)

The vehicle has a mass of 450kg. The vehicle is powered by an electric motor with 84% efficiency during braking. The electric motor regenerates energy during braking down to a speed of 8 m/s. There is no energy regenerated below a speed of 8m/s.

Calculate the kinetic energy available for energy regeneration during the braking from 27m/s in the above. (2 marks)

Determine the energy that is regenerated when braking from 27m/s. (3 marks)

The expression for kinetic energy is at the top of the formula sheet

Figures Q4 are on the next page. If this question is attempted then remove the next page from the question paper, annotate the figures and attach to your answer book.

(Total marks 25)

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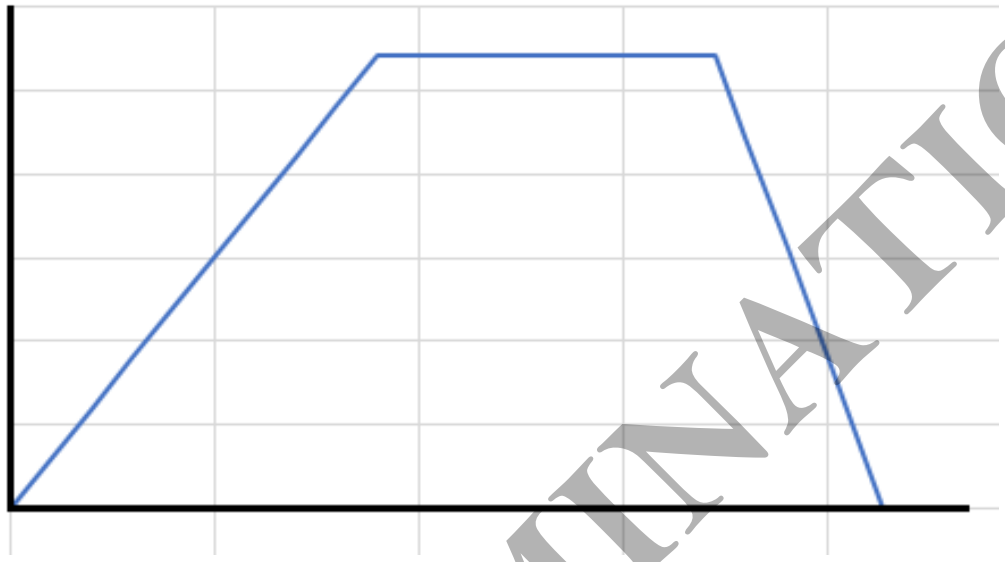

Figure Q4a

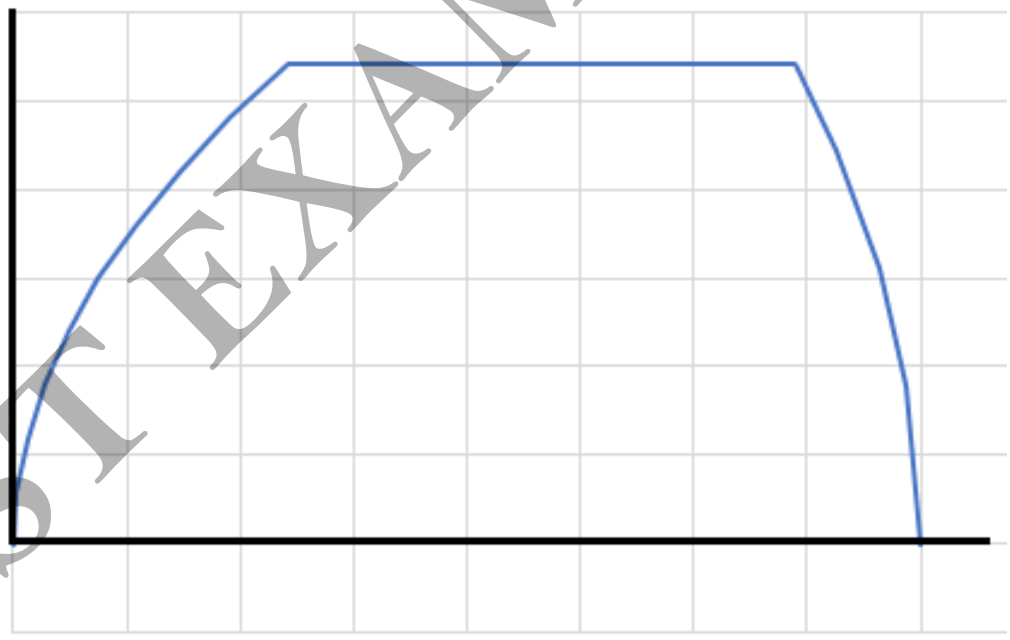

Figure Q4b

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Question 5.

(a) A tube has a mean diameter of 12mm with a wall thickness 0.5mm. The maximum working stress is 60 MPa.
Using the expression for the hoop stress in a thin-walled cylinder calculate a maximum pressure based on not exceeding the maximum working stress.
(5 marks)

(b) A load cell has a rectangular cross-section that is 10mm by 20mm with a length between the loading points of 100mm. During a test the load cell indicated a direct strain of $400*10^{-6}$. 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 $400*10^{-6}$ calculate the following:-

(i) the direct stress (5 marks)

(ii) the change in the distance between the loading points (5 marks)

(iii) the change in the 20mm dimension (5 marks)

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

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

(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)

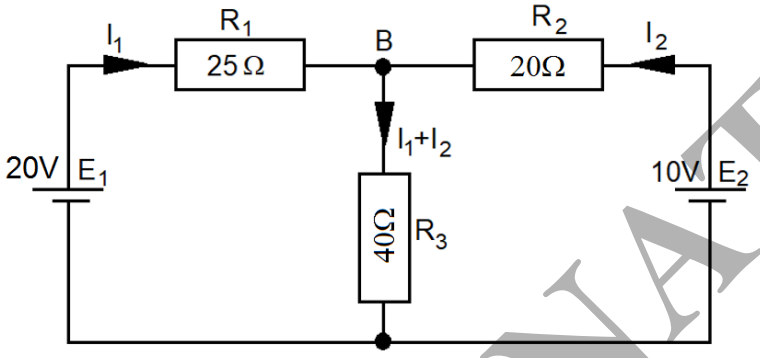

Figure Q6a

(b) Figure Q6b shows a connection for a linear suspension potentiometer. The resistance across A and B is 2 kΩ. The total movement for the potentiometer is 150mm.

What is the current supplied by the 12 volt emf?

What is the sensitivity of the potentiometer with this connection?

What is the energy used by the device during a 24 hour race? Express your answer in joules, amp-hours & watt-hours.

(9 marks)

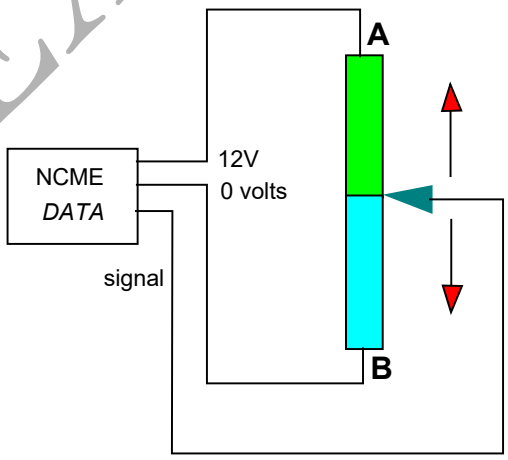

Figure Q6b

(Total marks 25)

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Question 7

Figure Q7a 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.

Figure Q7b 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.

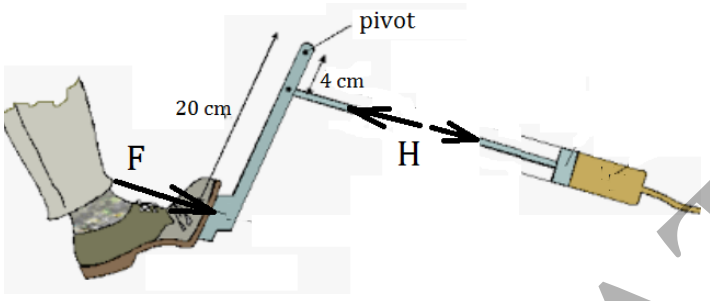

Figure Q7a

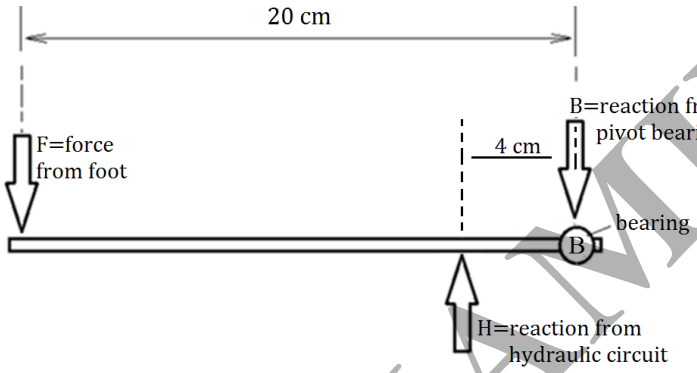

Figure Q7b

Figure Q7c

Using equilibrium of moments find the reaction force, H, from the hydraulics and the reaction force from the bearing at B. (4 marks)

Write the forces onto the free body diagram in figure Q7d. Draw the shear force and bending moment diagrams for the brake pedal on figure Q7d. **Figure Q7d is on the next page. Remove the page from the question paper and attach to your answer book. Write your student number on the page now.** (12 marks)

Figure Q7c shows the brake pedal cross section as 8mm by 30mm. Calculate the 2nd moment of area for the section. (3 marks)
Calculate a value for the maximum bending stress. (4 marks)

The suggested material for the beam is steel with a yield stress of 550MPa. Based on the above calculations what force from the foot would yielding commence?

(2 marks)

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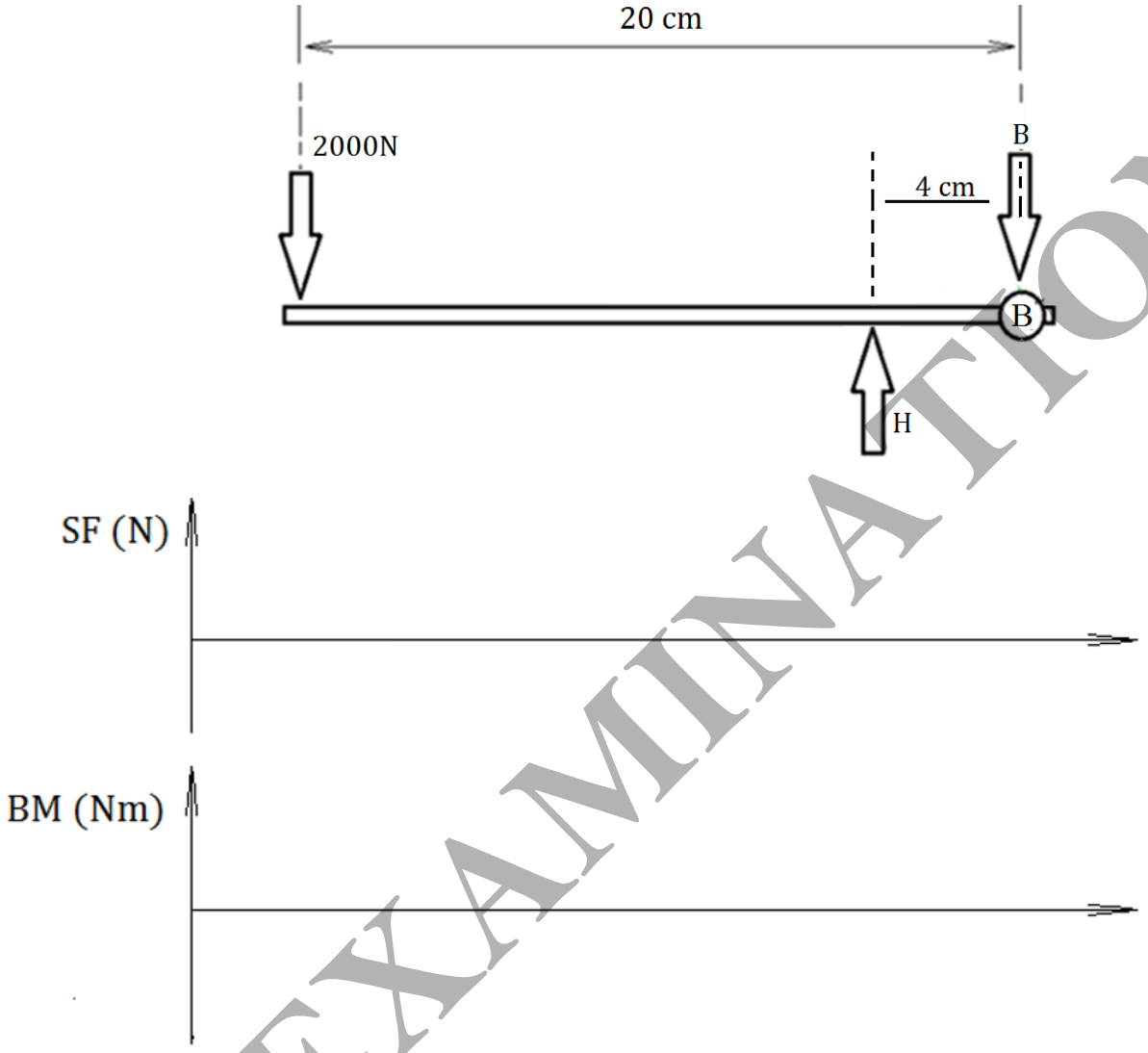

Figure Q7d

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FORMULA SHEET

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

$$\text{Kinetic energy} = \frac{1}{2}m(v^2 - u^2) \quad \& \quad \text{Potential energy} = mg(h_2 - h_1)$$

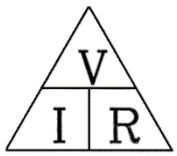
Law of Friction: $F=\mu R$ Torque & Power Expressions $T=Fr$; $P=Fv=T\omega$

Kinematic Equations

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

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

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

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

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

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

Thermodynamics

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

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

Polytropic process equation $pV^n=\text{constant}$
$$W_{ab} = \frac{p_a V_a - p_b V_b}{n - 1}$$

1st law $\sum$ sum of heat energy transfers around a cycle $= \sum$ sum of work transfers around a cycle

For air $\gamma=1.4$; $R=0.2871$kJ/(kg.K) and $c_v=0.718$ kJ/(kg.K) where appropriate

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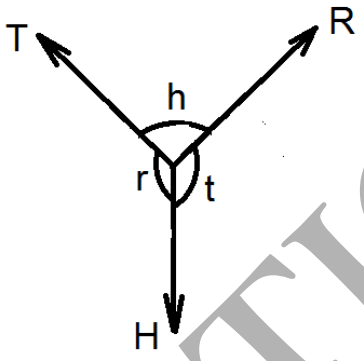
Lami's theorem

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



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	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 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

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