1. A Philips 89c51rd2 is running with a 20 Mhz crystal. Module 0 is functioning in pwm mode with the pwm signal output connected to a low pass RC filter to produce a digital to analog converter.
   
a) What is the Highest frequency $f_o$ that module 0 can output to the filter?
   $\frac{OSC}{2} = \frac{20 MHz}{2} = 10 MHz \quad f_o = \frac{10 MHz}{256} = 39.06 \text{ kHz}$

b) Assume the pwm output pulse amplitude is 5 volts. What is the smallest non-zero DC voltage that can be output by the digital to analog converter?
   $V_{dc} = \frac{5V \cdot \frac{T_c - 5V}{T_c \cdot 256}}{T_c} = 19.5 \text{ mV}$

c) If the filter cutoff frequency $\omega_c$ is one tenth the fundamental frequency of the pwm signal (needed to remove the fundamental frequency from the output of the pwm), what is the response time of the digital to analog converter?
   $\omega_c = \frac{2\pi f_o}{10} = 2.45 \times 10^6 \text{ Hz}
   - 2\pi RC
   - RC_{low pass} = \frac{R \cdot \ln 9}{10} = 89.5 \mu s$

2. A photo transistor (like the one discussed in class) has a 1k resistor connected between the emitter and ground. The collector is connected to +5 volts. When the sensor is placed in an environment with a certain low level illumination, the voltage at the emitter is .5 volts.
   
a) Assume the sensor is placed in a room with three times the illumination as mentioned above. What resistance value should be used to replace the 1k resistance so that the output will be 3 volts?
   $V_{out} = \frac{I_c R}{1k} \approx I_c 1k = .5 V \text{ volts}\$  \hspace{1cm} $I_c = \frac{.5}{1k} = .5 mA$

b) Assume a 1k resistor is connected between the collector and +5 volts and the emitter is connected to ground. The sensor is placed in the same illumination as described in a) above. What is the voltage at the collector of the transistor?
   $I_c = 1.5 mA$  \hspace{1cm} $V_c = 3.5 V$

2R = 2,500$
3. Sketch the circuitry needed to interface an ADC0848 analog to digital converter to an 89C51. Place the converter at memory location 0xF000. You may assume no external memory devices exist below 0x1000 but there may be some devices located at or above 0x1000. Connect the converter's pin 21 to P3.2 on the 89C51. Label all the signals needed for the interface.

4. Create the necessary C-51 modules main, and convert that will continuously trigger and read the converter described in problem 3 above. The main module should continually write the contents of the converter's analog value present on channel 5 (channels are 0 through 7) to port 1. Be sure to declare all variables used. Assume main and convert are different files in the same source group.

a) Code for main:
```
#include <AT89C51.h>

void main()
{
    while(1)
    {
        P1 = convert();
    }
}
```

b) Code for convert:
```
#include <AT89C51.h>

sbit mot_done = 0x82;

unsigned char convert()
{
    unsigned char xdata *ADC = 0xF000;
    *ADC = 0x0D;  // channel 5 single ended mode
    while (mot_done);
    return *ADC;
```
5. A C-51 project with comprised of three modules is shown below: Assume the code is running on an 89c51rd2 system in x2 mode and with a 12 Mhz crystal.

a) What PCA module is being used and how is it being used?

```
module 0 software timer for pwm
```

b) Sketch the signal out_bit showing the high time and the period.

```
\[ T = 10\text{ms} \]
\[ T_{\text{pcu}} = \frac{1}{2} \text{us} \]
\[ \text{cmod} \rightarrow \text{osc/6} \]
\[ T_{\text{per}} = \frac{1}{2} \text{us} = 500 \text{us} = 0.5 \text{ms} \]
\[ T = 2 \times \frac{1}{2} \times 1000 = 1000 \text{us} = 1 \text{ms} \]
```

c) Explain how you would modify the code to produce a pwm signal with a 2 ms high time and a 15 ms period.

```
high_time = 4000; // 4000 \times \frac{1}{2} \text{us} = 2 \text{ms}
```

```
\#define period 15000; // 15,000 \times \frac{1}{2} \text{us} = 15 \text{ms}
```

```c
extern void initialize_pca();
unsigned int high_time;
void main()
{
    initialize_pca();
    high_time = 1000;
    while(1);
}

#include<at89c51xd2.h>

\#define period 10000*2;
extern unsigned int high_time;
sbit out_bit = 0x97;
void pulse_interrupt() interrupt 6 using 1
{
    unsigned int PCA_time;
```
```