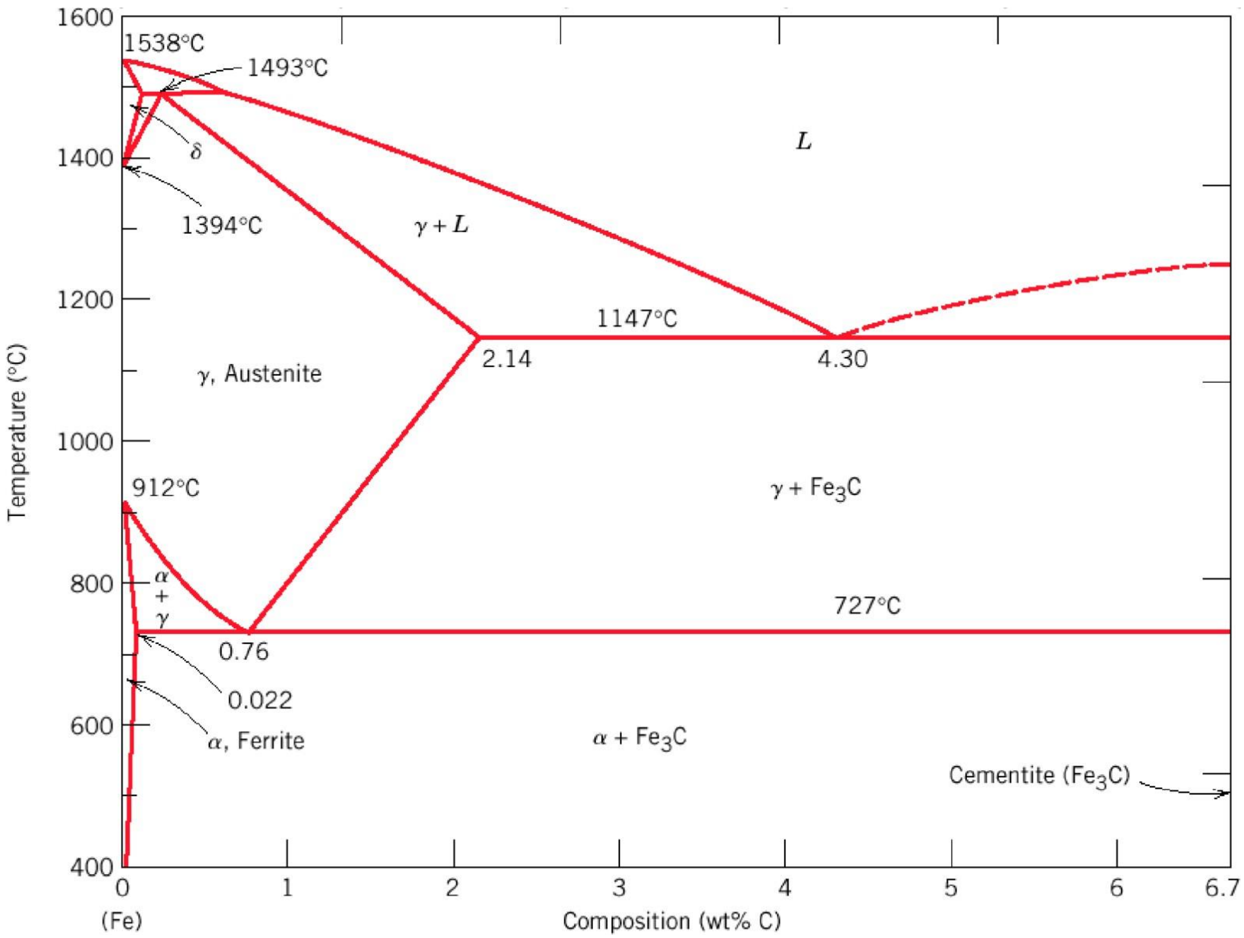
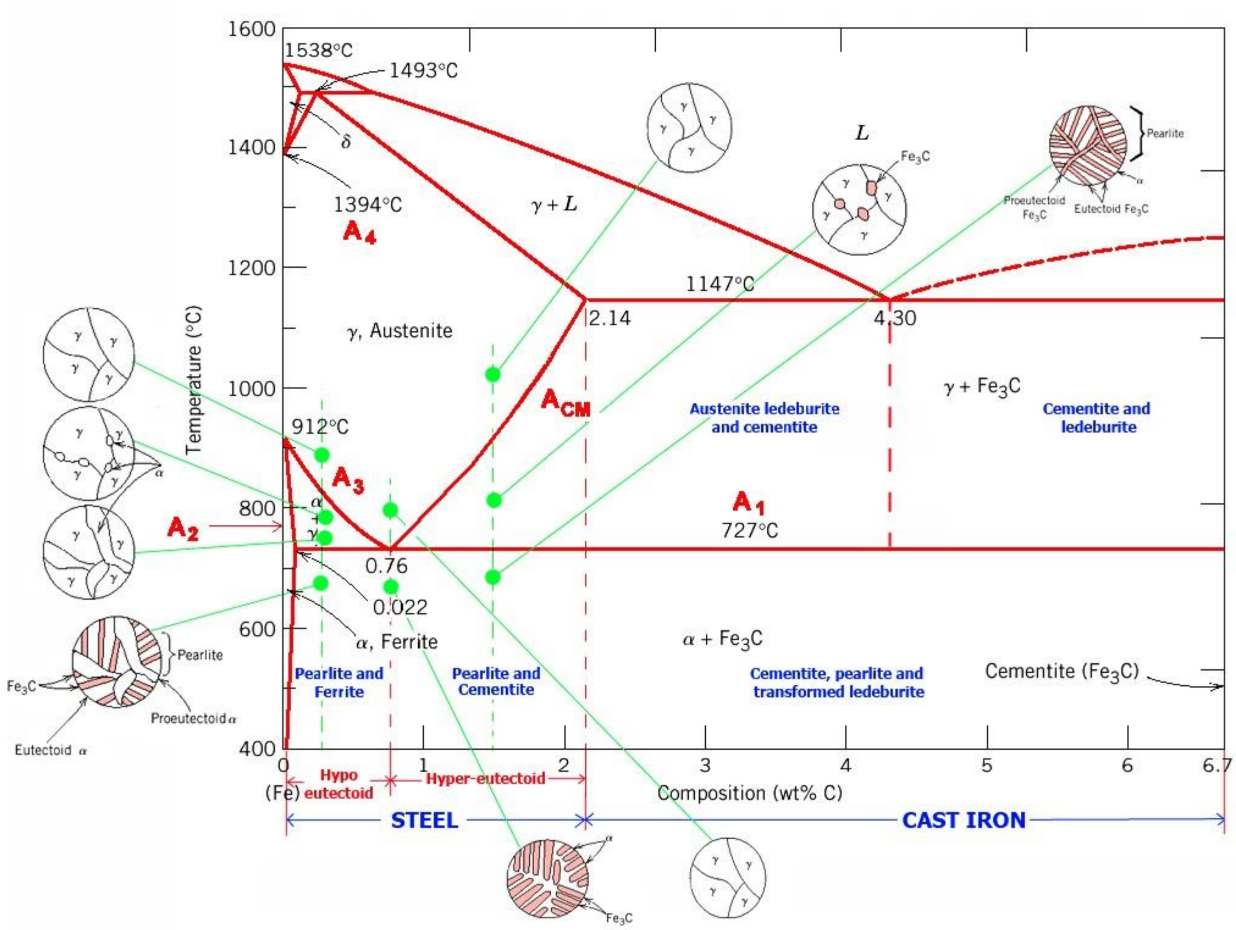
**M. Tech. (FFT)**

**Technology of Ferrous Casting**

# Iron–Iron Carbide (Fe–Fe3C) Phase Diagram

In their simplest form, steels are alloys of Iron (Fe) and Carbon (C). The Fe-C phase diagram is a fairly complex one, but we will only consider the steel part of the diagram, up to around 7% carbon.






# Phases in Fe–Fe3C Phase Diagram

- α-ferrite - solid solution of C in BCC Fe
  - Stable form of iron at room temperature.
  - The maximum solubility of C is 0.022 wt%.
  - Transforms to FCC γ-austenite at 912 °C.

- γ-austenite - solid solution of C in FCC Fe.
  - The maximum solubility of C is 2.14 wt %.
  - Transforms to BCC δ-ferrite at 1395 °C.
  - Is not stable below the eutectic temperature (727 ° C) unless cooled rapidly.

- δ-ferrite solid solution of C in BCC Fe.
  - The same structure as α-ferrite
  - Stable only at high T, above 1394 °C
  - Melts at 1538 °C

- $Fe_3C$ (iron carbide or cementite)
  This intermetallic compound is metastable, it remains as a compound indefinitely at room T, but decomposes (very slowly, within several years) into α-Fe and C (graphite) at 650 - 700 °C.
- Fe-C liquid solution

## A few comments on Fe–$Fe_3C$ system

- C is an interstitial impurity in Fe. It forms a solid solution with α, γ, δ phases of iron.
- Maximum solubility in BCC α-ferrite is limited (max. 0.022 wt% at 727 °C) - BCC has relatively small interstitial positions
- Maximum solubility in FCC austenite is 2.14 wt% at 1147 °C - FCC has larger interstitial positions
- Mechanical properties: Cementite is very hard and brittle - can strengthen steels. Mechanical properties also depend on the microstructure, that is, how ferrite and cementite are mixed.
- Magnetic properties: α -ferrite is magnetic below 768 °C, austenite is non-magnetic.

## Classification. Three types of ferrous alloys:

• Iron: less than 0.008 wt % C in α−ferrite at room T

• Steels: 0.008 - 2.14 wt % C (usually < 1 wt % ) α-ferrite + $Fe_3C$ at room T .

• Cast iron: 2.14 - 6.7 wt % (usually < 4.5 wt %)

## Eutectic and eutectoid reactions in Fe–$Fe_3C$

**Eutectoid: 0.76 wt% C, 727 °C**

$$\gamma(0.76\text{ wt\% C}) \leftrightarrow \alpha\ (0.022\text{ wt\% C}) + Fe_3C$$

**Eutectic: 4.30 wt% C, 1147 °C**

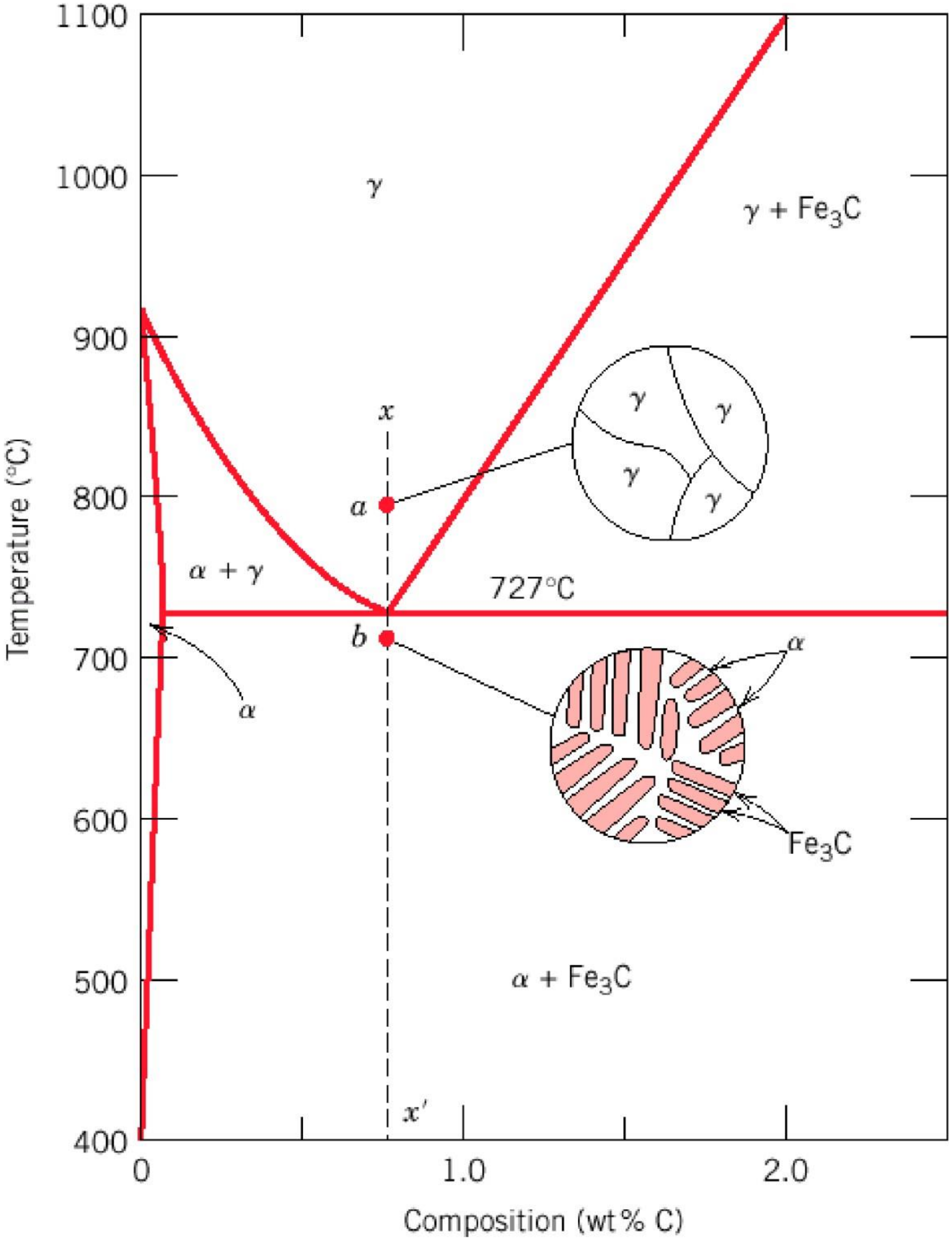
$$L \leftrightarrow \gamma + Fe_3C$$

Eutectic and eutectoid reactions are very important in heat treatment of steel.

# **Development of Microstructure in Iron**

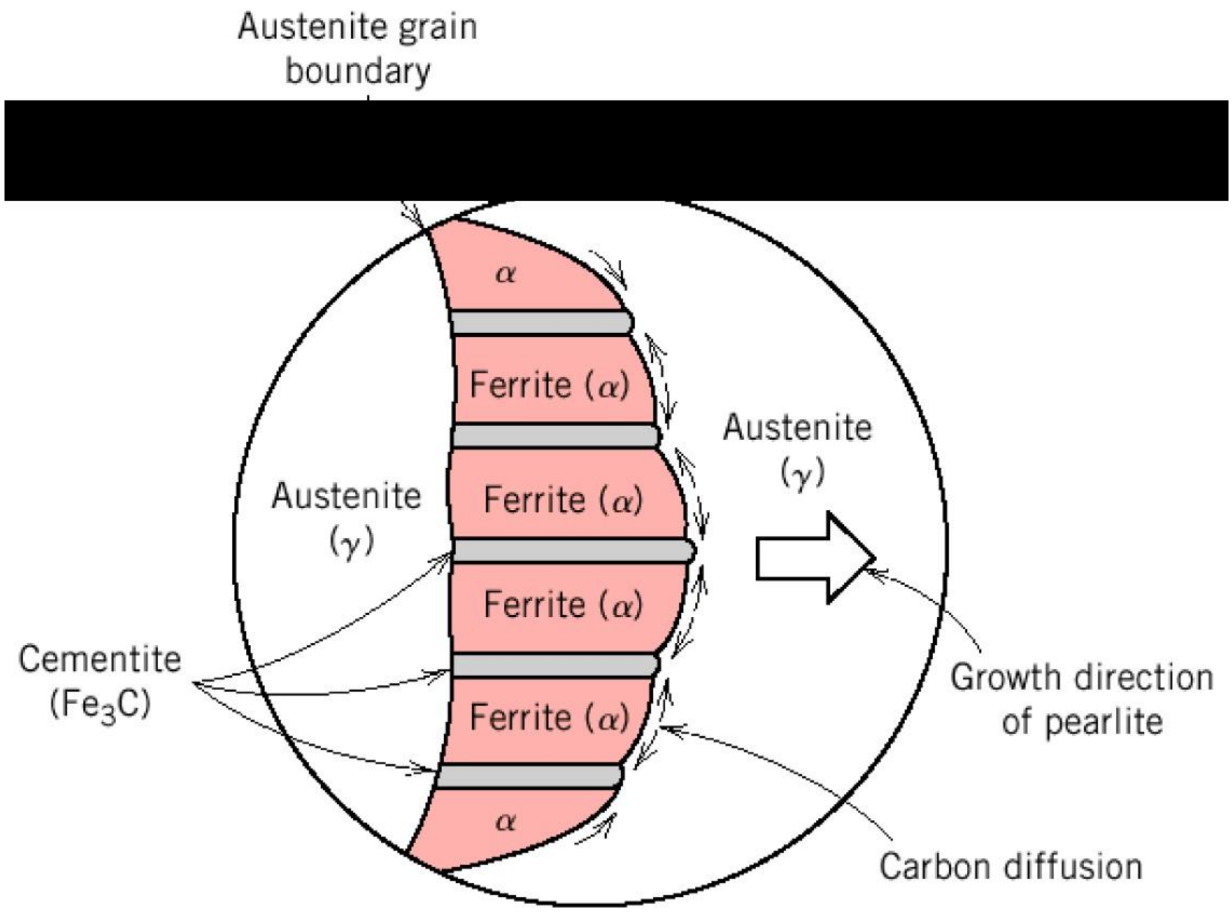
Carbon alloys Microstructure depends on composition (carbon content) and heat treatment. In the discussion below we consider slow cooling in which equilibrium is maintained.

Microstructure of eutectoid steel (I)



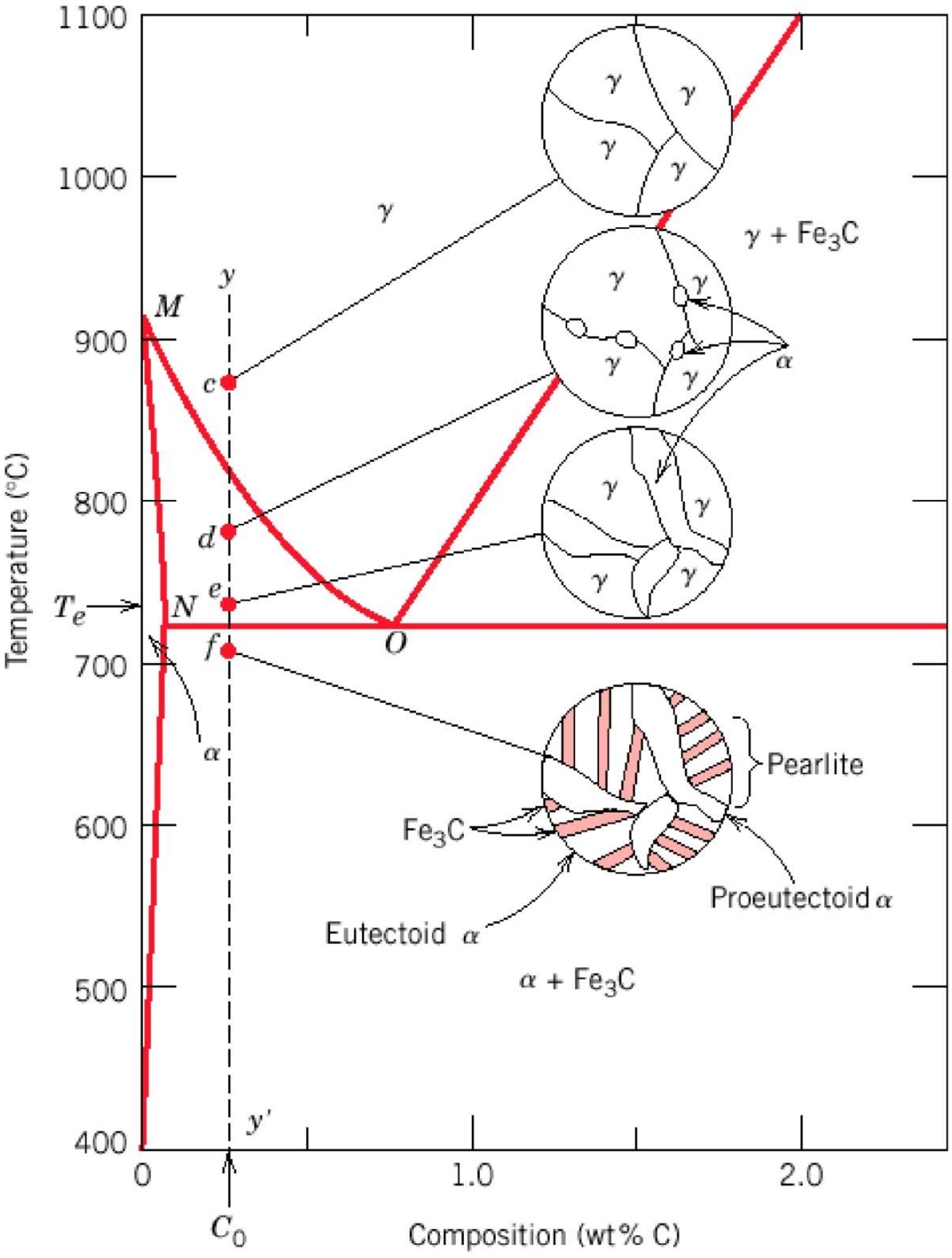
# Microstructure of eutectoid steel (II)

When alloy of eutectoid composition (0.76 wt % C) is cooled slowly it forms perlite, a lamellar or layered structure of two phases: α-ferrite and cementite (Fe3C) The layers of alternating phases in pearlite are formed for the same reason as layered structure of eutectic structures: redistribution C atoms between ferrite (0.022 wt%) and cementite (6.7 wt%) by atomic diffusion. Mechanically, pearlite has properties intermediate to soft, ductile ferrite and hard, brittle cementite. Microstructure of eutectoid steel (II) In the micrograph, the dark areas are Fe3C layers, the light phase is α- ferrite



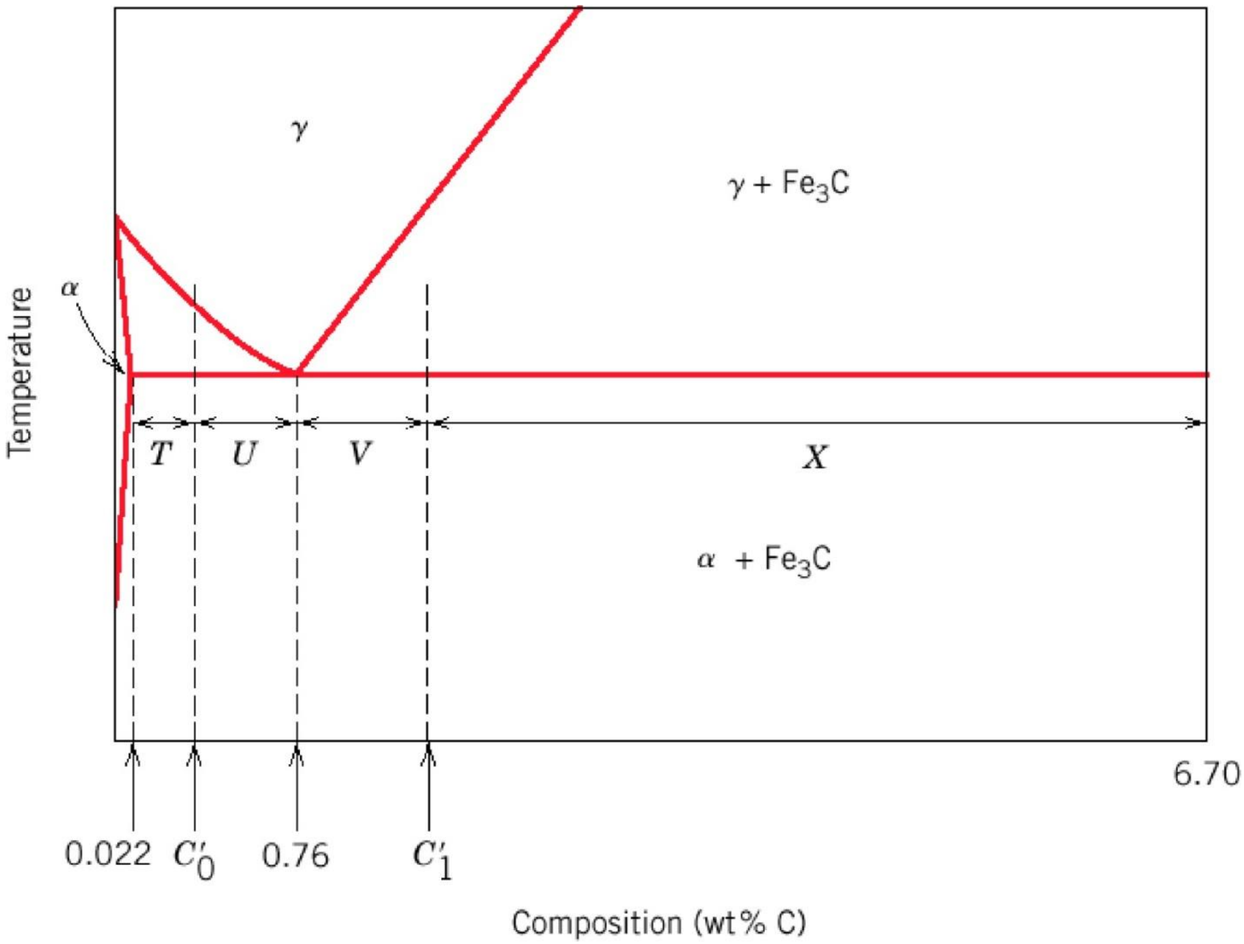
# Microstructure of hypoeutectoid steel (I)

Compositions to the left of eutectoid (0.022 - 0.76 wt % C) hypoeutectoid (less than eutectoid -Greek) alloys.



How to calculate the relative amounts of pro-eutectoid phase (α or Fe3C) and pearlite?

Application of the lever rule with tie line that extends from the eutectoid composition (0.76 wt% C) to α – (α + Fe3C) boundary (0.022 wt% C) for hypo eutectoid alloys and to (α + Fe3C) – Fe3C boundary (6.7 wt% C) for hypereutectoid alloys.




Fraction of α phase is determined by application of the lever rule across the entire (α + Fe3C) phase field

Example for hypereutectoid alloy with composition

C1 Fraction of pearlite: WP = X / (V+X) = (6.7 – C1) / (6.7 – 0.76)

Fraction of proeutectoid cementite: WFe3C = V / (V+X) = (C1 – 0.76) / (6.7 – 0.76)

**References:-**


- Wikipedia
- Callister (material science and engineering)
- Nptel.