MACHAKOS UNIVERSITY

University Examinations 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FOURTH YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMM 402: MECHANICS OF MACHINES III

DATE:27/9/2019 **TIME: 2.00-4.00 PM**

INSTRUCTIONS:

1) This paper consists of **FIVE** questions.
2) Answer question **ONE** (compulsory) and any other **TWO** questions.
3) Use **CLEAR, NEAT** and **WELL-LABELLED** sketches.

QUESTION ONE (30 MARKS)

a) Using a neat sketch, briefly explain the following terms as refers to gearing:

i) Pitch circle **(1 Mark).**

ii) Addendum **(1 Mark).**

iii) Circular pitch **(1 Mark).**

iv) Clearance **(1 Mark).**

v) Face width **(1 Mark).**

b) State **THREE** advantages of involute gear profile and **THREE** advantages of cycloidal gear profile **(3 Marks).**

c) Consider a pinion driving a wheel as shown in **Fig. Q1(c).** When the pinion rotates in clockwise direction, the contact between a pair of involute teeth begins at *K* and ends at *L*. *MN* is the common normal at the point of contacts and the common tangent to the base circles. The point *K* is the intersection of the addendum circle of wheel and the common

tangent. The point *L* is the intersection of the addendum circle of pinion and common tangent.

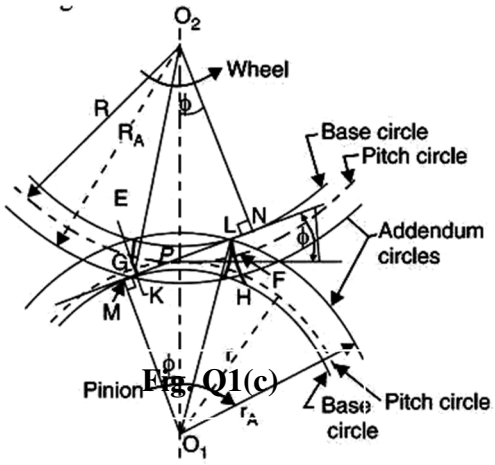

Fig. Q1(c)

Show that length of path of contact is;

$$\sqrt{(R_A)^2 - R^2\cos^2\phi} + \sqrt{(r_A)^2 - r^2\cos^2\phi} - (R+r)\sin\phi$$ **(10 Marks).**

and length of arc of contact is;

$$\frac{\text{Length of path of contact}}{\cos\phi}$$ **(5 Marks).**

d) A pinion having 20 teeth drives a gear having 80 teeth. The profile of the gears is involute with 14.5° pressure angle, 12 mm module and 8 mm addendum. Find the length of path of contact, arc of contact and the contact ratio **(10 Marks).**

QUESTION TWO (20 MARKS)

a) Discuss any **TWO** types of gear trains depending upon the arrangement of the wheels **(4 Marks).**

b) The speed ratio of the gear train, as shown in **Fig. Q2(b),** is to be 10. The module pitch of gears A and B is 3 mm and of gears C and D is 2 mm. Calculate the suitable numbers of teeth for the gears. No gear is to have less than 24 teeth **(6 Marks).**

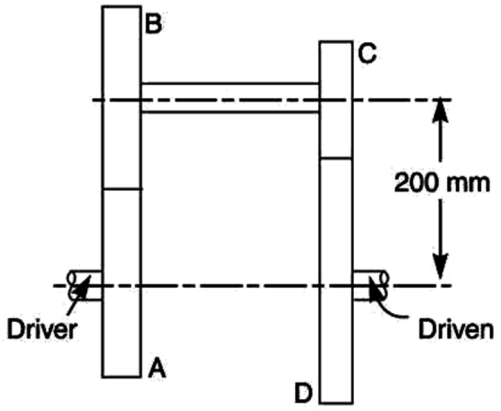

Fig. Q2(b)

c) An epicyclic train of gears is arranged as shown in **Fig. Q2(c).** How many revolutions does the arm, to which the pinions B and C are attached, make :

i) When A makes one revolution clockwise and D makes three quarters of a revolution anticlockwise **(5 Marks).**

ii) When A makes one revolution clockwise and D is stationary **(5 Marks).**

The number of teeth on the gears A and D are 40 and 90 respectively.

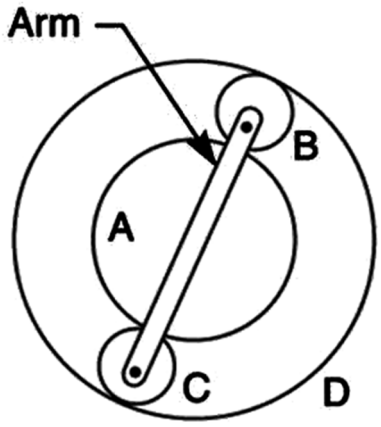

Fig. Q2(c)

QUESTION FOUR (THREE MARKS)

a) Depending upon the angles between the shafts and the pitch surfaces, state and briefly explain **FOUR** classifications of bevel gears **(2 Marks).**

b) Consider a pair of bevel gears in mesh, as shown in **Fig. Q3(b).**

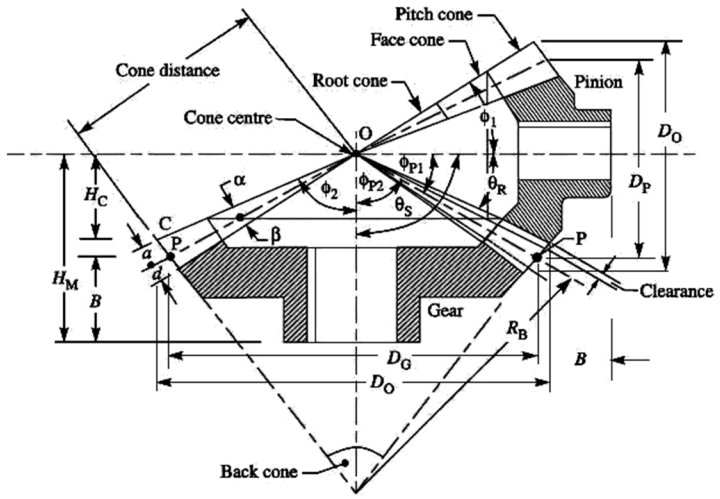

Fig. Q3(b)

Letting θ_{P1} = Pitch angle for the pinion, θ_{P2} = Pitch angle for the gear, θ_S = Angle between the two shaft axes, D_P = Pitch diameter of the pinion, D_G = Pitch diameter of the gear, T_P = Number of teeth on the pinion, T_G = Number of teeth on the gear, N_P = Speed of rotation of the pinion, N_G = Speed of rotation of gear and *V.R.* = Velocity ratio = $(D_G/D_P) = (T_G/T_P) = (N_P/N_G)$.

i) Show that $\theta_{P1} = \tan^{-1}\left(\frac{\sin\theta_S}{V.R+\cos\theta_S}\right)$ and $\theta_{P2} = \tan^{-1}\left(\frac{\sin\theta_S}{\frac{1}{V.R}+\cos\theta_S}\right)$. **(3 Marks).**

ii) When the angle between the shaft axes is 90º (θ_S = 90º), write other expressions for θ_{P1} and θ_{P2}. **(1 Mark).**

c) A 60 kW motor running at 1400 r.p.m. drives a compressor at 800 r.p.m. through a 90° bevel gearing arrangement. The pinion has 30 teeth. Determine; Velocity ratio, Number of teeth on the gear, T_G, θ_{P1}, θ_{P2}, Formative number of teeth for pinion, Formative number of teeth for the gear, Tooth form factor for the pinion and tooth form factor on the gear. The form factor for teeth may be taken as $0.124 - \frac{0.686}{T_E}$ where T_E is the number of teeth equivalent of a spur gear **(4 Marks).**

d) With neat sketches and brief explanations, state **TWO** types of worm and **TWO** types of worm gears **(5 Marks).**

e) A triple threaded worm has teeth of 6 mm module and pitch circle diameter of 70 mm. If the worm gear has 40 teeth of 14½° and the coefficient of friction of the worm gearing is 0.02. Find:

i) The lead angle of the worm **(1 Mark).**

ii) Velocity ratio **(1 Mark).**

iii) Centre distance **(1 Mark).**

iv) Efficiency of the worm gearing **(2 Marks).**

QUESTION FOUR (20 MARKS)

a) **Fig. Q3(a)** shows a rack and pinion in mesh. Letting t = Minimum number of teeth on the pinion to avoid interference, r = Pitch circle radius of the pinion = $m.t$ / 2, and ϕ = Pressure angle or angle of obliquity, and $A_R.m$ = Addendum for rack, where AR is the fraction by which the standard addendum of one module for the rack is to be multiplied. Show that

$$t = \frac{2A_R}{\sin^2 \phi}$$ **(1.5 Marks).**

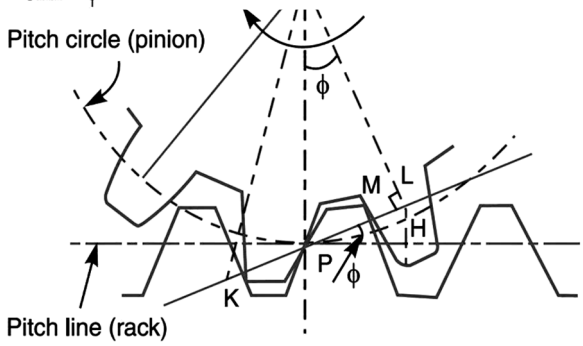

Fig. Q4(a)

b) A pinion of 30 involute teeth and 125 mm pitch circle diameter drives a rack. The addendum of both pinion and rack is 6.25 mm.

i) Find the least pressure angle which can be used to avoid interference **(2 Marks).**

With this pressure angle, find:

ii) The length of the arc of contact **(2 Marks).**

iii) The minimum number of teeth in contact at a time **(2 Marks).**

c) Using a neat sketch, define the following terms as applied to helical gears:

i) Normal pitch **(0.5 Mark).**

ii) Axial pitch **(0.5 Mark).**

iii) Helix angle **(0.5 Mark).**

a) A pair of spiral gears 1 and 2 in mesh is shown in **Fig. Q4(d)** below.

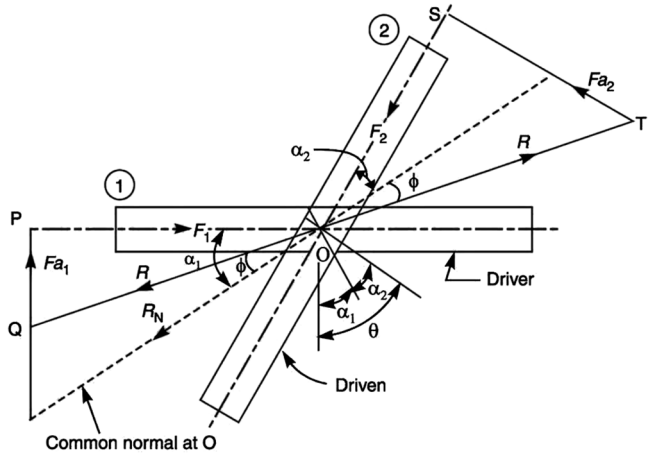

Fig. Q4(d)

Let the gear 1 be the driver and the gear 2 the driven. The forces acting on each of a pair of teeth in contact are shown in **Fig. Q4(d).** The forces are assumed to act at the centre of the width of each teeth and in the plane tangential to the pitch cylinders. Letting F_1 = Force applied tangentially on the driver, F_2 = Resisting force acting tangentially on the driven, F_{a1} = Axial or end thrust on the driver, F_{a2} = Axial or end thrust on the driven, R_N = Normal reaction at the point of contact, ∅= Angle of friction, R = Resultant reaction at the point of contact, θ = Shaft angle = $\alpha_1 + \alpha_2$ and η_{max} is the maximum efficiency. Show that;

$$\eta_{max} = \frac{\cos(\theta + \phi) + 1}{\cos(\theta - \phi) + 1}$$

(5 Marks)

b) A pair of spiral gears is required to connect two shafts 200 mm apart, the shaft angle being 55°. The velocity ratio is to be 1.5 to 1, the faster wheel having 80 teeth and a pitch circle diameter of 100 mm.

i) Find the spiral angles for each wheel **(4 Marks).**

ii) If the torque on the faster wheel is 85 N-m, find the axial thrust on each shaft, neglecting friction **(2 Marks).**

QUESTION FIVE (20 MARKS)

c) In order to avoid interference, the addendum circles for two mating gears must cut the common tangent to the base circles between the points of tangency as shown in Fig. Q5(a). The limiting condition reaches, when the addendum circles of pinion and wheel pass through points *N* and *M*. Letting t = Number of teeth on the pinion, T = Number of teeth on the wheel, r = Pitch circle radius of pinion = $m.t / 2$, G = Gear ratio = $T / t = R / r$ and $\emptyset$ = Pressure angle or angle of obliquity and m = Module of the teeth.

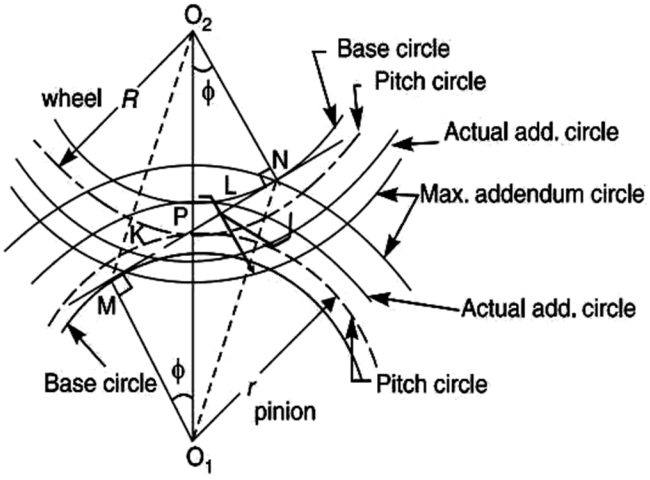

Fig. Q5(a): Interference in involute gears

Show that minimum number of teeth t, on the pinion in order to avoid interference (for G=1), is given by;

$$t = \frac{2A_p}{\sqrt{1+3\sin^2\phi - 1}}$$ **(6 Marks).**

d) Determine the minimum number of teeth required on a pinion, in order to avoid interference which is to gear with, (The pressure angle is 20° and a standard addendum of 1 module for the wheel)

i) A wheel to give a gear ratio of 3 to 1 **(2 Marks).**

ii) An equal wheel **(2 Marks).**

e) A pair of involute spur gears with 16° pressure angle and pitch of module 6 mm is in mesh. The number of teeth on pinion is 16 and its rotational speed is 340 r.p.m. When the gear ratio is 1.75, find in order that the interference is just avoided;

i) The addenda on pinion and gear wheel. **(2 Marks).**

ii) The length of path of contact **(3 Marks).**

iii) The maximum velocity of sliding of teeth on either side of the pitch point in the gear system **(5 Marks).**