UNIVERSITY OF JOHANNESBURG

PROGRAM	:	NATIONAL DIPLOMA *ENGINEERING: MECHANICAL TECHNOLOGY*
SUBJECT	:	**MECHANICS OF MACHINES 2**
CODE	:	**EMM2111**
DATE	:	SUMMER EXAMINATION 2017 27 NOVEMBER 2017
DURATION	:	(SESSION 1) 08:30 - 11:30
WEIGHT	:	40 :60
FULL MARKS	:	87
TOTAL MARKS	:	87

ASSESSOR	:	MR P STACHELHAUS	
MODERATOR	:	DR OT LASEINDE	2187
NUMBER OF PAGES	:	4 PAGES AND 1 ANNEXURE	

INSTRUCTIONS:

- AN A3 PORTABLE DRAWING BOARD OR DRAFTING HEAD MAY BE USED.
- A CALCULATOR OF ANY MAKE OR MODEL IS PERMITTED.

REQUIREMENTS:

- NIL

INSTRUCTIONS TO STUDENTS:

- IT WILL BE EXPECTED THAT THE STUDENT MAKES REASONABLE ASSUMPTIONS FOR DATA NOT SUPPLIED.
- NUMBER YOUR QUESTIONS CLEARLY AND UNDERLINE THE FINAL ANSWER.
- ANSWERS WITHOUT UNITS WILL BE IGNORED.
- ALL DIMENSIONS ON DIAGRAMS ARE IN mm UNLESS OTHERWISE SPECIFIED.

QUESTION 1 INERTIA

(1.1) Derive from 1st principles an expression for the 2nd Moment of Mass of a solid cylinder about a longitudinal axis in terms of its mass ***m*** and diameter ***d***. (6)

(1.2) Calculate the mass moment of inertia (second moment of mass) about the axis of rotation of a flywheel of diameter 0.6 m and thickness 0.04 m. The density of the flywheel material is 8000 kg·m^3. (4)

(1.3) Masses of 2 kg, 2.5 kg, 3 kg are now fixed to the flywheel at distances 0.3 m, 0.2 m and 0.1 m respectively from the axis of rotation. (Assume the masses to be concentrated). Calculate the second moment of mass of the flywheel about its axis of rotation due to the addition of the masses. (6)

(1.4) A solid cylinder of diameter 120 mm and mass of 50 kg rolls from rest, without slipping, down an incline plane which is 5 m high and 10 m long. Calculate the linear acceleration and speed of the cylinder at the instant it reaches the bottom of the plane. (8)

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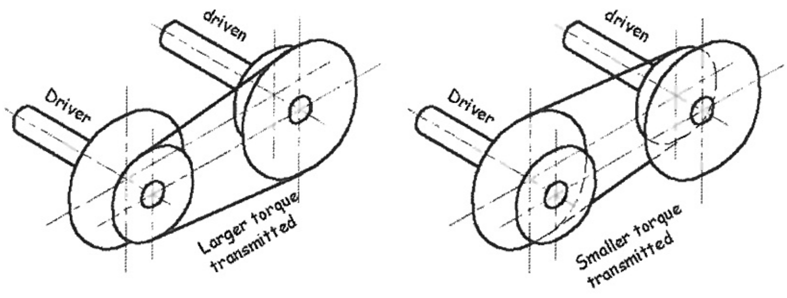
QUESTION 2 **BELT-DRIVES**

A V-grooved pulley on a motor shaft is stepped and has diameters of 360 mm and 300 mm. The driven pulley on the machine shaft is identical and mounted so that two speeds may be obtained using the same belt.



The constant torque motor runs at 2700 r/min and develops 16 kW. The center distance between the shafts is 400 mm. The coefficient of friction of the belt is 0.4. The belt has a mass of 0.5 kg/m. The groove angle is 45°.

(2.1) Calculate the two speeds available at the driven shaft by changing the belt. (3)

(2.2) Calculate the smallest angle of contact and the least velocity of the belt. (4)

(2.3) Calculate the maximum belt tension when the larger of the two torques is transmitted. (4)

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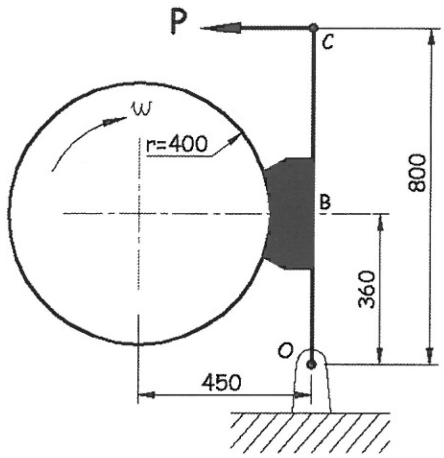
QUESTION 3 **BRAKES**



A brake drum, as shown, of radius 400 mm rotates at 180 r/min. The brake lever of total length 800 mm is operated on by a horizontal force ***P***. The brake shoe is rigidly fixed to the lever. The coefficient of friction is 0.3.

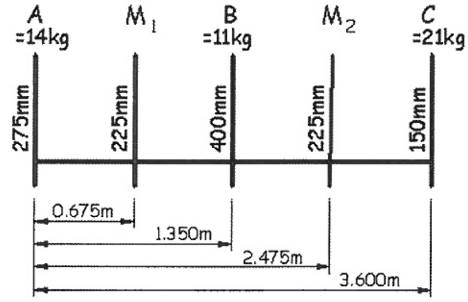
(3.1) If the drum rotates clockwise, calculate the power absorbed when a force ***P*** of 120 N is applied at point C. (9)

(3.2) If the mass of the rotating parts is 160 kg and has a radius of gyration of 300 mm, calculate the force P which would stop the machine from a speed of 180 r/min within 4 seconds. Assume the power supplied to the drum was switched off. (9)

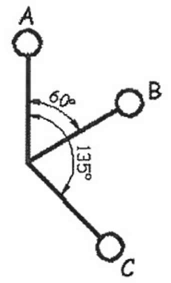
[18]

QUESTION 4 SIMPLE BALANCING

Three rotating masses, A = 14 kg, B = 11 kg and C = 21 kg, are carried on a shaft, with centers of mass 275 mm, 400 mm and 150 mm respectively from the shaft axis. The angular positions of B and C are 60° and 135° respectively from A, measured in the same direction. The distance between the planes of rotation of A and B is 1.350 m, and between those of A and C is 3.600 m, B and C being on the same side of A.



Incomplete front view



Incomplete end view

Two balance masses are to be fitted, each with its center of mass 225 mm from the shaft axis, in planes midway between those of A and B and midway between those of B and C. Determine:

(4.1) the magnitude of each balance mass.

(4.2) the angular position of the balance masses with respect to A.

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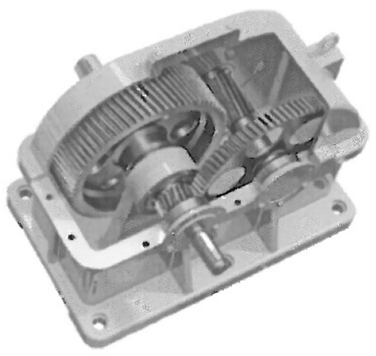
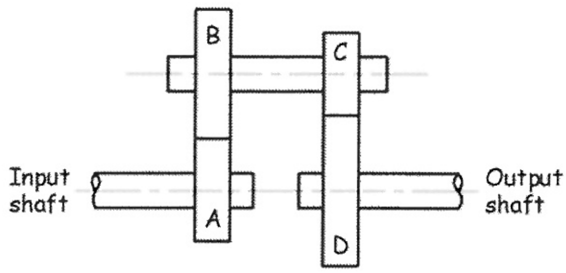
QUESTION 5 BALANCING





The overall speed reduction ratio of a gear-train (shown) is 14:1. A and D are gears on concentric shafts, (i.e. they are on the same center line). The module of the high speed pair, A and B, is 5 and that of the low speed pair, C and D, is 7. No wheel has less than 20 teeth. Hence, determine a suitable number of teeth for each of the four wheels.

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TOTAL : 87

ANNEXURE 1

FORMULA SHEET

	Rotation	Translation
Relationship	$s = r\theta \quad ; \quad v = r\omega \quad ; \quad a = r\alpha$	
Torque	$T = I \cdot \alpha$	$F = m \cdot a$
Energy	$K.E. = \frac{1}{2} \cdot I \cdot \omega^2$	$K.E. = \frac{1}{2} \cdot m \cdot v^2$
	$Work\ done = T \cdot \theta$	$Work\ done = F \cdot d$
	$P.E. = none$	$P.E. = m \cdot g \cdot h$
Power	$P = T \cdot \omega$	$P = F \cdot v$
Momentum	$M = I \cdot \omega$	$M = m \cdot v$
Equations of motion	$\omega_i = \omega_o + \alpha \cdot t$	$v = u + a \cdot t$
	$\theta = \omega \cdot t + \frac{1}{2} \cdot \alpha \cdot t^2$	$s = u \cdot t + \frac{1}{2} \cdot a \cdot t^2$
	$\omega_i^2 = \omega_o^2 + 2 \cdot \alpha \cdot \theta$	$v^2 = u^2 + 2 \cdot a \cdot s$

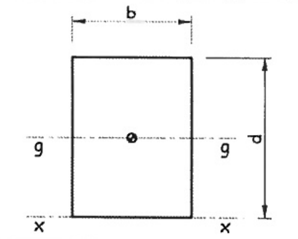
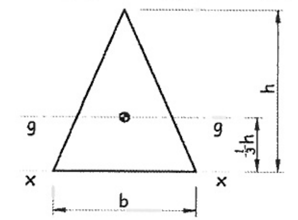
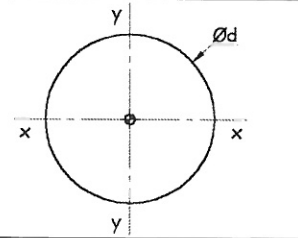
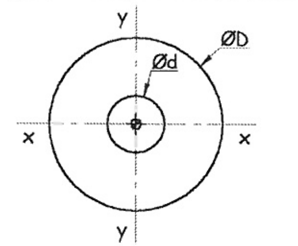
Conservation of energy:

$$Energy\ at\ datum\ 1 = Energy\ at\ datum\ 2 + Work\ Done\ against\ friction$$

$$(mgh)_1 + \left(\frac{1}{2}mv^2\right)_1 + \left(\frac{1}{2}I\omega^2\right)_1 = (mgh)_2 + \left(\frac{1}{2}mv^2\right)_2 + \left(\frac{1}{2}I\omega^2\right)_2 + F_f \cdot d + T_f \cdot \theta$$

More useful formulae:

Belt-tension ratio	$\frac{t_1 - t_C}{t_2 - t_C} = e^{\mu \cdot \theta}$
Belt power	$P = (t_1 - t_C)\left(1 - \frac{1}{e^{\mu\theta}}\right)v$
Effect of belt-mass	$t_C = \dot{m} \cdot v^2$
Block-brake tension ratio	$\frac{t_1}{t_2} = \left[\frac{1 + \mu \cdot \tan\theta}{1 - \mu \cdot \tan\theta}\right]^n$
Friction circle	$x = r \cdot \sin\emptyset$
Sin rule	$\frac{\sin\alpha}{r} = \frac{\sin\theta}{(r + c)} = \frac{\sin(180° - \emptyset)}{(r + c)}$

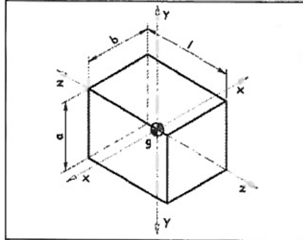
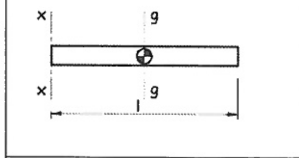
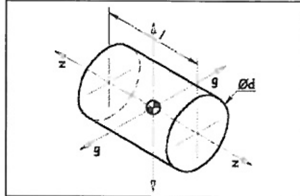
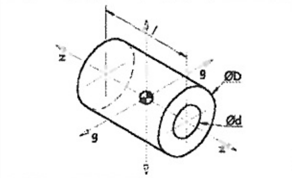
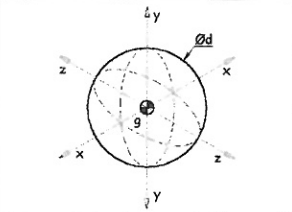
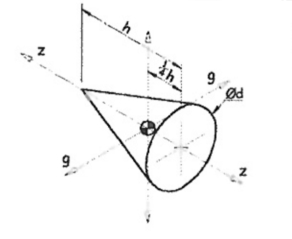
SECOND MOMENT OF MASS OF LAMINAE			
Figure	**Area**	**Centre of gravity**	**Moment of Inertia**
	$A = b \cdot d$	$\frac{1}{2}b$ & $\frac{1}{2}d$	$I_g = \frac{m \cdot d^2}{12}$ $I_x = \frac{m \cdot d^2}{3}$
	$A = \frac{1}{2} \cdot b \cdot d$	$\frac{1}{3}h$ from base	$I_g = \frac{m \cdot h^2}{18}$ $I_x = \frac{m \cdot h^2}{6}$
	$A = \frac{\pi}{4} \cdot d^2$	Centre	$I_x = I_y = \frac{m \cdot d^2}{16}$
	$A = \frac{\pi}{4}(D^2 - d^2)$	Centre	$I_x = \frac{m(D^2 + d^2)}{16}$

Definition: $I_x = \int y^2 \cdot dm$

Parallel axis theorem: $I_o = I_g + m \cdot h^2$

Perpendicular axis theorem: $I_z = I_x + I_y$ *(Laminae only)*

In general $I = m \cdot k^2$

SECOND MOMENT OF MASS OF SOLID BODIES		
Type of body	**Volume**	**Moment of Inertia**
	$V = a \cdot b \cdot l$	$I_x = \frac{m}{12}(a^2 + l^2)$ $I_y = \frac{m}{12}(b^2 + l^2)$ $I_z = \frac{m}{12}(a^2 + b^2)$
Slender rod – of any x-section 	$V = area \times l$	$I_g = \frac{m \cdot l^2}{12}$ $I_x = \frac{m \cdot l^2}{3}$
	$V = \frac{\pi}{4} \cdot d^2 \cdot l$	$I_z = \frac{m \cdot d^2}{8}$ $I_g = m\left(\frac{d^2}{16} + \frac{l^2}{12}\right)$
	$V = \frac{\pi}{4} \cdot (D^2 - d^2) \cdot l$	$I_z = \frac{m}{8}(D^2 + d^2)$ $I_g = m\left(\frac{D^2}{16} + \frac{d^2}{16} + \frac{l^2}{12}\right)$
	$V = \frac{\pi \cdot d^3}{6}$	$I_x = I_y = I_z = \frac{m \cdot d^2}{10}$
	$V = \frac{1}{3} \times \frac{\pi}{4} \cdot d^2 \cdot h$	$I_z = \frac{3 \cdot m \cdot d^2}{40}$ $I_g = \frac{3 \cdot m}{80} \cdot (d^2 + h^2)$