

Examination Answer Books

12 Pages

Instructions to Candidates

1. Please give the information requested in the boxes below
2. Enter your name in the space provided to the right, fasten the book together with the provided ties and seal down (using the label provided) to hide your name.
3. The answers must be legibly written. The Examiners can either ignore illegible script or have it typed and the expense of typing charged to the candidate.
4. Write your answers in ink.
5. Begin each answer on a fresh page. Do all rough work in the answer book and cross it through.
6. No part of this book is to be torn out; it must be handed in complete.
7. If more books than one are used, fasten them together using the tags available from the invigilator(s).
8. **Every book must be handed in. In no circumstances may answer books, used or unused, be taken out of the examination venue.**

Complete, fold and seal
(see note 2 below)

SURNAME: Noble

FORENAME(S): Andrew

John Alexander

1	Student Number	P151458
2	Title of Examination Paper	Advanced Vehicle Dynamics
3	Module Code	M6X00415
4	Date and Time of Examination	12:00 21-5-19
5	Examination Venue	IQ310
6	Seat Number	G052
7	Number of Answer Books handed in	1

List the numbers of the questions you have attempted	Office Use
1	17 1/2
2	19
3	17 1/2
	34
Total	90%



1.

$$a.) a = 2718 \times 0.42 = 1141.56 \text{ mm}$$

$$b.) C = \frac{I_{zz}}{ma} = \frac{1300}{1170 \times 1.14} = 0.975 \text{ m}$$

$$c.) I = mk^2$$

$$k^2 = I/m$$

$$k = \sqrt{I/m}$$

$$= \sqrt{\frac{1300}{1170}}$$

$$= 1.05 \text{ m}$$

$$d.) DI = \frac{I_{zz}}{mab}$$

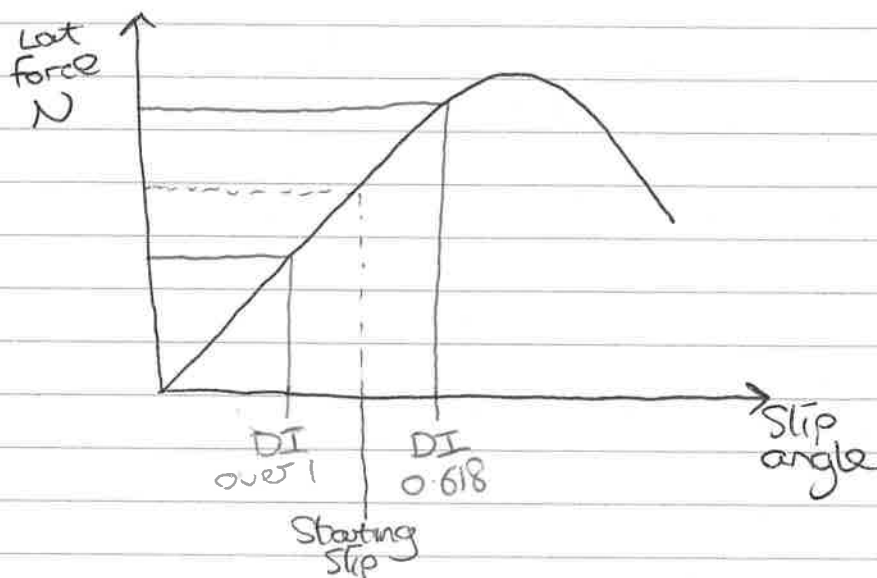
$$= \frac{1300}{1170 \times 1.14 \times \frac{(2718 - 1141.56)}{1000}}$$

$$= 0.618$$

This is a very low DI value, which will cause vehicle to turn in very sharply but will likely be difficult to control near limit of grip.

e.) With such a low DI value, when turning in the rear tyres will move outwards. This will increase slip angle rapidly and give more lateral grip, up to the point of saturation. Beyond saturation the rear tyres will lose grip rapidly. Near limit of grip low DI cars can be difficult to drive.

P10



Comparing this vehicle to one with a DI over 1, for the same initial slip angle & same steering input, above graph shows expected change.

f.) Brain receives inner ear & visual data about surrounding conditions. There is a processing delay in the brain interpreting these signals. Another delay occurs while the brain formulates a response strategy. Another delay then in the body's muscular system in acting out the desired response strategy. All of which create response lag.

g. 1.) New DI = 0.87 $k_{bumpers} = 1.5 \text{ m}$
 New $I_{zz} = 1850 \text{ kgm}^2$

$$DI = \frac{I_{zz}}{mab}$$

$$= \frac{mk^2}{mab}$$

$$= \frac{k^2}{ab}$$

Assuming mass is same in each bumper so CoG position unchanged.

$$\therefore k^2 = DI \times a \times b$$

$$k = \sqrt{DI \times a \times b}$$

$$= \sqrt{0.87 \times 1.14 \times 1.58}$$

$$= 1.25 \text{ m.}$$

3/3

$$(2.) \text{ Change in } I_{zz} = 1850 - 1300 = 550 \text{ kgm}^2$$

$$I = mk^2$$

$$m = \frac{I}{k^2}$$

$$= \frac{550}{1.5^2}$$

$$= 244.4 \text{ kg}$$

3/3

$$\therefore 122.2 \text{ kg per bumper.}$$

17 1/2
20

2.

$$a.) \text{ Centripetal accel} = \frac{V^2}{r}$$

$$50 \text{ kph} = 13.89 \text{ m/s.} = \frac{13.89^2}{25}$$

$$= 7.72 \text{ m/s}^2$$

 $\frac{2}{2}$

$$b.) \text{ Circumference} = 2\pi r = 2\pi(25) = 157.08 \text{ m.}$$

$$\text{Time per rev} = \frac{157.08}{13.89} = 11.31 \text{ secs.}$$

$$\text{Yaw rate} = \frac{360}{11.31} = 31.83 \text{ deg/sec.}$$

 $\frac{2}{2}$

$$c.) \text{ Static weight} = \left(\frac{750}{2}\right) \times 9.81 = 3678.75 \text{ N}$$

Per wheel.

$$\text{weight transfer} = \frac{mah}{t} = \frac{750 \times 7.72 \times 0.6}{1.5}$$

$$= 2316 \text{ N}$$

$$\text{Inner wheels: } 3678.75 - 2316 = 1362.75 \text{ N}$$

per wheel.

$$\text{Outer wheels: } 3678.75 + 2316 = 5994.75 \text{ N}$$

per wheel.

 $\frac{2}{2}$

$$d.) \text{ Aero res} = \frac{1}{2} \rho C_d A V^2 = \frac{1}{2} (1.2) (0.5) (3) (13.89^2)$$

$$= 173.64 \text{ N}$$

$$\text{Rolling res} = (1500 \times 9.81) \times 0.013 = 191.3 \text{ N}$$

$$\text{Tractive effort} = 173.64 + 191.3$$

$$= 364.94 \text{ N}$$

 $\frac{2}{2}$

e.) $\text{Lat } F = \text{Axle weight} \times \text{Coef Friction}$
 $= (750 \times 9.81) \times$

$$F = ma$$

$$= 750 \times \cancel{7.72} \quad 7.72$$

$$5790 \text{ N}$$

$$= \cancel{5790} \text{ lat force per axle.}$$

f.) $\text{Axle weight} = (750 \times 9.81) = 7357.5 \text{ N.}$

$$\text{Inner \%} = \frac{1362.75}{7357.5} = 18.52\%$$

$$\text{Outer \%} = \frac{5994.75}{7357.5} = 81.48\%$$

$$\therefore \text{Inner lat grip} = \frac{5790}{\cancel{3452.18}} \times 0.1852$$

$$= \cancel{1072.31} \quad 1072.31 \text{ N}$$

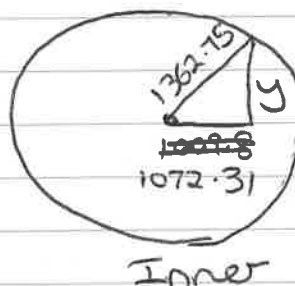
$$\text{Outer lat grip} = \frac{5790}{\cancel{8452.18}} \times 0.8148$$

$$= \cancel{4717.69} \quad 4717.69 \text{ N}$$

g.)



outer



Inner

$x = \text{Longitudinal grip}$
outer wheel

$y = \text{Longitudinal grip}$
inner wheel.

$$x = \sqrt{(5994.75)^2 - (\cancel{4442.7})^2}$$

$$3698.71$$

$$= \cancel{4000} \text{ N Outer wheel}$$

$$y = \sqrt{(1362.75)^2 - (\cancel{1009.8})^2}$$

$$840.97$$

$$= \cancel{915.09} \text{ N inner wheel.}$$

open diff so Symmetrical drive.

$$\therefore \text{Total available grip} = \frac{840.97}{915.09} \times 2$$

$$1681.94$$

$$= \cancel{1830.18} \text{ N}$$

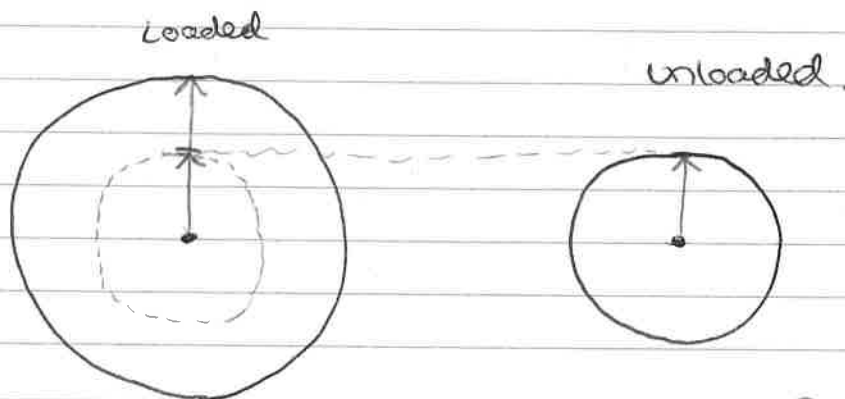
$$\text{Grip used for tractive effort} = 364.94 \text{ N}$$

$$\text{Remaining available grip} = \frac{1681.94}{1830.18} - 364.94$$

$$1317 \text{ N}$$

$$= \cancel{1468.2444}$$

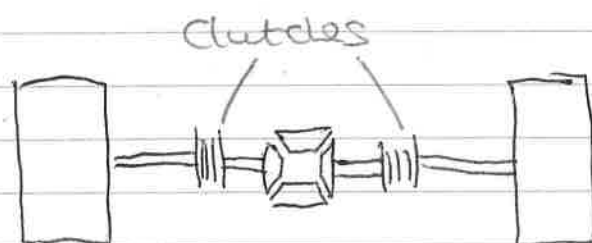
- h.) A torque vectoring diff can supply differing amounts of torque to each connected drive wheel, thereby enabling use of more of the available grip on the loaded wheel. See below Friction Circles:



Red = Drive available from open diff.

Green = Additional drive to loaded wheel from torque vectoring System.

This could be achieved through mechanical differentials, such as Torsen type. ~~or~~ Preferably, if cost not significant, a fixed differential, driving through two wet clutch packs to each wheel would allow total control over drive to each wheel.



mention
 Δ speed

Torque Capacity should be based on engine peak torque (not mean) and then multiplied due to the torque multiplication of the gearing to find a theoretical max torque. A suitable Safety Factor should then be applied.

19

20

3. 750 kg per side. For 100% slip.

a.) Low μ grip: $(750 \times 9.81) \times 0.05 = 367.88 \text{ N}$

High μ grip: $(750 \times 9.81) \times 0.7 = 5150.25 \text{ N}$

Total retarding force = $5150.25 + 367.88$

= 5518.13 N

$F = ma$ $a = \frac{F}{m} = \frac{5518.13}{1500}$

= 3.68 m/s^2

b.) Unbalanced $F = \frac{5150.25}{\cancel{5518.13}} - 367.88$

= $\frac{4782.37}{\cancel{8180.25}}$

Yaw moment = $\frac{4782.37}{\cancel{8180.25}} \times (1.5/2)$

= $\frac{3862.169}{\cancel{1000}} = 3586.78 \text{ Nm}$

c.) Rotational accel = $\frac{I_{zz}}{\text{Moment}}$

= $\frac{2200}{\cancel{3862.169}} \times 3586.78$

= $\frac{0.61}{\cancel{0.175}} \text{ rad/s}^2$

$T = I\alpha$

$\therefore \alpha = \frac{T}{I}$

d.) Yaw moment must equal moment from Steering.

Moment Steering = $\frac{3586.78}{\cancel{3862.169}} \text{ Nm}$

$\frac{3586.78}{\cancel{3862.169}} = F \times d$ where $d = \frac{2.65}{2}$

$F = \frac{\frac{3586.78}{\cancel{3862.169}}}{1.325}$

= $\frac{2707.244}{\cancel{2707.244}} = 2707 \text{ N}$

2.) Road wheel angle = $\frac{2707}{2915.24} \times 1000$
 $= 2.71$
 $= 2.71 \text{ degrees.}$

Steering ratio of 15:1

$\therefore$ Hand wheel angle = $\frac{2.71}{15} \times 15$
 $= 40.65$
 $= 40.65 \text{ degrees.}$

2/2

F.) wheels now rotating so μ changes.
 Assume system will use max available grip.

Low μ grip = $(750 \times 9.81) \times 0.1 = 735.75 \text{ N}$

High μ grip = $(750 \times 9.81) \times 0.9 = 6621.75 \text{ N}$

$\therefore$ Max braking force = $6621.75 + 735.75$
 $= 7357.5 \text{ N.}$

3/3

$a = \frac{F}{m} = \frac{7357.5}{1500}$

$= 4.91 \text{ m/s}^2$

g.) The ABS System will apply braking force asymmetrically across the vehicle wheels in order to utilise more of the available grip.

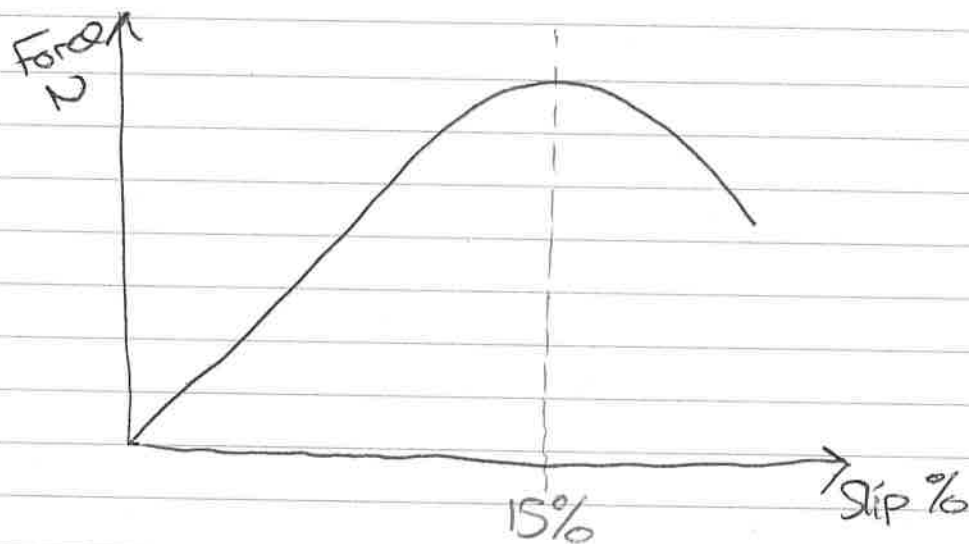
PTO

Using sensors that monitor vehicle condition, ~~the~~ such as:

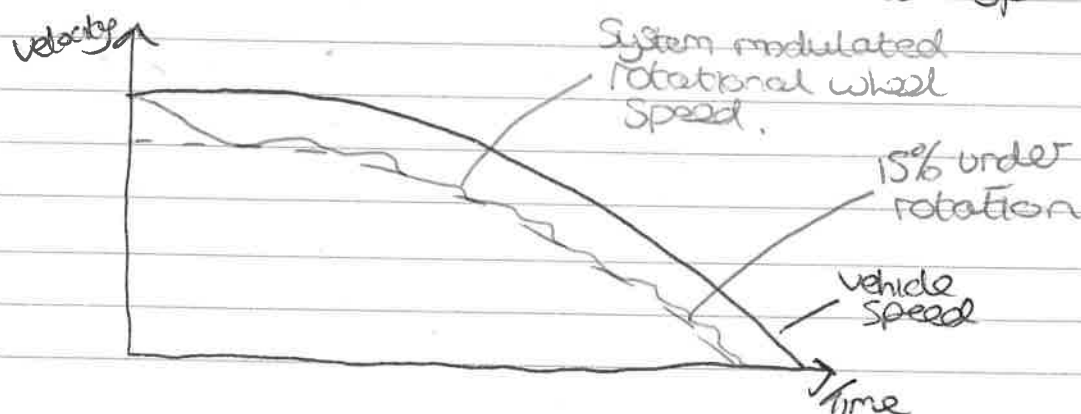
- Wheel Speed Sensors
- 3 axis accelerometers
- Yaw rate sensors
- Hard wheel position sensors

The system can monitor real time vehicle condition & attitude & use this data to determine optimal strategy.

System ideally wants to maintain around 15% under-rotation (slip) for peak forces!



Using wheel speed data, generally undriven wheels provide vehicle speed reference, the system can modulate line pressure to brakes to maintain desired rotational speed.



The System however must prioritise lateral grip over outright deceleration so that the vehicle's path following is not compromised.

Intended path can be determined by steering angle sensors & yaw sensors.

Braking induced yaw moments can then be monitored for & system can account for this with line pressure changes.

Due to complex, closed loop nature of system required, PID type controllers are often used.

ABS Systems often employ a Select Low Rear algorithm, where minimum rear braking is applied so that lateral grip for manoeuvring is remaining.

5/6

17 1/2
20

Question No.