Module 4: Technology

28. Gears

In this first learning activity, students are expected to understand the following definition and basic ideas with regard to gears.

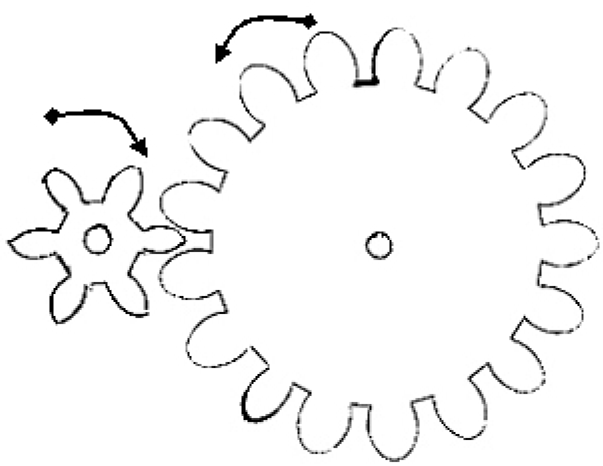
DEFINITION A gear is a toothed wheel attached to a rotating shaft. Most often, a gear is attached to another gear, and a system of gears can serve a variety of functions---for instance:

(1) In a bicycle, a chain connects large gears to a set of smaller gears in order to change the back wheel's speed of rotation.

(2) Gears are used in an automobile's differential to transmit motion at 90^o from the driveshaft to the wheels' axle.

(3) Gears are often connected to small motors so that a quick-turning small gear can transfer its energy to a larger gear, which has more turning force.

THE BASIC IDEAS

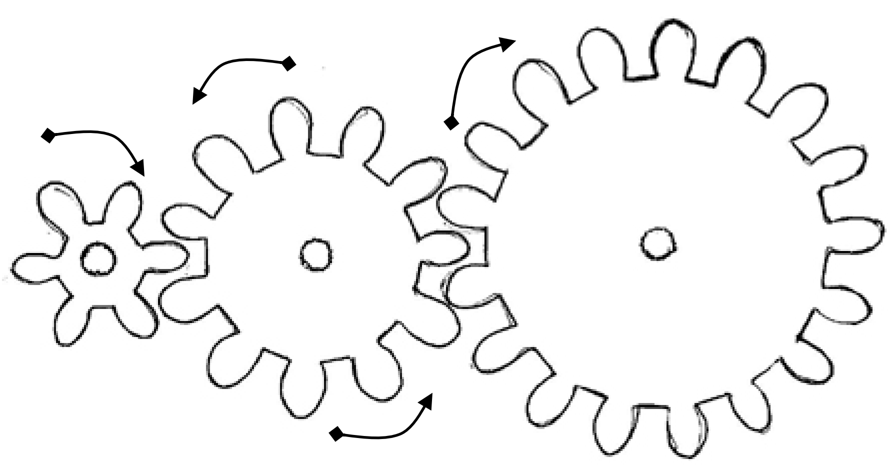


a. Gears and Direction of Motion

If the smaller gear is turned clockwise, the motion of the larger gear will be counterclockwise.

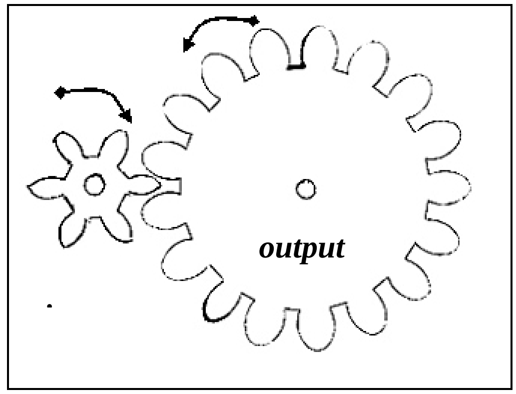
- Whenever we attach an *even* number of circular gears in sequence, the first and last gear will always turn in *opposite* directions.

-If an *odd* number of gears are attached in sequence, then the first and last gear will turn in the *same* direction.



b. Gear Ratios

A gear or speed ratio simply translates into how many turns will be produced in the output gear for every full turn of the input gear. In principle it is the ratio of the circumference[C]or diameter[d]) of the input wheel to that of the output wheel; but what makes it simple is that the gear's circumference is proportional to its number of teeth[n].



Gear or velocity ratio = $\frac{v_{output}}{v_{input}} = \frac{C_{input}}{C_{output}} = \frac{d_{input}}{d_{output}} = \frac{n_{input}}{n_{output}}$

$v_1 n_1 = v_2 n_2$

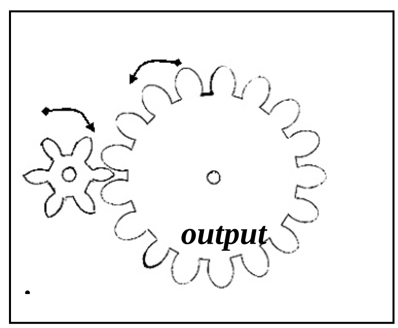
$v_1 n_1 = v_2 n_2$

What is being symbolized by the varying sizes of letters?

So in the above diagram, if the power is applied to the small wheel, the gear ratio will be 6 to 17 or 6/17. Since the fraction is less than 1 it implies that there will be a loss in velocity. If we apply the turning force to the larger gear, the ratio will be the reciprocal: 17/6, and the output gear will experience a gain in velocity.

c. Gears, Energy and Torque

Since the energy is almost completely transferred from the small to the larger gear, if there is a loss of speed, the larger gear ends up with more turning force or torque, which has practical advantages. In a VCR for example small gear attached to the small motor is easily and quickly turned, but the large gear's extra torque will be able to turn the heavy VHS tape.

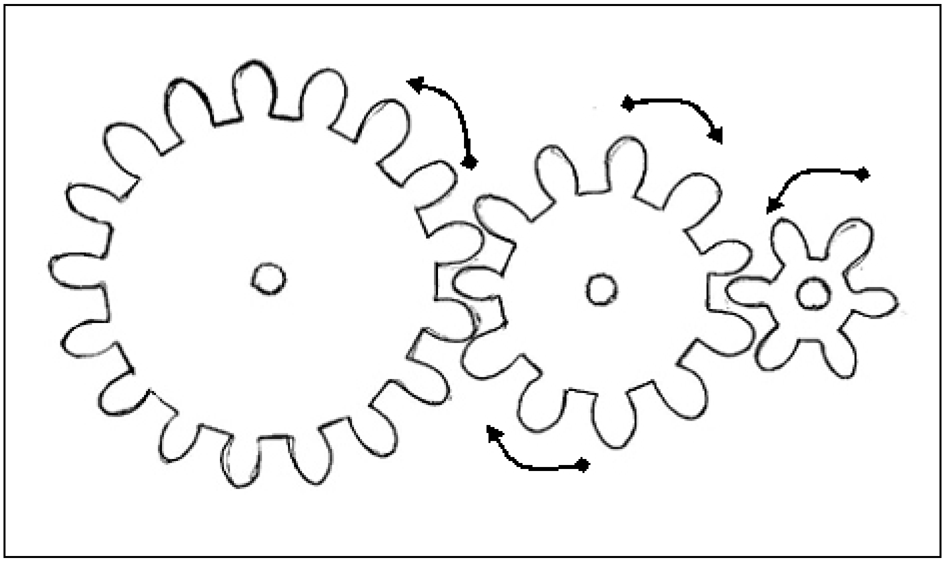


Conversely, a large gear ratio is favorable when we want turning power to be converted into a greater speed as occurs in a bicycle or car transmission gears.

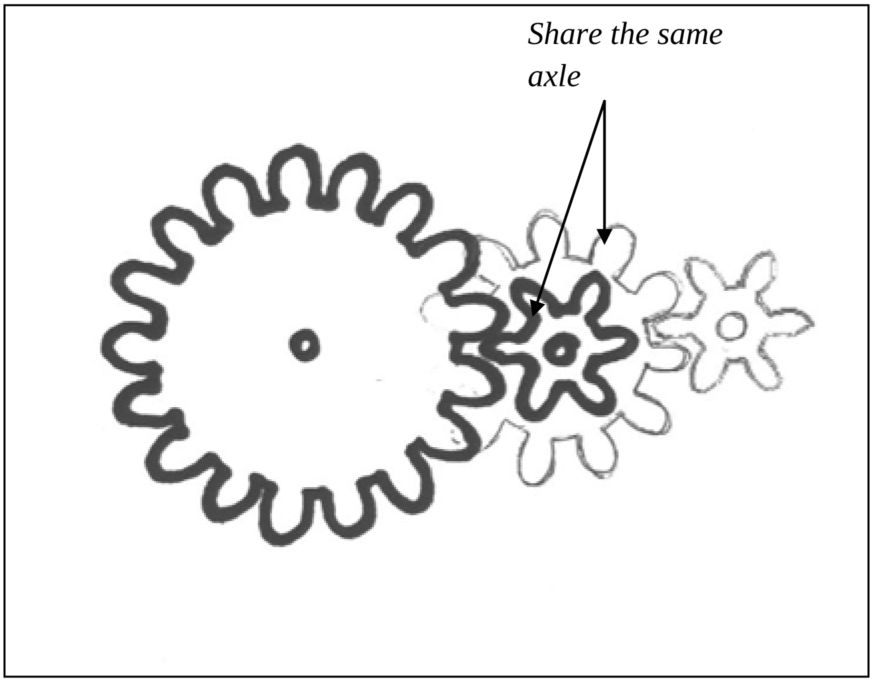
A ratio can be used to show the gain in torque: it is known as mechanical advantage, and it is the reciprocal of the velocity ratio.

Mechanical advantage = $\frac{C_{output}}{C_{input}} = \frac{d_{output}}{d_{input}} = \frac{n_{output}}{n_{input}}$. If we apply a force to the smaller gear, the larger one gains turning force at the expense of its slower speed. Recall that the velocity ratio was 6/17, but since the output dimension is in the numerator, the mechanical advantage becomes 17/6.

d. Gear Boxes



In the above, although we restore the counter clockwise motion of the large small gear, introducing the middle gear does not change the overall gear ratio. Specifically if we hooked up the large gear to the small gear, the ratio would have been 17/6. The gear ratio between the large and the medium and is 17/11. Between the medium and small it is 11/6. Overall then the ratio remains (17/11)(11/6) = 17/6.



Can we create a system of gears where we can create a larger ratio?

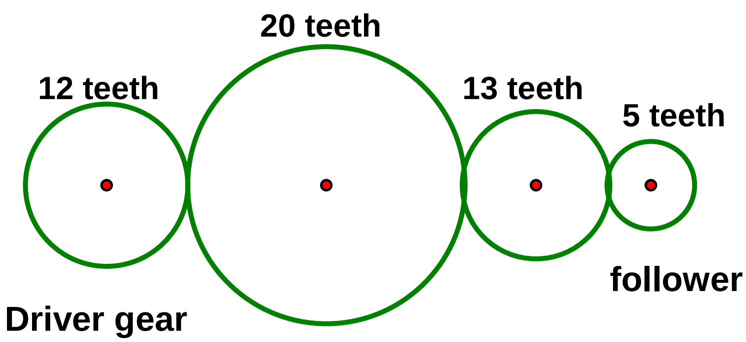
By letting the small gear share the same axle as the medium gear, we now have *two pairs* of gears working together in what is called a gear box. Since the middle gear is no longer caught in the middle, the overall ratio becomes (17/6)(11/6) = 187/36 = 5.19. So instead of turning almost 3 times faster (17/6), when we had the large-medium-small sequence) the gear box causes the last small wheel to turn more than 5 times faster than the larger wheel.

Module 4: Technology

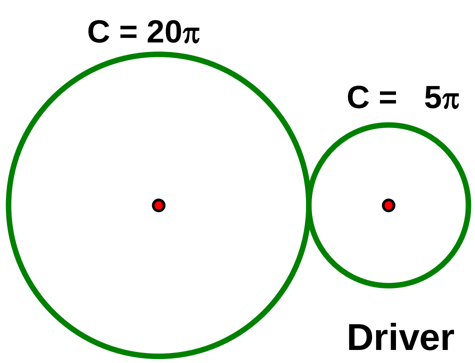
In Class Examples

1. For each of the following, please calculate the **gear ratio** from the driver to the follower. Explain the meaning

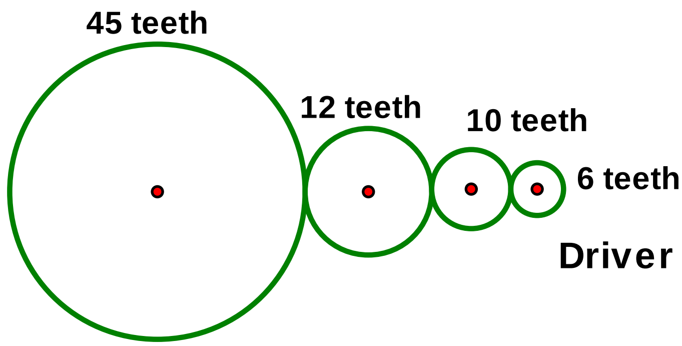
a)



b)

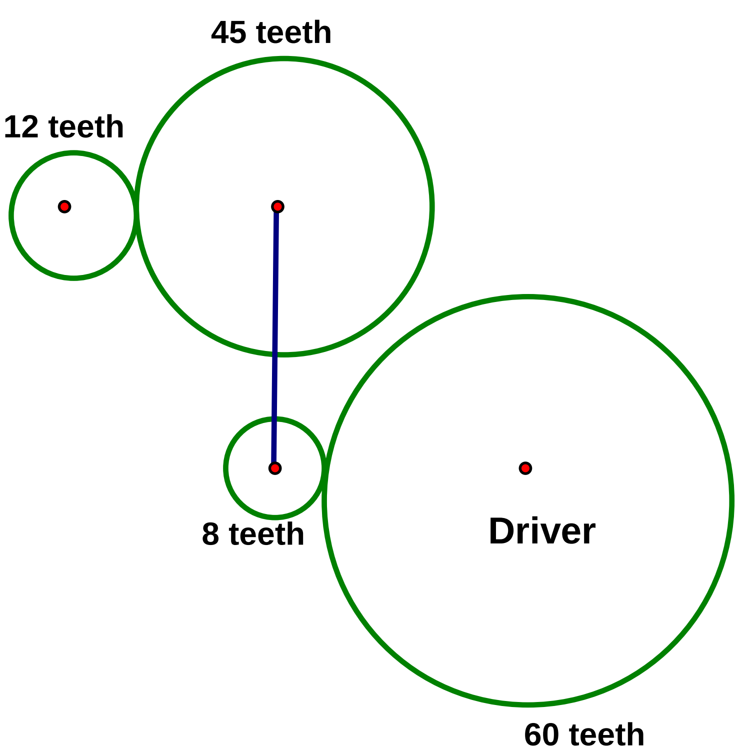


c)



d) What is the mechanical advantage for the diagram in (c)?

e) The vertical line symbolizes a gear box connection. Find the gear ratio.



Module 4: Technology

Exercises: Direction of Motion, Gear Ratios, and Mechanical Advantage

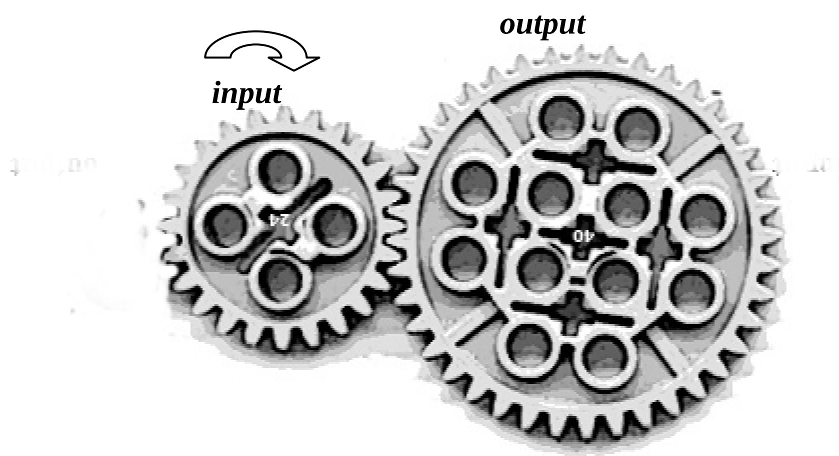
1. Instructions: For each of the following systems of gears,

(i) predict direction of the output gear

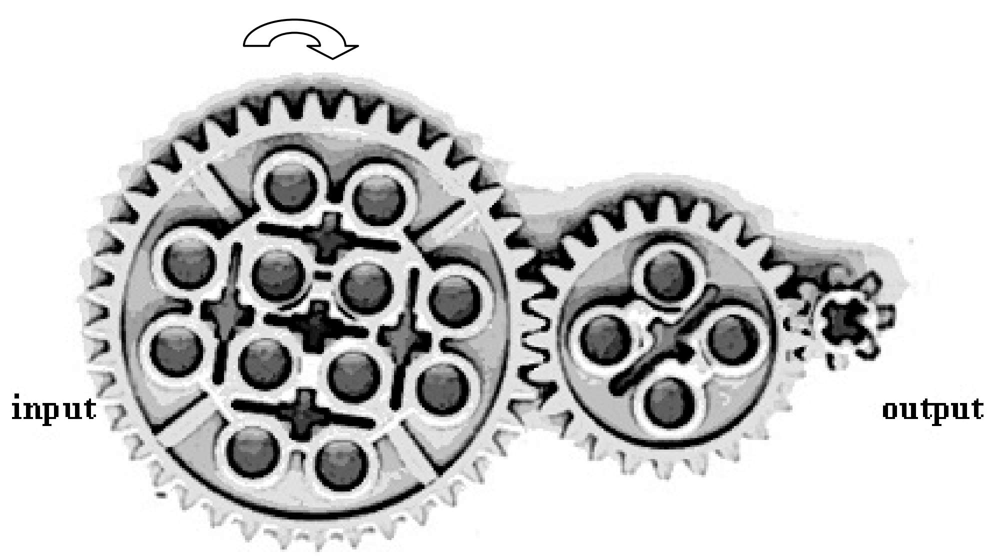
(ii) calculate the gear(velocity) ratio.

(iii) calculate the mechanical advantage(torque ratio).

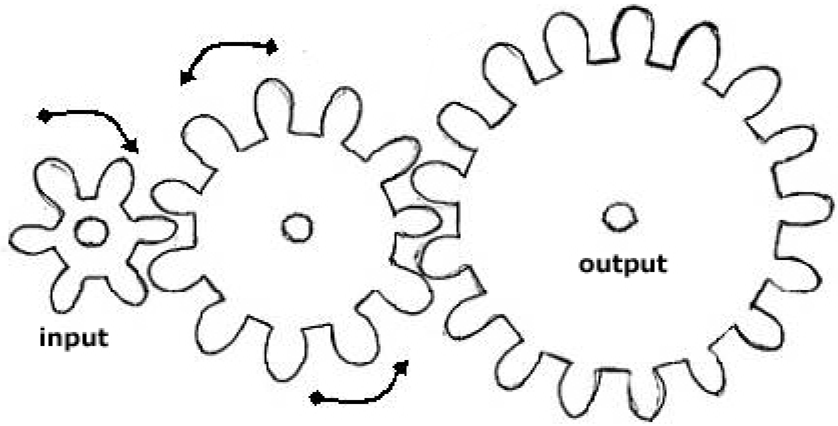
a)



b)

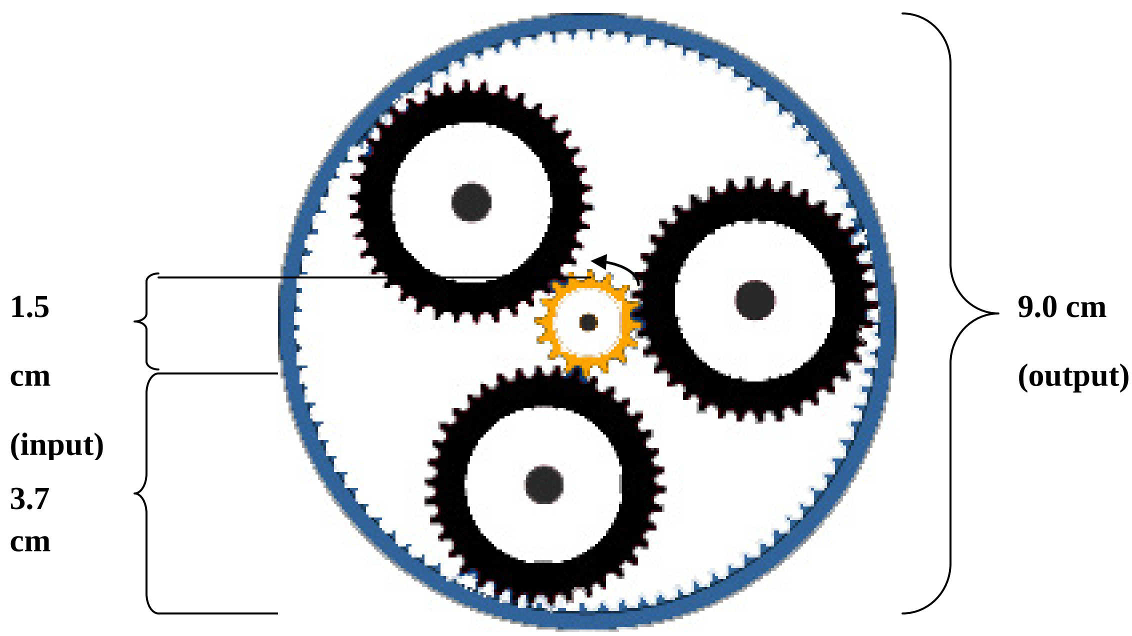


c)



d)

Careful: when trying to predict the direction of the output gear in this *planetary gear* system, notice that the teeth are on the *inside*. Imagine what will happen.

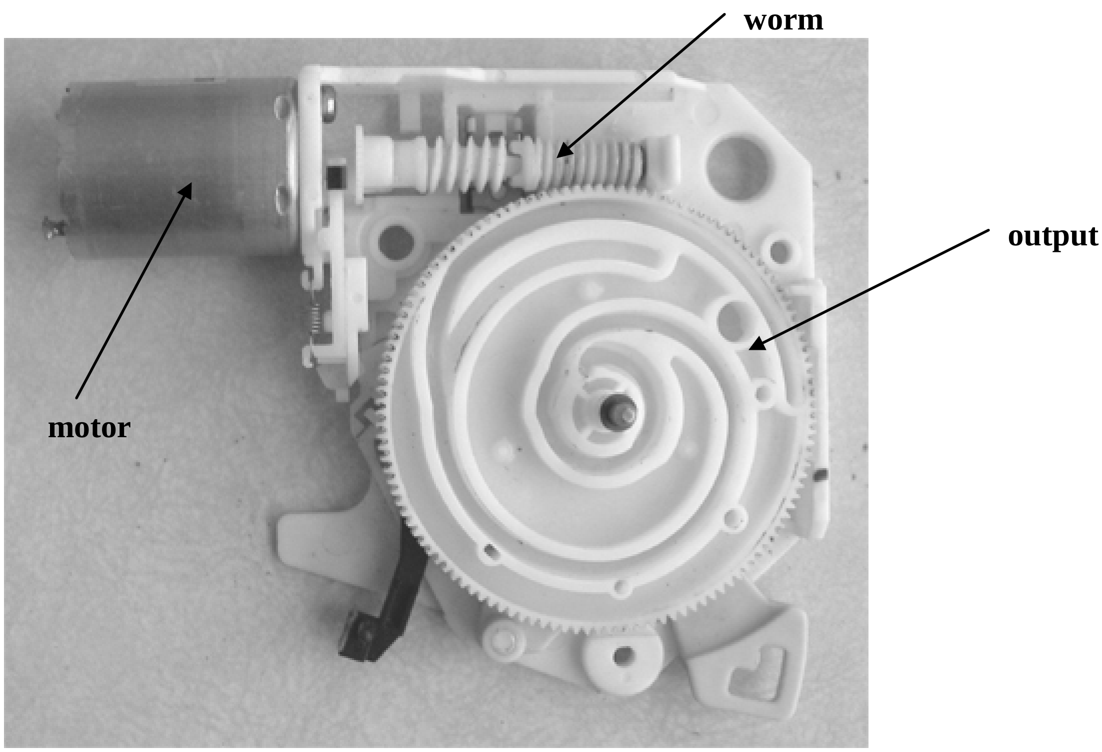


2. An input gear has 12 teeth. If the mechanical advantage is 3:1, how many teeth are on the output gear?

3. There are three gears available. One has 4 teeth. The second has 6, and the last has 8 teeth. Draw how they should be connected so that their gear (velocity) ratio is 2:1, and so that the output gear turns in the same direction as the input gear. Make sure that you label the input and out put gears.

4. You have a pair of 5 cm toothed gears and a pair of 10 cm toothed gears. You would like to create a gear(velocity) ratio of 4:1. How do you connect them? Draw the setup, and label the input and out put gears.

5.



The above, which was taken out of a VCR, is called a *wheel and worm-gear*. It is a type of gear which creates a surprisingly high mechanical advantage by connecting a cylinder with a spiral groove ("worm") to a regular toothed gear.

a) A student noticed that for every 31 turns of the worm, the output gear only made ¼ of a turn. What is the torque ratio (mechanical advantage) of this gear system?
b) When the student measured the diameters of the two gears, the student found a surprisingly lower ratio than what he calculated in part(a). The teacher told him that no mistake had been made in part(a), and that although the diameter formula does not apply to a worm, the ratio of gear teeth is still equal to the torque ratio.

   Based on this information, how many teeth does this (or any) worm gear have?

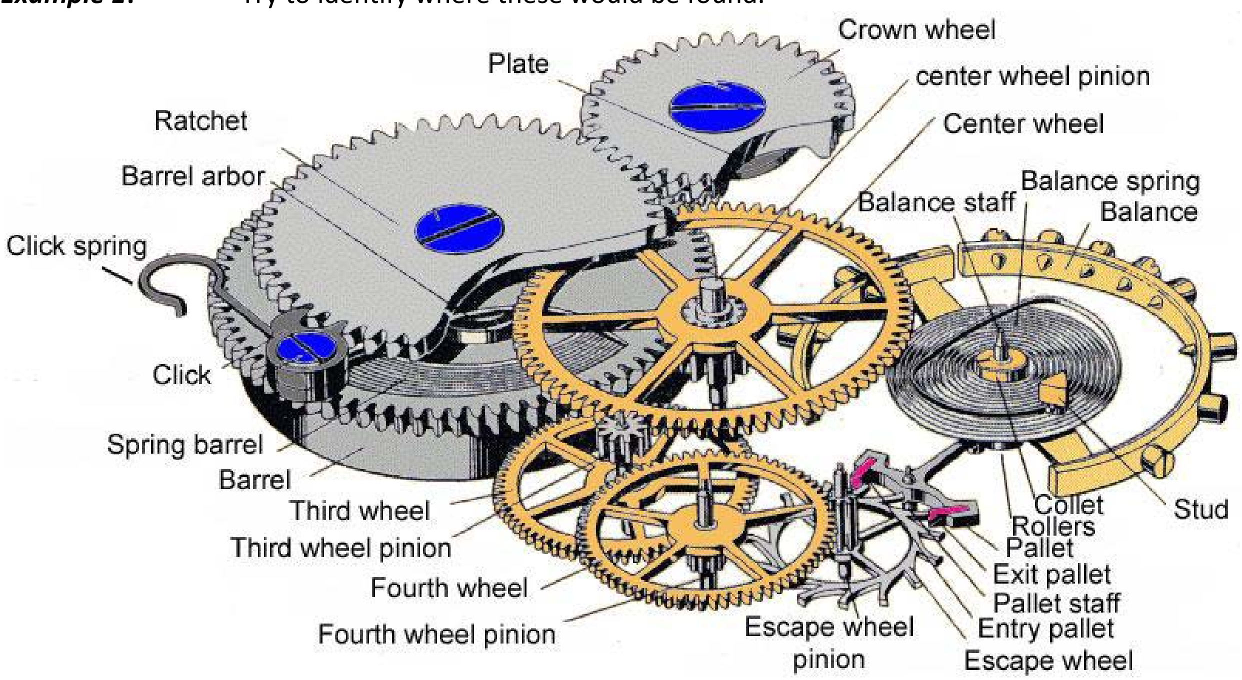
29. Gear Systems (Transmission Systems)

What is a transmission system?

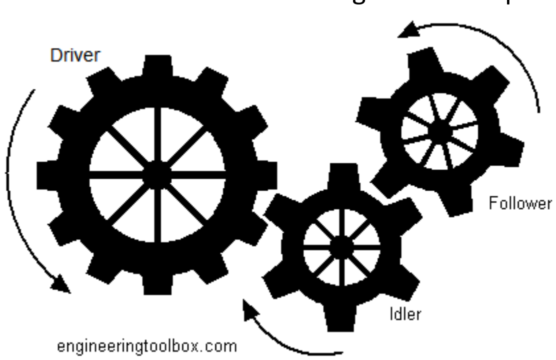
1. Gear Trains
2. Chain-Sprocket systems
3. Worm and Worm-gear Systems
4. Friction-Gear (toothless)Systems
5. Belt and Pulley Systems

1. **Gear Trains:** two or more toothed gears that mesh with each other; includes gear boxes that we've already studied.

Example 1: Try to identify where these would be found.

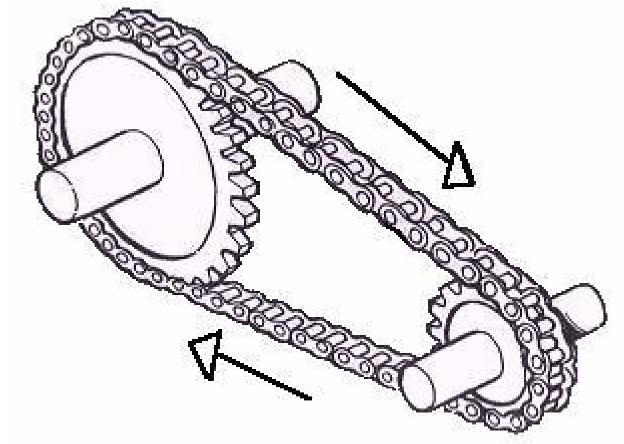


Example 2: Calculate the velocity ratio for the following.
Note that the "driver" gear is the input.



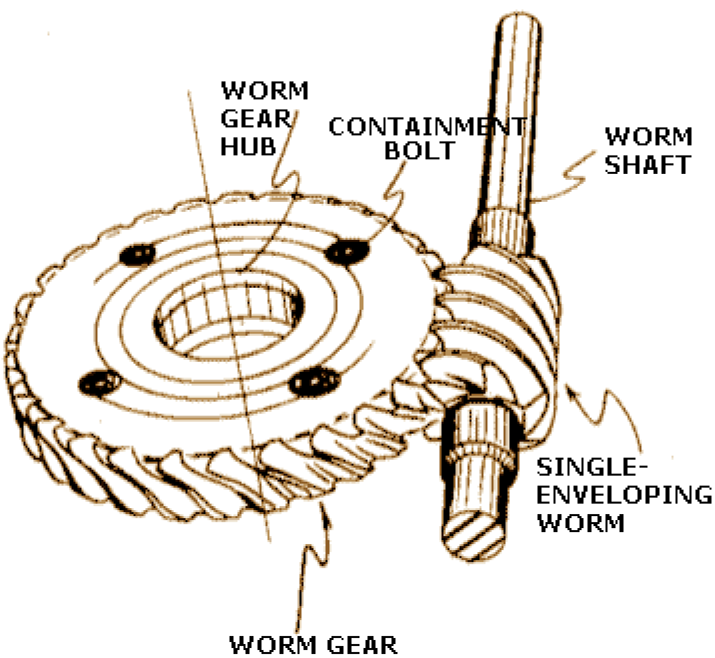
2. **Chain-Sprocket Systems:** toothed gears connected by a chain

Example 1: What advantage does this system have over a gear train?



3. **Worm& Worm-gear System:** The input gear is a screw-like "worm", and the output is one or more toothed gears known as worm-gears. It's not reversible.

Example 1: Which part do you think turns very easily?



Example 2: If the velocity ratio is low, what can be said about the mechanical ratio?

4. **Friction-Gear (toothless)Systems:** like a gear train without the teeth

Example 1: The two wheels ('gears") are made out of iron.

What makes them stick together?

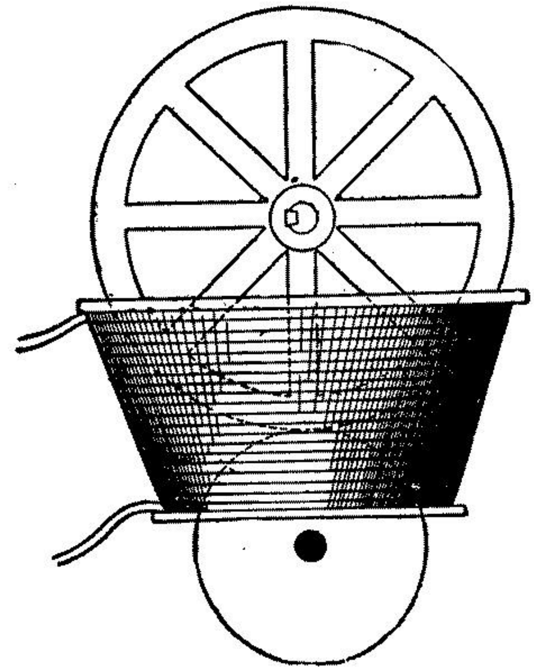
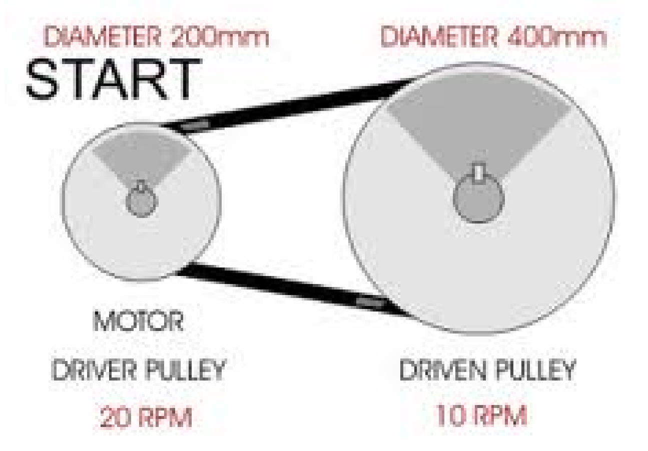


Fig. 190. MAGNETIC FRICTION GEAR.

5. **Belt and Pulley Systems:** has pulleys that include grooves that allow the belt to fit.

Example 1: What makes this system different from a chain-sprocket system?



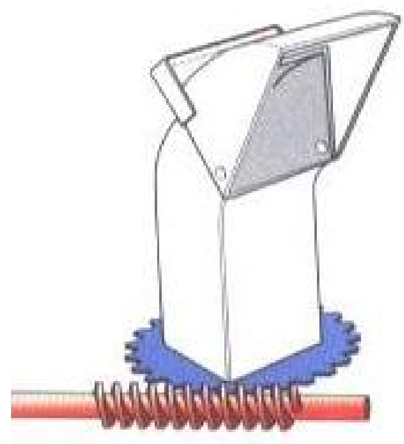
Example 2: What is the mechanical ratio of this system? Velocity ratio?

Module 4: Technology

In-Class Examples

1. a) This is part of a snow blower.

What type of gear system is this?

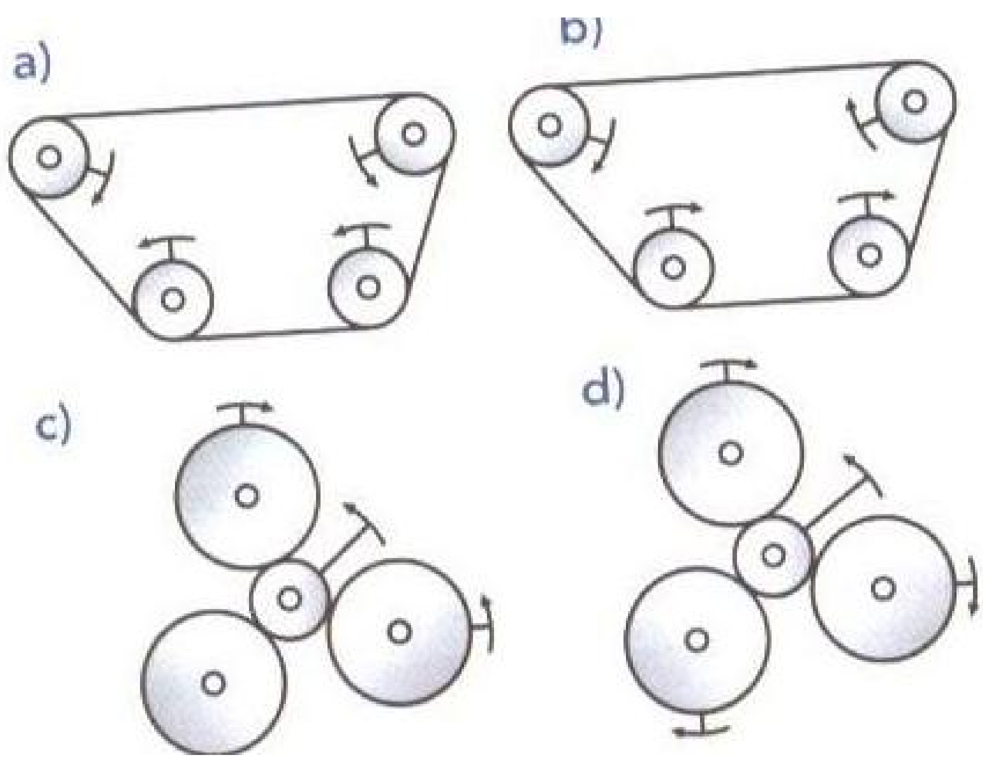


b) Name the input. (what type of gear is this?)

c) If you try to turn the chute manually,

why is that a bad idea?

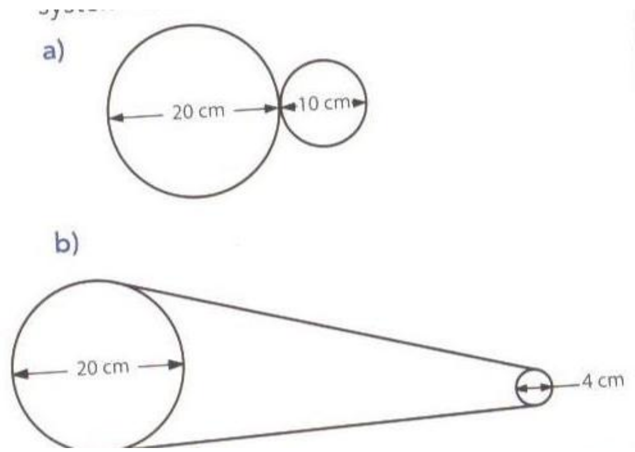
2. Which systems show the real motion?



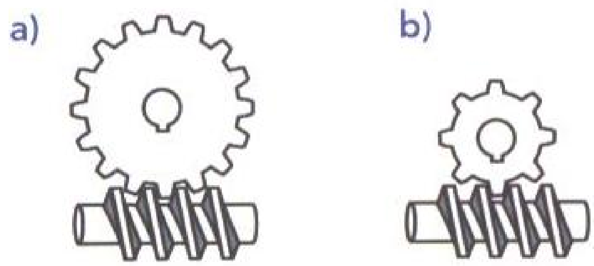
Module 4: Technology

3. a) Calculate the velocity(speed) ratio if the larger one is the input.

   b) What kind of systems are these, assuming no teeth on the gears?

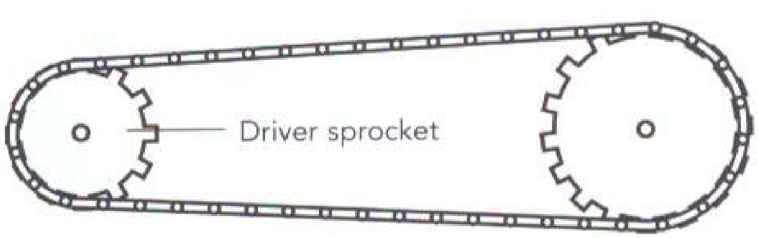


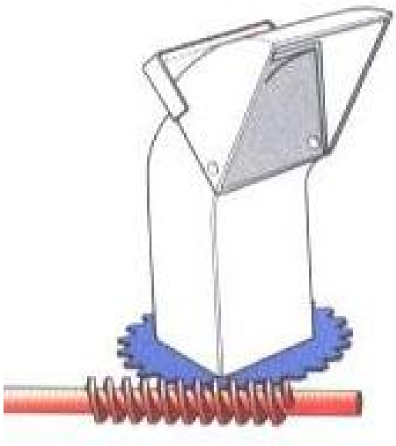
4. Look at the two worm and worm gear systems below.



In which system will the rotational speed be more greatly reduced? Explain your answer.

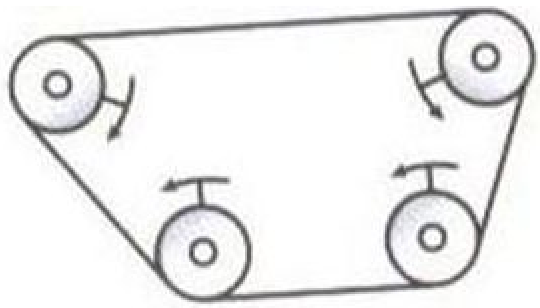
5. In the chain and sprocket system below, the rotational speed of the driver sprocket is 60 revolutions per minute. Based on the information provided by the illustration, calculate the rotational speed of the other sprocket. Express your answer in revolutions per minute.



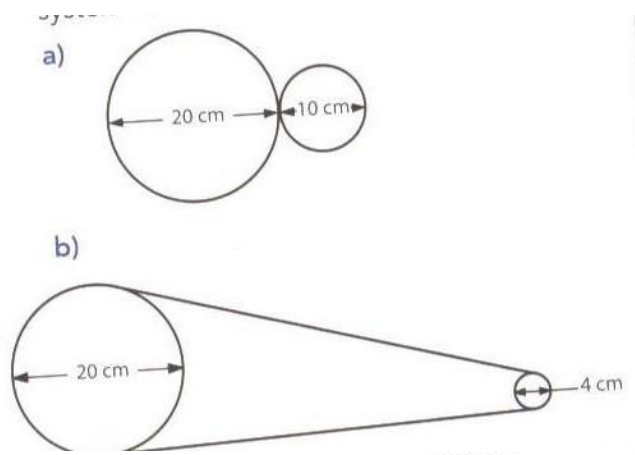


Exercises (homework)

1. Use the velocity (speed) ratio and mechanical advantage to explain why it makes sense to use a worm gear system for a snow blower.
2. The following diagram shows the incorrect motions. Fix it.



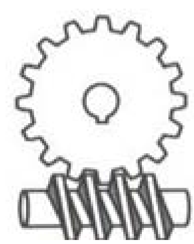
a) When the velocity ratio is high, it will be hard to pedal but the back wheel will move fast. If(b) was a bicycle, redraw the back(small) gear, so that the velocity ratio would become 4/1 instead of 5/1 and therefore slightly easier to pedal.



b) What would be the mechanical ratio in (a) if the small gear was the input gear?

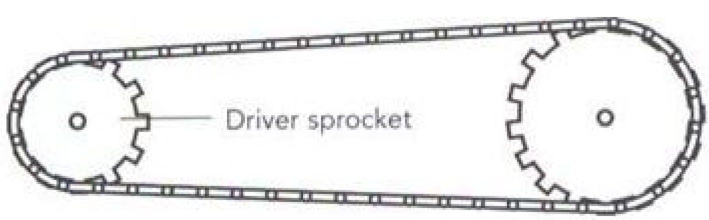
c) What would kind of gear system would (b) be if it involved a toothed gear and a chain?

d) What kind of gear system would (b) be if it involved smooth wheels?



3. a) What kind of gear system is shown to the right?
   b) If the worm is considered to have a single tooth, what is the mechanical advantage of this system?

4.



a) If the driver sprocket around turns clockwise, in what direction will the larger wheel turn?

b) If the 12-toothed wheel makes 4 turns, how many turns will be made by the 16-toothed wheel?

30. Links

I-Linking in Technical Objects

1. What is linking? Give examples.

2. Characteristics of Links

- A) **<u>Direct versus Indirect Links</u>**. What's the difference?

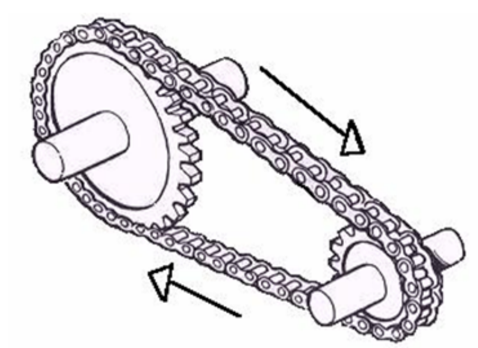
Examples Classify as direct or indirect.

a) Link between tire and wheel

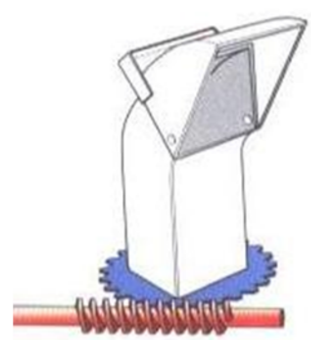
b) link between blade and shoe

More Examples Classify as direct or indirect.

c) The link between the two gears



d) The link between the two gears



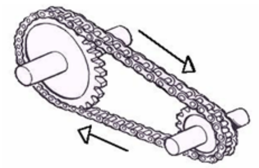
B) **Rigid versus Flexible Links**. What's the difference?

Examples Classify as rigid or flexible.

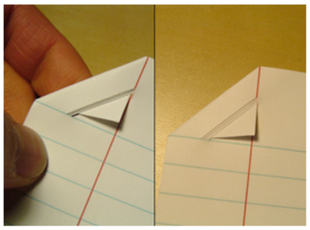
a) Link between tire and wheel

b) link between blade and shoe

c) The link between the two gears



d) The link between the two papers



C) **Removable versus Nonremovable Links**. What's the difference from the point of view of destruction?

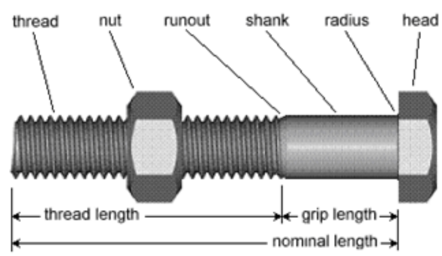
Examples Classify as **removable** or **nonremovable**.

a) Link between tire and wheel

b) link between blade and shoe

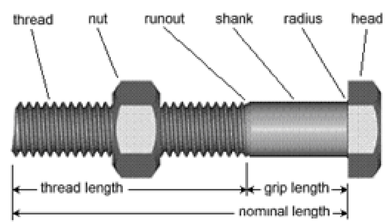
c) Link between shoe top and sole

d) link between nut and bolt



D) **<u>Complete Versus Partial Links</u>**. What's the difference?

Examples Classify as complete or partial links and explain why.



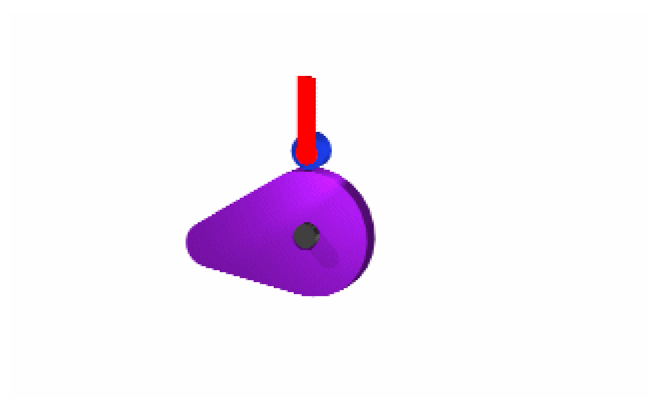
Module 4: Technology

Exercises: Links

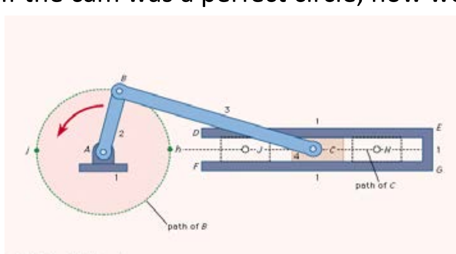
1. Classify as direct or indirect link.
   a) A car tire and wheel
   b) A highlighter and its cap
   c) the stems of eyeglasses(over the ears part) and the rest

2. Which of the above links are flexible?
3. Which are removable?
4. Classify as complete or partial link.
   a) Roller skate's shoe and wheels
   b) Shopping cart's wheel and bottom frame
   c) Chair and desk in the type where they are attached.

Exercises: Transformation Systems



5. Which two systems need to be regularly lubricated?
6. Give an example of a screw-gear system where the nut can be moved?
7. How do you make sure that the cam and follower remain in contact?_
8. a) What two transformation systems are found in engines?
   b) What other system is found in cars and what does it do?
9. If the cam was a perfect circle, how would the follower behave?



Would it defeat its purpose?

10. Why doesn't the piston of an engine move from side to side even though the connecting rod moves?

31. Transformation Systems

II-Transformation Systems: these turn rotational motion into a translation or vice versa

1) **<u>Rack (straight part) and Pinion</u>** convert rotational motion into linear motion(translation)

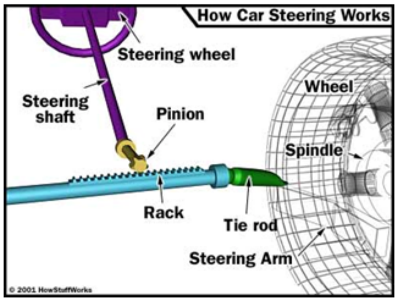
a) Where is this system found?

b) **<u>Characteristics</u>**

(1) Teeth must__________

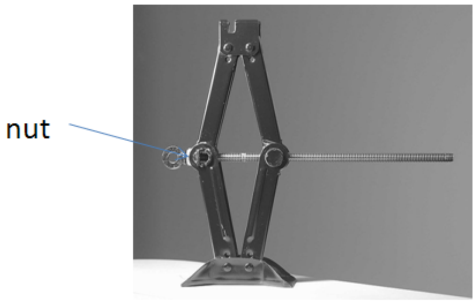
(2) To prevent wear and tear, the system needs to be ________

(3) What can be done to pinion to slow movement of rack?



2) Screw Gear System

a) What are the two types of screw gear systems?



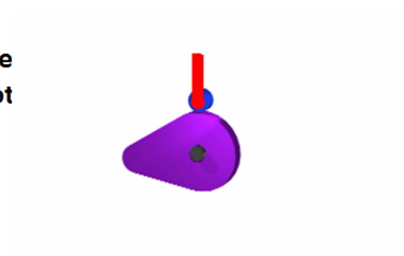
b) Characteristics

(1)Can the nut rotate with the screw in the jack?___________

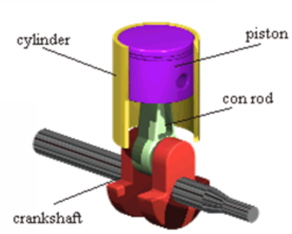
(2) In which system(s) should the screw's threads match those of the nut?_______

(3) In the wrench is the nut being held in place?_____

3) Cam and Follower System: the "followe part has a repetitive up and down mot The cam is the teardrop shape.



A) Where is this system used?



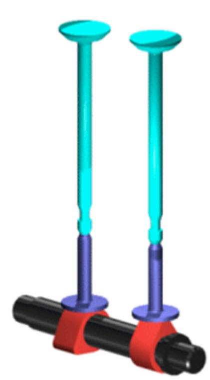
B) Characteristics

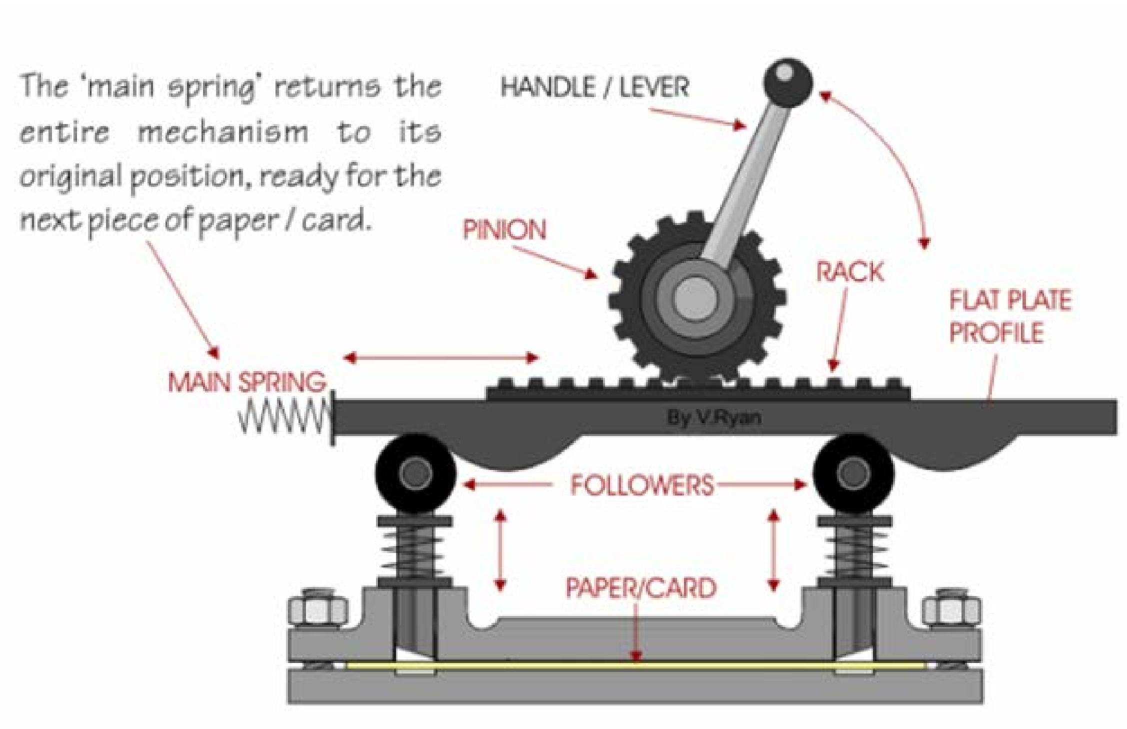
(1) Must the follower be "guided?___

(2) Is the cam's shape important?____

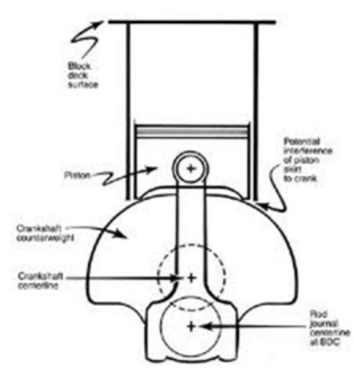
(3) How do you make sure that the cam follower remain in contact?______________________

____





4) Slider-Crank System: an up and down motion of a piston is turned into a circular motion



A) Where is this system used?

B) Characteristics

(1) What connects the piston to the crank?__

____

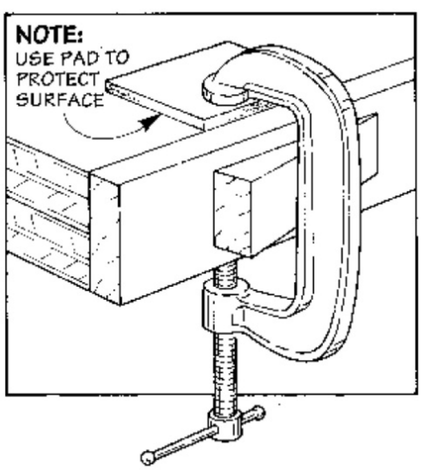
(2) What part of the engine keeps the piston in place("guides it")?________________________

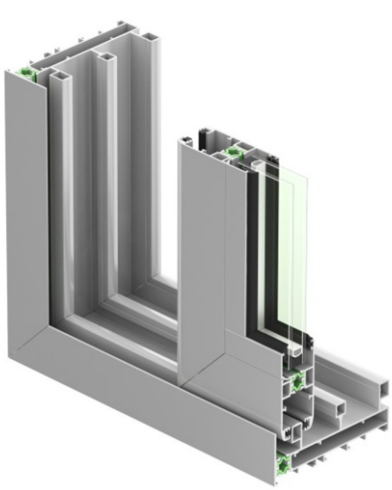
(3) How do you prevent wear and tear between the guiding part and the piston?

Module 4: Technology

32. <u>Guiding Controls: What are they?</u>

Use the bicycle, clamp and window as an example of how they help preserve a certain type of motion.





Module 4: Technology

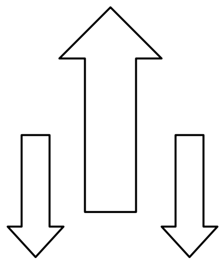
Exercises

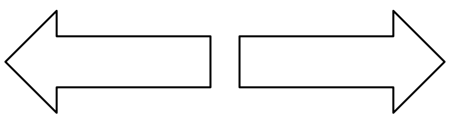
1. What is the guiding control for a sliding patio door?
2. What is the guiding control for the front wheel on a bicycle?
3. What is the guiding control for the screw on a clamp?
4. Match each of the above controls with the following:
   A) Translational guide
   B) Rotational guide
   C) Helicoidal guide

5. a) Think of a stapler. Is the link between the rubber part and the bottom shell direct? Or indirect?________
   b) Is it removable?_________
   c) Is it flexible?___________
   d) Is it complete? Or Partial?_________

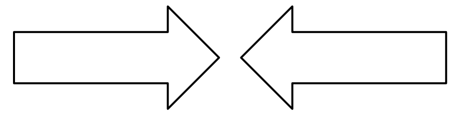
   e) Is the link between the staple bed and the part above complete or partial?____________
   f) Why?

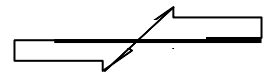
Module 4: Technology

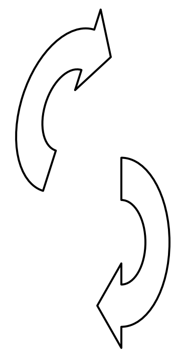




TOPIC	Pages in textbook
Constraints and types of material deformations	387
Mechanical Properties of Materials	388-89
Ceramics	392-394
Plastics	396-98
Composites	399-400







33. Constraints

Materials have to be able to withstand various constraints. A constraint is what describes the effect of external forces on a material.

Type of constraint	Description of forces	Symbol (choose from above)	Examples
Compression	Crushing		
Tension	Stretching Deflection		
Torsion	Twisting		
Deflection	Bending		
Shearing	Cutting		

34. **Mechanical properties** describe how an object reacts to constraints.

Mechanical Property	**Definiton**
hardness	Resists dents
elasticity	Reverts back to original after compression, deflection, tension or torsion
ductility	Can be stretched without breaking; ie. into wires
malleability	Can be flattened without breaking
stiffness	Resists deflection especially; not elastic

Examples:

Give examples of how each property is important in practical materials like wires and metallic sheets.

Module 4: Technology

Other Properties of Materials

Other Material Property	
Resistance to Corrosion	Will not react with water, oxygen, acids, salts or bases
Electrical Conductivity	G= 1/R; allows electricity to flow through it
Thermal Conductivity	Thermal conductivity is the measure of the quantity of (heat) energy which flows through a unit length, in unit time, when there is a unit temperature difference between the two ends of the length.

In Class Examples

1. What kind of wood is hard? Soft?

2. a) What elements of the periodic table are ductile and malleable?

   b) What family of elements are ductile, malleable but nowhere near as hard as the rest of the metals?

   c) List six elemental metals with at least some resistance to corrosion.

   d) Which elements corrode very easily and why?

   e) List four elements with an atomic number less than 10 that have poor thermal conductivity.

3. a) Which elements have low electrical conductivity?

   c) STE only---What is the difference between specific heat and thermal conductivity?

3. **Ceramic Materials**: do not include just tiles on floors and walls but also bricks, blocks, glass and dishes. They are prepared by the action of **heat** and subsequent cooling.

a) What do they have in common form the point of view of chemistry?

Brick composition	Tile composition	Glass composition
1. Silica (SiO_2) - 50% to 60% by weight 2. Alumina (Al_2O_3) - 20% to 30% by weight 3. Lime (CaO)- 2 to 5% by weight 4. Iron oxide(Fe_2O_3) - 5 to 6% (not greater than 7%) by weight 5. Magnesia(MgO) - less than 1% by weight	Al_2O_3. BeO, CeO_2, ZrO_2 and sometimes with non oxides but carbides	SiO_2 ,Na_2CO_3, CaO, MgO and Al_2O_3

Example: STE --- Give the charges of Fe, Al, Mg, Zr and carbonate in the above compounds.

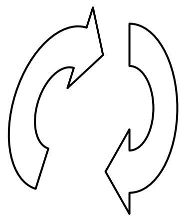
B)

Ceramic Material Property	
Resistance to Corrosion	
Electrical Conductivity	
Thermal Conductivity	

Module 4: Technology

Exercises

1. What is the difference between tension and crushing?
2. What constraint does the following symbolize?



3. a) What is shearing?
   b) Give an example of a material that is easily sheared.
   c) What malleable material allows it to be sheared? Explain.

4. a) Give 3 examples of elements with atomic numbers between 10 and 20 that conduct electricity.
   b) Which is the semiconductor among the three just listed?

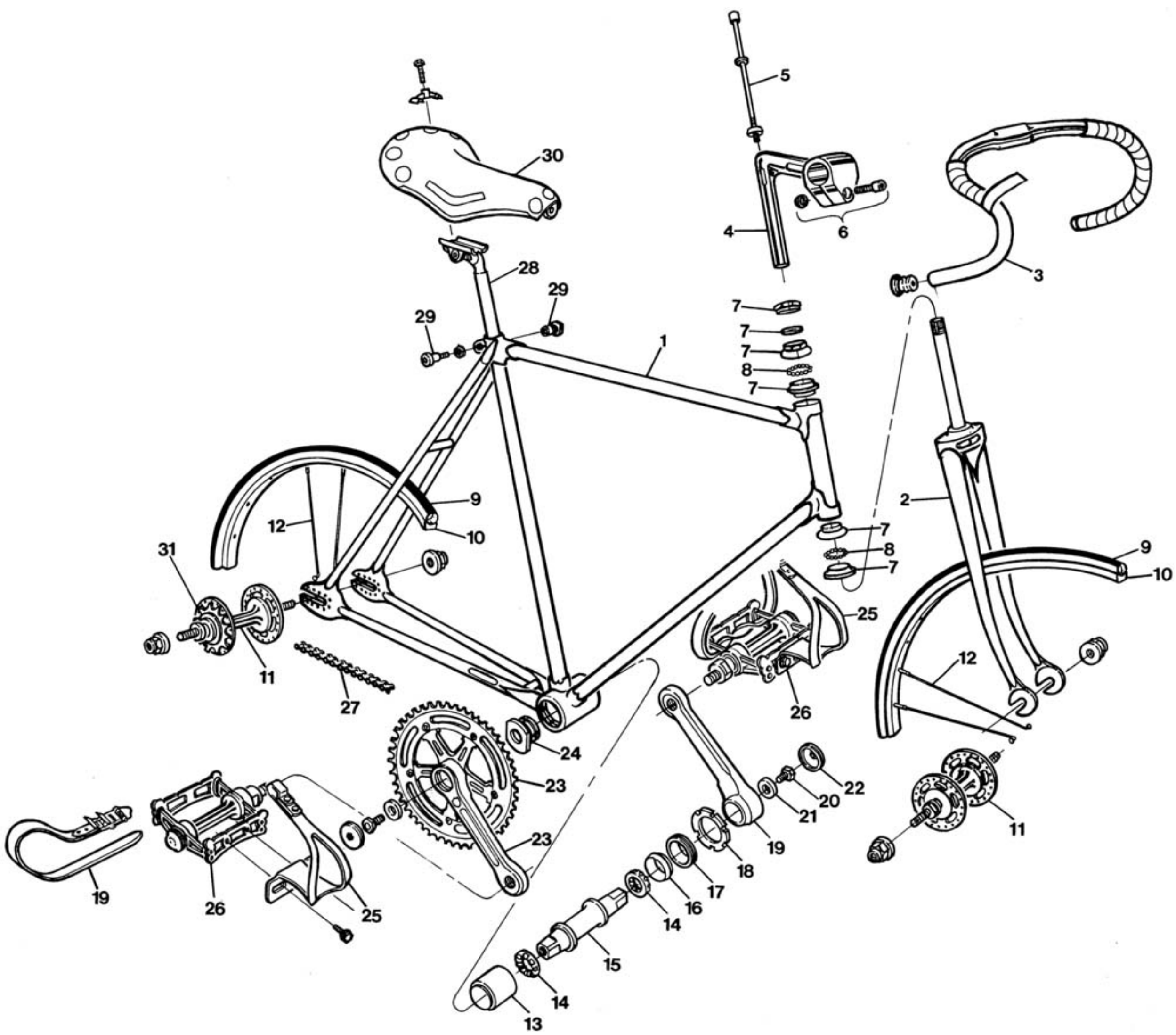
5. a) What material property has the following unit: J/(s*m*K)? K = Kelvin, a unit of temperature
   b) Why can this unit also be expressed as W/(m*K)? (what did we learn that was equivalent to J/s?)

6. What two ingredients do ceramics have in common?
7. What is common to the way they are prepared?
8. What three electrolytes attack them?
9. a) Are they resistant to attack from oxygen and water?
   b) Why?

10. Why are electrical wires sometimes wrapped in ceramic material?

35. **<u>Exploded View Drawings:</u> their purpose is to show the relationship between the assembly of all the parts of the object**

<u>Example 1</u>**:**

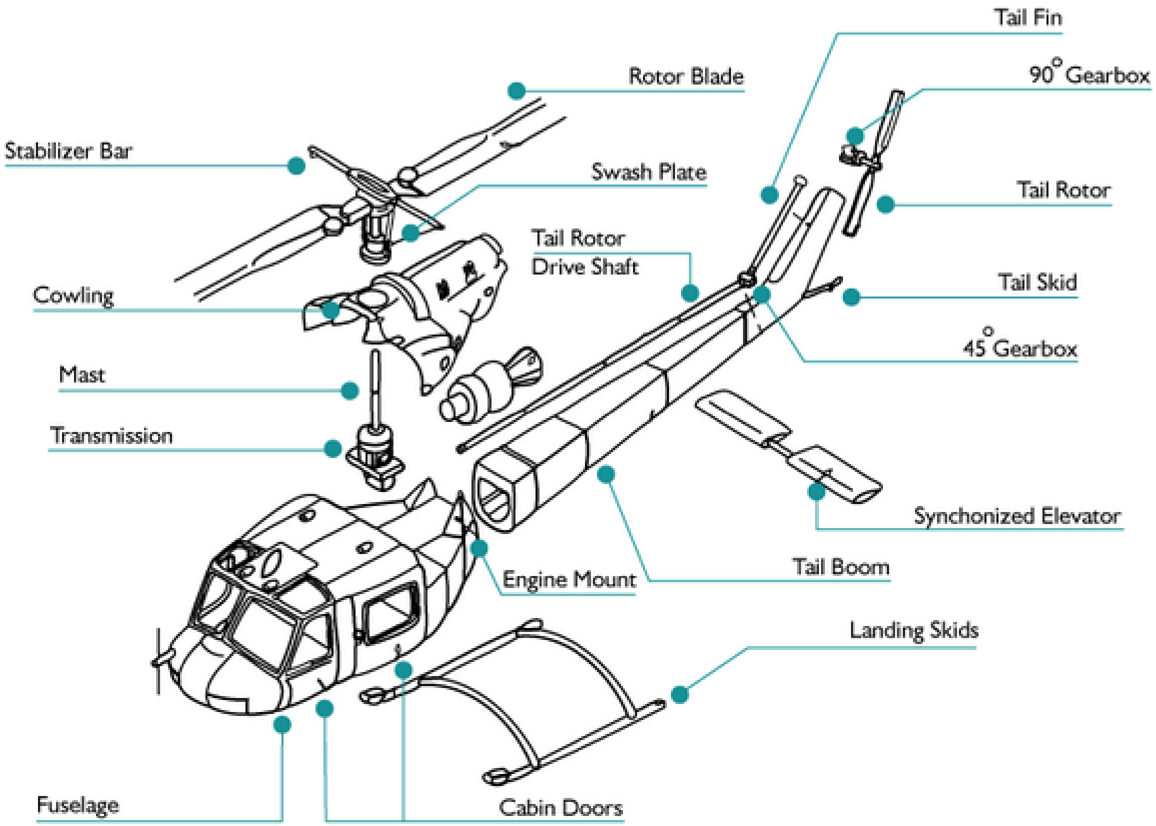


a) Are links shown?_______________

b) Which two numbered parts are guiding controls for the front wheel?

c) Is the link between the seat and seat support direct?_____________

Example 2



a) Us the apropriate symbols to show the motion of the three rotors.
b) Find two systems designed to amplify the velocity ratio.

Module 4: Technology

<u>Example 3</u> **Complete the following table.(see p 75 of Toolbox booklet)**

Type of Motion	**Symbol**
Unidirectional translational motion	
bidirectional translational motion	
Unidirectional rotational motion	
bidirectional rotational motion	
Unidirectional helical motion	
bidirectional helical motion	

Module 4: Technology

<u>Example 4</u> (based on p 76 of Toolbox Manual)

Draw the 5 gear systems(gear, train, friction gear, etc) and for each diagram include two motion symbols—one for each component.