Fluid Mechanics Homework #9

繳交期限：2019/11/27(三) 09:10

共五題，題號為：7-19,28,40,41,42

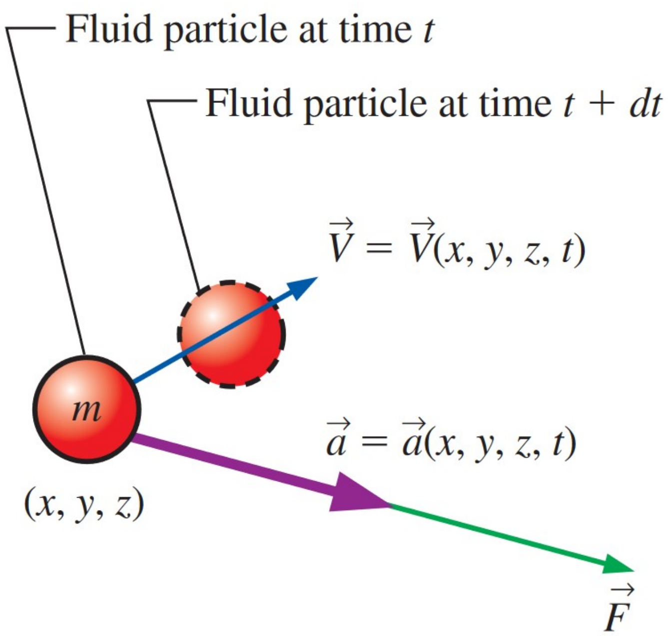
題號的對照書本是 Yunus A. Cengel and John M. Cimbala “Fluid Mechanics: Fundamentals and Applications 3/e (SI Units) “

$7-19$

In Chap. 4, we defined the *material acceleration*, which is the acceleration following a fluid particle,

$$\vec{a}(x, y, z, t) = \frac{\partial \vec{V}}{\partial t} + (\vec{V} \cdot \vec{\nabla})\vec{V}$$

(*a*) What are the primary dimensions of the gradient operator $\vec{\nabla}$? (*b*) Verify that each additive term in the equation has the same dimensions.



$7-28$

In an oscillating compressible flow field the volumetric strain rate is *not* zero, but varies with time following a fluid particle. In Cartesian coordinates we express this as

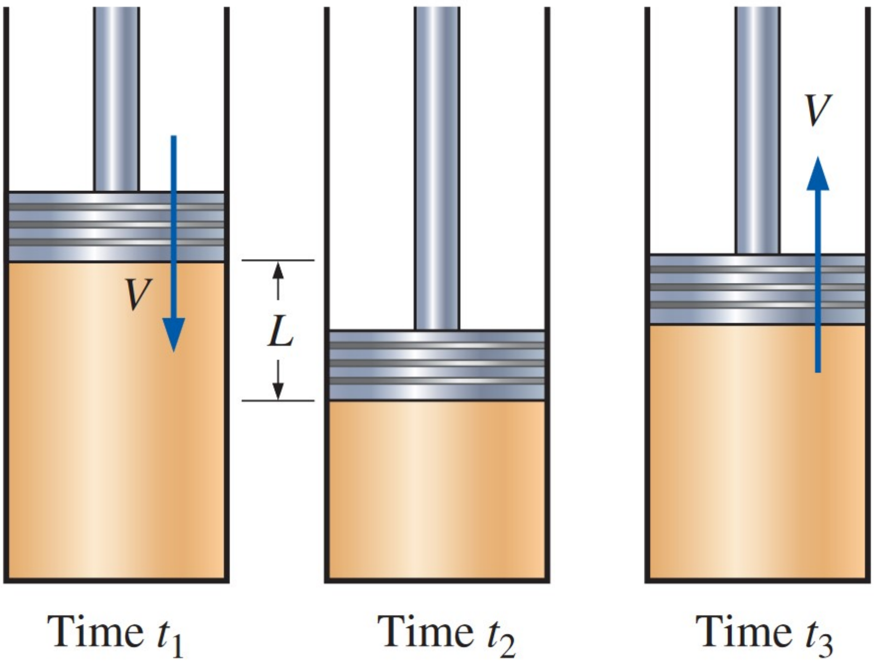
$$\frac{1}{\mathcal{V}}\frac{D\mathcal{V}}{Dt} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}$$

Suppose the characteristic speed and characteristic length for a given flow field are V and L, respectively. Also suppose that f is a characteristic frequency of the oscillation
Define the following dimensionless variables,

$$t^* = ft,\quad \mathcal{V}^* = \frac{\mathcal{V}}{L^3},\quad x^* = \frac{x}{L},\quad y^* = \frac{y}{L},$$

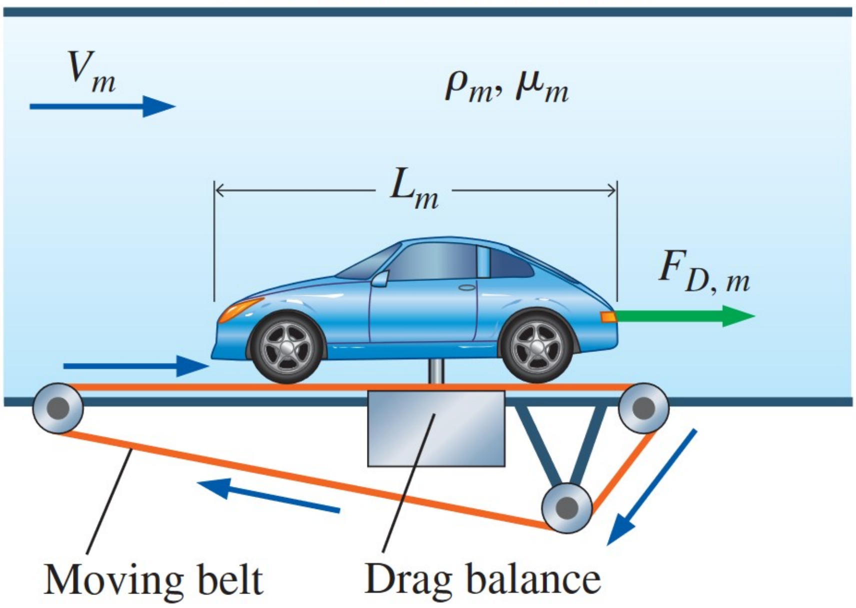
$$z^* = \frac{z}{L},\quad u^* = \frac{u}{V},\quad v^* = \frac{v}{V},\quad \text{and} \quad w^* = \frac{w}{V}$$

Nondimensionalize the equation and identify any established (named) dimensionless parameters that may appear.



f = frequency of oscillation

The aerodynamic drag of a new sports car is to be predicted at a speed of 95 km/h at an air temperature of 25°C. Automotive engineers build a one-third scale model of the car (Fig. P7–40) to test in a wind tunnel. The temperature of the wind tunnel air is also 25°C. The drag force is measured with a drag balance, and the moving belt is used to simulate the moving ground (from the car's frame of reference). Determine how fast the engineers should run the wind tunnel to achieve similarity between the model and the prototype.



Assumptions

1. Compressibility of the air is ignored
2. The wind tunnel walls are far enough away so as to not interfere with the aerodynamic drag on the model car.
3. The model is geometrically similar to the prototype.
4. Both the air in the wind tunnel and the air flowing over the prototype car are at standard atmospheric pressure.

Properties

For air at T = 25oC and atmospheric pressure, ρ = 1.184 kg/m3 and μ = 1.849 × 10-5 kg/m·s.

7 – 41

This is a follow-up to Prob. 7–40 The aerodynamic drag on the model in the wind tunnel (Fig. P7–40) is measured to be 150 N when the wind tunnel is operated at the speed that ensures similarity with the prototype car. Estimate the drag force (in N) on the prototype car at the conditions given in Prob. 7–40

Assumptions

1. The model is geometrically similar.
2. The wind tunnel is run at conditions which ensure similarity between model and prototype.

Properties

For air at T = 25oC and atmospheric pressure, ρ = 1.184 kg/m3 and μ = 1.849 × 10-5 kg/m·s.

$7-42$

Consider the common situation in which a researcher is trying to match the Reynolds number of a large prototype vehicle with that of a small-scale model in a wind tunnel. Is it better for the air in the wind tunnel to be cold or hot? Why? Support your argument by comparing wind tunnel air at 10°C and at 40°C, all else being equal.

Properties

For air at atmospheric pressure and at T = 10oC, ρ = 1.246 kg/m3 and μ = 1.778 × 10-5 kg/m·s. At T = 40oC, ρ = 1.127 kg/m3 and μ = 1.918 × 10-5 kg/m·s.