

HW #1 (Spring 2007) MAE 2314

#1

Pressure (p), Drag coefficient (C_D), Froude Number (Fr), Reynolds Number (Re) and the coefficient of viscosity (μ) are given by the following relations respectively:

$$p = \frac{F}{A}, C_D = \frac{D}{\frac{1}{2} \rho V^2 A}, Fr = \frac{V^2}{gL}, Re = \frac{\rho LV}{\mu}, \tau = \mu \frac{\partial V}{\partial y}$$

Where :

F : Force

D : Drag force

V : Velocity

L : Characteristic length

A : Characteristic Area

g : Acceleration due to gravity

τ : Shear stress

Find out whether these (p , C_D , Fr , Re and μ) are dimensionless or not (use dimensional analysis). Also find out their SI units wherever applicable.

#2

A mass m that is attached to a spring having spring constant k , when displaced from its equilibrium position and released in the absence of friction executes simple harmonic motion with time period of oscillation given as

$$T = 2\pi \sqrt{\frac{m}{k}}$$

Where k = restoring force per unit displacement. Find the dimensions of 2π .

#3

Volumetric strain rate is defined as the rate of increase of volume of fluid element per unit volume. In Cartesian coordinates we write the volumetric strain rate as

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

Where \forall is volume and u , v and w are velocity components. Write the primary dimensions of each term in the relation, and verify that the equation is dimensionally homogeneous.

#4

a.) Air is compressed isentropically such that its pressure is increased by 50%. The initial temperature is 70°C. What is the final temperature?

b.) Air is compressed in a piston cylinder arrangement to $1/10^{\text{th}}$ of its initial volume. If the initial temperature is 35°C and the process is frictionless and adiabatic, what is the final temperature?

#5

A piston-cylinder device initially contains 0.4 m^3 of air at 100 kPa and 80°C . The air is now compressed to 0.1 m^3 in such a way that the temperature inside the cylinder remains constant. Determine the work done during the process.

#6

In potential flow, velocity field can be expressed as gradient of a potential function, ϕ , called the velocity potential such that

$$\nabla\phi = \frac{\partial\phi}{\partial x}\hat{i} + \frac{\partial\phi}{\partial y}\hat{j} = u\hat{i} + v\hat{j} \quad \dots\dots\dots \text{(in 2D)}$$

Where u and v are the velocity components in x and y directions respectively. State in the {MLT} system the dimensions of the quantities (a) ϕ , (b) $\nabla\phi$, (c) $\frac{\partial\phi}{\partial x}$, (d)

$\frac{\partial^2\phi}{\partial y\partial x}$ and (e) $\int \frac{\partial\phi}{\partial x} dy$