NAME: ______________________________

CE 3305 – Fluid Mechanics

Exam#3

Useful data or equations

Atmospheric pressure	$P_{atm} = 10^5$ Pa	*Total pressure*
Gravity	$g = 9.81\ m.s^{-2}$	
Water density	$\rho_w = 1000\ kg.m^{-3}$	*At standard conditions*
Air density	$\rho_a = 1.42\ kg.m^{-3}$	*At standard conditions*
Water viscosity	$\mu = 1.0 * 100^{-3}\ SI$	*At standard conditions*

Buoyancy equation

$$F_B = \rho_f V_{imm} g$$

Continuity equation

$$\frac{dm}{dt} = \dot{m}_{in} - \dot{m}_{out}$$

Momentum equation

$$\frac{d(m\vec{v})_{CV}}{dt} = \dot{m}_{in}\vec{v}_{in} - \dot{m}_{out}\vec{v}_{out} + \sum \vec{F}$$

Energy equation

$$\left(\frac{P_1}{\rho g} + \alpha_1 \frac{\overline{v_1}^2}{2g} + z_1\right) + h_P = \left(\frac{P_2}{\rho g} + \alpha_2 \frac{\overline{v_2}^2}{2g} + z_2\right) + h_t + h_L$$

$$\mathcal{P}_{turbine} = \rho g Q h_t$$

$$\mathcal{P}_{pump} = \rho g Q h_p$$
$$\eta = \mathcal{P}_{useful} / \mathcal{P}_{required}$$

$$h_{L_{major}} = f \frac{L}{D} \frac{\bar{v}^2}{2g};\ h_{L_{minor}} = K \frac{\bar{v}^2}{2g}$$

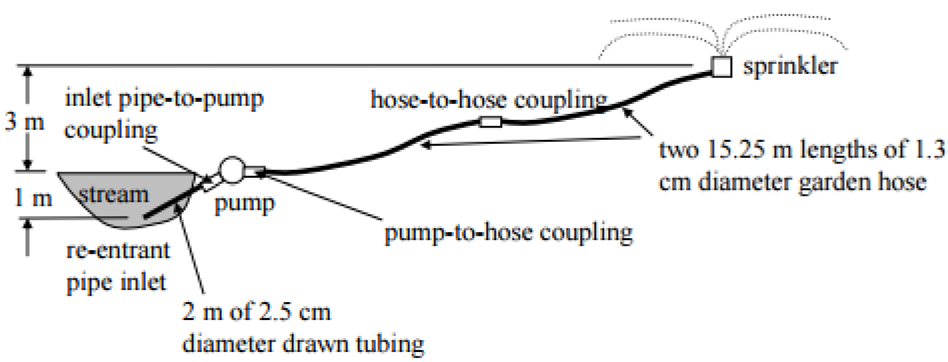
Head loss coefficients for energy equation:

Name	*Symbol*	*Value*
Friction factor (for steel)	f	0.015

Outlet	K	1
Inlet	K	0.8
Pipe to pump connection	K	0.1
Pipe to hose connection	K	0.2
Hose to hose connection	K	0.5
Valve ½ open	K	16
90º elbow	K	8

Problem 1

A homeowner plans to pump water from a stream in their backyard to water their lawn. A schematic of the pipe system is shown in the figure. The sprinkler diameter is 4mm and the pressure drop across it is 210kPa. The flow rate in the system is $2.5 * 10^{-4} m^3/s$. The pump efficiency is 80%. The water is leaving the sprinkler by making a jet and the kinetic correction coefficient value is 1.1.



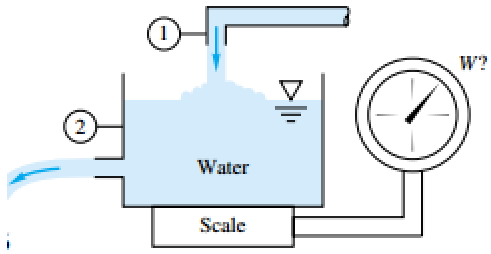
[10 pts] What is the head loss value associated with the sprinkler?

[20 pts] Assume that the pipe is in steel, what is the electrical power required by the pump? (Assume that the head pump is constant).

Problem 2

An urban legend says that if you throw a penny off the top of the Empire State Building it will have enough momentum when it reaches the ground to seriously harm a person. Use the equations of motion for a projectile with aerodynamic drag to calculate the speed of the penny when it hits the ground. Also calculate how far the penny has traveled when it reaches terminal velocity. For how long is the penny in the air? Treat the penny as a flat disk with the front face moving normal to the flow. The diameter of a penny is 19.05 mm, and it's mass is 2.5 g. Assume the penny is dropped from rest at the top of the building a height of 375 m. *Hint: you can exactly integrate the projectile's equation of motion in this case. You should get the velocity as a function of time in terms of the hyperbolic tangent. Assume a drag coefficient of 1.17 for the penny.*

Problem 3

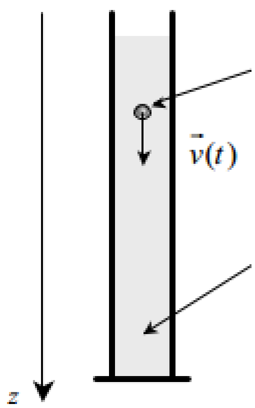


The tank weighs 50 kg empty and contains 0.6m^3 of water. Pipes 1 and 2 have equal diameters of 0.06 m and equal steady volume flows rate of 300m^3.h^(-1).

What should the scale reading W be in Newton?

Problem 4

We want to study the fall of a metallic sphere in a specific liquid, dropped with no initial velocity in a tube filled with a liquid. You are given a sphere with the following properties:



$$d_{sphere} = d_s = 0.1m;\ \rho_{sphere} = \rho_s = 7800\ kg.m^{-3}$$

We consider the drag force:

$$F_D = \frac{1}{2}\rho_f C_D S v^2; Re > 1000$$

or

$$F_D = 6\pi\ R\ \mu_f\ v; Re < 1000$$

Where CD=0.3 for a sphere and S=πr^2.

Using a force balance (gravity, buoyancy, drag), find the terminal velocity of the sphere in water and glycerin. Compute the Reynolds number in each case to make sure you are using the good formulas.

$$\rho_{gl} = 1260\ kg.m^{-3}; \mu = 1.49\ kg.m^{-1}.s^{-1}$$

$$\rho_w = 1000 kg.m^{-3};\ \mu_w = 10^{-3} kg.m^{-1}.s^{-1}$$

Using Bernoulli equation, find the difference of pressure $\Delta P = P_{front} - P_{bottom}$ between the front and the bottom of the sphere. Assume the fluid is not disturbed far from the fluid.