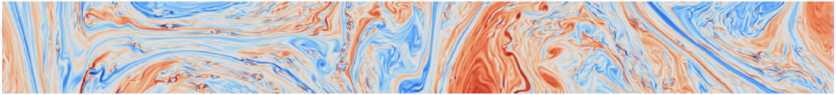
Turbulence
Zeroth Law of Turbulence



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Energy balance relation

$$\frac{1}{2}\frac{d}{dt}\left\langle |\mathbf{u}|^2 \right\rangle = -\nu\langle \nabla_j u_i \nabla_j u_i \rangle + \langle \mathbf{u}\cdot\mathbf{f}\rangle$$

$$\boxed{\frac{d}{dt}\mathcal{E} = -\epsilon + \mathcal{I}}$$

Reynolds number and Nondimensional dissipation rate

$$\boxed{Re = \frac{UL}{\nu}} \qquad \boxed{\mathcal{C}_{\mathcal{D}}(Re) = \frac{\epsilon L}{U^3}}$$

Laminar Estimate

$$\epsilon \propto \frac{\nu U^2}{L^2} \qquad \mathcal{C}_{\mathcal{D}}(Re \to 0) = \frac{1}{Re}$$

Flow behind an object

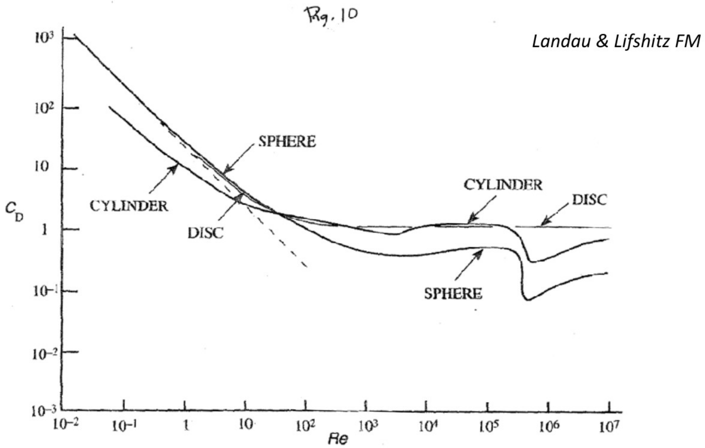

Figure 7.13 Log–log plot of drag coefficient C_D as a function of Reynolds Number *Re* for spheres, transverse cylinders, and face-on discs. The broken straight line represents Stokes's law.

Flow behind a grid

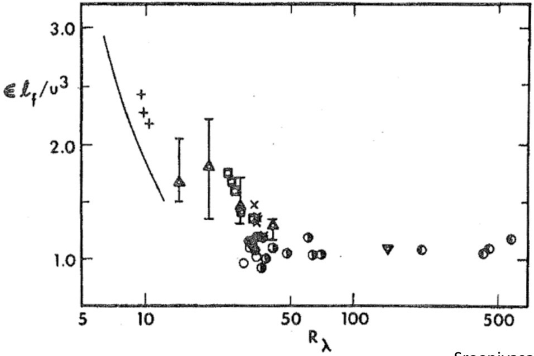

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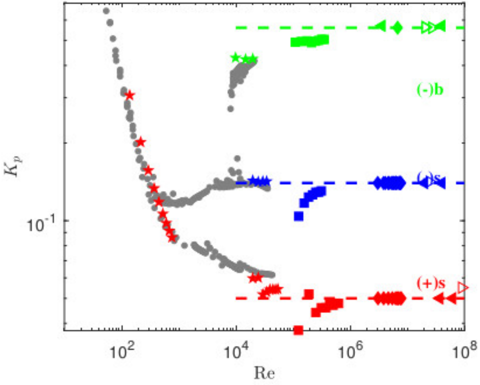
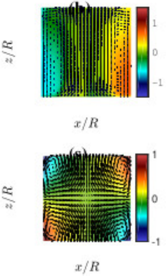
FIG. 1. The quantity $\epsilon L_f / u^3$ for biplane square-mesh grids. All data except $+$ are for the initial period of delay, and are explained in Table I. $+$ indicate typical data[13] in the final period of decay. — corresponds to Eq. (1).

Flow generated by propellers

VKS and SHREK experiment.





Flow in numerical simulations

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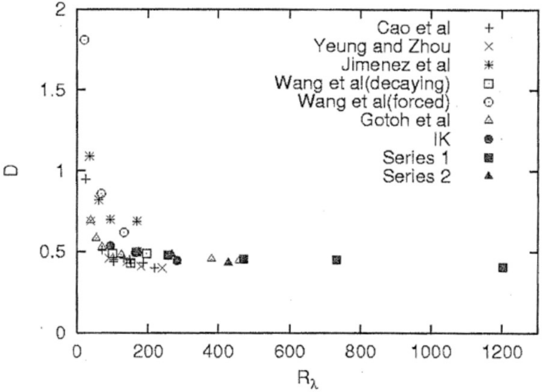

FIG. 3. Normalized energy dissipation rate D versus R from Ref. 5 data up to R 250), Ref. 3 , , and the present DNS databases , .

Zeroth law of turbulence

In the limit of infinite Re the normalized dissipation rate remains finite*

$$\boxed{\mathcal{C}_{\mathcal{D}}^{\infty} \equiv \mathcal{C}_{\mathcal{D}}(Re \to \infty) = \lim_{Re \to \infty} \frac{\epsilon L}{U^3} > 0}$$