1.1 In a certain city the amount of money people carry in their pockets is between $1 and $1000. The average amount per person depends on the zone of the city. In trying to represent the city as a continuum with respect to solvency, i.e., amount of money per person, find the smallest number of people you have to include in V_ε such that the error caused by one person going in or out of V_ε be less than 1%.

LET SOLVENCY BE DENOTED S, AND MEAN SOLVENCY $\bar{S}$.

$$\bar{S} = \frac{\sum_{n=1}^{N} M_n}{N}$$

, WHERE M_n IS THE AMOUNT OF MONEY THE n'th PERSON CARRIES AND N THE SIZE OF THE GROUP SAMPLED, I.E., THE GROUP WITHIN V.

$$S = \lim_{\substack{V \to V_\varepsilon \\ N \to N_\varepsilon}} \frac{\sum_{n=1}^{N} M_n}{N}$$

SINCE NO STANDARD DEVIATION IS GIVEN A FAIR A-PRIORI ASSUMPTION IS THAT N_ε PEOPLE CARRY $\$500 N_\varepsilon$.

THEN THE EXTRA PERSON MUST SATISFY BOTH

$$(1) \quad \frac{\dfrac{500 N_\varepsilon + 1000}{N_\varepsilon + 1} - \dfrac{500 N_\varepsilon}{N_\varepsilon}}{\dfrac{500 N_\varepsilon}{N_\varepsilon}} < 0.1$$

$$(2) \quad \frac{\dfrac{500 N_\varepsilon}{N_\varepsilon} - \dfrac{500 N_\varepsilon + 1}{N_\varepsilon + 1}}{\dfrac{500 N_\varepsilon}{N_\varepsilon}} < 0.1$$

1.1 CONT.

(1) $500N_\epsilon^2 + 1000N_\epsilon - 500N_\epsilon^2 - 500N_\epsilon < 50N_\epsilon(N_\epsilon+1)$

$10 < N_\epsilon + 1$, $N_\epsilon \geqslant 10$.

(2) $500N_\epsilon^2 + 500N_\epsilon - 500N_\epsilon^2 - N_\epsilon < 50N_\epsilon(N_\epsilon+1)$

$\frac{499}{50} < N_\epsilon + 1$, $N_\epsilon \geq 10$

V_ϵ MUST INCLUDE 10 PERSONS AT LEAST.

1.2 A cylindrical container is filled with water of density $\rho = 1000$ kg/m^3, up to the height $h = 5$ m, Fig. P1.2. The outside pressure is $p_o = 10^5$ Pa.

Is the water a continuum with respect to density? Is it with respect to pressure? What is the height Δz_ε of your V_ε if a deviation of 0.1% in p is negligible? Is the water a simple thermodynamic system in equilibrium? How are the answers modified if $p_o = 6\times10^7$ Pa? The top layer of the water is held for a long time at 310 K, and the bottom is held at 290 K. Is it a continuum with respect to temperature? Explain.

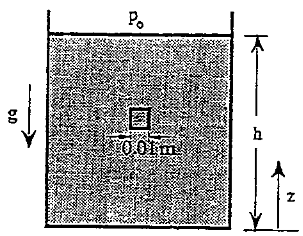


Figure P1.2 Water in a container and small cube.

1.2 YES, THE WATER IS A CONTINUUM WITH RESPECT TO DENSITY. FOR MOST PRACTICAL PURPOSES THE DENSITY MAY BE CONSIDERED CONSTANT.

THE WATER IS ALSO A CONTINUUM WITH RESPECT TO PRESSURE, AND $P = P_o + \rho g (h - z)$.

FOR DEVIATIONS NOT EXCEEDING 0.1% IN P:

$$0.001 = \frac{\Delta P}{P} = \frac{\rho g \Delta z_\varepsilon}{P_o + \rho g (h-z)} \;, \quad \Delta z_\varepsilon \le 0.001\left[\frac{P_o}{\rho g} + h\right] = 0.015.$$

THE WATER IS NOT A SIMPLE THERMODYNAMIC SYSTEM IN EQUILIBRIUM BECAUSE THE PRESSURE IN IT IS NOT UNIFORM.

FOR $P_o = 6\times10^7$ Pa , $\Delta z_\varepsilon \le 0.001\left[\frac{6\times10^7}{1000\, g} + 5\right] = 6\text{m} > h$

THE PRESSURE IS PRACTICALLY UNIFORM. THE WATER CONSTITUTE A SIMPLE THERMODYNAMIC SYSTEM.

THE WATER IS A CONTINUUM WITH RESPECT TO TEMPERATURE. A TEMPEPERATRE MAY BE ASSIGNED TO EACH POINT IN IT.

1.3 A body of water in the shape of a cube is selected inside the container of Fig. P1.2, such that the lower side of the cube coincides with $z = 2.0$ m. The side of the cube is 0.01 m. What is the body force acting on the fluid inside the cube? What are the surface forces acting on the six sides? What are the stresses? Is the whole cube in mechanical equilibrium? Is it a stable equilibrium?
What are the forces and the stresses if the cylinder is put in space, i.e., for $g=0$?
What are they if the cylinder falls freely ? How would you keep the water together?

1.3 THE BODY FORCE ACTING ON THE FLUID INSIDE THE CUBE IS GRAVITY, AND ITS MAGNITUDE IS

$$G = V\rho g = 0.1^3 \times 1000 \times 9.81 \approx 10 \text{ NEWTON}.$$

THE SURFACE FORCES ARE THE AVERAGE PRESSURES MULTIPLIED BY THE AREAS OF THE SIX SIDES, AND THE SURFACE STRESSES ARE THE PRESSURES.

THE WHOLE CUBE IS IN EQUILIBRIUM, BUT NOT IN A STABLE ONE.

IF PUT IN SPACE, WITH $g=0$, THE BODY FORCE WILL VANISH. IF THE CYLINDER IS CLOSED AND THE WATER IS PRESSURIZED, THE SURFACE STRESSES WILL BE THE UNIFORM PRESSURE, AND THE SURFACE FORCES WILL BE THE PRODUCTS OF THE PRESSURE AND THE AREAS OF THE SIDES.

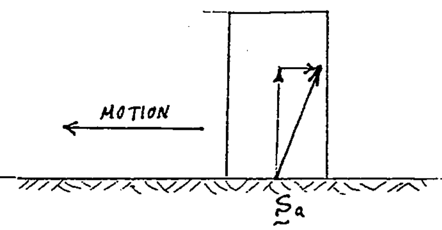
TO KEEP THE WATER TOGETHER THE CYLINDER MUST BE CLOSED AND COMPLETELY FULL WITH WATER.

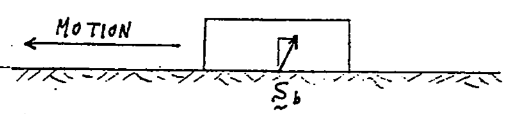
1.4 A box-like block of wood has the dimensions of 1 m×2 m×3 m. The density of the wood is ρ = 800 kg/m^3. The coefficient of dry friction between wood and concrete is 0.4, i.e., when the block is drawn on a concrete floor it is pulled with a force of 0.4 N per each 1 N force pushing the block normal to the floor. Calculate and draw the average stress on that side of the block which touches the floor, when this side is:

a. The 1 m×2 m side.

b. The 2 m×3 m side.

Note that stress is a vector.





THE FORCE THE BLOCK APPLIES NORMAL TO THE CONCRETE IS $1 \times 2 \times 3 \times 800 \times 9.81 = 47088N$

THE FRICTION FORCE IS $0.4 \times 47088 = 18835.2N$

THE FORCE ON THE BOTTOM SIDE OF THE BLOCK IS

$\underset{\sim}{F} = 47088\,\hat{j} + 18835.2\,\hat{i}$ AND THE STRESS IS

$\underset{\sim}{S}_a = \underset{\sim}{F}/(1\times2) = 23544\,\hat{j} + 9418\,\hat{i}$

$\underset{\sim}{S}_b = \underset{\sim}{F}/(2\times3) = 7848\,\hat{j} + 3139\,\hat{i}$

1.5 A certain oil has the viscosity of 2 poise. Its density is 62 lb/ft^3. What is its kinematic viscosity in m^2/s?

1.5 FROM EQ. (1.21) $1 \text{ poise} = 0.1 \frac{Kg}{m \cdot s}$, $1 = 0.1 \frac{Kg}{m \cdot s \cdot \text{poise}}$

$\mu = 2 \text{ poise} = 2 \text{ poise} \times 1 = 2 \text{ poise} \times 0.1 \frac{Kg}{m \cdot s \cdot \text{poise}}$

$= 0.2 \frac{Kg}{m \cdot s}$

$1 \text{ lb} = 0.454 \text{ Kg}$, $1 = 0.454 \frac{Kg}{lb}$

$1 \text{ ft} = 0.3048 \text{ m}$, $1 = 0.3048 \frac{m}{ft}$

$\rho = 62 \text{ lb/ft}^3 = 62 \frac{lb}{ft^3} \times 0.454 \frac{Kg}{lb} \times \frac{ft^3}{0.3048^3 \, m^3} = 994.04 \frac{Kg}{m^3}$

$\nu = \mu/\rho = 0.2/994.04 = 2.02 \times 10^{-4} \ m^2/s$

KINEMATIC VISCOSITY

1.6 A certain slurry is filtered at constant pressure at the rate of

$$\dot{V} = \frac{52.5V + 6.2}{t}$$

where $\dot{V}$ [lit/s] is the rate t [s] is the time, and V [liters] is the filtered volume. Is the equation dimensionally homogeneous ?

Try to rewrite the equation with V in cubic ft. Can you rewrite the equation in a homogeneous form ?

1.6 THE EQUATION IS NOT HOMOGENEOUS. WITH NO ADDITIONAL INFORMATION IT CANNOT BE WRITTEN IN A HOMOGENEOUS FORM.

TO HAVE V IN $[ft^3]$ AND $\dot{V}$ IN $[ft^3/s]$:

$1\ ft = 0.3048\ m$, $1\ ft^3 = 0.3048^3\ m^3$,

$1\ m^3 = 1000$ Liter, $1 = 1000 \frac{\text{Liter}}{m^3}$,

$1\ ft^3 = 0.3048^3 m^3 \times 1000 \frac{\text{Liter}}{m^3} = (0.3048^3)\cdot(1000)$ Liter ,

$1 = 3.048^3 \frac{\text{Liter}}{ft^3}$.

$V\ [ft^3] = V[ft^3] \times 3.048^3 \frac{\text{Liter}}{ft^3} = 28.32\ V\ [\text{Liter}]$,

$\dot{V}\ [ft^3/s] = 28.32\ V\ [\text{Liter}/s]$.

THE EQUATION: $28.32\ \dot{V} = t / [52.5 \times 28.32 V + 6.2]$,

OR,

$$\dot{V} = t / [42106.18 V + 175.58], \quad \text{WITH } V[ft^3]$$

1.7 A falling body has its z coordinate change in time as

$$z = z_o - 4.9t^2$$

where t [s] is the time, and z [m] is the height. Is the equation dimensionally homogeneous? Rewrite the equation with z [ft].

Can you rewrite the equation in a homogeneous form. Why is the answer here different from that in Problem 1.4?

Why do dimensionally homogeneous equations give more information? What is this information?

1.7 THE EQUATION IS NOT HOMOGENEOUS.

TO PUT Z IN ft:

$1\ ft = 0.3048\ m$, $1 = 0.3048\ \frac{m}{ft}$.

$Z\ [ft] = Z\ [ft] \times 0.3048\ \frac{m}{ft} = 0.3048\,[m]\ Z$

THE EQUATION BECOMES

$$0.3048\ Z = 0.3048\ Z_0 - 4.9\,t^2 ,$$

OR $Z = Z_0 - 16.1\ t^2$, $Z\,[ft]$.

THE HOMOGENEOUS FORM OF THE EQUATION IS

$$Z = Z_0 - \tfrac{1}{2} g t^2 .$$

WE CAN RETRIEVE THIS FORM BECAUSE WE KNOW SOLID MECHANICS. WE DO NOT KNOW MUCH ABOUT SLURRY FILTRATION, AND THEREFOR COULD NOT DO THE SAME IN 1.4.

DIMENSIONALLY HOMOGENEOUS EQUATIONS CONTAIN MORE OF THE PHYSICS OF THE PHENOMENA.

1.8 The following dimensionless numbers are defined:

$Re = (U.d.\rho) / \mu$ Reynolds number

$Pr = \mu c_p / k$ Prandtl number

$Pe = Re \cdot Pr$ Peclet number.

where $U = 2$ m/s is the flow velocity in the pipe, $d = 2$"[inch] is the pipe diameter, $\rho = 1000\ \mathrm{kg/m^3}$ is the fluid density, $\mu = 3$ cp is its viscosity, $c_p = 0.5$ Btu/(lbm·°F) is the specific heat of the fluid, and $k = 0.65$ W/m·°C is its thermal conductivity.

a. What are the numerical values of *Re, Pr* and *Pe*?

b. In a certain set of experiments the flow in the pipe became turbulent at $U = 11$ cm/s. In terms of which dimensionless numbers should the engineer record his findings? Are there hidden assumptions in your answer? What may the engineer do to verify these?

1.8 WE CHOOSE THE SI SYSTEM OF UNITS.

$1\ \text{INCH} = 0.0254\ m \quad , \quad 1 = 0.0254 \frac{m}{\text{INCH}}$

$d = 2\ \text{INCH} = 2 \times 0.0254\ \text{INCH} \cdot \frac{m}{\text{INCH}} = 0.0508\ m$

$1\ \text{POISE} = 0.1 \frac{kg}{m \cdot s} \quad , \quad 1\ CP = 0.001 \frac{kg}{m \cdot s} \quad , \quad 1 = 0.001 \frac{kg}{m \cdot s} / C$

$\mu = 3\ CP = 3\ CP \times 0.001 \frac{kg}{m \cdot s} / CP = 0.003 \frac{kg}{m \cdot s}$

$1\ °F = \frac{5}{9}\ K \quad , \quad 1 = \frac{5}{9} \frac{K}{°F}$

$1\ lb_m = 0.454\ kg \quad , \quad 1 = 0.454 \frac{kg}{lbm}$

$1 = 1055.05 \frac{J}{BTU}$

$C_p = 0.5 \frac{BTU}{lb_m \cdot °F} = 0.5 \frac{BTU}{lb_m \cdot °F} \times \left(\frac{9}{5} \frac{°F}{°K}\right) \times \left(\frac{1}{0.454} \frac{lb_m}{kg}\right) \times 1055.0$

$C_p = 2091.51 \frac{J}{kg \cdot K}$

$U = 11\ cm/s = 11 \frac{cm}{s} \cdot \frac{1}{100} \frac{m}{cm} = 0.11\ m/s$

1.8 CONT.

$$R_e = \frac{U d \rho}{\mu} = \frac{2 \times 0.0508 \times 1000}{0.003} = 33867$$

$$P_r = \frac{\mu C_p}{k} = \frac{0.003 \times 2091.51}{0.65} = 9.65$$

$$P_e = R_e \cdot P_r = 326922$$

THE ENGINEER RECORDS:

THE FLOW BECAME TURBULENT AT

$$R_e = \frac{U d \rho}{\mu} = \frac{0.11 \times 0.0508 \times 1000}{0.003} = 1863.$$

THE ONSET OF TURBULENCE DID NOT DEPEND ON THE PRANDTL NUMBER.

THE MAIN HIDDEN ASSUMPTION IS THAT ALL THE VARIABLES WHICH CAN INFLUENCE TURBULENCE ARE INDEED LISTED IN THE PROBLEM. THE ENGINEER MAY WONDER WHETHER THE ROUGHNESS OF THE PIPE WALL IS IMPORTANT, AND MAKE EXPERIMENTS WITH VARIOUS PIPES TO CHECK THIS.

1.9 Using Appendix A, change into the S.I. system:

Density	$\rho = 120$ lb/ft^3
Thermal conductivity	$k = 170$ Btu/(hr·ft·°F)
Thermal convection coefficient	$h = 211$ Btu/(hr·ft^2·F)
Specific heat	$c_p = 175$ Btu/(lb·°F)
Viscosity	$\mu = 20$ centipoise
Viscosity	$\mu = 77$ lbf·s/ft^2
Kinematic viscosity	$\nu = 3$ ft^2/s
Stefan-Boltzmann constant	$\alpha = 0.1713 \times 10^{-8}$ Btu/(ft^2·hr·°R^4)
Acceleration	$a = 12$ ft/s^2

THE RELEVANT RELATIONS ARE:

$1 = 3.281$ ft/m , $1 = 2.2046$ lb/kg , $1 = 1.05505$ kJ/Btu,

$1 = 3600$ s/hr , $1 = 1.8$ DEG.F/DEG.K , $1 = 1000$ cp/[kg/(m·s)]

$$\rho = 120 \frac{lb}{ft^3} = 120 \frac{lb}{ft^3} \times \frac{1}{2.2046} \frac{kg}{lb} \times 3.281^3 \left(\frac{ft}{m}\right)^3 = 1922.5 \frac{kg}{m^3}$$

$$k = 170\ Btu/(hr \cdot ft \cdot {}^\circ F) \times 1.05505 \frac{kJ}{Btu} \times \frac{1}{3600} \frac{hr}{s} \times 3.281 \frac{ft}{m} \times 1.8 \frac{{}^\circ F}{K}$$
$$= 0.2942\ kW/(m \cdot K).$$

$$h = 211\ Btu/(hr \cdot ft^2 \cdot {}^\circ F) \times 1.05505 \frac{kJ}{Btu} \times \frac{1}{3600} \frac{hr}{s} \times 3.281^2 \left(\frac{ft}{m}\right)^2 \times 1.8 \frac{{}^\circ F}{K}$$
$$= 1.1982\ kW/(m^2 \cdot K).$$

$$C_p = 175\ Btu/(lb \cdot {}^\circ F) \times 1.05505 \frac{kJ}{Btu} \times 2.2046 \frac{lb}{kg} \times 1.8 \frac{{}^\circ F}{K} = 732.7 \frac{kJ}{kg\,K}.$$

$$\mu = 20\ cp \times \frac{1}{1000} \cdot \frac{kg/(m \cdot s)}{cp} = 0.02\ kg/(m \cdot s)$$

$$\mu = 77\ lbf \cdot s/ft^2 \times 4.448 \frac{N}{lbf} \times 3.281^2 \frac{ft^2}{m^2} = 3687\ N \cdot s/m^2$$
$$= 3687\ kg/(m \cdot s)$$

$$\nu = 3 \frac{ft^2}{s} \times \frac{1}{3.281^2} \frac{m^2}{ft^2} = 0.279 \frac{m^2}{s}$$

$$\alpha = 0.1713 \times 10^{-8} \frac{Btu}{ft^2 \cdot hr \cdot {}^\circ R^4} \times 1.05505 \frac{kJ}{Btu} \times 3.281^2 \frac{ft^2}{m^2} \times \frac{1}{3600} \frac{hr}{s} \times 1.8^4 \frac{{}^\circ R^4}{K^4}$$
$$= 5.673 \times 10^{-11} \frac{kJ}{m^2 \cdot s \cdot K^4} = 5.673 \times 10^{-8} \frac{J}{m^2 \cdot s \cdot K^4}.$$

$$a = 12 \frac{ft}{s^2} \times \frac{1}{3.281} \frac{m}{ft} = 3.657 \frac{m}{s^2}$$

1.10 The following empirical equation gives the wall shear stress exerted on a fluid flowing in a concrete pipe

$$\tau_w = 0.0021\rho V^2 r^{-\frac{1}{3}}$$

where τ_w is the shear stress in lbf/in^2, ρ the fluid density in slug/ft^3, V the average velocity of the fluid in ft /s and r the hydraulic radius of the pipe in ft. Rewrite the equation in terms of S.I. units.

$$\rho \frac{slug}{ft^3} \times 32.174 \frac{lb}{slug} \times 16.018 \frac{kg/m^3}{lb/ft^3} = 515.363 \frac{kg}{m^3} \cdot \rho \quad ,$$

$$V \frac{ft}{s} \times \frac{1}{3.281} \frac{m}{ft} = 0.3048\ m/s . V,$$

$$r\ ft \times \frac{1}{3.281} \frac{m}{ft} = 0.3048\ m . r,$$

$$\tau_w \frac{lbf}{in^2} \times 4.448 \frac{N}{lbf} \times 12^2 \frac{in^2}{ft^2} \times 3.281^2 \frac{ft^2}{m^2} = 6895.1 \frac{N}{m^2} \cdot \tau_w$$

THE EQ. :

$$6895.1\ \tau_w = 0.0021 \times 515.362\rho \times 0.3048^2 V^2 \times 0.3048^{-\frac{1}{3}} r^{-\frac{1}{3}}$$

$$= 0.1494\ \rho V^2 r^{-\frac{1}{3}}$$

$$\tau_w\ [N/m^2] = 2.17 \times 10^{-5} \rho [kg/m^3]\ V^2 [(m/s)^2]\ r^{-1/3} [m^{-\frac{1}{3}}]$$

$$\tau_w = 2.17 \times 10^{-5} \rho V^2 r^{-\frac{1}{3}} \quad \text{IN S.I. UNITS.}$$

1.11 The distance between the plates in an experimental system, as shown in Fig. 1.4, is $h = 1$ inch. When the upper plate is pulled with the velocity $V = 40$ ft/min, the shear stress is $T = 12$ lbf/ft^2. Using Eq. (1.18) find the viscosity of the fluid, μ, in S.I. units.

$$h = 1\,in \times \frac{1}{12}\frac{ft}{in} \times \frac{1}{3.281}\frac{m}{ft} = 0.025\,m$$

$$V = 40\,ft/min \times \frac{1}{3.281}\frac{m}{ft} \times \frac{1}{60}\frac{min}{s} = 0.203\,m/s$$

$$T = 12\,\frac{lbf}{ft^2} \times 4.448\,\frac{N}{lbf} \times 3.281^2\,\frac{ft^2}{m^2} = 574.6\,N/m^2$$

EQUATION. (1.18) : $T = \mu \dfrac{V}{h} =$

$$574.6 = \mu \times \frac{0.203}{0.025}$$

$$\mu = 70.76\ N.s/m^2 = 70.76\ kg/(m.s)$$

1.12 A metal sphere of 1 ft in diameter is put on a scale. The scale shows a reading of 200 kg. Find the volume, the mass, the density, the specific volume, and the specific weight of the sphere, in:

a. The S.I. system of units.

b. The British system of units.

$$r = 1\,ft = 1\,ft \times \frac{1}{3.281}\frac{m}{ft} = 0.3048\,m$$

VOLUME : $Vol = \frac{4}{3}\pi r^3 =$

a. $0.1186\ m^3$ b. $4.1888\ ft^3$

DENSITY: a. $\rho = M/Vol = 200/0.1186 = 1686.3\ kg/m^3$

b. $= 1686.3\ \frac{kg}{m^3} \times \frac{1}{16.018}\ \frac{lb/ft^3}{kg/m^3} = 105.3\ lb/ft^3$

SPECIFIC VOLUME : $v = \frac{1}{\rho} =$

a. $0.000593\ m^3/kg$ b. $0.00950\ ft^3/lb$

SPECIFIC WEIGHT:

$$\gamma = \rho g$$

a. $\gamma = 1686.3 \times 9.81 = 16542.6\ N/m^3$

b. $\gamma = 105.3\ lbf/ft^3$

1.13 A volume of 30 l of alcohol, subjected to a pressure of 500 atm. at 25°C, contracts to 28.8 l.

a. What is the modulus of elasticity of alcohol?

b. What is its compressibility?

$$p = 500 \frac{kgf}{m^2} \times 9.807 \frac{N}{kgf} = 4903.5 \frac{N}{m^2} = 4903.5\ Pa$$

b. COMPRESSIBILITY, EQ. (1.24), EQ. (1.25)

$$K = K_T = -\frac{1}{V}\frac{\Delta V}{\Delta p} = -\frac{2}{(30+28.8)} \cdot \frac{30-28.8}{4903.5}$$

$$= -8.3 \times 10^{-6}\ m^2/N$$

a. MODUL OF ELASTICITY, EQ. (1.33)

$$E_T = E = \frac{10^6}{8.3} = 0.12 \times 10^6\ N/m^2.$$

2.1 A unidirectional flow between three infinite flat plates is shown in Fig. P2.1. The two outer plates are stationary, while the mid plate moves at a constant velocity U = 1 m/s, as shown in the figure. The gap between the plates is h = 0.005 m. The fluid has a viscosity of μ = 2 kg/(m·s), and is Newtonian, i.e., it obeys Newton's law of viscosity, Eq. (1.18).

a. Consider Eqs. (2.34)-(2.36) and calculate the shear stress on the surfaces of all the plates.

b. Find the force, per unit area of plate, needed to maintain the steady motion of the mid plate.

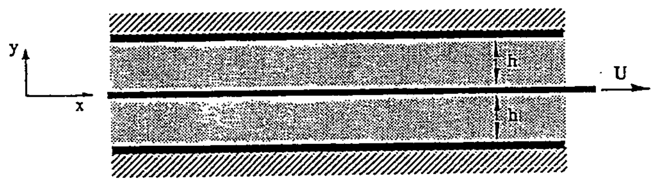


Figure P2.1

a. THE MAGNITUDE OF THE SHEAR STRESS ON ALL PLATES IS FOUND AT ONCE BY EQ. (2.35)

$$|\tau_{yx}| = \mu \frac{V}{h} = 2 \times \frac{1}{0.005} = 400 \ N/m^2$$

TO FIND THE SIGN WE NOTE THAT FOR $Y>0$

$u = U\frac{h-Y}{h}$, AND EQ. (1.18): $\tau_{yx} = \mu \frac{du}{dy} = -\mu \frac{U}{h}$,

HENCE ON THE MID PLATE: $\tau_{yx} = -400 \ N/m^2$

AND ON THE UPPER PLATE: $\tau_{-yx} = -\tau_{yx} = 400 \ N/m^2$.

FOR $Y<0$, $u = U\frac{h+Y}{h}$, $\tau_{yx} = \mu\frac{U}{h}$,

HENCE ON THE MID PLATE: $\tau_{-yx} = -\tau_{yx} = -400 \ N/m^2$

AND ON THE LOWER ONE: $\tau_{yx} = 400 \ N/m^2$.

b. $F = 2 \cdot [-(-400)] = 800 \ N/m^2$.