

NEAR EAST UNIVERSITY
Department of Mechanical/Automotive Engineering
MAK304/ME304 Machine Design II
(Spring 2017)

Midterm Examination (Vize Sınavı)

April 1, 2017, 09:00 - 12:00

Name: Answer Key

ID Number: _____

Question No	Maximum Point	Point
1	30	
2	30	
3	30	
4	30	
Total	120	

Instructions

1. Yükseköğretim Kurumları 2015 Öğrenci Disiplin Yönetmeliği Madde 5-d ve 7-e'ye göre "sınavlarda kopyaya teşebbüs veya kopya çekmek yapmak veya yaptırmak veya bunlara teşebbüs etmek" fiilinin suçu YÜKSEKÖĞRETİM KURUMUNDAN BİR VEYA İKİ YARIYIL İÇİN UZAKLAŞTIRMA cezasıdır.

UYARI VE KURALLARI OKUDUM.

Signature: _____

Good luck!

Question 1 (30 points)

20-mm bore çapına sahip (02-series) derin yivli rulman (deep-groove ball bearing) 2000 dev/dak (rpm) dönerken 2.196 kN radyal ve 1.054 kN eksenel yükle yüklenmiştir. Rulmanın ömrünü

- (a) Dış bileziğin döndüğünü (the outer ring rotates) ve yüklemenin düzgün (steady) olduğu durumda bulunuz
- (b) İç bileziğin döndüğünü (the inner ring rotates) ve rulmanın hafif şoka (light shock) maruz kaldığını varsayıarak bulunuz.

A 20-mm (02-series) deep-groove ball bearing carries a combined load of 2.196 kN radially and 1.054 kN axially at 2000 rpm. Determine the rating life in hours if

- (a) The outer ring rotates and the load is steady
- (b) The inner ring rotates and the bearing is subjected to a light shock load

From Table 10.3 Bore diameter $D = 20 \text{ mm}$

$$C = 12.7 \text{ kN} \quad C_s = 6.20 \text{ kN}$$

$$F_r = 2.196 \text{ kN}$$

$$F_a = 1.054 \text{ kN}$$

- a) The outer ring rotates ($V = 1.2$)
load is steady $K_s = 1$

$$\frac{F_a}{\sqrt{F_r}} = \frac{1.054}{(1.2)(2.196)} = 0.4$$

$$\frac{F_a}{C_s} = \frac{1.054}{6.20} = 0.17$$

From Table 10.5 $\frac{F_a}{C_s} = 0.17 \Rightarrow e = 0.34$

$$\frac{F_a}{\sqrt{F_r}} = 0.4 > e = 0.34 \Rightarrow X = 0.56, Y = 1.31$$

$$P = K_s(XV F_r + Y F_a) = 1((0.56)(1.2)(2.196) + (1.31)(1.054)) = 2.856 \text{ kN}$$

$$L_{10} = \frac{10^6}{60n} \left(\frac{C}{P}\right)^9 = \frac{10^6}{(60)(2000)} \left(\frac{12.7}{2.856}\right)^3 = 732.75 \text{ hr}$$

b) The inner ring rotates ($V=1.0$)
 Bearing is subjected to light shock ($K_s=1.5$)

$$\frac{F_a}{V F_r} = \frac{1.054}{(1.0)(2.196)} = 0.48$$

$$\frac{F_a}{C_s} = \frac{1.054}{6.20} = 0.17$$

From Table 10.5 $\frac{F_a}{C_s} = 0.17 \Rightarrow e = 0.34$

$$\frac{F_a}{V F_r} = 0.48 > e = 0.34 \Rightarrow X = 0.56, Y = 1.31$$

$$P = K_s (X V F_r + Y F_a) = (1.5) ((0.56)(1.0)(2.196) + (1.31)(1.054))$$

$$P = 3.916 \text{ kN}$$

$$L_{10} = \frac{10^6}{60n} \left(\frac{C}{P} \right)^a = \frac{10^6}{(60)(2000)} \left(\frac{12.7}{3.916} \right)^3 = 284.25 \text{ hr}$$

Problem 2 (30 points)

Aşağıdaki şekilde gösterilen köşebent plaka (gusset plate) kolona (column) üç civata ile bağlanmıştır. Uzunluklar mm cinsindendir.

- Civataların serbest cisim diyagramını çiziniz
- Civataların ağırlık merkezini bulunuz
- Her bir civatadaki kesme kuvvetini bulunuz
- Civatanın çapı 14 mm olduğuna göre, her bir civatadaki kayma gerilmesini hesaplayınız

A gusset plate is attached to a column by three identical bolts and vertically loaded as shown in Figure below. The dimensions are in millimeters.

- Draw the free body diagram of the bolts
- Find the centroid of the bolts
- Determine shear forces in each bolt
- Calculate shear stress at each bolt if the diameter of the bolt is 14 mm.

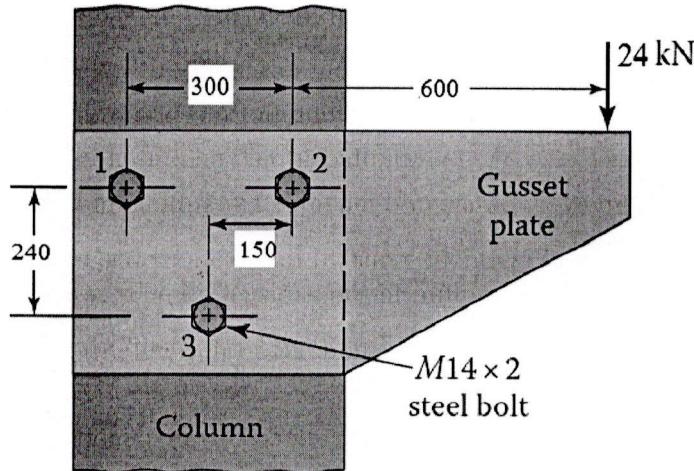
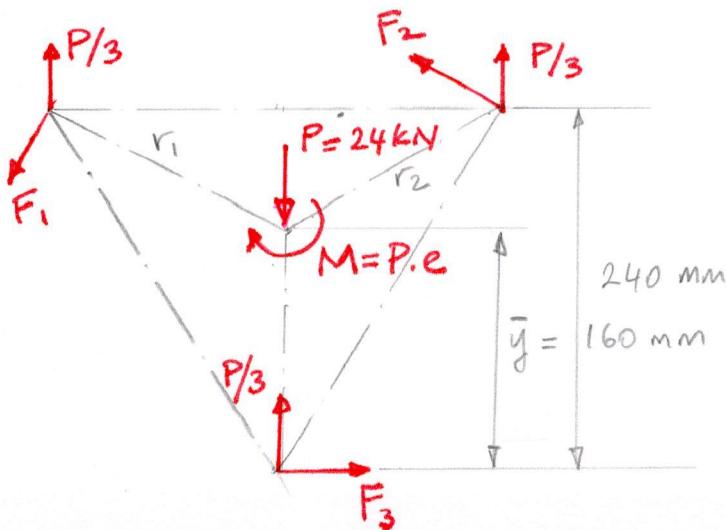


Figure 1: Figure for Question 2



$$\bar{x} \sum A = \sum_{i=1}^3 x_i A_i ; \quad \bar{y} \sum A = \sum_{i=1}^3 y_i A_i$$

$$\bar{x} = \frac{x_1 A_1 + x_2 A_2 + x_3 A_3}{A_1 + A_2 + A_3} = \frac{(-150)A + (150)A + 0A}{3A} = 0$$

$$\bar{y} = \frac{y_1 A_1 + y_2 A_2 + y_3 A_3}{A_1 + A_2 + A_3} = \frac{(240)A + (240)A + 0A}{3A} = 160 \text{ mm}$$

$$M = P \cdot e = (24000 \text{ N})(750 \text{ mm}) = 18 \times 10^6 \text{ N mm}$$

$$r_1 = r_2 = \sqrt{(150)^2 + 80^2} = 170 \text{ mm}$$

$$r_3 = 160 \text{ mm}$$

$$M = P \cdot e = F_1 r_1 + F_2 r_2 + F_3 r_3$$

$$\frac{F_1}{r_1} = \frac{F_2}{r_2} = \frac{F_3}{r_3} \quad \therefore \quad F_2 = F_1 \cdot \frac{r_2}{r_1}, \quad F_3 = F_1 \cdot \frac{r_3}{r_1}$$

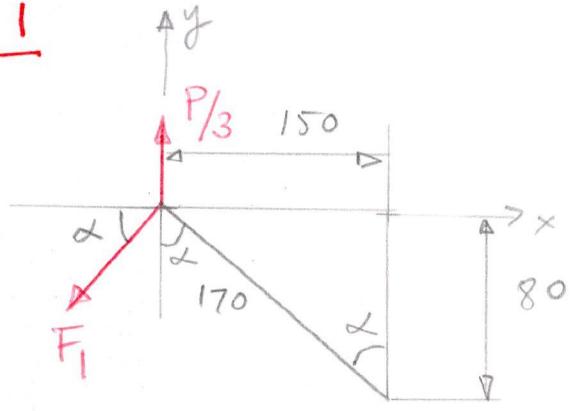
$$\begin{aligned} 18 \times 10^6 &= F_1 r_1 + \left(F_1 \frac{r_2}{r_1} \right) r_2 + \left(F_1 \cdot \frac{r_3}{r_1} \right) r_3 \\ &= \frac{F_1}{r_1} (r_1^2 + r_2^2 + r_3^2) \end{aligned}$$

$$F_1 = \frac{(18 \times 10^6) r_1}{r_1^2 + r_2^2 + r_3^2} \Rightarrow F_1 = 36690.65 \text{ N}$$

$$F_2 = F_1 \cdot \frac{r_2}{r_1} = 36690.65 \text{ N}$$

$$F_3 = F_1 \cdot \frac{r_3}{r_1} = 34532.38 \text{ N}$$

Bolt 1



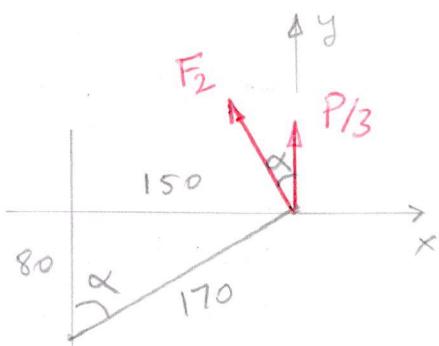
$$\cos \alpha = \frac{80}{170}, \sin \alpha = \frac{150}{170}$$

$$V_{1x} = -F_1 \cos \alpha = -17266.2$$

$$V_{1y} = \frac{P}{3} - F_1 \sin \alpha = -24374.1 \text{ N}$$

$$V_1 = \sqrt{V_{1x}^2 + V_{1y}^2} = 29870 \text{ N} = 29.87 \text{ kN}$$

Bolt 2



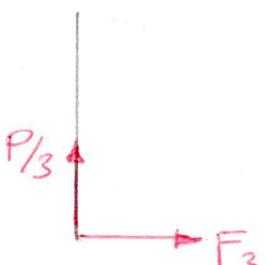
$$\cos \alpha = \frac{80}{170}, \sin \alpha = \frac{150}{170}$$

$$V_{2x} = -F_2 \sin \alpha = 32374.1 \text{ N}$$

$$V_{2y} = \frac{P}{3} + F_2 \cos \alpha = 25266.2 \text{ N}$$

$$V_2 = \sqrt{V_{2x}^2 + V_{2y}^2} = 41066.6 \text{ N} = 41.07 \text{ kN}$$

Bolt 3



$$V_{3x} = F_3 = 34532.38 \text{ N}$$

$$V_{3y} = \frac{P}{3} = 8000 \text{ N}$$

$$V_3 = \sqrt{V_{3x}^2 + V_{3y}^2} = 35446.96 \text{ N} \\ = 35.45 \text{ kN}$$

d)

$$\tau_1 = \frac{V_1}{A} = \frac{29870}{\frac{\pi (14)^2}{4}} = 194.04 \text{ MPa}$$

$$\tau_2 = \frac{V_2}{A} = \frac{41066.6}{\frac{\pi (14)^2}{4}} = 266.77 \text{ MPa}$$

$$\tau_3 = \frac{V_3}{A} = \frac{35446.96}{\frac{\pi (14)^2}{4}} = 230.27 \text{ MPa}$$

Problem 3 (30 points)

Aşağıdaki şekilde gösterilen kaynaklı bağlantı P yüklemesine maruz kalmaktadır as shown in the Figure below.

- Kaynak merkezini bulunuz
- Kaynakların polar atalet momentini bulunuz
- Emniyet faktörünü $n = 2.5$ alarak kaynak boyutunu belirleyiniz. Kaynak malzemesinin akma gerilmesi $S_y = 400$ MPa.

$$L_1 = 200 \text{ mm} \quad L_2 = 300 \text{ mm} \quad d = 2000 \text{ mm} \quad P = 5000 \text{ N}$$

A welded joint is subjected to out-of-plane eccentric force P as shown in the Figure below.

- Find the center of the welds
- Determine the polar moment inertia of the welds
- Determine the weld size h , if factor of safety is $n = 2.5$. Yield stress for the electrode rod is $S_y = 400$ MPa.

$$L_1 = 200 \text{ mm} \quad L_2 = 300 \text{ mm} \quad d = 2000 \text{ mm} \quad P = 5000 \text{ N}$$

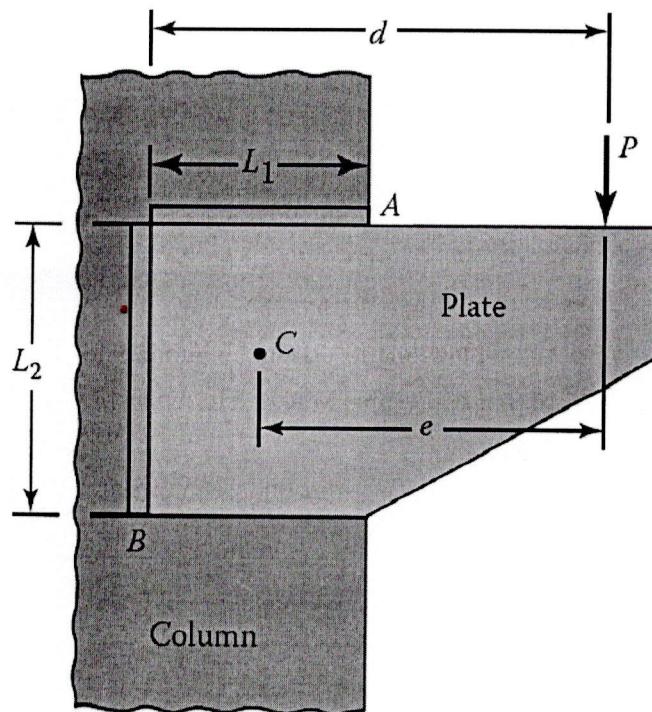
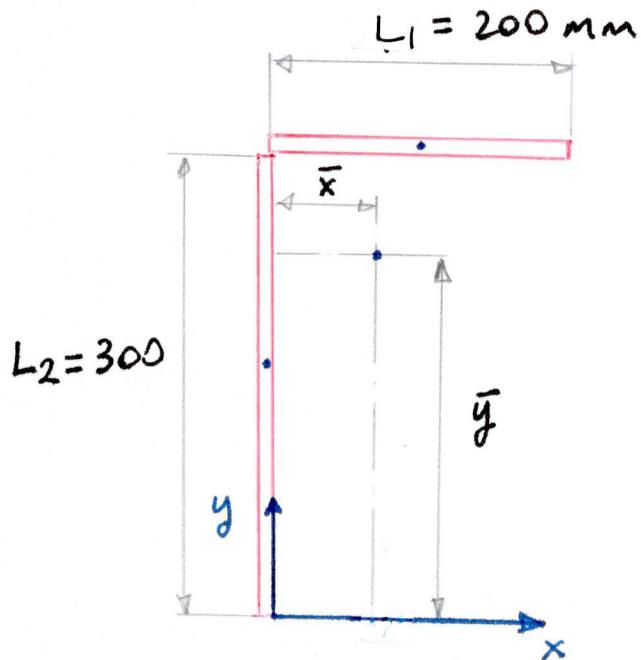


Figure 2: Figure for Question 3



$$A_1 = L_1 t = 200 t$$

$$A_2 = L_2 t = 300 t$$

$$\bar{x} = \frac{A_1 x_1 + A_2 x_2}{A_1 + A_2}$$

$$= \frac{(200t)(100) + (300t)(-\frac{t}{2})}{200t + 300t}$$

$$= \frac{20000t}{500t} = 40 \text{ mm}$$

$$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2}$$

$$= \frac{(200t)(300 + \frac{t}{2}) + (300t)(150)}{200t + 300t}$$

$$= \frac{60000t + 45000t}{500t} = 210 \text{ mm}$$

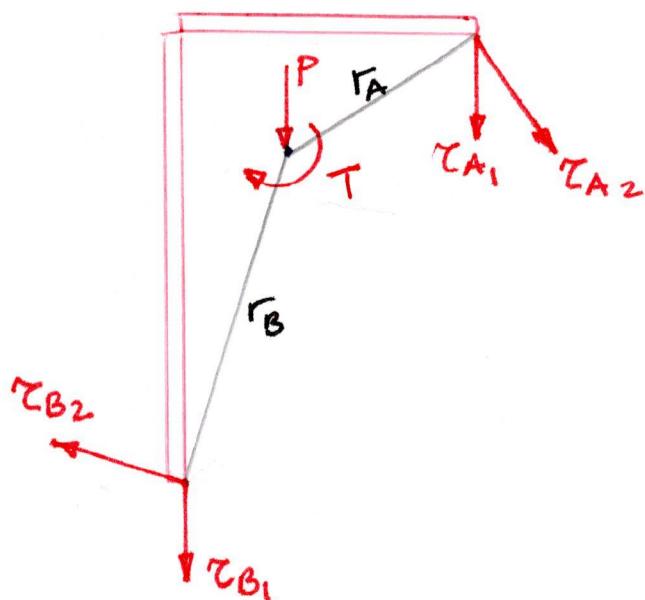
$$P = 5000 \text{ N}$$

$$e = d - \bar{x} = 2000 - 40 = 1960 \text{ mm}$$

$$T = P \cdot e = 9.8 \times 10^6 \text{ N mm}$$

$$r_A = \sqrt{160^2 + 90^2} = 183.576 \text{ mm}$$

$$r_B = \sqrt{210^2 + 40^2} = 213.776 \text{ mm}$$



$$I_{xx} = \frac{(200)t^3}{12} + (200t)90^2 + \frac{t300^3}{12} + (300t)60^2$$

$$= 4.95 \times 10^6 t$$

~~$$I_{yy} = \frac{t(200)^3}{12} + (200t)60^2 + \frac{300t^3}{12} + (300t)40^2$$~~

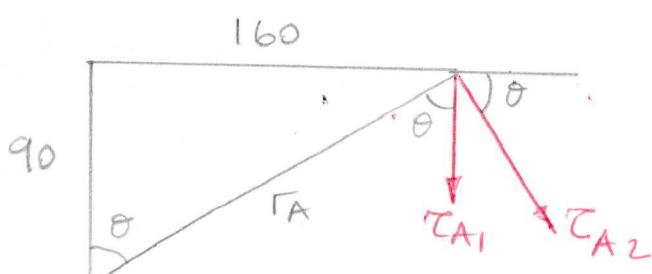
$$= 1.867 \times 10^6 t$$

$$J = I_{xx} + I_{yy} = 6.817 \times 10^6 t$$

$$\tau_{A_2} = \frac{T \cdot r_A}{J} = \frac{(9.8 \times 10^6)(183.576)}{6.817 \times 10^6 t} = \frac{263.9}{t} \text{ MPa}$$

$$\tau_{B_2} = \frac{T \cdot r_B}{J} = \frac{(9.8 \times 10^6)(213.776)}{6.817 \times 10^6 t} = \frac{307.3}{t} \text{ MPa}$$

$$\tau_{A_1} = \tau_{B_1} = \frac{P}{A_1 + A_2} = \frac{5000}{200t + 300t} = \frac{10}{t} \text{ MPa}$$



$$\cos\theta = \frac{90}{r_A}, \sin\theta = \frac{160}{r_A}$$

$$\tau_{Ax} = \tau_{A_2} \cos\theta = \frac{129.38}{t}$$

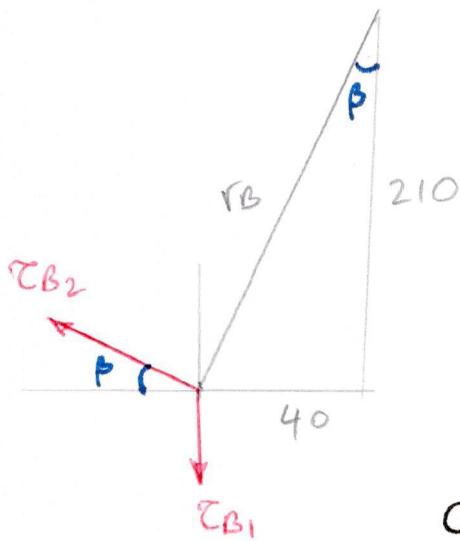
$$\tau_{Ay} = \tau_{A_1} + \tau_{A_2} \sin\theta$$

$$\tau_A = \sqrt{\tau_{Ax}^2 + \tau_{Ay}^2}$$

$$\tau_{Ay} = \frac{240}{t}$$

$$= \frac{272.65}{t}$$

$$\cos \beta = \frac{210}{r_B} , \sin \beta = \frac{40}{r_B}$$



$$\tau_{Bx} = \tau_{B2} \cos \beta = \frac{301.87}{t}$$

$$\tau_{By} = \tau_{B2} \sin \beta - \tau_{B1} = \frac{47.5}{t}$$

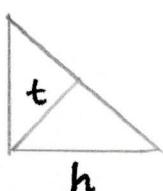
$$\tau_B = \sqrt{\tau_{Bx}^2 + \tau_{By}^2} = \frac{305.58}{t}$$

Critical point is B

$$\tau_{all} = (0.5) s_y = (0.5) 400 = 200 \text{ MPa}$$

$$n = \frac{\tau_{all}}{\tau_B} \Rightarrow \tau_B = \frac{\tau_{all}}{n} = \frac{200}{2.5} = 80 \text{ MPa}$$

$$80 = \frac{305.58}{t} \Rightarrow t = 3.82 \text{ mm}$$



$$h = \frac{t}{\cos 45} = 5.4 \text{ mm}$$

Problem 4 (30 points) Aşağıdaki şekilde gösterilen A ve B millerin merkezleri arasındaki mesafe c 'dir ve çapsal adımı 3-teeth/in., basınç açısı, 20° olan düz dişlilerle (1 ve 2) bağlanmıştır. Bu dişliler arasındaki hız oranı r_s 'tir. Pinyon ve dişli için

- (a) Diş sayısını, N .
- (b) temel dairenin yarıçapını (the radius of the base circle r_b) ve dış çapı (outside diameter d_o)
- (c) boşluğu (clearance, f).
- (d) 2. dişlinin n_2 hızında döndüğünü varsayıarak, taksimat dairesindeki hızı (The pitch-line velocity V)

bulunuz.

Verilenler: $n_2 = 1000$ rpm, $r_s = 1/4$, $c = 20$ in, $P = 2 \text{ in}^{-1}$, $\phi = 20^\circ$

$$pN = \pi d, \quad pP = \pi, \quad m = 1/P$$

Two shafts A and B with center distance c are to be connected by 2-teeth/in. diametral pitch, 20° pressure angle, spur gears 1 and 2 providing a velocity ratio of r_s as shown in the Figure below. Determine for each gear

- (a) The number of teeth N .
- (b) The radius of the base circle r_b and outside diameter d_o
- (c) Clearance f .
- (d) The pitch-line velocity V , if gear 2 rotates at speed n_2 .

Given: $n_2 = 1000$ rpm, $r_s = 1/4$, $c = 20$ in, $P = 2 \text{ in}^{-1}$, $\phi = 20^\circ$

$$pN = \pi d, \quad pP = \pi, \quad m = 1/P$$

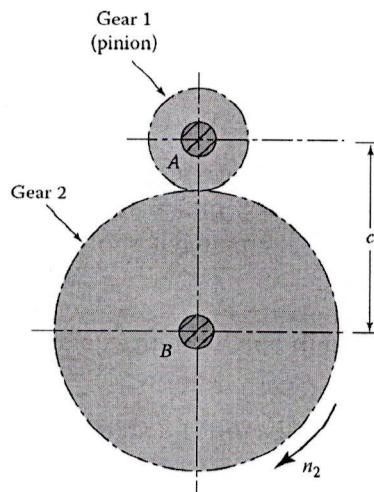


Figure 3: Figure for Question 3

4)

$$pN = \pi d$$

$$pP = \pi \Rightarrow P = \frac{\pi}{P} \Rightarrow \frac{\pi}{P} N = \pi d \Rightarrow d = \frac{N}{P}$$

$$P = 2 \text{ m}^{-1} \Rightarrow d = \frac{N}{2} \Rightarrow d_1 = \frac{N_1}{2}, d_2 = \frac{N_2}{2}$$

$$c = \frac{d_1 + d_2}{2} = 20 \text{ m} \Rightarrow d_1 + d_2 = 40 \text{ m} \Rightarrow \frac{N_1 + N_2}{2} = 40$$

a)

$$r_s = \frac{1}{4} = \frac{d_1}{d_2} = \frac{N_1}{N_2} \Rightarrow N_2 = 4N_1 \Rightarrow N_1 + 4N_1 = 80$$

$$5N_1 = 80$$

$$N_1 = 16$$

$$N_2 = 4N_1 = 64$$

$$r_1 \cos \phi = r_{b1}$$

$$r_{b1} =$$

$$d_1 = \frac{N_1}{2} = \frac{16}{2} = 8 \text{ m}$$

$$d_2 = \frac{N_2}{2} = \frac{64}{2} = 32 \text{ m}$$

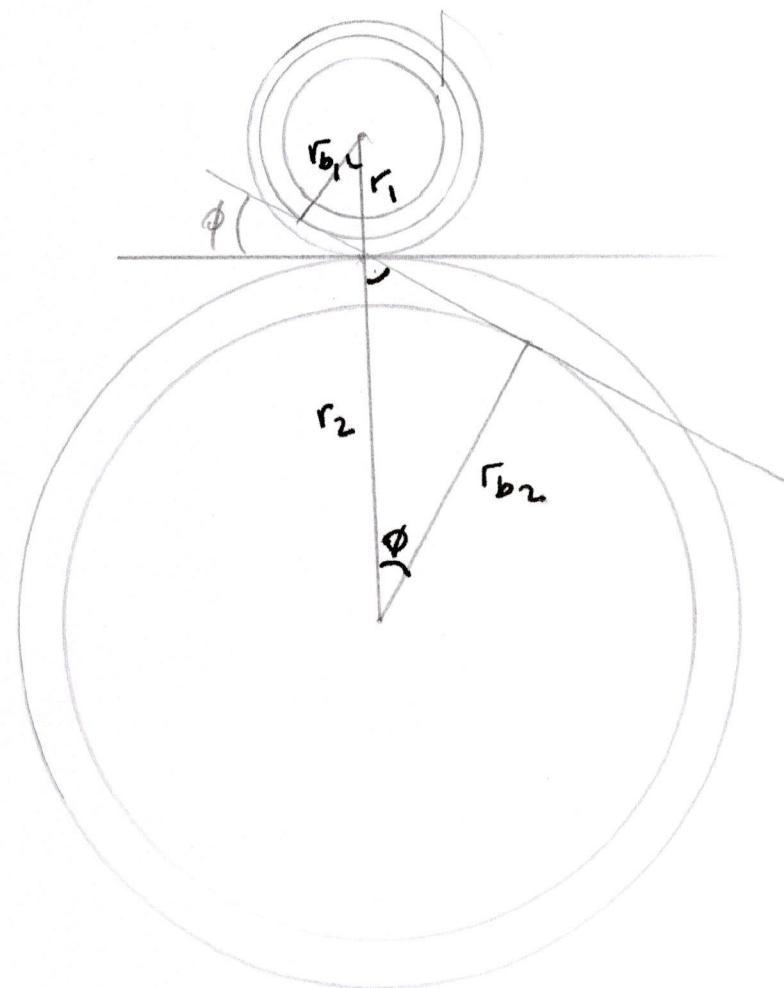
$$r_{b1} = r_1 \cos \phi = 4 \cos 20^\circ =$$

$$r_{b1} = 3.759 \text{ m}$$

$$r_{b2} = r_2 \cos \phi = 16 \cos 20^\circ$$

$$r_{b2} = 15.035 \text{ m}$$

b.)



c) For 20° full depth

$$a = \frac{1}{P} = \frac{1}{2} \text{ in}$$

$$r_{o1} = r_1 + a = 4 + 0.5 = 4.5 \text{ in} \Rightarrow d_{o1} = 9 \text{ in}$$

$$r_{o2} = r_2 + a = 16 + 0.5 = 16.5 \text{ in} \Rightarrow d_{o2} = 33 \text{ in}$$

C clearance

$$f = \frac{0.25}{P} = \frac{0.25}{2} = 0.125$$

d) $V = \omega_2 r_2$

$$\omega_2 = n_2 \frac{2\pi}{60} = 1000 \cdot \frac{2\pi}{60} = \frac{100\pi}{3}$$

$$V = \frac{100\pi}{3} \times 16 \text{ in} = 1675.5 \frac{\text{in}}{\text{s}} =$$

$$V = 1675.5 \frac{\text{in}}{\text{s}} \cdot \frac{1 \text{ ft}}{12 \text{ in}} = 139.63 \text{ fps}$$

$$V = 139.63 \frac{\text{ft}}{\text{s}} \cdot \frac{60 \text{ s}}{1 \text{ min}} = 8377.6 \text{ fpm}$$