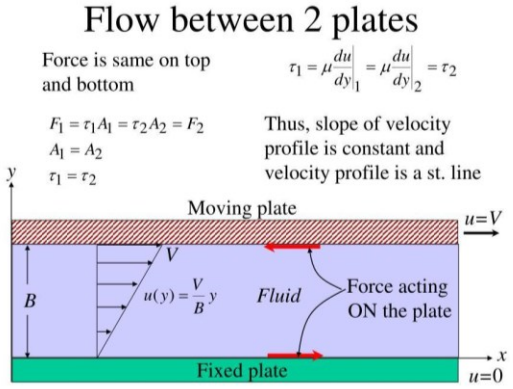
Oct 15th, 2026

AE510 HOMEWORK-2

(Submit it at the start of the next lecture, 22 Oct 2026)

Question Figure



Problem statement

An incompressible Newtonian fluid of dynamic viscosity $\mu = 0.01\ \mathrm{Pa\,s}$ occupies the region between two infinite parallel plates separated by $h = 0.01\ \mathrm{m}$. The lower plate is stationary, and the upper plate moves in the x-direction at constant velocity $U = 0.5\ \mathrm{m/s}$.

Assume steady, fully developed flow with no pressure gradient and no body forces.

(a) Velocity field and rate of strain

Starting from the incompressible Navier–Stokes equations, derive the velocity profile $u(y)$. Then calculate the nonzero components of the rate-of-strain tensor e_{ij}.

(b) Stress tensor

Using the constitutive equation

$$\sigma_{ij} = -p\delta_{ij} + 2\mu e_{ij},$$

derive the stress tensor in matrix form. Calculate the wall shear stress and explain why rigid-body rotation does not generate viscous stress.

(c) Viscous dissipation

Calculate the viscous dissipation per unit volume,

$$\Phi = 2\mu e_{ij} e_{ij},$$

and the total rate of viscous energy dissipation per unit plate area. Verify that the latter equals the mechanical power supplied by the moving plate per unit area.

(d) MATLAB investigation

Plot the velocity profile and shear stress distribution across the gap. Then vary the upper-plate velocity over 0.1–$1.0\ \mathrm{m/s}$ and plot wall shear stress against U.

(e) Interpretation

Explain how the stress and dissipation results change if the gap is halved while U remains constant. State which conclusions depend on the Newtonian constitutive assumption.