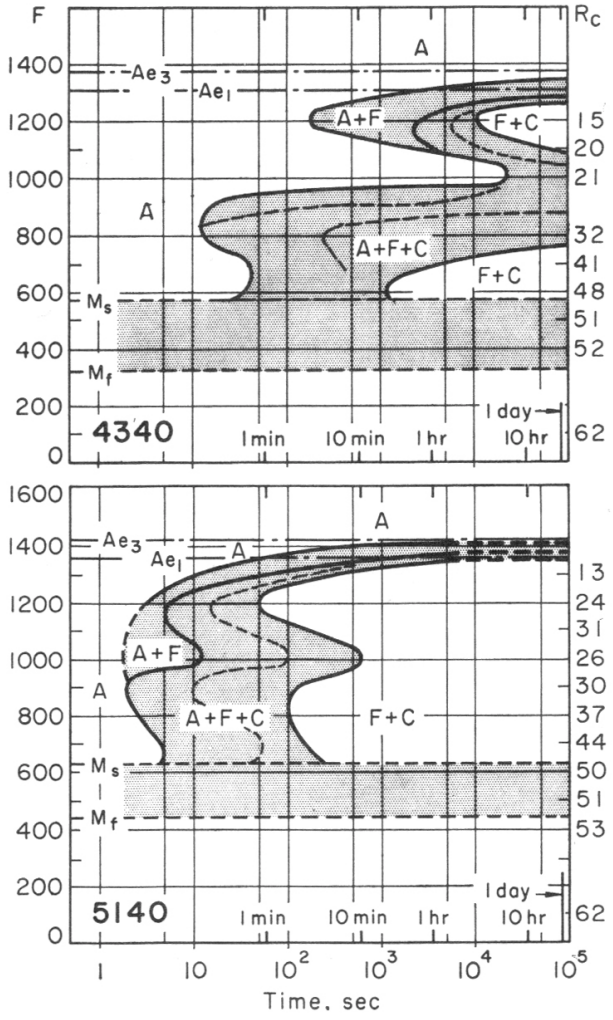
ENGR 240 Materials Engineering
Homework 15 Solutions – 10 points

1. [2 points] What is the purpose of tempering?

   Tempering is used to increase the ductility of quenched (martensitic) steels.

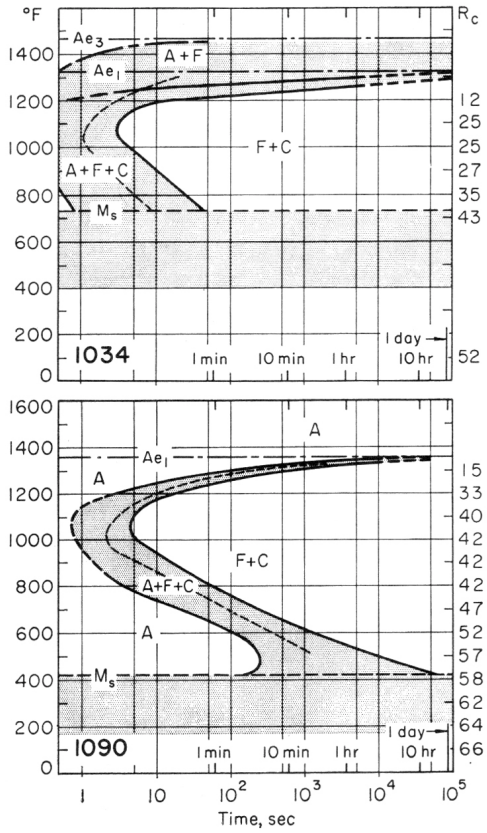
2. [2 points] The TTT diagrams for two steels are shown below. If the two steels were tested for hardenability using the Jominy end quench method, which steel would you expect to show higher hardenability? Explain your answer.

   The 4340 steel would be expected to show higher hardenability. The 5140 steel is composed of iron, carbon, and some chromium. The 4340 steel is composed of iron and carbon with chromium, molybdenum, and nickel alloying additions. The additional alloying elements in the 4340 steel delay the austenite to ferrite and austenite to pearlite transformation, which allows more martensite to form upon cooling. The effect of the alloying elements is seen on the TTT diagram as a shift of the entire transformation curve toward the right, indicating longer times before the start of the austenite to ferrite, pearlite, and bainite transformations (leaving more time to cool to the martensite transformation temperature).



3. [2 points] TTT diagrams for AISI 1034 and AISI 1090 steels are shown below. Based on the appearance of the two diagrams, what effect does carbon have on the ease of martensite formation upon quenching of the steels?

   The 1034 steel has 0.34 wt.% carbon, and the 1090 steel has 0.90 wt.% carbon. The transformation curve for the 1090 steel is shifted more to the right of the TTT diagram, indicating that more time is allowed to quench the steel and form martensite. The left side of the 1034 transformation curve is off the left side of the TTT diagram, indicating that it would be extremely difficult to quench the 1034 steel fast enough to form martensite – ferrite and pearlite will form even with a rapid quench. So, with more carbon added to steel, martensite is easier to form.



4. [4 points] Two complete Jominy hardenability curves for steels A and B are given below.

   a. Which steel has more alloying elements? Steel B (flatter curve…higher hardness with lower cooling rates)
   b. Which steel will have more pearlite present at the center of a bar 2 inches in diameter? Steel A
   c. Which steel has higher hardenability? Steel B
   d. Which steel contains harder martensite? Steel A – quenched end is harder