Gears

ME 423: Machine Design
Instructor: Ramesh Singh

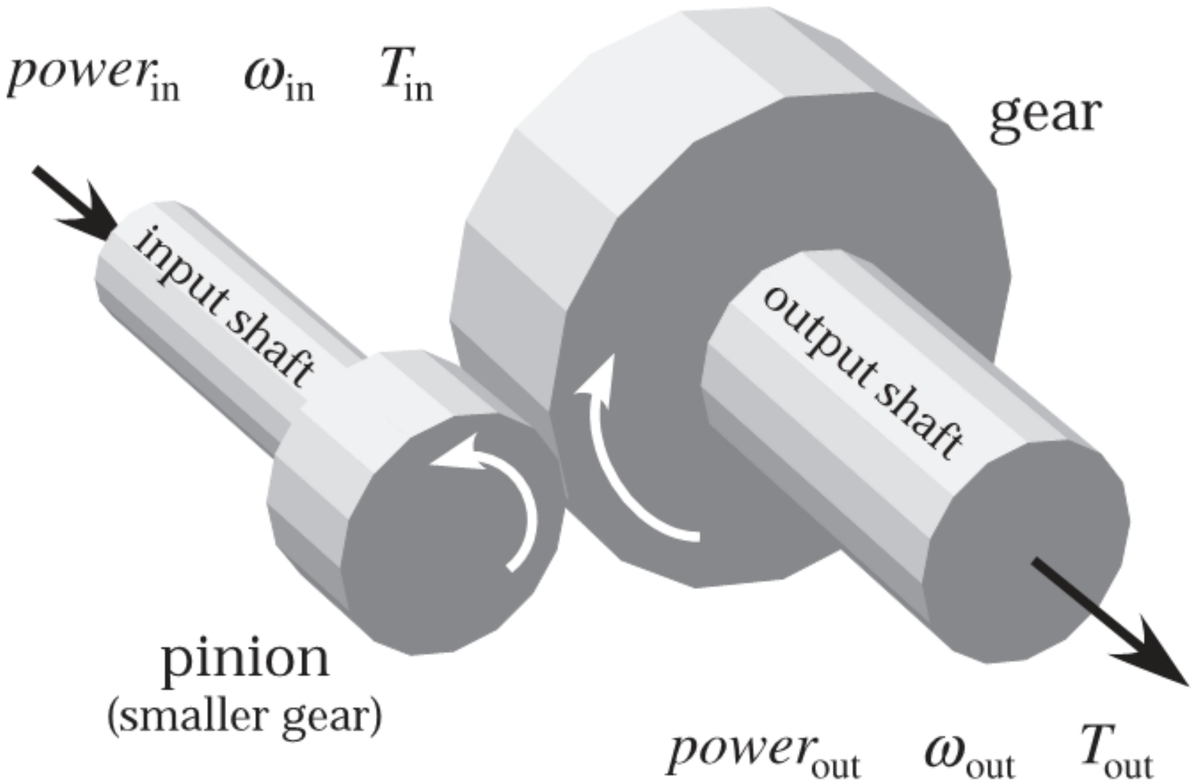
Outline

- Types of Gear
- Nomenclature
- Basic Gear Concepts
- Gear Trains

Functions of a Gear

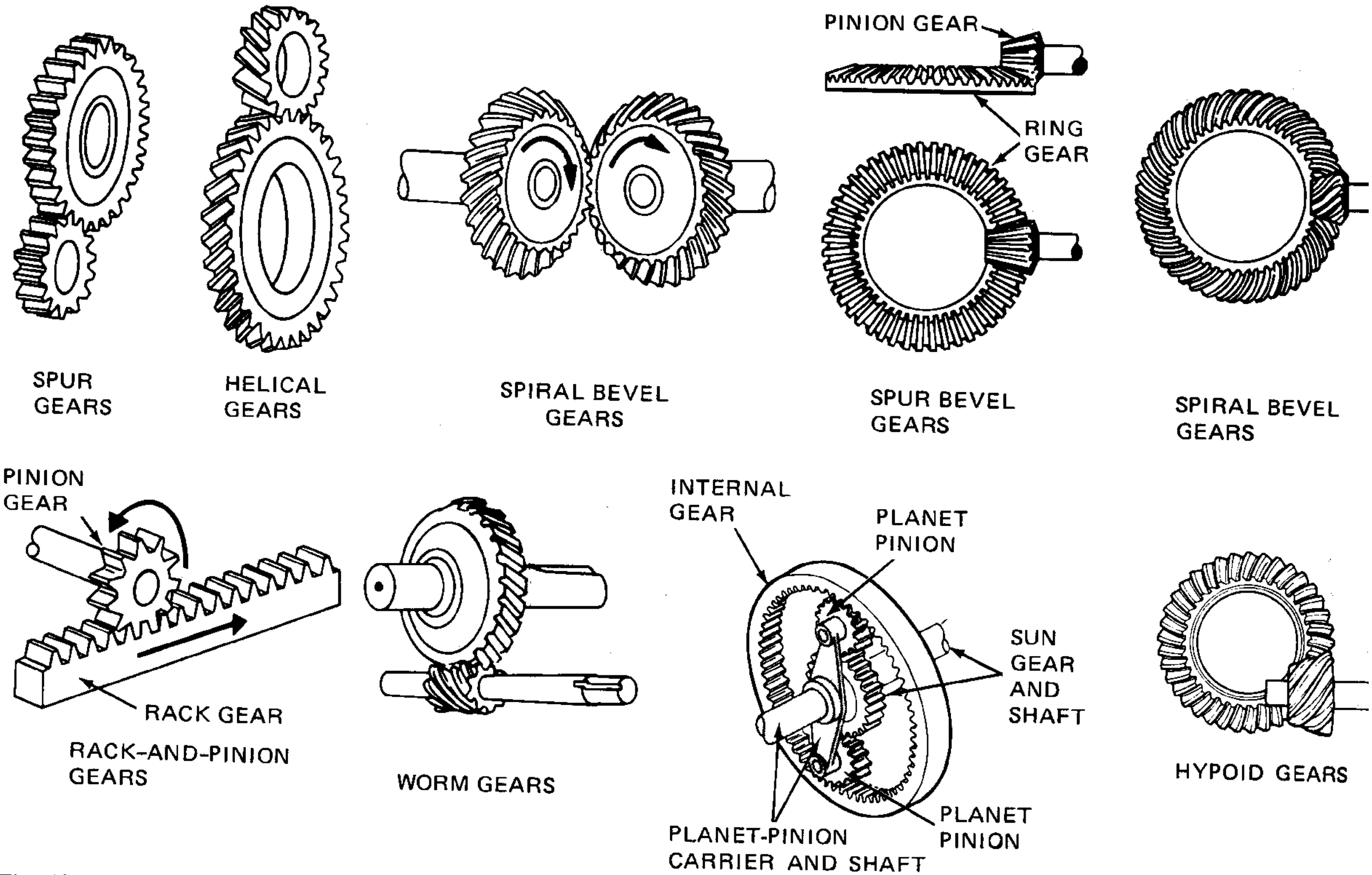
- Power transmission
- Change rotational speed/torque
- Maintain constant speed ratio

Gear

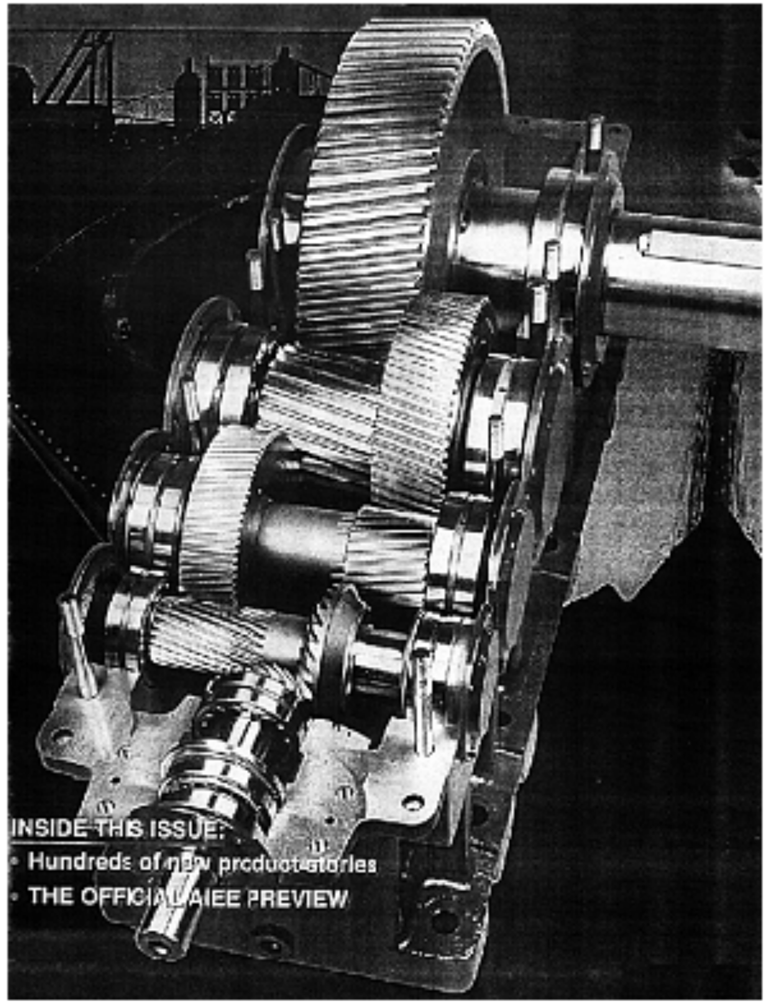


$power_{in}$ ω_{in} T_{in}
input shaft
gear
output shaft
pinion
(smaller gear)
$power_{out}$ ω_{out} T_{out}

Types of Gears



Gear Box



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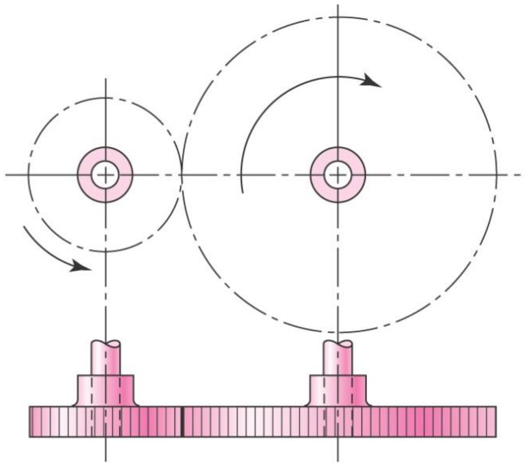
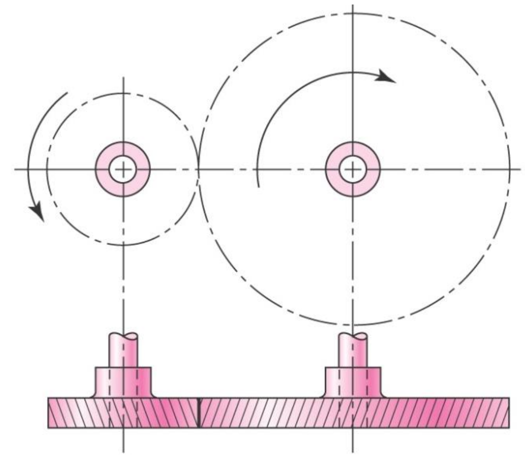
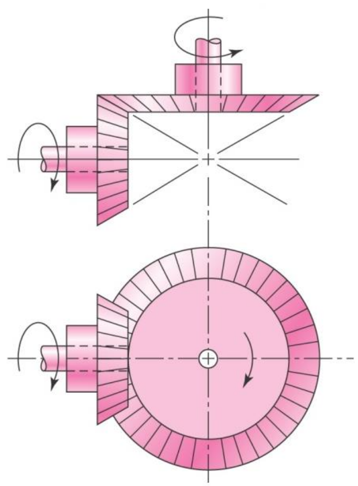
Type of Gears



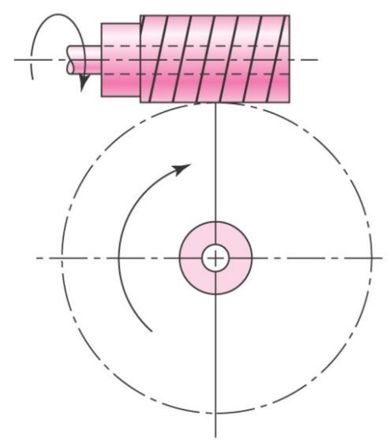
Spur



Helical



Bevel



Worm

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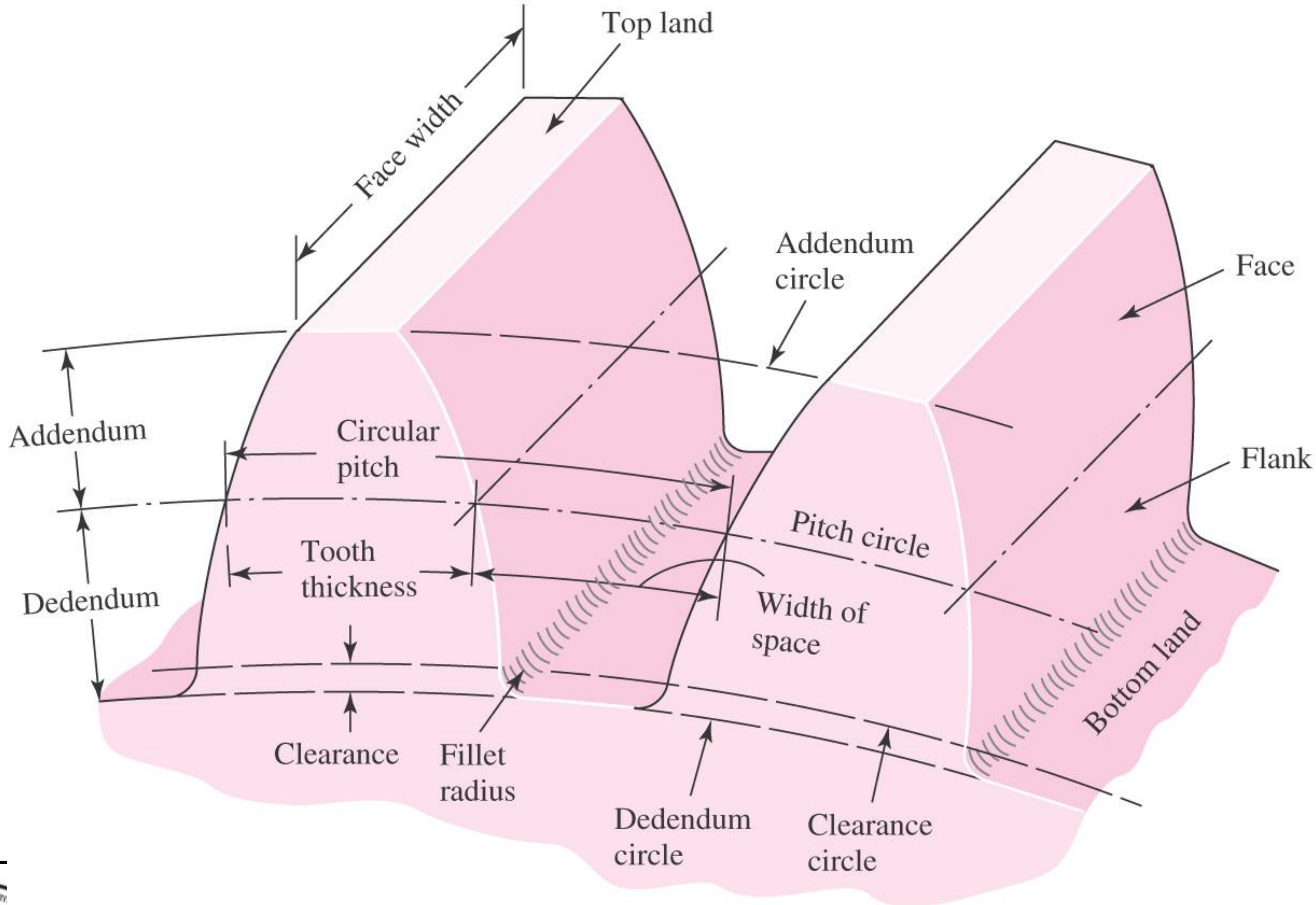
Nomenclature



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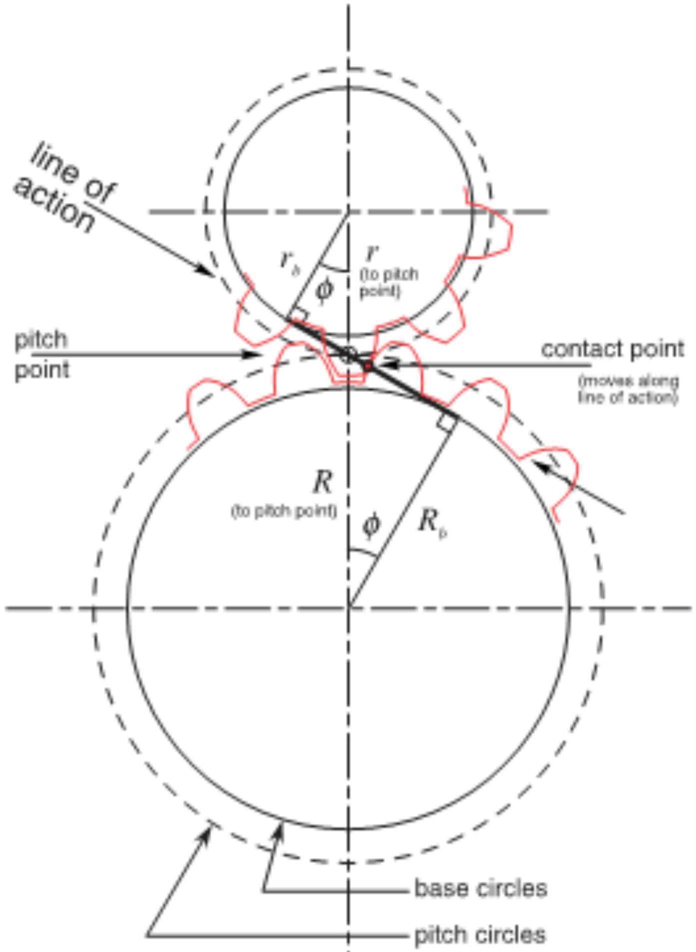
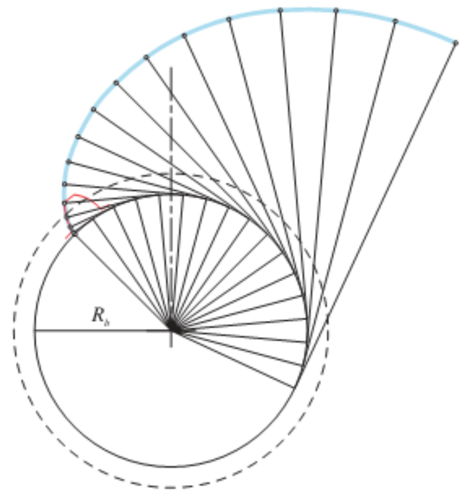
Line of Action

Contact between a meshing pair of gears is arranged to occur purely along a specified "line of action":

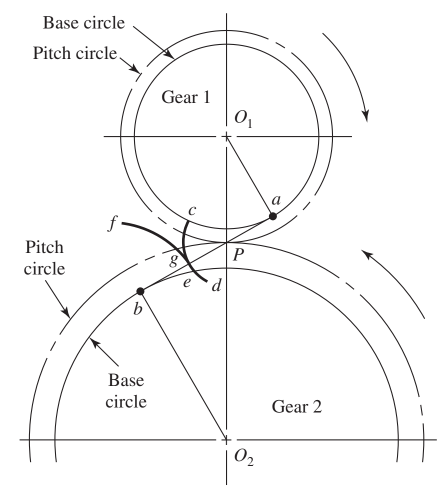


Involute Profile

- When the tooth profiles are designed so as to produce a constant angular- velocity ratio during meshing, these are said to have conjugate action
- Involute profile is required for conjugate action
- Formed by unwrapping a tangent chord from the base circle



$$V = |r_1\omega_1| = |r_2\omega_2|$$



(b)

Definitions

- Diametral pitch, P = N/D
- Module M is reciprocal of P = D/N
- Circular pitch = πM (arc on pitch circle from flank of one tooth to other tooth)
- Base pitch = $P_b = \pi M \cos\phi$ (base circle $r_b = r \cos\phi$)
- Addendum = M
- Dedendum = 1.157 M/1.250M/1.400M
- Clearance = Dedendum-addendum
- M, N, ϕ are required for characterization

Standardized Tooth Systems

- Common pressure angles ϕ: 20^o and 25^o
- Older pressure angle: $14\ 1/2^o$
- Common face width:

$$3p < F < 5p$$

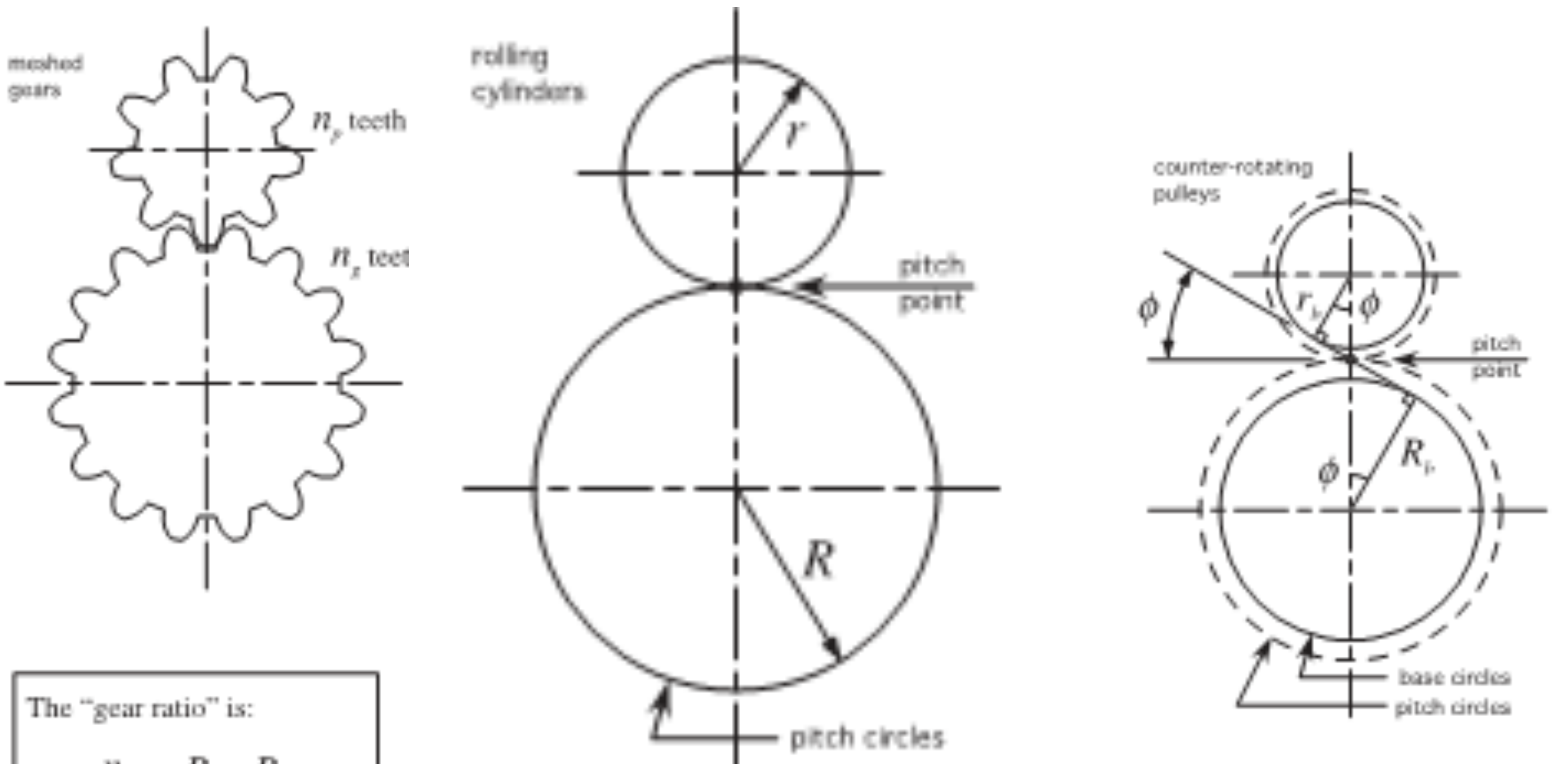
$$p = \frac{\pi}{P}$$

$$\frac{3\pi}{P} < F < \frac{5\pi}{P}$$

Fundamental Law of Gearing

- The common normal of the tooth profiles at all points within the mesh must always pass through a fixed point on the line of the centers called pitch point. Then <u>the gearset's velocity ratio will be constant through the mesh and be equal to the ratio of the gear radii.</u>

Gear Kinematics

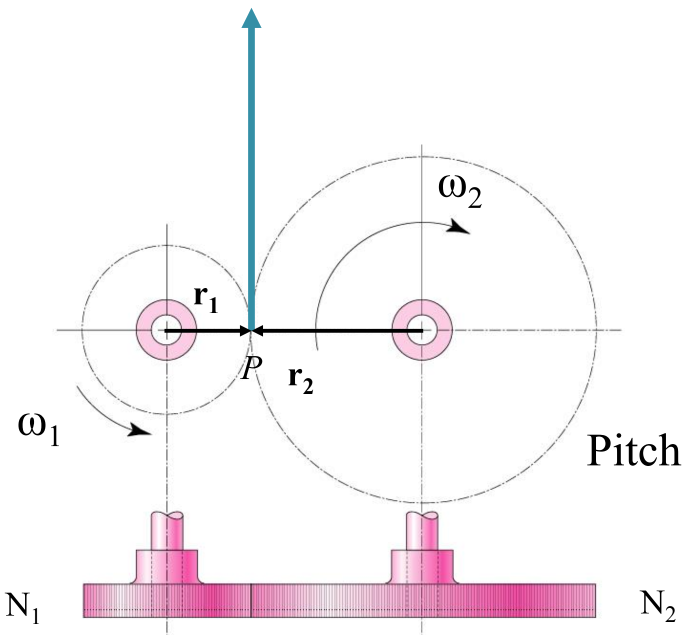


The "gear ratio" is:

$$\frac{n_g}{n_p} = \frac{R}{r} = \frac{R_b}{r_b}$$

Gear Ratio

- V_P of both gears is the same at point P, the pitch (circle contact) point
- $V_P = \omega_1 r_1 = \omega_2 r_2$



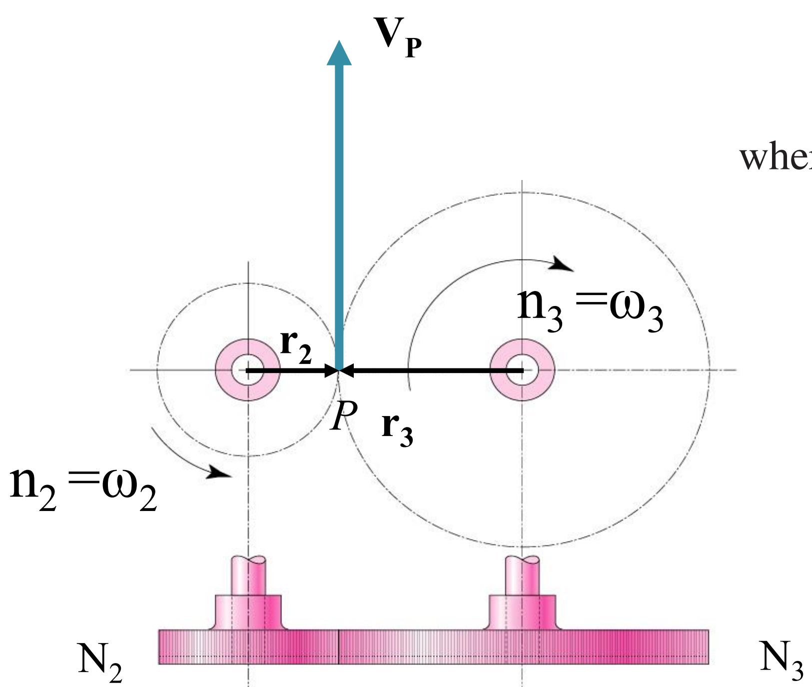
Gear Ratio ≥1

$$\frac{\omega_1}{\omega_2} = \frac{r_2}{r_1} = \frac{N_2}{N_1}$$

ω_2 rotates opposite of ω_1

Simple Gear Trains

- For a pinion 2 driving a gear 3, the speed of the driven gear is



$$n_3 = \left| \frac{N_2}{N_3} n_2 \right| = \left| \frac{d_2}{d_3} n_2 \right|$$

where n = revolutions or rev/min

N = number of teeth

d = pitch diameter

Simple Gear Trains

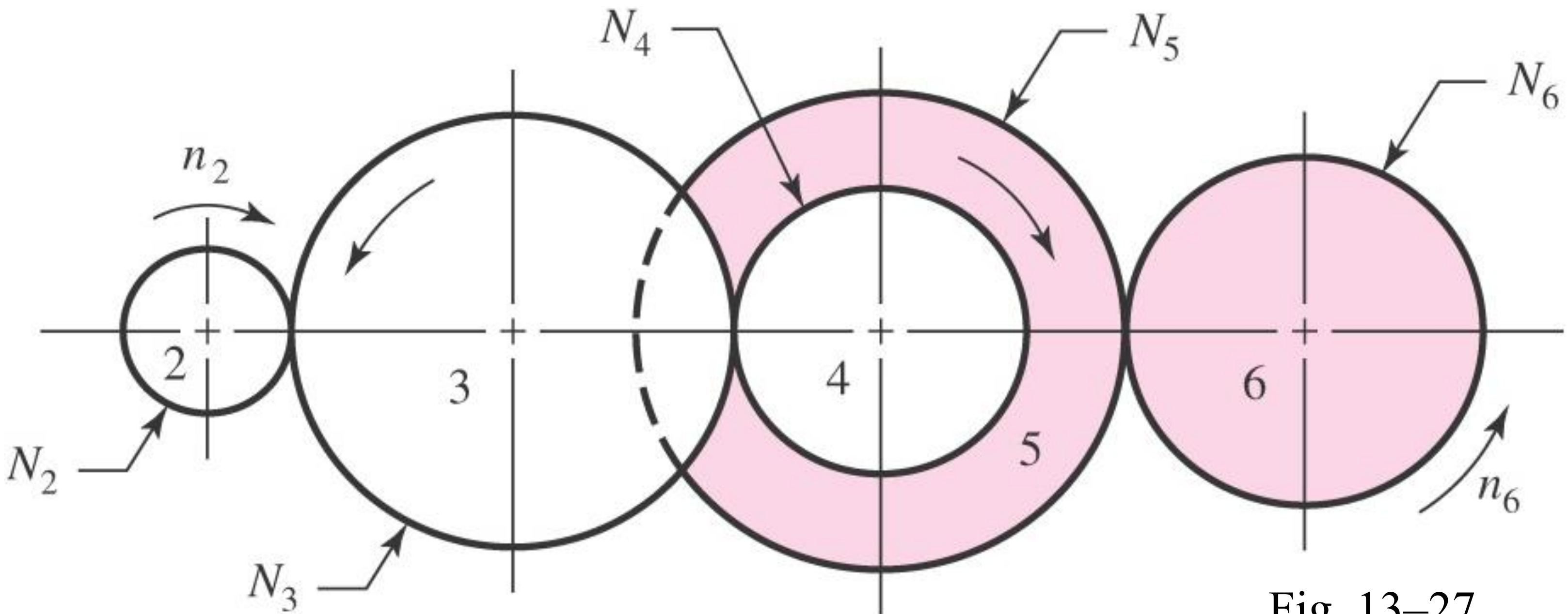


Fig. 13–27

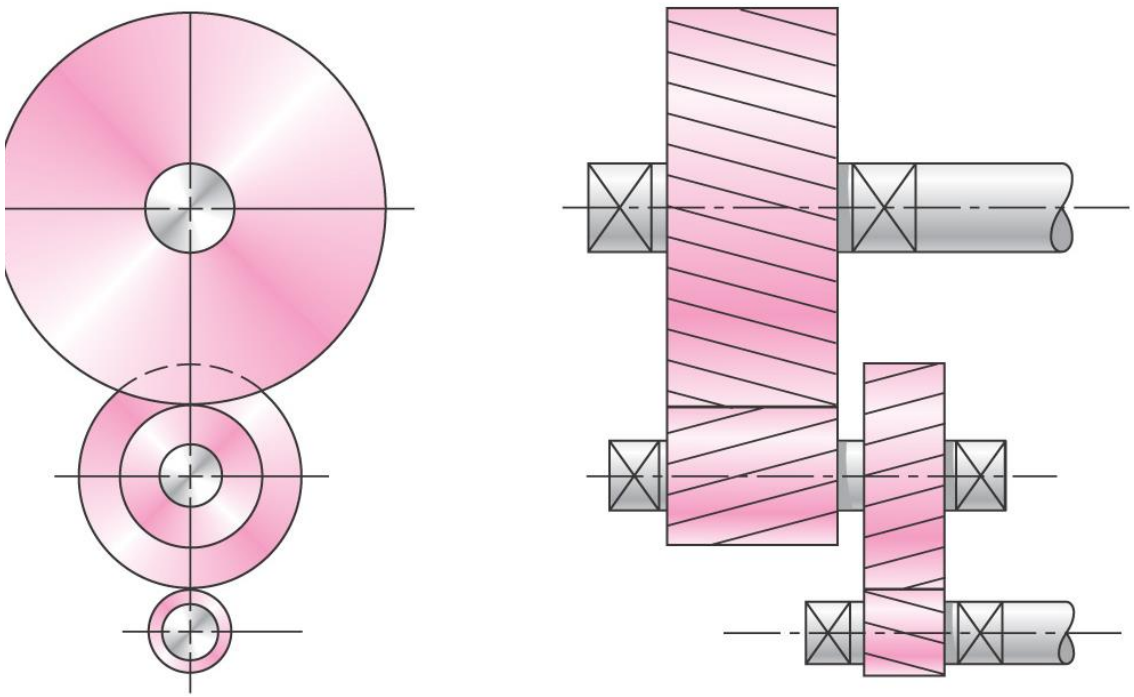
$$n_6 = -\frac{N_2}{N_3}\frac{N_3}{N_4}\frac{N_5}{N_6}n_2$$

$$e = \frac{\text{product of driving tooth numbers}}{\text{product of driven tooth numbers}} \qquad (13\text{–}30)$$

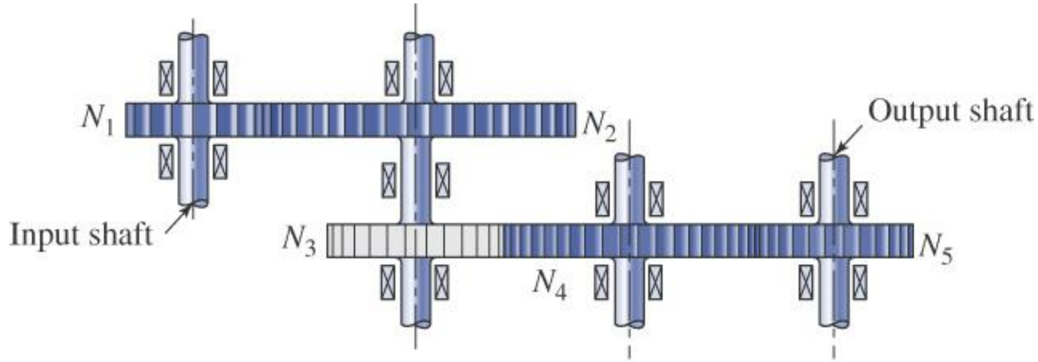
$$n_L = e n_F \qquad (13\text{–}31)$$

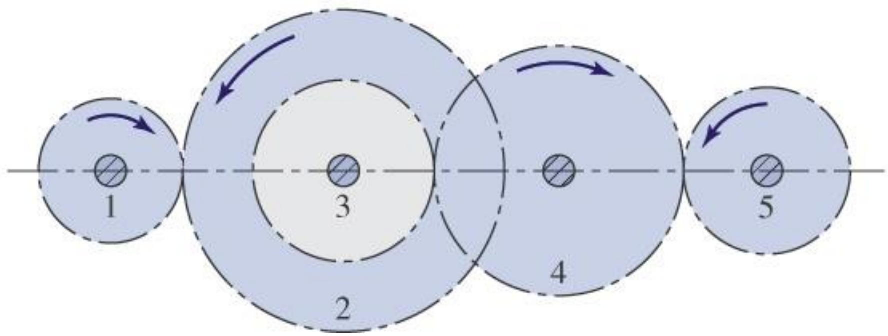
Gear Trains

- A practical limit on train value for one pair of gears is 10 to 1
- To obtain more, compound two gears onto the same shaft



Compound Gear Trains





$$\frac{n_5}{n_1} = \left(-\frac{N_1}{N_2}\right)\left(-\frac{N_3}{N_4}\right)\left(-\frac{N_4}{N_5}\right)$$

Example Problem

- A gearset consists of a 16-tooth pinion driving a 40-tooth gear. The diametral pitch is 2, and the addendum and dedendum are $1/P$ and $1.25/P$, respectively. The gears are cut using a pressure angle of 20deg
- (*a*) Compute the circular pitch, the center distance, and the radii of the base circles. (*b*) In mounting these gears, the center distance was incorrectly made 1/4 in larger. Compute the new values of the pressure angle and the pitch-circle diameters.

Solution

Solution

Answer (*a*)

$$p = \frac{\pi}{P} = \frac{\pi}{2} = 1.57 \text{ in}$$

The pitch diameters of the pinion and gear are, respectively,

$$d_P = \frac{16}{2} = 8 \text{ in} \qquad d_G = \frac{40}{2} = 20 \text{ in}$$

Therefore the center distance is

Answer

$$\frac{d_P + d_G}{2} = \frac{8 + 20}{2} = 14 \text{ in}$$

Since the teeth were cut on the 20° pressure angle, the base-circle radii are found to be, using $r_b = r \cos \phi$,

Answer

$$r_b \text{ (pinion)} = \frac{8}{2} \cos 20^\circ = 3.76 \text{ in}$$

Answer

$$r_b \text{ (gear)} = \frac{20}{2} \cos 20^\circ = 9.40 \text{ in}$$

Solution

(*b*) Designating d'_P and d'_G as the new pitch-circle diameters, the $\frac{1}{4}$-in increase in the center distance requires that

$$\frac{d'_P + d'_G}{2} = 14.250 \qquad (1)$$

Also, the velocity ratio does not change, and hence

$$\frac{d'_P}{d'_G} = \frac{16}{40} \qquad (2)$$

Solving Eqs. (1) and (2) simultaneously yields

Answer $$d'_P = 8.143 \text{ in} \qquad d'_G = 20.357 \text{ in}$$

Since $r_b = r \cos\phi$, the new pressure angle is

Answer $$\phi' = \cos^{-1} \frac{r_b \text{ (pinion)}}{d'_P/2} = \cos^{-1} \frac{3.76}{8.143/2} = 22.56^\circ$$