**Question 1**

(a) How does Ergonomics in general and the man-machine interface specifically help in the design of a motor car interior? [7 marks]

(b) What are crumple zones, side bars and survival spaces? [3 marks]

(c) What is ENCAP and how does it influence the design of automobile body shells. [5 marks]

(d) During the 1920’s the UK speed limit in towns was set at 30 mph. Why hasn’t the speed limit changed, given the advances in automobile technology in the last 80 years? [2 marks]

(e) Explain how vehicle crash dynamics is used together with a CAD system, such as CATIA, to design vehicles which meet or exceed ENCAP. [8 marks]

**Question 2**

(a) With reference to the data sheet explain the concept of Dynamic Balancing. How does the inertia tensor determine whether a solid object is balanced or not? [8 Marks]

(b) Draw a simple sketch of a wheel balancing machine and explain how to calculate where to put the balance weights, and the required mass of the balance weights. [10 Marks]

(c) How could a solid body modeller program, such as CATIA, help in the design of an automobile disc brake and wheel hub. (Your answer should refer specifically to your answer for Question 2(a)). [7 Marks]

**Question 3**

(a) Describe three workbenches which you may find in an industry standard CAD system such as CATIA. [10 marks]

(b) Describe in detail how to use Catia to model a monocoque automobile body shell. [10 marks]

(c) How could Catia calculate whether a component is dynamically balanced? [5 marks]
Question 4

(a) How does technology help to implement the *Congestion Charge* in London?  

(b) Road pricing has been seriously suggested as an alternative to the annual vehicle licence fee (road tax). Is it technically feasible to monitor the time, route and duration of every vehicle journey in the country and charge the driver accordingly? If not why not, and if so how could it be done? How difficult would it be to introduce the scheme with a mixture of old and new vehicles on the road?

(c) What factors delayed the introduction of microprocessors in automobile design? How will microprocessors be used in the future?

(d) To what extent do technological developments in other fields, e.g. Aeronautical Engineering, ‘trickle down’ to Automotive Engineering? Give some examples of design ideas from other fields of Engineering, e.g. Aeronautical, Formula 1 racing, which are now used in production automobiles.

Question 5

(a) Western economies have been developing steadily ever since the industrial revolution, which began about 1750. Given the rapid development of China and India how much longer do you think economic development, specifically in the automotive industry, can continue on a global scale?

(b) What global political, social and economic factors will influence the design of road vehicles in the next 10 years?

(c) What are the alternatives to petrol and diesel, as automotive fuels? Why are many researchers looking for an alternative to petrol?

(d) The American division of the Ford Motor Company recently posted an annual trading lost of $12 billion US dollars, for the last fiscal year, but the European division of Ford made a modest profit. How can this be explained?
Question 6

(a) Copy Lagrange’s equation from the data sheet and explain the terms L and qi.  
[2 marks]

(b) Draw a diagram of the suspension system for a two wheeled motor cycle, including unsprung mass, tyre stiffness and damping (shock absorber). Assuming the vehicle remains in a vertical plane how many degrees of freedom are there? 
[3 marks]

(c) Apply Lagrange’s equation to the suspension system in (b) above, and obtain a set of simultaneous equations to define the vehicle’s motion in 2 dimensions. (Assume the engine and/or brakes exert a single force and a single torque on the centre of gravity. Also assume the vehicle travels in a straight line and remains vertical, i.e. no steering forces.). 
[10 marks]

(d) For each degree of freedom define state space variables qi and d(qi)/dt. 
[2 marks]

(e) Rewrite the Lagrange’s equations in matrix form as functions of the state space variables. 
[8 marks]
DATA SHEET

Inertia Tensors

\[
\begin{bmatrix}
I_{xx} & -I_{xy} & -I_{xz} \\
-I_{xy} & I_{yy} & -I_{yz} \\
-I_{xz} & -I_{yz} & I_{zz}
\end{bmatrix},
\]

where the scalar elements are given by

\[
I_{xx} = \int \int \int (y^2 + z^2) \rho dv,
\]

\[
I_{yy} = \int \int \int (x^2 + z^2) \rho dv,
\]

\[
I_{zz} = \int \int \int (x^2 + y^2) \rho dv,
\]

\[
I_{xy} = \int \int \int xy \rho dv,
\]

\[
I_{xz} = \int \int \int xz \rho dv,
\]

\[
I_{yz} = \int \int \int yz \rho dv,
\]

Euler's Equation

\[
N = C I \dot{\omega} + \omega \times C I \omega,
\]

where \( C I \) is the inertia tensor of the body written in a frame, \( \{C\} \), whose origin is located at the center of mass.

Coriolis Theorem

\[
\frac{d^2 \mathbf{r}}{dt^2} = \frac{d}{dt} \left( \frac{d \mathbf{r}}{dt} \right) + \omega \times \frac{d \mathbf{r}}{dt} + \frac{d \omega}{dt} \times \mathbf{r}
\]

\[
= \frac{d^2 \mathbf{r}}{dt^2} + \omega \times \frac{d \mathbf{r}}{dt} + \omega \times \left( \frac{d \mathbf{r}}{dt} + \omega \times \mathbf{r} \right) + \frac{d \omega}{dt} \times \mathbf{r}
\]

\[
= \frac{d^2 \mathbf{r}}{dt^2} + 2\omega \times \frac{d \mathbf{r}}{dt} + \omega \times (\omega \times \mathbf{r}) + \frac{d \omega}{dt} \times \mathbf{r}
\]
Lagrange's Equation

\[
\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q_i} = \tau_i \quad i = 1, 2, \ldots, n
\]

where

- \(L\) = lagrangian function = kinetic energy
- \(K\) = potential energy
- \(P\) = total kinetic energy of the robot arm
- \(P\) = total potential energy of the robot arm
- \(q_i\) = generalized coordinates of the robot arm
- \(\dot{q}_i\) = first time derivative of the generalized coordinate, \(q_i\)
- \(\tau_i\) = generalized force (or torque) applied to the system at joint \(i\) to drive link \(i\)

Vector cross product

If \(A = ax\mathbf{i} + ay\mathbf{j} + az\mathbf{k}\)

and \(B = bx\mathbf{i} + by\mathbf{j} + bz\mathbf{k}\)

then vector cross product

\[
A \times B = (aybz - azby)\mathbf{i} + (azbx - axbz)\mathbf{j} + (axby - aybx)\mathbf{k}
\]