1. (15 points) (a) The two-dimensional steady flow in Fig. 1 has constant properties and is fully developed. (i.e., its velocity vector \( V = u \hat{i} + v \hat{j} \) does not vary with \( x \).) Which terms in the continuity and momentum equations (Equations A1 - A3) can be dropped (i.e., are equal to zero) for this fully developed flow? Explain.

(15 points) (b) Show that \( p \) (reduced pressure) is a function of \( x \) alone and varies linearly with \( x \) (i.e., \( p = a + bx \)) in Fig. 1.

![Velocity distribution](image)

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2. The velocity field of a two-dimensional steady flow is \( V = -2y \hat{i} + 2x \hat{j} \) (m/s).

(10 points) (a) Is the flow compressible or incompressible?

(10 points) (b) A square is marked in the fluid as shown at \( t = 0 \). After \( \tau \) seconds the marked area will look like (a), (b), (c) or (d)? Justify your answer.

![Square](image)

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3. A small round object is tested in a low-speed wind tunnel. The tunnel diameter is 1 m. Velocity measurements at two sections give the results shown in Fig. 3. Evaluate the drag force on the object. Neglect viscous resistance at the tunnel wall.
Equations for steady, two-dimensional flow of constant properties in Cartesian coordinates:

Continuity:
\[
\frac{\partial w}{\partial x} + \frac{\partial v}{\partial y} = 0
\]  \hspace{1cm} (A1)

x-momentum:
\[
\rho \left( u \frac{\partial w}{\partial x} + v \frac{\partial w}{\partial y} \right) = -\frac{\partial p}{\partial x} + \mu \left( \frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right)
\]  \hspace{1cm} (A2)

y-momentum:
\[
\rho \left( u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} \right) = -\frac{\partial p}{\partial y} + \mu \left( \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right)
\]  \hspace{1cm} (A3)
4. (10 points) (a) Define turbulent flow
Reynolds stress

(10 points) (b) Shown in Fig. 4 is the x component of velocity measured at a fixed location in a pipe. Is the flow laminar or turbulent? Why?