

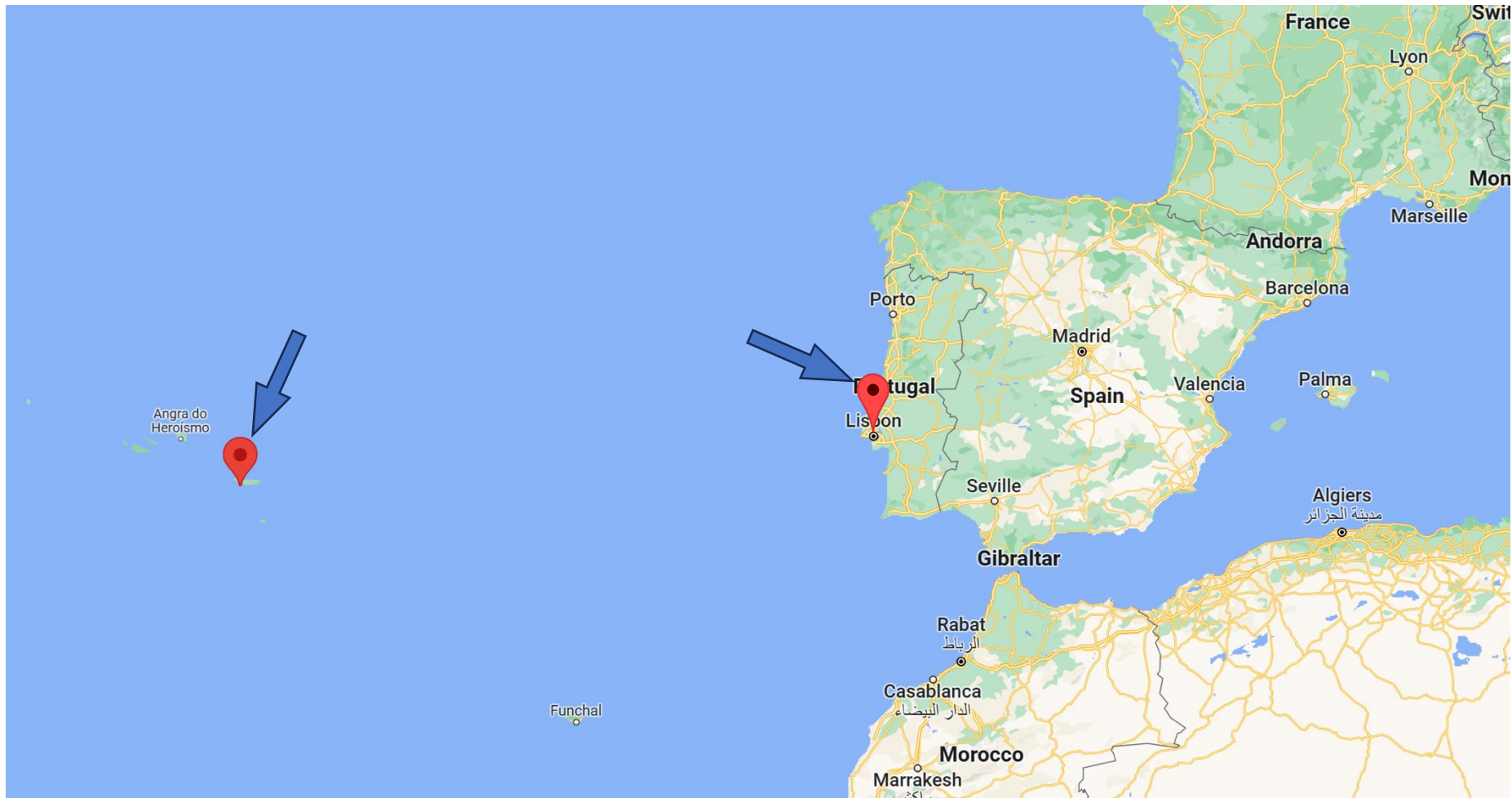
MASTER IN **RENEWABLE ENERGY IN THE MARINE**
ENVIRONMENT



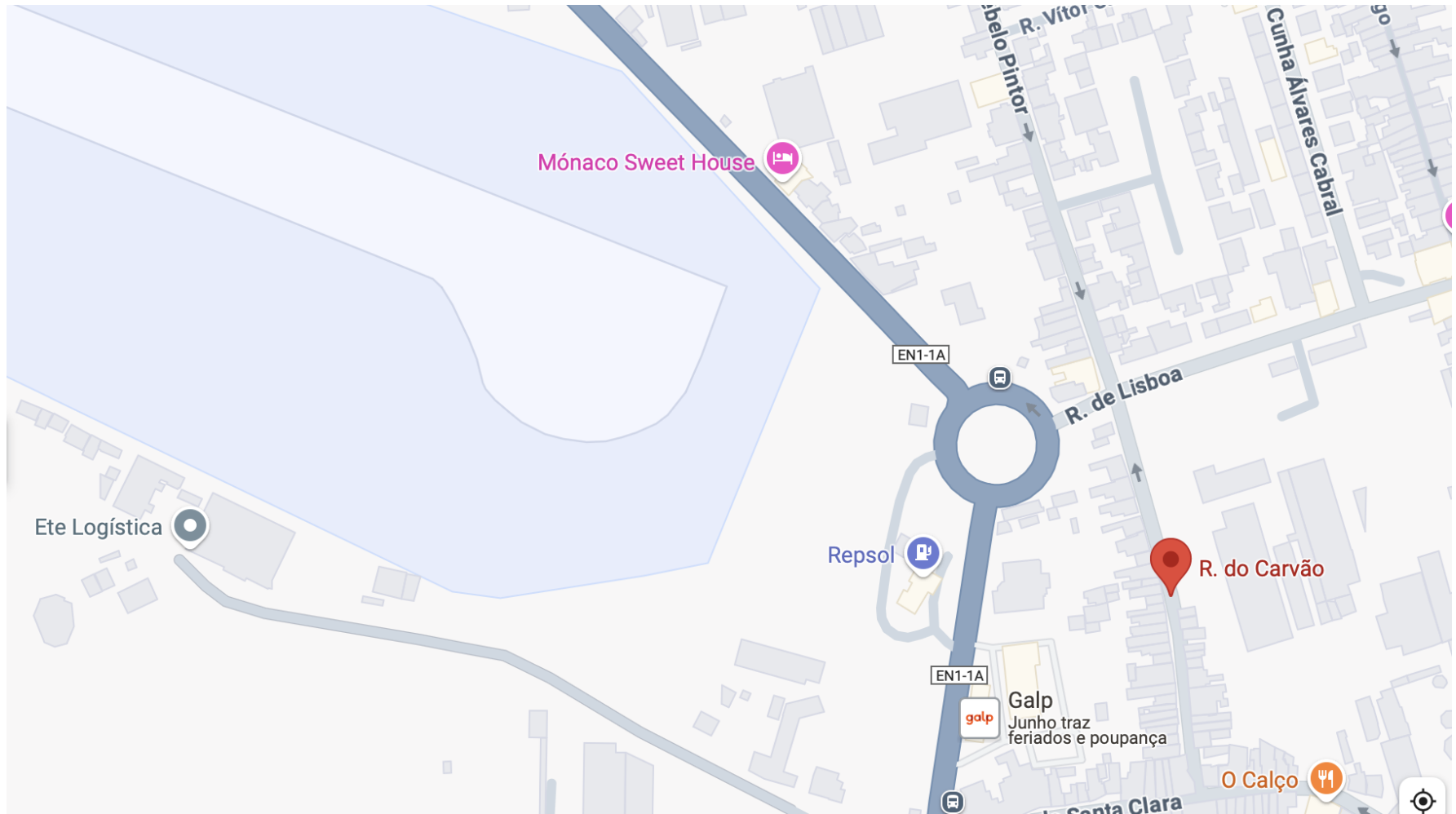
Balances of physical quantities:
applications to renewable energies

João C. C. Henriques
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Where and when it all began...



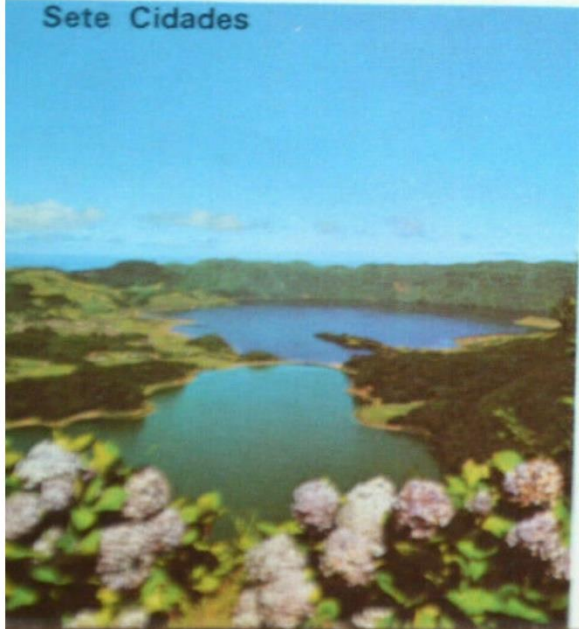
Where and when it all began...



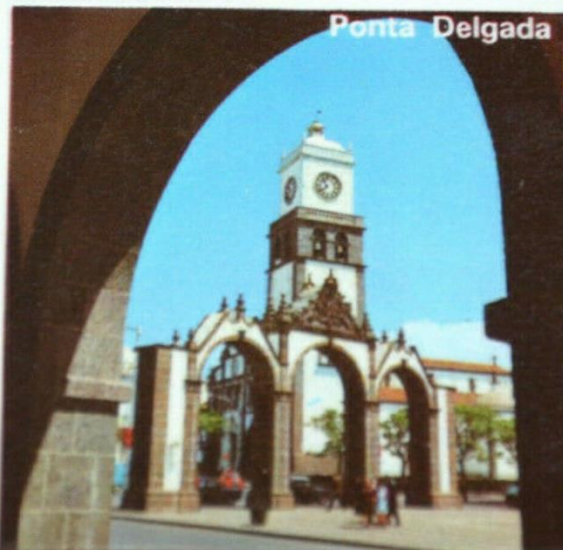
Where and when it all began...



Sete Cidades



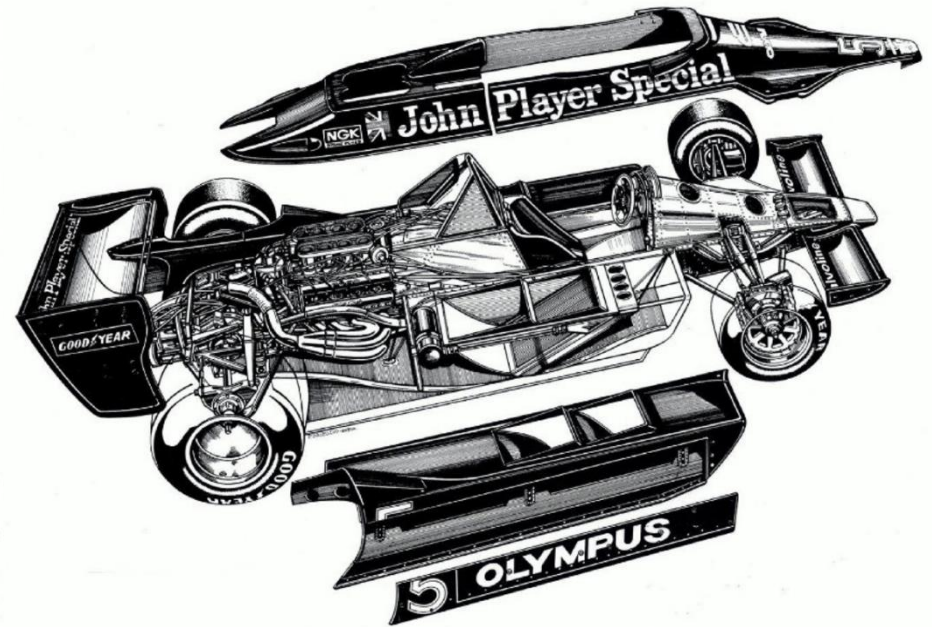
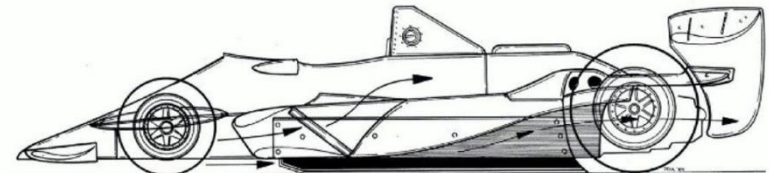
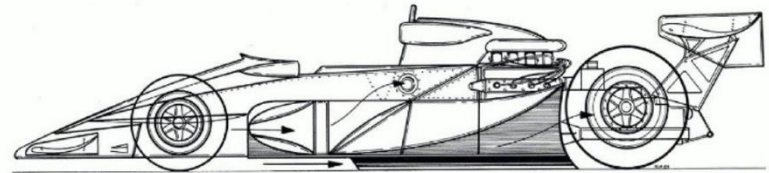
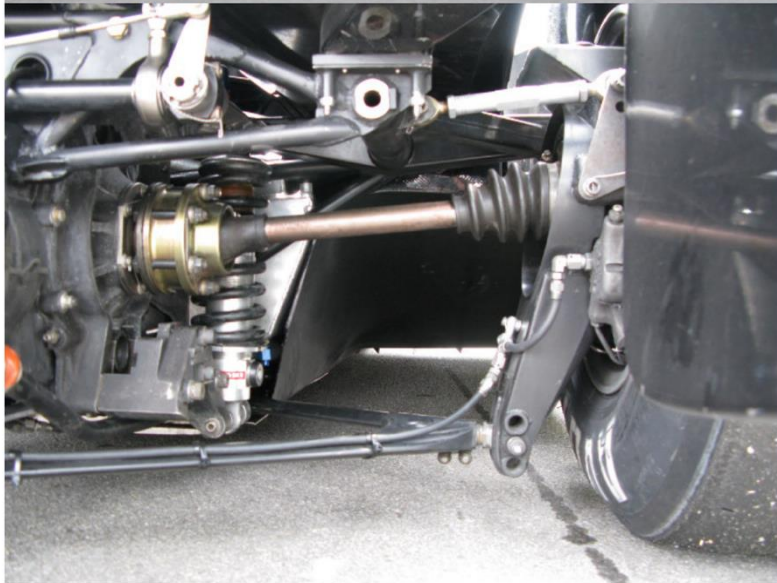
S. MIGUEL — Açores



Furnas



Where and when it all began...



The basics...



Navier-Stokes Equations 3 - dimensional - unsteady

Glenn
Research
Center

Coordinates: (x,y,z)	Time: t	Pressure: p	Heat Flux: q
Velocity Components: (u,v,w)	Density: ρ	Stress: τ	Reynolds Number: Re
	Total Energy: Et		Prandtl Number: Pr

Continuity:
$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

X - Momentum:
$$\frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial z} = -\frac{\partial p}{\partial x} + \frac{1}{Re_r} \left[\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} \right]$$

Y - Momentum:
$$\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho uv)}{\partial x} + \frac{\partial(\rho v^2)}{\partial y} + \frac{\partial(\rho vw)}{\partial z} = -\frac{\partial p}{\partial y} + \frac{1}{Re_r} \left[\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} \right]$$

Z - Momentum
$$\frac{\partial(\rho w)}{\partial t} + \frac{\partial(\rho uw)}{\partial x} + \frac{\partial(\rho vw)}{\partial y} + \frac{\partial(\rho w^2)}{\partial z} = -\frac{\partial p}{\partial z} + \frac{1}{Re_r} \left[\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} \right]$$

Energy:

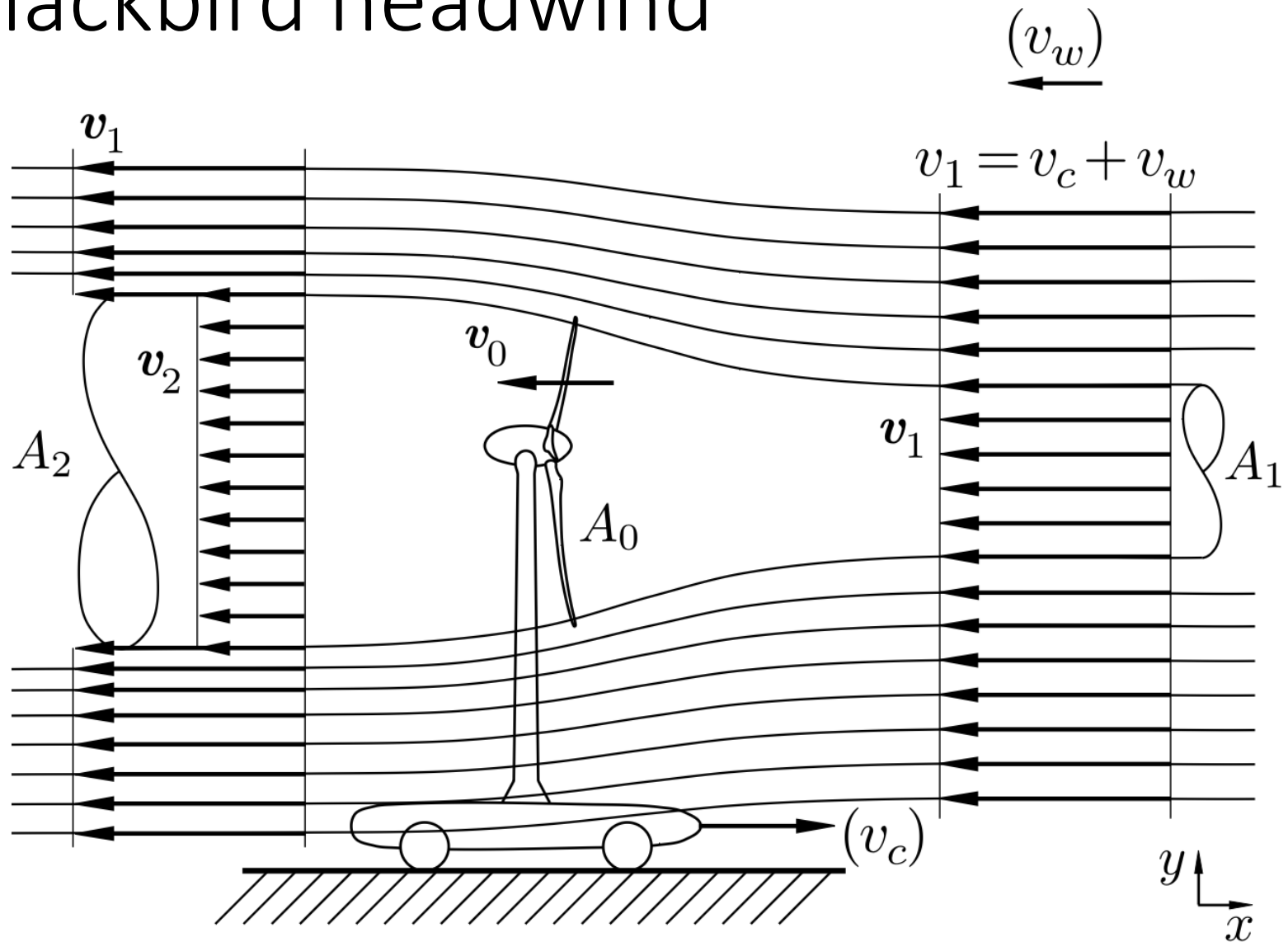
$$\begin{aligned} \frac{\partial(E_T)}{\partial t} + \frac{\partial(uE_T)}{\partial x} + \frac{\partial(vE_T)}{\partial y} + \frac{\partial(wE_T)}{\partial z} = & -\frac{\partial(up)}{\partial x} - \frac{\partial(vp)}{\partial y} - \frac{\partial(wp)}{\partial z} - \frac{1}{Re_r Pr_r} \left[\frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} + \frac{\partial q_z}{\partial z} \right] \\ & + \frac{1}{Re_r} \left[\frac{\partial}{\partial x}(u \tau_{xx} + v \tau_{xy} + w \tau_{xz}) + \frac{\partial}{\partial y}(u \tau_{xy} + v \tau_{yy} + w \tau_{yz}) + \frac{\partial}{\partial z}(u \tau_{xz} + v \tau_{yz} + w \tau_{zz}) \right] \end{aligned}$$

Blackbird

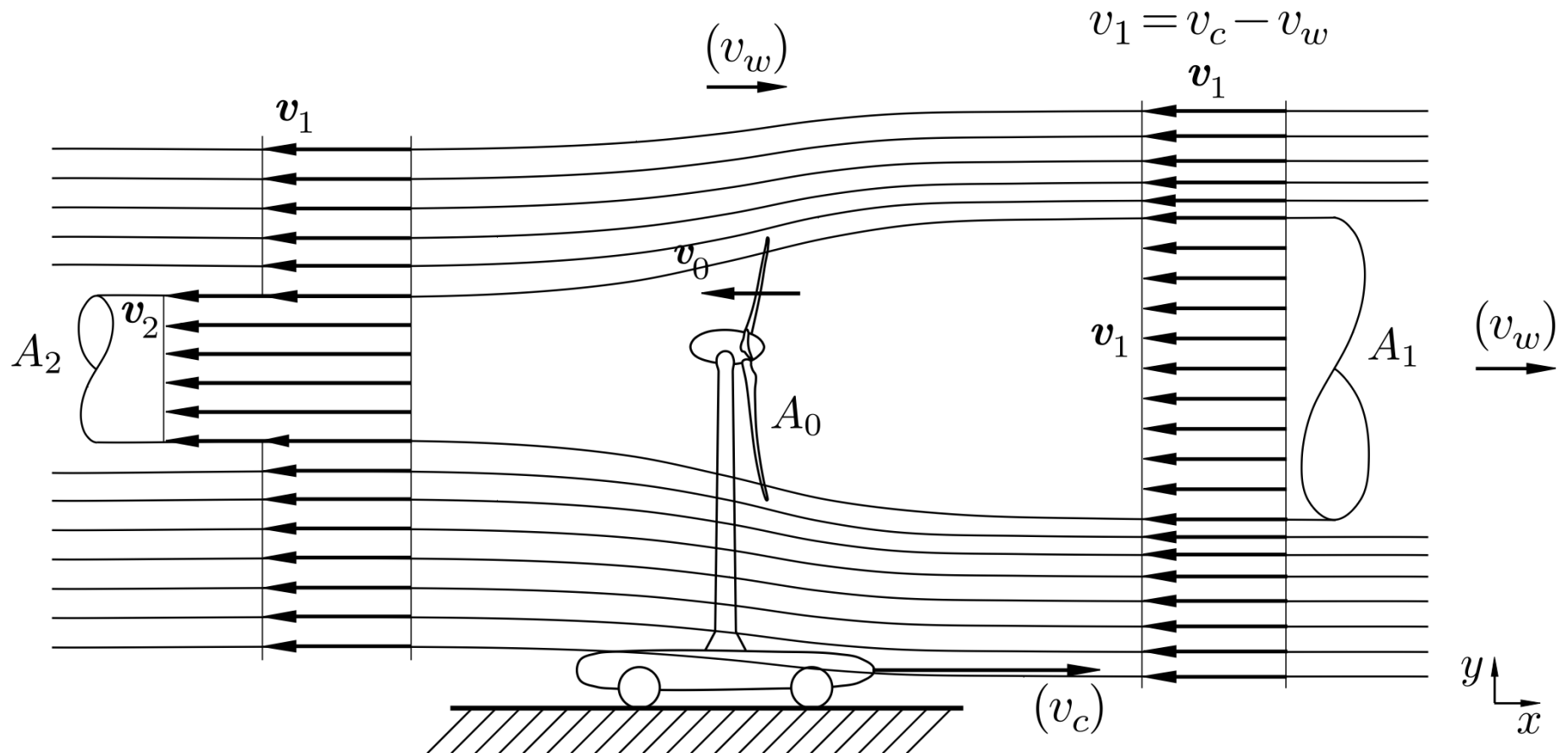


https://www.youtube.com/watch?v=yCsgoLc_fzI

Blackbird headwind



Blackbird tailwind



Blackbird tailwind

