

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 6

LEFEL 6

EXAMINATION PERIOD
MAY 2018

CYFNOD ARHOLIADAU

MODULE CODE: M3X8818
ADVANCED VEHICLE DYNAMICS

TIME: 2 HOURS

ANSWER THREE QUESTIONS OUT OF FOUR

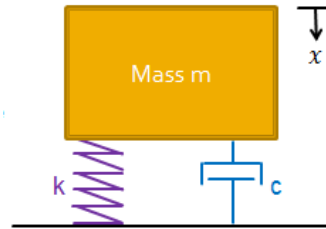
Equipment or materials required – None

Adnoddau neu ddefnyddiau sydd eu hangen – Dim

Calculators are permitted.

QUESTION ONE

- a) Explain how caster angle and caster trail can be used to effect load distribution within a corner and how this effect could be used to modify vehicle handling behaviour. What other effects does increasing caster angle have on tyre usage? (5 marks)
- b) A certain suspension system may be modelled by a simple spring mass damper system as shown below.



The system has a mass of 5 kg, a damping coefficient of 2 Ns/m and a spring rate of 10N/m.

- i) Write down the governing differential equation which describes the motion of the mass. (1 marks)
- ii) Determine the particular solution for this differential equation given that the initial conditions are; when $t=0$, $x = 0$ and $\frac{dx}{dt} = 4$. (7 marks)
- iii) If the system is to be critically damped (*i.e.* $\zeta = 1$), calculate the required damping coefficient. (2 marks)

Case	Roots	Characteristic Equations
Overdamped	r_1 and r_2	$x = Ae^{r_1 t} + Be^{r_2 t}$
Critically Damped	$r_1 = r_2 = r$	$x = (A + Bt)e^{rt}$
Underdamped	$r = \alpha \pm i\beta$	$x = e^{\alpha t}(A\cos(\beta t) + B\sin(\beta t))$

- c) Dampers normally take the form of three main types,
- i. Illustrate these three main types of damper construction and label the main components within the dampers (3 marks)
- ii. Explain the function of nitrogen gas, often found in dampers and the limitation of a twin tube damper layout which includes nitrogen. (2 marks)

Question Two



A four wheel drive Metro 6R4 Group A Rally Car has the following specification

Mass = 1000 kg

Mass distribution: 42% front, 58% rear

Max Engine Power = 225 kw

Wheelbase = 2248mm

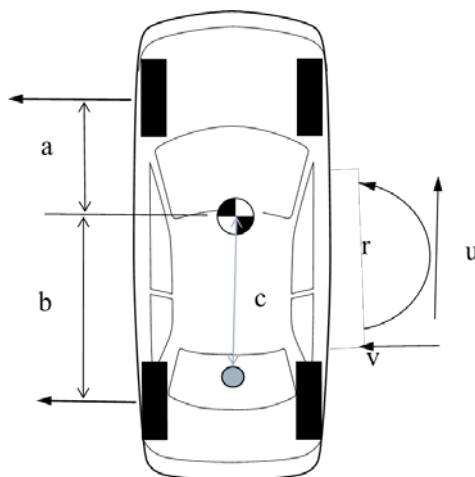


Figure One

- a) Calculate the distance from the front axle to the Centre of Gravity : distance 'a'.

(2 marks)

The vehicle mass can be represented as a simple lumped mass model as shown.
Where $M_1 = 420 \text{ kgs}$ and $M_2 = 580 \text{ kgs}$

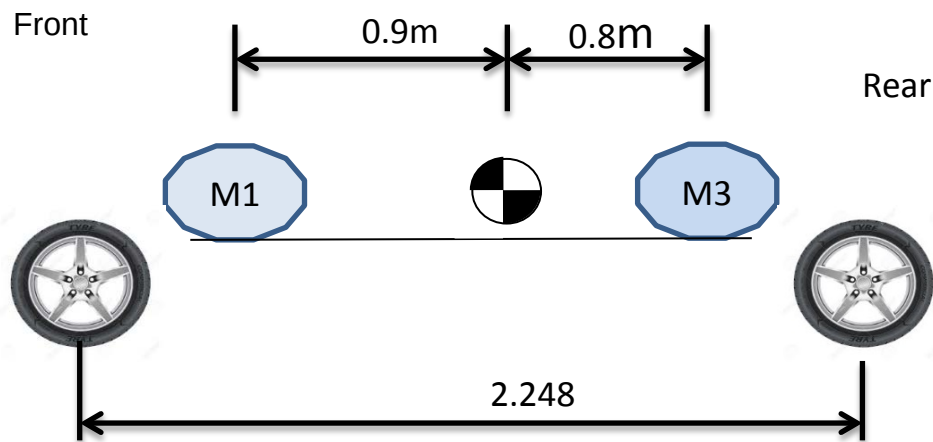


Figure Two

- b) Calculate the rotational inertia of the vehicle I_{zz} .
(2 marks)
- c) Calculate the distance from the Centre of Gravity to the Inertia Conjugate.
Which is distance 'c' on the diagram (Figure One).
(2 marks)
- d) Calculate the Dynamic Index (DI) for the vehicle and comment on your findings and the effect of $DI = 1$, <1 and >1
(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 0.8 by placing additional mass in the front and rear bumpers (Each bumper is 1.6m from the centre of gravity). The vehicle inertia will have to increase to 1095.4 kg.m^2
 1. What will be the new radius of gyration (k) of the complete vehicle?
 2. Assume the mass is distributed evenly between the front and rear bumpers. What mass should be placed in each bumper?
(6 marks)

Question Three



A car is driving anti-clockwise on packed snow around a 15m radius curve at a constant 5 m/s. The car has the following specification.

Feature	Unit	Value	Feature	Unit	Value
Front axle mass	kg	750	Rear axle mass	kg	750
Track	m	1.65	Wheelbase	m	2.5
Power	bhp	140	Torque	Nm	200
CofG height	m	0.6	Inertia	Kg.m ²	2500
Coefficient rolling resistance		0.1	Coefffcient of friction		0.3
Tyre rolling radius	m	0.29			
Frontal area	m ²	3	Coefficient of drag		0.5

- a) What is the total tractive effort required to maintain 5 m/s in the snow?
(2 marks)
- b) What is the centripetal acceleration?
(2 marks)
- c) What is the yaw rate in the steady state condition?
(2 marks)
- d) Assuming the spring rate is the same front and rear. What is the vertical force on each wheel?
(2 marks)
- 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 lateral grip will be shared out in proportion to the vertical loading.
(3 marks)
- g) The driver senses danger and lifts her foot from the accelerator pedal. What will be the rate of deceleration ?
Draw and label two frictions circles with the longitudinal and lateral forces. One for the front outer wheel and one for the front inner wheel. The driver wishes to make an emergency stop. Calculate the brake force that could be applied before the inside wheel forces exceed the available grip. (wheel lock condition)
(2 marks)
- h) What initial deceleration could the vehicle achieve with a conventional braking system prior to locking the inside wheels ?

Assume the vehicle has no anti-lock braking system what and the driver locks all four wheels, how would the vehicle behave?
(2 mark)
- i) Assuming the vehicle is fitted with all wheel anti-lock braking control system. What is the maximum deceleration whilst maintaining the path around the circle? Discuss limiting factors.
(2 marks)
- j) What is the resulting yaw moment on the vehicle? Discuss system compromises and driver reaction requirements
(2marks)

QUESTION FOUR



A front wheel drive vehicle has the following specification

Mass distribution : front 750kg, rear 500kg

Rotational inertia – 1850 kgm²

Centre of gravity height 600mm

Track width 1.8m

Wheel base 2.650m

Tyre rolling radius 280mm

Steering ratio 15:1

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

The left of the vehicle is on ice with:

a coefficient of friction 0.1

The right of the vehicle is on asphalt with

a coefficient of friction 0.85

Initially the vehicle is equipped with an open differential.

- a) What is the initial maximum rate of acceleration, this is before any weight transfer has occurred?

(2 marks)

- b) What is the resulting yaw moment generated ?

(1 marks)

The vehicle is now equipped with a geared type torque biasing differential.

Where the torque bias ratio is 3 : 1.

- c) Calculate the resulting maximum acceleration
(2 marks)
- d) What is the resulting yaw moment generated?
(1 mark)
- e) What lateral force from the front steered wheels is required to counter the asymmetric tractive force rotational moment?
(2 marks)
- f) 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 ?
(3 marks)

The vehicle is now equipped with an additional brake based traction control system.

- g) Draw a diagram and explain the torque transfer process across the vehicle
(4 marks)
- h) What would be the maximum rate of acceleration?
(2 marks)
- i) As the vehicle accelerates it reaches 30 kph. At this speed what is the rate of energy passing into the brake disc?
(3 marks)

Equations

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

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

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

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

$DI = \text{Inertia} / \text{Mass} \times a \times b$

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	θ	Angular position
Velocity	v	ω	Angular velocity
Acceleration	a	α	Angular acceleration
Motion equations	$x = \bar{v}t$	$\theta = \bar{\omega}t$	Motion equations
	$v = v_0 + at$	$\omega = \omega_0 + \alpha t$	
	$x = v_0t + \frac{1}{2}at^2$	$\theta = \omega_0t + \frac{1}{2}\alpha t^2$	
	$v^2 = v_0^2 + 2ax$	$\omega^2 = \omega_0^2 + 2\alpha\theta$	
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