Fluid Mechanics: Assignment 1

Due date: September 3, 2018

1. Knudsen number is defined as -

$$Kn = \frac{\lambda}{L}$$

where, λ, L are molecular mean free path and characteristic physical length scale of the system (say, cross-sectional radius of a spacecraft) respectively.

Plot Knudsen Number (Kn) as a function of altitude in the atmosphere. Consider any reasonable assumption for gas laws in atmosphere, and state them if used.

2. For the advection-diffusion equation, we derived in class-

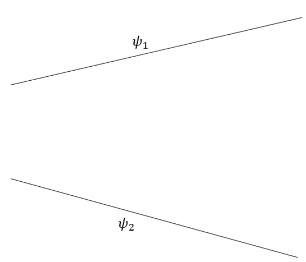
$$\phi = \kappa e^{-\frac{\eta^2}{4D}}$$

where $\phi = \partial_x C$, η is the similarity variable, C(x,t) is the concentration.

Using the above relation, and similarity variable, plot concentration, C(x, t) for various t.

3. a) Derive the form for stream function, ψ in cylindrical polar coordinates. (*Hint: Get the continuity equation in cylindrical polar coordinates, then find a function that will always satisfy this relation*)
Sketch the streamlines for incompressible flow past a moving cone. Comment why it's reasonable using qualitative features. Assume slip-condition at the fluid-cone interface.

b) For a part of 2D flow with the given set of streamlines with stream functions, ψ_1, ψ_2, find the velocity field.



4. We expressed motion of a fluid parcel by writing velocity field as a superposition of pure translation, pure strain, and pure rotation in class. Now, the velocity field as a combination of pure translation, **shear strain**, and pure rotation.

(*Some definitions:*
Pure strain is when a fluid parcel undergoes deformation in the principal directions, i.e. dilates/contracts;
Pure rotation is change in parcel's orientation with respect to a fixed coordinate without shape change;
Shear strain involves distortion in shape - angular deformation)