The force, *P,* that is exerted on a spherical particle moving slowly through a liquid is given by the equation *P=3DV* where  is a fluid property (viscosity) having dimensions of *FL-2T*, *D* is the particle diameter, and *V* is the particle velocity. What are the dimensions of the constant, 3? Would you classify this equation as a general homogeneous equation?

According to information found in an old hydraulics book, the energy loss per unit weight of fluid flowing through a nozzle connected to a hose can be estimated by the formula *h=(0.04 to 0.09)(D/d)4V2/2g,* where *h* is the energy loss per unit weight, *D* the hose diameter, *d* the nozzle tip diameter, *V* the fluid velocity in the hose, and *g* the acceleration of gravity. Do you think this equation is valid in any system of units? Explain.

An important dimensionless parameter in certain types of fluid flow problems is the *Froude number* defined as *V/*$\sqrt{gl}$ where *V* is a velocity, *g* the acceleration of gravity, and l a length. Determine the value of the Froude number for V=10 ft/s, g=32.2 ft/s2 and l=2 ft. Recalculate the Froude number using SI units for *V*, *g*, and l. Explain the significance of the results of these calculations.

A closed tank is partially filled with glycerin. If the air pressure in the tank is 6 lb/in2 and the depth of glycerin is 10 ft, what is the pressure in lb/ft2 at the bottom of the tank?

Blood pressure is usually given as a ratio of the maximum pressure (systolic pressure) to the minimum pressure (diastolic pressure). Such pressures are commonly measured with a mercury manometer. A typical value for this ratio for a human would be 120/70, where the pressures are in mm Hg. (a) What would these pressures be in pascals? (b) If your car tire was inflated to 120 mm Hg, would it be sufficient for normal driving?

An unknown immiscible liquid seeps into the bottom of an open oil tank. Some measurements indicate that the depth of the unknown liquid is 1.5 m and the depth of the oil (specific weight=8.5 kN/m3) floating on top is 5.0 m. A pressure gage connected to the bottom of the tank reads 65 kPa. What is the specific gravity of the unknown liquid?

What pressure, expressed in pascals, will a skin diver be subjected to at a depth of 40 m in seawater?

Sometimes when riding an elevator or driving up or down a hilly road a person’s ears “pop” as the pressure difference between the inside and outside of the ear is equalized. Determine the pressure difference (in psi) associated with this phenomenon if it occurs during a 150-ft elevation change.

A U-tube mercury manometer is connected to a closed pressurized tank as illustrated in the figure. If the air pressure is 2 psi, determine the differential reading, h. The specific weight of the air is negligible.



Two pipes are connected by a manometer as shown in the figure. Determine the pressure difference, pA-pB, between the pipes.



An inverted open tank is held in place by a force R as shown in the figure. If the specific gravity of the manometer fluid is 2.5, determine the value of h.



A flowrate measuring device is installed in a horizontal pipe through which water is flowing. A U-tube manometer is connected to the pipe through pressure taps located 3 in. on either side of the device. The gage fluid in the manometer has a specific weight of 112 lb/ft3. Determine the differential reading of the manometer corresponding to a pressure drop between the taps of

0.5 lb/in.2

Determine the elevation difference, h, between the water levels in the two open tanks shown in the figure.



An inverted U-tube manometer containing oil (SG = 0.8) is located between two reservoirs as shown in the figure. The reservoir on the left, which contains carbon tetrachloride, is closed and pressurized to 8 psi. The reservoir on the right contains water and is open to the atmosphere. With the given data, determine the depth of water, h, in the right reservoir.



Three different liquids with properties as indicated fill the tank and manometer tubes as shown in the figure. Determine the specific gravity of Fluid 3.



Determine the ratio of areas, A1/A2, of the two manometer legs of the figure if a change in pressure in pipe B of 0.5 psi gives a corresponding change of 1 in. in the level of the mercury in the right leg. The pressure in pipe A does not change.



A large, open tank contains water and is connected to a 6-ft-diameter conduit as shown in the figure. A circular plug is used to seal the conduit. Determine the magnitude, direction, and location

of the force of the water on the plug.



A circular 2-m-diameter gate is located on the sloping side of a swimming pool. The side of the pool is oriented 60º relative to the horizontal bottom, and the center of the gate is located 3 m below the water surface. Determine the magnitude of the water force acting on the gate and the point through which it acts.

A pump supplies water under pressure to a large tank as shown in the figure. The circular-plate valve fitted in the short discharge pipe on the tank pivots about its diameter A–A and is held shut against the water pressure by a latch at B. Show that the force on the latch is independent of the supply pressure, p, and the height of the tank, h.



A vertical plane area having the shape shown in the figure is immersed in an oil bath (specific weight = 8.75 kN/m3). Determine the magnitude of the resultant force acting on one side of the area as a result of the oil.



The velocity field of a flow is given by **V**=(3*y*+2)**i** + (*x*-8)**j** + 5*z***k** ft/s, where x, y, and z are in feet. Determine the fluid speed at the origin (x = y= z= 0) and on the y axis (x=z=0).

The components of a velocity field are given by *u=x+y, v=xy3* and *w=0*. Determine the location of any stagnation points in the flow field.

The velocity field of a flow is given by *u= -V0y/(x2 + y2)1/2* and *v= V0x/(x2 + y2)1/2*, where V0 is a constant. Where in the flow field is the speed equal to V0? Determine the equation of the streamlines and discuss the various characteristics of this flow.

At time *t=0* the valve on an initially empty (perfect vacuum, *=0*) tank is opened and air rushes in. If the tank has a volume of *V0* and the density of air within the tank increases as *=∞(1-e-bt)*, where b is a constant, determine the time rate of change of mass within the tank.

Air enters an elbow with a uniform speed of 10 m/s as shown in the figure. At the exit of the elbow, the velocity profile is not uniform. In fact, there is a region of separation or reverse flow. Thefixed control volume ABCD coincides with the system at time t = 0. Make a sketch to indicate (a) the system at time t = 0.01 s and (b) the fluid that has entered and exited the control volume in that time period.



From calculus, one obtains the following formula (Leibnitz rule) for the time derivative of an integral that contains time in both the integrand and the limits of the integration:



Discuss how this formula is related to the time derivative of the total amount of a property in a system and to the Reynolds transport theorem.

Water flows in the branching pipe shown in the figure with uniform velocity at each inlet and outlet. The fixed control volume indicated coincides with the system at time t=20 s. Make a sketch to indicate (a) the boundary of the system at time t=20.1 s, (b) the fluid that left the control volume during that 0.1-s interval, and(c) the fluid that entered the control volume during that time interval.



Blue and yellow streams of paint at 60 ºF (each with a density of 1.6 slugs/ft3 and a viscosity 1000 times greater than water) enter a pipe with an average velocity of 4 ft/s as shown in the figure. Would you expect the paint to exit the pipe as green paint or separate streams of blue and yellow paint? Explain. Repeat the problem if the paint were “thinned” so that it is only 10 times more viscous than water. Assume the density remains the same.



Air at 200ºF flows at standard atmospheric pressure in a pipe at a rate of 0.08 lb/s. Determine the minimum diameter allowed if the flow is to be laminar.

To cool a given room it is necessary to supply 4 ft3/s of air through an 8-in.-diameter pipe. Approximately how long is the entrance length in this pipe?

The pressure distribution measured along a straight, horizontal portion of a 50-mm-diameter pipe attached to a tank is shown in the table below. Approximately how long is the entrance length? In the fully developed portion of the flow, what is the value of the wall shear stress?



For fully developed laminar pipe flow in a circular pipe, the velocity profile is given by
*u(r)=2(1-r2/R2)* in m/s, where R is the inner radius of the pipe. Assuming that the pipe diameter is 4 cm, find the maximum and average velocities in the pipe as well as the volume flow rate.

The pressure drop needed to force water through a horizontal1-in.-diameter pipe is 0.60 psi for every 12-ft length of pipe. Determine the shear stress on the pipe wall. Determine the shear stress at distances 0.3 and 0.5 in. away from the pipe wall.

Water at 20ºC flows through a horizontal 1-mm-diameter tube to which are attached two pressure taps a distance 1 m apart. (a) What is the maximum pressure drop allowed if the flow is to be laminar? (b) Assume the manufacturing tolerance on the tube diameter is D = 1.0 ± 0.1 mm. Given this uncertainty in the tube diameter, what is the maximum pressure drop allowed if it must be assured that the flow is laminar?

Glycerin at 20 ºC flows upward in a vertical 75-mm diameter pipe with a centerline velocity of 1.0 m/s. Determine the head loss and pressure drop in a 10-m length of the pipe.

A fluid flows through a horizontal 0.1-in.-diameter pipe. When the Reynolds number is 1500, the head loss over a 20-ft length of the pipe is 6.4 ft. Determine the fluid velocity.

Asphalt at 120 ºF, considered to be a Newtonian fluid with a viscosity 80,000 times that of water and a specific gravity of 1.09, flows through a pipe of diameter 2.0 in. If the pressure gradient is

1.6 psi/ft determine the flowrate assuming the pipe is (a) horizontal; (b) vertical with flow up.

For oil (SG = 0.86, = 0.025 Ns/m2) flow of 0.3 m3/s through a round pipe with diameter of 500 mm, determine the Reynolds number. Is the flow laminar or turbulent?

A person with no experience in fluid mechanics wants to estimate the friction factor for 1-in.-diameter galvanized iron pipe at a Reynolds number of 8,000. The person stumbles across the simple equation of *f = 64/Re* and uses this to calculate the friction factor. Explain the problem with this approach and estimate the error.

During a heavy rainstorm, water from a parking lot completely fills an 18-in.-diameter, smooth, concrete storm sewer. If the flowrate is 10 ft3/s, determine the pressure drop in a 100-ft horizontal section of the pipe. Repeat the problem if there is a 2-ft change in elevation of the pipe per 100 ft of its length.

Oil (SG = 0.9), with a kinematic viscosity of 0.007 ft2/s, flows in a 3-in.-diameter pipe at 0.01 ft3/s. Determine the head loss per unit length of this flow.

Blood (assume  = 4.5x10-5 lb·s/ft2, SG = 1.0) flows through an artery in the neck of a giraffe from its heart to its head at a rate of 2.5x10-4 ft3/s. Assume the length is 10 ft and the diameter is 0.20 in. If the pressure at the beginning of the artery (outlet of the heart) is equivalent to 0.70 ft Hg, determine the pressure at the end of the artery when the head is (a) 8 ft above the heart, or (b) 6 ft below the heart. Assume steady flow. How much of this pressure difference is due to elevation effects, and how much is due to frictional effects?

Two equal length, horizontal pipes, one with a diameter of 1 in., the other with a diameter of 2 in., are made of the same material and carry the same fluid at the same flow rate. Which pipe produces the larger head loss? Justify your answer.

Gasoline flows in a smooth pipe of 40-mm diameter at a rate of 0.001 m3/s. If it were possible to prevent turbulence from occurring, what would be the ratio of the head loss for the actual turbulent flow compared to that if it were laminar flow?

Given 90º threaded elbows used in conjunction with copper pipe (drawn tubing) of 0.75-in. diameter, convert the loss for a single elbow to equivalent length of copper pipe for wholly turbulent flow.

Water flows steadily through the 0.75-in.-diameter galvanized iron pipe system shown in the figure at a rate of 0.020 cfs. Your boss suggests that friction losses in the straight pipe sections are negligible compared to losses in the threaded elbows and fittings of the system. Do you agree or disagree with your boss? Support your answer with appropriate calculations.



Air flows through a rectangular galvanized iron duct of size 0.30 m by 0.15 m at a rate of 0.068 m3/s. Determine the head loss in 12 m of this duct.

The 1/2-in.-diameter hose shown in the figure can withstand a maximum pressure of 200 psi without rupturing. Determine the maximum length *l* allowed if the friction factor is 0.022 and the flowrate is 0.010 cfs. Neglect minor losses.



The pump shown in the figure adds 25 kW to the water and causes a flowrate of 0.04 m3/s. Determine the flowrate expected if the pump is removed from the system. Assume *f* = 0.016 for either case and neglect minor losses.



Water is to be moved from a large, closed tank in which the air pressure is 20 psi into a large, open tank through 2000 ft of smooth pipe at the rate of 3 ft3/s. The fluid level in the open tank is 150 ft below that in the closed tank. Determine the required diameter of the pipe. Neglect minor losses.

The three water-filled tanks shown in the figure are connected by pipes as indicated. If minor losses are neglected, determine the flowrate in each pipe.



As shown in the figure, cold water (T=50ºF) flows from the water meter to either the shower or the hot water heater. In the hot water heater it is heated to a temperature of 150ºF. Thus, with equal amounts of hot and cold water, the shower is at a comfortable 100ºF. However, when the dishwasher is turned on, the shower water becomes too cold. Indicate how you would predict this new shower temperature (assume the shower faucet is not adjusted). State any assumptions needed in your analysis.



A centrifugal water pump having an impeller diameter of 0.5 m operates at 900 rpm. The water enters the pump parallel to the pump shaft. If the exit blade angle, 2, is 25º, determine the shaft power required to turn the impeller when the flow through the pump is 0.16 m3/s. The uniform blade height is 50 mm.