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UNIVERSITY OF BOLTON

SCHOOL OF THE BUILT ENVIRONMENT & ENGINEERING

BENG (HONS) IN AUTOMOBILE ENGINEERING

SEMESTER 2 EXAMINATIONS 2010/2011

VEHICLE HANDLING & AERODYNAMICS

MODULE NO: ATT3011

Date: **Friday, 3 June 2011** **Time:** **2.00 – 5.00 p.m.**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions on this paper.

Answer FOUR questions.

All questions carry equal marks.

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Q1 Describe how you would measure the aerodynamic forces acting upon a vehicle being tested in a wind tunnel, using :

(a) (i) one method of direct force measurement
(ii) one method using pressure sensors (6 marks)

(b) The car in Figure Q1 has pressure sensors along the centre line of the car, which give the profile shown in the upper diagram of pressure coefficient, C_p, against the position of each sensor.

Describe what is happening to the air flow over the car (at the centre line), from the results of C_p. (7 marks)

(c) For the car in Figure Q1, calculate the total force acting upon the windscreen of the car (pressure sensors 15 to 20), if the width of the window is 1.6m, length 15 to 20 is 0.8m, and air speed is 20m/s. Air density = 1.2kg/m^3.
(12 marks)

Total 25 marks

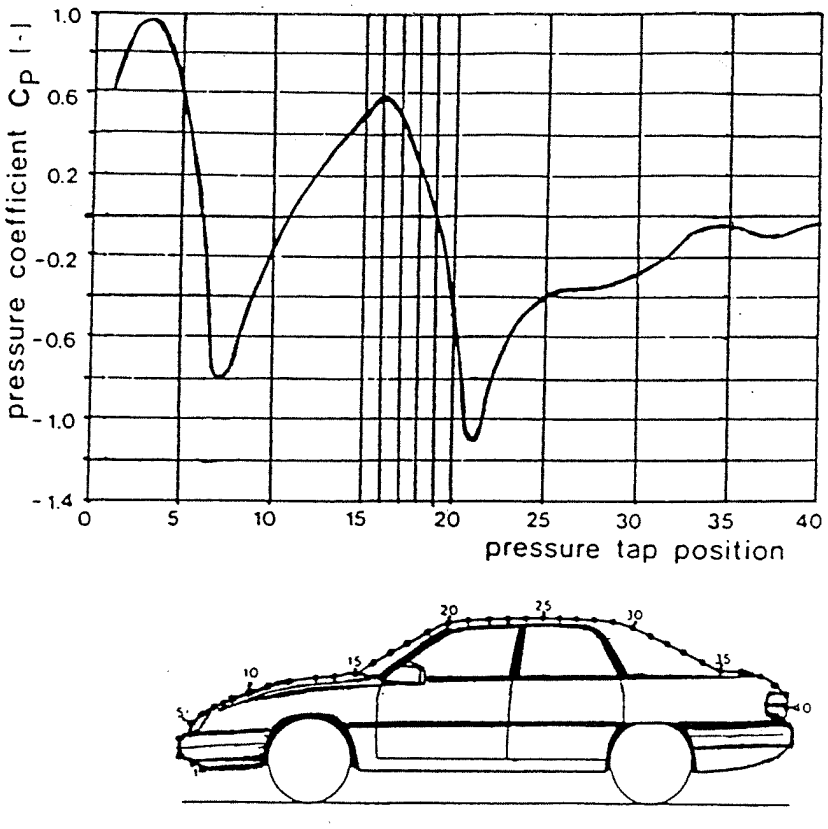

Figure Q1

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Q2 A $1/5^{th}$ scale model of a van is tested in a model wind tunnel at a series of air velocities. The following results were measured :

Velocity (m/s)	Drag Force (N)
10	4.5
15	9.9
20	17.5
25	27.1
30	39.0

(a) Calculate the values of Drag coefficient and Reynolds number, and draw a graph of C_D against R_e. Explain the significance of the results and identify the Reynolds Number at which you would continue the work in the model wind tunnel. (12 marks)

Air density, ρ = 1.25 kg/m^3
Air viscosity, η = 1.35 x 10^{-5} m^2/s
Model length = 0.95m
Model width = 0.32m
Model height = 0.4m

(b) (i) The van was tested in a wind tunnel with a height of 0.9m and a width of 1.2m in the working section. State clearly if you think the results are realistic in comparison to the full size vehicle, due to the sizing of the model and wind tunnel. (4 marks)

(ii) It is proposed to study a full-size vehicle mock-up in the wind tunnel at the Motor Industry Research Association, which is 7m wide and 5m high. Again, identify if this will be suitable in terms of van size to wind tunnel size. (4 marks)

(iii) The wind tunnel can achieve a maximum air speed of 110 km/h, discuss how the full-size C_D is likely to differ from the model C_D, calculated in part (a). (5 marks)

Total 25 marks

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Q3 (a) Figure Q3 shows the results of a "coastdown" test carried out on the first prototype van from Q2. From this, calculate the rolling resistance coefficient of the van and hence the drag coefficient.
Vehicle mass = 3500kg, g = 9.81 m/s^2
Air density 1.25 kg/m^3 (13 marks)

(b) In order to study the effects of various changes and optional extras for this van, a number of further coastdown tests are carried out to measure the effect on drag coefficient of the changes. Describe WHY the following differences are found for THREE of these modifications :

(i) Exterior mirrors, + 0.01 on C_D
(ii) Smooth wheel trims, - 0.005 on C_D
(iii) Suspension lowered by 10mm, - 0.008 on C_D
(iv) Surfboard on roof, + 0.10 on C_D (12 marks)

Total 25 marks

Question 3 continued over

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Question 3 continued

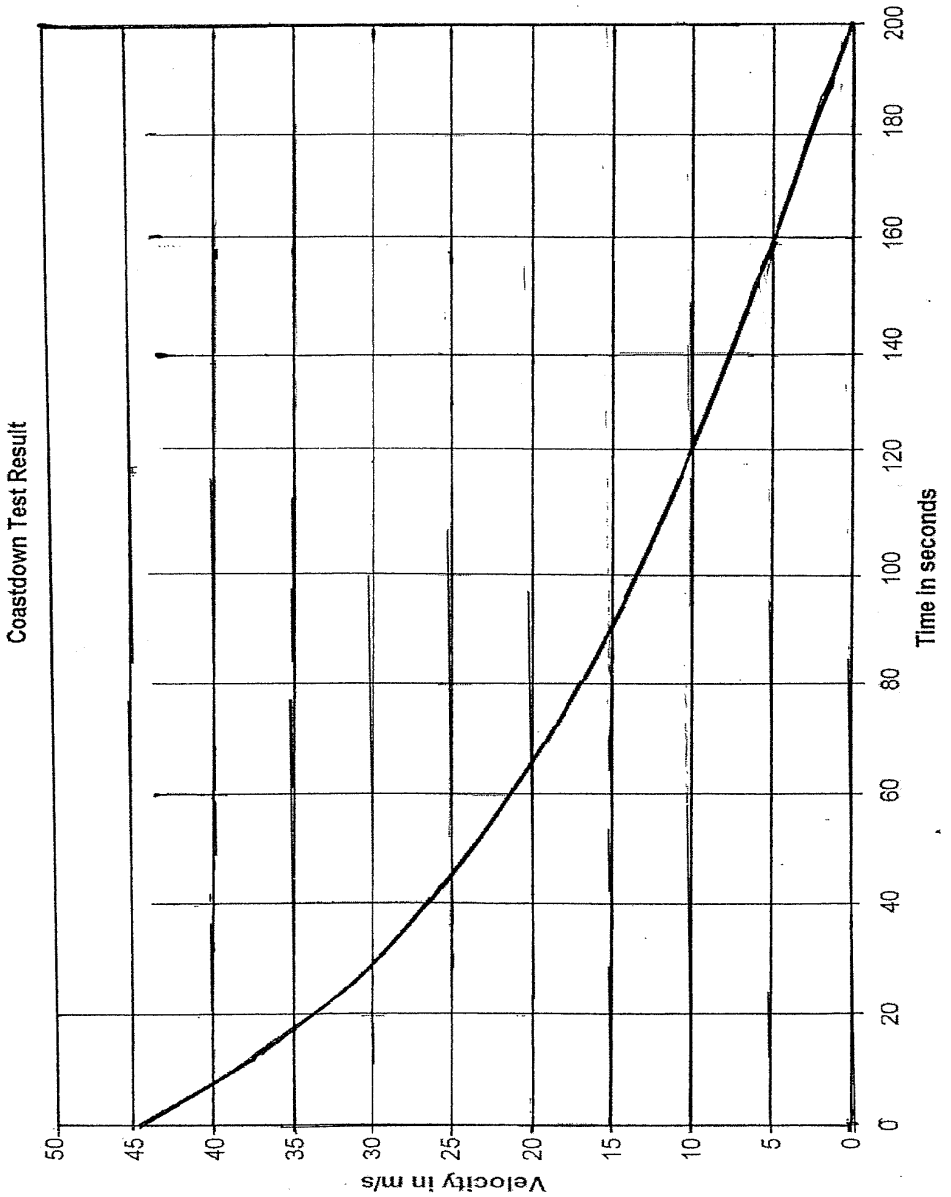

Figure Q3

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Q4 (a) A car has been instrumented with an 8-channel data logger. The data logger's channels measure :

- vehicle speed (1)
- steering angle (1)
- lateral acceleration (2) – front and rear
- vertical wheel movement (4) – front right, front left, rear right, rear left

Explain how the FOUR types of transducer described above work, and identify where you would fit them on the car. (8 marks)

(b) If you now consider the use of a data logging system by a saloon car racing team which has a 16-channel data logger, identify EIGHT additional parameters which you would need to log continuously during a practice session or race. (8 marks)

(c) From the car in (a), a series of constant speed, constant radius tests are carried out on a steering pad. Show how you would calculate the amount of body roll which the car exhibits in these tests, using appropriate analysis of the 8 data channels. (5 marks)

Describe the difference in data which you would get between an UNDERSTEERING car and an OVERSTEERING car in the steering pad tests. (4 marks)

Total 25 marks

Q5 (a) Most modern car and van bodies are designed to have a "high torsional rigidity". Explain the meaning of the term "torsional rigidity" in relation to a body shell, and describe in detail how the torsional rigidity is measured, using diagrams to illustrate your answer. (8 marks)

(b) Explain the importance of high torsional rigidity to the design of a vehicle suspension and the selection of appropriate suspension stiffnesses and damping rates to give good vehicle handling and ride (using model diagrams as appropriate). (7 marks)

(c) Describe the meanings of the terms "bump" and "rebound" in relation to vehicle suspension. (4 marks)

(d) A truck chassis is built to carry a maximum of 7000kg on the front two wheels, and 11500kg on the rear two wheels. However, in the unladen condition, the front wheels support 5500kg and the rear wheels only support 2000kg. Explain, using diagrams, two ways in which the suspension designer can design a suspension to give good ride and handling for both <u>laden</u> and <u>unladen</u> conditions. (6 marks)

Total 25 marks

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6. An automobile suspension system is shown in Figure Q6(a). It is assumed that the wheel is a spring. The input of the system is the force F(s) and the output is the displacement $y_1(s)$. Figure Q6(b) shows the open-loop output response of the suspension system obtained from Q6(a) above, where the system experiences a unit impulse input. As an automobile design engineer,

(a) Comment on the performance of the suspension system design. (6 marks)

(b) Suggest, with reasons, two possible approaches to improve the performance of the suspension system. (6 marks)

(c) If a PID controller is decided to be used, sketch a block diagram to represent the suspension system with the PID controller and clearly indicate the input, output, error signal, forward-path and feedback-path in the diagram. (7 marks)

(d) Sketch the demanded output response of the suspension system after applying the PID controller. (6 marks)

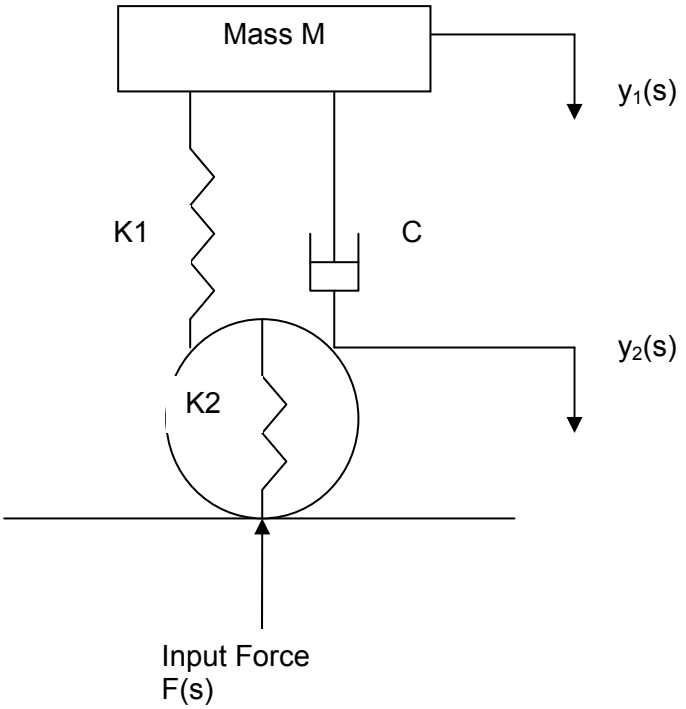

Figure Q6 An Automobile Suspension System

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Question 6 continued

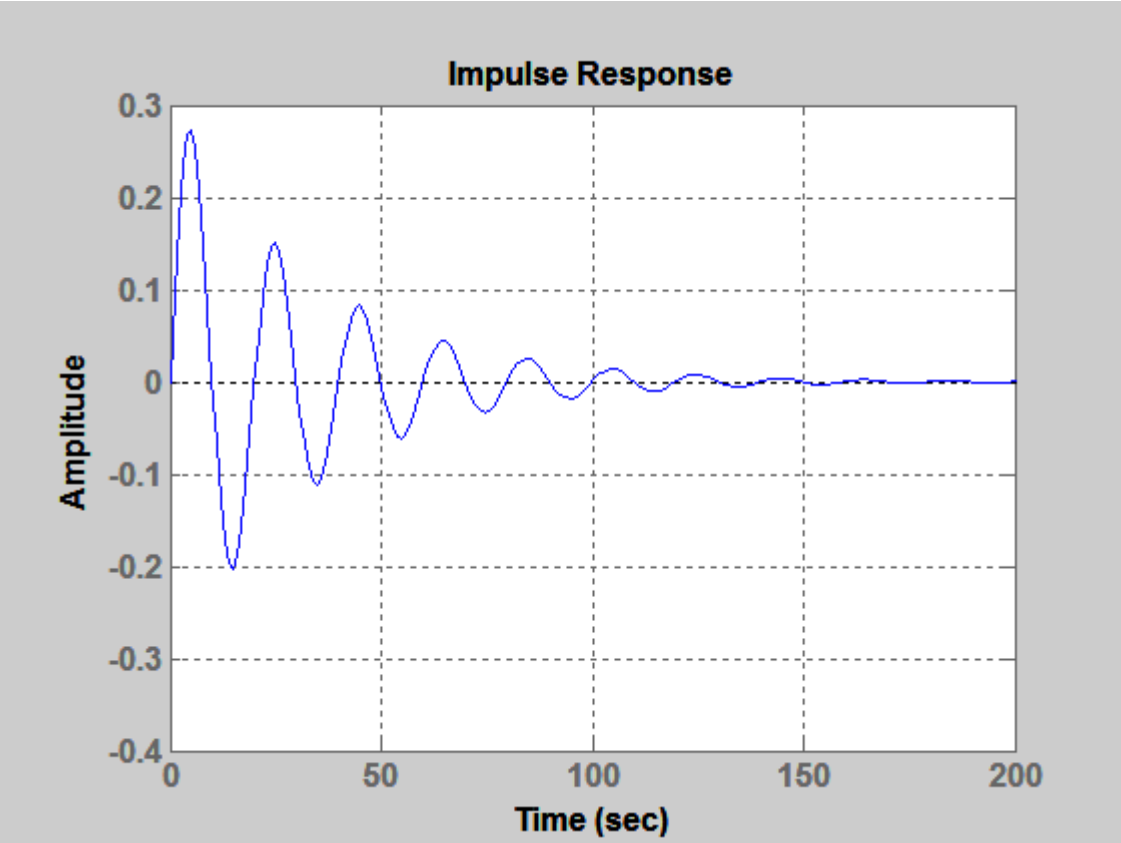

Figure Q6 (b) The Open-loop Output Response of the Suspension System

END OF QUESTIONS