

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 5

LEFEL 5

**EXAMINATION PERIOD
MAY 2017**

**CYFNOD ARHOLIADAU
2017**

**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

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A formula sheet is provided for reference.

Calculators are permitted.

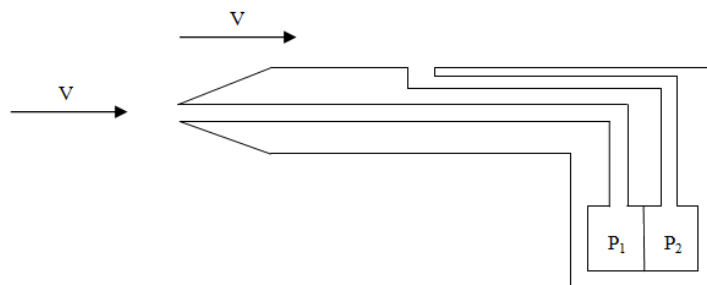
Assume 'g' = 9.81 m/s^2 .

SECTION A

ANSWER ALL QUESTIONS

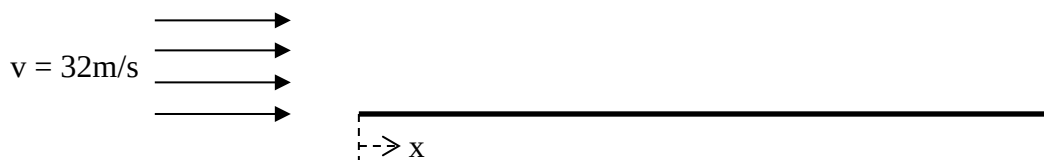
QUESTION ONE

- a) A Pitot tube is positioned in free stream air flow as shown below. By applying Bernoulli's equation derive an equation for the velocity of the flow in terms of the two pressures P_1 and P_2 and the density of air, ρ . If $\rho = 1.256 \text{ Kg/m}^3$, $P_1 = 1.02 \times 10^5 \text{ Pa}$ and the air flow velocity is 35 m/s calculate the static pressure P_2 .



[2 marks]

- b) A thin aerodynamic surface is positioned axially within an air flow of 36 m/s as shown below



- i) Sketch and label the features of the boundary layer as it builds along the aerodynamic surface.
- [1 mark]
- ii) Given that the flow transition between lamina and turbulent occurs at a Reynold's number of $600,000$ for this case, calculate the distance x , from the leading edge of the surface to the point at which transition occurs. Assume $\rho = 1.223 \text{ Kg/m}^3$ and $\mu = 1.8205 \times 10^{-5} \text{ Kg/ms}$
- [2 marks]
- iii) Explain what is meant by the term separation and describe when/why it may occur under a positive pressure gradient.
- [3 marks]
- c) Describe, with diagrams if necessary, your understanding of the mechanism by which the following vehicle aerodynamic design features can be used to enhance aerodynamic performance:

- i. Wings [3 Marks]
- ii. Splitters [2 Marks]
- iii. Diffusers [2 Marks]

- d) Discuss why an aerodynamic wind tunnel designed by the aviation industry may not be suitable for automotive testing. Highlight and explain possible sources of error and discuss wind tunnel design features which could be implemented to reduce these errors.

[5 Marks]

SECTION B

ANSWER TWO QUESTIONS FROM THREE

QUESTION TWO

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



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

The left side of the vehicle is on wet asphalt with a coefficient of friction $\mu = 0.85$

The vehicle has the following specification

The vehicle is rear wheel drive

Mass as tested 1800 kg

Front rear weight distribution 55% / 45%.

Assume left – right weight distribution is symmetrical

Vehicle track width (front and rear) 1.6m

Vehicle wheelbase 2.9m.

- a) With an open rear differential what is the maximum initial acceleration that can be generated ?
(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 electronically controlled locking differential device what is the maximum initial acceleration that can be generated ?
(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 $\mu = 0.85$ the tyres will generate a lateral force 400N per degree slip angle.

With a diagram, explain how the tractive forces in c) affect vehicle handling.
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 2500kg/m/m

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

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/sec.

What is happening to the vehicle?

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.

Which front wheel should brake force be applied

How much braking force is required?

(6 marks)

QUESTION THREE

Transport for London has recently taken delivery of a series flywheel hybrid buses for its new fleet.

The buses are equipped with a 4.5 litre Cummins diesel engine (ICE), rated at 185Kw.

A standard bus has a fuel consumption of 5.8mpg.

The hybrid bus has achieved 11.8 mpg under similar test conditions.

The bus has the following specification:

Width 2.5m. Height 4.4m

Coefficient of drag (CD) 0.8

Density of air = 1.2kg/m^3

For a bus tyre on a tarmac road: rolling (force) resistance (newtons) = 0.01 N per applied N of vertical force.

Vehicle operating speed 30 kph

Vehicle acceleration 1.2 m/s^2

Vehicle deceleration with regenerative capacity 1.2 m/s^2

Unladen weight 11800kgs

Assume a partloaded passenger capacity 67 seated (assume one person plus luggage = 100kgs)

Assume that during acceleration and deceleration phase aerodynamic resistive forces need not be considered..

The bus utilises a direct drive flywheel. The flywheel to wheel driveline system.

Drive efficiency is 80%

Kinetic Energy Recovery System efficiency is 60%

The bus is fitted with a 30.6 Mega joule capacity flywheel

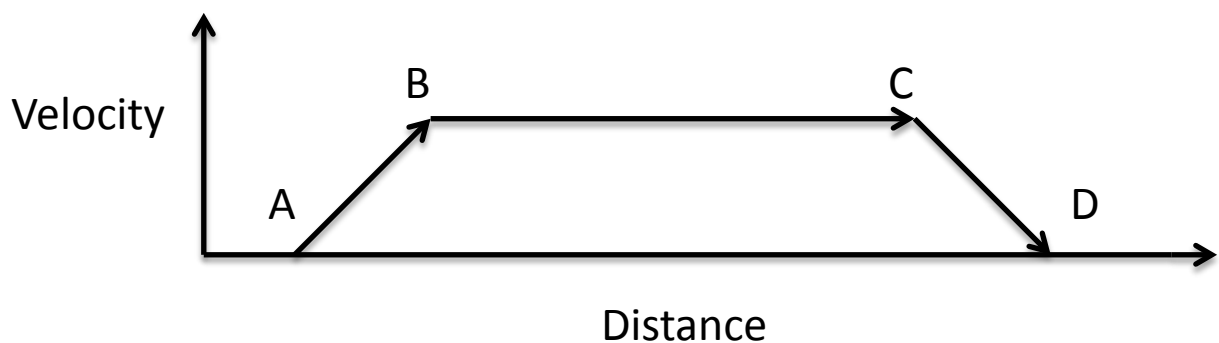
The bus begins a cycle at point A.

It then accelerates up to operational speed at point B

It continues for 150m to point C.

The bus then decelerates to a stop at point D.

This cycle is undertaken on flywheel storage energy only (i.e. the ICE is not running)



- a) What is the total force required to accelerate the vehicle?
2 marks
- b) What is the distance covered during the acceleration phase?
2 marks
- c) How much energy from the flywheel is required to accelerate the vehicle?
2 marks
- d) What is the maximum power required at the end of the acceleration at point B?
1 mark
- e) How much energy is required from the flywheel during the constant speed phase?
3 marks
- f) How much energy can be recovered and stored to the flywheel during the deceleration phase?
3 marks
- g) Assuming the ICE is not operational. What is the total energy drain from the flywheel per cycle?
2 marks
- h) When starting with a fully charged flywheel. How many cycles can the bus achieve before the ICE must be started to provide additional power?
2 marks
- i) The flywheel has a mass of 200 kg and rotates at 8000rpm. Assuming the flywheel is a plain disc. What is the outer diameter?
3 marks

QUESTION FOUR

- (a) A competition car's transmission system incorporates a multiplate clutch unit with two plates, ie four contact surfaces.

Each of the clutch plates has an external diameter of 200 mm and an internal diameter of 100 mm.

- (i) When the clutch is new and unused find the total spring force required to transmit 150 kw at 4000 rpm. Take the coefficient of friction (μ) between the friction surfaces to be 0.4.

8 marks

- (ii) The clutch is now worn by 1 mm per surface. The original springs provided 3500 N of axial force. The spring rate is 100 kN/m. What torque can the clutch now transmit?

4 marks

- (b) Determine the time required to accelerate a fly wheel of mass 400 kg with a radius of gyration 0.3 m with a single plate cone clutch the following specification

2 acting surfaces

Outer effective clutch diameter 200 mm

Cone angle 5° (included angle 10°)

0 – 2500 rpm

Applied axial load 4000 N

$\mu = 0.3$

8 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:

$$AR = \frac{b}{c} \qquad C_L = \frac{C_{l_1}}{1 + \frac{2}{AR}}$$

Wings with endplates:

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

Wings in ground effect:

$$C_{l_1}(ige) = C_{l_1}(oge) \times \left(1 + \frac{1}{16 \left(\frac{h}{c}\right)^2}\right)$$

Wings with a Gurney flap:

$$\Delta C_{l_1} = 3.8 \times \left(\frac{h}{c}\right)^{0.5}$$

Equations

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

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

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

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

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 $T = \frac{F \cdot \mu \cdot (r_0 + r_i)}{2}$

Plate clutch

Uniform wear theory $T = \frac{F \cdot \mu \cdot (r_0 + r_i)}{2 \cdot \sin \alpha}$

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