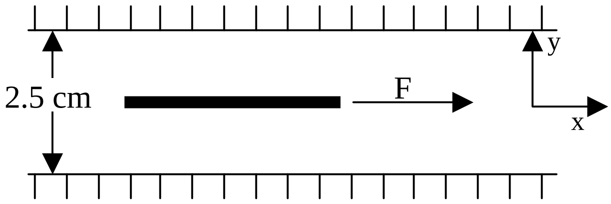
Example -1.3-

The space between two large plane surfaces kept 2.5 cm apart is filled with liquid of viscosity 0.0825 kg/m.s. What force is required to drag a thin plate of surface area 0.5 m^2 between the two large surfaces at speed of 0.5 m/s, (i) when the plate is placed in the middle of the two surfaces, and (ii) when the plate is placed 1.5 cm from one of the plates surfaces.

Solution:

(i) Shear stress on the upper side of the plate is



$$\tau_1 = -\mu\frac{du}{dy} = \frac{F_1}{A}$$

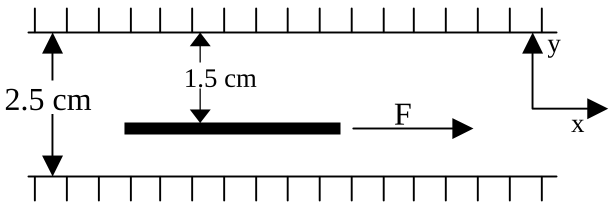
$$\frac{du}{dy} \cong \frac{\Delta u}{\Delta y} = \frac{u|_{y=1.25} - u|_{y=0}}{1.25x10^{-2} - 0} = \frac{0 - 0.5m/s}{1.25x10^{-2}m} = -40s^{-1}$$

$$F_1 = A(-\mu\frac{du}{dy}) = 0.5m^2[-0.0825Pa.s(-40s^{-1})] = 1.65N$$

Likewise on the lower surface $F_2 = A\tau_2 = 1.65N$

The total force required $= F_1 + F_2 = 3.3N$

(ii) Shear stress on the upper side of the plate is



$$\tau_1 = -\mu\frac{du}{dy} = \frac{F_1}{A}$$

$$\frac{du}{dy} \cong \frac{\Delta u}{\Delta y} = \frac{u|_{y=1.5} - u|_{y=0}}{1.5x10^{-2} - 0} = -\frac{100}{3}s^{-1}$$

$$F_1 = A(-\mu\frac{du}{dy}) = 0.5m^2[-0.0825Pa.s(-\frac{100}{3}s^{-1})] = 1.375N$$

$$\tau_2 = -\mu\frac{du}{dy} = \frac{F_2}{A} \quad \text{and} \quad \frac{du}{dy} = \frac{0-0.5}{0.01} = -50s^{-1}$$

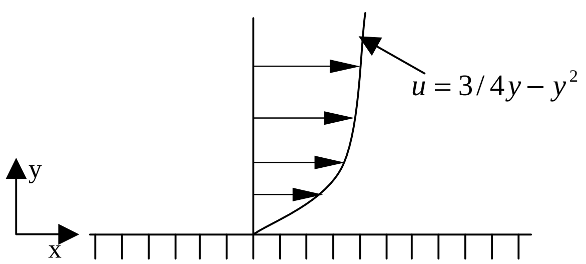
$$F_2 = 0.5m^2[-0.0825Pa.s(-50s^{-1})] = 2.0625N$$

The total force required $= F_1 + F_2 = 3.4375N$

Example -1.4-

The velocity distribution within the fluid flowing over a plate is given by $u = 3/4y - y^2$ where u is the velocity in (m/s) and y is a distance above the plate in (m). Determine the shear stress at y=0 and at y=0.2 m. take that μ=8.4 poise.

Solution:



$$u = 3/4y - y^2 \Rightarrow \frac{du}{dy} = \frac{3}{4} - 2y \Rightarrow \frac{du}{dy}\bigg|_{y=o} = \frac{3}{4}s^{-1}$$

$$\text{and } \frac{du}{dy}\bigg|_{y=0.2} = \frac{3}{4} - 2(0.2) = 0.35s^{-1}$$

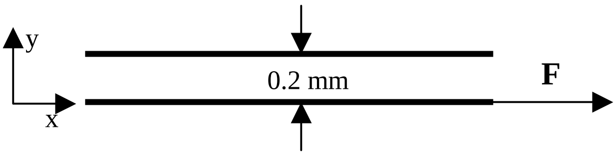
$$\tau = -\mu\frac{du}{dy} = \frac{F}{A};\ \mu = 8.4\frac{g}{cm.c}\left(\frac{100cm}{m}\right)\left(\frac{kg}{1000g}\right)$$

$$\tau|_{y=0} = 0.84Pa.s(3/4s^{-1}) = 0.63Pa \quad \text{and } \tau|_{y=0.2} = 0.84Pa.s(0.35s^{-1}) = 0.294Pa$$

Example -1.5-

A flat plate of area $2\text{x}10^4$ cm^2 is pulled with a speed of 0.5 m/s relative to another plate located at a distance of 0.2 mm from it. If the fluid separated the two plates has a viscosity of 1.0 poise, find the force required to maintain the speed.

Solution:



$$\tau = -\mu \frac{du}{dy} = \frac{F}{A} \quad \mu = 1.0 \frac{g}{cm.c}\left(\frac{100cm}{m}\right)\left(\frac{kg}{1000g}\right)$$

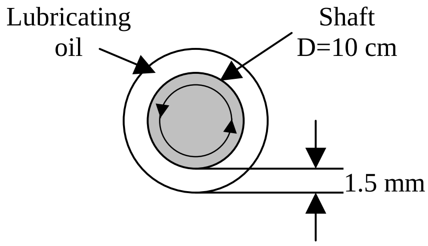
$$\frac{du}{dy} \cong \frac{\Delta u}{\Delta y} = \frac{u_2 - u_1}{y_2 - y_1} = \frac{0 - 0.5m/s}{0.2x10^{-3}m - 0} = -2500s^{-1}$$

$$\tau = 0.1Pa.s(2500s^{-1}) = 250Pa \Rightarrow F = 250Pa(2m^2) = 500N$$

Example -1.6-

A shaft of diameter 10 cm having a clearance of 1.5 mm rotates at 180 rpm in a bearing which is lubricated by an oil of viscosity 100 c.p. Find the intensity of shear of the lubricating oil if the length of the bearing is 20 cm and find the torque.

Solution:



The linear velocity of rotating is

$$u = \pi DN = \frac{\pi(0.1m)180\,rpm}{60\,s/\min} = 0.9425\,m/s$$

$$\mu = 100c.p = 1.0\frac{g}{cm.c}\left(\frac{100cm}{m}\right)\left(\frac{kg}{1000g}\right) = 0.1Pa.s$$

$$\tau = \mu\frac{du}{dy} = \frac{F}{A} = 0.1Pa.s\left(\frac{0.9425m/s}{0.0015m}\right) = 62.83Pa \Rightarrow F = \tau(\pi DL) = 62.83Pa(\pi\,0.1(0.2)) = 3.95\,N$$

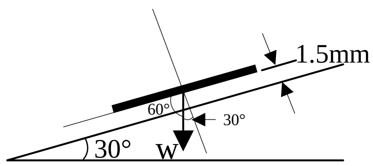
The torque is equivalent to rotating moment

$$\Gamma = F\,\frac{D}{2} = 3.95N\left(\frac{0.1}{2}\right) = 0.1975J$$

Example -1.7-

A plate of size 60 cm x 60 cm slides over a plane inclined to the horizontal at an angle of 30°. It is separated from the plane with a film of oil of thickness 1.5 mm. The plate weighs 25kg and slides down with a velocity of 0.25 m/s. Calculate the dynamic viscosity of oil used as lubricant. What would be its kinematic viscosity if the specific gravity of oil is 0.95.

Solution:



Component of W along the plane =W cos(60) =W sin(30)

= 25 (0.5) = 12.5 kg

F = 12.5 kg (9.81 m/s^2) =122.625 N

τ = F/A = 122.625 N/(0.6 x0.6) m^2 = 340.625 Pa

$$\mu = \frac{\tau}{(du/dy)} = \frac{340.625\ Pa}{(0.25/0.0015)s^{-1}} = 2.044Pa.s = 20.44\ poise$$

$$\nu = \frac{\mu}{\rho} = \frac{2.044\ Pa.s}{950\ kg/m^3} = 0.00215\ m^2/s = 21.5\ stoke$$