Laboratory Exercise 4 – Civil Engineering Laboratory

The purpose of this laboratory is to examine the relationship between the force exerted on a beam and the beams relative deflection. Civil engineers calculate deflections of beams all the time to ensure that the structures they build are safe for the given loads. The apparatus will be set up as described below.

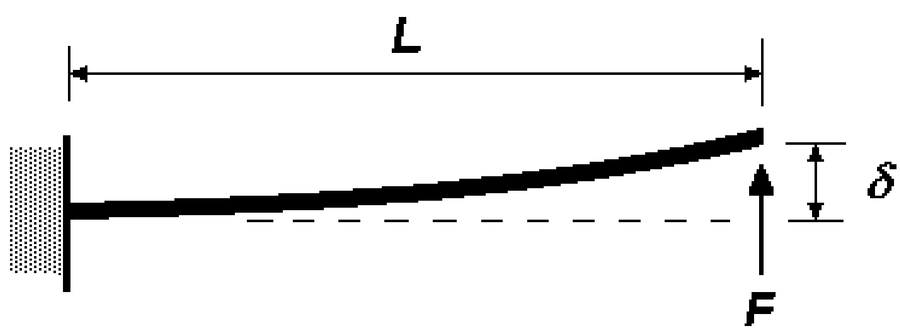
Apparatus

Materials

- Force Sensor
- Thin pine beam
- Thin aluminum beam
- Linear Actuator
- Clamps
- 2x4 piece of wood
- screws

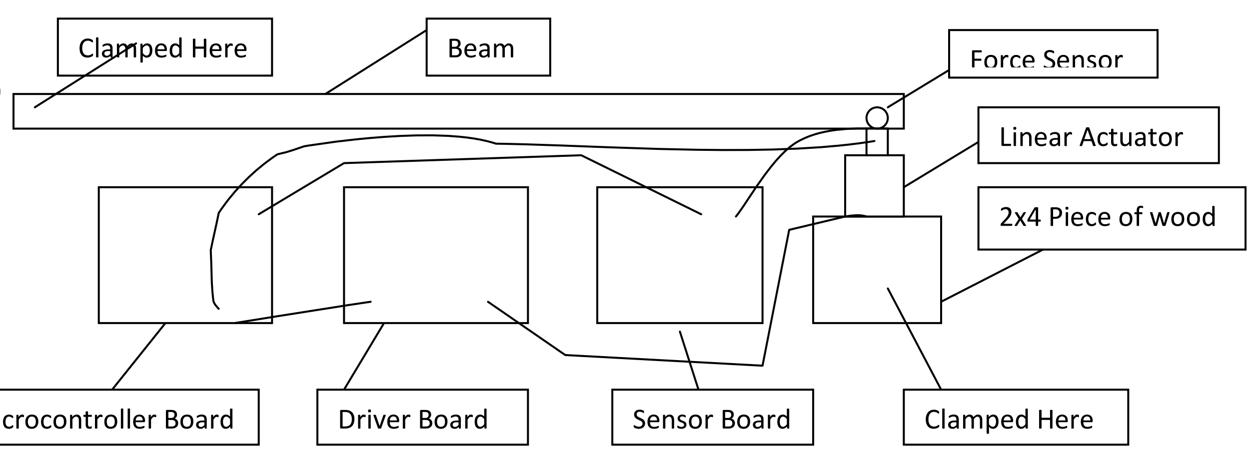
Notes: A force sensor can be readily obtained from www.robotshop.com for $14.55. A linear actuator can also be obtained from www.firgelli.com for ~$70.

Part I - Cantilever



Setup

(Top View)



The linear actuator should be attached to the DC1 motor module of the driver board. The force sensor should be attached to the resistive module of the sensor board, and its output should be attached to RA0 on the microcontroller board. The position feedback of the linear actuator should be attached to RA1 on the microcontroller board.

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(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
	{
		RC1 = 1;
		counter1++;
		if(counter1 == 100)
		{
			counter2++;
			if(counter2 == 100)
			{
				counter3++;
				if(counter3 == 35)
				{
				counter4++;
				RC1 = 0;
				__delay_ms(1000);
	//Delay 2 seconds
				__delay_ms(1000);
				lcd_clear();
				unsigned char SensorForce = Get_Force();
				unsigned char SensorHeight = Get_Height();
				EEPROM_WRITE(addresscounter,SensorForce);
				addresscounter++;
				EEPROM_WRITE(addresscounter,SensorHeight);
				if(addresscounter==10)
				{
					Done();
				}
				addresscounter++;
				unsigned char lcd_buffer1[16];
				sprintf(lcd_buffer1,"%d",SensorForce);
				unsigned char lcd_buffer2[16];
				sprintf(lcd_buffer2,"%d",SensorHeight);
				lcd_puts("Force: ");
				lcd_puts(lcd_buffer1);
				lcd_goto(0x40);
				lcd_puts("Height: ");
				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();
}
```

- Set up the apparatus as shown in the Setup section
- press * to start the experiment
- Retrieve data from EEPROM
- Repeat experiment for other beams/lengths

In part I, the relationship between force exerted on the end of a cantilever, and the deflection of the cantilever is examined. The following equation governs this relationship:

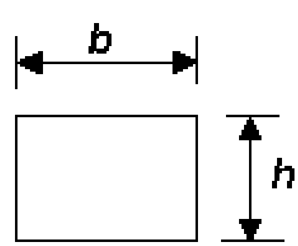
$\delta = FL^3/3EI$

where δ is the deflection of the beam
F is the force exerted on the beam
L is the length of the beam
E is the modulus of Elasticity of the beam
and I is the moment of inertia of the beam

The modulus of Elasticity is a property of the material, and for aluminum and pine wood it is 69 GPa and 11 GPa respectively.

The Moment of inertia for a rectangular section is determined by the equation:

I = bh3/12



where I is the moment of inertia
h is the dimension in the plane of bending
and b is the dimension not in the plane of bending

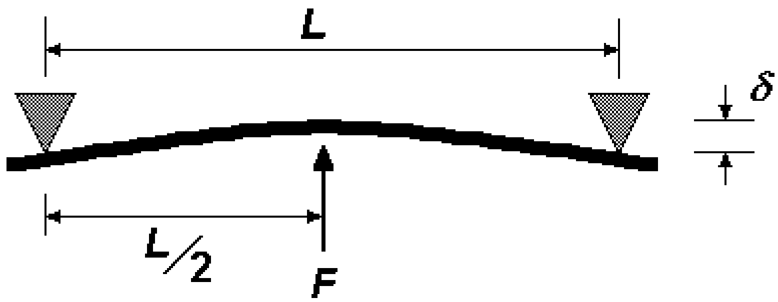
Discussion Questions

1. Graph deflection of the beam vs. the force exerted. Is the relationship linear? Comment on why or why not.

2. How close are the theoretical deflections to the actual deflections measured? Comment on the differences.

Part II - Load at the centre of a beam

Repeat part I, this time supporting the beam in between two supports of even heights. It is important that these supports must allow the beam to move freely, unlike the fixed support of the clamp. The linear actuator should also be positioned in a manner such that it is positioned over the middle of the beam and pushing downwards. The code must also be altered to make the linear actuator move much less.



The beam should resemble the figure above, but inverted.

In part II, the relationship between force exerted on the middle of a simply supported beam and the deflection of the beam is examined. The following equation governs this relationship:

$\delta = FL^3/48EI$

where δ is the deflection of the beam
F is the force exerted on the beam
L is the length of the beam
E is the modulus of Elasticity of the beam
and I is the moment of inertia of the beam

Discussion Questions

1. Graph deflection of the beam vs. the force exerted. Is the relationship linear? Comment on why or why not.

2. How close are the theoretical deflections to the actual deflections measured? Comment on the differences.