

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 5

LEFEL 5

**EXAMINATION PERIOD
MAY 2018**

**CYFNOD ARHOLIADAU
2018**

**MODULE CODE: M5X000403 & M5X00407
Vehicle Dynamics and Motorsport Vehicle Dynamics**

TIME: 2 HOURS

ANSWER ALL OF SECTION A

ANSWER TWO OUT OF THREE IN SECTION B

Equipment or materials required – None

Adnoddau neu ddefnyddiau sydd eu hangen - Dim

A formula sheet is provided for reference.

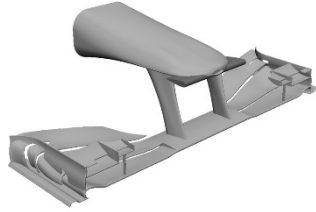
Calculators are permitted.

Assume 'g' = 9.81 m/s^2 .

SECTION A

ANSWER ALL QUESTIONS

QUESTION ONE



- a) Wings are often used on vehicles to produce downforce, increasing vertical load on the tyres and hence lateral acceleration capability.
- Explain, with reference to fundamental theories, how wings produce this force.
(3 Marks)
 - Draw streamline diagrams and corresponding lift versus angle of attack curves to illustrate the two typical types of wing stall.
(2 Marks)
 - Explain why high aspect ratio wings are more efficient than low aspect ratio wings and why endplates are generally implemented on race car wings to improve efficiency.
(2 Marks)
- b) Describe what is meant by the term flow separation and explain, with the aid of diagrams, why the phenomenon may occur under a positive pressure gradient.
(3 Marks)
- c) Air dams are often used to increase downforce and decrease drag on passenger based race vehicles. Explain how air dams may achieve this and why they are often used in conjunction with side skirts.
(4 Marks)
- d) Wind tunnels are used extensively to evaluate automotive aerodynamics.
- Sketch the two types of wind tunnel configuration and label the features you would expect to find specifically on an automotive wind tunnel.
(5 Marks)
 - Scale models are often used for aerodynamic testing. Explain, with diagrams if necessary, why it is important to match Reynold's number between the scale tunnel and full size scenarios.
(2 Marks)

SECTION B

Question Two



A Black Cab Taxi vehicle has the following characteristics.

Mass 2000kg

Frontal area 3m^2

Coefficient of drag (CD) 0.5

Density of air = 1.2kg/m^3

The rolling (force) resistance of a tyre on asphalt RF (Newtons) = 0.016N per applied N of vertical force.

The vehicle is equipped with a mechanical flywheel battery kinetic energy recovery system (KERS). Assume the electrical system is 100% efficient in both directions. The vehicle begins its journey from the Cadogan Building down Mount Pleasant hill with a stationary flywheel.

The vehicle descends through a vertical drop of 30m along 400m of road at a constant speed of 40kph. Assume the vehicle captures all of the available energy and the vehicle friction brakes are not applied.

- a) How much energy is stored by the flywheel at the bottom of the hill?
(8 Marks)
- b) If the vehicle turns left and continues at the same speed along level ground how far will it travel before the energy in the flywheel has been exhausted?
(4 Marks)
- c) A similar vehicle is equipped with a similar KERS device. The flywheel has been specified to store 400Kj of energy.
The device has a maximum rotational speed of 10,000rpm
Packaging dictates that the disc can be no larger than 0.4 m outer diameter
Density of steel = 7820 kg/m^3
Calculate the dimensions and mass for a suitable solid (plain section) flywheel.
(3 Marks)
- d) Discuss power transmission problems from the road wheels to a flywheel storage device. Suggest and analyse possible solutions to overcome these problems. Use diagram and example calculations to support your discussion.
(5 Marks)

Question Three

A stationary vehicle is about to attempt to launch in a straight line on a split μ road surface as shown in the photograph below.



The right side on the vehicle is on polished ice with a coefficient of friction $\mu = 0.1$

The left side of the vehicle is on dry asphalt with a coefficient of friction $\mu = 1.0$

The vehicle has the following specification

The vehicle is rear wheel drive

Mass as tested 1600 kg

Front rear weight distribution 40% / 60%.

Assume weight distribution is symmetrical

Vehicle track width (front and rear) 1.8m

Vehicle wheelbase 2.8m.

- a) With an open rear differential what is the maximum initial acceleration that can be generated ignoring longitudinal weight transfer?

(4 Marks)

- b) What steering action would the driver have to take to ensure straight line acceleration?

(1 mark)

- c) If the vehicle was equipped with a locking differential device what is the maximum initial acceleration that can be generated ignoring longitudinal weight transfer ?

(4 Marks)

- d) The vehicle steering and tyres have the following characteristics.

Maximum wheel rotation ± 45 degrees

Handwheel rotation 3.5 turns from 'lock to lock'.

For the vehicle front wheel loading: on a road surface with a coefficient of friction $\mu = 1.0$ the tyres will generate a lateral force 400N per degree slip angle.

Assume that the front lateral force acts about the centre of the rear axle.

- i) With a diagram, explain how the tractive forces in c) affect vehicle handling.
ii) What handwheel angle, and in what direction must the driver apply to ensure that the vehicle launches in a straight line?

(5 Marks)

e) The vehicle has a rotational inertia about the 'z' axis of 2200kg/m^2

The vehicle is going clockwise around a roundabout with a path radius of 15m at a constant speed of 10m/s

i) What is the yaw rate of the vehicle ?

The vehicle yaw rate begins to change, one second later the on-board yaw rate sensors measures a yaw rate of 0.917 rads/sec^2 .

ii) What is happening to the vehicle?

iii) What is the yaw rate acceleration?

The brake based vehicle stability controller wishes to correct the vehicle and regain the original vehicle yaw rate within one second.

iv) To which front wheel should brake force be applied ?

v) How much braking force is required?

(6 Marks)

Question Four

A vehicle is equipped with a single driven plate (2 surfaces) drive clutch

With the following specification:

Inner effective diameter = 100mm

Outer effective diameter = 180mm

Dry plate friction material to cast iron. Coefficient of friction (μ) = 0.3

The clutch is actuated with a linear diaphragm spring with a rate of 961.5 N/mm

The fitted load is 6410N.

a) How much torque can be transmitted? (assume uniform wear)

(3 Marks)

b) Each of the clutch plate surfaces wears by 1.5 mm. How much torque can now be transmitted?

(3 Marks)

The clutch is fitted to a vehicle with the following specification

Mass 1500kg

1st Gear ratio = 3.5 : 1

Final drive ratio = 3.5 : 1

Wheel rolling radius = 0.29m

Transmission and drive efficiency = 96%

The clutch has worn such that it slips at 100Nm engine torque

Assume the rotational inertia of the driveline components is insignificant.

c) How long will it take for the vehicle to reach 10 m/s ?

(4 Marks)

A vehicle is equipped with an air-conditioning system.
 The air conditioning pump pulley is driven at one half engine speed.
 The air conditioning pump has a rotational inertia of $0.014 \text{ kg} \cdot \text{m}^2$
 The pumping resistance can be considered constant at 0.8 Nm
 The engine is on tick-over at 800 rpm
 There is a single surface cone clutch between the pulley and the pump with the following dimensions :
 Outer diameter = 80 mm
 Inner diameter = 70 mm
 Effective face width = 20 mm
 The coefficient of friction (μ) = 0.25
 An electric solenoid provides a force of 15 N to actuate the cone clutch.

- d) What is the torque transfer generated by the cone clutch?
 (Assume constant wear)
(3 Marks)
- e) How long will it take to accelerate the pump from standstill to the engine's tickover speed?
(4 Marks)
- f) Explain the advantages and disadvantages of reducing the cone angle?
(3 Marks)

Equations

Bernoulli's Equation:

$$P_{Total} = \frac{1}{2} \rho v^2 + P_{Static}$$

Reynold's Number:

$$R_e = \frac{\rho u l}{\mu}$$

Viscosity:

$$\tau = \mu \frac{du}{dy}$$

Pressure Coefficient:

$$C_p = 1 - \frac{V}{V_\infty}$$

Lift and Drag:

$$Lift\ Force = C_L \times 1/2 \rho V^2 \times A$$

$$Drag\ Force = C_D \times 1/2 \rho V^2 \times A$$

Wing Equations:

$$AR = \frac{b}{c} \qquad C_L = \frac{C_1}{1 + \frac{2}{AR}}$$

Wings with endplates:

$$AR_{effective} = AR_{actual} \times (1 + 1.9 \frac{h}{b})$$

Wings in ground effect:

$$C_1(ige) = C_1(oge) \times \left(1 + \frac{1}{16 \left(\frac{h}{c} \right)^2} \right)$$

Wings with a Gurney flap:

$$\Delta C_1 = 3.8 \times \left(\frac{h}{c} \right)^{0.5}$$

Equations

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

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

For a plain disc : radius of gyration $k = \text{Outer radius} / \sqrt{2}$

So $k = \text{Outer radius} \times 0.707$

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

Reflected inertia = component inertia x ratio²

Clutch torque transfer values.

Uniform pressure theory $T = \frac{2}{3} \mu \cdot F \cdot \frac{(r_0^3 - r_1^3)}{(r_0^2 - r_1^2)}$

Plate clutch

Uniform wear theory $T = \frac{F \cdot \mu \cdot (r_o + r_i)}{2}$

Plate clutch

Uniform wear theory $T = \frac{F \cdot \mu \cdot (r_o + r_i)}{2 \cdot \sin \alpha}$

Cone clutch

	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
	$v = v_0 + at$	$\omega = \omega_0 + \alpha t$	
	$x = v_0 t + \frac{1}{2} at^2$	$\theta = \omega_0 t + \frac{1}{2} \alpha t^2$	
	$v^2 = v_0^2 + 2ax$	$\omega^2 = \omega_0^2 + 2\alpha\theta$	
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