



Complete, fold and seal
(see note 2 below)

SURNAME: 

Hadwick

FORENAME(S): Oscar Ligzby

1. Please give the information requested in the boxes below.
2. Enter your name in the space provided to the right, fold over 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.**

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)



2a) F - 750kg
CoG h = 600mm
Track = 1.5m
radius = 25m

R - 750kg
Wheel B = 2.1m
V = 50 kph

$$\frac{\text{Kilom}}{\text{hr}} \rightarrow \frac{\text{m}}{\text{s}}$$

$$V \rightarrow \text{m/s} = 13.8 \text{ m/s}$$

Cent. Acc = velocity² × radius.

$$= \frac{(13.8)^2}{\text{m/s}^2} \times \frac{25}{\text{m}}$$

$$= \underline{7.72 \text{ rad/s}^2}$$

$$\frac{1/2}{2}$$

b) Yaw rate = degrees/sec (rate of yaw)
ω
rads/sec. ✓ m/s.

$$13.8 \text{ rads/s} \times \frac{2\pi}{60}$$

$$\underline{1.45 \text{ deg/s}}$$

$$\frac{1/2}{2}$$

c) $\frac{750 \times 9.81}{2} = \underline{3678.75 \text{ N}}$ ✓



same F and R

due to 50:50 weight dist.

$$\frac{1/2}{2}$$

- d) Drive force means over come $U + F$, drag and wheel resistance.

$$\text{So } \underbrace{U + F}_{\text{Total}} = 14715 \text{ N.}$$

$$\text{Aero Res} = 0.5 \times 3 \times 0.5 \times 1.2 \times (13.8)^2 \\ = 173.6 \text{ N.}$$

$$\text{Rolling Res} = 0.013 \times 0.29 \text{ m} \\ = \text{Minimal.}$$

$$0.013 \times 1500 \times 9.81$$

→ Assuming that any rolling resistance is so small that it is negligible to the total:

To maintain 50 kph 14889 N required.

QED

- e) First find front axle $\Rightarrow$ CofG dist.

$$= \underbrace{2.1 \text{ m}}_{\text{Wheel base}} \times 0.5 = 1.05 \text{ m}$$

3.) Forward MF = 750 kg MR = 750 kg

Rot I = 2200 kgm² CoG h = 600mm

Track = 1.5m Wheel B = 2.65m

^{high}
~~low~~ μ (no ABS) = 0.05 μ (no ABS) = 0.1

μ (no ABS) = 0.7 ~~high~~ ^{low} μ (ABS) = 0.9

$v = 50 \text{ kph} = 13.8 \text{ m/s}$

3a) Lat out Grip L & R.

loading

Front $F(\text{vertical}) = 750 \times 9.81 = 7357.5 \text{ N}$

Rear $F(\text{vertical}) = 750 \times 9.81 = 7357.5 \text{ N}$

~~low~~ $\mu = (2 \times 7357.5) \times 0.7 = 10300.5 \text{ N}$
 only 7358N
 now +2

$\mu = (2 \times 7357.5) \times 0.05 = 735.75 \text{ N}$

$F = ma$

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

Total $F = 10300.5 + 735.75 = 11036.25$

Total $M = 1500 \text{ kg}$

$a = \frac{11036.25}{1500}$

$a = 7.36 \text{ m/s}^2$

-ve as decel

1 1/2
3

$$3b) \text{ Yaw Moment} = \Delta \text{ Grip} \times \frac{\text{Track}}{2}$$

$$\Delta \text{ Grip} = 10300.5 - 735.75 \\ = 9564.75 \text{ N}$$

error
carried

2/2

$$\frac{\text{Track}}{2} = (1.5\text{m} / 2) = 0.75\text{m}$$

$$\text{Yaw Moment} = 9564.75 \times 0.75 \\ = \underline{\underline{7173.6 \text{ NM}}}$$

$$3c) \text{ Rot Acc} = \text{Yaw Moment} / \text{Rot Inertia.}$$

$$= 7173.6 / 2200 \text{ kgm}^2$$

$$= \underline{\underline{3.26}}$$

error
carried

2/2

$$3d) \text{ Lat F} = \text{Yaw Moment} / \underbrace{\text{Dist axel} \rightarrow \text{CoFG dist}}_{\text{50/50 weight dist.}}$$

$$\text{Wheel Base} \times 0.5 = \text{F Axel} \rightarrow \text{CoFG.}$$

$$= 1.325\text{m}$$

$$\text{Lat F} = 7173.6 / 1.325\text{m}$$

$$\text{Lat F} = \underline{\underline{5414 \text{ N}}}$$

2/2

3e) find steering Angle.

$$\text{Cornering } k = 1000 \text{ N/deg.}$$

$$\text{Steering Ratio} = 15:1$$

$$\text{Angle @ wheels} = \text{Yaw Moment} / \text{Cornering } k$$

$$= 7173.6 / 1000$$

$$= 7.17$$

Torque
should use
force

1/2

$$7.17 \times \underbrace{15}_{\text{steering ratio}} = \underline{107.6^\circ}$$

of steering
lat to center.

3f) Now has ABS $\therefore$ No locking. ✓

$$\mu = 0.9 \quad \text{or} \quad \mu = 0.1$$

$$(2 \times V \times F) \times 0.9 = 13243.5 \text{ N (Front)}$$

$$(2 \times V \times F) \times 0.1 = 1471.5 \text{ N (Rear)}$$

1/3

$$\text{Total Grip} = 14715$$

$$F = Ma$$

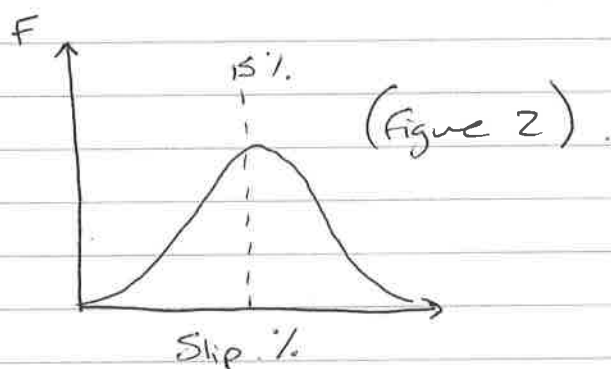
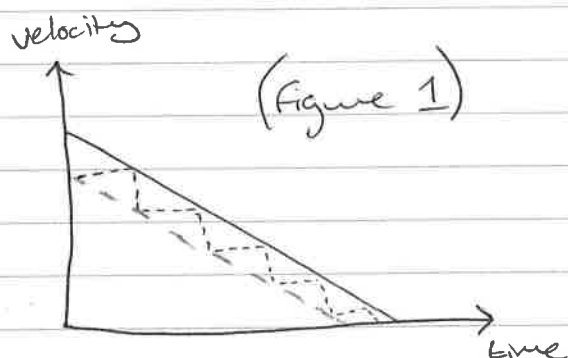
$$\text{Total Mass} = 1500 \text{ kg}$$

$$a = \frac{14715}{1500} = 9.81 \text{ m/s}^2$$

-ve as decel.

You should
question
this kg?

3g)



• Wherever a control system is implemented (in this case ABS or anti-lock braking system) the human factor must be considered:

↳ Human reaction time

↳ How that is affected (age, mood etc...)

• ABS is used so that brakes do not lock up under sudden braking leading to a low likelihood of induced slip & loss of control.

• (Figure 1) shows deceleration. The solid black line indicates the optimal linear deceleration. The dashed black line indicates ABS trying to achieve this. Whilst the green dashed line shows a point at which the highest braking force that will never lock the wheels sits.

In practice the ABS allows for maximum brake force up to a point of pre-determined slip, typically at about 15% as visualised in (Figure 2).

3g) Continued...

• When the ABS system detects this amount of slip in any of the wheels it automatically releases the brakes down to the min. pressure (as shown in figure 1) before once again applying the brakes. This allows for a more controlled stop. The rate at which the brakes apply and release on an ABS system is usually with a frequency of 8-10 Hz.

• Certain other elements can be considered as well. For example more conservative (lower) slip values may be applied to the rear brakes. This is because the rear brakes locking will induce a slip angle more quickly and the oversteer from that is more difficult to control than understeer that may be produced from front locking.

• Additionally, to suitably detect the slip suitable sensors must be utilized within the ABS itself. You may regularly find that by calculating the differences in wheel speed along with overall vehicle yaw rate sensors. ABS can use those to determine slip occurring at each corner of the vehicle and apply specific brake modulation on specific wheels when necessary.

QED

3/6

12/1/20

1a) To find distance a : wheel base $\times$ rear Mass distribution

$$= 2.718 \text{ m} \times 0.42$$

$$= \underline{1.14 \text{ m}} = "a"$$

2/2

b) $C = I_{zz} / M \times a$

$$1300 / 1170 \times 1.14$$

$$C = \underline{\underline{0.975 \text{ m}}}$$

2/2

c) $I = Mk^2$ $k = \text{radius of gyration}$

$$\therefore k^2 = \frac{I}{M}$$

$$k = \sqrt{\frac{I}{M}}$$

$$k = \sqrt{\frac{1300}{1170}} = \underline{\underline{1.05}}$$

2/2

d) $DI = I_{\text{net}} / \text{Mass} \times a \times b$

$$a = 1.14$$

$$b = 2.718 - 1.14 = 1.578$$

$$\text{Mass} = 1170 \text{ kg}$$

$$I_{\text{net}} = 1300$$

$$DI = 1300 / 1170 \times 1.14 \times 1.578$$

$$= 0.62$$

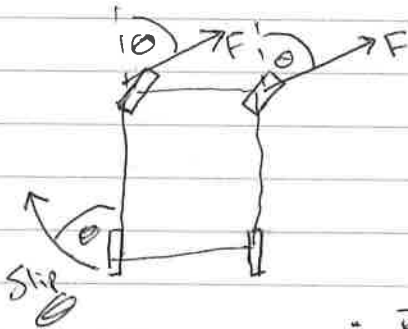
1d) Continued...

$$DI = 0.62$$

This dynamic index is very low. Because of this the stability of the vehicle would also be very low and the potential turn in of the vehicle very high.

$\frac{1\frac{1}{2}}{2}$

1e)



- With a low calculated DI, turn in would be very effective and sudden.

- Because of this any slip angle generated would also be generated suddenly. Leading to a "snappy" difficult to drive vehicle with very intense "oversteer" characteristics.

$\frac{1}{4}$

1f)

- A humans optimum response time comes from detecting changes of balance using fluid from their inner ear as the detectors of this change. This produces reaction times of about 0.3 seconds on average.

- However, with a Dynamic Index as low as 0.6 for example. The yaw rate change or rate of slip angle change may be happening in time frames less than 0.3 seconds. This means at best a delayed response which may itself lead to the wrong correction and incident.

1f) Continued...

• Additionally, humans cannot be treated as computers. Dependent on age, mood, health and experience driving, reaction times may become slower and the reaction itself further from the appropriate correction.

$\frac{1/2}{2}$

• In cases such as these suitable, fast reacting, electronic control systems would likely be required to meet safety standards.

1g) 1. new k

$$DI = 0.87 \quad 0.87 = \frac{1850}{\text{mass}} \times 1.14 \times 1.578$$

$$DI = \text{momenta} / \text{mass} \times a \times b$$

$$DI \times \text{mass} \times a \times b = \text{Inertia}$$

$$\text{mass} = \frac{\text{Inertia}}{DI \times a \times b} = \frac{1850}{0.87 \times 1.14 \times 1.578}$$

$$\text{New } M = 1182.1 \text{ kg}$$

$$\therefore I = Mk^2$$

$$k = \sqrt{\frac{I}{M}}$$

$$k = \sqrt{\frac{1850}{1182.1}} = \underline{\underline{1.25}}$$

$\frac{3}{3}$

lg) continued).

$$2: \text{Total Mass (New)} = 1182.1 \text{ kg}$$

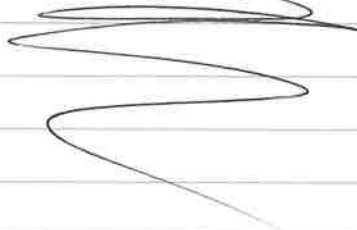
$$\text{Total Mass (Old)} = 1170 \text{ kg}$$

$$\text{Total additional Mass} = 12.1 \text{ kg.}$$

Assuming 50/50 distribution

$\therefore$ 6.05 kg should be placed in each bumper.

QED



0/3

13/20