Question 1

A thin plate moves between two parallel, horizontal, stationary flat surfaces at a constant velocity of 5 m/s as shown in the figure. The two stationary surfaces are spaced 4 cm apart, and the medium between them is filled with oil whose viscosity is 0.9 N $\cdot$ s/m^2. The part of the plate immersed in oil at any given time is 2-m long and 0.5-m wide. If the plate moves through the mid-plane between the surfaces, determine the force required to maintain this motion. What would your response be if the plate was 1 cm from the bottom surface (h_2) and 3 cm from the top surface (h_1)?

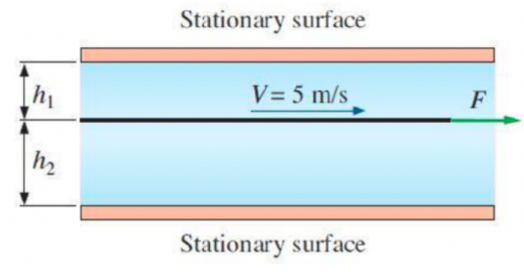

Figure 1: Problem diagram for Question 1.

(a)

The plate moves through the mid-plane between the surfaces.

Assumptions:

- The velocity profile is linear
- Oil is a Newtonian fluid

Since the velocity profile is linear, the shear stress can be calculated using the following equation:

$$\tau = \mu \frac{du}{dy} \tag{1}$$

The velocity as a function of y is:

$$u(y) = \frac{u_{max}}{h_1} y \tag{2}$$

$$\frac{du}{dy} = \frac{u_{max}}{h_1} \tag{3}$$

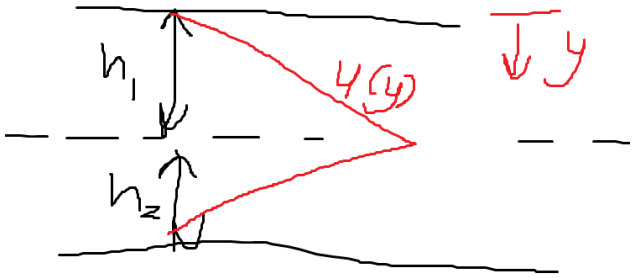

Figure 2: Velocity profile for Question 1.

Substituting Equation (3) into Equation (1) yields:

$$\begin{aligned}\tau_{top} &= \mu \frac{u_{max}}{h_1} \\ &= 0.9 \frac{5}{0.02} \\ &= 225\text{N/m}^2\end{aligned}$$

Similarly, $\tau_{bottom} = -0.09\text{N/m}^2$.

The force required to maintain the motion is:

$$\begin{aligned}F &= \tau_{top} A \\ &= 225 \cdot 2 \cdot 0.5 \\ &= 225\text{N}\end{aligned}$$

By symetry, the force required to maintain the motion is the same for the bottom surface. Therefore,

$$\boxed{F = 450\text{N}}$$