

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 6

LEFEL 6

EXAMINATION PERIOD

MAY 2017

CYFNOD ARHOLIADAU

2017

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.

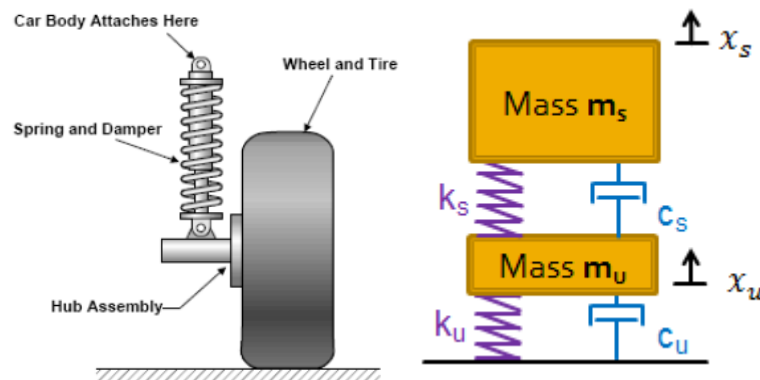
ANSWER THREE QUESTIONS OUT OF FOUR

QUESTION ONE

- a) Explain with respect to optimising tyre slip angles, why a car may utilise Pro or Anti Ackerman steering geometry. Use sketches of tyre slip angle versus lateral force curves at different vertical loads to support your explanation.

[3 marks]

- b) A vehicles suspension may be modelled as a combination of spring mass damper systems. A quarter car system may be modelled as shown below. Write down an equation in matrix form which describes the motions of the two masses.



[5 marks]

- c) The motion of a certain spring mass damper (SMD) system may be described by the following equation:

$$15 \frac{d^2x}{dt^2} + 3 \frac{dx}{dt} + 4x = 0$$

- i) Determine the particular solution for this differential equation with the initial conditions, given the characteristic equations below, when $t=0$, $x = 0$ and $\frac{dx}{dt} = 3$. State whether this SMD system under damped, over damped or critically damped.

[6 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	$r = \alpha \pm i\beta$	$x = e^{\alpha t}[A \cos(\beta t) + B \sin(\beta t)]$

- ii) Race vehicle suspension systems do not have a single damping coefficient. Draw typical damper curves and explain how these could be modelled for use in the analysis above.

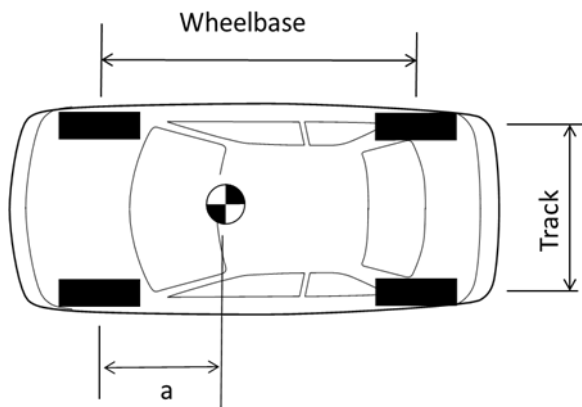
[2 marks]

- d) Outline the 3 main damper constructions available and give advantages for each construction.

[4 marks]

QUESTION TWO

Two vehicles have dimensions as shown.



Where the centre of gravity is identified by



Vehicle A

Wheelbase = 2400 mm

Track = 1480 mm

Distance from centre of gravity to the front wheel contact patch = 950 mm

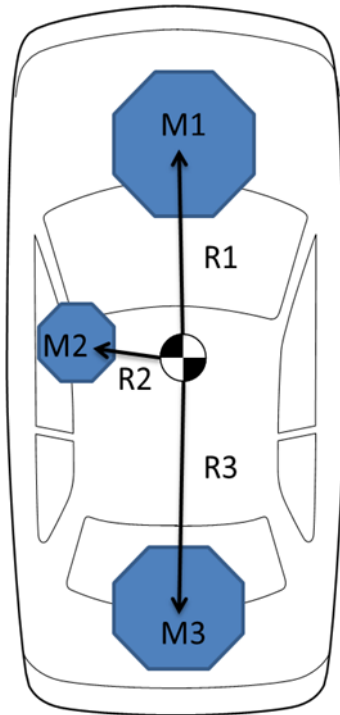
Vehicle B

Wheelbase = 2600 mm

Track = 1560 mm

Distance from centre of gravity to the front wheel contact patch = 1300 mm

The vehicles have a rotational inertia and are modelled as lumped mass systems as shown.



	M1 (kg)	M2 (kg)	M3 (kg)	R1 (mm)	R2 (mm)	R3 (mm)
Vehicle A	750	200	400	1100	200	1300
Vehicle B	840	200	840	1300	380	1500

- Calculate the Rotational Inertial (I) for both vehicles
[4 marks]
- Calculate the Dynamic Index for both vehicles (DI)
[4 marks]
- Discuss the concept centre of percussion (inertial conjugate) and how the position of it relates to the dynamic index.
[4 marks]
- Describe the rear tyre grip behaviour of the two vehicles and how this will affect the vehicle during corner 'turn-in' and the in corner vehicle behaviour.
[8 marks]

QUESTION THREE



Vauxhall have recently released an updated Insignia Grand Sport Elite car. The vehicle is primarily front wheel drive with an open differential, however there is now an additional direct drive propshaft to a rear drive unit. The rear drive unit consists of two clutch packs running a 15% overspeed compared to the front wheels (there is no differential). The car is driving 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	257	Torque	Nm	400
CofG height	m	0.6	Inertia	Kg.m ²	2500
Coefficient rolling resistance		0.1	Coefficient 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) 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. 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.)
[3 marks]
- h) What initial acceleration could the vehicle achieve with a standard open differential front wheel drive arrangement? (assume no longitudinal weight transfer)
[1 mark]
- i) The all wheel drive control system wishes to provide maximum acceleration. What is the maximum acceleration on the curve? 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



Feature	Unit	Value	Feature	Unit	Value
Front axle mass	kg	1100	Rear axle mass	kg	750
Track	m	1.9	Wheelbase	m	2.5
Steering ratio		12:1	Inertia (z-z)	Kg.m ²	3000

The vehicle above is driving in a straight line on a surface of split friction.

The left side of the vehicle is on wet asphalt with a maximum coefficient of friction $\mu = 0.8$ and a 100% slip $\mu = 0.6$

The right side of the vehicle is on a wet epoxy resin surface with a maximum coefficient of friction $\mu = 0.2$ and a 100% slip $\mu = 0.1$

Initially the vehicle is not equipped with an Antilock Braking System (ABS) and is travelling at 40kph.

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

- What is the rate of deceleration? [3 marks]
- What is the yaw moment generated? [2 marks]
- Calculate the resulting rotational acceleration [2 marks]
- 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 high μ 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]

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

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	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