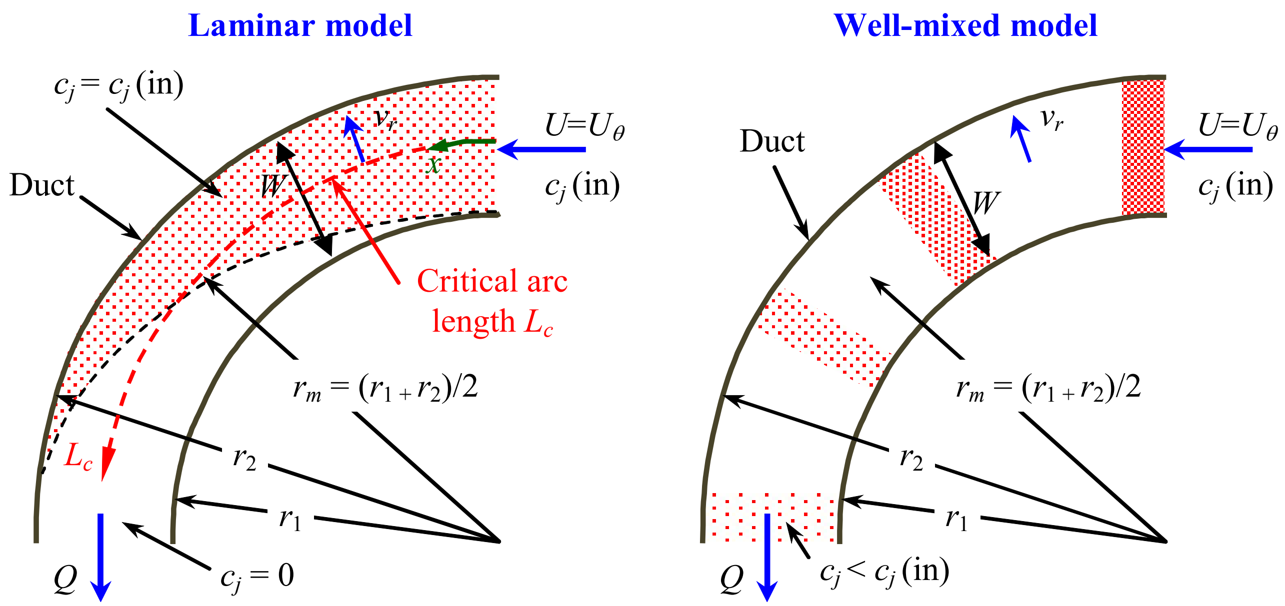
Today, we will:

- Continue to discuss inertial separation, and laminar vs. well-mixed settling in ducts
- Discuss an application of inertial separation: **cyclone separators**

Inertial separation in a curved duct (review from previous lecture):



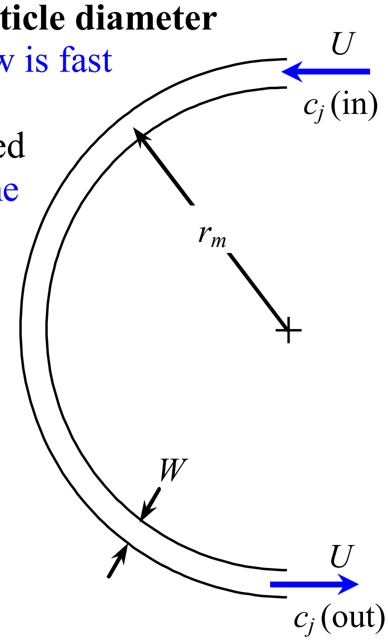
The simplest case is when $r_m >> W$, so we treat r and v_r as constants in the equations.

Laminar settling model: $\boxed{E = 1 - \frac{c_j}{c_j(\text{in})} = \frac{x}{L_c}}$, where x is the arc length $\boxed{x = r_m\theta}$, $\boxed{L_c = W\frac{U_\theta}{v_r}}$ is the critical arc length.

Well-mixed settling model:

Example: Grade efficiency of a curved duct as a function of particle diameter

Given: A polydisperse aerosol enters a 180° curved duct. The flow is fast enough to be considered turbulent in the duct, so we make the well-mixed settling approximation. For convenience, I have pre-calculated the inertial settling velocity v_r for various particle diameters. Assume that particles stick to the outer wall when the hit the wall, and are therefore removed from the flow. The particles are of unit density (ρ_p = 1000 kg/m^3). The middle duct radius is r_m = 0.500 m, the duct width is W = 22.5 mm (0.0225 m), the air is at STP (ρ = 1.184 kg/m^3, μ = 1.849 × 10^{-5} kg/(m s)), and U = 8.50 m/s.



To do: For each diameter, calculate the removal grade efficiency $E(D_p)$ (in %) for each particle diameter D_p in the table below.

Solution: **Table to be filled in during class:**

D_p (μm)	v_r (m/s)	$E(D_p)$ (%)
1	0.000506747	
1.5	0.001085343	
2	0.001880751	
2.5	0.002892936	
3	0.004121854	
4	0.007229597	
5	0.011203123	
7	0.021741295	

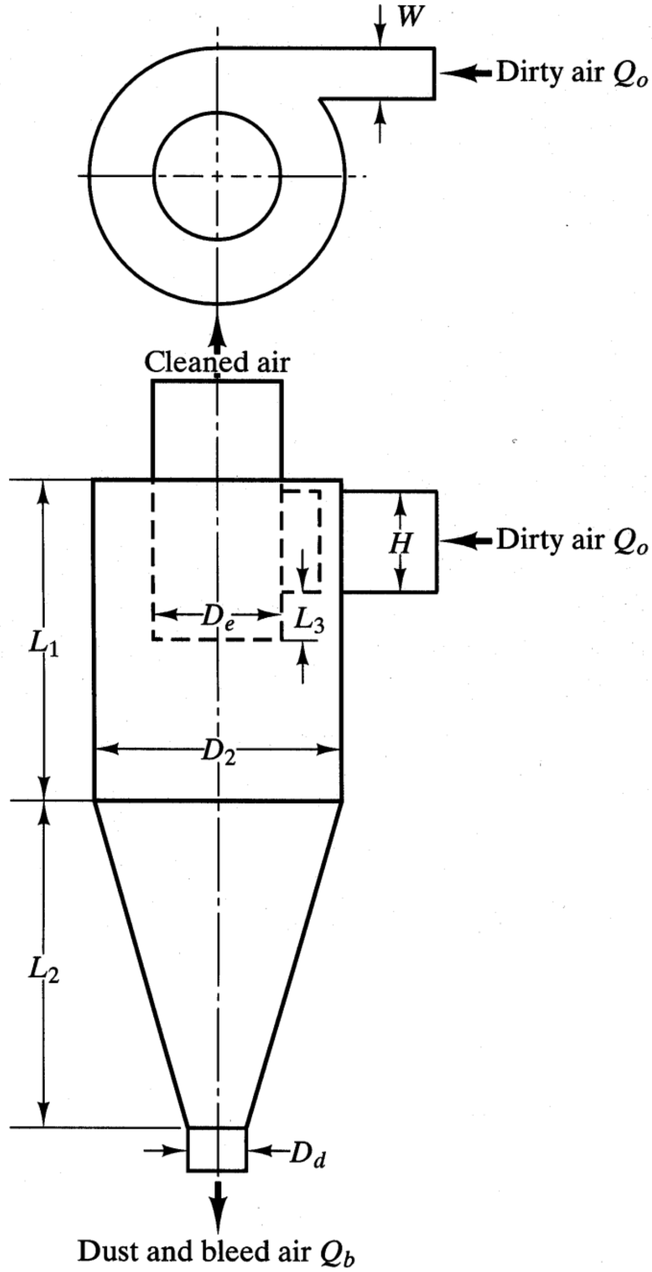
D_p (μm)	v_r (m/s)	$E(D_p)$ (%)
10	0.043982967	
20	0.171476946	
25	0.262745185	
30	0.368588815	
40	0.609606668	
50	0.867242208	
70	1.388132409	

Equations: Well-mixed: $\boxed{E\left(D_p\right) = 1 - \frac{c_j}{c_j(\text{in})} = 1 - \exp\left(-\frac{x}{L_c}\right)}$, where $\boxed{L_c = W\frac{U_\theta}{v_r}}$, $\boxed{x = r_m\theta}$.

Standard Lapple reverse-flow cyclone (from Heinsohn and Cimbala, 2003):

top view

side view



Example: Lapple Cyclone

Given: A standard reverse flow Lapple cyclone is used to clean up a dusty air flow exhausted by a sanding machine in a wood shop. The main body diameter of the cyclone is D_2 = 45.0 cm (0.450 m).

- particle density ρ_p = 730 kg/m^3
- bulk volume flow rate of air Q = 0.55 m^3/s
- Air is at STP: ρ = 1.184 kg/m^3, μ = 1.849 × 10^{-5} kg/(m s).

To do: Calculate the grade efficiency $E(D_p)$ for 10-μm particles. Give your answer as a percentage to 3 significant digits.

Solution: Some equations: $\boxed{D_{p,\text{cut}} = \sqrt{\dfrac{3\mu D_2^{\,3}}{128\pi Q\left(\rho_p - \rho\right)}}}$, $\boxed{E\left(D_p\right) = \dfrac{1}{1+\left(\dfrac{D_p}{D_{p,\text{cut}}}\right)^{-2}}}$.