

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 5

LEFEL 5

EXAMINATION PERIOD
JANUARY 2019

CYFNOD ARHOLIADAU
IONAWR 2019

MODULE CODE: M5X00403&407
VEHICLE DYNAMICS

TIME: 2 HOURS

ANSWER THREE QUESTIONS OUT OF FOUR

Equipment or materials required – None

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Question 1

- a) For an off road race buggy calculate the wheel slip torque if all the vehicle mass is on the rear wheels.

Vehicle mass = 1500 kg

Limiting friction $\mu = 1.2$

Rolling radius = 0.32 m

2 marks

A rear wheel drive off road race vehicle has experienced transmission and engine damage due to shock torsional forces entering the drive line when the vehicle lands after a jump. To stop this damage the engineering director wishes to incorporate a 'mechanical fuse' in the form of a cone clutch incorporated into the driveshaft. The clutch should slip once a drive force of 3000Nm has been exceeded

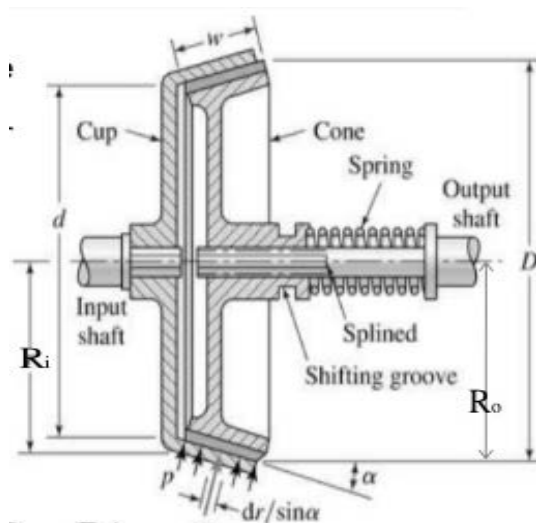
The clutch has the following dimensions:

Outer diameter 100mm

Inner diameter 95mm

Cone angle $\alpha = 7$ degs

Steel on steel coefficient of friction = 0.2



- b) Calculate the clamp force required to cause clutch slip at 3000Nm. Use uniform pressure as the clutch will not wear.
- c) Discuss any possible errors with the provided clutch assumptions. What practical steps could be taken to ensure the correct clamp load is achieved to cause slip at 3000 Nm drive torque.

6 marks

3 marks

A vehicle is equipped with a steel flywheel of plain section.
 Storage capacity = 1Mjoule
 Max rpm = 10,000
 Max outer diameter = 0.5m

- d) Find the mass of the flywheel 4 marks
- e) Calculate the thickness of the flywheel.. 3 marks
- f) Discuss flywheel shapes other than a plain disc that could be used to reduce mass and/or package size. 2 marks

Question 2

The city and county of Swansea are currently redeveloping links between the city centre, marina area and the sea front. To improve transport and avoid the cost and safety concerns of overhead cables they are considering a flywheel powered tram or trolley bus. The flywheel is recharged while the tram is stopped at the stations.



The tram has the following specification

Width 2m. Height 3m
 Coefficient of drag (CD) 0.7
 Density of air = 1.2kg/m^3
 For a steel wheel on a steel rail rolling (force) resistance (newtons) = 0.005 N per applied N of vertical force.
 Vehicle operating speed 40 kph
 Vehicle acceleration 1 m/s^2
 Vehicle deceleration with regenerative capacity 1 m/s^2
 Unladen weight 5500kgs
 Passenger capacity 20 seated (assume one person plus luggage = 100kgs)
 Assume that during acceleration and deceleration phase the speed used to calculate the drag force is 20 kph.

The rail vehicle utilises a Linde hydrostatic transmission with an 80% efficiency in each direction.

The maximum distance between stations is 600m
There should be 20% of the required energy left in the flywheel in reserve.

- a) What is the total force required to accelerate the vehicle?
4 marks
- b) What is the distance covered during the acceleration phase?
1 mark
- c) How much energy is required to accelerate the vehicle?
1 mark
- d) How much energy is required during the constant speed phase?
2 marks
- e) How much energy can be recovered during the deceleration phase?
3 marks
- f) What is the required flywheel energy storage capacity?
4 marks
- g) A similar vehicle is equipped with a flywheel of energy capacity 1.2Mj
When the vehicle is at the station the flywheel is reaccelerated from 1000 rpm to 5000rpm in preparation for the next section of the journey.

What torque is required from the electric drive to accelerate the flywheel in 60 sec
(5 marks)

Question 3



The driver of this rear wheel drive BMW 3 series has stopped on a split μ slope of 15% (15/100). The left side of the car is on dry asphalt ($\mu = 1$). The right side of the car is on polished ice ($\mu = 0.1$).

On level ground the vehicle has the following characteristics.

Front axle mass	900 kg	Track width	1.5 m
Rear axle mass	900 kg	Wheel base	2.8 m
Centre of gravity height	0.7 m	Tyre rolling radius	0.35 m

As the slope is small you can assume that all of the vehicles weight acts directly onto the road surface.

- a) Find the vertical force acting on the rear axle.

(4 marks)

The car is fitted with an open differential, the driver releases the brakes and drives away.

- b) What is the resulting vehicle acceleration ?

(4 marks)

The vehicle has an optional torque biasing (torsen) differential with a torque biasing ration of 3 to 1.

- c) What is the resulting vehicle acceleration ?

(3 marks)

As an alternative to the torsen differential the vehicle fitted with the open differential can be fitted with a brake based traction control system. Where the wheel on the low friction side is applied allowing drive force to reach the high friction. Therefore all of the available rear axle grip can be utilised.

- d) What is the resulting vehicle acceleration? What will be the vehicle dynamic response and what must the driver do to ensure acceleration in a straight line up the slope

(5 marks)

- e) If the vehicle is moving at 10 kph what is the rate of energy entering the brake disc?

(4 marks)

Question 4

Many electric hybrid vehicles utilise regenerative braking to capture all or some of the energy used to decelerate a vehicle.

- a) Explain and contrast the two categories of regenerative braking, series and parallel ?
(6 marks)
- b) Evaluate and explain which of the series or parallel system would be more appropriate for a 24hr Lemans race car ?
(2 marks)

- c) A small front engined front wheel drive petrol internal combustion small car has been hybridised with an additional electrically drive rear axle. Analyse the limitations to recovering energy from the rear axle. Use diagrams and numbers to illustrate your answer.

Typical values:

Mass 1200kg Weight distribution 63% front / 37% rear

Wheel base 2.5m

Height of centre of gravity 0.6m above the ground

Rolling radius 0.26m

(6 marks)

- d) A vehicle has the following specification.

Mass	600kg	Wheel rolling radius	0.264m
Inertia (engine and driveline)	0.15 kgm ²	Final drive ratio	3.4 : 1
Inertia (per wheel assembly)	0.8 kgm ²	Top gear ration	1 : 1

During braking in a straight line, the vehicle decelerates from 144 kph to standstill. Determine the maximum energy recoverable (include effects of inertia from the engine, driveline and the wheels). Assume that the vehicle remains in top gear throughout the deceleration.

You may assume total equivalent mass = actual mass + $4 \left(\frac{I_w}{r_w^2} \right) + I_e \cdot \left(\frac{G^2}{r_w^2} \right)$

Where :

I_w = wheel inertia,

I_e = Engine and driveline inertia,

r_w = wheel rolling radius

G = the overall effective gear ratio.

(6 marks)

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 $k = \text{Outer radius} / \sqrt{2}$ (= Outer radius x 0.707)

Reflected inertia = component inertia x ratio²

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

Gradient resistance = mass x gravity x (sin) angle of slope = $m.g.\sin\theta$

Clutch torque transfer values.

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

Plate clutch

Uniform pressure theory $T = \frac{1}{\sin\alpha} . \frac{2}{3} \mu . F . \frac{(r_0^3 - r_1^3)}{(r_0^2 - r_1^2)}$

Cone clutch

Uniform wear theory $T = \frac{F . \mu . (r_0 + r_1)}{2}$

Plate clutch

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

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