Final Exam **January 2023**

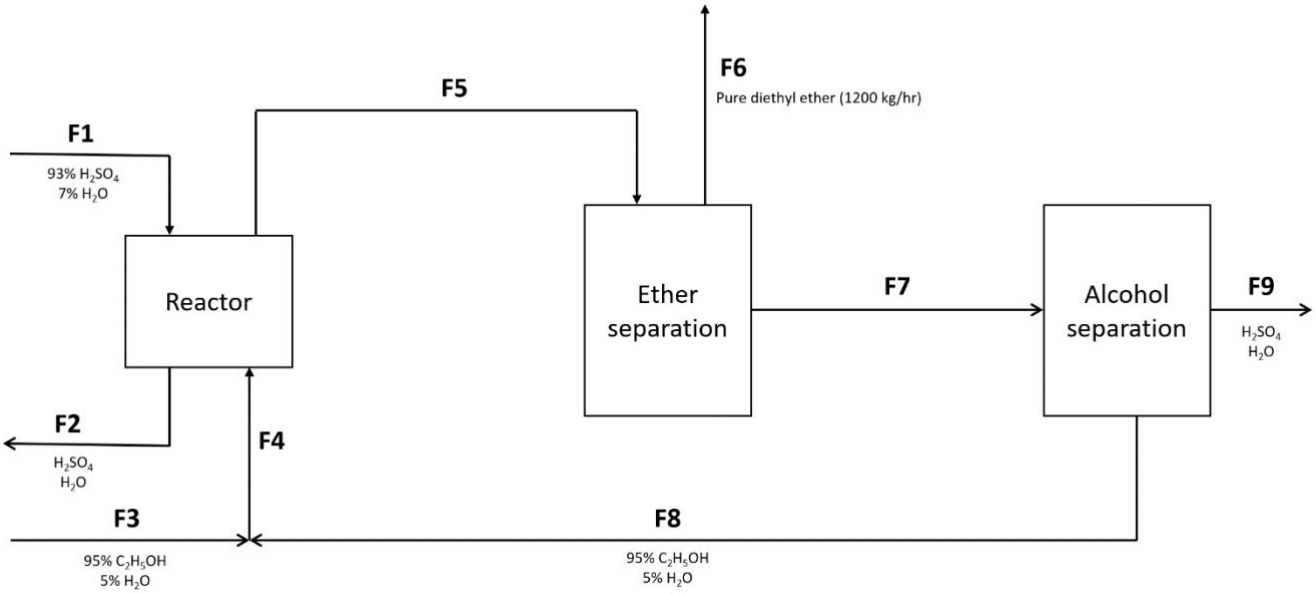
Introduction to Chemical Engineering

Problem 1: Mass Balance-Reactive

Diethyl ether is made by the dehydration of ethyl alcohol in the presence of sulfuric acid at 140°C:

$$2C_2H_5OH \rightarrow (C_2H_5)_2O + H_2O$$

The figure below is a simplified process diagram:



If there is an 87% single-pass conversion of the ethyl alcohol fed to the reactor, calculate:

(a) The flux in kilograms per hour of fresh feed **F3**

(b) The flux in kilograms per hour of recycle **F8**

Final Exam **January 2023**

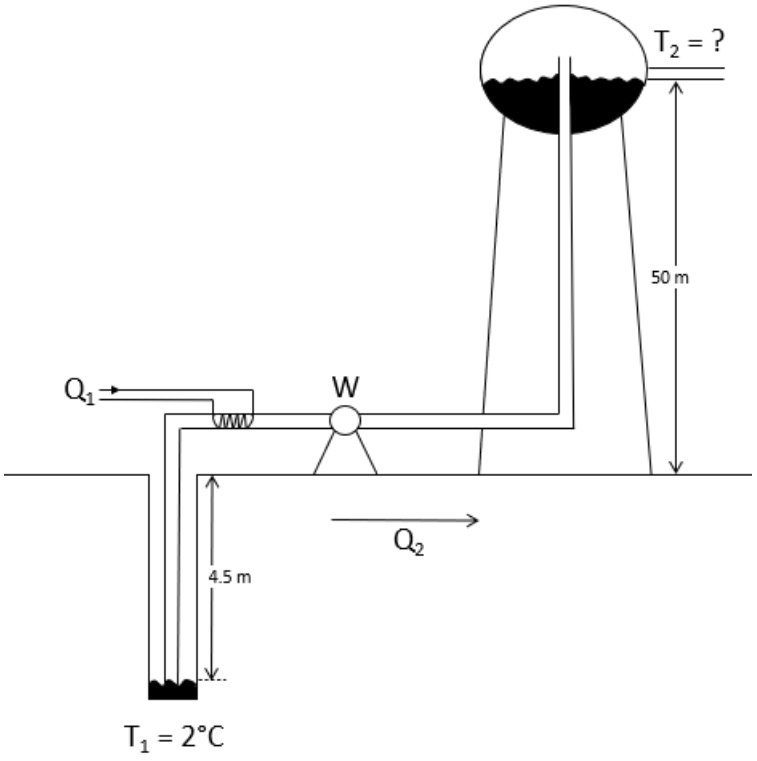
Introduction to Chemical Engineering

Problem 2: Energy Balance-Nonreactive

Water is pumped from the bottom of a well 4.5 meters deep at the rate of 760 L/hr into a storage tank 50 meters above the ground. A small heater provides 32 000 kJ/h during its transfer from the well to the storage tank. Heat is lost from the whole system at the constant rate of 24 000 kJ/h. A 2-horsepower pump is used to pump the water into a pipe with a diameter of 10 cm. About 55% of the energy from the pump provides work, and the rest is dissipated in the form of heat. What is the temperature of the water in the storage tank?

Hints:

- The water in the well is at 2°C.
- Do not neglect kinetic energy or potential energy.
- 1hp = 745.7 J/s



Final Exam **January 2023**

Introduction to Chemical Engineering

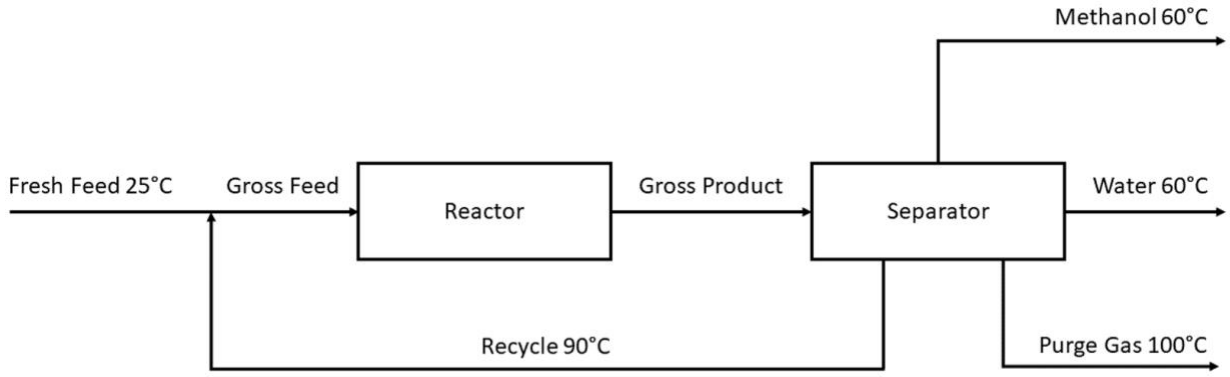
Problem 3: Energy Balance-Reactive

A proposed method of producing methanol as an alternate source of fuel and to capture carbon dioxide is to react CO_2 with H_2

$$CO_2 + H_2 \rightarrow CH_3OH + H_2O$$

Assume that the Gross Feed enters the reactor in stoichiometric quantities needed for the reaction. Also, 0.5% g/g N_2 flows in the fresh feed. On one pass through the reactor, 57% mol conversion is obtained. The concentration of N_2 in the gross feed can not exceed 2% g/g.

Assume the process is in the steady state, that all gases are ideal, and the following process flowchart



1. How much heat must be added or removed from the system? (Comment on the sign and the magnitude of the answer)

   If the heat is provided by the system, it is assimilated in the form of evaporation of water into saturated steam at 270°C.

   If the heat is consumed by the system, it is provided in the form of condensation of saturated steam into water at 270°C.

2. At what rate should the water or saturated steam be supplied?