



SWANSEA METROPOLITAN UNIVERSITY
PRIFYSGOL FETROPOLITAN ABERTAWE

EXAMINATIONS 2012/2013 Semester 1 **ARHOLIADAU 2012/2013**

FACULTY OF: APPLIED DESIGN & ENGINEERING

NAME OF COURSE/PROGRAMME:

BEng Motorcycle Engineering

YEAR OR LEVEL:

Level 6

NAME OF MODULE/UNIT/EXAM

PAPER: Advanced Motorcycle Dynamics

MODULE NO: M3X8817

DATE OF EXAMINATION: 31st January
2013

EXAMINATION TIMES:

START TIME: 9.00 am

FINISH TIME: 11.00 am

TIME ALLOWED: 2 hours

INSTRUCTIONS TO CANDIDATES:

Answer any 3, from the 4 questions

For a simple gyroscope arranged as shown below:



The gyroscope has the following properties and is precessing at 45 degrees from the vertical position:

Weight = 114.2g

Speed = 8,000 rpm

Disk Radius (Assume solid disk) = 36.5 mm

Axle length (Axle end to disk centre) = 40 mm

- a. Explain with the aid of a diagram ('Dot Method'), what is meant by gyroscopic precession and why it happens?
(4 marks)
- b. Considering the rate of change of angular momentum during precession, derive mathematically, the normal equation for the gyroscopic moment.
(8 marks)
- c. From the information you have been given, calculate the precession rate of the gyroscope about its central pivot.
(4 marks)
- d. Explain the process by which a motorcycle rider gets from steady state straight-line motion, to steady state cornering for both high speed and low speed conditions.
(4 marks)

Question 2.

Consider the case of a rider negotiating a tight turn on a ‘Supermotard’ style motorcycle:

Corner radius, $R_c = 14 \text{ m}$

Forward speed, $V = 45 \text{ km h}^{-1}$



The properties of the motorcycle are:

Mass, $m = 165 \text{ kg}$ (including rider)

Height of centre of gravity, $h = 0.88 \text{ m}$

Mechanical (Ground) Train, $a_g = 118 \text{ mm}$

Rear wheel radius, $R_r = 0.33 \text{ m}$, Front wheel radius $R_f = 0.3 \text{ m}$

Spin inertia of front wheel, $I_{w_f} = 0.38 \text{ kgm}^2$

Spin inertia of rear wheel, $I_{w_r} = 0.48 \text{ kgm}^2$

- Calculate the *ideal* roll angle of the motorcycle through this turn. (3 marks)
- What corrections do you expect, taking the tyre thickness into account? (3 marks)
- Calculate the gyroscopic moment generated by the motion of both wheels. (3 marks)
- What influence do you think the engine will have on this moment? (3 marks)

The case described above is not in equilibrium if you are considering the gyroscopic influence. There are two ways in which the rider will be able to achieve equilibrium.

The first method is to change the roll angle ($\square\square$).

- Determine the new ‘corrected’ lean angle?

(4 marks)

The second method is to displace the mass centre toward the centre of the turn.

- With reference to the picture shown above, the rider is not doing this. What is the rider doing to facilitate the turn and how is the lateral centre of gravity position, ‘d’ and the vehicle roll angle affected by this action?

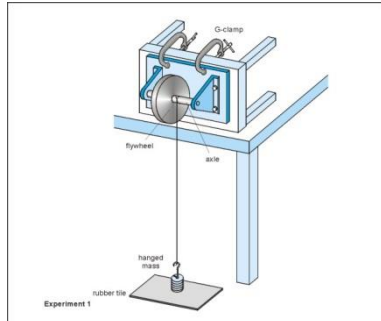
(4 marks)

Question 3.

- a. Explain what you understand by the terms
- 'Moment of Inertia'
 - 'Angular Momentum'

(4 marks)

There are a number of experimental methods for determining the moment of inertia of a motorcycle wheel. In the case of the method shown in the diagram below:



- b. Using the principles of Forces, Torques and the 'Tension in a String', derive an equation that can be used to calculate the moment of inertia of the wheel.

(5 marks)

The dynamics of rotating bodies are influenced greatly by gyroscopic moments and forces. These are crucial in the understanding of the motorcycle, as well as other vehicles with rotating features.

- c. Explain in detail how the Yamaha M1 'reverse spinning crankshaft' influences the cornering and handling performance of the motorcycle.
- d. During qualifying at the Jerez MotoGP in 2008, Colin Edwards was recorded on film performing a rather impressive crash/save manoeuvre. He reported to the press that "I obviously got into turn one too hot," he said of his 'fall'. "It went, came back, went away again and I thought I was down. I tried to dig my elbow in but it kept going so I kind of lifted my arm up and pulled it up on the handlebars. And it came back somehow." Describe your understanding of the event based on your understanding of motorcycle dynamics.

(5 marks)

(6 marks)



Question 4.

The photograph below shows Cameron Donald on the Isle of Man TT course.



As you can see from the picture, the bike is mid-corner, clearly moving at high speed and has both wheels off the ground. Clearly this is not a stable situation.

Explain in detail, the sequence of events experienced by the motorcycle as a system as the wheels come back into contact with the ground. (This should be a technical analysis of the step by step dynamics of the bike and not a description of how it feels to the rider). You may assume that either wheel touches first or that both touch the road together.

(6 marks)

Assuming the following properties for Cameron's GSX1000:

Moment of inertia (Wheels), $I_{\omega f} = 0.42 \text{ kgm}^2$, $I_{\omega r} = 0.55 \text{ kgm}^2$

Wheel Radius, $R_f = 0.31 \text{ m}$, $R_r = 0.33 \text{ m}$

Velocity of the motorcycle, $v = 55 \text{ ms}^{-1}$

Moment of inertia of front assembly about steer axis, $I_{zf} = 0.44 \text{ kgm}^2$

Moment of inertia of motorcycle about the roll axis, $I_x = 30.25 \text{ kgm}^2$

Roll angle at beginning of instability $\phi = 32^\circ$

Rake angle, $\alpha = 23.5^\circ$

Normal trail, $a_n = 0.98 \text{ m}$

Handlebar width = 440mm

- (a) Assuming while moving forward at 55 ms^{-1} at 32° lean angle, the bike hits a small bump in the road, which causes a wobble of the front frame (Tank-Slapper). If the frequency of the oscillation is 5Hz and the steer angle moves through $\pm 14.3^\circ$ from the straight ahead position, Determine the reaction at the front wheel and the effect on the vehicles steer and roll angles.

(12 marks)

- (b) What force is seen by the rider through the handlebars?

(2 marks)