Laboratory Exercise 1 – Fluid Mechanics Laboratory

The purpose of this laboratory is to verify Bernoulli's principle for fluids using the microcontroller board, and sensor board. Bernoulli's principle can be derived from the principle of conservation of energy, and states that for an inviscid flow, an increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy. The mathematical equation below can be derived from Bernoulli's principle for incompressible flows:

$$\frac{v^2}{2} + gz + \frac{p}{\rho} = \text{constant}$$

where:

v is the fluid flow speed at a point on a streamline
g is the acceleration due to gravity
z is the elevation of the point above a reference plane, with the positive z-direction pointing upward - so in the direction opposite to the gravitational acceleration
p is the pressure at the chosen point, and
ρ is the density of the fluid at all points in the fluid

It is important to note that the above equation only applies to steady, incompressible flows. A steady flow is defined as a flow in which the velocity does not change with time.

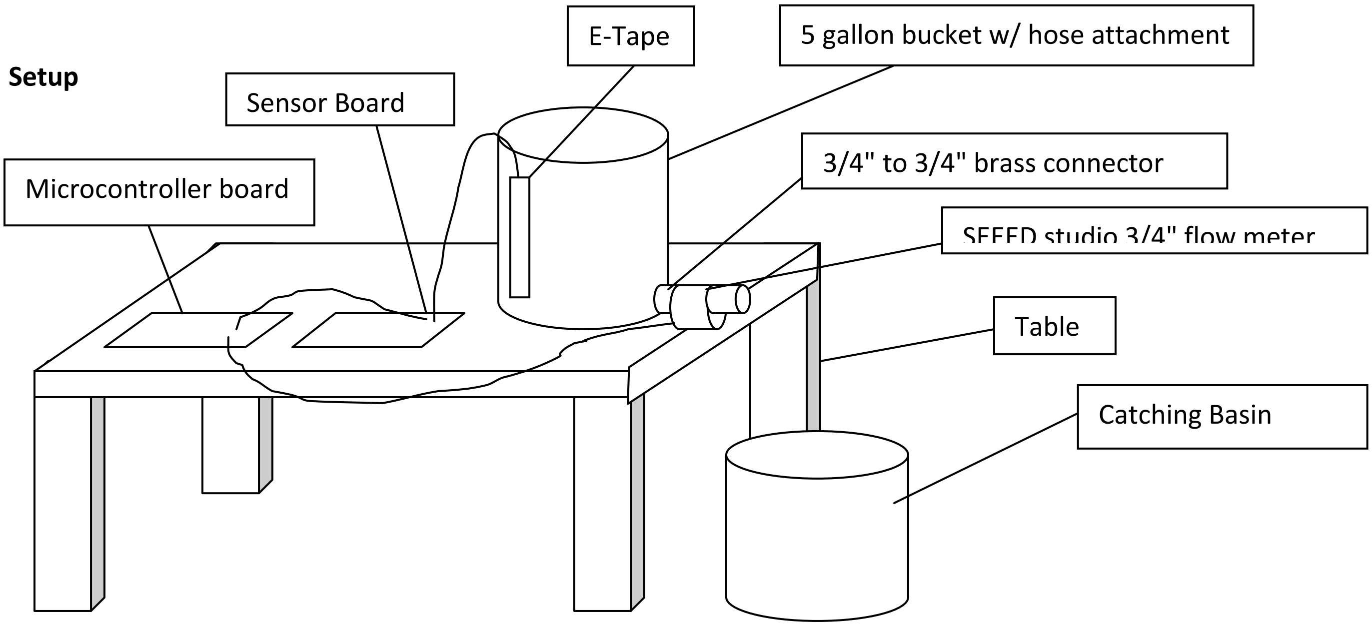
Apparatus

Materials

- 5 gallon bucket with hose attachment
- SEEED studio 3/4" flow meter
- Sink/Catching Basin
- Gilmour double female swivel brass connector 3/4" by 3/4"
- 12" E tape
- Wires
- Ribbon Cable
- Resistor
- Water
- Sensor Board
- Microcontroller Board

Note: 5 gallon bucket w/ hose attachment is available on amazon.com for $19.99. SEEED studio water flow meter is available on www.robotshop.com for $14.90. E-tape is available at http://www.milonetech.com.

Setup



Notes: An appropriate resistor will have to be selected based on the voltage divider circuit shown in the sensor board manual for the resistive sensor module. The E-tape is connected to the resistive module on the sensor board, and its output is connected to RA1 on the microcontroller board. The flow meter is directly attached to RA0 on the microcontroller board to be converted to a digital signal via the ADC module.

Procedure

Below is a snippet from the sample code for pic16f877 that should be put on the microcontroller before continuing the procedure. The complete code can be found in the samples folder

```
main(void)
{

TRISB = 0b11111111;
TRISD = 0;
TRISC = 0;
lcd_init();
lcd_clear();
lcd_puts("Press * to start");
unsigned char counter1 = 0;
unsigned char counter2 = 0;
unsigned char counter3 = 0;
unsigned char counter4 = 0;
unsigned char addresscounter = 0;
unsigned char Pressed = 0;
```

```
{
	while(RB1 == 0) //Check if a key is pressed
	{
		;
	}
	if( (PORTB>>4) == 0b1100)
	{
		Pressed = 1;
	}
}
while(RB1 != 0)  //wait for key to be released
{
	;
}
Pressed = 0;
lcd_clear();
lcd_puts("Press * to stop");
while(Pressed == 0)
{
	while(RB1 == 0) //Check if a key is pressed
	{
		counter1++;
		if(counter1 == 100)
		{
			counter2++;
			if(counter2 == 100)
			{
				counter3++;
				if(counter3 == 75)
				{
				counter4++;
				lcd_clear();
				unsigned char FlowRate = Get_Flow_Rate();
				unsigned char WaterLevel = Get_Height();
				EEPROM_WRITE(addresscounter,FlowRate);
				addresscounter++;
				EEPROM_WRITE(addresscounter,WaterLevel);
				if(addresscounter == 255)
				{
					Done();
				}
```

```
                    addresscounter++;
                    unsigned char lcd_buffer1[16];
                    sprintf(lcd_buffer1,"%d",WaterLevel);
                    unsigned char lcd_buffer2[16];
                    sprintf(lcd_buffer2,"%d",FlowRate);
                    lcd_puts("Height: ");
                    lcd_puts(lcd_buffer1);
                    lcd_goto(0x40);
                    lcd_puts("Flowrate: ");
                    lcd_puts(lcd_buffer2);
                    counter3 = 0;
                    }
                    counter2 = 0;
                }
                counter1 = 0;
            }
        }
        if( (PORTB>>4) == 0b1100)
        {
            Pressed = 1;
        }
        while(RB1 != 0) //wait for key to be released
        {
            ;
        }
}
Pressed = 0;
Done();
}
```

Part I – Measuring Flow Rates

- Turn on the sensor board to monitor the height of the water
- Turn on the microcontroller board to monitor the flow meter
- Pour water into the top reservoir
- Press * on the microcontroller board to obtain measurements of flow rate and water level
- Press * on the microcontroller board to stop taking measurements
- Obtain the measurements from the EEPROM memory
- Repeat the experiment at different water levels

Part 2 – Verifying Bernoulli's law

Having obtained the appropriate measurements in part 1, Bernoulli's law can now be verified. The microcontroller board will automatically take readings of the height and flow meter every 5 seconds and save them in the EEPROM memory. The following is a derivation for the relationship between the height of the water and velocity of the flow from Bernoulli's law.

$$\frac{v^2}{2} + gz + \frac{p}{\rho} = \text{constant}$$

Taking one point to be the top of the bucket, and the second point to be the flow from the top bucket, with a reference point of the bottom of the top bucket yields:

$0.5\rho v_{top}^2 + \rho gh + p_{atm} = 0.5\rho v_{bottom}^2 + \rho g(0) + p_{atm}$

V_{top} can be approximated as 0, and therefore the equation above can be rearranged and solved for $V_{bottom.}$

$\rho gh + p_{atm} = 0.5\rho v_{bottom}^2 + \rho g(0) + p_{atm}$

$\rho gh = 0.5\rho v_{bottom}^2$

$2gh = v_{bottom}^2$

$v_{bottom} = (2gh)^{1/2}$

Perform a % difference calculation for each pair of flow rate and height, and determine whether the experiment validates Bernoulli's law.