This is the last lecture! 😊 Today, we will:

- Finish a few notes about filters
- Watch and honors presentation by Rebecca Denby
- Review for final exam
- Do Candy Questions for Candy Friday

The Calvert and Englund model for filter performance includes inertial separation, but does NOT include Brownian diffusion. Here is a grade efficiency curve for an actual air filter at two different air flow speeds. This dip in the curve is typical for air filters.

It is very hard to remove particles between about 0.03 and 1.3 microns. Why?

Example from a real air filter, showing the “dip” ranging from around 0.05 to 1 microns:

Filter grade efficiency for two face velocities; filter thickness $H = 1.0 \text{ mm}$, solids fraction $f_f = 0.05$ (porosity $\varepsilon = 0.95$), single fiber diameter $D_f = 2 \mu\text{m}$ (adapted from Hinds, 1982).

The “dip” is typically centered around $D_p \approx 0.1$ to 0.5 microns, so these are the hardest particles to filter out of the air.
This is why air filters are tested with $D_p = 0.12$ or 0.3 micron particles!
**Air Filter Classification**

- **HEPA Filter** = High Efficiency Particulate Air Filter.
  A HEPA filter is defined as $\eta(D_p) > 99.97\%$ for $D_p = 0.3\ \mu m$.

- **ULPA Filter** = Ultra Low Penetration Air Filter.
  An ULPA filter is defined as $\eta(D_p) > 99.999\%$ for $D_p = 0.12\ \mu m$.

\[ \text{Huge } \Delta p \]

- Option: use a pleated filter

\[ \text{Structurally more rigid} \]
Example: Junction flow

**Given:** Air enters a “tee” as sketched. The bulk volume flow rates and mass concentrations are shown.

\[
\begin{align*}
Q_2 &= fQ \\
Q_1 &= (1-f)Q \\
Q_3 &= Q
\end{align*}
\]

**To do:** When volume flow fraction \( f = 0.2 \), \( c_1 = 50 \text{ mg/m}^3 \), and \( c_2 = 80 \text{ mg/m}^3 \), calculate \( c_3 \) in units of \( \text{mg/m}^3 \).

**Solution:**

Bulk flow: \( Q_1 + Q_2 = Q_3 \)

\[
(1-f)Q + fQ = Q
\]

Species mass flow: \( Q_1 c_1 + Q_2 c_2 = Q_3 c_3 \)

\[
(1-f)Q c_1 + fQ c_2 = Q c_3
\]

\[
c_3 = (1-f) c_1 + f c_2
\]

\[
c_3 = \sqrt{6} \text{ mg/m}^3
\]
Question: Which is better, series or parallel for these two particulate air cleaners?

**Series**

- Cleaner A
  - \( \eta (D_p)_A \)
  - \( D_{p, \text{cut}} = 10 \, \mu m \)

- Cleaner B
  - \( \eta (D_p)_B \)
  - \( D_{p, \text{cut}} = 1 \, \mu m \)

**Parallel**

- Cleaner A
  - \( \eta (D_p)_A \)
  - \( D_{p, \text{cut}} = 10 \, \mu m \)

- Cleaner B
  - \( \eta (D_p)_B \)
  - \( D_{p, \text{cut}} = 1 \, \mu m \)

It is rare to have unequal cleaners in parallel.

Review for final:

- Comprehensive, but weighted more heavily on stuff since E2

- Same format as E1 & E2
  - Concepts, definitions
  - Simple path
  - More involved path

- Study old exam, examples, handouts, review notes
Know how to \textit{derive} to get $V_b$ or $V_r$

\textit{Separate variables and integrate.}

\textit{1st-order ODEs}

\[ C_{out} = (1 - n) C_{in} \]
HVAC Flow

\[ \Delta p \]
\[ Q \]

Parities:
- Inertial separation
- Cavitation settling
- Grade Efficiency \( \eta(\Delta p) \)

\( \text{(e.g., low, } \eta = \text{ one #)} \)

- Laminar vs. well-mixed
  \rightarrow
  \text{Linear } \rightarrow \text{Exponential}

\text{THE END}