

**LOCATION: SWANSEA**

**LLEOLIAD: ABERTAWE**

**LEVEL 6**

**LEFEL 6**

**EXAMINATION PERIOD**  
**MAY 2019**

**CYFNOD ARHOLIADAU**  
**2019**

**MODULE CODE: M6X00415**  
**ADVANCED VEHICLE DYNAMICS**

**TIME: 2 HOURS**

**ANSWER THREE QUESTIONS OUT OF FOUR**

*Equipment or materials required – None*

*Adnoddau neu ddefnyddiau sydd eu hangen – Dim*

Calculators are permitted.

## Question One



A front wheel drive Touring Racing Car has the following specification

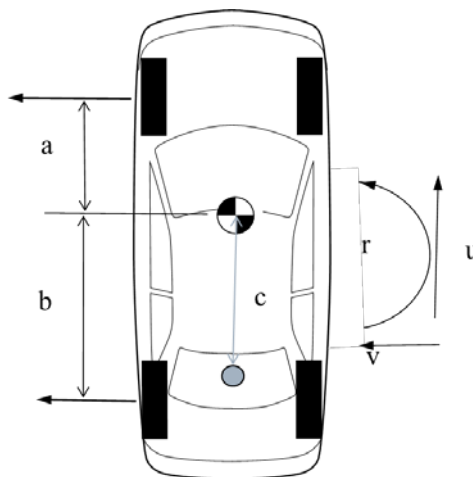
Mass = 1170 kg

Mass distribution: 58% front, 42% rear

Max Engine Power = 225 kW

Wheelbase = 2718mm

Yaw Inertia = 1300 kg.m<sup>2</sup>



a) Calculate the distance from the front axle to the Centre of Gravity : distance 'a'.  
[2 marks]

b) Calculate the distance from the Centre of Gravity to the Inertia Conjugate.  
Which is distance 'c' on the diagram.  
[2 marks]

c) Calculate the Radius of Gyration (k) for the vehicle.  
[2 marks]

- d) Calculate the Dynamic Index (DI) for the vehicle and comment on your findings  
[2 marks]
- e) Draw a diagram to show the effect of the calculated DI on rear tyre slip angle.  
Analyse the effect of the rear tyre slip angle on vehicle dynamic behaviour.  
[4 marks]
- f) Discuss the physiological limitations affecting vehicle driver's perception and response times.  
[2 marks]
- g) The vehicle engineers wish to increase the Dynamic Index to 0.87 by placing additional mass in the front and rear bumpers (3m apart). The vehicle inertia will increase from  $1300\text{kg.m}^2$  to  $1850\text{kg.m}^2$
1. What will be the new radius of gyration (k) ?
  2. Assume the mass is distributed evenly between the front and rear bumpers. What mass should be placed in each bumper?
- [6 marks]

## Question Two

A rear wheel drive vehicle has the following specification

Mass distribution: front 750kg, rear 750kg

Centre of gravity height 600mm

Track width 1.5m

Wheel base 2.1m

Frontal area =  $3\text{m}^2$

Coefficient of drag = 0.5

Coefficient of rolling resistance = 0.013 N/N

Tyre rolling radius 290mm

Assume the tyre road interface has a constant coefficient of friction ( $\mu$ ) of 1.0 which is the same at all vertical loads.

The vehicle enters a corner with a 25m constant radius at 50 kph rotating clockwise.

- a) What is the centripetal acceleration? **[2 marks]**
- b) What is the vehicle yaw rate in a steady state condition? **[2 marks]**
- c) Assuming the spring rate is constant front and rear. What is the weight on each wheel? **[2 marks]**
- d) What drive force is required to maintain the constant 50kph vehicle speed? **[2marks]**
- e) What is the lateral force on each axle? **[1 mark]**
- f) What is the lateral force resistance on the inside and the outside wheels?  
Each wheel has the same amount of slip therefore the lat grip will be shared out in proportion to the vertical loading. **[3marks]**
- g) Draw and label two frictions circles with the longitudinal and lateral forces. One for the rear outer wheel and one for the rear inner wheel. Calculate the additional drive force that could be applied before the inside wheel forces exceed the available grip. (assume the vehicle has an open differential.) **[4 marks]**
- h) The addition of a torque vectoring differential would allow additional drive force to be directed to the outside wheel.  
Explain how a torque vectoring differential can obtain a greater drive force to the outside wheel. Use graphs and/or diagrams to support your discussion. How would the torque capacity of the unit be selected? **[4 marks]**

### Question Three



A front wheel drive vehicle has the following specification

Mass distribution : front 750kg, rear 750kg

Rotational inertia – 2200 kgm<sup>2</sup>

Centre of gravity height 600mm

Track width 1.5m

Wheel base 2.650m

Tyre rolling radius 290mm

Steering ratio 15:1

The vehicle is braking on a surface with split levels of grip. As shown.

The left of the vehicle is on ice with:

a rolling coefficient of friction 0.1

and a sliding (locked wheel) coefficient of friction of 0.05

The right of the vehicle is on asphalt with

a rolling coefficient of friction 0.9

and a sliding (locked wheel) coefficient of friction of 0.7

Initially the vehicle is not equipped with ABS and is travelling at 50kph.

The driver applies the brakes on an emergency stop and locks all four wheels.

- a) What is the rate of deceleration? **[3 marks]**
- b) What is the yaw moment generated? **[2 marks]**
- c) Calculate the resulting rotational acceleration **[2 marks]**
- d) What lateral force from the front steered wheels is required to counter the asymmetric braking force rotational moment? **[2 marks]**

- e) The tyre on the right hand side provides a tyre cornering stiffness of 1000N/degree.  
What steering handwheel angle would be required to counter the rotational moment ?

**[2 marks]**

The vehicle is now equipped with ABS

- f) . In ideal conditions what would be the maximum rate of deceleration

**[3 marks]**

- g) Describe using graphs and diagrams how the ABS system would operate in order to achieve controllable vehicle deceleration.

**[6 marks]**

## Question Four



Above is an image of part of Junction 42, east of Swansea, between the A483 and the M4 motorway.

In order to join the motorway from the A483 and head in a easterly direction a vehicle must negotiate a 210 degree turn of 62m radius, there is a constant uphill slope of 2.5 degrees.

A front wheel drive vehicle has the following specification, together with the wet road conditions.

| Feature                        | Unit           | Value | Feature                 | Unit              | Value |
|--------------------------------|----------------|-------|-------------------------|-------------------|-------|
| Front axle mass                | kg             | 750   | Rear axle mass          | kg                | 750   |
| Track                          | m              | 1.85  | Wheelbase               | m                 | 2.75  |
| Power                          | bhp            | 130   | Torque                  | Nm                | 300   |
| CofG height                    | m              | 0.6   | Inertia                 | Kg.m <sup>2</sup> | 2500  |
| Coefficient rolling resistance |                | 0.02  | Coefficient of friction |                   | 0.8   |
| Tyre rolling radius            | m              | 0.36  |                         |                   |       |
| Frontal area                   | m <sup>2</sup> | 3     | Coefficient of drag     |                   | 0.6   |

The driver approaches the curve at 54 kph.

The driver applies 47 degrees of hand-wheel (steering wheel) angle to follow the 62m radius curve (anti clockwise)

- a) What is the total tractive effort required to maintain 54 kph during the turn?  
[2 marks]

- b) What is the yaw rate in the steady state condition?  
[1 mark]
- c) Due to changing road conditions the vehicle yaw rate increases. The yaw acceleration that occurs is  $4 \text{ degs/sec}^2$ . After 2 seconds what is the vehicle's yaw velocity?  
[2 marks]
- d) The vehicle is equipped with Electronic Stability Controller. The driver has made no adjustment to the handwheel (steering wheel) angle or to the tractive drive torque. What braking force must be applied to the front right wheel to counter the yaw acceleration? Discuss limiting factors.  
[3 marks]
- e) In order to generate variable brake line pressure the vehicle braking system requires a pump and a Proportional Pressure Regulating Valve (PPRV). The PPRV has an electrical range of 0 - 12v for a pressure control range of 0-110 bar. The brake calliper applies a force between the pads of 1500N per bar of applied pressure at a radius of 100mm. Assume a brake pad to disc friction coefficient of 0.5. What Voltage applied to the PPRV will result in 190N brake force at the contact patch?  
[3 marks]
- f) Initially the engineers specified a Proportional controller. Draw a diagram of the controller. Explain the proportional gain theory. Analyse the Plant or Process element. Evaluate possible variables that could affect the repeatability of the plant model  
[3 marks]
- g) Analyse how employing an integrator element into the controller can help to eliminate steady state error from the gain function of the proportional element of the controller. Use diagrams/graphs to support your discussion.  
[3 marks]
- h) If the integrator is over enthusiastic, what are the consequences? How can a differentiator be employed to limit any adverse effects? Use diagrams/graphs to support your discussion.  
[3 marks]

## Equations

Potential Energy = mass x gravity x height  $PE = m.g.h$

Moment of Inertia = mass x (radius of gyration)squared  $I = mk^2$

Centripetal Acceleration =  $v^2 / r$

For a plain disc : radius of gyration = radius/squareroot of 2  $k = \text{outer radius} \times 0.707$

Aero dynamic resistance =  $0.5 \times \text{area} \times cd \times \text{density of air} (1.2 \text{ kg/m}^2) \times \text{velocity}^2$

DI = Inertia / Mass x a x b

Distance of the Centre of Percussion behind the Center of Gravity (C).

$C = I_{zz} / m \times a$  (where a is the distance from front axle to C of G)

|                       | Linear Motion                  | Rotational Motion                              |                      |
|-----------------------|--------------------------------|------------------------------------------------|----------------------|
| Position              | $x$                            | $\theta$                                       | Angular position     |
| Velocity              | $v$                            | $\omega$                                       | Angular velocity     |
| Acceleration          | $a$                            | $\alpha$                                       | Angular acceleration |
| Motion equations      | $x = \bar{v} t$                | $\theta = \bar{\omega} t$                      | Motion equations     |
|                       | $v = v_0 + at$                 | $\omega = \omega_0 + \alpha t$                 |                      |
|                       | $x = v_0 t + \frac{1}{2} at^2$ | $\theta = \omega_0 t + \frac{1}{2} \alpha t^2$ |                      |
|                       | $v^2 = v_0^2 + 2ax$            | $\omega^2 = \omega_0^2 + 2\alpha\theta$        |                      |
| Mass (linear inertia) | $m$                            | $I$                                            | Moment of inertia    |
| Newton's second law   | $F = ma$                       | $\tau = I \alpha$                              | Newton's second law  |
| Momentum              | $p = mv$                       | $L = I \omega$                                 | Angular momentum     |
| Work                  | $Fd$                           | $\tau\theta$                                   | Work                 |
| Kinetic energy        | $\frac{1}{2} mv^2$             | $\frac{1}{2} I \omega^2$                       | Kinetic energy       |
| Power                 | $Fv$                           | $\tau\omega$                                   | Power                |

Diwedd/End