



SWANSEA METROPOLITAN UNIVERSITY
PRIFYSGOL FETROPOLITAN ABERTAWE

Faculty of Applied Design and Engineering

School of Automotive Engineering

BEng Automotive/Motorsport/Motorcycle/ Mechanical Engineering

Year 1

Engineering Science

Phase Test 2

Tuesday 14th May 2013

9am

Instructions to candidates:

There are four questions in this paper, answer all questions.

Name:.....Solutions.....

Course:.....

1.

A 100N load is added to the end of circular cross section steel rod that has a length of 0.3m and a diameter of 0.025m. The steel has a Young's modulus value of 210GN/m^2 ; calculate the stress and extension of the rod. [18marks]

$$E = \frac{\sigma}{\epsilon}$$

Space for answers:

$$\begin{aligned} l &= 0.3\text{m} \\ d &= 0.025\text{m} \\ F &= 100\text{N} \\ E &= 210 \times 10^9 \text{ N/m}^2 \end{aligned}$$

$$\sigma = \frac{F}{A} = \frac{F}{\left(\frac{\pi d^2}{4}\right)} = \frac{100}{\left(\frac{\pi \times 0.025^2}{4}\right)} = 203718.33 \text{ N/m}^2 = 203.72 \text{ kN/m}^2$$

$$\epsilon = \frac{\sigma}{E} \therefore E = \frac{\sigma}{\epsilon} = \frac{203718.33}{210 \times 10^9} = 9.7 \times 10^{-7} \text{ (no units)}$$

$$\epsilon = \frac{x}{l} \therefore x = l \cdot \epsilon = 0.3 \times 9.7 \times 10^{-7} = 2.91 \times 10^{-7} \text{ m}$$

2.

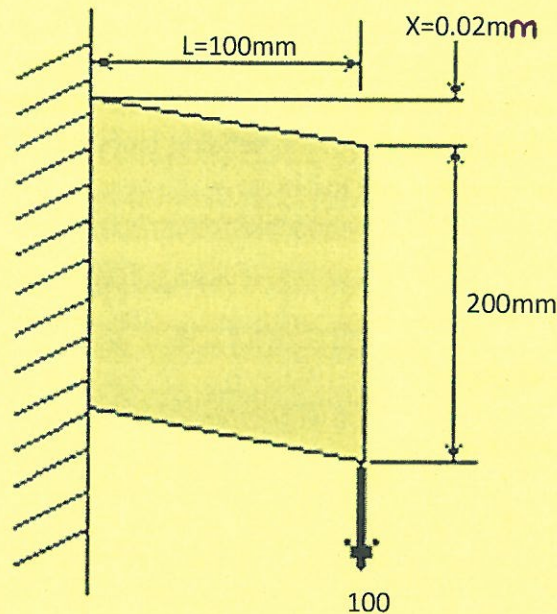


Figure 1.

Figure 1 shows an experiment to determine the modulus of rigidity of a sample of rubber, a rectangular block of the material, measuring 200 x 100 x 20mm, was firmly fastened, so that it projected a distance of 100mm from a vertical wall. It was found that when a downward load of 100N was applied to the free vertical edge, a vertical deflection of 0.02mm was obtained as shown. Determine the experimental value of the modulus of rigidity of this rubber sample. [12 marks]

$$G = \frac{\tau}{\gamma}$$

Space for answers:

$$\tau = \frac{F}{A} = \frac{100}{(200 \times 10^{-3} \times 20 \times 10^{-3})} = \frac{25000 \text{ N/m}^2}{25 \text{ kN/m}^2}$$

$$\gamma = \frac{x}{l} = \frac{0.02 \times 10^{-3}}{100 \times 10^{-3}} = 2 \times 10^{-4} \text{ (no units)}$$

$$G = \frac{\tau}{\gamma} = \frac{25000}{2 \times 10^{-4}} = 125 \times 10^6 \text{ N/m}^2 = 125 \text{ MN/m}^2$$

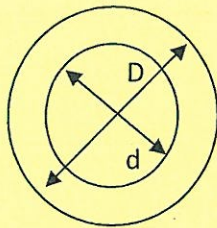
3.

A cross member of length 0.80m is supported at each end and has point loads of 650N and 250N at 0.3m and 0.4m respectively from one end. Calculate the reaction forces at the supports.

[10 marks]

Figure 2 shows the dimensions of the cross section of the chassis member made from titanium with a Young's modulus of elasticity of 120GN/m^2 . A bending moment of 300Nm is subjected to the beam, calculate the radius of curvature and the stress of the beam.

[15 marks]



$D=0.08\text{m}$

$d=0.06\text{m}$

Figure 2

$$I = \frac{\pi}{64} [D^4 - d^4] \quad \frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

Space for answers:

$$E = 120 \times 10^9 \text{ N/m}^2 \quad y = \frac{D}{2} = \frac{0.08}{2} = 0.04 \text{ m}$$

$$M = 300 \text{ Nm}$$

$$R = ?$$

$$\sigma = ?$$

$$I = \frac{\pi}{64} [0.08^4 - 0.06^4]$$

$$I = 1.37 \times 10^{-6} \text{ m}^4$$

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

$$\frac{M}{I} = \frac{\sigma}{y} \quad \therefore \quad \sigma = \frac{My}{I} = \frac{300 \times 0.04}{1.37 \times 10^{-6}} = 8759124.09 \text{ N/m}^2$$

$$= 8.76 \text{ MN/m}^2$$

$$\frac{M}{I} = \frac{E}{R} \quad R = \frac{EI}{M} = \frac{120 \times 10^9 \times 1.37 \times 10^{-6}}{300} = 548 \text{ m}$$

4.

If a drive shaft 0.8m long is to be subjected to a torque of 2.2kNm and the maximum shearing stress must not exceed 40MN/m², calculate the solid shaft diameter required to satisfy these conditions. Calculate the angle of twist in degrees given G=85GN/m². [20 marks]

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

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

Space for answers:

$$\begin{aligned} l &= 0.8\text{m} \\ T &= 2.2\text{kNm} = 2.2 \times 10^3\text{Nm} \\ \tau &= 40 \times 10^6\text{N/m}^2 \\ D &= ? \\ G &= 85 \times 10^9\text{N/m}^2 \\ \theta &= ? \end{aligned} \quad \frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{l}$$

$$\frac{T}{J} = \frac{\tau}{r} \quad r = \frac{D}{2}$$

$$\frac{T}{\frac{\pi D^4}{32}} = \frac{\tau}{\frac{D}{2}} \quad J = \frac{\pi D^4}{32}$$

$$T \cdot \frac{1}{2} = \tau \cdot \frac{\pi D^3}{32}$$

$$32 \cdot T \cdot \frac{1}{2} = \tau \cdot \pi D^3$$

$$16 T = \tau \pi D^3$$

$$\frac{16 T}{\tau \pi} = D^3$$

$$\therefore D = \sqrt[3]{\frac{16 T}{\tau \pi}} = \sqrt[3]{\frac{16 \times 2.2 \times 10^3}{(40 \times 10^6 \times \pi)}} = 0.065\text{m}$$

$$\frac{\tau}{r} = \frac{G\theta}{l} \quad \therefore \theta = \frac{\tau l}{r G} = \frac{(40 \times 10^6 \times 0.8)}{(0.0325 \times 85 \times 10^9)}$$

$$\therefore r = 0.0325\text{m} \quad \theta = 0.012\text{radians} \times \frac{360}{2\pi}$$

$$\theta = 0.66\text{degrees}$$



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Wednesday 5th September 2012

2pm

Instructions to candidates:

There are five questions in this paper, answer all questions.

Name:.....

Course:.....

1.



The elastic surface of a trampoline is held to the frame with 20 steel bolts. Given the maximum shear stress of the steel bolts is 120 MN/m^2 and the maximum estimated force on the trampoline is 150 kN , calculate the diameter needed for the bolts. [12 marks]

$$\tau = \frac{F}{A}$$

Space for answers:

20 bolts

$$\tau = 120 \times 10^6 \text{ N/m}^2$$

$$F = 150 \times 10^3 \text{ N}$$

$d = ?$

$$\tau = \frac{F}{A} \quad \therefore A = \frac{F}{\tau} = \frac{150 \times 10^3}{120 \times 10^6} = 1.25 \times 10^{-3} \text{ m}^2$$

$$\text{Area of 20 bolts} = 1.25 \times 10^{-3} \text{ m}^2$$

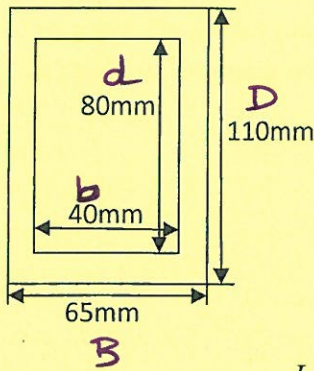
$$\text{Area of 1 bolt} = \frac{1.25 \times 10^{-3}}{20} = 6.25 \times 10^{-5} \text{ m}^2$$

$$\text{Area} = \frac{\pi d^2}{4}$$

$$\frac{4 \times A}{\pi} = d^2$$

$$d = \sqrt{\frac{4 \times A}{\pi}} = \sqrt{\frac{4 \times 6.25 \times 10^{-5}}{\pi}} = 7.96 \times 10^{-3} \text{ m}$$

2.



A single sided swing arm for a motorcycle can be modelled as box section with dimensions as seen in the diagram left. When the beam experiences full load it is observed to have a radius of curvature of 620m. Given that the material of the swing arm has a Young's modulus of elasticity of 210GN/m^2 , calculate the maximum stress and the bending moment experienced by the beam.

[15 marks]

$$I = \frac{BD^3}{12} - \frac{bd^3}{12}$$

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

Space for answers:

$$R = 620\text{m}$$

$$E = 210 \times 10^9 \text{ N/m}^2$$

$$\sigma = ?$$

$$M = ?$$

$$y = \frac{D}{2} = \frac{0.11}{2} = 0.055\text{m}$$

$$I = \frac{BD^3}{12} - \frac{bd^3}{12} = \left[\frac{(0.065 \times 0.11^3)}{12} \right] - \left[\frac{(0.04 \times 0.08^3)}{12} \right]$$

$$I = 5.5 \times 10^{-6} \text{ m}^4$$

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

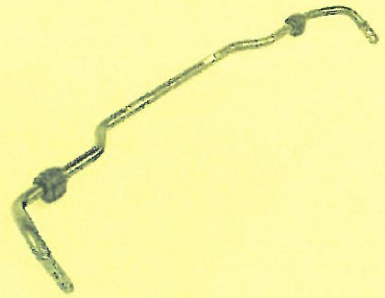
$$\frac{\sigma}{y} = \frac{E}{R} \quad \therefore \sigma = \frac{Ey}{R} = \frac{210 \times 10^9 \times 0.055}{620} = 18.63 \times 10^6 \text{ N/m}^2$$

$$= 18.63 \text{ MN/m}^2$$

$$\frac{M}{I} = \frac{E}{R} \quad \therefore M = \frac{EI}{R} = \frac{210 \times 10^9 \times 5.5 \times 10^{-6}}{620} = 1862.9 \text{ Nm}$$

3.

An anti roll bar of diameter 40mm experiences a maximum torque of 4.8kNm which results in a twist of 3.5° . The anti roll bar has an active length of 0.55m and the modulus of rigidity of spring steel is of the order of 90GN/m^2 . Calculate:



- The polar moment of area, J . [3 marks]
- The maximum shear stress on the anti roll bar. [10 marks]

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

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

Space for answers:

$$\begin{aligned} d &= 0.04\text{m} & l &= 0.55\text{m} \\ T &= 4.8 \times 10^3 \text{Nm} & G &= 90 \times 10^9 \text{N/m}^2 \\ \theta &= 3.5^\circ \times \frac{2\pi}{360} = 0.061 \text{ radians} \end{aligned}$$

$$a) \quad J = \frac{\pi D^4}{32} = \frac{\pi \times 0.04^4}{32} = 2.51 \times 10^{-7} \text{m}^4$$

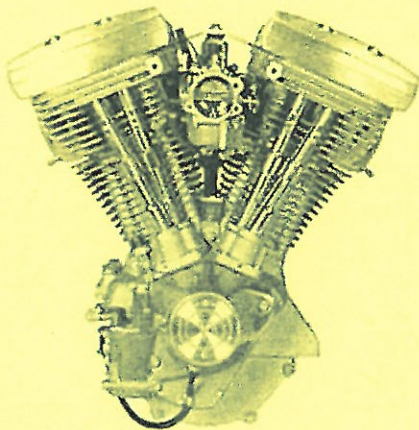
$$b) \quad \tau = ? \quad \frac{T}{J} = \frac{G\theta}{l}$$

$$r = 0.02\text{m} \quad r = \frac{d}{2}$$

$$\tau = \frac{G\theta r}{l} = \frac{90 \times 10^9 \times 0.061 \times 0.02}{0.55} = 199.64 \times 10^6 \text{N/m}^2$$

$$= 199.64 \text{ MN/m}^2$$

4.



A twin cylinder engine has 20 cooling fins per cylinder, each fin having an outer diameter of 150mm and an inner diameter of 100mm. If the engine has an average fin temperature of 600K, calculate the heat flow from the engine through radiation if the atmospheric temperature is 288K. Assume an emissivity value of 0.70.

$$Q = 56.7 \epsilon A \left[\left(\frac{T_2}{1000} \right)^4 - \left(\frac{T_1}{1000} \right)^4 \right]$$

Space for answers:

$$T_2 = 600K \quad T_1 = 288 - 5 = 283K. \quad \epsilon = 0.7$$

$$\text{Area of 1 side of 1 fin} = \frac{\pi}{4} (d_o^2 - d_i^2)$$

$$= \frac{\pi}{4} (0.15^2 - 0.1^2)$$

$$= 9.82 \times 10^{-3} \text{ m}^2$$

$$\text{Area of both sides of 1 fin} = 2 \times 9.82 \times 10^{-3}$$

$$= 0.02 \text{ m}^2 \quad (\text{2dp})$$

$$20 \text{ fins per cylinder} = 0.02 \times 20$$

$$= 0.4 \text{ m}^2$$

$$2 \text{ cylinders} = 2 \times 0.4$$

$$= 0.8 \text{ m}^2$$

$$Q = 56.7 \epsilon A \left[\left(\frac{T_2}{1000} \right)^4 - \left(\frac{T_1}{1000} \right)^4 \right]$$

$$Q = 56.7 \times 0.7 \times 0.8 \left[\left(\frac{600}{1000} \right)^4 - \left(\frac{283}{1000} \right)^4 \right]$$

$$Q = 3.911 \text{ kW.}$$

6.

A dyno' cell has a large circular double glazed reinforced window consisting of 2 layers of 4mm thick toughened glass sandwiching a 5 mm layer of air. The window has a diameter of 1.5m and that glass and air have thermal conductivities of 1.05 W/mK and 0.024 W/mK respectively. Given that the internal temperature of the dyno' cell is 35°C and the external temperature is 15°C calculate the heat transfer due to conduction from the window.

Is this model for the heat transfer through a double glazed window accurate? Justify your answer.

[10 marks]

$$Q = -UA(T_2 - T_1) \quad \frac{1}{U} = \frac{1}{U_a} + \frac{1}{U_b} + \frac{1}{U_c}$$

Space for calculations:

$$\text{Area of window} = \frac{\pi d^2}{4} = \frac{\pi \times 1.5^2}{4} = \underline{1.77 \text{ m}^2}$$

$$\frac{1}{U} = \frac{1}{U_a} + \frac{1}{U_b} + \frac{1}{U_c} \quad U = \frac{k}{x}$$

$$\therefore \frac{1}{U} = \frac{x_a}{k_a} + \frac{x_b}{k_b} + \frac{x_c}{k_c}$$

$$\frac{1}{U} = \frac{4 \times 10^{-3}}{1.05} + \frac{5 \times 10^{-3}}{0.024} + \frac{4 \times 10^{-3}}{1.05}$$

$$\frac{1}{U} = 0.22$$

$$\therefore U = \frac{1}{0.22} = 4.54 \text{ W/mK}$$

$$T_2 = (15 + 273) = 288 \text{ K}$$

$$T_1 = (35 + 273) = 308 \text{ K}$$

$$Q = -UA(T_2 - T_1)$$

$$Q = -4.54 \times 1.77 \times (288 - 308)$$

$$Q = \underline{160.72 \text{ W}}$$

7. An air cooled 'V' twin engine has 25 cooling fins per cylinder, each with an inner diameter and outer diameter of 220mm and 280mm respectively. The average fin temperature on a day with ambient temperature of 28°C is 500°C. Given the heat transfer rate by radiation is 35kW and the emissivity is 0.75, prove the Stefan-Boltzman constant.

[12 marks]

$$Q = 56.7 \epsilon A \left[\left(\frac{T_2}{1000} \right)^4 - \left(\frac{T_1}{1000} \right)^4 \right]$$

Space for calculations:

$$T_2 = (500 + 273) = 773 \text{ K} \quad T_1 = (28 - 5 + 273) = 296 \text{ K}$$

$$\epsilon = 0.75 \quad Q = 35 \text{ kW}$$

$$\begin{aligned} \text{Area of 1 side of 1 fin} &= \frac{\pi}{4} (d_o^2 - d_i^2) \\ &= \frac{\pi}{4} (0.28^2 - 0.22^2) \\ &= 0.024 \text{ m}^2 \end{aligned}$$

$$\begin{aligned} \text{Area of 2 sides of 1 fin} &= 2 \times 0.024 \\ &= 0.047 \text{ m}^2 \end{aligned}$$

$$\begin{aligned} 25 \text{ fins} &= 25 \times 0.047 \\ &= 1.175 \text{ m}^2 \end{aligned}$$

$$2 \text{ cylinders} = \underline{2.35 \text{ m}^2}$$

$$Q = 56.7 \epsilon A \left[\left(\frac{T_2}{1000} \right)^4 - \left(\frac{T_1}{1000} \right)^4 \right]$$

$$56.7 = \frac{Q}{\epsilon A \left[\left(\frac{T_2}{1000} \right)^4 - \left(\frac{T_1}{1000} \right)^4 \right]}$$

$$56.7 = \frac{35}{0.75 \times 2.35 \left[\left(\frac{773}{1000} \right)^4 - \left(\frac{296}{1000} \right)^4 \right]}$$

$$56.7 = 56.84$$

Not bad!

6. A composite panel of dimensions 0.8m by 0.55m is situated between an engine bay of temperature 42°C and a passenger compartment of temperature 15°C. The composite consists of an inner layer of glass fibre weave of thickness 3mm and thermal conductivity 0.05W/mK and an outer layer of epoxy resin of thickness 1.5mm and thermal conductivity 280 W/mK. Calculate the steady heat flow from the engine bay to the passenger compartment. [8 marks]

$$Q = -UA (T_2 - T_1)$$

$$A = 0.8 \times 0.55 \\ = \underline{0.44 \text{ m}^2}$$

$$1/U = (1/U_A + 1/U_B + 1/U_C)$$

$$T_1 = 42^\circ\text{C} = 315 \text{ K} \quad T_2 = 15^\circ\text{C} = 288 \text{ K}$$

$$\frac{1}{U} = \frac{1}{U_a} + \frac{1}{U_b} + \frac{1}{U_c}$$

$$U = \frac{k}{x}$$

$$\frac{1}{U} = \frac{x_a}{k_a} + \frac{x_b}{k_b} + \frac{x_c}{k_c}$$

$$\frac{1}{U} = \frac{1.5 \times 10^{-3}}{280} + \frac{3 \times 10^{-3}}{0.05} + \frac{1.5 \times 10^{-3}}{280}$$

$$\frac{1}{U} = 0.06 \quad \therefore U = \frac{1}{0.06} = 16.66 \text{ W/mK}$$

$$Q = -UA (T_2 - T_1)$$

$$= -16.66 \times 0.44 \times (288 - 315)$$

$$= \underline{197.92 \text{ W}}$$

6. Find the heat transfer coefficient for the material of a door (dimensions 2m x 1m) of a furnace given the heat flow rate is 40,000W and that the internal temperature is 450°C and the external temperature is 32°C. Given that the door is made from steel of thermal conductivity 54W/m°C, calculate how thick the door is.

[6 marks]

$$Q = -UA (T_2 - T_1)$$

Space for calculations:

$$A = 2 \times 1 \\ = 2 \text{ m}^2.$$

$$Q = 40,000 \text{ W}.$$

$$T_2 = (32 + 273) = 305 \text{ K} \quad T_1 = (450 + 273) = 723 \text{ K}.$$

$$U = ?$$

$$Q = -UA (T_2 - T_1)$$

$$U = \frac{Q}{-A (T_2 - T_1)} = \frac{40000}{-2 \times (305 - 723)}$$

$$U = 47.85 \text{ W/mK}.$$

$$U = \frac{k}{x} \quad \therefore x = \frac{k}{U} = \frac{54}{47.85} = \underline{\underline{1.13 \text{ m}}}$$