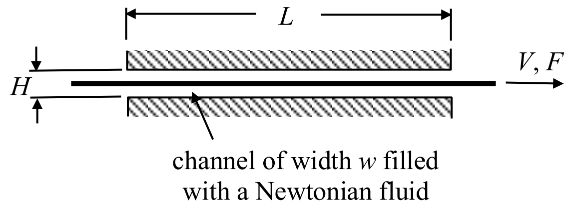
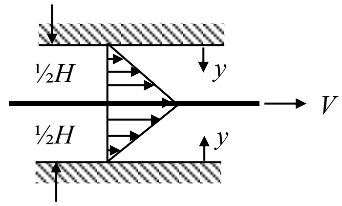
During a coating process, a thin, flat tape of width w is pulled through a channel of length L containing a Newtonian fluid of density ρ and dynamic viscosity μ. The fluid is in contact with both sides of the tape. Estimate the force required to pull the tape through the channel if the tape has velocity V and the channel has height H. You may assume that the tape is much thinner than H.



SOLUTION:

Assume that the gap between the tape and the channel walls is sufficiently small so that a laminar Couette flow can be assumed in the gaps. Hence, the velocity profile in each gap is:



$$u = V\left(\frac{y}{\frac{1}{2}H}\right) \tag{1}$$

The shear stress acting on the tape is:

$$\tau\Big|_{y=\frac{1}{2}H} = \mu \frac{du}{dy}\Big|_{y=\frac{1}{2}H} = \frac{2\mu V}{H} \tag{2}$$

The total shear force acting on the tape is then:

$$F_{\text{shear}} = \underbrace{2}_{\substack{\text{since there}\\ \text{are two sides}\\ \text{to the tape}}} \underbrace{\left(\tau\Big|_{y=\frac{1}{2}H}\right)(Lw)}_{\substack{\text{shear force acting on}\\ \text{one side of the tape;}\\ Lw \text{ is the area over which}\\ \text{the shear stress acts}}} \tag{3}$$

$$\boxed{\therefore F_{\text{shear}} = \frac{4\mu V L w}{H}} \tag{4}$$