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

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

Where:

- \( F \): Force
- \( D \): Drag force
- \( V \): Velocity
- \( L \): Characteristic length
- \( A \): Characteristic Area
- \( g \): Acceleration due to gravity
- \( \tau \): Shear stress

Find out whether these \( (p, C_D, Fr, Re \text{ and } \mu) \) 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 \( 2\pi \).

#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

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

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 $1/10^{th}$ of its initial volume. If the initial temperature is $35^\circ$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 $80^\circ$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, $\phi$, called the velocity potential such that
\[
\nabla \phi - \frac{\partial \phi}{\partial x} i + \frac{\partial \phi}{\partial y} j = u \hat{i} + v \hat{j} \quad \text{.......... (in 2D)}
\]
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) $\phi$, (b) $\nabla \phi$, (c) $\frac{\partial \phi}{\partial x}$, (d) $\frac{\partial^2 \phi}{\partial y \partial x}$ and (e) $\int \frac{\partial \phi}{\partial x} dy$