ME 161
Introduction to Mechanical Engineering
Lec Note 6: Brig Gen Humayun

Please go through class notes and reference materials discussed in the class. This is just a guideline for those who missed the classes

6. Material Science 161

Types of Gears


Helical Gear


Spur Gear


Rack & Pinion Gear


Worm Gears


Bevel Gear


Sprockets Gear

- Spur Gear:
- These gears are used to transmit the power in same plane or when the driving and driven shafts are parallel to each other. In this type of gear teeth are cut parallel to the axis of the shafts so when is meshes with another spur gear it transmit the power in parallel shaft and when it connects with the helical gear it will transmit power at an angle from the driving axis.

- Helical Gear:
- On the helical gears teeth are cut at an angle from the axis of it. It has cylindrical roller with helicoid teeth. The main advantage of helical gears is that they work with less noise and vibration because the load is distributed on the full helix as compared to spur gears. It also has less wear and tear due to which they are widely used in industries.

- Double Helical or Herringbone Gear:
- This gear has both right and left handed teeth on one gear. This gear is use to provide additional shear area on gear which further required for higher torque transmission. This is same as helical.

<u>Worm Gear:</u>

- This type of gear is used to transmit the power in nonintersecting shaft which makes right angle. In this type of arrangement the driving gear is a screw gear and the driven gear is helical gear or gear with spiral teeth.
- <u>Rack and Pinion Gear</u>:
- This gear is used in steering system of automobile. In this type of gear, teeth are cut on a straight rectilinear geometry know as rack and one spur gear known as pinion.
- <u>Bevel Gear</u>:
- This gear is used to transmit power between perpendiculars. The driving shaft and driven shaft makes a right angle with each other and both the axis of shaft meets each other at one point. This gear has helical or spiral teeth on a conical shaped geometry and meshes with the same gear.

Different types of bearings

Ball Bearings

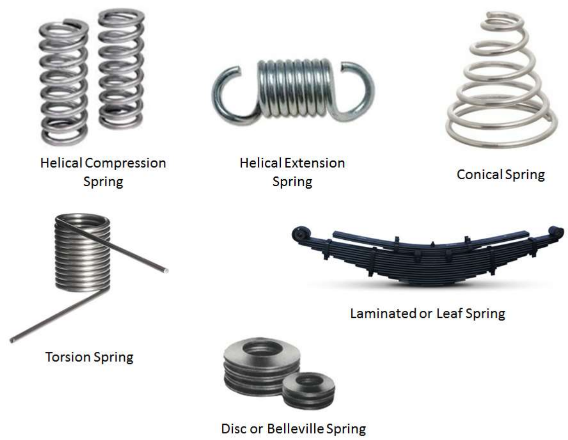
Ball Bearings utilize balls as the **rolling elements.** They are characterised by **point contact** between the **balls** and the **raceways**. As a rule, ball bearings rotate very quickly but cannot support substantial loads.

Roller Bearings

Roller Bearings are characterized by **line contact**. Line contact offers higher **load rating** than ball bearings of the same size; however the speed ability is lower than a ball bearing due to the increased **friction** of a contact line.

- All bearings need to demonstrate low friction, guidance with minimum runout or play, quiet running, low lubricant requirements, little wear and a long service life.
- In addition to all of these factors, different industries have their own special requirments based on special operating environments. Some of these include:
  - Very high or low temperatures
  - Variances in temperature
  - Moisture
  - Speeds/revolutions per minute
  - Resistance to dirt
  - Ability to function in acid and alkaline solutions
  - Ability to function in liquid gas and process dust
  - Suitable for use in clean envirnments such as those in medical and food and beverage

Various types of spring



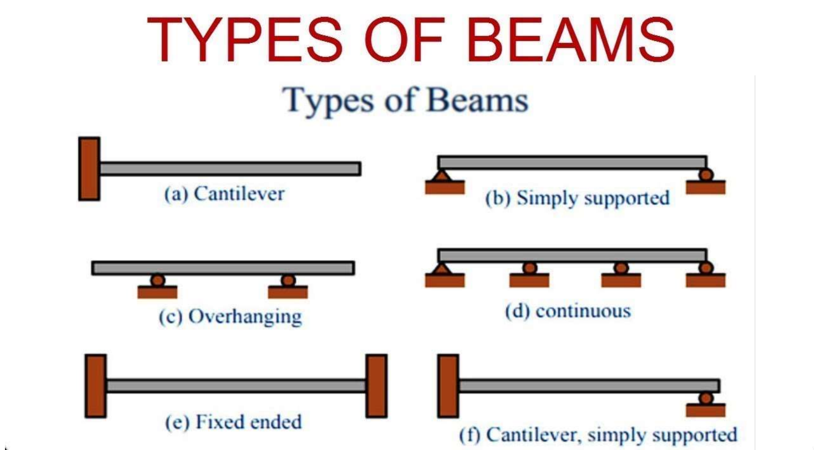
Spring materials:

The material used to made springs are called a spring steel. Spring steels are mostly low-alloy manganese, low carbon steel or high carbon steel with very high yield strength. Examples of spring materials are as follows:

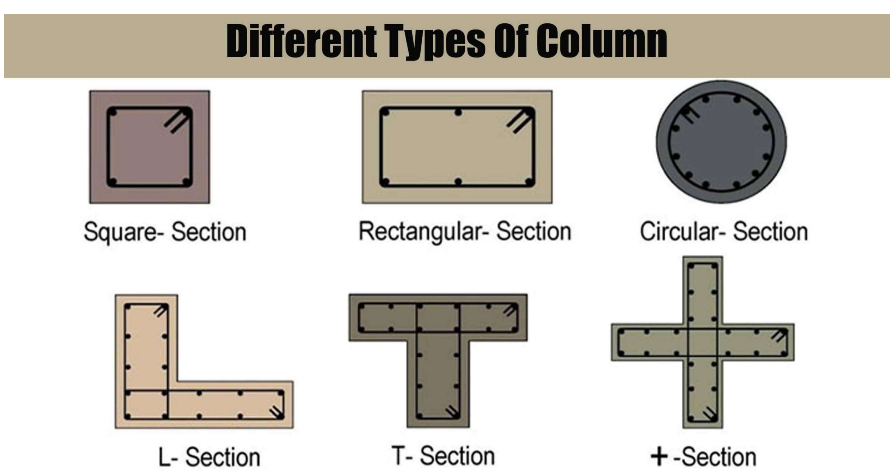
1. Oil Tempered Steel
2. Stainless Steel
3. Elgiloy
4. Carbon Value
5. Iconel
7. Monel
6. Titanium
7. Chrome Silicon

Purposes of spring:

- To absorb shock load
- To store energy
- To measure force
- To motive power
- To Return motion
- To control of vibrations
- To retaining of rings



The beam is defined as the structural member which is used to bear different loads. It resists the vertical loads, shear forces and bending moments.



Metals

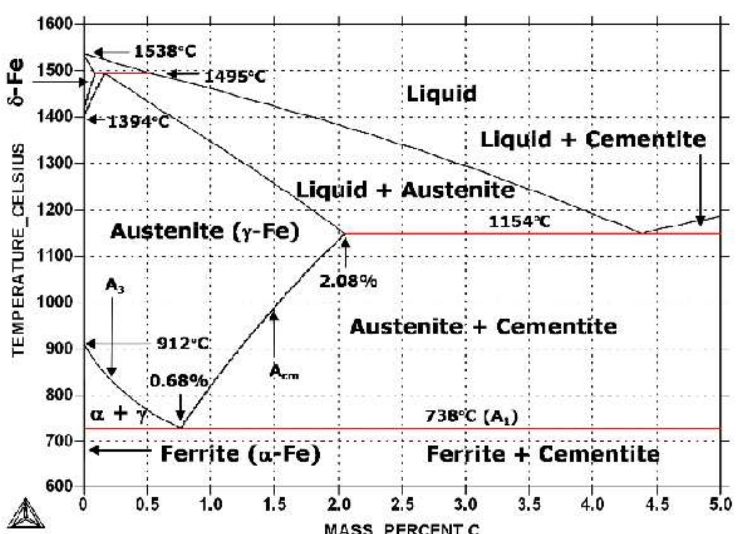
- Metals are solids. (except mercury)
- Metals are hard. (except Lithium, Potassium, Sodium)
- Metals have metallic lustre. (shine)
- Metals are malleable. (can be beaten into thin sheets)
- Metals are ductile. (can be drawn into wires)
- Metals have high melting points. (Gallium and Caesium have low melting points. They melt in the palm of the hand)
- Metals have high boiling points.
- Metals are good conductors of heat. (Best conductors are silver and copper. Poor conductors are Lead and Mercury)
- Metals are good conductors of electricity. (Best conductors are Silver and Copper)
- Metals are sonorous. (produce sound when beaten)

• Metals	•Non metals
• Metals are solids (except mercury).	•Non metals may be solids, liquids or gases.
• Metals are hard (except sodium, potassium etc.	•Non metals which are solids are brittle (diamond is the hardest).
• Metals have metallic lustre.	•Non metals do not have lustre some have a dull luster.
• Metals have high melting points and boliling points.	•Non metals have low melting points.
• Metals are malleable (can be made into thin sheets).	•Non metals are not malleable.
• Metals are ductile (can be made into thin wires).	•Non metals are not ductile.
• Metals are good conductors of heat and electricity.	•Non metals are bad conductors of heat and electricity (except graphite).
• Metals are sonorus (produces sound).	•Non metals are not sonorus.

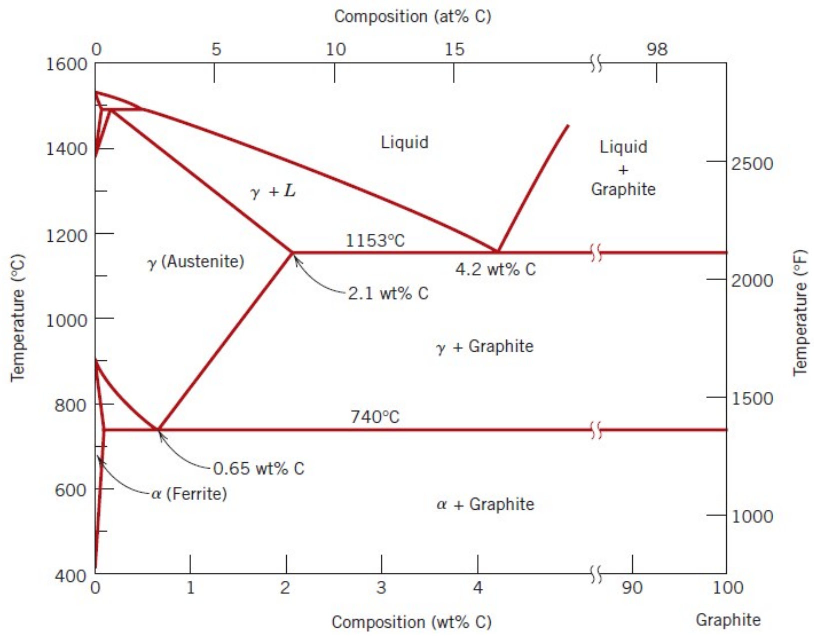
An alloy is a homogeneous mixture of a metal with other metals or non metal.

Alloy	Constituents	Uses
Steel	iron, carbon	construction of tools, machines, tanks, vehicles, ships, rails, building, bridges, dams etc.
Stainless steel	iron, chromium	utensils, cutlery, surgical instruments etc.
Brass	copper, zinc	utensils, handicrafts musical instruments etc.
Bronze	copper, tin	statues, medals, bells ornaments etc.

Iron Carbon diagram

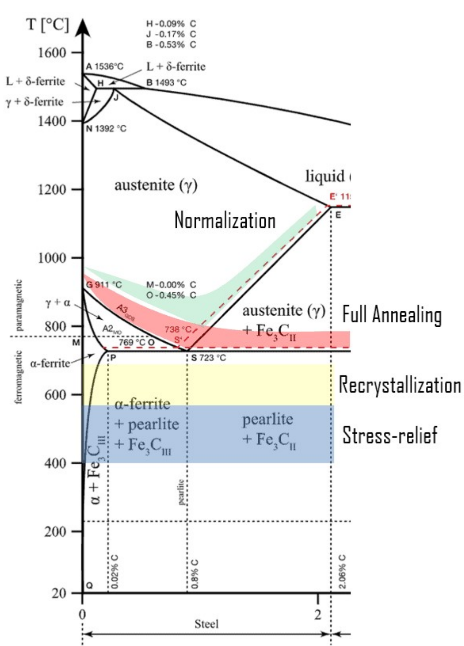


- Differences between cast iron and steel
- Various structures
- Varios lines and points



Steel Heat/Colour Chart

Colour	C	F
Faint Red	600	1112
Dark Red	700	1292
Cherry Red	800	1472
Dull Orange	900	1652
Orange	950	1742
Lemon Yellow	1000	1832
Yellow	1050	1922
Bright Yellow	1100	2012
White	1200	2192
Glowing White	1300	2372



The surface of some metals gets corroded when exposed to moist air for a long time. This is called corrosion.

Prevention of corrosion of metals :-

The corrosion of metals can be prevented by:-

i) Applying oil or grease.

ii) Applying paint

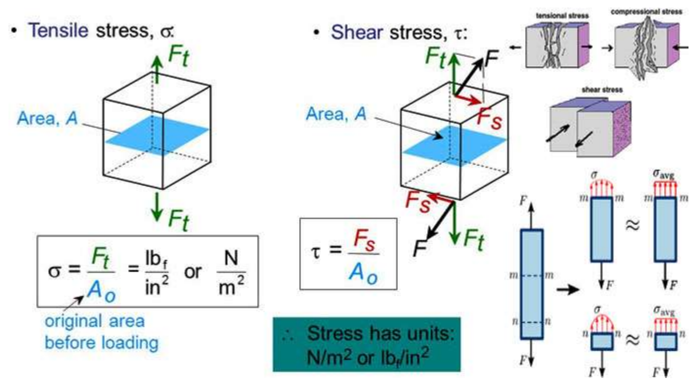
iii) Galvanisation (coating of metals with non corrosive metals like zinc)

iv) Electroplating (coating of metals with non corrosive metals like chromium tin by passing electricity)

v) Alloying (Eg. When iron is alloyed with chromium and nickel, it forms stainless steel which is resistant to corrosion)

	Modulus of Elasticity		Shear Modulus		
Metal Alloy	GPa	10^6 psi	GPa	10^6 psi	Poisson's Ratio
Aluminum	69	10	25	3.6	0.33
Brass	97	14	37	5.4	0.34
Copper	110	16	46	6.7	0.34
Magnesium	45	6.5	17	2.5	0.29
Nickel	207	30	76	11.0	0.31
Steel	207	30	83	12.0	0.30
Titanium	107	15.5	45	6.5	0.34
Tungsten	407	59	160	23.2	0.28

Stress



Stress

- When an external force is applied on a body, it undergoes deformation which is resisted by the body. The magnitude of the resisting force is numerically equal to the applied force. This internal resisting force per unit area of the body is known as stress.
- Stress = Resistive Force/Area
- In equation form: σ = P/A,
- **Units are**
  - – N/m^2, kN/m^2 MPa (Mega Pascal)
  - – Psi (lb/in^2), psf (lb/ft^2)
  - – Ksi ($kips/in^2$), ksf ($kips/ft^2$)

Strain

- When a body is subjected to an external force, there is some change of dimension in the body. Numerically the strain is equal to the ratio of change in length to the original length of the body.
- Strain = Change in length/Original length
- In equation form: $\varepsilon = \delta L/L$
- **Units**
  - m/m, mm/m
  - In/in, in/ft

Hooks law

- This law states that when a material is loaded, within its elastic limit, the stress is directly proportional to the strain.
- Stress α Strain
- $\sigma \alpha \varepsilon$
- $\sigma = E\varepsilon$
- $E = \sigma/\varepsilon$
- Its unit is same as that of Stress Where, – E is Young's modulus – σ is Stress – ε is Strain

Poisson Ratio

- It is the ratio of the lateral strain to the longitudinal strain and is constant property of each material. Poisson' ratio (μ or 1/m) = Lateral strain /Longitudinal strain

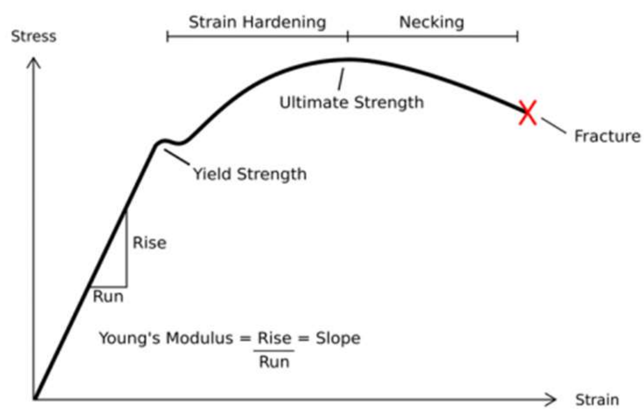
Young's Modulus:

- It is the ratio of the normal stress to the normal strain.
- $E = \sigma/\varepsilon$

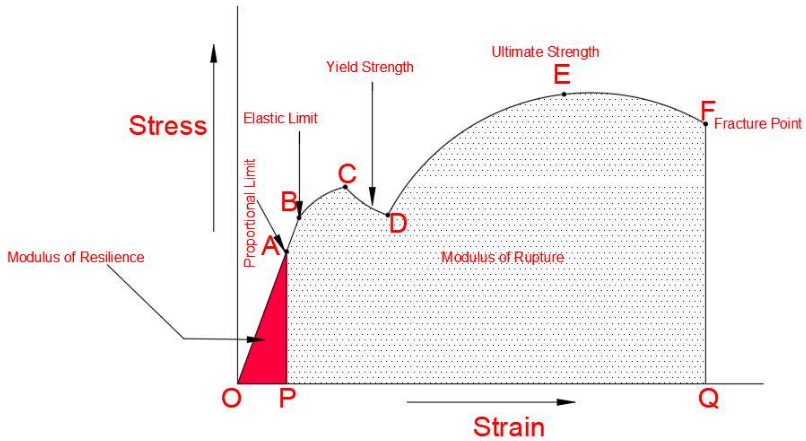
Rigidity Modulus:

- Its is the ratio of the shear stress to the shear strain.
- N = Shear stress/Shear strain
- **N = τ/G**

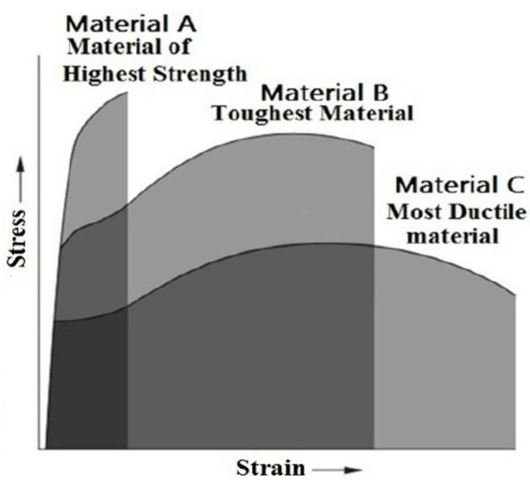
Stress strain curve of Iron



Resilience



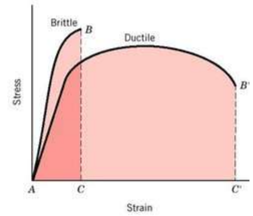
toughness



TOUGHNESS

Toughness is the **area under σ - ε curve up to fracture**.

$$Toughness = \int_0^{\varepsilon_f} \sigma \, d\varepsilon$$



Where ϵ_f is the true strain at fracture.

Note that ***toughness*** is the energy per unit volume that has been dissipated up to the point of fracture

Toughness is the material's ability to absorb energy before **fracture**

- Similar to Resilience (same units J/m³).
- Larger area ⇒ **tougher** material.

So tough materials have a **combination of ……strength…. And ……ductility…. such as ruber**

Can be measured by an impact test.

- **Toughness** is the ability of a material to absorb energy and plastically deform without fracturing. Toughness is the strength with which the material opposes rupture. One definition of material toughness is the amount of energy per unit volume that a material can absorb before rupturing.
- **Resilience** is the ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading. The **modulus of resilience** is defined as the maximum energy that can be absorbed per unit volume without creating a permanent distortion.

- Elasticity, **ability of a deformed material body to return to its original shape and size when the forces causing the deformation are removed**. A body with this ability is said to behave (or respond) elastically.
- **Plasticity**, also known as **plastic deformation**, is the ability of a solid material to undergo permanent deformation, a non-reversible change of shape in response to applied forces.
- Ductility is **the ability of a material to be drawn or plastically deformed without fracture**. It is therefore an indication of how 'soft' or malleable the material is. The ductility of steels varies depending on the types and levels of alloying elements present.

- **Metal hardness** is **a characteristic that determines the surface wear and abrasive resistance**. The ability of a material to resist denting from impact is related to hardness as well as a material's ductility.
- Heat treatment is **the process of heating metal without letting it reach its molten, or melting, stage, and then cooling the metal in a controlled way to select desired mechanical properties**. Heat treatment is used to either make metal stronger or more malleable, more resistant to abrasion or more ductile.
- **Annealing** is a heat treatment that alters the physical and sometimes chemical properties of a material to increase its ductility and reduce its hardness, making it more workable. It involves heating a material above its recrystallization temperature, maintaining a suitable temperature for an appropriate amount of time and then cooling.
- Normalizing involves **heating the steel to an elevated temperature, followed by slow cooling to room temperature**. The heating and slow cooling changes the microstructure of the steel. This reduces the hardness of the steel and will increases its ductility.

- Micro-electromechanical systems (MEMS) is **a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components**. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a few micrometers to millimetres.
- Bioengineering is a discipline that applies engineering principles of design and analysis to biological systems and biomedical technologies. Examples of bioengineering research include bacteria engineered to produce chemicals, new medical imaging technology, portable disease diagnostic devices, and tissue engineered organs.

$$HB = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

where

- HB = Brinell Hardness Number (kgf/mm^2)
- P = applied load in kilogram-force (kgf)
- D = diameter of indenter (mm)
- d = diameter of indentation (mm)