

Question 1.

The suspension system of a motorcycle can be simply represented as a 4 degree of freedom 'half car model' in which 3 masses are connected by springs and dampers.

- (a) Sketch the above model showing both springs and dampers for both the suspension and tyre contributions and the motions allowable in the model.
(4 marks)
- (b) For an un-damped version of the model described above, derive a set of equations which could be used to solve the model.
(8 marks)
- (c) Show how this set of equations can be represented in matrix form and how damping can easily be included.
(4 marks)
- (d) Explain the principles of how this model is solved on a computer and explain what results you would expect to see from the model.
(4 marks)

Question 2.

The steering of a motorcycle is heavily influenced by the gyroscopic effects of the wheels and to a lesser extent, the rotating components in the engine.

- (a) Describe how the gyroscopic contribution of the front wheel effects the ability of the rider to steer the machine at speed.

(4 marks)

- (b) Explain how the influence of the rotating components in the engine contribute to the steering/stability of the motorcycle and how different configuration engines may provide different dynamic contributions.

(4 marks)

- (c) From first principles, derive an equation which relates the gyroscopic moment to the moment of inertia and the rates of rotations. You may use diagrams to assist you.

(8 marks)

- (d) Using your understanding of the gyroscopic effect, explain how the gyroscope operating in the configuration shown below is seemingly 'able to defy gravity'. You may provide a sketch to help illustrate your answer.

(4 marks)



Question 3

Consider the case of a rider negotiating 'Hatchets Hairpin' at Pembrey circuit on a Yamaha R1 motorcycle:

Corner radius, $R_c = 14 \text{ m}$
Forward speed, $V = 38 \text{ km h}^{-1}$

The properties of the motorcycle are:

Mass, $m = 265 \text{ kg}$ (including rider)
Height of centre of gravity, $h = 0.63 \text{ m}$
Rear wheel radius, $R_r = 0.33 \text{ m}$, Front wheel radius $R_f = 0.3 \text{ m}$
Spin inertia of front wheel, $I_f = 0.48 \text{ kgm}^2$
Spin inertia of rear wheel, $I_r = 0.6 \text{ kgm}^2$

- (a) Determine the *ideal* roll angle of the motorcycle through this turn. (2 marks)
- (b) Calculate the gyroscopic moment generated by the motion of both wheels. (3 marks)

Due to the yaw rate of the motorcycle, the case described above is not in equilibrium. There are two ways in which the rider will be able to achieve equilibrium.

The first method is to increase the roll angle, the second is to displace the mass centre toward the centre of the turn (to hang off).

- (c) Derive an equation that can be used to determine how much the rider would need to displace his/her mass centre in the turn in order to keep the system in equilibrium through the turn. (6 marks)
- (d) Determine the value of this displacement for the case described above, commenting on the result? (4 marks)
- (e) Should the rider 'lose the front' mid corner, what would theoretically allow him/her to recover the crash if he/she were able to act fast enough. (5 marks)

Question 4.

The motorcycle can exhibit a number of different oscillatory and non-oscillatory modes. Define the following terms and describe how they manifest themselves in motorcycle dynamics.

(a) Capsize (2 marks)

(b) Wobble (3 marks)

(c) Weave (3 marks)

For each of the 3 cases described above, write down an equation which can be used to represent each of the 3 stability modes, explaining all the terms used.

(6 marks)

The stiffness of the main frame of the motorcycle has a significant influence over its handling ability. The increased frame stiffness of modern bikes has greatly reduced the propensity for one of the out of plane stability modes.

(d) Which stability mode has been effected by this increasing of frame stiffness and what has been the effect on the amplitude and frequency of this oscillatory mode due to this stiffness increase?

(2 marks)

(e) Can the frame of a motorcycle be 'too stiff'? Discuss.

(4 marks)