3. Gear Teeth

George Grant

If you're asked to divide two numbers like this 216928 ÷ 391167 . . . what's the first thing you reach for? An electronic calculator, of course. But did you know that calculators were in use before such a thing as electronics even existed?

In 1876 there was a centennial exhibit in Philadelphia, Pennsylvania. On display was a working mechanical calculator called "Grant's Difference Engine". It was 5 feet × 8 feet in size, and weighed almost a ton, but it could mechanically do accurate arithmetic computations. Three years before, in 1873, a young man from Maine had invented it while a student at Harvard. After months of painstaking effort he had succeeded in building a working model for display.

The young man's name was George Grant, and he can be called, not the father of computers, but the father of the American gear industry. How did he get involved with gears?

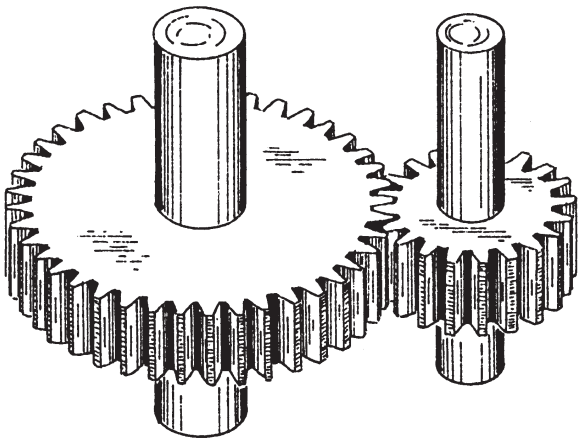
His calculators required many small, but precision gears, and in 1876 few knew how precision gears should be designed and made. So George Grant himself worked out much of the theory of modern gear forms, profiles and geometry.

He set up shop in Charlestown, Boston, Massachusetts to cut the first gears he needed, and later started four separate gear companies. Three descendants survive today - Grant Gear Co., Boston Gear Co., and Philadelphia Gear Co.

Grant wrote a book, "A Treatise on Gear Wheels" which was widely read and which helped to begin a process of standardizing gear teeth - so that gears made by different manufacturers, any place in the country, can mesh together properly, and so that tooling to make gears can be made in standard sizes at reduced cost.

Gears in Mesh

Imagine two spur gears in mesh.



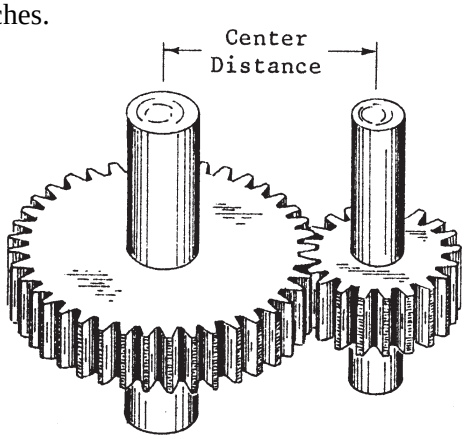
For purposes of illustration, let's say one gear has 40 T., and the other has 20 T. Gear ratio is 2 : 1.

Speed Ratio

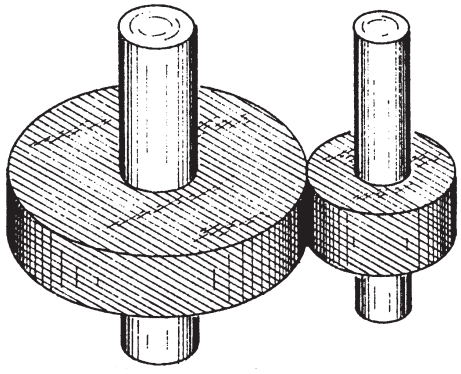
The **speed ratio** between the two shafts will be exactly 2 : 1. It is not 2.001 : 1 or 1.999 : 1, but exactly 2.000 : 1.

Center Distance

The distance between the center of each shaft is called **center distance**, and is measured in inches.



Imagine we now slide the gears off the shafts, and put in their place two rolls, or plain cylinders.



Imagine that the rolls press against each other. If one roll rotates, it will press on the other and cause it to rotate also.

Imagine also that the rolls are covered with something like hard rubber so that they don't slip or slide against each other at all. They only roll against each other.

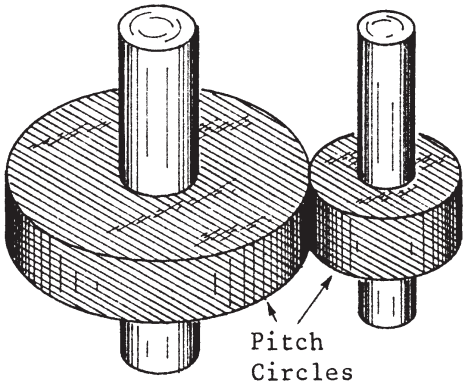
Let's say we want the shafts to turn at the same exact 2 : 1 speed ratio as they did with the gears. To get that exact 2 : 1 ratio one roll has to be exactly two times as big as the other.

If it is not quite exact - say 2.001 : 1 - then the speed ratio will also be 2.001 : 1.

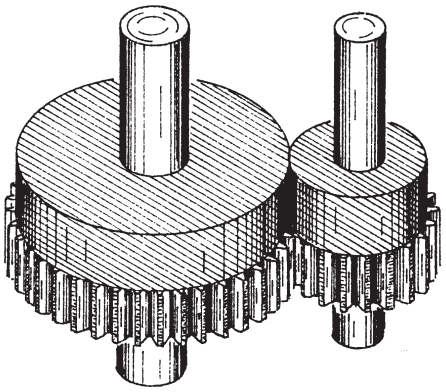
The speed ratio will be exactly the same as the roll diameter ratio, with the larger roll having the slower speed.

Pitch Circle

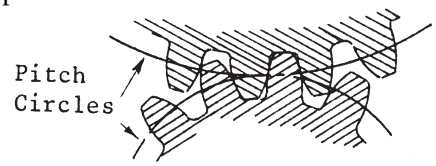
Call the circumference of these imaginary rolls the **pitch circle**



Imagine we put both gears and rolls on the shafts together, side by side.



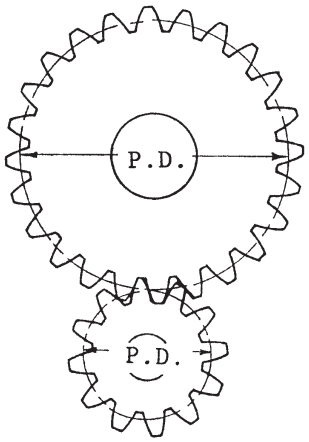
The outside diameter of the rolls (pitch circles) will come approximately, but not exactly, half way up the teeth.



Every set of gears in mesh has a set of imaginary pitch circles. Pitch circle diameters (pitch diameters) have the same ratio as the gear ratio. Pitch circles touch each other and roll without slipping.

Pitch Diameter

Pitch circle diameter is called the gear's pitch diameter **(P.D.)**.



On a gear set in mesh, the ratio between the two pitch diameters is the same as the gear ratio.

$$\frac{P.D.\ \#1}{P.D.\ \#2} = \frac{Number\ of\ Teeth\ \#1}{Number\ of\ Teeth\ \#2}$$

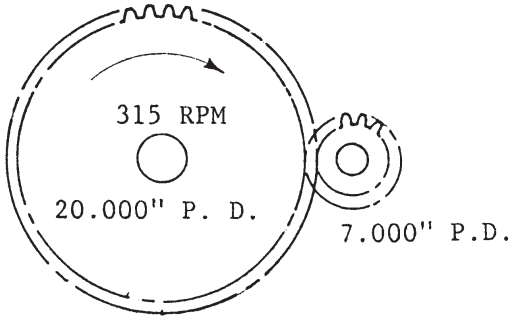
Study Questions A.

1. Imagine a 21 T. pinion in mesh with a 63 T. gear. What is the ratio of P.D. gear to P.D. pinion?

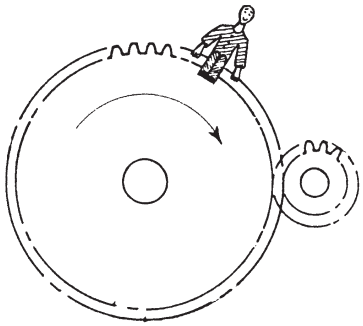
2. Which goes slower, the 21 T. pinion or the 63 T. gear?

3. What is the pitch diameters ratio of a 19 T. pinion with a 59 T. gear, with tooth size 6 D.P.?

4. What RPM does the pinion turn?



5. If a miniature man sits exactly on the pitch circle of the gear shown in question 4, he will go round and round at a speed of 1649.3 feet per minute, or 18.7 miles per hour.



How fast would he go if he sat on the pinion pitch circle?

Pitch Radius

For a given center distance and speed ratio, there is only one pair of pitch circles (and P.D.'s) that will work.

Half of one pitch diameter plus half of the other pitch diameter equals the center distance. (Half a diameter is called a radius.)