

PRIFYSGOL CYMRU : UNIVERSITY OF WALES

**DEGREE EXAMINATIONS 2012
ARHOLIADAU GRADD 2012**

**Swansea Metropolitan University
Prifysgol Fetropolitan Abertawe**

Faculty of Applied Design and Engineering

NAME OF COURSE/PROGRAMME: *BEng Motorcycle Engineering*

YEAR or LEVEL (state which): *Year III*

NAME OF MODULE/UNIT: *Advanced Motorcycle Dynamics*

NAME OF EXAM PAPER: *Advanced Motorcycle Dynamics (A)*
(if different to module name)

DATE OF EXAMINATION: 26th January 2012

EXAMINATION TIMES:

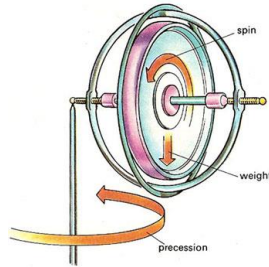
**Start Time: 9.00
Finish Time: 11.00
Time Allowed: 2hrs**

INSTRUCTIONS TO CANDIDATES:

Answer 3 from 4 Questions

Question 1.

For a simple gyroscope arranged as shown below:



The gyroscope has the following properties:

Weight = 144.2g

Speed = 4,000 rpm

Disk Radius (Assume solid disk) = 36.5 mm

Axle length (Origin to disk) = 40 mm

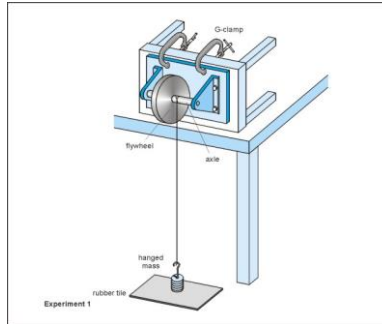
- Explain with the aid of a diagram ('Dot Method'), what is meant by gyroscopic precession and why it happens?
(4 marks)
- Considering the rate of change of angular momentum during precession, derive mathematically, the normal equation for gyroscopic moment.
(8 marks)
- From the information you have been given, calculate the time taken for the gyroscope to make one revolution (precession) about its central pivot.
(4 marks)
- Using the same diagrammatical method ('Dot Method') that you used in part 'a', Show how this method can be used to explain the process of 'countersteering' a motorcycle.
(4 marks)

Question 2.

- a. Explain what you understand by the terms
- 'Moment of Inertia'
 - 'Radius of Gyration'

(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 Conservation of Energy, 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 applying a torque to a rotating gyroscope affects its orientation? (5 marks)
- d. The blades and hub of a helicopter rotor have a mass of 64kg and a radius of gyration of 3m. With the rotor turning at 500 RPM during vertical takeoff, the helicopter tilts forward at a rate of $\dot{\phi} = 10$ deg/sec in order to move forward. Determine the gyroscopic moment M_g transmitted to the body of the helicopter (4 marks)



- e. If the main rotor is spinning anti-clockwise what will be the result of this moment as seen by the pilot. (2 marks)

(2 marks)

Question 3.

- (a) Explain the process by which the rider gets from steady state straight-line motion, to steady state cornering for both high speed and low speed conditions.
(3 marks)
- (b) During a jump on a motocross bike, if you find your front wheel coming up too high, what measures can be taken to resolve the situation? How would you go about performing a calculation to determine the effects that your theory suggests?
(4 marks)

In recent years, the ‘whip’ has become a popular addition to the motocross riders ‘mid-air’ repertoire. This manoeuvre takes the motorcycle from the vertical plane during take-off, to the horizontal plane during mid-flight returning to vertical plane for the landing.



Moment of inertia, $I\omega_f = 0.42 \text{ kgm}^2$, $I\omega_r = 0.55 \text{ kgm}^2$
Wheel Radius, $R_f = 0.55$, $R_r = 0.38 \text{ m}$
Roll velocity (Both directions), $\dot{\phi} = 1.8 \text{ rad s}^{-1}$
Velocity of the motorcycle, $v = 16 \text{ ms}^{-1}$
Rake angle, $\varepsilon = 25.5^\circ$
Normal trail, $a_n = 0.12 \text{ m}$
Handlebar width = 520mm

- (c) Calculate the gyroscopic moment M_g that acts on the steering axis of the motorcycle during this manoeuvre
(5 marks)
- (d) What force at the handlebars is required to get the bike back from the horizontal to the vertical position for landing?
(5 marks)
- (e) To control the pitch of the motorcycle in a jump, the rear brake can be used. If the rear brake is applied hard (speed of rear wheel = 0 m/s) to get the front wheel down, what will be the result on the ability of the rider to control the motorcycle.
(3 marks)

Question 4.

Consider the case of a rider negotiating 'Hatchets Hairpin' at Pembrey circuit on a Yamaha R6 motorcycle:

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

Forward speed, $V = 35 \text{ km h}^{-1}$



The properties of the motorcycle are:

Mass, $m = 255 \text{ kg}$ (including rider)

Height of centre of gravity, $h = 0.65 \text{ m}$

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

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

Spin inertia of rear wheel, $I_{w_r} = 0.58 \text{ kgm}^2$

- Calculate the yaw velocity of the motorcycle. (2 marks)
- Calculate the angular velocity of each wheel. (3 marks)
- Determine the *ideal* roll angle of the motorcycle through this turn. (3 marks)
- Calculate the gyroscopic moment generated by the motion of both wheels. (4 marks)

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 ($\Delta\phi$).

- Determine the new 'corrected' lean angle? (4 marks)

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

- Calculate by how much the mass centre must move ' d ' in order to keep the bike at an angle of 30° ? (4 marks)