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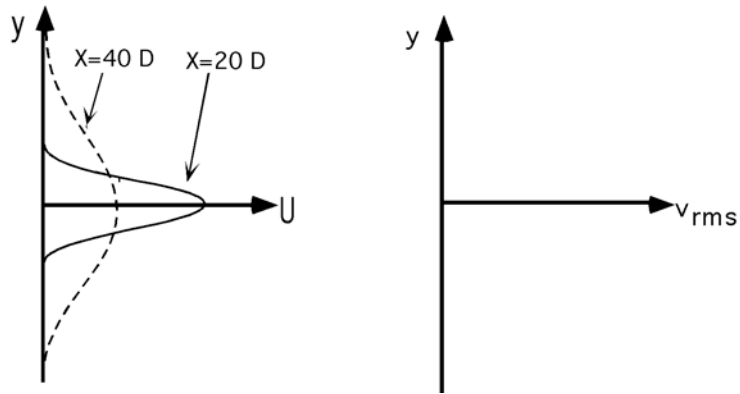
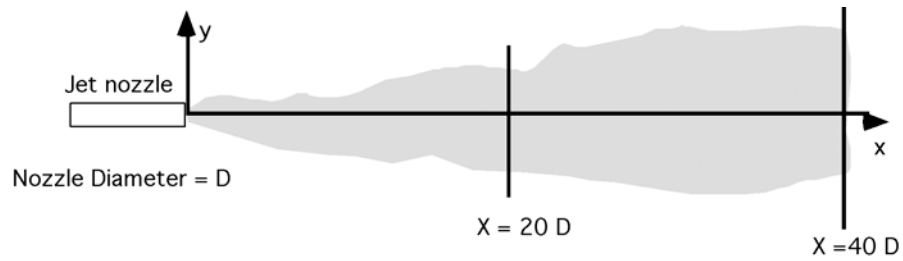
1.061 / 1.61 Transport Processes in the Environment
Fall 2008

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Problem 7.1

Velocity profiles were measured at two locations downstream of a jet exiting a nozzle of diameter D . The locations are: $X = 20 D$ and $40 D$.

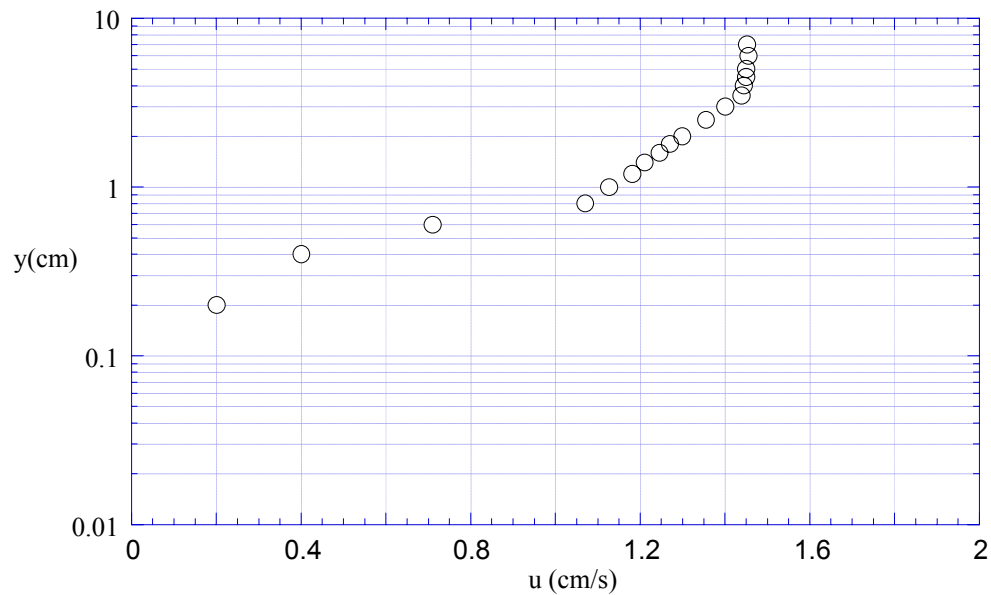
- 1) Sketch the profile, $v_{rms}(y)$, at each station. Explain the shape of your plot.
- 2) What is the length scale of the eddies which dominate mixing within the jet? Sketch this length scale and the corresponding eddy below.



Problem 7.2

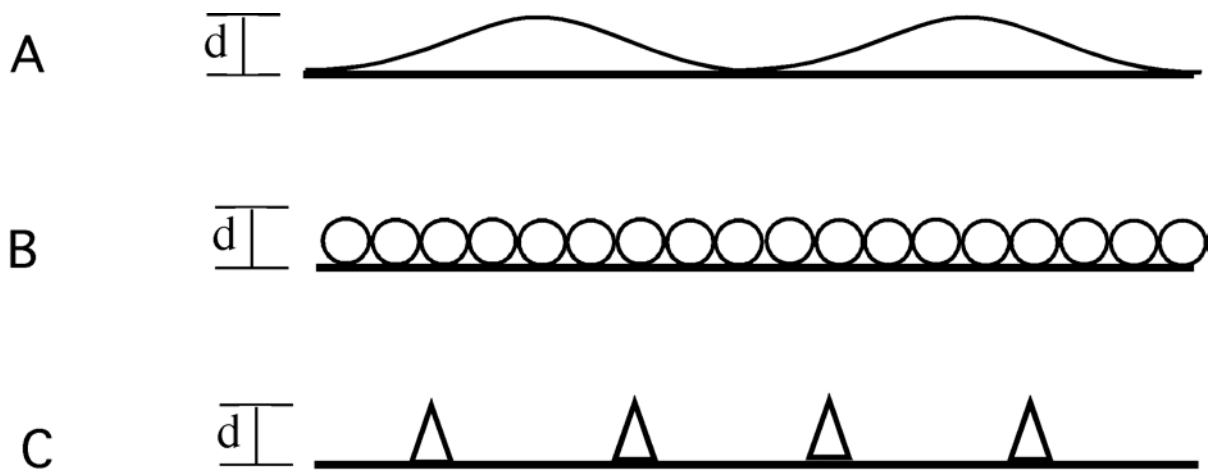
The velocity profile shown below was measured above a sandy bed for which the mean sand grain diameter was $d = 1\text{ mm}$. Use the plot to answer the following questions.

- Use the logarithmic section of the profile to find the friction velocity, u_*
- Using the answer to a), what is the bed stress, τ_w ?
- What is the thickness of the laminar sub-layer?
- Using a velocity measured within the laminar sub-layer estimate the bed stress.
- Is this flow rough or smooth turbulent?
- Imagine that you introduce two sources of dye at elevations, $y = 3\text{ mm}$, and $y = 3\text{ cm}$. Sketch the dye streak-line and describe the differences in flow at these two points.



Problem 7.3. Nikuradse used uniform sand grains of diameter ϵ to characterize the impact of surface texture on velocity profiles. Based on his experiments the length scale ϵ , now called the equivalent sand grain diameter, has become a standard for describing roughness of any shape. The ‘equivalency’ is interpreted as providing the same drag. The equivalent roughness is estimated by measuring the velocity profile and fitting it to a logarithmic profile to determine y_0 . If the flow is Rough Turbulent, then $y_0 = \epsilon/30$. This tells us that the roughness provides the same drag to the flow as uniform sand grains of diameter $30 y_0$.

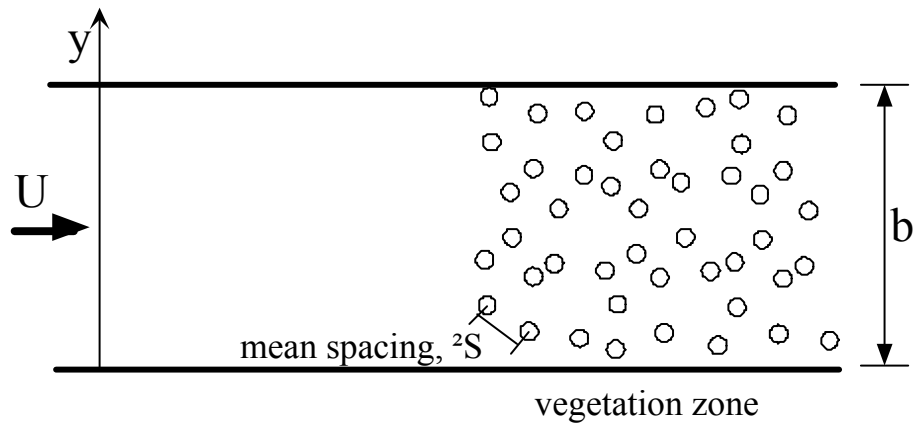
Consider the roughness elements depicted below. Although the shapes have the same physical scale, d , they will not necessarily offer the same roughness to the flow, that is they will not necessarily produce the same y_0 . Consider two cases, $d \ll \delta_s$, and $d \gg \delta_s$, and order the three cases from highest to lowest y_0 .



Problem 7.4

Below is a top view of a channel of width b . The cross section of the channel is constant, so that the velocity, U , is also constant along the channel. Part of the channel is filled with vegetation whose morphology is uniform over depth, and emerges through the water surface. The mean stem diameter is d , and the mean spacing between stems is ΔS . Consider the model, $D_{t,y} \sim v' l_y$, to describe the lateral diffusivity.

- a) How will the lateral turbulent diffusivity change as the flow enters the vegetation?
- b) Compare the diffusivity in the vegetated zone for $Ud/v = 1$ versus $Ud/v = 1000$?
- c) Suppose the flow is unconfined, *i.e.* no side-walls, but the lateral extent of the vegetated zone is unchanged, how will the turbulence scales, turbulence intensity, and diffusivity differ in the vegetated and unvegetated zones?



Problem 7.5

The velocity profile shown below was measured in a stream above a gravel bed for which the mean gravel size was 1 cm.

- Find the friction velocity, u_* .
- What is the thickness of the laminar sub-layer?
- Does the gravel's roughness contribute to the resistance at the bed?
- What diameter of spherical sand grain would produce the same flow resistance?

