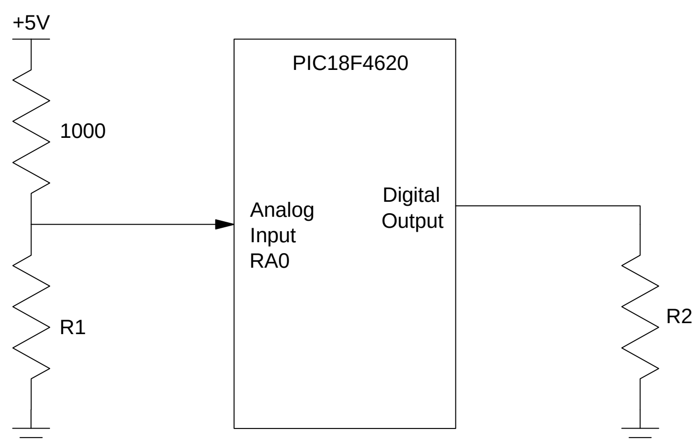
ECE 376 - Solution to Homework #1

PIC Background. Due Monday, August 28th

	Answer
1) A PIC processor can drive up to 25mA on its I/O pins. Assuming the output is 5V, what is the smallest R2 can be?	1) 200 Ohms
2) The PIC processor we're using can measure time to 100ns. (Each instruction takes 100ns to execute) Human reflex time is about 1/4 second. How many instructions does a PIC execute before you can react?	2) 2,500,000
3) Suppose you use a PIC to measure how high you can jump. What is the resolution in distance assuming that you can jump 500mm?	3) 157 nm 0.000 000 157 m
4) The PIC processor we're using also has a 10-bit analog input with a range of 0V-5V, meaning that 0V reads 0 and 5V reads as 1023. The resolution on the A/D is 4.88mV (5V/1024). Suppose you use your PIC to measure resistance using a voltage divider shown below. If R1 is 1000 Ohms, what is the resolution of the ohm-meter? (Can you detect the difference between 1000 Ohms and 1001 Ohms - i.e. does that difference cause the voltage to change by 4.88mV?)	4) 3.91 Ohms
5) If R1 is a temperature sensor (in your kit) with $R \approx 1000 \cdot \exp\left(\frac{3903}{T} - \frac{3903}{298}\right)$ where T is the temperature in degrees Kelvin, what is the smallest change in temperature you can measure at 25C (298 Kelvin)? (Can you detect the difference between 25C and 25.1C - i.e. does that difference cause the voltage to change by 4.88mV?)	5) 0.088C



Problem 1) A PIC processor can drive up to 25mA on its I/O pins. Assuming the output is 5V, what is the smallest R2 can be?

$$R = \frac{5V}{25mA} = 200\Omega$$

Problem 2) The PIC processor we're using can measure time to 100ns. (Each instruction takes 100ns to execute) Human reflex time is about 1/4 second. How many instructions does a PIC execute before you can react?

$$\#\text{clocks} = \left(10,000,000\frac{\text{clocks}}{\text{sec}}\right)(0.25\,\text{sec}) = 2,500,000\text{clocks}$$

The PIC processor we're using can execute 2.5 million instructions in the time it takes you to react.

Problem 3) Suppose you use a PIC to measure how high you can jump. What is the resolution in distance assuming that you can jump 500mm?

From physics

$$h = \tfrac{1}{2}at^2$$

This is for half of the time you're in the air. For the total time you're in the air

$$h = \tfrac{1}{2}a\left(\tfrac{t}{2}\right)^2$$

$$h = \tfrac{1}{8}at^2$$

To jump 500mm

$$0.5m = \tfrac{1}{8}\cdot\left(9.8\tfrac{m}{s^2}\right)t^2$$

t_{total} = 0.638 876 565 seconds

The smallest time change you can detect is one clock (100ns). If the total time becomes 100ns longer

t_{total} = 0.638 876 **6**65 seconds

you're jump becomes (noting that the previous equation was for 1/2 of the time you're in the air

$$h = \tfrac{1}{2}a\left(\tfrac{t}{2}\right)^2 = 0.500\ 000\ 157 \text{ meters}$$

The difference is the resolution:

Resolution = 0.000 000 157 meters

You can also solve using derivatives to find the tangent at 500mm:

$$h = \frac{1}{8}at^2$$

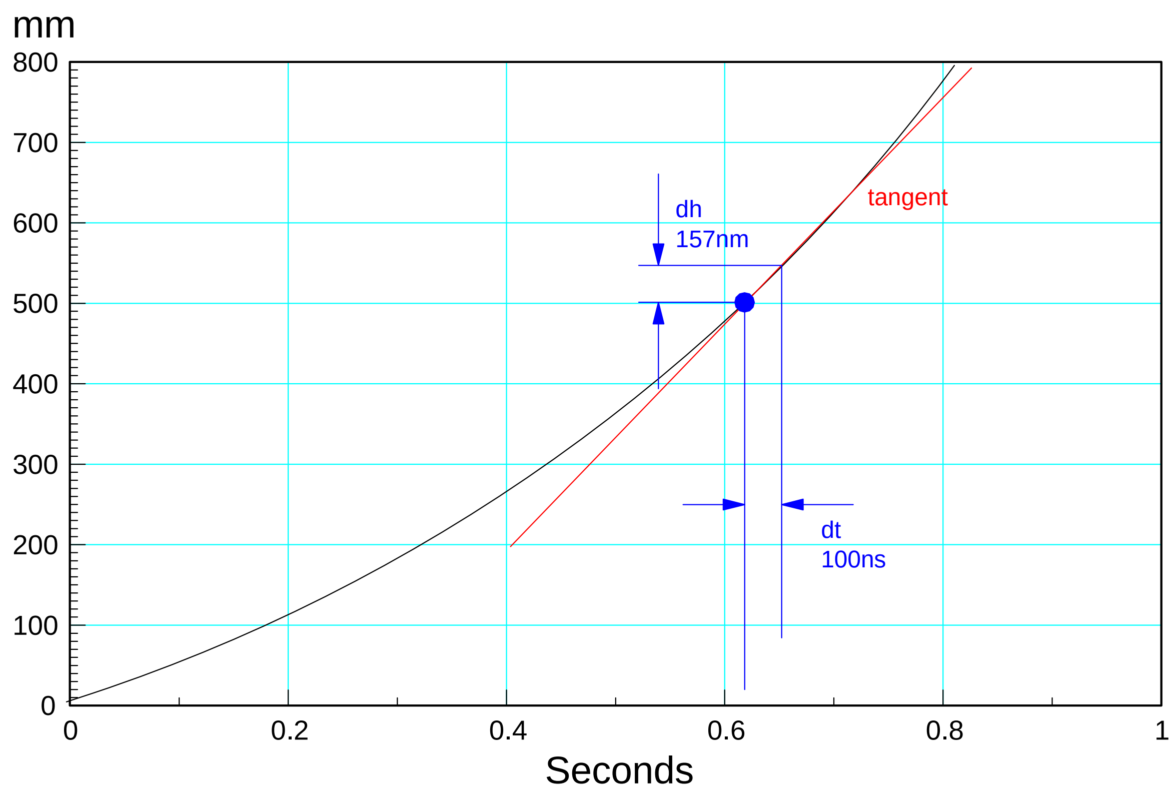
$$\frac{dh}{dt} = \frac{1}{4}at$$

$$dh = \frac{1}{4} \cdot a \cdot t \cdot dt$$

$$dh = (0.25)(9.8)(0.638876)(0.0000001) = 157nm$$

For comparison,

- A human hair is typically 30 to 100 microns (um) (Wikipedia). (1000x more)
- A bacteria is 0.5 to 5.0 microns (5x to32x)
- A virus is typically 400nm (3x)



Problem 4) The PIC processor we're using also has a 10-bit analog input with a range of 0V-5V, meaning that 0V reads 0 and 5V reads as 1023. The resolution on the A/D is 4.88mV (5V/1024). Suppose you use your PIC to measure resistance using a voltage divider shown below. If R1 is 1000 Ohms, what is the resolution of the ohm-meter? (Can you detect the difference between 1000 Ohms and 1001 Ohms - i.e. does that difference cause the voltage to change by 4.88mV?)

At 1000 Ohms, the voltage is

$$V = \left(\frac{R}{R+1000}\right) 5V = 2.5V$$

The smallest voltage change you can detect is 4.88mV. Find R so that

$$V = 2.50488 = \left(\frac{R}{R+1000}\right) 5V$$

$$R = \left(\frac{2.50488}{5-2.50488}\right) \cdot 1000\Omega$$

$$R = 1003.91\Omega$$

The resolution of the PIC when used as an Ohm meter in this configuration is 3.91 Ohms.

Problem 5) At 25C (298K), the resistance is 1000 Ohms (2.5000V)

The smallest voltage change you can detect is 4.88mV (2.5048V)

This corresponds to 1003.91 Ohms

Which corresponds to

$$R = 1003.91\Omega = 1000 \cdot \exp\left(\frac{3903}{T} - \frac{3903}{298}\right)$$

$$T = 297.91K = 24.91C$$

The difference is the resultion: you can detect a temperature change of 0.088C