Your company has decided to produce \( P \) by the reaction \( A \rightarrow P \). Unfortunately, there is a parallel reaction, \( A \rightarrow B \). Both reactions are irreversible. Both reactions are incomplete; the reactor effluent contains reactant \( A \), product \( P \) and worthless by-product \( B \).

The boiling points at 1 atm are \( P \) (30°C), \( A \) (50°C), and \( B \) (55°C). Purifying \( P \) to \( \geq 99\% \) (minimum purity to sell) by distillation is easy, but separating \( A \) and \( B \) is more difficult.

A generic process is shown below. To produce and sell product \( P \), you need only a reactor and separator I. You have three options for the \( A+B \) mixture in the “separator I bottoms” stream: (1) you may discard the \( A+B \) mixture by sending 100\% of the stream to the purge, or (2) you may recycle some of the \( A+B \) mixture, for example, by purging 50\% and sending 50\% through the recycle, or (3) you may purchase a second separator to separate \( A \) from \( B \) before recycling.

There are two options for the reactor. Reactor Type 1 has a high conversion of \( A \) but has poor selectivity for \( P \) over \( B \). Another reactor has a lower conversion of \( A \), but has better selectivity for \( P \) over \( B \).

There are two options for separator I. Both options produce a tops product with 99\% \( P \), but differ by the amount of \( P \) in the liquid bottoms. Separator I Type 1 recovers more of the product \( P \) (the ratio \( P:A \) in the bottoms is \( <1:20 \)). Separator I Type 2 allows more \( P \) to escape via the liquid stream, but is smaller and less expensive to operate.

If one decides to purchase a second separator, there are two options for separator II. The expensive option (Type 1) has a high \( A:B \) ratio in the tops and a low \( A:B \) ratio in the bottoms. The cheaper option (Type 2) has a moderate \( A:B \) ratio in the tops and a moderate \( A:B \) ratio in the bottoms.

Because \( B \) is toxic, disposal requires special treatment and is expensive. The disposal cost is determined by the total amount of any effluent that contains \( B \). That is, the disposal cost for 1 mol of a mixture with 10\% \( A \) and 90\% \( B \) is the same as the disposal cost for 1 mol with 90\% \( A \) and 10\% \( B \).
Engineering and Economic Data for Manufacturing $P$ from $A$.

Equipment specifications, equipment costs, operating costs, chemical costs, and disposal costs vary with Design League and Division. Identify your team’s League and Division and then download the data from the EngrD 2190 homepage - see “Design Competition.”

Wednesday Design League: Galbraith Division: Teams W1 - W5
Keynes Division: Teams W6 - W10
Smith Division: Teams W11 - W16

Thursday Design Leagues: Friedman Division: Teams Th1-Th6
Von Mises Division: Teams Th7-Th12

Reactor and separator prices are given by the formula \( \text{price} = k \times (F_T)^{0.6} \), where \( k \) is a constant conversion factor, \( F_T \) is the flow through the unit, in mol/day, and \( \text{price} \) is in $. For example, a reactor with double the capacity costs only 1.5 times as much. Operating costs for reactors and separators are given by the formula \( \text{operating cost} = c \times F_T \); the units of \( \text{operating cost} \) are $/year.

All economic parameters - equipment prices, operating costs, chemical prices, and disposal cost - are constant. Equipment depreciation is calculated with straight-line formula, with a lifetime of 10 years. The process operates 365 days/year.

Equipment purchase costs are paid at the beginning of the year. Operating costs are paid during the year. Revenue from $P$ sales is received at the end of the year.

---

**Goal:** Start with $10,000,000 and maximize the ROI for your process in the first year.

You must decide what type of reactor, separator I, and separator II (if any) to purchase, and the capacity of each. You must specify the fraction of Separator I bottoms to be purged and the fraction to be recycled. You also must decide how much reactant to purchase.

Annual Plans are due by 2:30 p.m. on the day of your Calculation Session, either Wednesday October 18 or Thursday October 19. You will receive an Annual Report of your team’s results by Friday, October 20.

If your team achieves a positive Return On Investment, your team will receive 25 homework points. If your ROI is greater than 0.2, your team will receive an additional 10 points. If your team has the highest Return On Investment in your Division, your team will receive an additional 10 points.