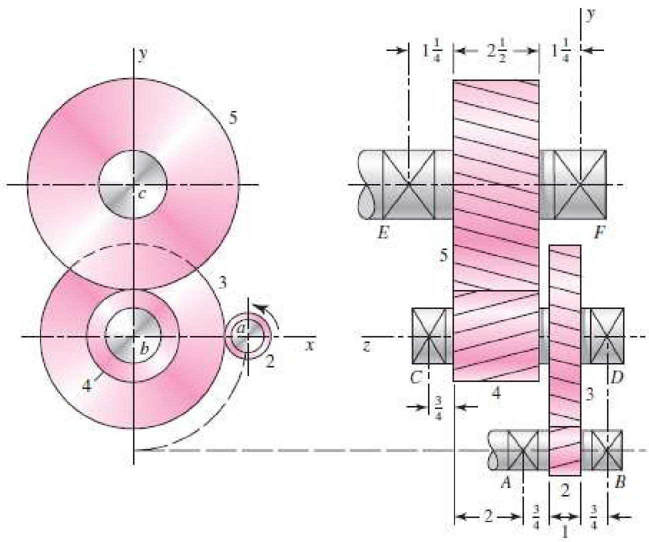
13–16 The double-reduction helical gearset shown in the figure is driven through shaft a at a speed of 700 rev/min. Gears 2 and 3 have a normal diametral pitch of 12 teeth/in, a 30° helix angle, and a normal pressure angle of 20°. The second pair of gears in the train, gears 4 and 5, have a normal diametral pitch of 8 teeth/in, a 25° helix angle, and a normal pressure angle of 20°. The tooth numbers are: $N_2 = 12$, $N_3 = 48$, $N_4 = 16$, $N_5 = 36$. Find:

(*a*) The directions of the thrust force exerted by each gear upon its shaft

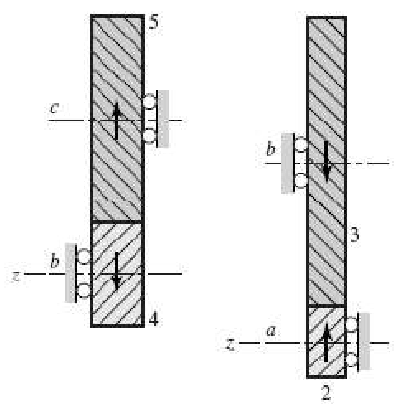
(*b*) The speed and direction of shaft c

(*c*) The center distance between shafts

Problem 13–16
Dimensions in inches.



13-16 (a) Sketches of the figures are shown to determine the axial forces by inspection.



The axial force of gear 2 on shaft a is in the negative z-direction. The axial force of gear 3 on shaft b is in the positive z-direction. *Ans.*

The axial force of gear 4 on shaft b is in the positive z-direction. The axial force of gear 5 on shaft c is in the negative z-direction. *Ans.*

(b) $$n_c = n_5 = \frac{12}{48}\left(\frac{16}{36}\right)(700) = +77.78 \text{ rev/min ccw} \quad \textit{Ans.}$$

(c) $$d_{P2} = 12/\left(12\cos 30^\circ\right) = 1.155 \text{ in}$$

$$d_{G3} = 48/\left(12\cos 30^\circ\right) = 4.619 \text{ in}$$

$$C_{ab} = \frac{1.155 + 4.619}{2} = 2.887 \text{ in} \quad \textit{Ans.}$$

$$d_{P4} = 16/\left(8\cos 25^\circ\right) = 2.207 \text{ in}$$

$$d_{G5} = 36/\left(8\cos 25^\circ\right) = 4.965 \text{ in}$$

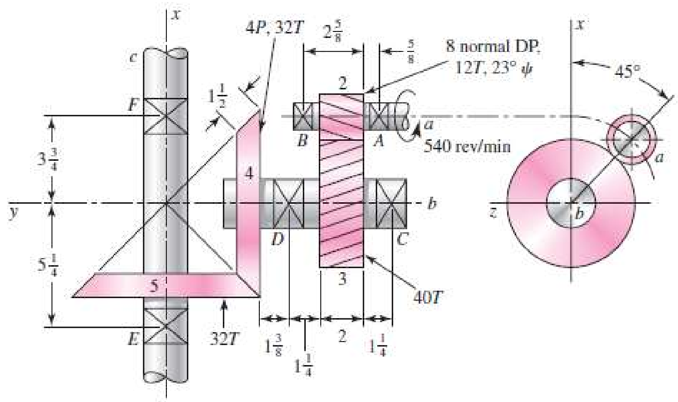
$$C_{bc} = 3.586 \text{ in} \quad \textit{Ans.}$$

13–19 The figure shows a gear train consisting of a pair of helical gears and a pair of miter gears. The helical gears have a $17\frac{1}{2}^\circ$ normal pressure angle and a helix angle as shown. Find:

(*a*) The speed of shaft *c*

(*b*) The distance between shafts *a* and *b*

(*c*) The diameter of the miter gears



Problem 13–19
Dimensions in inches.

13-19 (a) $n_c = \dfrac{12}{40} \cdot \dfrac{1}{1}(540) = 162$ rev/min cw about x. *Ans.*

(b) $d_P = 12/(8\cos 23^\circ) = 1.630$ in

$d_G = 40/(8\cos 23^\circ) = 5.432$ in

$\dfrac{d_P + d_G}{2} = 3.531$ in *Ans.*

(c) $d = \dfrac{32}{4} = 8$ in at the large end of the teeth. *Ans.*

13–24 A gearbox is to be designed with a compound reverted gear train that transmits 25 horsepower with an input speed of 2500 rev/min. The output should deliver the power at a rotational speed in the range of 280 to 300 rev/min. Spur gears with 20° pressure angle are to be used. Determine suitable numbers of teeth for each gear, to minimize the gearbox size while providing an output speed within the specified range. Be sure to avoid an interference problem in the teeth.

13-24 $H = 25$ hp, $\omega_i = 2500$ rev/min
Let $\omega_o = 300$ rev/min for minimal gear ratio to minimize gear size.

$$\frac{\omega_o}{\omega_i} = \frac{300}{2500} = \frac{1}{8.333}$$

$$\frac{\omega_o}{\omega_i} = \frac{1}{8.333} = \frac{N_2}{N_3}\frac{N_4}{N_5}$$

Let $$\frac{N_2}{N_3} = \frac{N_4}{N_5} = \sqrt{\frac{1}{8.333}} = \frac{1}{2.887}$$

From Eq. (13-11) with $k = 1$, $\phi = 20°$, and $m = 2.887$, the minimum number of teeth on the pinions to avoid interference is 15.

Let $N_2 = N_4 = 15$ teeth
$N_3 = N_5 = 2.887(15) = 43.31$ teeth

Try $N_3 = N_5 = 43$ teeth.

$$\omega_o = \left(\frac{15}{43}\right)\left(\frac{15}{43}\right)(2500) = 304.2$$

Too big. Try $N_3 = N_5 = 44$.

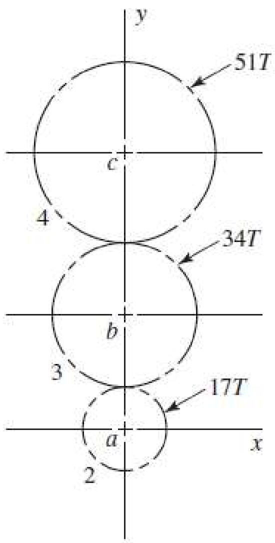
$$\omega_o = \left(\frac{15}{44}\right)\left(\frac{15}{44}\right)(2500) = 290.55 \text{ rev/min}$$

$N_2 = N_4 = 15$ teeth, $N_3 = N_5 = 44$ teeth *Ans.*

13–31 Shaft a in the figure has a power input of 75 kW at a speed of 1000 rev/min in the counter-clockwise direction. The gears have a module of 5 mm and a 20° pressure angle. Gear 3 is an idler.

(a) Find the force F_{3b} that gear 3 exerts against shaft b.

(b) Find the torque T_{4c} that gear 4 exerts on shaft c.



13-31 (a)

$$\omega = 2\pi n/60$$

$$H = T\omega = 2\pi T n/60 \quad (T \text{ in N}\cdot\text{m}, H \text{ in W})$$

So

$$T = \frac{60H(10^3)}{2\pi n}$$

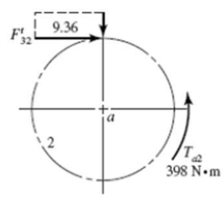
$$= 9550\ H/n\ (H \text{ in kW}, n \text{ in rev/min})$$

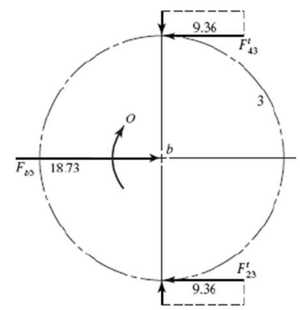
$$T_a = \frac{9550(75)}{1800} = 398\ \text{N}\cdot\text{m}$$

$$r_2 = \frac{mN_2}{2} = \frac{5(17)}{2} = 42.5\ \text{mm}$$

So

$$F_{32}^t = \frac{T_a}{r_2} = \frac{398}{42.5} = 9.36\ \text{kN}$$





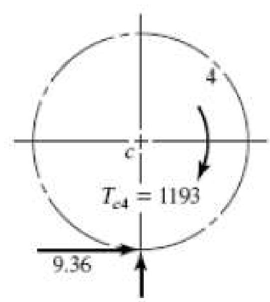
$$F_{3b} = -F_{b3} = 2(9.36) = 18.73 \text{ kN in the positive } x\text{-direction.} \quad \textit{Ans.}$$

(b)

$$r_4 = \frac{mN_4}{2} = \frac{5(51)}{2} = 127.5\ \text{mm}$$

$$T_{c4} = 9.36(127.5) = 1193\ \text{N}\cdot\text{m ccw}$$

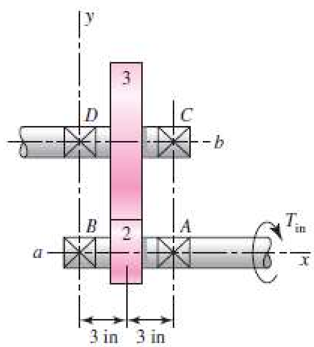
$$\therefore T_{4c} = 1193\ \text{N}\cdot\text{m cw} \quad \textit{Ans.}$$



Note: The solution is independent of the pressure angle.

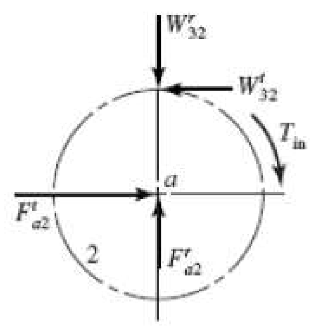
13–34 The figure shows a pair of shaft-mounted spur gears having a diametral pitch of 5 teeth/in with an 18-tooth 20° pinion driving a 45-tooth gear. The horsepower input is 32 maximum at 1800 rev/min. Find the direction and magnitude of the maximum forces acting on bearings *A*, *B*, *C*, and *D*.

Problem 13–34



13-34 Given: $P = 5$ teeth/in, $N_2 = 18T$, $N_3 = 45T$,
$\phi_n = 20^\circ$, $H = 32$ hp, $n_2 = 1800$ rev/min

Gear 2



$$T_{in} = \frac{63025(32)}{1800} = 1120 \text{ lbf} \cdot \text{in}$$

$$d_P = \frac{18}{5} = 3.600 \text{ in}$$

$$d_G = \frac{45}{5} = 9.000 \text{ in}$$

$$W^t_{32} = \frac{1120}{3.6/2} = 622 \text{ lbf}$$

$$W^r_{32} = 622 \tan 20^\circ = 226 \text{ lbf}$$

$$F^t_{a2} = W^t_{32} = 622 \text{ lbf}, \quad F^r_{a2} = W^r_{32} = 226 \text{ lbf}$$

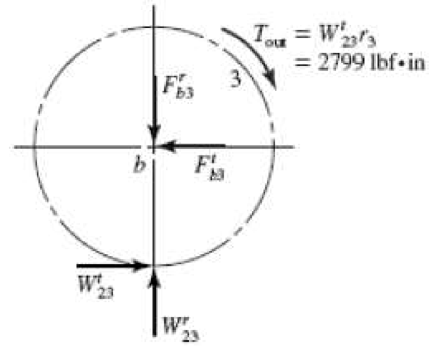
$$F_{a2} = \left(622^2 + 226^2\right)^{1/2} = 662 \text{ lbf}$$

Each bearing on shaft a has the same radial load of $R_A = R_B = 662/2 = 331$ lbf.

Each bearing on shaft *a* has the same radial load of $R_A = R_B = 662/2 = 331$ lbf.

Gear 3

$$W_{23}^{t} = W_{32}^{t} = 622 \text{ lbf}$$
$$W_{23}^{r} = W_{32}^{r} = 226 \text{ lbf}$$
$$F_{b3} = F_{b2} = 662 \text{ lbf}$$
$$R_C = R_D = 662/2 = 331 \text{ lbf}$$



Each bearing on shaft *b* has the same radial load which is equal to the radial load of bearings *A* and *B*. Thus, all four bearings have the same radial load of 331 lbf. *Ans.*