

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 5

LEFEL 5

EXAMINATION PERIOD
MAY 2021

CYFNOD ARHOLIADAU
2021

MODULE CODE: ACHA5004 & 5009 & 5013
VEHICLE DYNAMICS

TIME: 2 HOURS

ANSWER ALL QUESTIONS

Equipment or materials required – None

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Calculators may be used.

Question 1



A vehicle and rider have the following characteristics.

Total Mass	250kg		
Static Front Mass	125kg	Static rear mass	125kg
Centre of gravity height	0.55m	Wheelbase	1.435m
Primary drive ratio	1 to 1	ICE inertia	0.05 kg.m ²
Sixth gear ratio	1 to 1	Clutch & gearbox input inertia	0.04 kg.m ²
Final drive ratio	3 to 1	Chain and gearbox output inertia	0.02 kg.m ²
Tyre rolling radius	300mm	Front wheel inertia	0.8 kg.m ²
		Rear wheel inertia	1.0 kg.m ²

Ignore rolling resistance and aerodynamic resistance.

The motorcyclist is decelerating as quickly as possible, using the front brakes only. The rear wheel is just above the road surface

- a) What braking force is required to just lift the rear wheel? **(3 marks)**

The vehicle is decelerating in sixth gear from 50 m/s.

- b) What is the equivalent mass of the rotating components? **(10 marks)**

You may assume equivalent mass = $\left(\frac{I_{wheels}}{r_w^2}\right) + I_e \cdot \left(\frac{G^2}{r_w^2}\right)$

Where :

I_w = wheel inertia,

I_e = Engine and driveline inertia,

r_w = wheel rolling radius

G = the overall effective gear ratio.

- c) What is the deceleration of the motorcycle? **(2 marks)**

The vehicle has two steel front disc brakes, each has a mass of 1.5kgs. Assuming that there is no air cooling effect during the braking to vehicle stop.
(Specific heat capacity of steel 420 j/kg.k)

- d) What is the temperature increase of the brake discs? **(5 marks)**

Question 2



A multi-plate clutch must transmit 20 kW of power without slipping at 4000 rev/min. The coefficient of friction is 0.25. The inner and outer diameters are 80 and 160 mm respectively. The axial force applied to the plates is 600 N.

Determine the number of plates required using:

- a) The uniform pressure theory **(10 Marks)**
b) The uniform wear theory **(10 Marks)**

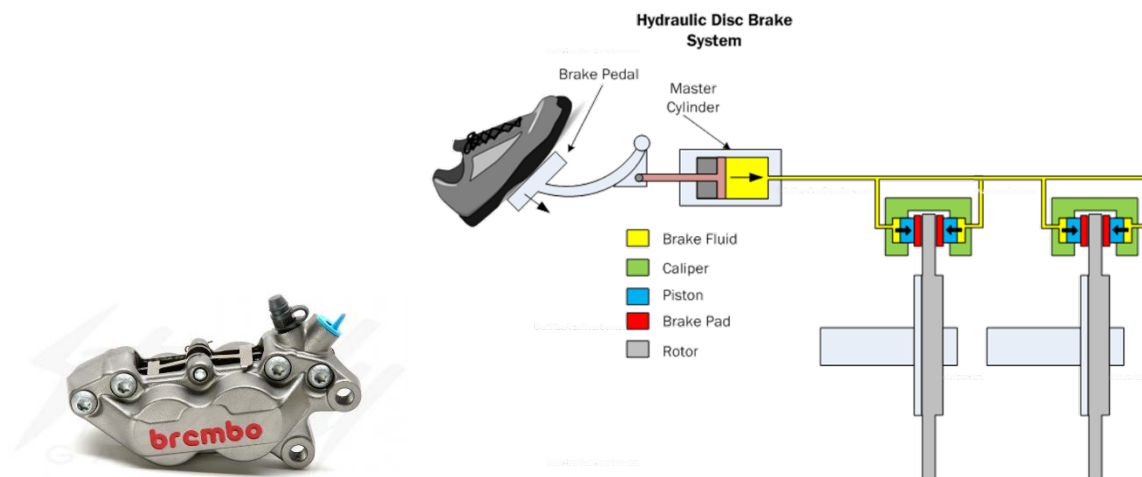
Friction Clutches	Constant Wear	Constant Pressure
Plain disc clutches	$T = \frac{\mu W (r_2 + r_1)}{2} \times 2n$	$T = \frac{2}{3} \mu W \left(\frac{r_2^3 - r_1^3}{r_2^2 - r_1^2} \right) \times 2n$
Conical clutches	$T = \frac{\mu R}{3 \sin \beta} \left[\frac{D_o^3 - D_i^3}{D_o^2 - D_i^2} \right]$	$T = \frac{\mu W (D_o + D_i)}{4 \sin \beta}$

Question 3

A motorcycle braking system with two front discs has the following characteristics.
The rear brakes are not used.

Total Effective Mass	300kg		
Deceleration	9 m/s ²		
Tyre rolling radius	350mm		
Disc effective radius	125 mm	Pad/disc coefficient of friction (μ)	0.4
Pistons per calliper	4	Piston diameter	25 mm
Master cylinder diameter	10 mm	Master lever ration	5 : 1

Ignore rolling resistance and aerodynamic resistance.



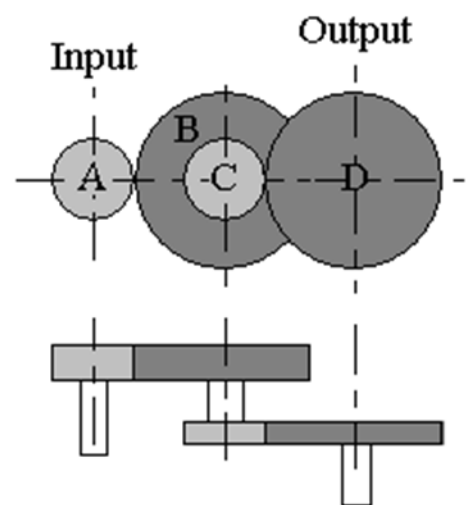
- What is the required wheel torque to decelerate the vehicle at 9 m/s²? (5 marks)
- What force is required from one piston? (5 marks)
- What is the pressure of the brake fluid (5 marks)
- What is the applied force to actuate the brake system? (5 marks)

Question 4

The diagram below shows a compound gear train. Gear A is the input gear and revolves at 7000 rev/min clockwise. If the input torque is 55 Nm and the gear train efficiency is 85% calculate the following;

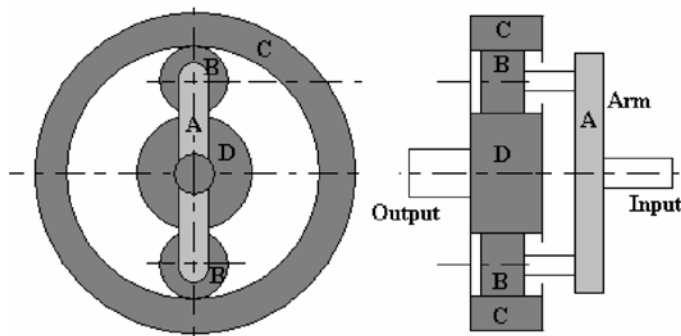
- a) the output speed and direction **(8 Marks)**
- b) the output power and torque **(8 Marks)**
- c) the holding torque required **(4 Marks)**

Gear A has 26 teeth
Gear B has 42 teeth
Gear C has 28 teeth
Gear D has 42 teeth



Question 5

An epicyclic gearbox has a typical arrangement as indicated below.



Annulus (ring)	C	50 teeth
Planet	B	13 teeth
Sun	D	24 teeth
Arm (carrier)	A	

$$\frac{\text{Annulus speed} - \text{Arm speed}}{\text{Sun speed} - \text{Arm speed}} = \frac{-\text{Sun teeth}}{\text{Annulus teeth}}$$

(This is the 'generic epicyclic equation')

The epicyclic is using a 'planetary' arrangement, where the Annulus (C) is held stationary.

The system efficiency is 90%

The arm is being driven clockwise with 25kw at 973 rpm.

Calculate:

- The output speed of the sun **(5 marks)**
- The output torque **(5 marks)**
- Generate an equation showing the relationship of the tooth numbers of the toothed elements. **(5 marks)**
- Explain why epicyclic arrangements generally utilise more than one planet gear. You may use diagrams to support your discussion. **(5 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 = $m.g.\sin\theta$

Rolling resistance = mass x gravity x coefficient of rolling resistance

Longitudinal weight transfer = Acceleration force x CofG height / wheelbase

	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
	$v = v_0 + at$	$\omega = \omega_0 + \alpha t$	
	$x = v_0t + \frac{1}{2}at^2$	$\theta = \omega_0t + \frac{1}{2}\alpha t^2$	
	$v^2 = v_0^2 + 2ax$	$\omega^2 = \omega_0^2 + 2\alpha\theta$	
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

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 pressure theory

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

Cone clutch

Uniform wear theory

$$T = \frac{F \cdot \mu \cdot (r_0 + r_1)}{2}$$

Plate clutch

Uniform wear theory

$$T = \frac{F \cdot \mu \cdot (r_0 + r_1)}{2 \cdot \sin \alpha}$$

Cone clutch

Epicyclic Arrangement	Fixed member	Input member	Output member	Overall gear ratio	Typical ranges
Planetary	Ring	Sun	Carrier	$\frac{(Speed_{Sun})}{(Speed_{Carrier})} = 1 + \frac{N_{teeth_{Ring}}}{N_{teeth_{Sun}}}$	3:1 12:1
Star	Carrier	Sun	Ring	$\frac{(Speed_{Ring})}{(Speed_{Sun})} = - \frac{N_{teeth_{Sun}}}{N_{teeth_{Ring}}}$	2:1 11:1
Solar	Sun	Ring	Carrier	$\frac{(Speed_{Ring})}{(Speed_{Carrier})} = 1 + \frac{N_{teeth_{Sun}}}{N_{teeth_{Ring}}}$	1.2:1 1.7:1

Diwedd/End