

ST EST  
AST SE

# Mechanical Engineering



Chapter 13  
Observatory  
pp. 424-454

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## 13.0 Linking in Technical Objects

◆ **Linking** is the mechanical function performed by any component that **connects** different parts of a technical object.

- p428.



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### ◆ Vocabulary:

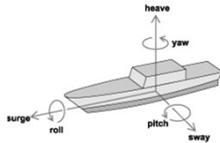
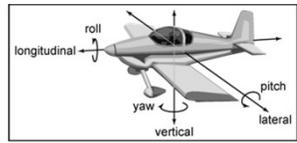
- **Direct:** held together on its own.
- **Indirect:** requires a linking part (nail, screw, etc.)
- **Rigid:** all parts are solid.
- **Flexible:** one part is flexible (rubber)
- **Removable:** is intended to come apart & reassembled without breaking.
- **Non-removable:** part must be broken to disassemble. (held by a rivet)
- **Complete:** there is no movement between linked parts.
- **Partial:** at least one part can move with respect to the other.

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## 13.1 Degrees of Freedom of Movement

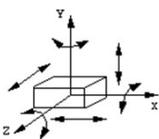
◆ are the set of independent movements that are possible for a given part in a technical object.

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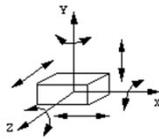
- ◆ The motion can be:  
Translational (back & forth) or Rotational
- ◆ Which axis?  
• X (horizontal),  
• Y (vertical), or  
• Z (out at you!)
- ◆ Notation – 6 possible degrees of freedom  
 $T_x, T_y, T_z, R_x, R_y, R_z$

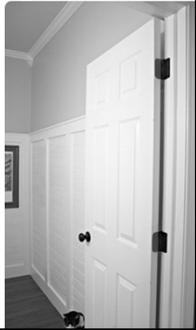


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- ◆ Example: a regular door  
• can only rotate around the hinges  
→ 1 degree freedom  $R_y$



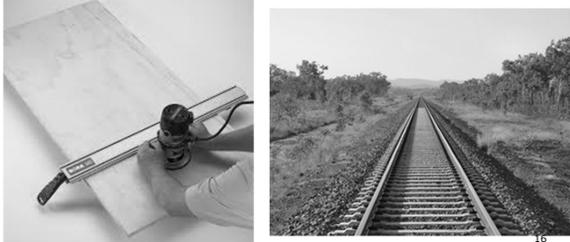


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### 13.2 Types of Guiding Controls

- ◆ **Translational Guiding** ensures the straight translational motion of a moving part.
  - E.g. a vertical window groove



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- ◆ **Rotational Guiding** ensures the rotational motion of a moving part.
  - E.g. a bicycle wheel hub



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- ◆ **Helical Guiding** ensures the translational motion of a moving part while it rotates about the same axis.
  - E.g. threaded screw.



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### 13.3 Adhesion and Friction of Parts

- ◆ **Adhesion** = two surfaces remain in contact with each other without slipping.
- ◆ **Friction** is a force that resists slipping
- ◆ **Lubrication** reduces friction between two parts.

Phone book demo & [Mythbusters click here](#)

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### 5 Factors affecting friction

1. Nature of materials (eg: steel on asphalt vs. rubber on asphalt)
2. Presence of a lubricant (water, oil, wax) or adhesive (glue)
3. Temperature: the colder the temperature the less the adhesion
4. Surfaces (rough vs. smooth)
5. Mass of the object (a heavy object will have better adhesion, more friction)

**SURFACE AREA does NOT affect friction! Remember  $P = F/A$**

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### 13.4 Motion Transmission Systems

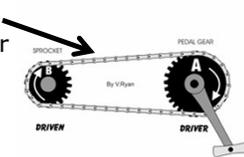
- ◆ **Motion Transmission** relays motion from one part to another without altering the nature of the motion.
  - Translation → translation
  - Rotation → rotation
- ◆ A **Motion Transmission System** is a set of parts that transmit motion.



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- ◆ **Driver component:** receives the force required to activate the system  
Eg: Pedal gear on a bike
- ◆ **Driven component:** receives the motion  
Eg: rear gears on a bike
- ◆ **Intermediate component:** located between the driver and driven component  
not all systems have this!  
Eg: the chain on a bike



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**Please Write ONTO handout**

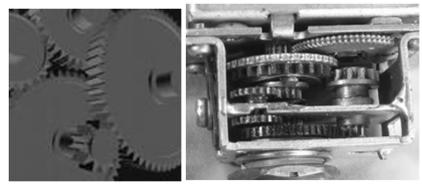
- ◆ Common rotational transmission systems:
  1. Gear Train System
  2. Chain & Sprocket Systems
  3. Worm & Worm Gear Systems
  4. Friction Gear Systems
  5. Belt & Pulley Systems

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## 1. Gear Train System

- ◆ The direction of rotation **alternates from one gear to the next.**
- ◆ **Yes !** It is reversible.



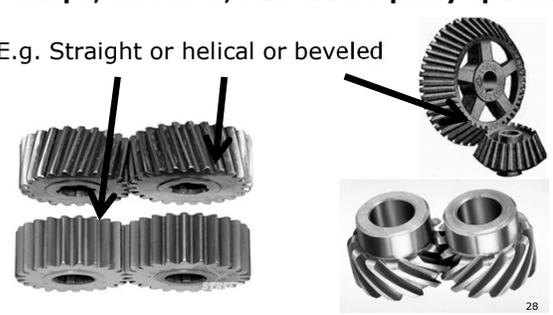
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## Other information – Gear Trains

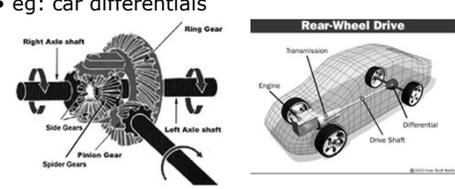
- ◆ **Gear teeth must be identical – same shape, direction, size & be equally spaced.**

E.g. Straight or helical or beveled



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- ◆ The rotational axis of the gears can be positioned different ways
  - eg: car differentials



**Rear-Wheel Drive**



- ◆ Gear size:  
**Larger gears** (with more teeth) **rotate slower.**  
**Smaller gears rotate faster.**

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## 2. Chain & Sprocket Systems

- ◆ The direction of rotation:  
**Sprockets turn in the same direction when they are located on the same side of the chain (opposite on the other side of the chain)**
- ◆ **Yes** it is reversible!
- ◆ **Larger = slower**
- ◆ **Smaller = faster**
- ◆ **Requires frequent lubrication**



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### 3. Worm & Worm Gear Systems 440

- ◆ The direction of rotation **depends on the direction of the threads on the worm screw axle.**
- ◆ **NO!** It is not reversible.
- ◆ **Worm screw** must be the driver!
- ◆ Larger worm gear = slower rotation

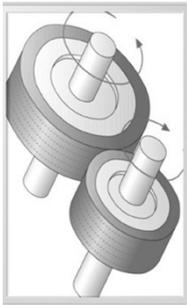


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### 4. Friction Gear Systems 440

- ◆ The direction alternates from one gear to the next.
- ◆ **Yes** it is reversible!
- ◆ Smaller = faster
- ◆ Larger = slower

**Same as gear trains**



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◆ Friction gear systems are similar to gear trains except that **motion is transferred by FRICTION** not by **GEAR TEETH.**

◆ They are **prone to slip** at times.

◆ **Friction is affected by:**

- gear **type** (straight or beveled),
- gear **size** &
- choice of **material.**

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### Belt and Pulley systems



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### 5. Belt and Pulley Systems 441

- ◆ **Similar to the chain and sprocket system.**
  - The chain is replaced by a belt.
  - The sprocket is replaced by a pulley.
  - The choice of the **belt material and how tight the belt is will affect the friction** and hence the efficiency of the system.
- ◆ The direction is the same for any pulley on the same side of the belt.
- ◆ **Yes!** It is reversible.
- ◆ Smaller = faster
- ◆ Larger = slower

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### Speed Changes in Motion Transmission Systems 442

- ◆ A Speed Change occurs when the driver does not turn at the same speed as the driven component(s).
- ◆ The speed change depends on the size ratio of the driver compared to that of the driven component.



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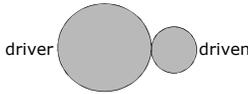
### 13.5 Speed Changes in Motion Transmission Systems

- You can compare:
  - # of teeth
  - Diameter
  - Circumference
- Speed ratio  $\frac{\text{Driver}}{\text{Driven}} = \frac{15 \text{ mm}}{5 \text{ mm}} = \frac{3}{1} = 3$  or 3:1

**So the driven pulley turns 3 times FASTER than the driver.**

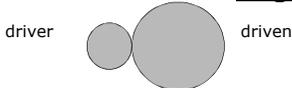
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- To **increase** the speed, the driven component should have a **smaller** diameter

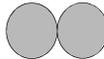


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- To **decrease** the speed, the driven component should have a **larger** diameter.



- To keep the **same** speed, the two components should have the **same** diameter.



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### Calculating Gear Speed Ratios

Ex. 1

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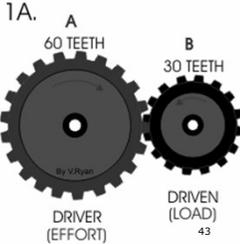
Driver (A) =  $\frac{60}{30} = \frac{2}{1} = 2$  speed ratio is 2:1  
 Driven (B) =  $\frac{30}{1}$

**Reduce the fraction**

Driven is twice as fast!

If A is turning at 22 rpm, how fast is B turning?  
 $22 \text{ rpm} \times 2 = 44 \text{ rpm}$

(more examples p443)



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Ex. 2

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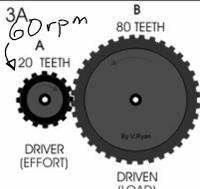
**Reduce the fraction**

$\frac{A}{B} = \frac{20}{80} = \frac{1}{4} = 0.25$

**Speed ratio 1:4**

If A is turning at 60 rpm how fast is B turning?  
 $60 \text{ rpm} \times 0.25 = 15 \text{ rpm}$

**B rotates at a speed 1/4 that of A**  
 =  
**A turns 4 times faster than B**



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### Speed Changes in Worm & Worm Gear Systems

- Larger worm gear = slower
- Smaller worm gear = faster
- 1 turn of the worm = the worm gear will rotate by the width of 1 tooth!

speed ratio =  $\frac{1}{\text{\#of teeth in worm gear}}$

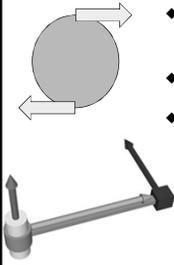


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### 13.6 Torque

- Torque involves 2 equal forces in opposite directions.
- Causes rotation
- Engine Torque** increases the rotational speed of components
  - Power from engine
- Resisting Torque** slows or stops the rotation
  - caused by friction, air resistance, gravity



$T = r \times F$

T is the torque vector  
 r is the vector from the point from which torque is measured to the point where force is applied.  
 F is the force vector  
 X denotes cross product

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### Torque and Speed Change

engine torque = resisting torque,  
→ No speed change

engine torque > resisting torque,  
→ speed increases

engine torque < resisting torque,  
→ speed decreases

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Fill in table as we go!

### 13.7 Types of MOTION TRANSFORMATION Systems

- ◆ Relays motion by changing the type.
  - Translation ↔ Rotational
- ◆ The most common systems are:
  1. Rack and Pinion
  2. Screw Gear Type 1
  3. Screw Gear Type 2
  4. Cam and Followers
  5. Slider-Crank systems

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### Rack and Pinion

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### 1. Rack and Pinion Systems

- ◆ Convert rotational ↔ translational
- ◆ **“Rack”** = straight bar with teeth.
- ◆ **“Pinion”** = the gear.
  - ◆ Used in steering systems.
  - ◆ Larger the pinion = slower the rotation
- ◆ **Yes** it is reversible.

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### Rack and Pinion

How Car Steering Works

© 2001 HowStuffWorks

### 2 & 3 Screw Gear Systems

- ◆ Converts **rotation to translation**
- ◆ The screw gear uses a threaded bolt to move another gear or itself.
- ◆ **Not reversible**

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### Screw Gear Type 1

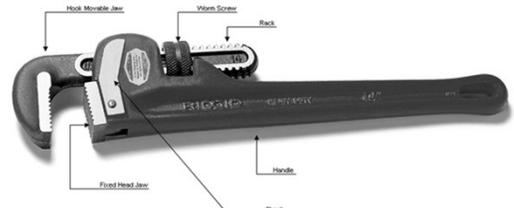
- ◆ Screw is the driver
  - Car Jack



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### Screw Gear Type 2

- ◆ Nut is the driver
  - Pipe wrench



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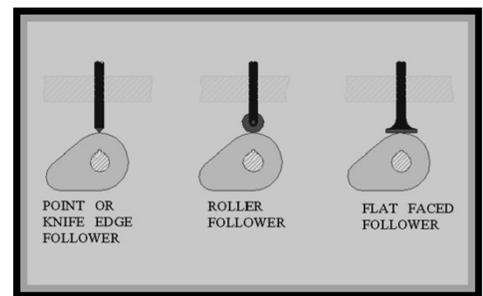
### 4 Cam and Followers

- ◆ Converts **rotational to reciprocating (back and forth) translational motion**
  - Eg. A **sewing machine**



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### Cams and followers

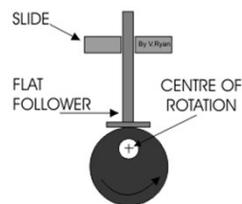


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### Eccentric Cams

- ◆ Rotational axis of an eccentric cam is off center, p. 449

- ◆ Reversible?

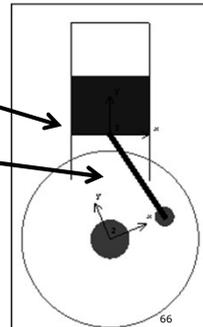


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### 5 Slider-crank System

- ◆ Converts **rotation  $\leftrightarrow$  translation**
  - ◆ Used in **car engines**

- ◆ The **slider** is the piston.
- ◆ The **crank** attaches the a **wheel**.
- ◆ Usually the slider is the component.



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