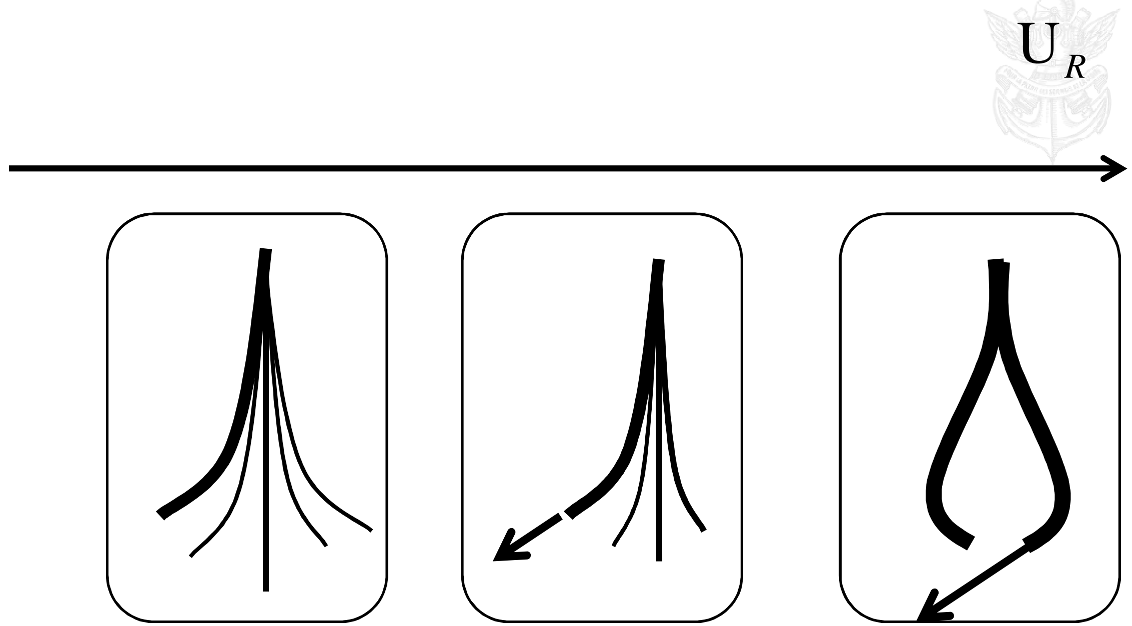
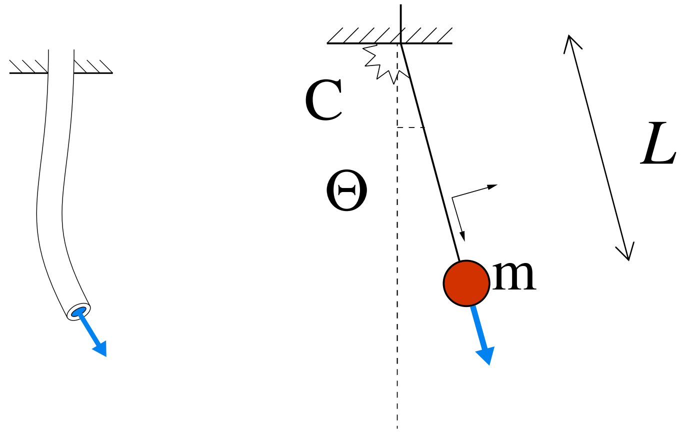
MODELS FOR FLUID SOLID INTERACTIONS



THE FLUID-CONVEYING PENDULUM



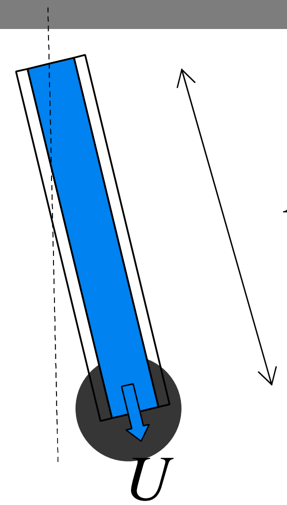
$$mL^2\ddot{\Theta} + C\Theta = 0$$

$$\bar{t} = \frac{t}{L\sqrt{m/C}}$$

$$\boxed{\ddot{\theta} + \theta = 0}$$

$$\theta(\mathrm{t}) = \frac{\Theta(t)}{\Theta_0}$$

THE FLUID-CONVEYING PENDULUM

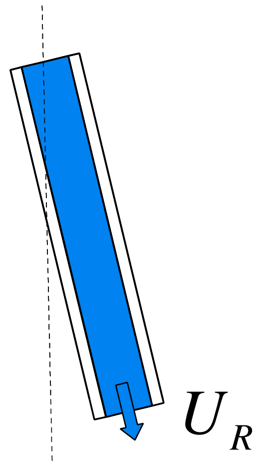


$$M = \frac{\rho S L}{m}$$

$$U_R = \frac{T_{solid}}{T_{fluid}} = \frac{L}{\sqrt{C/m}} \frac{1}{L/U}$$

$$U_R = \frac{U}{\sqrt{C/m}}$$

THE FLUID-CONVEYING PENDULUM AT **VERY SMALL** REDUCED VELOCITY



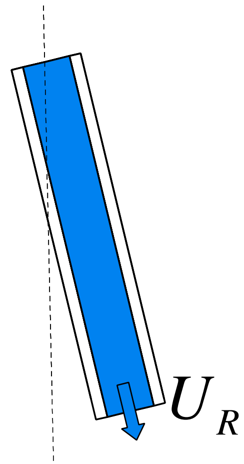
Very small reduced velocity

Added moment of inertia

$$\frac{\rho S L^3}{3}$$

$$\boxed{\left(1+\frac{M}{3}\right)\ddot{\theta}+\theta=0}$$

THE FLUID-CONVEYING PENDULUM
AT **VERY LARGE** REDUCED VELOCITY



Very large reduced velocity

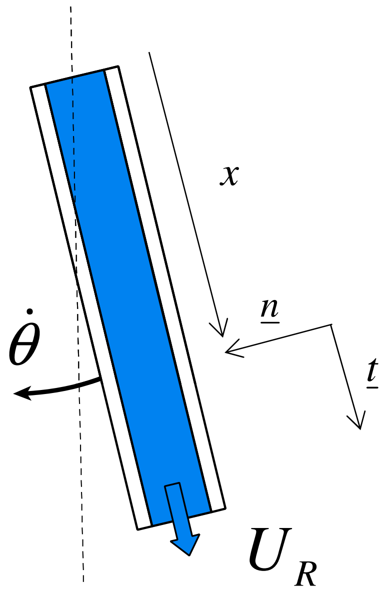
θ Frozen in time

⬇

No fluid torque on the pipe.

$$\boxed{\ddot{\theta} + \theta = 0}$$

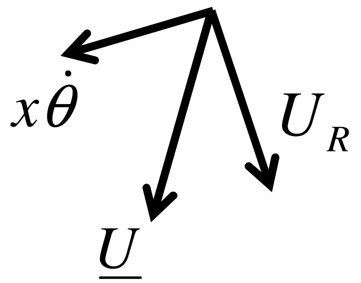
THE FLUID-CONVEYING PENDULUM
AT **INTERMEDIATE** REDUCED VELOCITIES



Intermediate reduced velocity

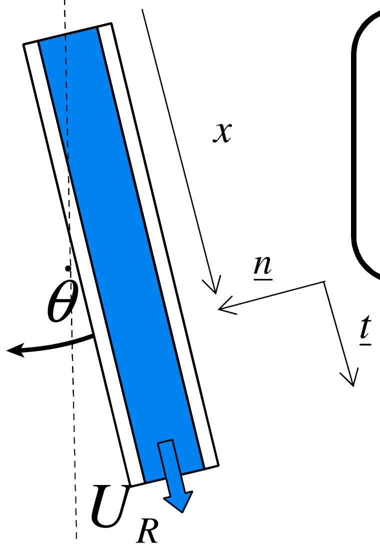
$\dot{\theta}$ Frozen in time

Mass balance



$$\underline{U} = U_R \underline{t} + x\dot{\theta}\underline{n}$$

THE FLUID-CONVEYING PENDULUM
AT **INTERMEDIATE** REDUCED VELOCITIES



Angular momentum of the fluid

$$\underline{r} = \underline{x} \wedge M\,\underline{U}$$

$$\underline{U} = U_R \underline{t} + x\dot{\theta}\underline{n}$$

$$r = x^2 M\dot{\theta}$$

Angular momentum theorem

$$T_{Solid-Fluid} = \frac{\partial}{\partial t} \int_{\text{Fluid domain}} x^2 M\dot{\theta}\, dV + \int_{\text{Fluid boundaries}} \left(x^2 M\dot{\theta}\right)\left(\underline{U}.\underline{\mathrm{n}}\right) dS$$

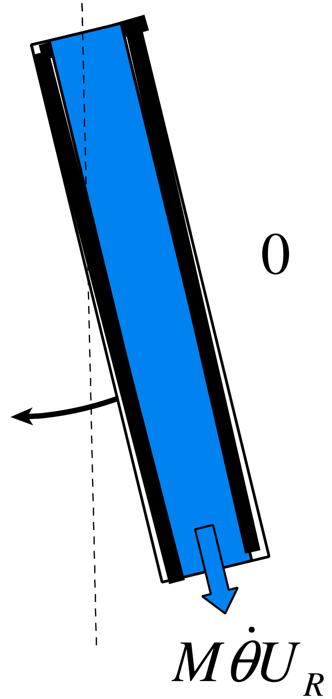
THE FLUID-CONVEYING PENDULUM AT INTERMEDIATE REDUCED VELOCITIES

$$T_{Solid-Fluid} = \frac{\partial}{\partial t}\int_{\text{Fluid domain}} x^2 M\dot{\theta}\, dV + \int_{\text{Fluid boundaries}} \left(x^2 M\dot{\theta}\right)\left(\underline{U}.\underline{\mathrm{n}}\right) dS$$

$\dot{\theta}$ Frozen in time

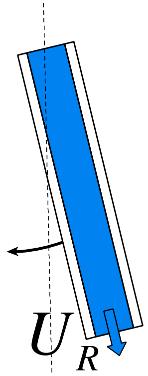
0

0



$$\boxed{T_{Solid-Fluid} = M\dot{\theta}U_R}$$

CORIOLIS DAMPING

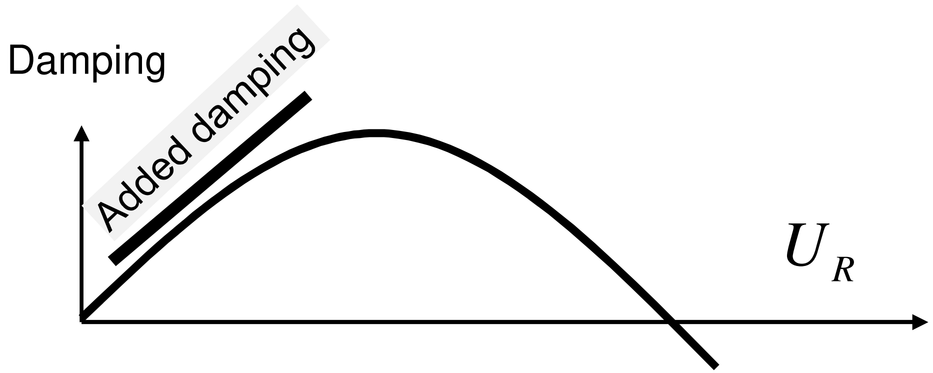


$$T_{Solid-Fluid} = M\dot{\theta}U_R$$

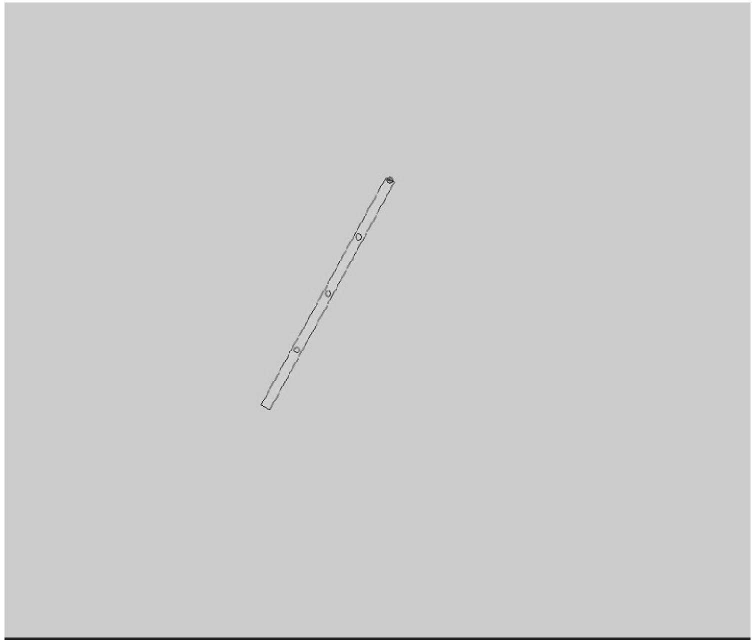
$$\ddot{\theta} + \theta = -MU_R\dot{\theta}$$

$$\boxed{\ddot{\theta} + MU_R\dot{\theta} + \theta = 0}$$

Flow-induced Coriolis damping



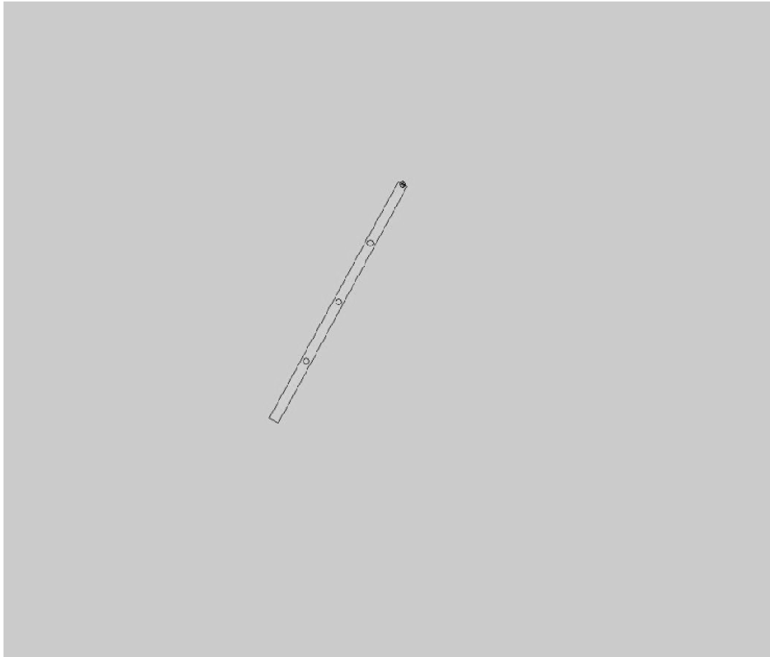
CORIOLIS DAMPING



$$U_R = 0.1$$

$$M = 1$$

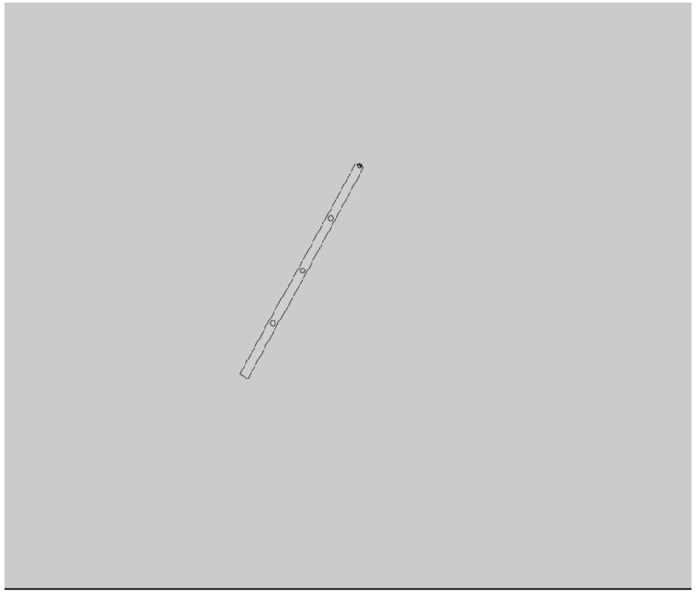
CORIOLIS DAMPING



$$U_R = 0.5$$

$$M = 1$$

CORIOLIS DAMPING



$$U_R = 0.8$$

$$M = 1$$

FLUID-CONVEYING PENDULUM

Added mass

Added damping

No effect