UNIVERSITY OF JOHANNESBURG

PROGRAM : NATIONAL DIPLOMA
MECHANICAL ENGINEERING

SUBJECT : **THEORY OF MACHINES III**

CODE : **MHT302**

DATE : SUMER EXAMINAT ION 2014
19th November 2014

DURATION : (SESSION 1) 8:30 – 11:30

WEIGHT : 40 : 60

TOTAL MARKS : 100

FULL MARKS : 100

EXAMINER : MRS. D IONESCU
MODERATOR : MR. W. HAUPT 2373
NUMBER OF PAGES : 8 PAGES AND 1 ANNEXURE

INSTRUCTIONS :

1. ATTEMPT ALL QUESTIONS.
2. ALL DIMENSIONS ON DIAGRAMS ARE IN mm UNLESS OTHERWISE SPECIFIED.
3. THE CANDIDATES MAY BRING INTO THE EXAM CENTRE:
   - CALCULATORS OF ANY MAKE OR MODEL.
   - ANY DRAWING BOARD OR DRAFTING HEAD
   - DRAWING INSTRUMENTS
4. ANSWERS WITHOUT UNITS WILL BE IGNORED.
5. RULE A LINE AFTER EACH QUESTION.
6. ANY UNKNOWN INFORMATION MAY BE ASSUMED WITH THE APPROPRIATE REFERENCING.

REQUIREMENTS : ONE SHEET OF A3 DRAWING PAPER PER CANDIDATE

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QUESTION 1

Figure 1 – a shows the schematic representation of a quick return mechanism. The crank OA is driven by link CB through a sliding and rotating block at A. The end C of the driving link CB is constrained to move vertically while the end B is constrained to move horizontally. When the members of the mechanism are in the position shown in figure 1 – a the sliding bloc C has a downward velocity and acceleration of 5 m/s and 120 m/s^2 respectively. Figure 1 – b shows an intermediate position of the mechanism when the driving link CB is assumed to rotate contra-clockwise. The velocity diagram shows the corresponding velocities of the different members for the position shown in figure 1 – a. For the given data, determine:

1.1 The values of the centripetal accelerations for AO; BC; and the Coriolis component of acceleration for block A; (4)

1.2 Draw a neat sketch to show the direction and sense of the sliding velocity and Coriolis component of acceleration for the block A; (2)

1.3 For the instant shown in figure 1 – a, construct the acceleration diagram inserting all salient (important) values; (15)

1.4 Determine the magnitude of the angular acceleration of the link OA; (2)

- ***For the acceleration diagram use a reducing scale of 1:4 (i.e. 4 m/s^2 = 1 mm on the drawing)***
- ***Draw your acceleration diagram on Annexe A, staring from the point "O" considering the following steps:***

1. ***Draw f_c***

2. ***Find point B using the following accelerations $(f_{bc})_c$; $(f_{bc})_t$ and the horizontal acceleration f_b;***

3. ***Join "b" with "c" and determine the position of point "a' "on the line "bc" using the proportionality rule;***

4. ***Find point "a" using the following two sets of accelerations: $(f_{aa'})_t$; $(f_{aa'})_c$ and $(f_{ao})_c$; $(f_{ao'})_t$ N.B. draw first $(f_{aa'})_t$ from point "a' ";***

Identify all your accelerations by values and name on your acceleration diagram.
Diagrams without acceleration values and names will be not considered.

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Question 1 continued

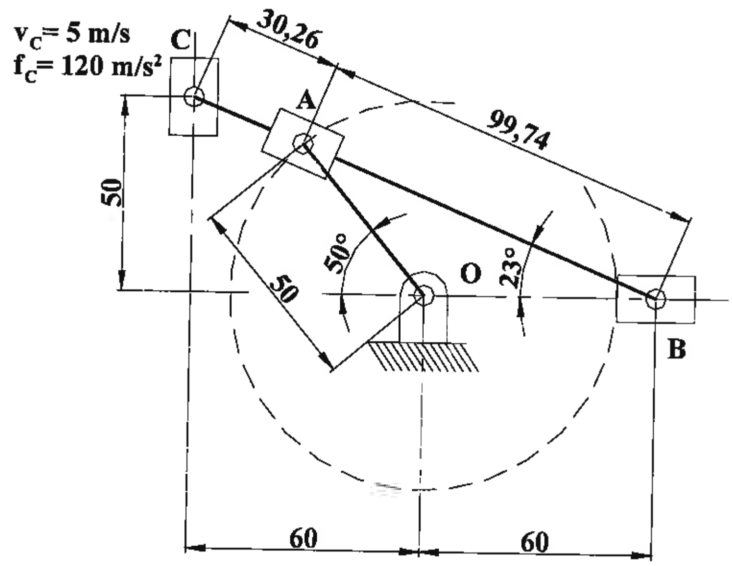

Figure 1 - a

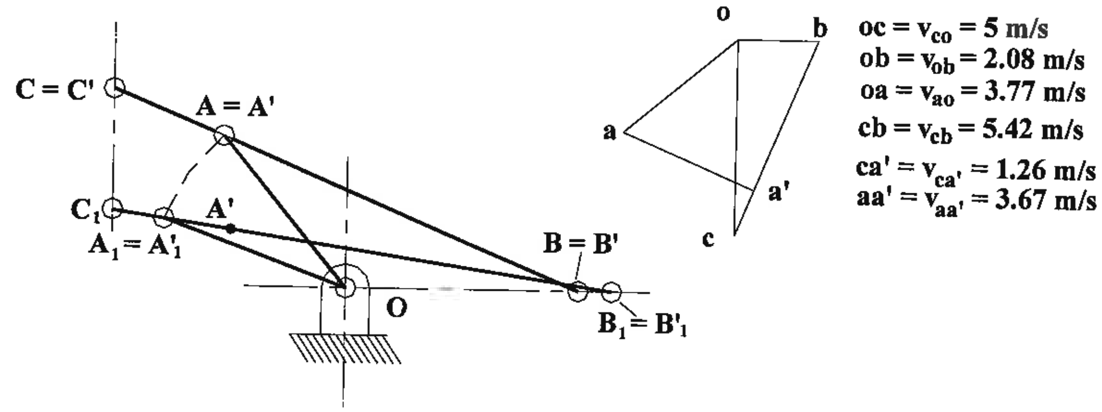

Figure 1 - b

Figures 1 – a and 1 – b

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QUESTION 2

A crank of a one piston engine rotates at 220 rev/min; the piston movement can be considered a simple harmonic motion. The piston has to overcome a resisting force which occurs at one-fifth of the stroke length as the piston is moving away from the top dead center (TDC).
The following data is available:

- Stroke length = 360 mm;
- Piston mass = 21 kg;
- Resisting force = 3.47 kN

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Question 2 continued

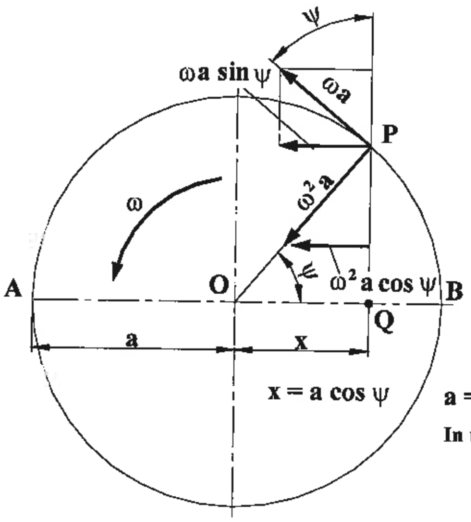
For the data given above:

2.1 Draw a neat sketch of a piston driven by a crank (i.e. represent the crank and the connecting rod by simple lines) shoving all salient values; (2)

2.2 Calculate the amplitude of the movement, the value of "x" and the angle "ψ" for the given position; (5)

2.3 Calculate the piston inertia force and the total resisting force. (2)

The following formulae may be used:



$\psi = \omega t$

$v = \omega a \sin\psi = \omega\sqrt{a^2 - x^2}$

$v_{max} = \omega a$ when $x = 0$

$f = \omega^2 a \cos\psi = \omega^2 x$

$f_{max} = \omega^2 a$ when $x = a$

a = amplitude of the motion

In triangle PQO, $PQ = \sqrt{a^2 - x^2}$

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QUESTION 3

A curved flank cam operating a flat-faced follower has the following dimensions:

- Base radius = 26 mm;
- Maximum lift = 17 mm;
- Nose radius = 5 mm;
- Total angle of action = 176^0; camshaft angular velocity = 1350 rev/min.

For the data given above determine:

3.1 The radius of the flank curvature; (6)

3.2 The angle at which the cam transfers the follower from flank to nose; (2)

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Question 3 continued

3.3 The change in acceleration of the follower as it transfers from flank to nose. (8)
N.B. see the diagram in figure 3 – a

Solving hints:

- ***Use the value of the maximum lift to calculate the value of "d" and then calculate "ρ"***

The following formulae may be used:

- ***Figure 3 – a shows the displacement, velocity and acceleration diagram for a curved flanked cam;***
- ***Figure 3 – b shows the general geometry for a curved flanked cam***

Cams with curved flanks, flat - ended follower

Flank

$$x = (\rho - R)(1 - \cos\theta)$$

$$v = \omega(\rho - R)\sin\theta$$

$$f = \omega^2(\rho - R)\cos\theta$$

$$\rho = \frac{R^2 - r^2 + d^2 - 2Rd\cos\alpha}{2(R - r - d\cos\alpha)}$$

$$\sin\psi = \frac{d\sin\alpha}{\rho - r}$$

Nose

$$x = (d\cos\phi + r) - R$$

$$v = \omega\, d\sin\phi$$

$$f = -\omega^2 d\cos\phi$$

Displacement, velocity and acceleration diagrams
Cam with curved flanks with flat ended follower

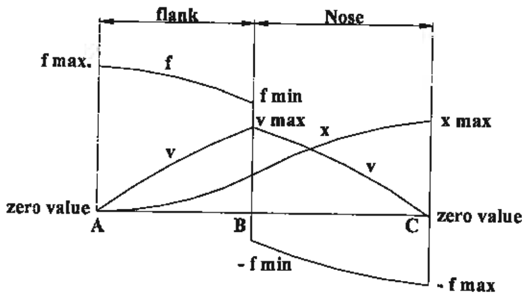

Fig. 3 – a

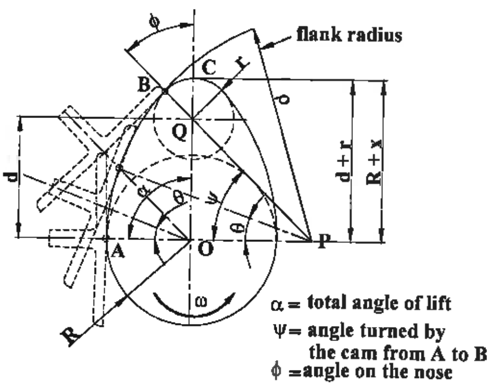

Fig. 3 – b

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QUESTION 4

A ship traveling in straight line, in order to enter the harbor, has to turn turns toward right (starboard) round a curve of 210 m radius, as seen by an observer from the back (aft) of the ship looking in the direction of movement. The power generating set is fixed on the ship with its longitudinal axis parallel to the longitudinal center-line of the ship. The following data is available:

- Total mass of the revolving parts of the generating set = 1750 kg;
- Radius of gyration of the revolving parts = 520 mm;
- Angular velocity of the generating set rotor = 460 rev/min;
- **The generating set rotates clockwise as seen from the back (aft) of the ship;**
- Velocity of the ship 44 km/hour;

4.1 With the aid of a sketch show the direction and sense of the inertia vectors "oa", "ob", the precession and the applied and reaction gyroscopic couples; (3)

4.2 Calculate the magnitude of the gyroscopic couple transmitted to the ship, when turning toward starboard; (5)

4.3 With the aid of a sketch show what is the effect of the reaction gyroscopic couple over the ship equilibrium position. Will the ship roll (oscillate from port to starboard) or pitch (oscillate from aft to bow)? (3)

Solving hints:

- ***Do not forget that the axis of precession is in the centre of the turning curve;***
- ***When looking forward in the direction of movement from the back of the ship:***
  Bow = the front of the ship; Aft = the back of the ship; Port = the left side of the ship; Starboard = the right side of the ship.

The following formulae may be used:

$$\mathbf{I = mk^2;\quad \Omega_{precession} = \frac{V_{ship}}{R_{curve}};\quad C = I \times \omega_{generator\ set} \times \Omega_{precession};}$$

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QUESTION 5

Figure 5 shows the graphic representation of an engine torque approximated by the equation: $\mathbf{T_e = 9500 + 1530 \sin 2\theta - 1230 \cos 2\theta}$, where θ is the crank-shaft angular displacement from the inner dead centre. The machine has a constant resisting torque of T_r = 9500 N·m and is driven by the engine through a direct coupling. If the engine runes at 160 rev/min, determine:

5.1 The power of the engine; (2)

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Question 5 continued

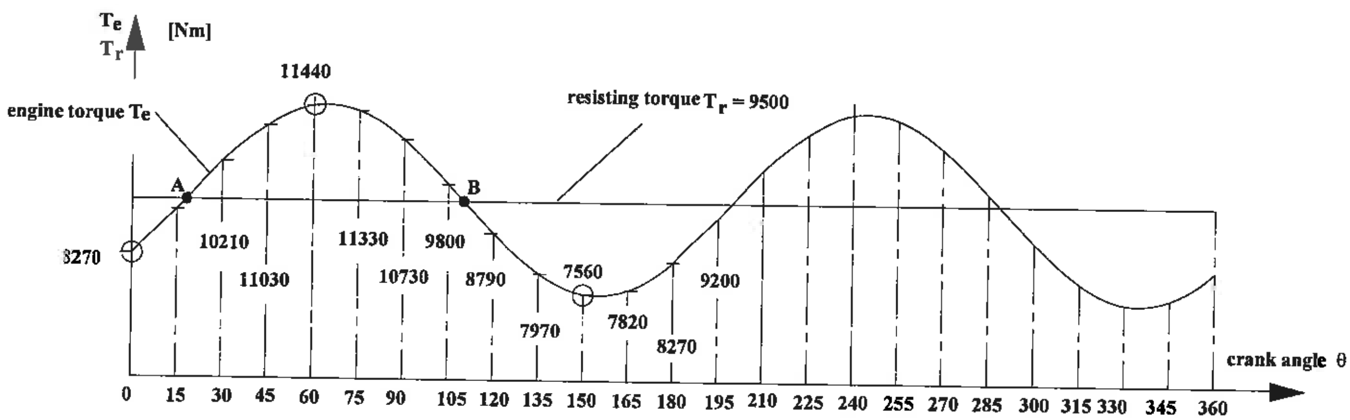
5.2 The moment of inertia of the flywheel if the speed variation is not to exceed ± 0.6 %; (12)

5.3 The angular acceleration of the flywheel when the crank has turned through 45^0. (4)

The following formulae may be used:

$$T_{mean} = T_r;\quad \text{Power} = T_{mean} \times \omega;\quad U = \int_A^B (T_e - T_r);\quad C_s = \frac{U}{I\omega^2};\quad \int_A^B \sin(cx) = \left[-\frac{1}{c}\cos(cx)\right]_A^B;$$

$$\int_A^B \cos(cx) = \left[\frac{1}{c}\sin(cx)\right]_A^B;\ \text{In points A and B } T_e = T_r;\quad (T_{neat})_{45^0} = (T_e)_{45^0} - (T_r)_{45^0};\quad T = I \times \alpha$$



θ	0	15	30	45	60	75	90	105	120	135	150	165	180	195
cos 2θ	1	0,866	0,5	0	-0,5	-0,866	-1	-0,866	-0,5	0	0,5	0,866	1	0,866
sin 2θ	0	0,5	0,866	1	0,866	0,5	0	-0,5	-0,866	-1	-0,866	-0,5	0	0,5

Fig. 5

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QUESTION 6

The centre-lines of successive cylinders of a four – cylinder in line reciprocating engine are spaced as follows: A to B 220 mm, B to C 260 mm, and C to D 220 mm. All the cranks have a radius of 80 mm. The crank A is positioned on vertical direction and the angle between cranks A and B is 70^0 measured in clockwise direction.

6.1 If the reciprocating masses of the outer cylinders A and D are 13 kg whilst those of the inner cylinders are each 18 kg, determine the angular disposition of the cranks for the primary forces to be in balance. Draw a neat sketch of the cranks arrangement showing clearly the angles between cranks (16)

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Question 6 continues

6.2 Find the magnitude and direction of the unbalanced primary couple for a crank speed of 20 rad/s. (7)

Solving hints:

- ***Place the reference plane at mid distance between cylinders B and C;***

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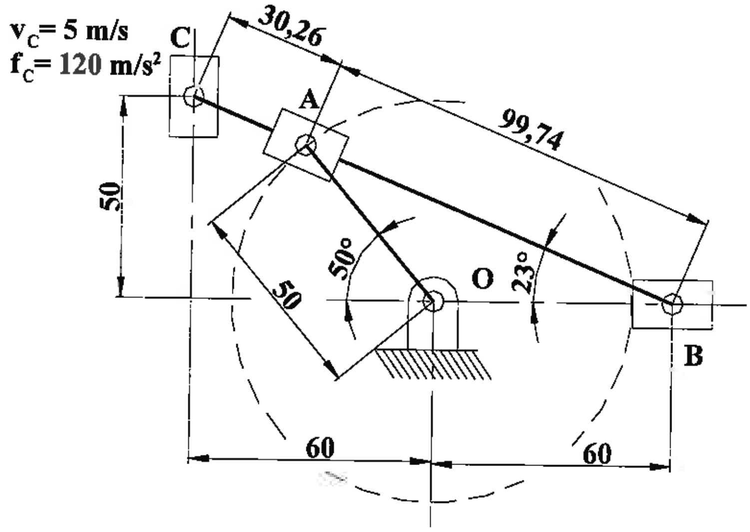
TOTAL MARKS = 100
FULL MARKS = 100

Annexe A



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