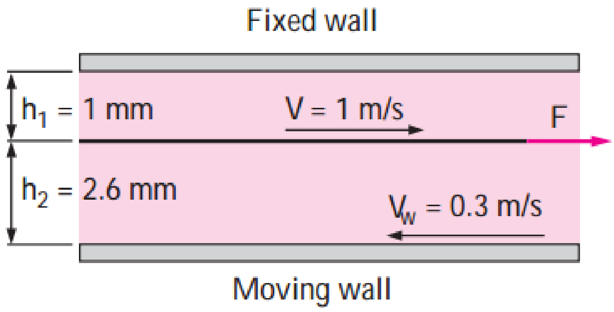
Fluid Mechanics
University of Massachusetts, Lowell – Department of Chemical Engineering
CHEN.3030 – Spring 2017

Name:______________________ Student ID: ____________________________

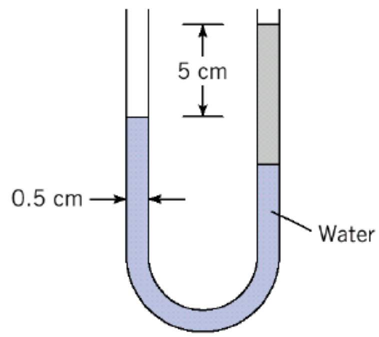
Exam 1; Time: 5:00PM – 7:00PM; Location: Ball Hall 210; Exam type: Open book (Only text book is allowed) without any additional writing or attachment. (Do all six (6) problems, with each problem having equal weight.)

Q1. A thin 20 cm by 20 cm flat plate is pulled at 1 m/s horizontally through a 3.6 mm-thick oil layer sandwiched between two plates, one stationary and the other moving at a constant velocity of 0.3 m/s, as shown in Figure. The dynamic viscosity of oil is 0.027 Pa·s. Assume the velocity in each oil layer varies linearly.

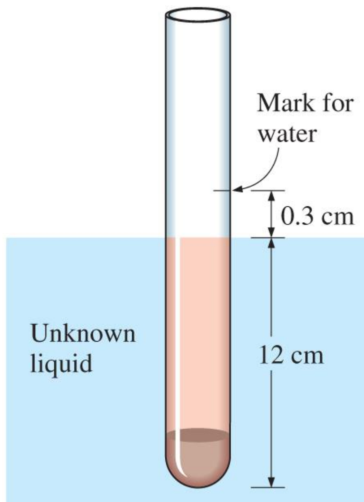
(a) Plot the velocity profile and find all the location where the oil velocity is zero.
(b) Determine the force that needs to be applied on the plate to maintain this motion.



Q2. A device for measuring the specific gravity of a liquid consists of a U-tube manometer as shown. The manometer tube has an internal diameter of 0.5 cm and originally has only water in it. Exactly 2 cm^3 of unknown liquid is then poured into one leg of the manometer, and a displacement of 5 cm is measured between the surfaces as shown in the sketch. For these conditions, what is the specific gravity of the unknown liquid?



Q3. The density of a liquid is to be determined by an old 1-cm-diameter cylindrical hydrometer whose division marks are completely wiped out. The hydrometer is first dropped in water, and the water level is marked. The hydrometer is then dropped into the other liquid, and it is observed that the mark for water has risen 0.3 cm above the liquid-air interface. If the height of the original water mark is 12.3 cm, determine the density of the liquid in (kg/m^3).



Q4. A flow field has velocity components of $u = -(4x + 6)$ m/s and $v = 10y$ m/s where x and y are in meters.

(a) Determine the equation for the streamline that passes through point (1 m, 1 m).

(b) Find the acceleration of a particle at the same point.

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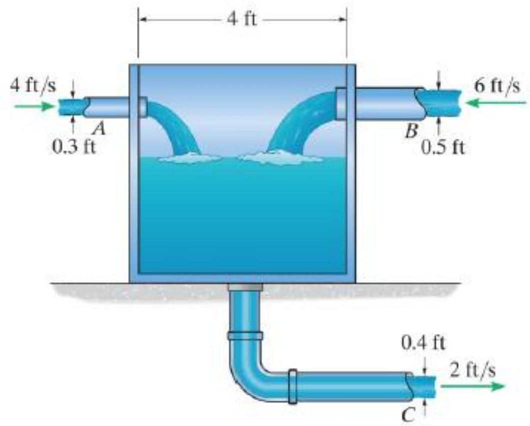
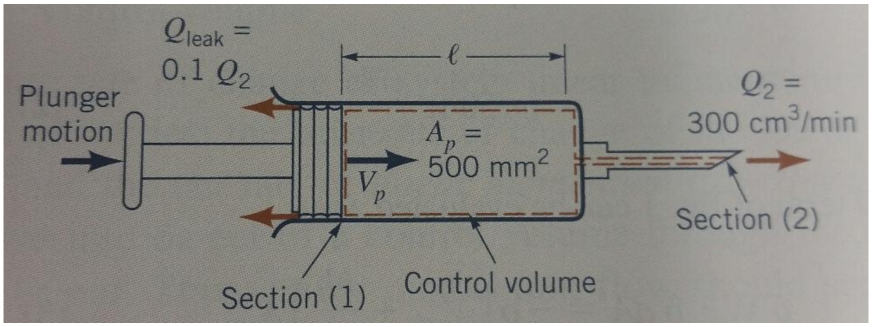
Q5. Three circular pipes are connected to the rectangular water tank as shown in the sketch. If the average velocities of water flowing through the pipes are v_A= 4 ft/s, v_B=6 ft/s and v_C=2 ft/s, determine the rate (ft/s) at which the water level in the tank changes. The tank has a width of 3.5 ft (into the page)



Q6. A syringe in used to inoculate a cow. The plunger has a face area of 500 mm^2. The liquid in the syringe is to be injected steadily at a rate of 300 cm^3/min. The leakage rate past the plunger is 0.1 times the volume flowrate out of the needle. With what speed in (mm/min) should the plunger be advanced?



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DIMENSION	METRIC	METRIC/ENGLISH
Viscosity, kinematic	1 m^2/s = 10^4 cm^2/s 1 stoke = 1 cm^2/s = 10^{-4} m^2/s	1 m^2/s = 10.764 ft^2/s = 3.875 × 10^4 ft^2/h 1 m^2/s = 10.764 ft^2/s
Volume	1 m^3 = 1000 L = 10^6 cm^3 (cc)	1 m^3 = 6.1024 × 10^4 in^3 = 35.315 ft^3 = 264.17 gal (U.S.) 1 U.S. gallon = 231 in^3 = 3.7854 L 1 fl ounce = 29.5735 cm^3 = 0.0295735 L 1 U.S. gallon = 128 fl ounces
Volume flow rate	1 m^3/s = 60,000 L/min = 10^6 cm^3/s	1 m^3/s = 15,850 gal/min = 35.315 ft^3/s = 2118.9 ft^3/min (CFM)

*Exact conversion factor between metric and English units.

Some Physical Constants

PHYSICAL CONSTANT	METRIC	ENGLISH
Standard acceleration of gravity	g = 9.80665 m/s^2	g = 32.174 ft/s^2
Standard atmospheric pressure	P_{atm} = 1 atm = 101.325 kPa = 1.01325 bar = 760 mm Hg (0°C) = 10.3323 m H_2O (4°C)	P_{atm} = 1 atm = 14.696 psia = 2116.2 lbf/ft^2 = 29.9213 inches Hg (32°F) = 406.78 inches H_2O (39.2°F)
Universal gas constant	R_u = 8.31447 kJ/kmol · K = 8.31447 kN · m/kmol · K	R_u = 1.9859 Btu/lbmol · R = 1545.37 ft · lbf/lbmol · R

Commonly Used Properties

PROPERTY	METRIC	ENGLISH
Air at 20°C (68°F) and 1 atm		
Specific gas constant*	R_{air} = 0.2870 kJ/kg · K = 287.0 m^2/s^2 · K	R_{air} = 0.06855 Btu/lbm · R = 53.34 ft · lbf/lbm · R = 1716 ft^2/s^2 · R
Specific heat ratio	$k = c_p/c_v$ = 1.40	$k = c_p/c_v$ = 1.40
Specific heats	c_p = 1.007 kJ/kg · K = 1007 m^2/s^2 · K c_v = 0.7200 kJ/kg · K = 720.0 m^2/s^2 · K	c_p = 0.2404 Btu/lbm · R = 187.1 ft · lbf/lbm · R = 6019 ft^2/s^2 · R c_v = 0.1719 Btu/lbm · R = 133.8 ft · lbf/lbm · R = 4304 ft^2/s^2 · R
Speed of sound	c = 343.2 m/s = 1236 km/h	c = 1126 ft/s = 767.7 mi/h
Density	ρ = 1.204 kg/m^3	ρ = 0.07518 lbm/ft^3
Viscosity	μ = 1.825 × 10^{-5} kg/m · s	μ = 1.227 × 10^{-5} lbm/ft · s
Kinematic viscosity	ν = 1.516 × 10^{-5} m^2/s	ν = 1.632 × 10^{-4} ft^2/s
Liquid water at 20°C (68°F) and 1 atm		
Specific heat ($c = c_p = c_v$)	c = 4.182 kJ/kg · K = 4182 m^2/s^2 · K	c = 0.9989 Btu/lbm · R = 777.3 ft · lbf/lbm · R = 25,009 ft^2/s^2 · R
Density	ρ = 998.0 kg/m^3	ρ = 62.30 lbm/ft^3
Viscosity	μ = 1.002 × 10^{-3} kg/m · s	μ = 6.733 × 10^{-4} lbm/ft · s
Kinematic viscosity	ν = 1.004 × 10^{-6} m^2/s	ν = 1.081 × 10^{-5} ft^2/s

* Independent of pressure or temperature

Conversion Factors

DIMENSION	METRIC	METRIC/ENGLISH
Acceleration	1 m/s² = 100 cm/s²	1 m/s² = 3.2808 ft/s² 1 ft/s² = 0.3048* m/s²
Area	1 m² = 10⁴ cm² = 10⁶ mm² = 10⁻⁶ km²	1 m² = 1550 in² = 10.764 ft² 1 ft² = 144 in² = 0.09290304* m²
Density	1 g/cm³ = 1 kg/L = 1000 kg/m³	1 g/cm³ = 62.428 lbm/ft³ = 0.036127 lbm/in³ 1 lbm/in³ = 1728 lbm/ft³ 1 kg/m³ = 0.062428 lbm/ft³
Energy, heat, work, and specific energy	1 kJ = 1000 J = 1000 N · m = 1 kPa · m³ 1 kJ/kg = 1000 m²/s² 1 kWh = 3600 kJ	1 kJ = 0.94782 Btu 1 Btu = 1.055056 kJ = 5.40395 psia · ft³ = 778.169 lbf · ft 1 Btu/lbm = 25,037 ft²/s² = 2.326* kJ/kg 1 kWh = 3412.14 Btu
Force	1 N = 1 kg · m/s² = 10⁵ dyne 1 kgf = 9.80665 N	1 N = 0.22481 lbf 1 lbf = 32.174 lbm · ft/s² = 4.44822 N 1 lbf = 1 slug · ft/s²
Length	1 m = 100 cm = 1000 mm = 10⁶ μm 1 km = 1000 m	1 m = 39.370 in = 3.2808 ft = 1.0926 yd 1 ft = 12 in = 0.3048* m 1 mile = 5280 ft = 1.6093 km 1 in = 2.54* cm
Mass	1 kg = 1000 g 1 metric ton = 1000 kg	1 kg = 2.2046226 lbm 1 lbm = 0.45359237* kg 1 ounce = 28.3495 g 1 slug = 32.174 lbm = 14.5939 kg 1 short ton = 2000 lbm = 907.1847 kg
Power	1 W = 1 J/s 1 kW = 1000 W = 1 kJ/s 1 hp† = 745.7 W	1 kW = 3412.14 Btu/h = 1.341 hp = 737.56 lbf · ft/s 1 hp = 550 lbf · ft/s = 0.7068 Btu/s = 42.41 Btu/min = 2544.5 Btu/h = 0.74570 kW 1 Btu/h = 1.055056 kJ/h
Pressure or stress, and pressure expressed as a head	1 Pa = 1 N/m² 1 kPa = 10³ Pa = 10⁻³ MPa 1 atm = 101.325 kPa = 1.01325 bar = 760 mm Hg at 0°C = 1.03323 kgf/cm² 1 mm Hg = 0.1333 kPa	1 Pa = 1.4504 × 10⁻⁴ psi = 0.020886 lbf/ft² 1 psi = 144 lbf/ft² = 6.894757 kPa 1 atm = 14.696 psi = 29.92 inches Hg at 30°F 1 inch Hg = 13.60 inches H_2O = 3.387 kPa
Specific heat	1 kJ/kg · °C = 1 kJ/kg · K = 1 J/g · °C	1 Btu/lbm · °F = 4.1868 kJ/kg · °C 1 Btu/lbmol · R = 4.1868 kJ/kmol · K 1 kJ/kg · °C = 0.23885 Btu/lbm · °F = 0.23885 Btu/lbm · R
Specific volume	1 m³/kg = 1000 L/kg = 1000 cm³/g	1 m³/kg = 16.02 ft³/lbm 1 ft³/lbm = 0.062428 m³/kg
Temperature	T(K) = T(°C) + 273.15 ΔT(K) = ΔT(°C)	T(R) = T(°F) + 459.67 = 1.8T(K) T(°F) = 1.8 T(°C) + 32 ΔT(°F) = ΔT(R) = 1.8* ΔT(K)
Velocity	1 m/s = 3.60 km/h	1 m/s = 3.2808 ft/s = 2.237 mi/h 1 mi/h = 1.46667 ft/s 1 mi/h = 1.6093 km/h
Viscosity, dynamic	1 kg/m · s = 1 N · s/m² = 1 Pa · s = 10 poise	1 kg/m · s = 2419.1 lbm/ft · h = 0.020886 lbf · s/ft² = 0.67197 lbm/ft · s