Engineering Science Fluid Mechanics Midterm Examination 2017-12-5

(10) 1. Matter is commonly classified into three phases: solid, liquid, and gas. What are the main difference between solid and fluid? How do you classify silly putty (slime), solid or fluid? Sometimes, a fourth phase, plasma, is included. What is plasma?

(10) 2. Describe Mach number, Reynolds number, and Knudsen number; and their applications.

(10) 3. The continuity equation describes the conservation of mass. Mathematically, it can be written as: $\frac{\partial \rho}{\partial t} + \nabla \cdot \rho\vec{V} = 0$ or $\frac{d}{dt}\iiint_{CV} \rho dV + \oiint_{CS} \rho\vec{V} \cdot d\vec{A} = 0$

(a) Explain the meaning of the terms in each formula.

(b) Derive both formulas from the first principle.

(c) Derive one from the other (make your own choice)

(10) 4. Derive the following Reynolds transport equation and explain what is B:

$$\left(\frac{dB}{dt}\right)_{system} = \frac{d}{dt}\iiint_{CV} \rho b dV + \oiint_{CS} b\rho\vec{V} \cdot d\vec{A}$$

(10) 5. In our approach to fluid mechanics, we adopt the "continuum" hypothesis. What is it? Also, what is the "no-slip" condition? How do you design an experiment to show the no-slip condition?

(10) 6. Sometimes, a ship could capsize when carrying more people than designed. Please explain it using stability theory; also, devise some engineering mechanism to prevent it from occurring.

(10) 7. Define a fluid particle for continuum application. Given the particle velocity as $\vec{V} = \vec{V}(x, y, z, t)$, show that its acceleration can be expressed as:

$$\vec{a} = \frac{d\vec{V}}{dt} = \frac{D\vec{V}}{Dt} = \frac{\partial\vec{V}}{\partial t} + (\vec{V} \cdot \nabla)\vec{V}$$

Also, explain the meaning of each term in the above equation.

(30) 8. So far, the following equations were met: $\nabla p = -\rho g\vec{j}$; $\rho\vec{a} = -\nabla p - \rho g\vec{j}$; $\rho\left(\frac{\partial\vec{V}}{\partial t} + (\vec{V} \cdot \nabla)\vec{V}\right) = -\nabla p - \rho g\vec{j}$. (a) Derive one of them of your choice; (b) Explain their relationships; (c) Use a case for each to show each application.

(10) 9. Explain hydrophilic and hydrophobic phenomena when water is in contact with a solid surface and possible applications.

(10) 10 Place a rectangular plate of length L and width W vertically in water with its top edge H from the water surface, determine the magnitude and location of the force acting on one side of the plate. Extend the result if the plate is 45 degrees from its original vertical position.

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