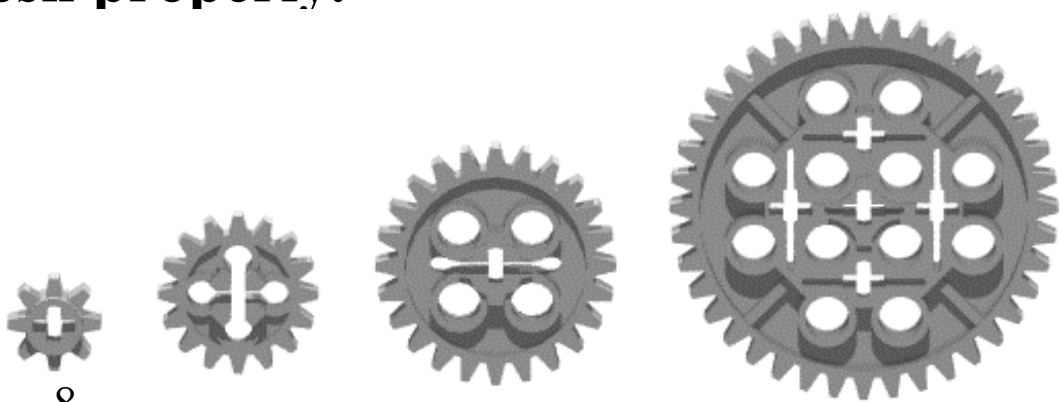
# Gears

# Why Use Gears?

- To transmit torque from one axle to another
- To increase or decrease the speed of rotation
- To reverse the direction of rotation
- To move rotational motion to a different axis
- To change rotary motion to linear motion
- To keep the rotation of two axles synchronized

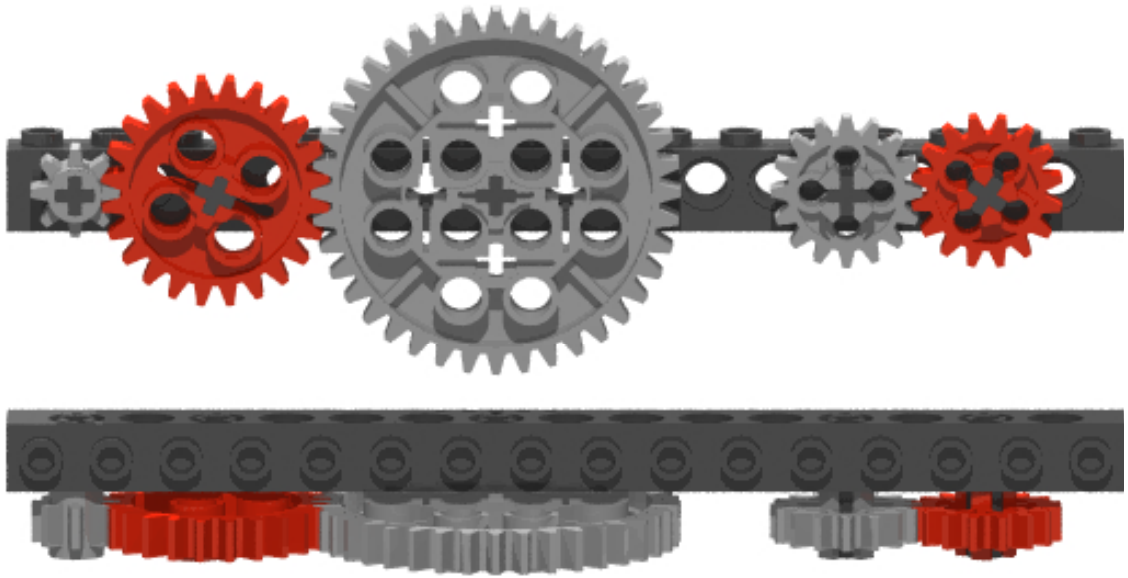
# Spur Gear

- **Most common gear**
- **Used when shafts rotate in same plane**
- **Gear sizes counted by number of teeth**
- **All LEGO spur gears have the same size teeth so they can mesh properly.**



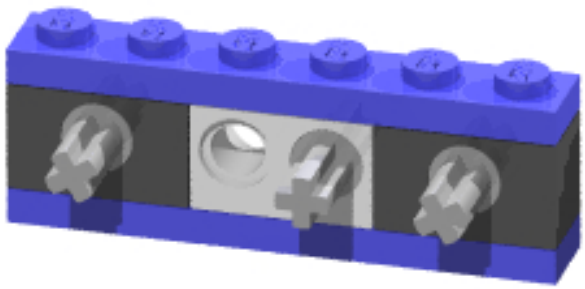

| Teeth | 8 | 16 | 24 | 40 |
|---|---|---|---|---|
| Radius (studs) | 0.5 | 1 | 1.5 | 2.5 |

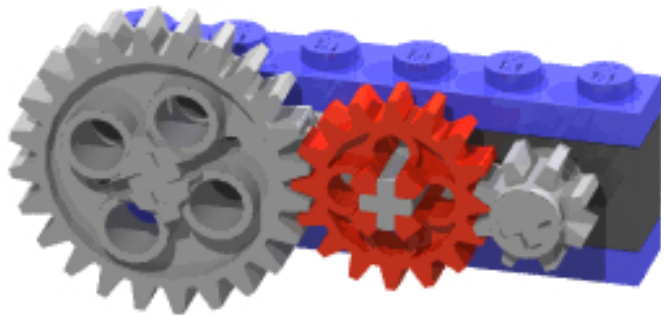
# Spur Gear Spacing



| | 8 tooth | 16 tooth | 24 tooth | 40 tooth |
|---|---|---|---|---|
| 8 tooth | 1.0 studs | 1.5 studs | 2.0 studs | 3.0 studs |
| 16 tooth | 1.5 studs | 2.0 studs | 2.5 studs | 3.5 studs |
| 24 tooth | 2.0 studs | 2.5 studs | 3.0 studs | 4.0 studs |
| 40 tooth | 3.0 studs | 3.5 studs | 4.0 studs | 5.0 studs |

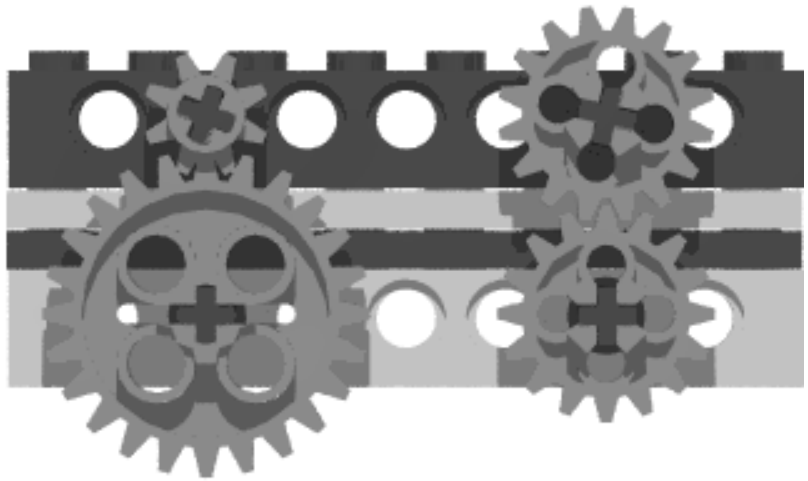
# Half-Stud Spacing





- **Here is a trick to get half-stud spacing using 2 holed 1 x 2 beam**

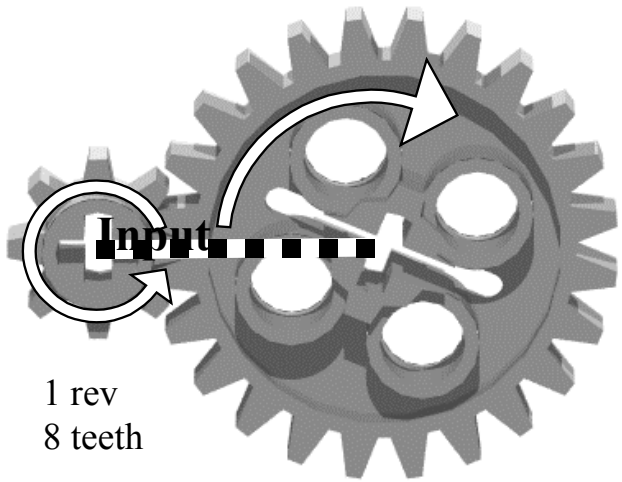
# Vertical Gear Spacing



| | 8 tooth | 16 tooth | 24 tooth | 40 tooth |
|---|---|---|---|---|
| 8 tooth | | | 2.0 studs | |
| 16 tooth | | 2.0 studs | | |
| 24 tooth | 2.0 studs | | | 4.0 studs |
| 40 tooth | | | 4.0 studs | |

- **Vertical spacing is difficult**
- **Really only 2 and 4 stud distances work well**
  - **Our old friend 1-2-1**

# Gear Ratio




**Output**

**The 24t gear turns 1/3 revolution for every turn of the input 8t gear.**

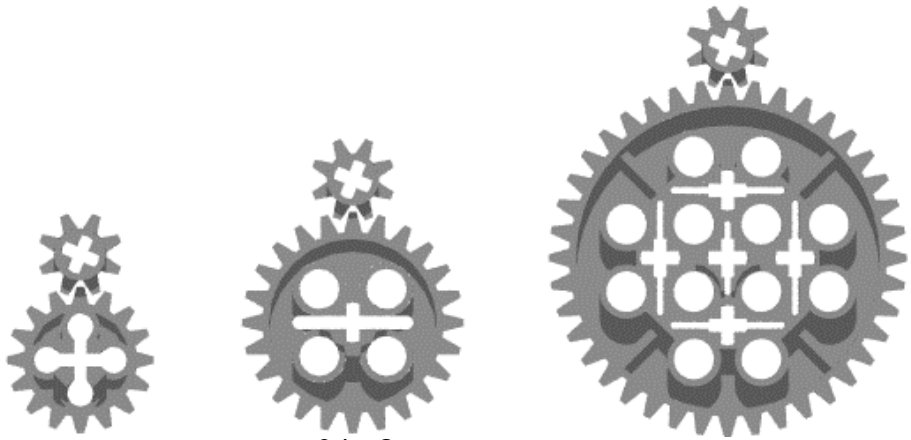
**This is a 3:1 gear ratio**

**Gear ratio is defined as the ratio of how much the output shaft of a gearbox turns for a given rotation of the input shaft.**

# Gearing Up and Down

- The 3:1 gear ratio tells us that the input shaft (attached to the 8t gear) has to complete three full revolutions for the output shaft (attached to the 24t gear) to rotate all the way around just once.
- Using gears to slow down rate of rotation or decrease the amount of rotation is called gearing down.
- If we were to switch the 8t and 24t gears around the output shaft would spin three revolutions for each revolution of the input shaft.
- This is gearing up, and the gear ratio would be 1:3

# Gear Ratios



16 : 8
or
2 : 1

24 : 8
or
3 : 1

40 : 8
or
5 : 1

**Output Shaft or Driven Gear**

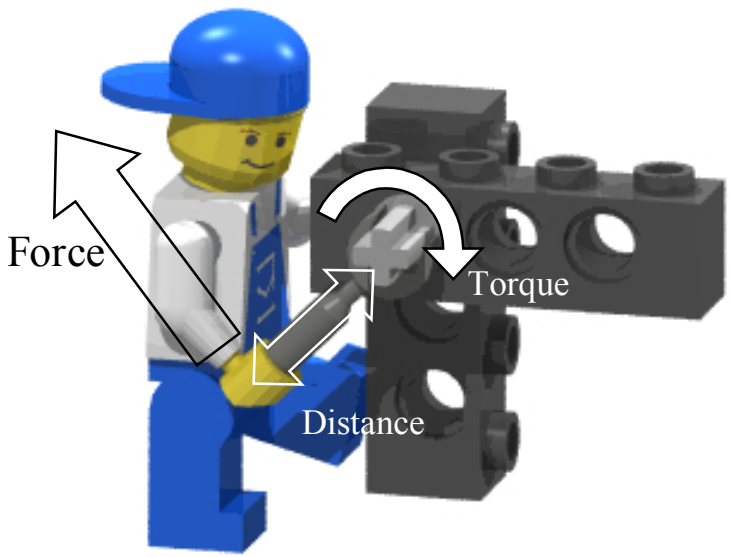
| Input Shaft or Driving Gear | Driven 8 tooth | 16 tooth | 24 tooth | 40 tooth |
|---|---|---|---|---|
| Driving 8 tooth | **1:1** | **2:1** | **3:1** | **5:1** |
| 16 tooth | **1:2** | **1:1** | **3:2** | **5:2** |
| 24 tooth | **1:3** | **2:3** | **1:1** | **5:3** |
| 40 tooth | **1:5** | **2:5** | **3:5** | **1:1** |

# Gear Ratio and Torque

- **Gears operate by transmitting forces at the teeth of the gear.**
- **When two gears mesh, the force that is transmitted can be multiplied by the radius to obtain the torque applied to the gear.**
- **Torque is a force that tends to rotate or turn things. For example, you generate a torque any time you apply a force using a wrench. When you use a wrench, you apply a force to the handle. This force creates a torque on the nut, which tends to turn the nut.**

# Torque

- **A force applied to the teeth of a large gear will generate more torque than the same force applied to the teeth of a small gear. This also means that for a given torque, a larger gear will transmit less force than a smaller gear**




**Torque = Force * Distance**

# Torque

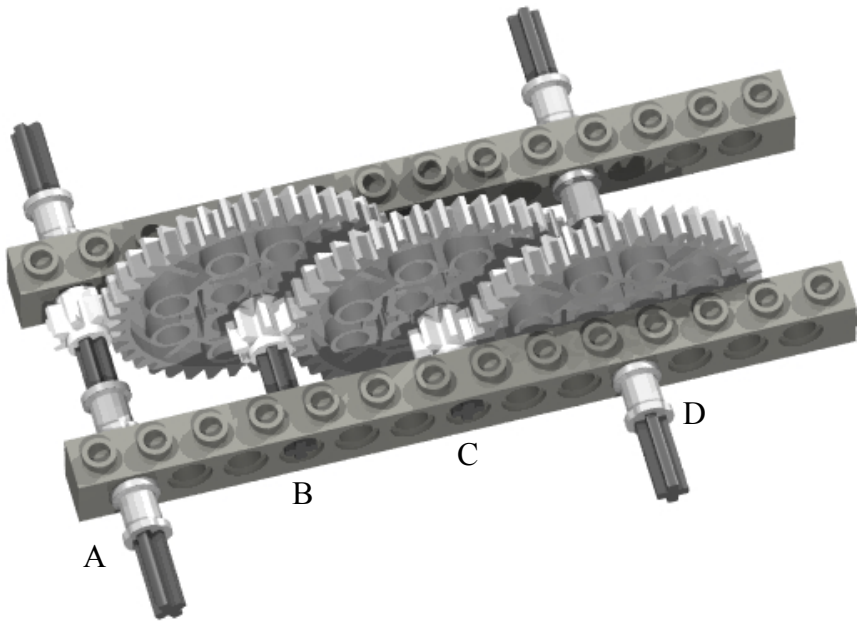
- **The teeth of a large gear travel faster than the teeth of a small gear at a given angular velocity.**
- **So there is no free lunch. If you gear down to get an increase in torque, you will also get a proportional decrease in angular velocity.**
- **The driven gear will turn stronger and slower.**

**Strong and Slow**

**or**

**Fast and Weak**

# Gear Trains



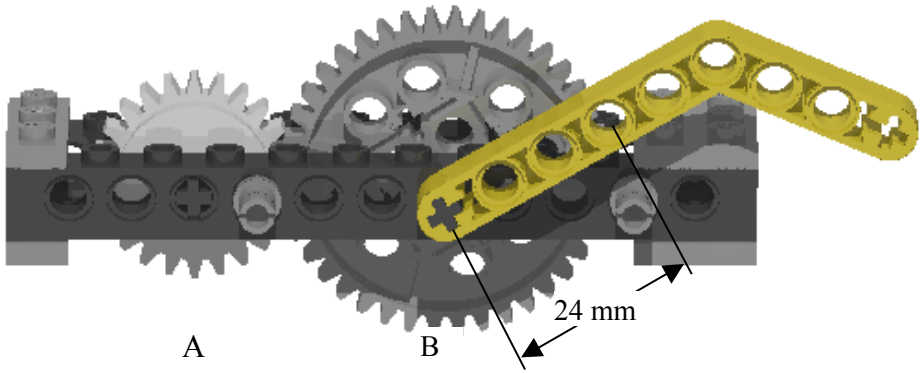

**A->B = 5:1**
**B->C = 5:1**
**C->D = 5:1**
**A->D = (A->B) x (B->C) x (C->D)**
**= 5:1 x 5:1 x 5:1**
**= 5 x 5 x 5:1 x 1 x 1**
**= 125:1**

**If you connect shaft A to a motor spinning at 300 revolutions per minute (rpm), shaft D will spin at 2.4 rpm or 1 revolution every 25 seconds. Shaft D will have a LOT OF TORQUE!!! It could break gear teeth or snap axles.**

# Idler Gear

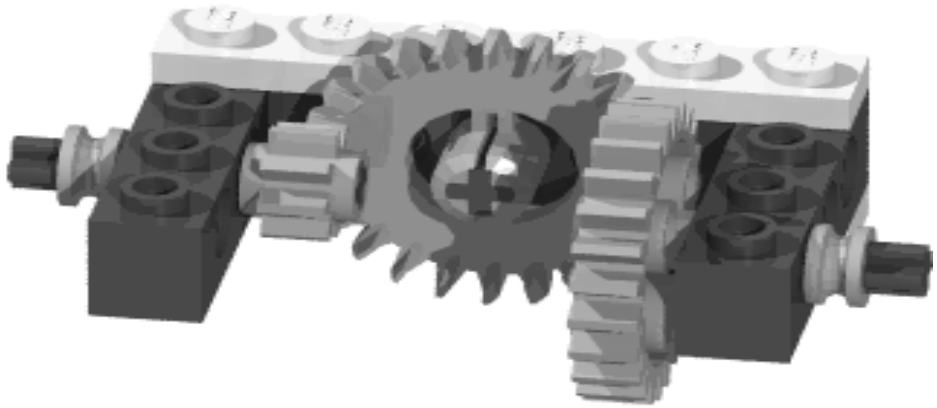

- **The 24 tooth gear is an idler gear. An idler gear does not affect the gear ratio of a gear train**
- **Idler gears are quite common in machines where they are used to connect distant axles. Idler gears may also used to change the direction of rotation of the output shaft**

# Clutch Gear



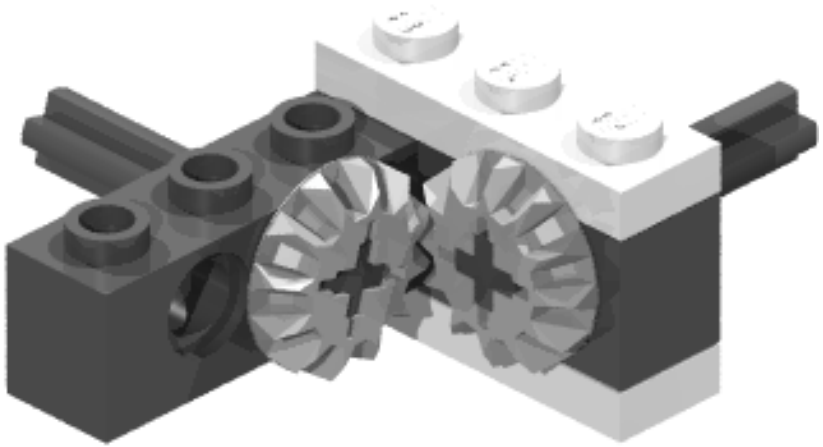

- **The white gear with writing on it is called a clutch gear**
- **The clutch gear is special in that the gear teeth are able to rotate about the shaft.**
- **It has an internal clutch mechanism that starts to slip when its maximum rated torque is exceeded. The clutch gear is used to limit the torque of a geared system, saving motors and preventing your robot from tearing itself apart.**

# Crown Gear



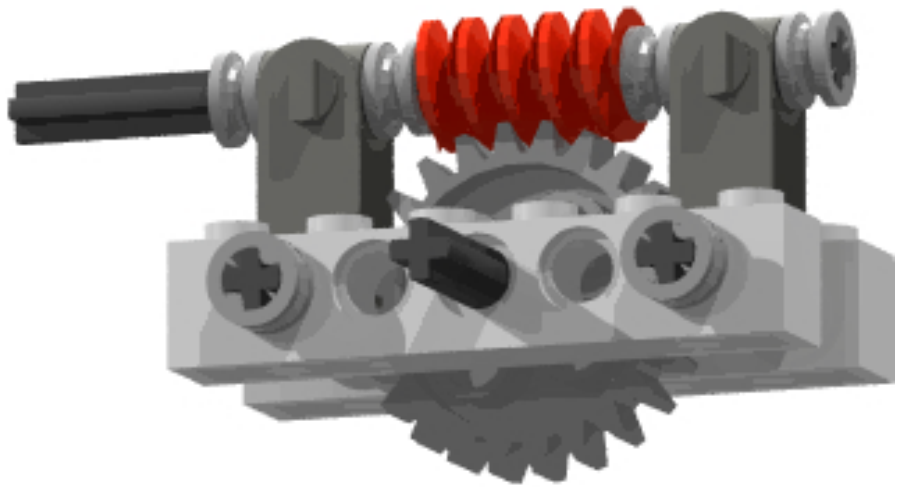
- The crown gear has teeth that are raised on one side and rounded-off on the other to give it a crown-like appearance.
- Used when the shafts to be turned meet at an angle. It can be meshed to spur gears and worm gears, but it doesn't mesh well with other crown gears.
- Can  also be used in place of a 24 tooth spur gear.

# Bevel Gear



- The bevel gear has teeth that slope along one surface of the disc. It is used when the shafts to be turned meet at an angle.
- It has less friction than the crown gear, but can only mesh with another bevel gear.
- Can also be used as a small wheel

# Worm Gear



- A worm gear is a screw which usually turns along a spur gear.
- Motion is transmitted between shafts that are at right angles.
- Can create very high gear ratio as each time the shaft spins one revolution, the spur gear moves one tooth forward.