SINGAPORE POLYTECHNIC

SCHOOL OF MECHANICAL & AERONAUTICAL ENGINEERING

Aeronautical Engineering (DARE)
Aerospace Electronics (DASE)
Computer Engineering (DCPE)
Electrical & Electronic Engineering (DEEE)
Energy Systems and Management (DESM)
Engineering Systems (DES)
Engineering with Business (DEB)
Mechanical Engineering (DME)

EM 0524
ENGINEERING EXPLORATION AND DESIGN

AY2020/2021
(VERSION 1.0)

MODULE OVERVIEW

1. Introduction

Engineering Exploration and Design is an EA(Engineering Academy) module for the 2nd year students offered in the 1st Semester

This module is 4 hours per week and it is an ICA module with no MST and EST.

2. Module Aims

Engineering Exploration and Design aims to induct students into Engineering Academy culture and objectives, get them to understand the spirit of the program and the challenges it comes with. The module will expose students to the fundamental skills required of successful innovators: teamwork, goal setting, ideation, and iteration. It builds upon the Digital Fabrication skills learnt in the 1st year in Introduction to Engineering. The module aims to empower students to realize their ideas and is conducted in blended (e-learning & hands-on) mode.

3. Means of Assessment

This is an In-Course Assessment (ICA) module with the following components:

Assessments		Weightage
CA1	Mechanical Assignments	30%
CA2	Electrical Assignment and Quiz	30%
CA3	Group Project	40%

4. <u>Module Contents and Teaching Schedule for AY2019/2020</u>

The schedule of topics to be covered in this module are as listed:

week	Mechanical Topics	Electrical Topics	Comments
1	Fabrication Techniques and Mechanical Components and Mechanism Design	Circuit Design	CA1a (15%) Briefing How Stuff Works
2	Product Creation Process	Sensors	CA1b(15%) Briefing Mechanism Design
3	3D/2D CAD Documentation	Actuators	
4	CA3 - Introduction	Embedded Programming	CA3 - Project Assignment Brief
5	CA3 - Brainstorm and Concept Selection	Embedded Programming	
6	CA3 – Concept Selection	CA2a - Assignment Brief	
7	CA3 - Design	CA2a – Assignment clarification	Submission of CA1a report
8	MST		
9 - 10	2 week vacation		
11	CA3 - Documentation		Submission of CA1b report
12	CA3 - Documentation		
13	CA3 - Documentation		
14	CA3 - Documentation		
15	1 week vacation		
16	CA3 - Documentation	CA2b - Quiz	
17	CA3 - Documentation		
18	CA3 - Documentation		
19	CA3 – Presentation		CA3 - Report Submission
20 - 21	EST Exam		

Note: The schedule may be adjusted to accommodate resource constraints, public holidays or poly-wide events. All information relating to this module will be posted on Blackboard. Students are to access Blackboard frequently for updated information and if necessary, clarify with their lecturers or instructors.

Teaching Methods / Learning Tasks

Instruction will take place through a combination of lectures, tutorials, e-learning and practical workshop sessions. To aid the students better grasp the basic essential concepts, demonstrations will also be conducted in the workshop.

Audio visual media, hardware and various teaching aids will be used in the module delivery for effective learning. Students would require a computer and an active internet connection for e-learning.

Students are required to demonstrate their ability to work individually and in groups to encourage teamwork, personal and interpersonal communication skills.

5. Resource Materials

   a. **Lecture Notes** Each student will be given a set of common handouts. The lecture handouts contain the content covered in this module. However, students are encouraged to source for relevant material from the library or internet, in order to secure a better grade.

   b. Blackboard (BB)

   Students are required to access the Blackboard frequently. Announcements, schedule and module materials are available in BB. All e-learning will be done via BB.

   c. Lecture Slides

   Slides used during the lectures and tutorial are uploaded into Blackboard. Students are to use the slides as guides.

6. Recommended Texts

   Mikell P. Groover (2007), Fundamentals of Modern Manufacturing, New York NY: John Wiley & Sons

7. References

   a. Tim Brown. (2009), Change by Design, New York NY: Harper Collins

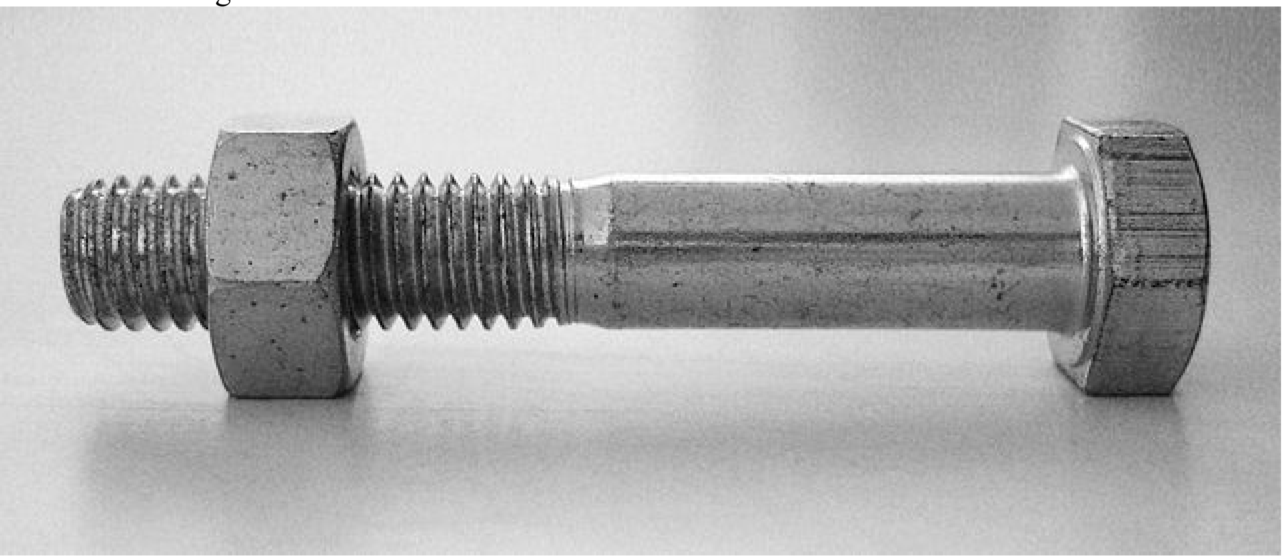
   b. Sclater,Neil. (2007), Mechanisms and mechanical devices sourcebook, New York: McGraw-Hill

   c. Sandin,Paul E. (2003), Robot mechanisms and mechanical devices illustrated, New York: McGraw-Hill

d. Pahl,G. (2007), Engineering Design: a systematic approach, London: Springer

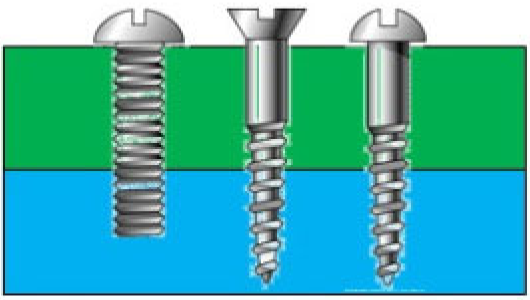
Unit 1. Mechanical Components and Mechanisms

1. **Bolts and nuts**
These are used in high stress applications. The user needs to drill a hole to put the bolt through then, fasten nut on the opposite end. Compression and friction between the materials is the main factor to hold the parts together. The figure below shows how they are used to hold materials together.



Bolts and Nuts are identified in Metric standard as M6 – for 6mm bolt, M8 – for a 8mm bolt, and the same goes to the corresponding nut.

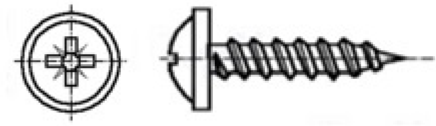
2. **Screws**
These are another type of fasteners. Friction between the screw threads and the materials is the main factor to hold the parts together. The figure below shows how screws are used to hold two materials together.



There are many types of screws but the 3 main types are as follows

a) **Wood Screws**
These screws are used to hold wood pieces together and have the following features:
• Tapered tip
• Wide pitch distance (the distance between screw threads)
The tapered tip allows the screws to be used without drilling a hole and since wood is

generally soft, the wide pitch distance allows more material to be in-between the threads.



b) **Plastic Screw**

These screws are used to hold plastic pieces together and have the following feature:

• Wide pitch distance

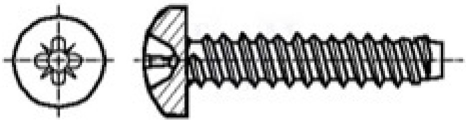
Similar to the wood screw, the wide pitch distance allows more material in-between the threads. However, most of these screws do not have a tapered tip, thus the user needs to drill a hole before using it or design a pilot hole for the screw.

c) **Metal Screws**

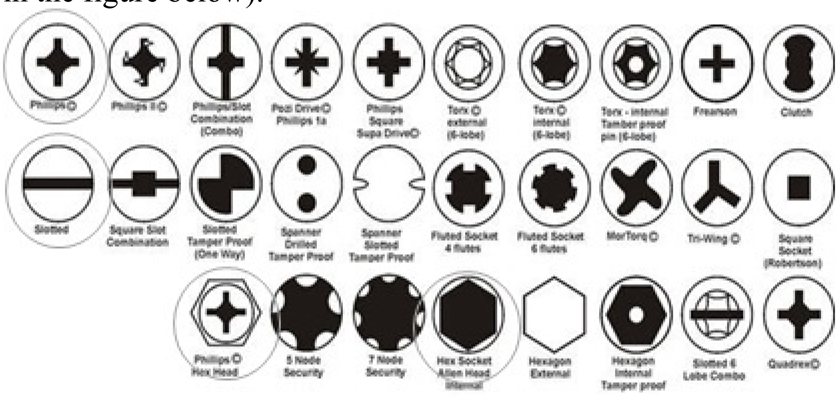
These screws are used to hold metal pieces together and have the following feature:

• Narrow pitch distance

Since metal is a much stiffer material, lesser material is needed in-between the material. Furthermore, the user needs to drill a hole and tap (a process of creating screw threads) the material before using the screws.

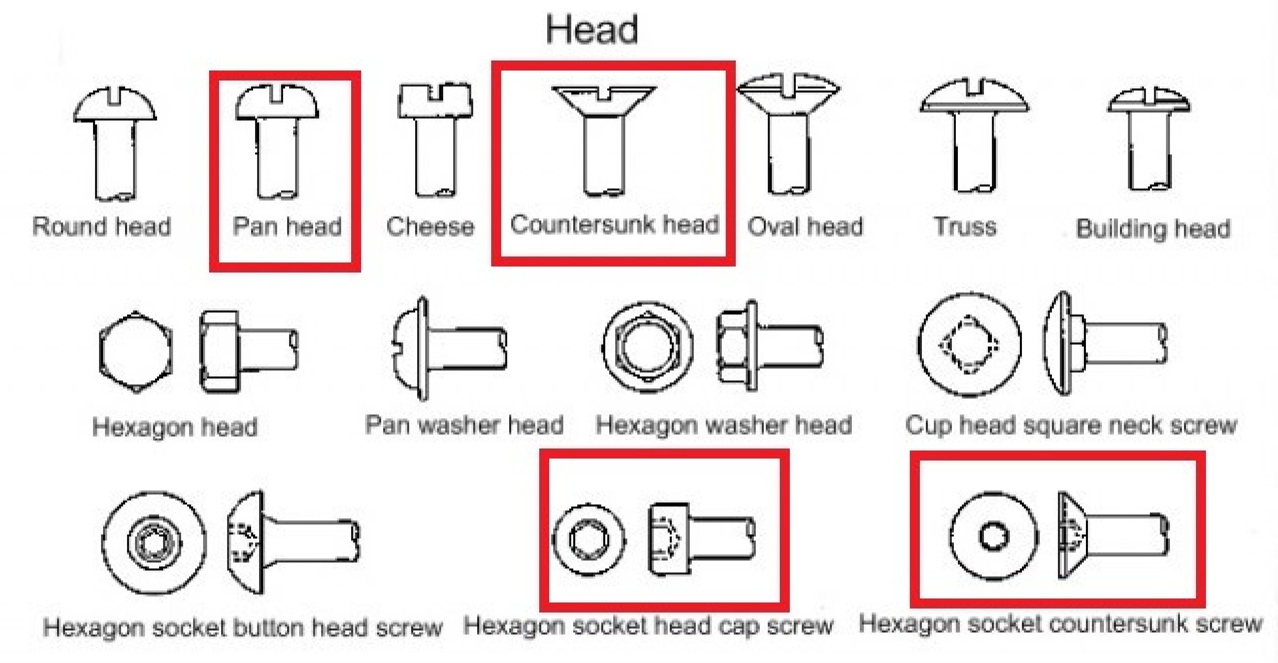


There are various types of screw heads in the market. Most are uncommon, thus they need special tools to be used. This is to prevent consumers from opening and tempering with the devices. The common types of heads are the Philips, Flathead and Hexagonal Head (circled in the figure below).

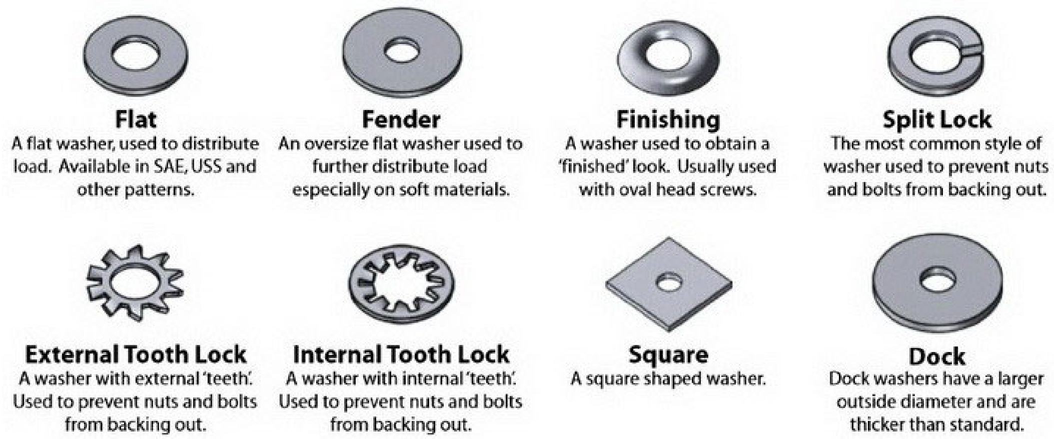


There are various types of shape of screw heads too. To achieve a flushed surface the top workpiece may need additional process of creating a countersunk or counterbore.

Boxed in red are the types that can be found in a typical workshop.

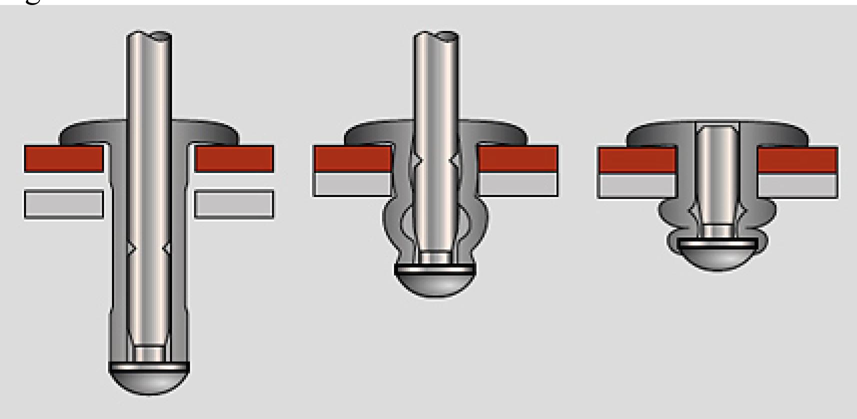


3. **Washers**
Washers are sometimes used together with bolts and nuts. The function of the washer is to ensure a evenly distributed pressure of the bolt/nut. In certain circumstances, where thin sheets are fastened, washers help prevent pull out of bolts. Again there are many types of washers that aim to prevent the loosening of bolts.



4. **Rivets**
Rivets are permanent fasteners. The common ones are pop rivets where they are riveted with a pop rivet gun. The gun pulls a long segment which deforms the shaft and fill up the clearances of the hole and creating a secondary head on the other end that holds the 2 plates

together.



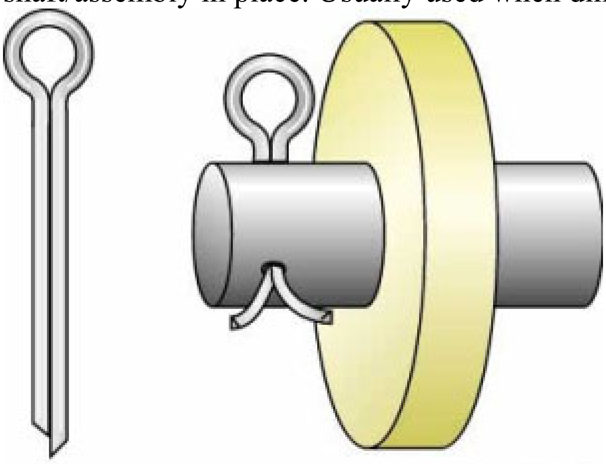
5. **Circlips – Eclips**
For the securing of components that are mounted axially along a shaft, Circlips and e-clips are used to secure them.

6. **Pins**
Dowel Pins are used for precise location purposes.


you can find them on shafts too. However that is not the most ideal especially for thin shafts as it could weaken the strength of the shaft. This particular design would allow the pin to shear or fail hence preventing damage to the engine or drive transmission.

There are also spring dowels that would make dismantling easier then conventional dowel.

Split Cotter Pins are inserted through holes or slots, the ends are split to hold the shaft/assembly in place. Usually used when dimension control is not critical.



7. **Collars**
Collars help position components on shafts, commonly used with a grub screw. Excellent in the early design phase as this could be easily removed through the loosening of the grub

screw. More examples would be shown in the section Drive Mechanism Design.

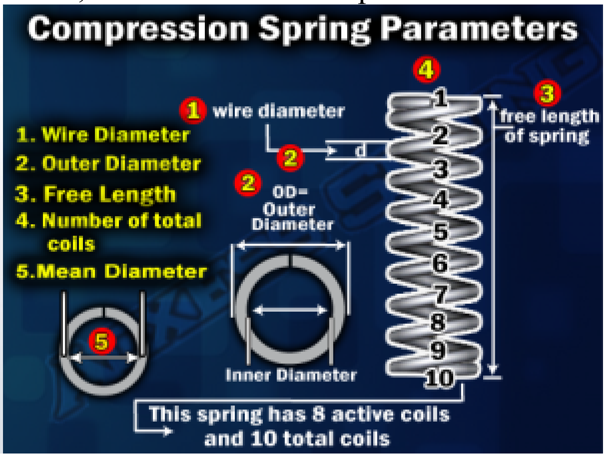
Springs

Springs are used to store energy from moving components. The stored energy can be re-used during the reverse motion. Like how a spring helps in a pogo-stick. There are three main types of springs to store energy from three types of motions – Push – Pull – Twist. Common Spring materials are music wire, Oil tempered wire, Hard Drawn wire, Chrome vanadium(Spring Steel) and Chrome silicon.

Springs are costly. Some hardware shops in the neighborhood have them. But most of the time I go to

Elite Springs Industries
50 Bukit Batok Street23 #06-22/23/24
Midview Building Singapore 659578
Tel: +65 65662252
Fax: +65 65662115
enquiries@elitesprings.com
http://www.elitesprings.com

1. **Compression Springs**
Compression springs are used when it is compressed, like in a mechanical pencil.



Below shows the formula and necessary dimensions to consider in choosing a compression spring. When you are selecting your springs, know that you can never find one that fits your requirements exactly. Unless the spring is custom made to your design and that would cost a whole lot more to make. Knowing what you need from your design, use the spring catalog to find the spring that best fits your requirement.

$$y = \frac{8FD^3N}{d^4G}$$

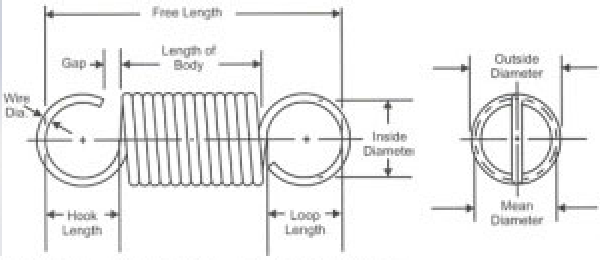
$$k = \frac{d^4G}{8D^3N}$$

$$F = k.y$$

y – Deflection
F – Force
D – Mean Diameter of Spring
N – Number of Active coils
d – wire diameter
G – Young's Modulus of Elasticity
k – Spring Constant

2. **Tension Springs**

Tension springs are used when it is pulled apart. Trampolines use tension springs to return the energy back to the user when he lands in it.



EXTENSION SPRING END TYPES

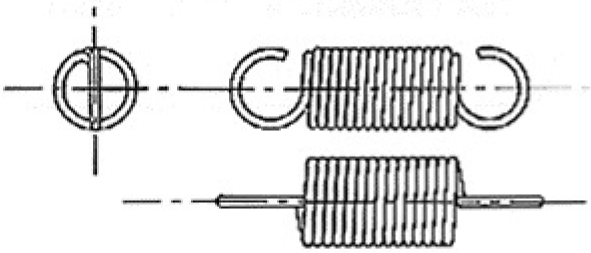
EXTENSION SPRING DESIGN FORMULAS

$$R = \frac{Gd^4}{8nD^3}$$

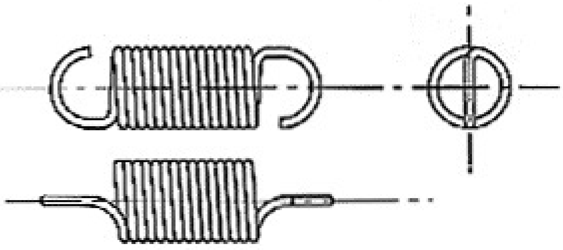
$$P = P_i + R(L - L_i)$$

$$P = P_i + RF$$

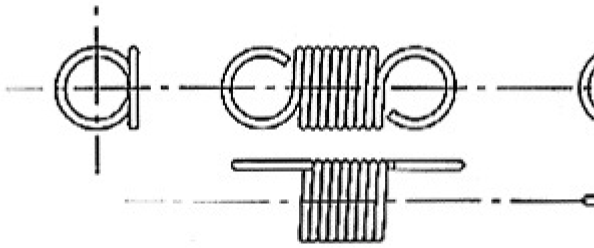
- R = Spring Rate
- G = Modulus of Rigidity
- d = Wire diameter
- n = Number of active coils
- D = Mean coil diameter
- P = Load when extended to length L
- P_i = Initial Tension
- L_i = Free Length
- L = Extended Length
- F = Deflection



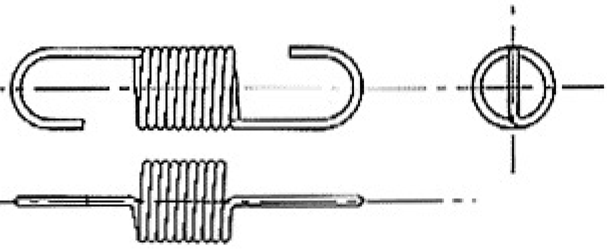
CROSSOVER LOOPS
LEFT HAND HELIX, LOOPS IN LINE



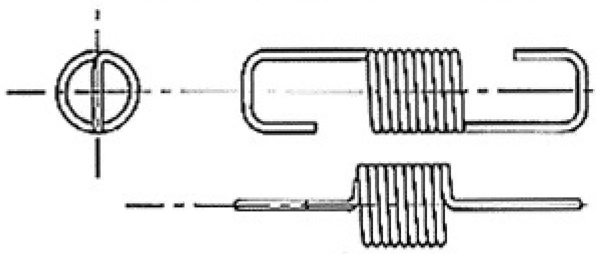
MACHINE LOOPS
RIGHT HAND HELIX, LOOPS OPPOSITE



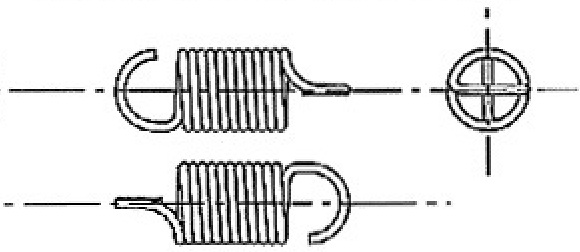
SIDE LOOPS
LEFT HAND HELIX, LOOPS IN LINE



EXTENDED ROUND HOOKS
LEFT HAND HELIX, HOOKS OPPOSITE

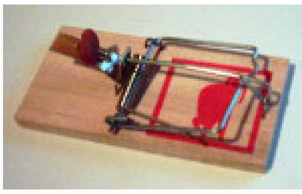


EXTENDED SQUARE HOOKS
RIGHT HAND HELIX, HOOKS OPPOSITE



MACHINE LOOPS
RIGHT HAND HELIX, RIGHT ANGLE LOOPS

3. **Torsion Springs**
Torsion springs are used when it is rotated. An example is a mouse trap.

$$Spring\ Rate\ (per\ turn) = R = \frac{\Delta T}{\Delta \theta} = \frac{Ed^4}{10.8 D_m N_A}$$

$$Spring\ Rate\ (per\ degree) = R \cdot \frac{1\ turn}{360\ degrees} = \frac{Ed^4}{3888 D_m N_A}$$

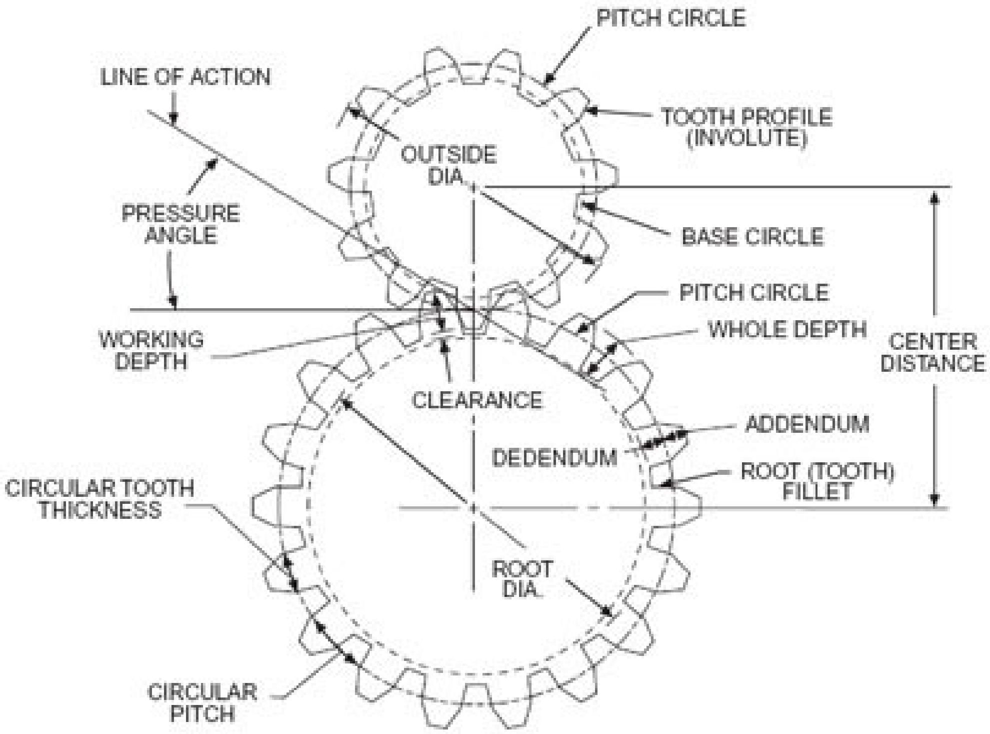
There are a lot more to consider when you go into the details of spring design for example fatigue and spring critical frequency. But for a initial prototype, the above information should be enough.

Gears

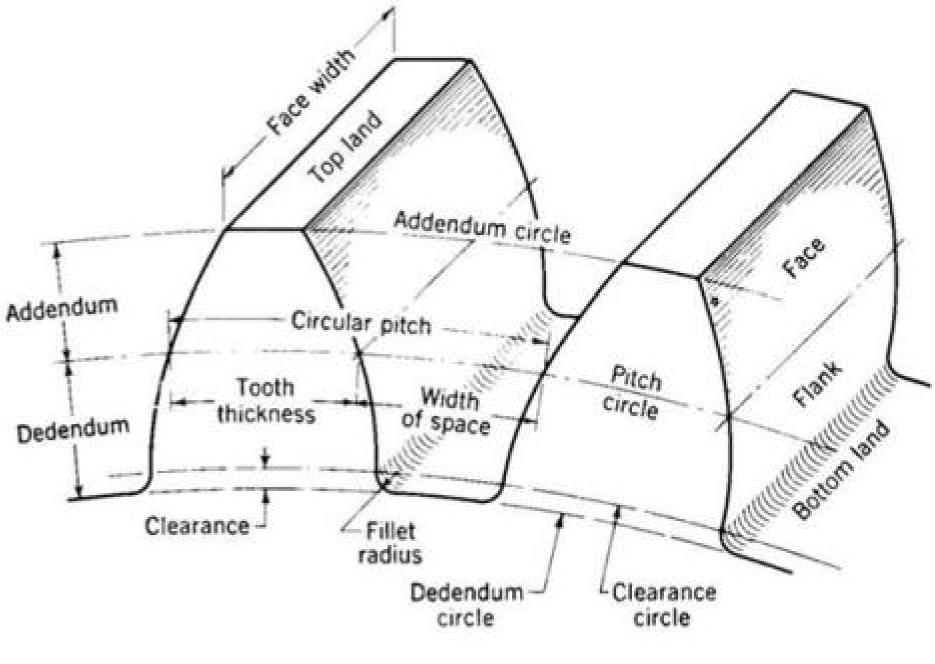
Gears are used to transmit motion. They are also used to alter speed and torque. Torque is the force to rotate an object. Usually, gears are used to reduce speed to obtain a higher torque. This allows high speed motors, which have very little torque output, to drive a heavy load. When there is a system of gears aligned to transmit motion/power, the system is called a Gear Train. There are various types of gears and each has its own features specific of an application.

1. **Spur Gears**

These are the most common type of gears that we encounter. They transmit motion across 2 parallel shaft.
Common materials for gears are Nylon and steel gears.
The gear that is attached to the motor is called the pinion gear, the other is called the driven gear.



GEAR NOMENCLATURE



m = module
PCD = Pitch Circle Diameter
N = Number of teeth

$m = PCD / N$
$PCD = m \cdot N$
$N = PCD / m$

The calculation of gear tooth stresses is not covered. Please refer to the recommended text.

Gear Train – Speed and Torque Calculation
Torque and speed in a drive system could be manipulated through the design of the gear transmission system. The Gear Ratio is the ratio of the number of teeth between the driven gear and the driver gear. It allows us to calculate the speed and torque of output gear if the input gear is known and vice versa. The equation is shown below.

$$\frac{N_2}{N_1} = \frac{\omega_1}{\omega_2} = \frac{T_2}{T_1}$$

$$N = number\ of\ teeth$$

$$\omega = speed\ in\ \frac{radians}{seconds}\ or\ RPM\ (rotation\ per\ minute)$$

$$T = torque\ in\ Nm$$

$$1 = Driver\ gear\ (input\ gear)$$

$$2 = Driven\ gear\ (output\ gear)$$

Example:

Gear 1 has 15 teeth & rotates at 100RPM

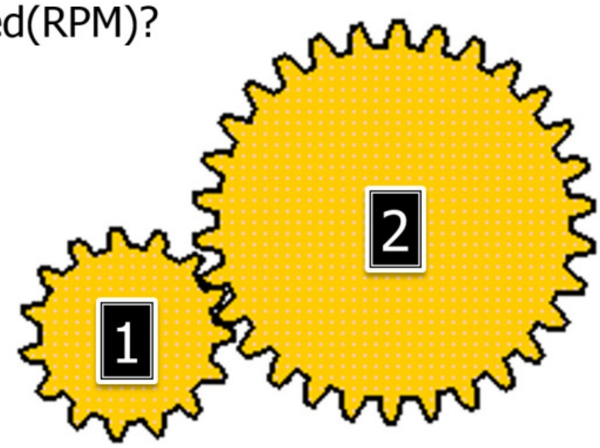
Gear 2 has 50 teeth

What is gear 2 speed(RPM)?

$$\frac{N_2}{N_1} = \frac{\omega_1}{\omega_2} = \frac{T_2}{T_1}$$

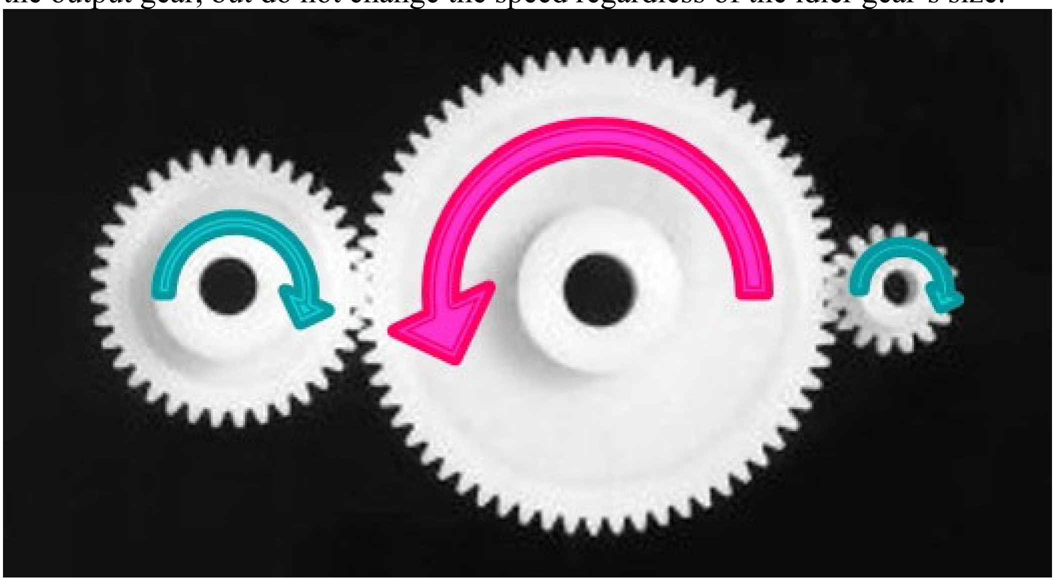
$$\frac{50}{15} = \frac{100}{\omega_2}$$

$$\omega_2 = 30RPM$$



Idler Gears

Idler Gears and placed between the drive and driven gears. They are change the direction of the output gear, but do not change the speed regardless of the idler gear's size.



Compound Gears

These are 2 spur gears of different sizes rigidly attached co-axially.

When these gears are used in gear trains, larger gear ratios could be achieved. They are commonly found in gear boxes. Gear boxes are used to lower the speed of motors and increase the torque. Very often in robotics and hobbyist shops, when you get a DC motor it comes attached with a gear box. This reduces the need to further design a gear reduction train.

Compound Gear Train Calculation

The formula for speed ratio is given as:

Speed Ratio = Input Shaft Speed / Output Shaft Speed

For Gear pair A and B:

$$\frac{\omega_A}{\omega_B} = \frac{N_B}{N_A}$$

For Gear pair B and C:

$$\frac{\omega_B}{\omega_C} = 1$$

(This is because they share the same driveshaft so the speed is the same)

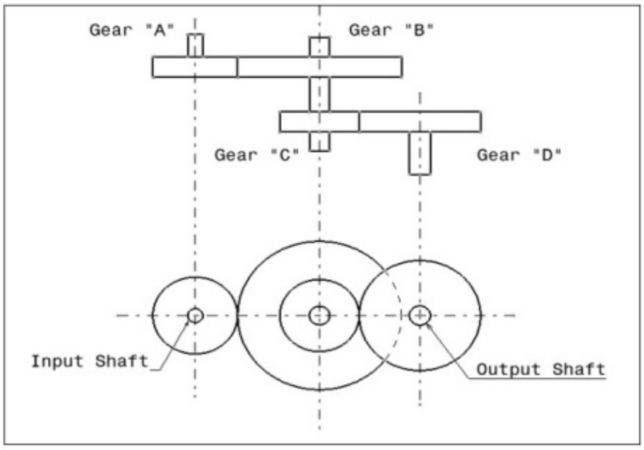
For Gear pair C and D:

$$\frac{\omega_C}{\omega_D} = \frac{N_D}{N_C}$$

Therefore:

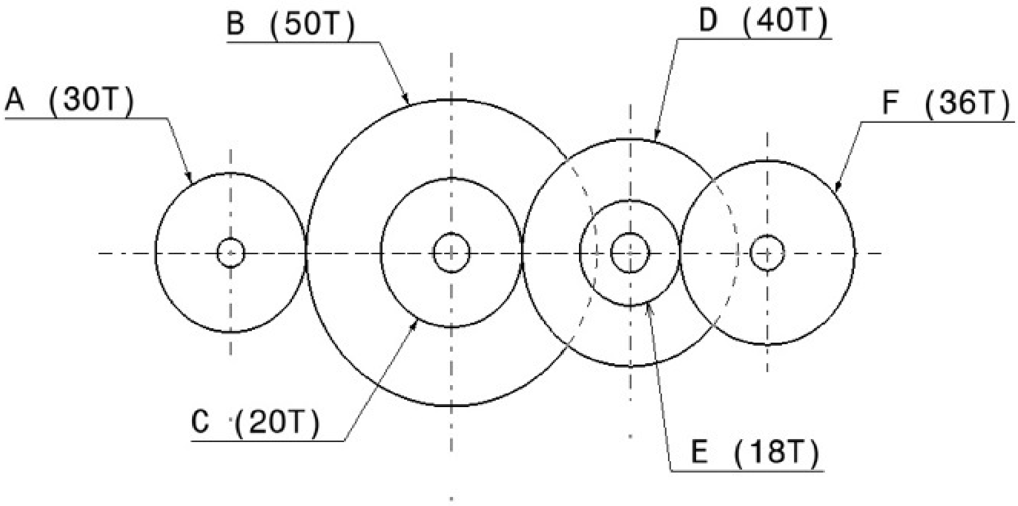
$$\frac{\omega_A}{\omega_D} = \frac{\omega_A}{\omega_B} \times \frac{\omega_B}{\omega_C} \times \frac{\omega_C}{\omega_D}$$

$$= \frac{N_B}{N_A} \times 1 \times \frac{N_D}{N_C} = \frac{N_B\ N_D}{N_A\ N_C}$$



Example: If ω_A = 1600 rpm, find ω_F and the direction of rotation of gear F.

Hint: B and C, D and E are compound gears.



$$\frac{\omega_A}{\omega_F} = \frac{\omega_A}{\omega_B} \times \frac{\omega_B}{\omega_C} \times \frac{\omega_C}{\omega_D} \times \frac{\omega_D}{\omega_E} \times \frac{\omega_E}{\omega_F}$$

$$\frac{\omega_A}{\omega_F} = \frac{\omega_A}{\omega_B} \times \frac{\omega_C}{\omega_D} \times \frac{\omega_E}{\omega_F}$$

$$\frac{\omega_A}{\omega_F} = \frac{N_B}{N_A} \times \frac{N_D}{N_C} \times \frac{N_F}{N_E}$$

$$\frac{1600}{\omega_F} = \frac{50}{30} \times \frac{40}{20} \times \frac{36}{18}$$

$$\omega_F = 240 \text{ rpm}$$

To understand more there are multiple sources online, that may improve your understanding.
http://bowlesphysics.com/images/Robotics_-_Gears_and_Gear_Ratios.pdf

2. **Helical Gears**

These gears have higher strength compared to spur gears. It is effective in reducing noise and vibration due to the sliding action. The gears produces thrust forces in axial directions, hence design considerations for the appropriate bearings are required.

3. **Rack and Pinion**

This configuration rotational movement to linear movement.
Consideration is designing the constrains/guides for the rack is required for proper function. The teeth profile on the rack is straight and not involute.

4. **Worm and Worm Wheel**

The worm and worm wheel provides high gear reduction ratio. As the worm needs to rotate 1 full revolution before the wheel moves by just one tooth. They are commonly used in gear boxes.

This configuration is the only one that has a self locking mechanism due to its geometry. However, due to the sliding action, the efficiency is fairly low compared to spur gears.

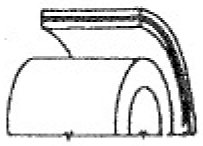
5. **Bevel Gears**

This pair transmit motion between intersecting shafts. Where there is a change in angle of the power flow. For higher strength, the profile of the teeth could be hypoid.

Belts

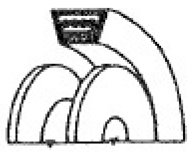
Belts and Pulleys are used to transmit motion and move objects. Similar to gears, speed and torque can be altered by varying the pulley sizes. A common problem in belt and pulley systems is Slippage. Slippage occurs when the belt slips on the pulley and power is not transmitted efficiency. It causes heat to build up and wear the belt. If slippage occurs frequently, a possible reason is poor selection of belt (load is too high for the belt system to drive it) or if there is too much slack.

1. **Types of Belts**



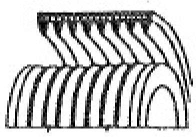
(a)Flat Belts

They are the simplest and the least expensive. They are used at high speed and relatively low power. They can operate on pulley diameters too small for V-belts; thus used extensively in business machines.



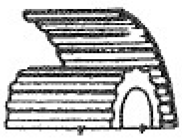
(b) Vee Belts

When the primary consideration is high power, V-belts are used instead of flat belts. In terms of low cost and space, V-belts provide the best overall power transmission capability for the normal range of power requirements.(Mitsuboshi Belting)



(c)Ribbed Belts

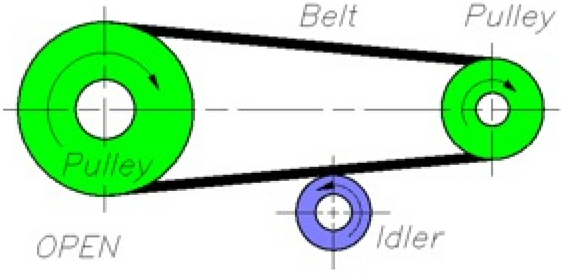
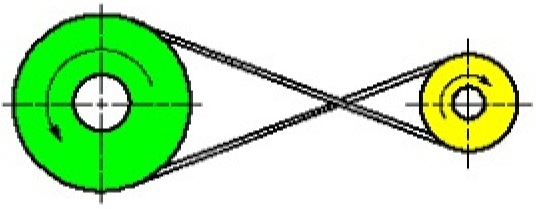
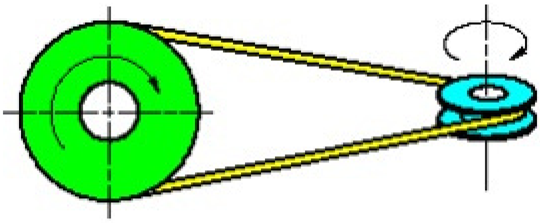
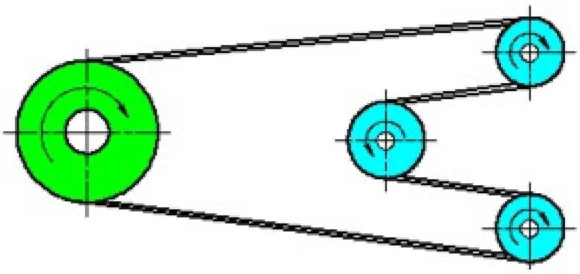
They are used for light duty application requiring high speed ratios. For instance, in a clothes dryer, a V-ribbed belt operates at a speed ratio of 30:1. The ribs provide a better grip on the pulley by wedging action.



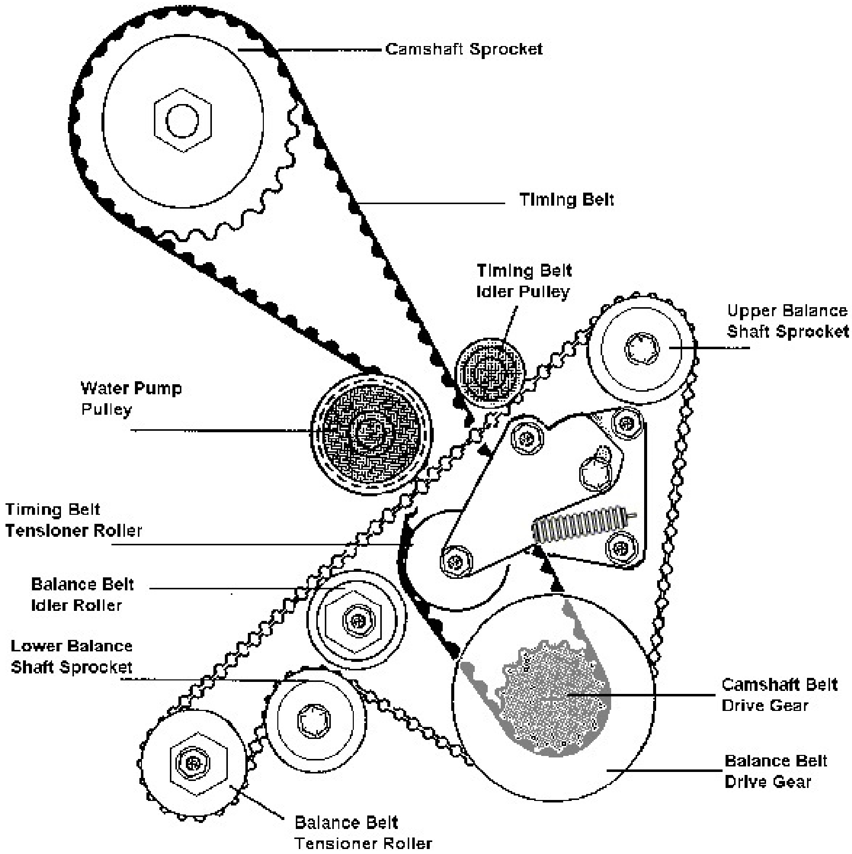
(d) Timing Belts

They do not creep or slip, and thus transmit power at constant angular velocity ratio and are suitable for synchronous motion. Timing belts combine the high velocity characteristic of flat belt with high power capacity.(Misumi catalogue)

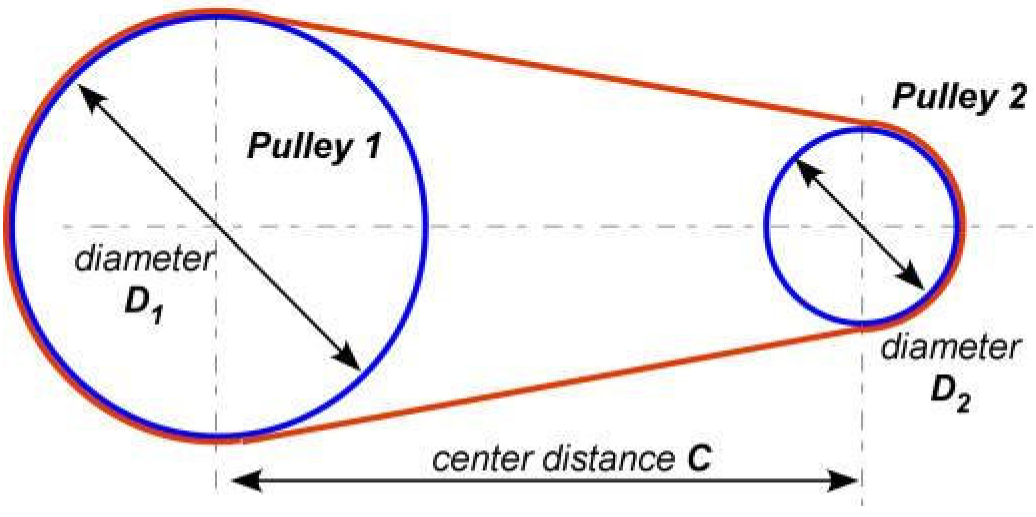
2. **Belt Drive Design**
Belts drives can be designed to achieve different types of desired output.

Types of Installation	Features
 Open	This is common installation. The idler pulley is used to ensure the belt is taut. The output direction is the same as the input.
 Crossed	This is used to reverse the output direction. However, the belt will wear out faster as it rubs against each other at the criss-cross.
 Turned	When there are two shafts perpendicular to each other, this installation is used.
 Serpentine	This is a better installation than Crossed. However, more pulleys are needed.

Slack occurs when the belt extends and is not taut from pulley to pulley. To counter slack, an adjustable Idler pulley is used. The pulley can be shifted to “tighten” the belt around the driver and driven pulley. This assembly is called a belt tensioner.
There are times when during belt selection you would have to choose a belt length that is longer than what you need. This is where the belt tensioner system would help take up the slack.
The tensioner’s position could even be designed to increase the wrap angle on the pulley. This would reduce slippages when the drive load increases.



Below shows the formula to determine the belt length.

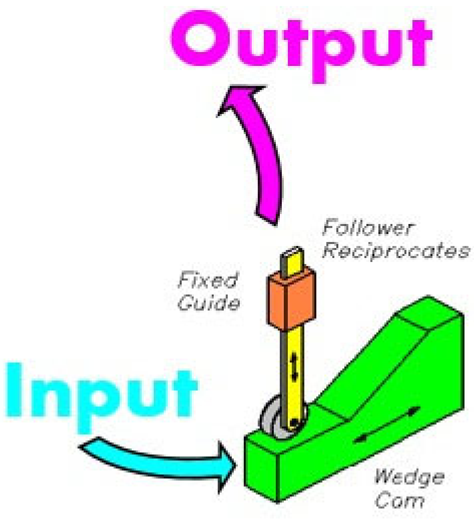


$$Length = 2C + \frac{\pi(D_1 + D_2)}{2} + \frac{(D_1 - D_2)^2}{4C}$$

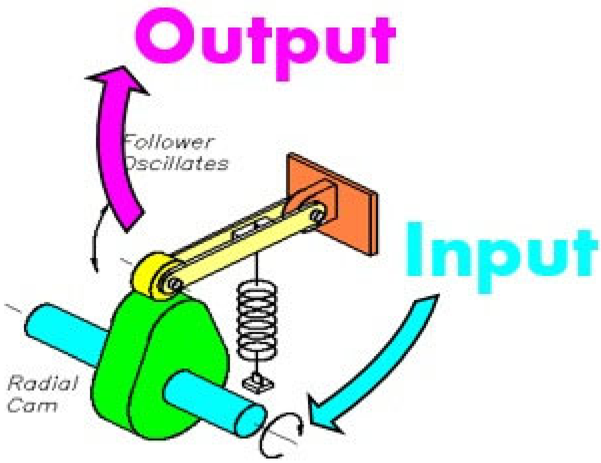
CAMs

Cams and Followers are used to transmit a specific type of linear motion from either linear or rotary motion.

There are two types of Cams. The wedge cam is used when a reciprocating linear motion needs to be converted. The picture below shows how the follower moves and the wedge cam moves front and back.



The Radial Cam is used to convert rotary motion to linear motion. The shape of the cam controls the displacement, speed and acceleration of the linear motion in the follower.

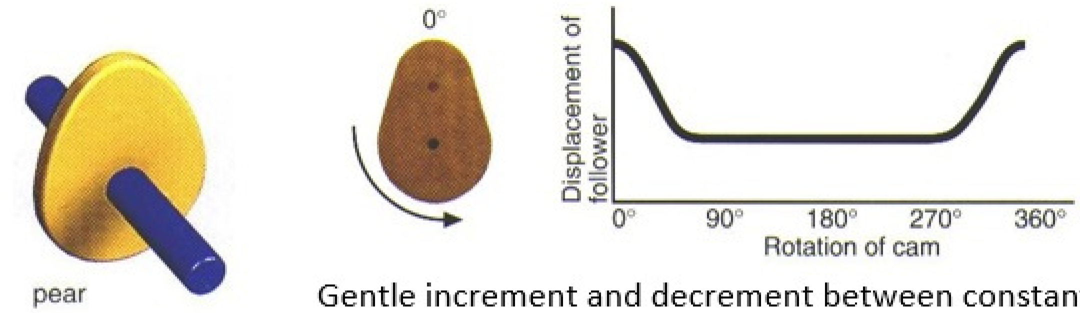


There are 3 types of Radial CAMs. The rotation of CAM vs follower displacement chart aids

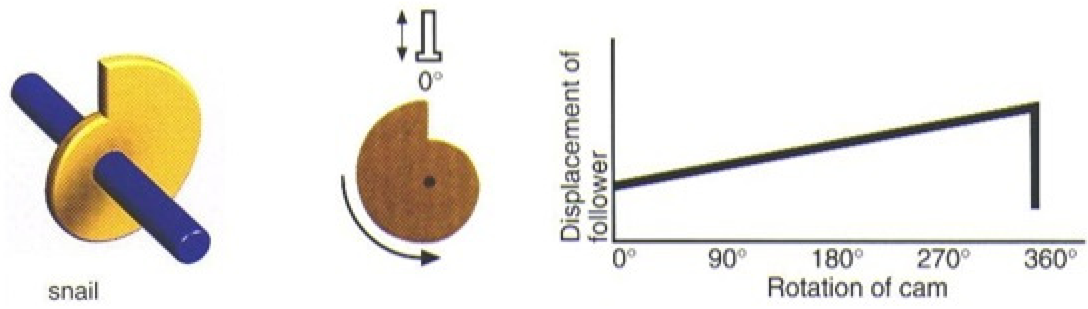
The designer in the selection of the profile that he requires.

Types and Shape of Cam

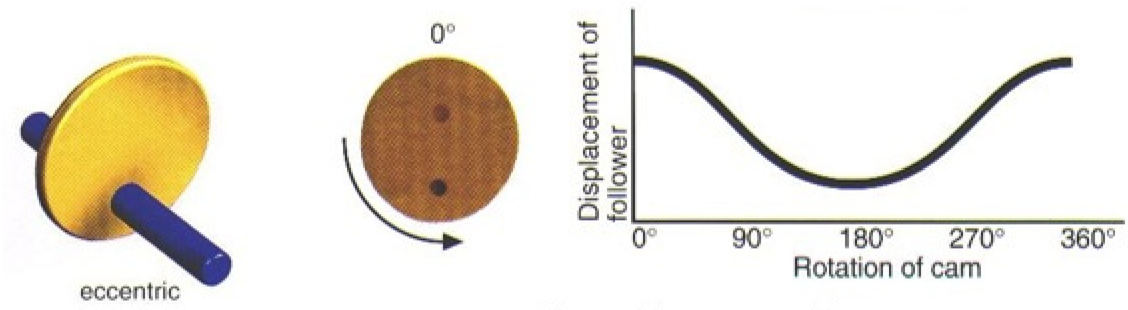
Types of Motion



Gentle increment and decrement between constant displacements.



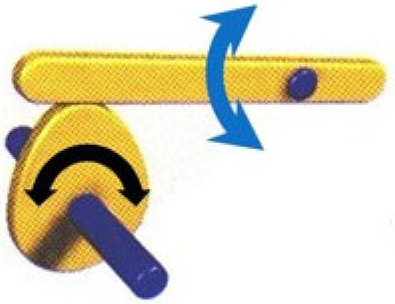
Gradual increment then a sudden drop.



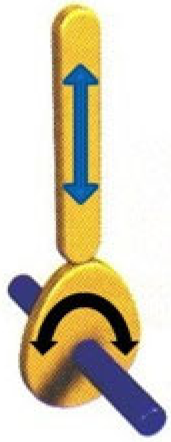
Smooth wave motion.

Followers

There are two types of followers: Sliders and Lever. The slider follower slides up and down as the profile changes, while the lever rocks about a pivot point.

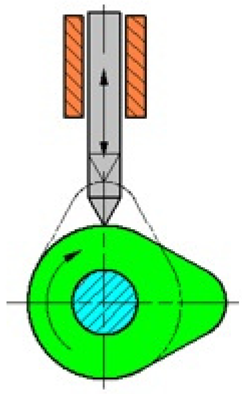
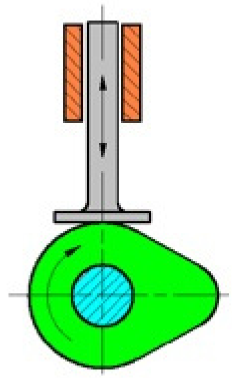
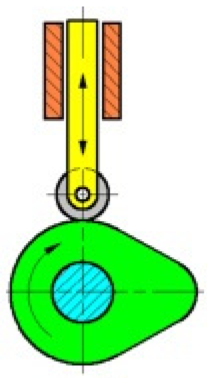


Lever Follower



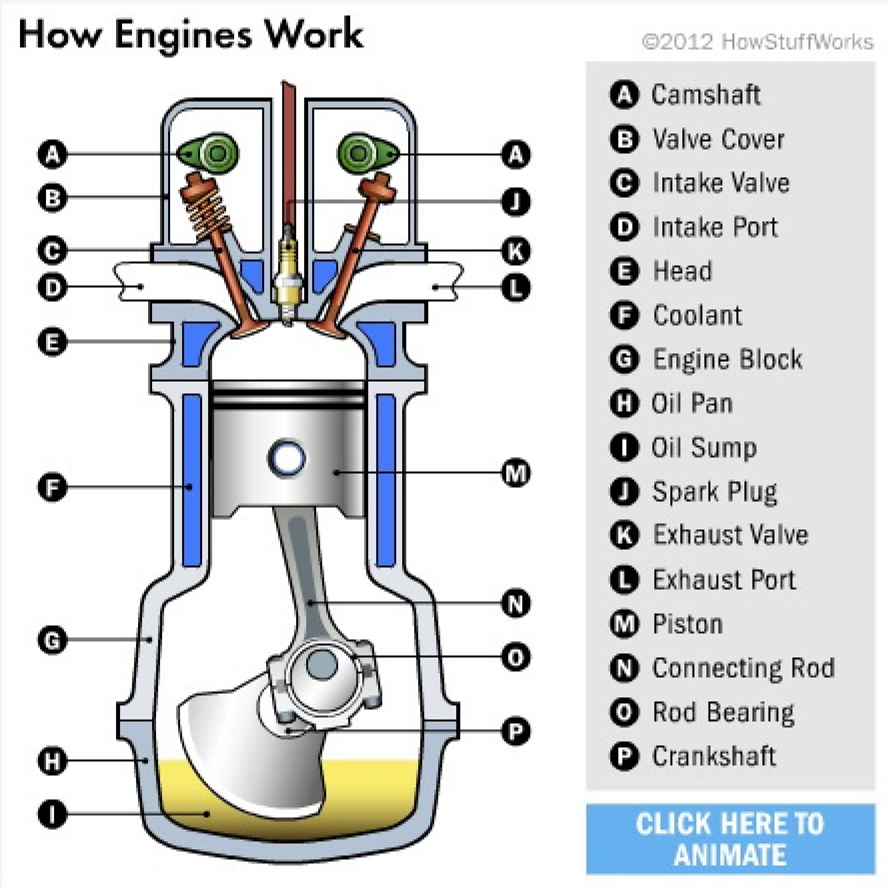
Slider Follower

There are three types of follower ends. Each of the ends has features for various needs.

Type of Follower Ends	 Knife	 Flat	 Roller
Uses	Used for intricate profiles at slow speed. Allows the follower to follow the shape closely.	Used for simple profiles at low speeds. Cannot be used at high speeds due to frication. The follower is simple to be manufactured.	Used for simple profile at high speeds. The roller reduces friction.

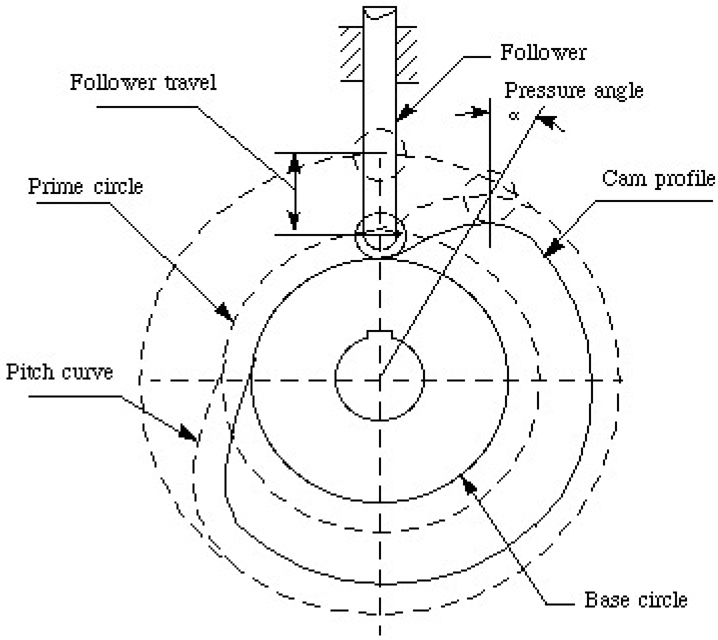
CAM application

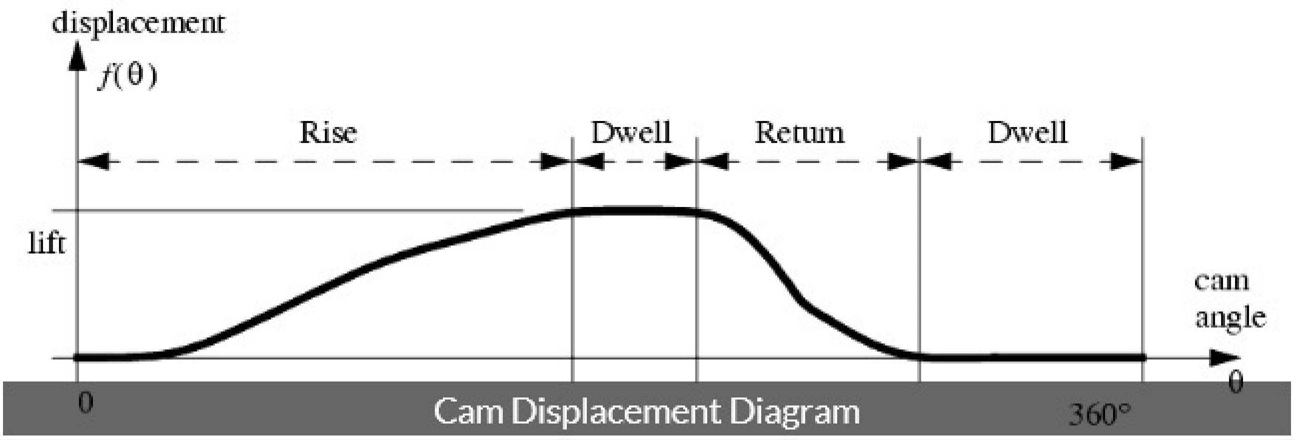
Application of CAM systems can be found in the Car Engines.



To check out the full animation click on
http://auto.howstuffworks.com/engine1.htm

CAM Design
CAM Terminology





Cam Displacement Diagram

Here is a step by step instruction on how CAM profiles are drawn given the desired displacement graph.

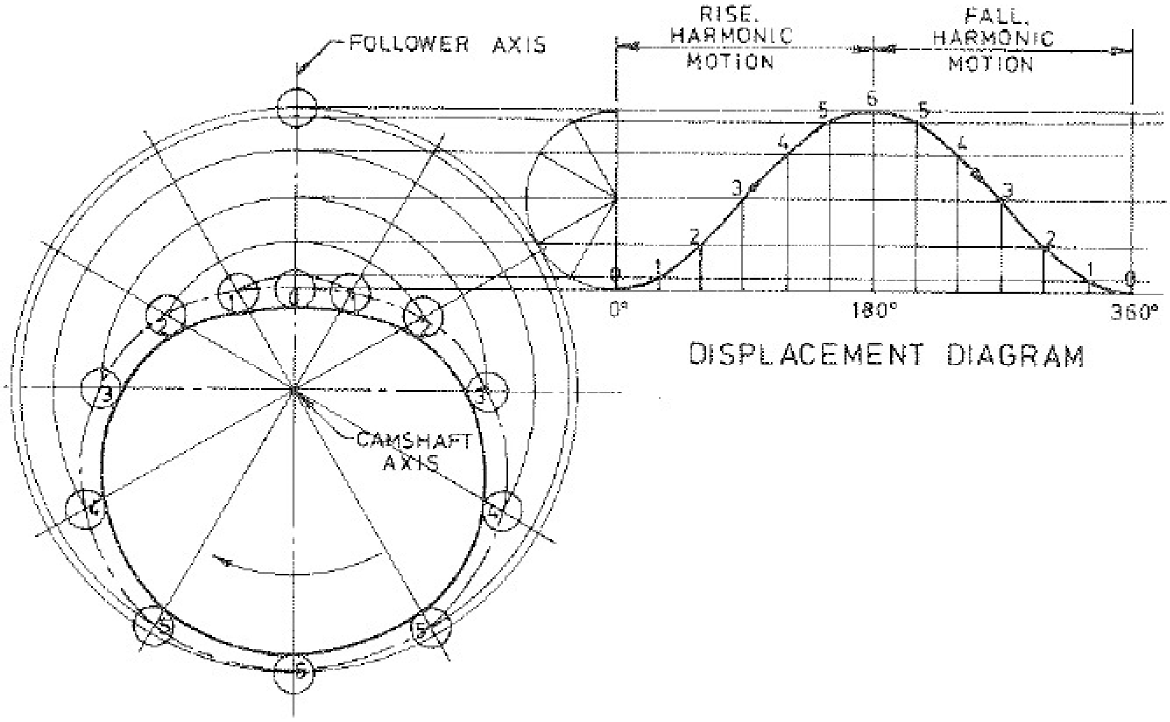
To construct a radial disc cam profile for a roller follower

Construct a radial cam profile for a roller follower, 4 mm in diameter, so that it rises and falls a distance of 16 mm with harmonic motion equally over one revolution of the cam. Consider the following two cases:

(a) when the follower axis is in line with the camshaft centre line

The least radius of the cam in each case is 10 mm, and the cam rotation is in a clockwise direction (scale: full size).

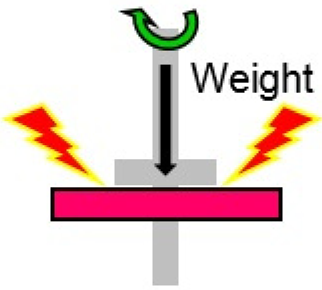
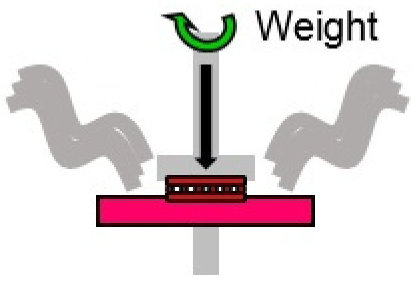
1. Draw the displacement diagram as shown.
2. Position the camshaft axis to the side of the displacement diagram and a distance equal to the radius of the roller (2 mm) plus the least radius of the cam (10 mm) below it.
3. Draw six radial lines through the camshaft axis 30° apart to give the equivalent number of divisions on the cam as on the displacement diagram.
4. Project points 0 to 6 from the harmonic curve to the follower axis.
5. With centre the camshaft axis and radius to the points of division on the follower axis, describe arcs to intersect the radial line through the camshaft axis at points 1, 2, 3, 4, 5 and 6.
6. Draw roller circles at the points of intersection found in the previous step.
7. Draw a tangential curve to the roller circles to give the required cam profile.



Bearings

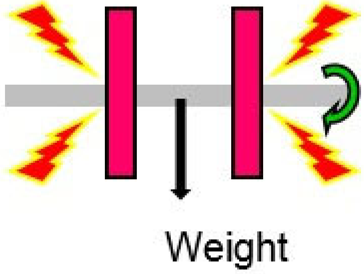
Bearing and Sliders are used to reduce friction, due to the weight or applied forces, in moving parts. This helps to improve efficiency and reduce noise, wear and tear. For rotational movement, bearings are used. For linear movement, sliders are used.

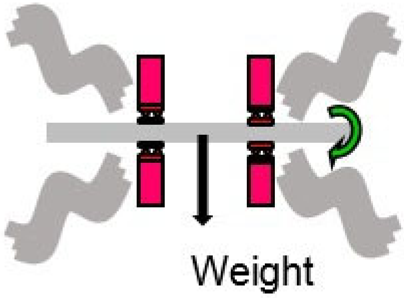
Axial Bearings are used to reduce friction along the axis of a shaft (round rod). When a vertical shaft is supported, there is friction between the support and rod. This would cause heat and noise, thus lowering efficiency.

Type of Bearing	Without Bearing	With Bearing
	 	
Axial Bearing		

Radial Bearings are used to reduce friction along the radius of the shaft. These bearings are used when a horizontal shaft is supported.

Radial Bearing

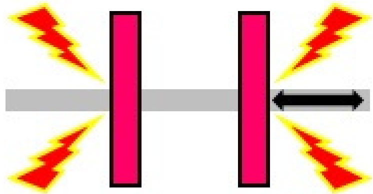


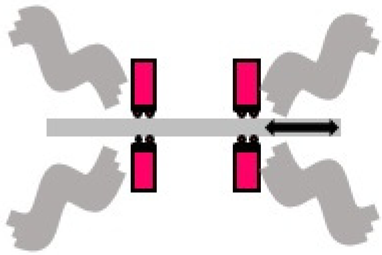


Sliders and Circular Sliders are used when there is a shaft sliding in a linear motion. Linear Motion Guides are used if there is a component sliding on top of another.

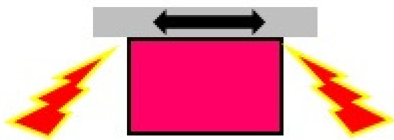
Type of Bearing	Without Bearing	With Bearing

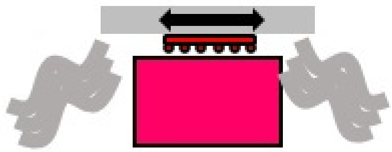
Circular Sliders





Linear Motion Guides





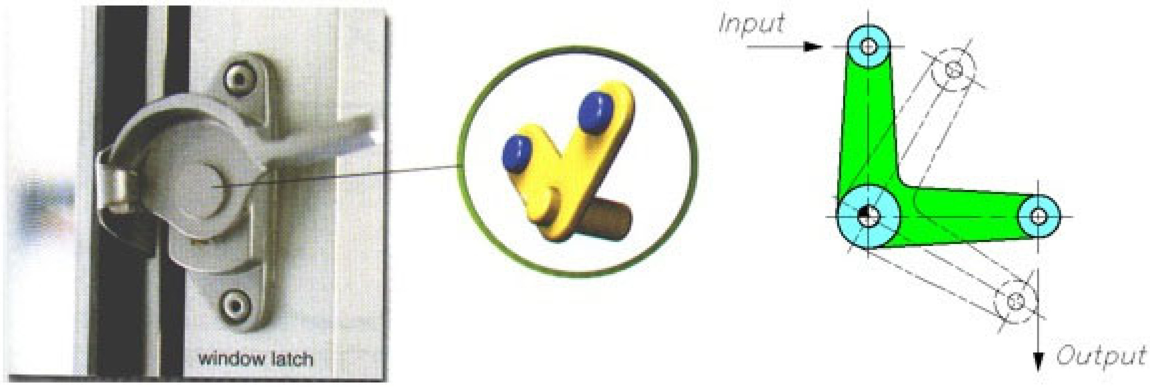
Bushings are the simplest type of bearings with just the bearing surface and no rolling elements. They are made of Nylon, Polyacetal, PTFE(small sizes) or bronze and cast iron.

Mechanisms

Mechanisms are components assembled together to perform functions which generally has Mechanical Advantage (MA). MA is the ability to increase the applied force or other words, to make things easier to do. Usually moments are used to increase MA. There are instances where it's function is just the transfer of motion.

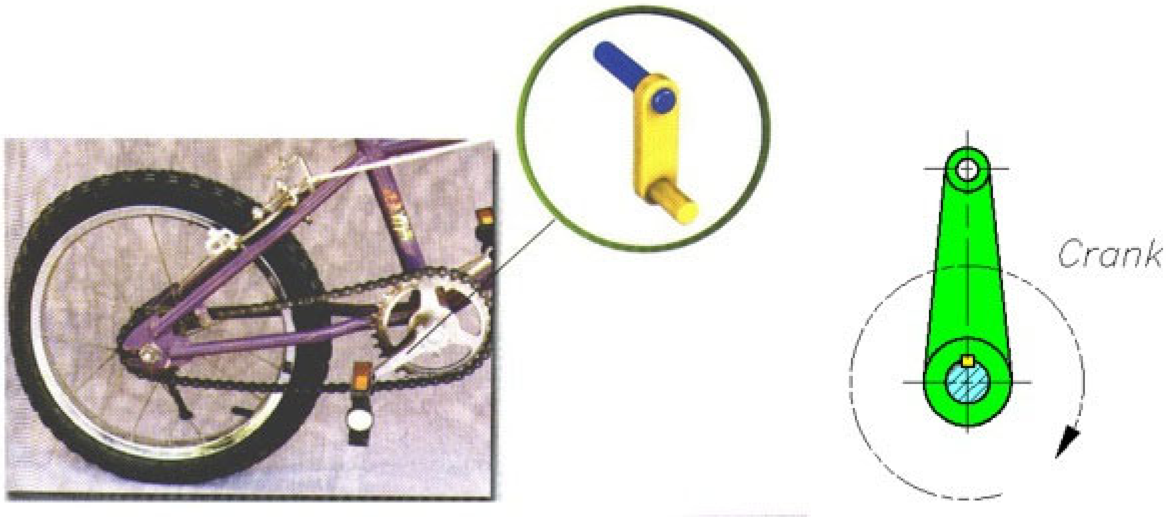
Bell Cranks

Bell Cranks transmit motion and magnifies the applied force at the output. For example, a window latch is easy to open with a small handle.



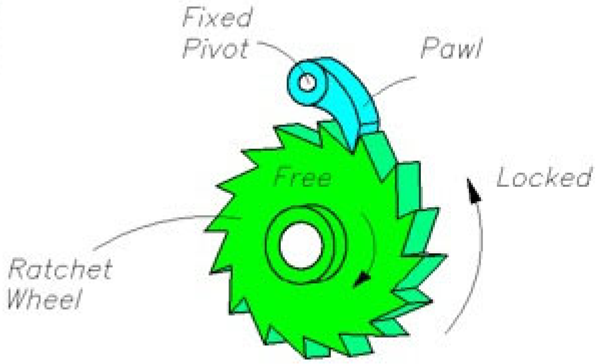
Cranks

Cranks are used to increase MA in rotary motion. One such example is the bicycle crank.

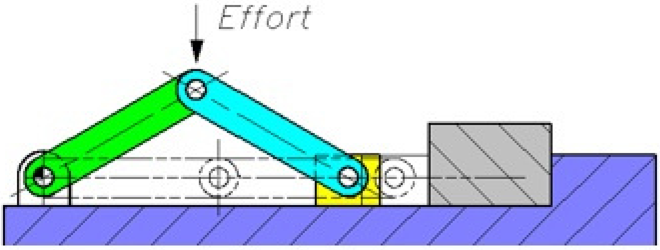
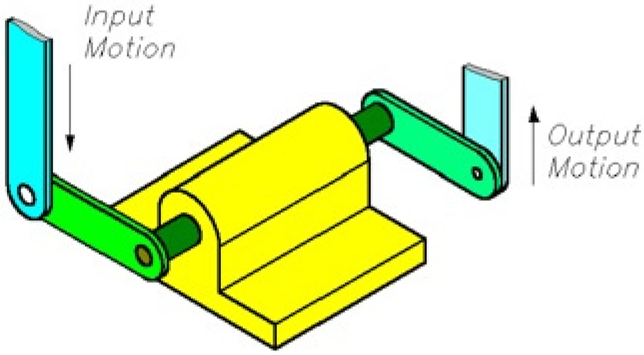
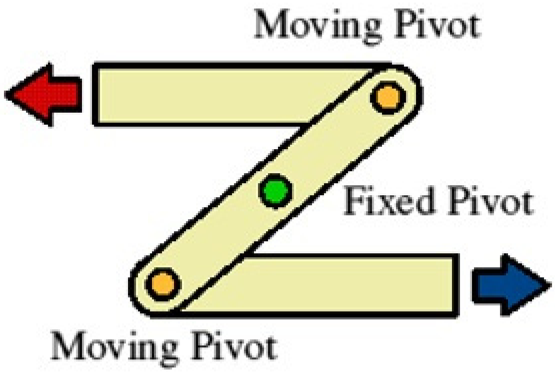


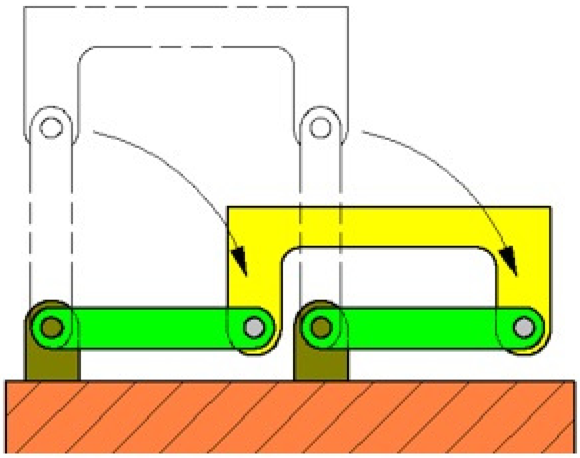
Ratchet and Pawl

The Ratchet and Pawl mechanism allows rotation to occur in one direction. This is mainly used in the fishing reels and hoists. The pawl will lock into the ratchet teeth and will only allow the ratchet to rotate in one direction.



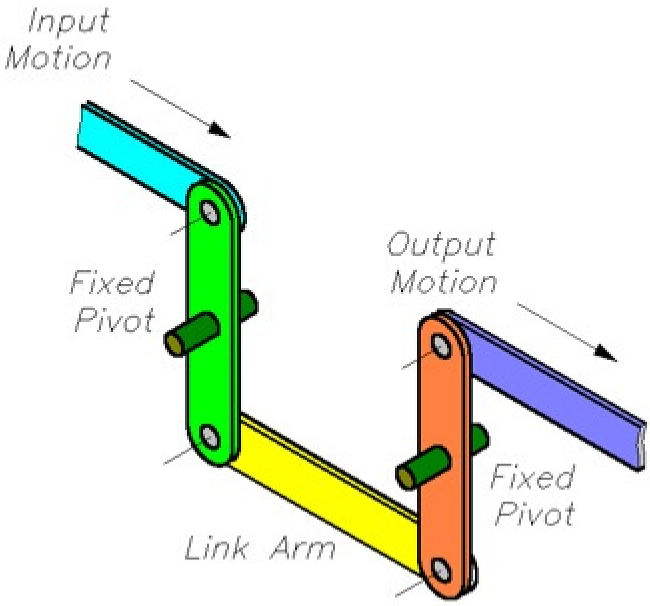
Linkages
Linkages are bars that are linked or fixed at certain points to increase MA is certain direction or to alter the output direction or motion. Below are some common linkages.

Types of Linkage Mechanisms	Features
 Toggle Linkage	This linkage allows a part or component to be clamped. As movable pivot is pushed down, the linkage will “snap” close. This allows the user to use little effort to clamp a component.
 Rotary Motion Linkage	This linkage allows a linear motion to be converted to a rotary motion and vice versa.
 Reverse Motion Linkage	This linkage allows the output linear motion to be the opposite of the input motion.



Parallel Motion Linkage

This linkage is to keep the bars parallel during motion. This is mainly used in toolboxes.



Push-Pull Linkage

This linkage allows the input and output motion to be the same. The range of motion can be altered by increasing or decreasing the length of the vertical input linkage.

These linkages can be found in our everyday consumer products. You need to observe to appreciate their existence.

Unit 2. BASIC WORKSHOP TOOLS

Learning Objectives:

On completion of this chapter, students should be able to:

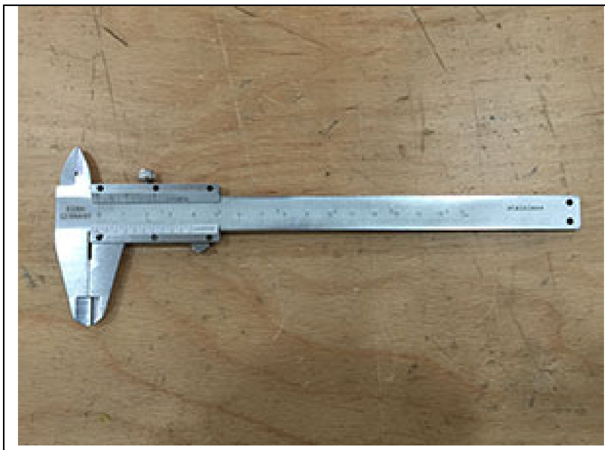
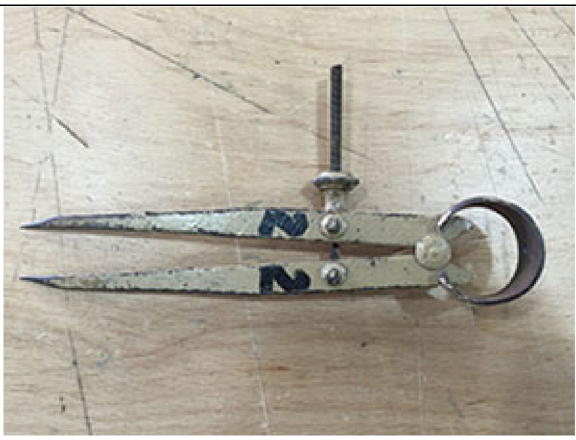
a. Identify the different types of workshop tools and list their uses.

In any Mechanical workshop, there are basic tools. Tools mostly fall into 3 categories; Measuring and Marking Out Tools, Clamping and Securing Devices, Metal Removing – Shaping and Cutting Tools.

Tools help us in our fabrication process and it is important to use the correct tool for the appropriate task. Failure to do so may lead to the damage of the tool and compromise safety of the user and those in the vicinity.

1. <u>Measuring and Marking Out Tools</u>

Prior to any cutting process, it is common that the lines are marked out. The following are tools that aid in measurement and marking out.

	**Vernier Calliper** This is a measuring instrument that measures better than a ruler. You can measure and attain readings up to 2 decimal places. The rectangular segment is the vernier scale that indicates where the measurement lies in between two of the marks on the main scale. The bottom jaw measures other diameter/dimensions. The top jaws measure inner diameter/dimensions. The tail at its end is used to measure depth in steps.
	**Spring Divider** This tool is used to mark out on work pieces. It could scribe straight lines and arcs. It is useful tool for marking out several fixed distances along a line.

<table>
<tr><td></td><td>Centre Punch

This tool is used with a hammer to mark out the centre of the circle on your work piece before you start to drill. The indentation created helps the drill bit to securely sit and begin drilling at the exact location marked out.

Without this mark, your drill bit would tend to walk and the centre distance of your drilled hole would be off.</td></tr>
<tr><td></td><td>Scriber

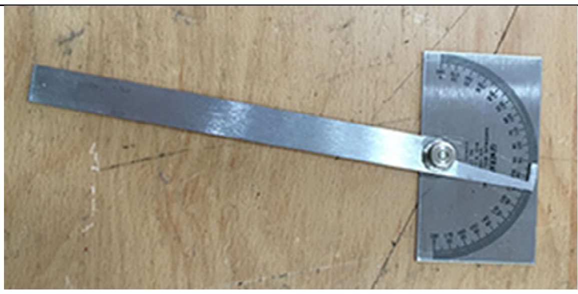
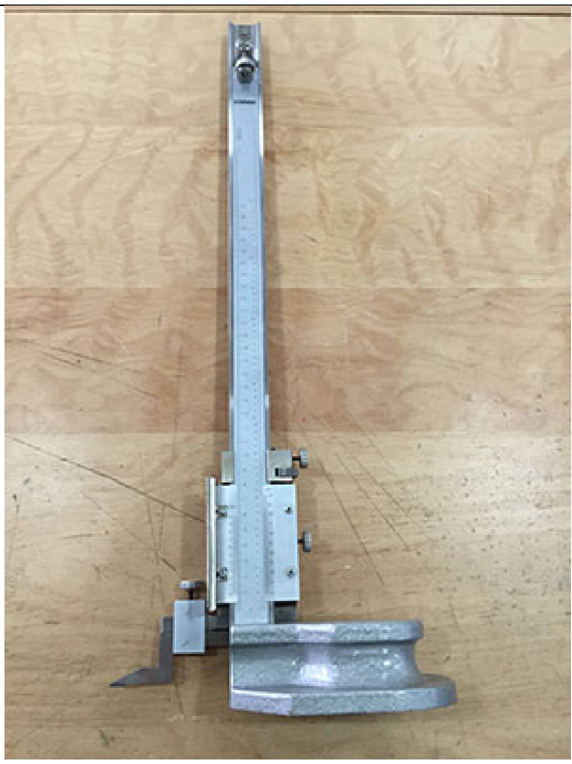
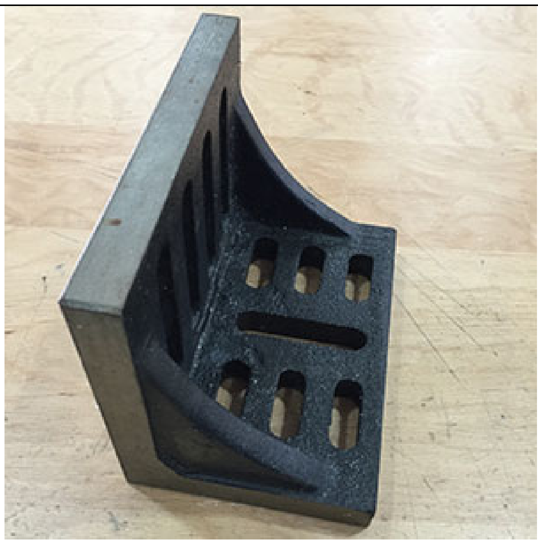
Used together with an engineer’s square or steel rule to mark out dimensions on your work piece.</td></tr>
<tr><td></td><td>Ball Peen Hammer

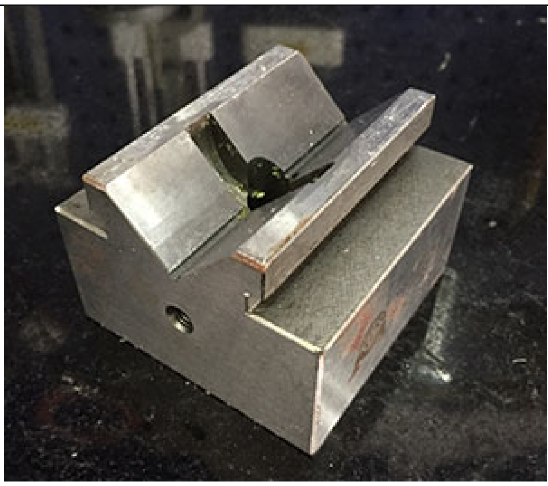
There are many different types of hammers. The picture on the left is a ball peen hammer. It is used to hammer nails, use with other tools like chisels and centre punch and other types of punches, used for forming of sheet metal over the vice or tool.</td></tr>
<tr><td colspan="2">Before using the hammer do a visual inspection to ensure that the handle is in good condition and will not fail during your use. Check also the the head is secured to the handle. Never use a hammer with a loose head.

To find out more about the different types of hammer, click on http://www.me-mechanicalengineering.com/2015/03/different-types-of-hammers.html</td></tr>
<tr><td></td><td>Engineer Square

Used with a scriber, this is a tool that aids in marking out lines perpendicular to an edge on the workpiece.

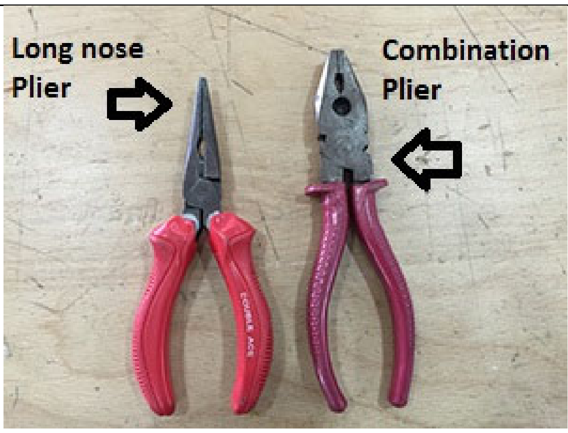
During metal work, fitting or assembly, the engineers square is a valuable tool to check for Perpendicularity of the part/assembly.</td></tr>
</table>

	**Protractor** Used with a scriber, this is a tool that aids in marking out lines at an angle to an edge on the workpiece.
	**Height Gauge** This instrument works like a vernier, but its additional function is to mark out on the work piece the height that was set on the scale. Usually used with an Angle plate.
	**Angle Plate** This is a work holding device used as a fixture in metalworking or machining The angle plate is made from high quality material (generally spheroidal cast iron) that has been stabilized to prevent further movement or distortion. Slotted holes or T bolt slots are machined into the surfaces to enable the secure attachment or clamping of workpieces to the plate, and of the plate to the worktable. Angle plates also may be used to hold the workpiece square to the table during marking out operations with a height guage.

	**Vee Block** This is a work holding device used as a fixture for the machining or marking out of cylindrical workpieces.

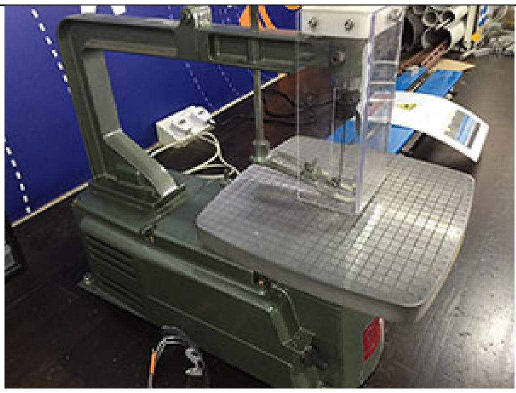
2. <u>Clamping and Securing Devices</u>

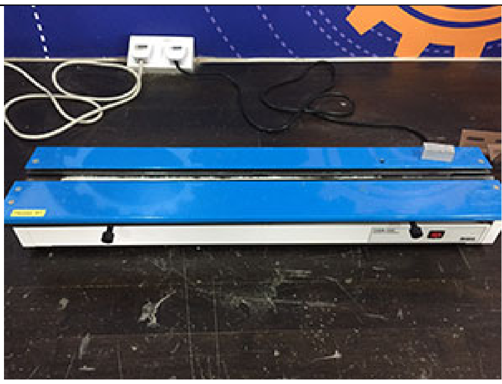
	**Table Vice** The Table Top Vice is an essential to mechanical device that is used to secure an object to allow work to be performed on it. Vices have two parallel jaws, one fixed and the other movable, threaded in and out by a screw and lever.
	**F-Clamp** An F-clamp, also known as a bar clamp or speed clamp. The name comes from its "F" shape. The F-clamp is similar to a G-clamp in use, but has a wider opening capacity (throat). It is also able to quickly slide open and does not need a long screw.

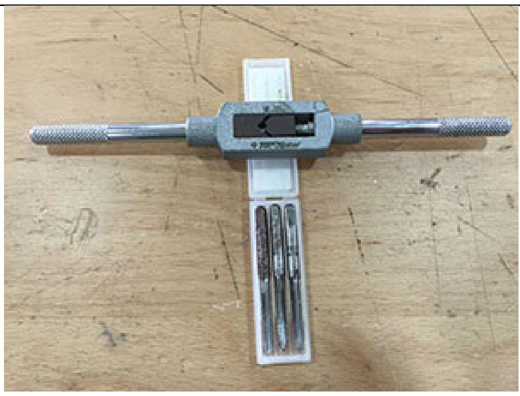
	**G-Clamp** The G-Clamp has a similar function as the F-clamp however the construction is different. Used for clamping workpiece to the bench or work table so that work can be done. It can also be used to hold pieces that have been joined by adhesive during the curing time.
	**Pliers** The one on the right is a combination plier, also known as a linesman plier. It is used for gripping, twisting, bending of wires or work pieces. the inner jaw is curved for gripping cylindrical surfaces. It can cut wires and crimp on the inner jaw near the joint. The one on the left is a long nose plier. It is great for gripping wires or components in hard to reach areas.
	**Screwdriver** Use drive screws manually by turning screws. There are various types the most common being the Phillip head screw (or cross head) and the flat head screwdriver.
	**Hexagonal Keys** A hex key or Allen key is a tool of hexagonal cross-section used to drive bolts and screws that have a hexagonal socket in the head.
	**Adjustable Spanner** This is an adjustable spanner, used on hexagonal boltheads. Its jaw is adjustable with the screw feature.

	**Locking Pliers** Mole grips (Mole wrench) or Vise-Grips are pliers that can be locked into position, using an over-center action. One side of the handle includes a bolt that is used to adjust the spacing of the jaws, the other side of the handle (especially in larger models) often includes a lever to push the two sides of the handles apart to unlock the pliers.

3. <u>Metal Removing – Shaping and Cutting Tools</u>

	**Hacksaw for Metal** This saw is for metal (aluminium and steel). It is important that the blade is installed with the correct tooth orientation for efficient cutting. With proper sawing technique, the task is effortless.
	**Hand Drill** This is a hand drill, has a hammer mode, for drilling into concrete walls. The drill bits used for concrete is different from those used for metal and plastic. Use with care and always wear safety glasses.
	**Scroll Saw** The scroll saw is great for cutting curves and non-linear lines. You could also cut internal profiles by drilling a pilot hole and re-installing the blade to begin the inner profile cut. Make sure to always have the guard on.

	**Hand Files** Hand files are used in the workshop to smooth rough edges. They can be used to smooth a range of materials including metals such as brass and steel. The roughest file is called the Bastard file, and that removes material quickly due to its coarse tooth pattern. Next is the Second cut and finally for the fine work we use the Smooth cut file. There are also many shapes of files, like flat, square, round and triangle.
	**Acrylic Bender** This is basically a strip heater element that helps to bend your acrylic and polycarbonate plates.
	**Pop Rivet Gun** Used together with rivets to fasten 2 plates of sheets together using rivets.
	**Die Thread** This tool helps create external thread on shafts and pins.



Tap

This tool helps create internal thread in holes. Prior to tapping the correct hole size must be drilled.

(refer to chart below)

Metric Tap Size Chart

Tap size	Diameter (in)	Diameter (mm)	Thread count (TPI)	Thread pitch (mm)	Tap drill size
M1x0.2	0.0394	1.0000	~127	0.200	0.8 mm
M1x0.25	0.0394	1.0000	~102	0.250	0.75 mm
M1.1x0.25	0.0433	1.1000	~102	0.250	0.85 mm
M1.1x0.2	0.0433	1.1000	~127	0.200	0.9 mm
M1.2x0.2	0.0472	1.2000	~127	0.200	1 mm
M1.2x0.25	0.0472	1.2000	~102	0.250	0.95 mm
M1.4x0.2	0.0551	1.4000	~127	0.200	1.2 mm
M1.4x0.3	0.0551	1.4000	~85	0.300	1.1 mm
M1.6x0.2	0.0630	1.6000	~127	0.200	1.4 mm
M1.6x0.35	0.0630	1.6000	~73	0.350	1.25 mm
M1.8x0.2	0.0709	1.8000	~127	0.200	1.6 mm
M1.8x0.35	0.0709	1.8000	~73	0.350	1.45 mm
M2x0.25	0.0787	2.0000	~102	0.250	1.75 mm
M2x0.4	0.0787	2.0000	~64	0.400	1.6 mm
M2.2x0.25	0.0866	2.2000	~102	0.250	1.95 mm
M2.2x0.45	0.0866	2.2000	~57	0.450	1.75 mm
M2.5x0.35	0.0984	2.5000	~73	0.350	2.1 mm
M2.5x0.45	0.0984	2.5000	~57	0.450	2.05 mm
M3x0.35	0.1181	3.0000	~73	0.350	2.6 mm
M3x0.5	0.1181	3.0000	~51	0.500	2.5 mm
M3.5x0.35	0.1378	3.5000	~73	0.350	3.1 mm
M3.5x0.6	0.1378	3.5000	~43	0.600	2.9 mm
M4x0.35	0.1575	4.0000	~73	0.350	3.6 mm
M4x0.5	0.1575	4.0000	~51	0.500	3.5 mm
M4x0.7	0.1575	4.0000	~37	0.700	3.3 mm
M4.5x0.5	0.1772	4.5000	~51	0.500	4 mm
M4.5x0.75	0.1772	4.5000	~34	0.750	3.8 mm