

- **Fluid dynamic framework:**
 - **Mass and momentum conservation equations**
 - **Boundary layer flow (the case of flat plate)**
 - **Vortex flow: Velocity and pressure fields (Free vortex, Rankine model)**
 - **Similarity:**
 - **π - Buckingham theorem**
 - **Dimensionless numbers**
(Reduced velocity, Reynolds, Strouhal, Froude, Stokes, ...)
 - **Wake instability : alternate vortices, dimensionless numbers**
 - **Free surface flows : the case of rotating cylindrical container**
 - **Aerodynamics:**
 - **Aerodynamic force decomposition: Drag and lift forces**
 - **Thin airfoil theory – basic knowledge**
 - **Stall and boundary layer dynamics**

- ***General formulation of fluid-structure interaction:***
 - ***The fluid-structure coupling:***
 - ***Understand conservation of mass and momentum in the fluid***
 - ***Modal equation of the solid***
 - ***Interface: Understand continuity of the velocity (kinematic condition) and forces (dynamic conditions)***
 - ***Dimensionless form:***
 - ***Understand the difference of time scales in the solid and the fluid***
 - ***Describe the role of reduced velocity***

- **Fluid-structure interaction in the case of small reduced velocity:**
 - **Describe the concept of added mass**
 - **Analytical solutions of added mass for simple geometries :**
 - **Cylinder, sphere**
- **Quasi-static aeroelasticity :**
 - **Hypothesis : Large reduced velocity ($U_R \gg D \gg 1$)**
 - **Static instability: Divergence**
 - **Understand the risk of negative flow-induced stiffness**
→ Unbounded increase of oscillation amplitude
 - **Particular case of a flow over an airfoil**
 - **Develop conservation equations → Torsional divergence**
 - **Divergence speed, Control reversal**

- ***Quasi-static aeroelasticity :***
 - ***Hypothesis : Large reduced velocity ($U_R \gg D \gg 1$)***
 - ***Dynamic instability: Flutter (2 modes approximation):***
 - ***Particular case of a 2D flow over an airfoil (Torsional & plunge modes)***
 - ***Express the aerodynamic forces and moments on the foil***
 - ***Express potential and kinetic energies***
 - ***Write the equations of the solid motion using the Lagrangian***
 - ***Solve the eigen value problem $\rightarrow$ flutter speed***

- ***Pseudo-static aeroelasticity :***
 - ***Hypothesis and framework (single mode approximation)***
 - ***Case of a 2D flow over an airfoil with plunge mode***
 - ***Develop conservation equations and show that beyond the stall angle, the flow induces a negative damping: Stall flutter***
- ***Case of an arbitrary bluff body: Lift galloping***
- ***Drag crisis in the case of a flow over a cylinder***
 - ***Show how drag may induce a negative damping***

- ***Vortex Induced Vibration:***
 - ***Describe the alternate shedding of vortices in the wake of a cylinder***
 - ***Define and discuss the role of Reynolds and Strouhal numbers***
 - ***Describe the role of the boundary layer and trailing edge shape in the case of a flow over an airfoil***
- ***Explain the lock-in phenomenon and its importance in engineering applications***

- ***Flow Control to mitigate vortex induced vibration:***
 - ***Boundary layer control:***
 - ***Vortex generators***
 - ***Distributed roughness***
 - ***Synthetic jets***
 - ***Wake control***
 - ***Shape of the trailing edge***
- ***Sloshing:***
 - ***Describe the flow motion in linear and orbital sloshing***
 - ***Understand the proper modes of sloshing and how to estimate their frequency for simple cases***
 - ***Explain why sloshing is useful in various bioengineering applications***