Learning objectives:

- Degree-of-Freedom (DoF) analysis with multiple process units

Reading assignment: Complete this before coming to class.

- (3 pages) FR Section 4.4 and Example 4.4-1
- (3 pages) Example 4.4-2
- FR Problem 4.28

Pre-App problem 2-C: This problem is to be completed and submitted individually. It is due at the beginning of class. In the production of a bean oil, beans containing 13.0 wt% oil and 87.0% solids are ground fed to a stirred tank (the extractor) along with a recycled stream of liquid \( n \)-hexane. The feed ratio is 3 kg hexane/kg beans. The ground beans are suspended in the liquid, and essentially all the oil in the beans is extracted into the hexane. The extractor effluent passes to a filter. The filter cake contains 75.0 wt% bean solids and the balance bean oil and hexane, the latter two in the same ratio in which they emerge from the extractor. The filter cake is discarded and the liquid filtrate is fed to a heated evaporator in which the hexane is vaporized and the oil remains as a liquid. The oil is stored in drums and shipped. The hexane vapor is subsequently cooled and condensed, and the liquid hexane condensate is recycled to the extractor. A labeled process flow chart is attached.

1. What is the basis for the labeled process flow chart?

2. There are three productivity indicators of interest for this process: the yield of bean oil product (kg oil/kg beans fed), the required fresh hexane feed (kg \( C_6H_{14} \)/kg beans fed, and the recycle to fresh feed ratio (kg hexane recycled/kg fresh hexane feed). Write each productivity indicator in terms of the process variables listed on the flow chart. The first one is written as an example:

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\text{bean oil yield: } \frac{\text{kg oil}}{\text{kg beans fed}} = \frac{m_{\text{oil}}}{100}
\]

3. Perform a DoF analysis on the system and determine for which system balances can be written to begin solving for the productivity indicators written above. You do not need to write any balances nor do any calculations. Just figure out which system you would start with to derive the balance equations.
Figure 1: Huvard and Felder, *Elementary Principles of Chemical Processes: Student Workbook*, 2005.