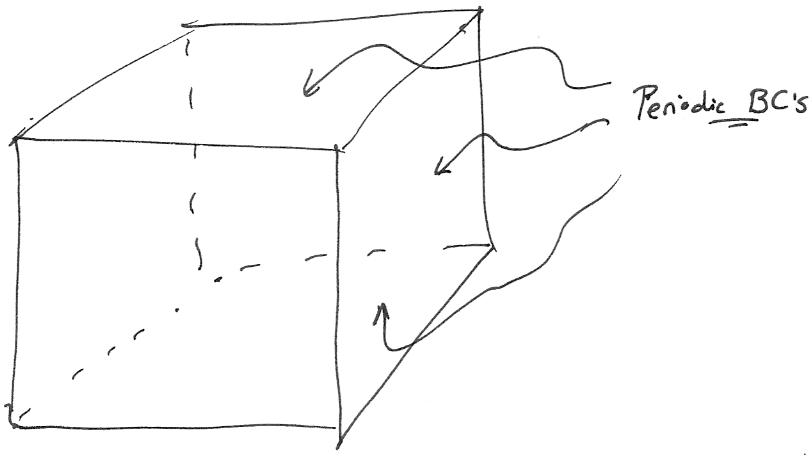
Statistics of Common Turbulent Flows:

At this point, let us take a small detour and examine some statistics for common turbulent flows.

Forced Isotropic Turbulence:

The first example we consider is forced isotropic turbulence. In this case, the flow field is on an idealized, cubic domain with periodic BCs on each side:



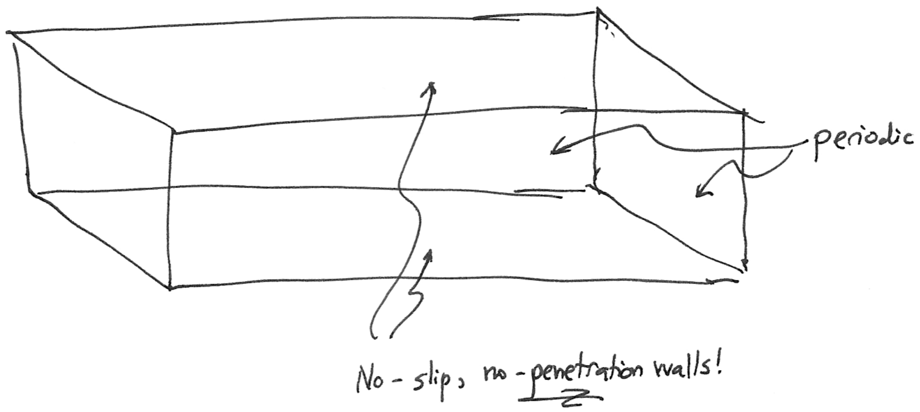
A constant power input in the lowest velocity modes is supplied for all time, resulting in a turbulent flow field which is homogeneous, isotropic, and stationary. Various snapshots and movies of one realization (obtained via numerical simulation) are available on the D2L website in the PDF file, FIT.pdf. Also displayed are plots of the energy spectrum for the cases $Re_\lambda = 164$, where Re_λ is the Taylor Reynolds number, and $Re_\lambda = 500$. Note that in the initial part of the spectrum, corresponding to the energy-containing range, is nearly flat, while the next part of the spectrum, corresponding to the inertial subrange, scales like:

$$E(\kappa) \sim \kappa^{-5/3}$$

This is the famous Kolmogorov $-5/3$ spectrum, which we will discuss later in the class. The last part of the spectrum corresponds to the dissipation range where viscous effects dominate.

Turbulent Channel Flow:

The second example we consider is fully developed turbulent channel flow:



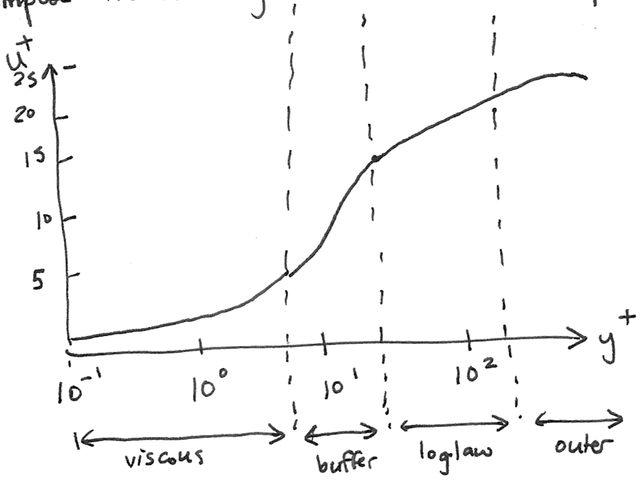
Of engineering interest is the structure of the boundary layer for high Re flow. The mean velocity profile exhibits different character in several regions of the layer:

Inner layer:

1. The viscous sublayer: The Reynolds shear stress is negligible and viscous effects dominate.
2. The buffer layer: Turbulent and viscous effects are comparable.
3. The log-law layer: Turbulent effects dominate.

4. The outer layer: Direct effects of viscosity on the mean flow profile are negligible.

The first three regions compose the inner layer while the fourth composes the outer layer.



$$u^+ \equiv \frac{\langle u \rangle}{u_\tau}$$

(u_τ: Friction velocity)

$$y^+ \equiv \frac{y}{\delta_v}$$

(δ_v: Viscous lengthscale)

Various snapshots and movies of one realization of turbulent channel flow are available on the D2L website in the PDF file, TCF.pdf, as are plots of the turbulent boundary layer.