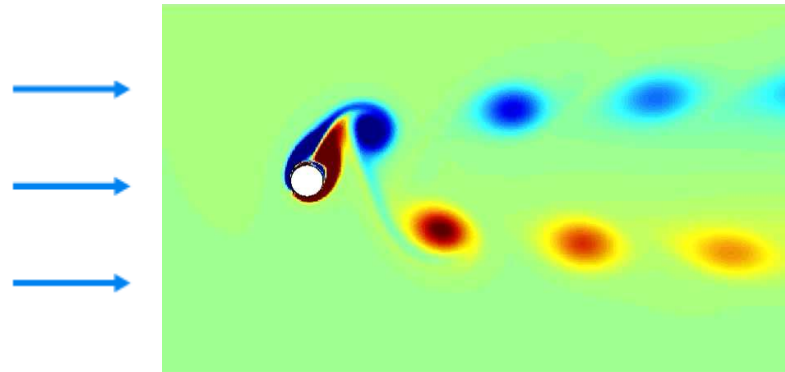
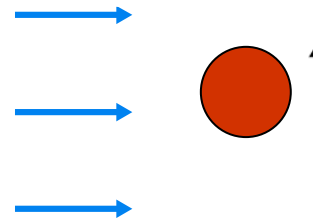
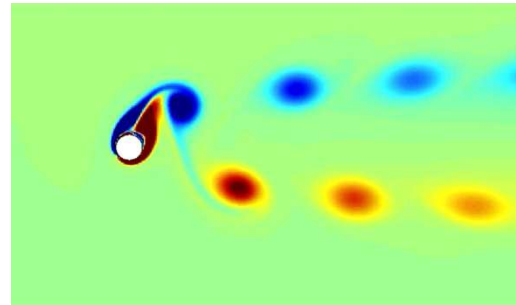


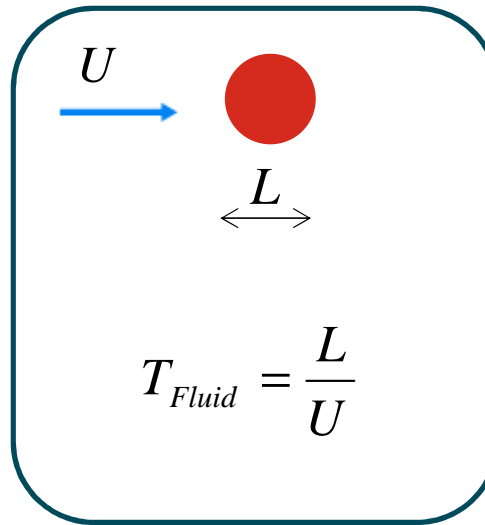
# VORTEX-INDUCED VIBRATION



# VORTEX-INDUCED VIBRATION



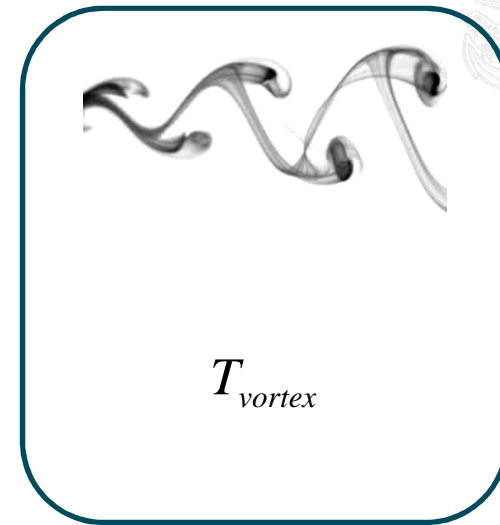
## TIME SCALES



$$T_{Fluid} = \frac{L}{U}$$



$$U_R = \frac{T_{Solid}}{T_{Fluid}}$$



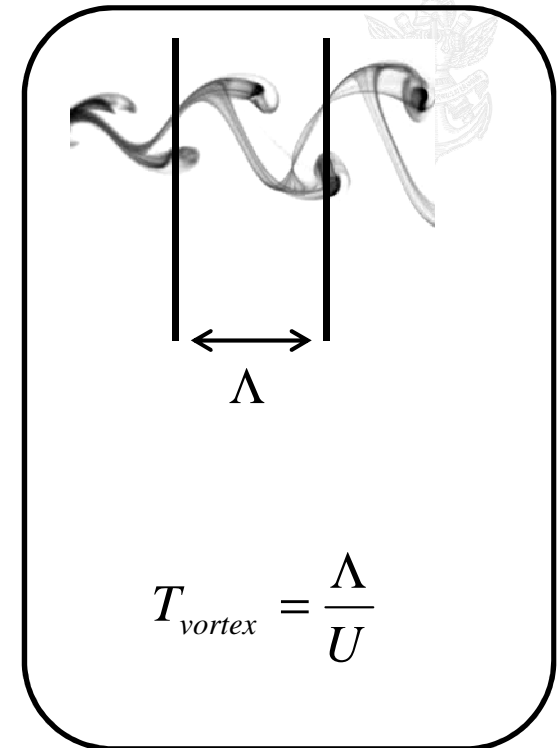
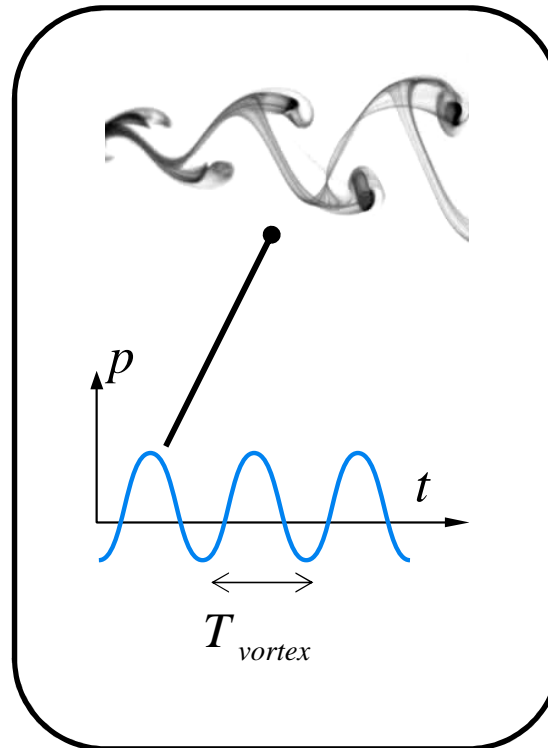
$$T_{vortex}$$



?



## TIME SCALE OF VORTEX SHEDDING



# STROUHAL LAW



Strouhal law

$$T_{vortex} = \frac{1}{S} T_{Fluid}$$



Strouhal number  $S$



$$S \approx 0.2$$



## STROUHAL LAW

$$\frac{T_{Solid}}{T_{Fluid}} = U_R$$

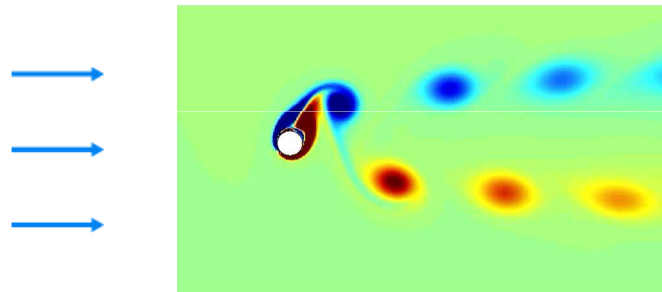
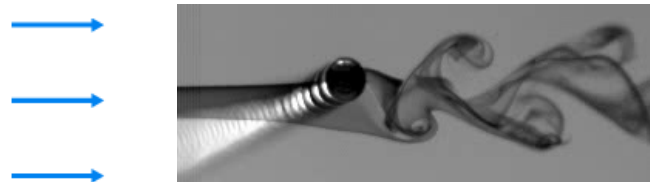


$$U_R = 1 \quad \Leftrightarrow \quad T_{Solid} = T_{Fluid}$$

$$\frac{T_{Solid}}{T_{Vortex}} = \frac{T_{Solid}}{\left(\frac{1}{S}\right)T_{Fluid}} = S \frac{T_{Solid}}{T_{Fluid}} = SU_R$$

$$SU_R = 1 \quad \Leftrightarrow \quad T_{Solid} = T_{Vortex}$$

# VORTEX-INDUCED VIBRATION



5-10

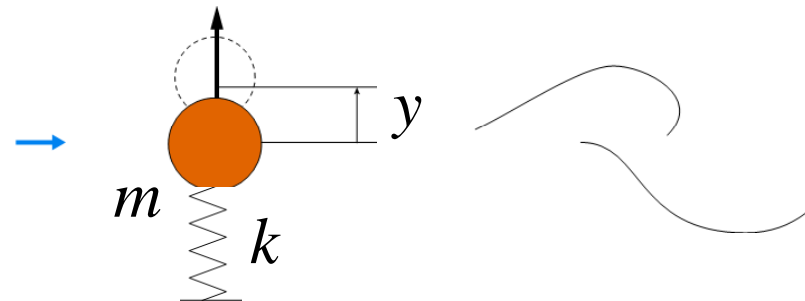
$U_R$

1-2

$SU_R$

## VORTEX-INDUCED VIBRATION AS A RESONANCE

$$F_{\text{vortex}}(t) = \frac{1}{2} \rho U^2 L C_l \sin\left(2\pi \frac{t}{T_{\text{vortex}}}\right)$$



$$m\ddot{y} + ky = \frac{1}{2} \rho U^2 L C_l \sin\left(2\pi \frac{t}{T_{\text{vortex}}}\right)$$

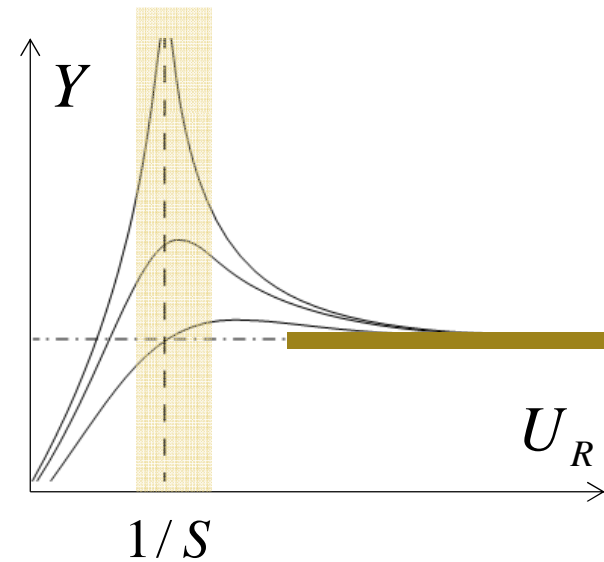


## VORTEX-INDUCED VIBRATION AS A RESONANCE

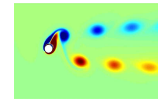
$$Y = \frac{MC_l}{2\pi^3} \frac{U_R^2}{(1 - S^2 U_R^2)}$$

$$Y = y / L$$

$$M = \frac{\rho \pi L^2}{4m}$$



# AVOIDING VORTEX-INDUCED VIBRATIONS



5-10



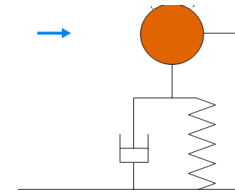
$U_R$



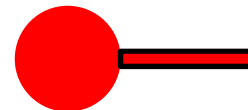
Avoiding resonance



Adding damping



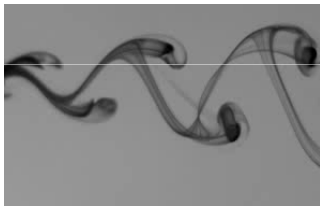
Suppressing the wake oscillations



# WAKE AND SOLID DYNAMICS



Wake dynamics



Solid dynamics

