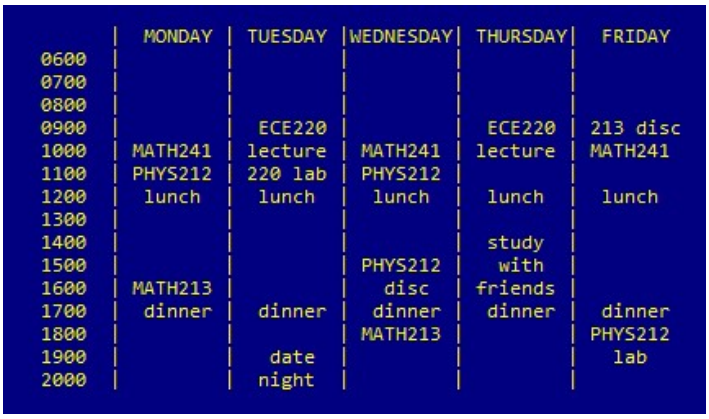
ECE220: Computer Systems & Programming **Fall 2018 ZJUI**
Machine Problem 1 **due: Saturday 26 September, 11:59:59 p.m.**

Printing Subroutines



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
0600					
0700					
0800					
0900		ECE220		ECE220	213 disc
1000	MATH241	lecture	MATH241	lecture	MATH241
1100	PHYS212	220 lab	PHYS212		
1200	lunch	lunch	lunch	lunch	lunch
1300					
1400				study	
1500			PHYS212	with	
1600	MATH213		disc	friends	
1700	dinner	dinner	dinner	dinner	dinner
1800			MATH213		PHYS212
1900		date			lab
2000		night			

Your task this week is to write two subroutines to support printing of a student's daily schedule. One subroutine prints an hour, such as "0600" or "1200", preceded by three spaces and followed by two spaces. The second subroutine prints an arbitrary string centered in nine spaces, truncating the string or adding extra space characters as necessary. Together, the two subroutines require about 100 lines of LC-3 assembly, including comments. In the next two MPs, you will make use of these subroutines.

The objective for this week is to give you some experience with decomposing tasks into algorithms, with writing LC-3 assembly code, and with formatting output.

The Task

The first subroutine is PRINT_SLOT. A number from 0 to 14 is passed to your subroutine in R1. The number corresponds to one of the rows of a schedule, as shown in the figure above. Your subroutine must print the time corresponding to the specified slot. If R1=0, for example, your subroutine must print "0600" preceded by three spaces (ASCII x20) and followed by two trailing spaces.

The second subroutine is PRINT_CENTERED. A string (the address of the first ASCII character in sequence terminated by an ASCII NUL, x00) is passed to your subroutine in R1. Your subroutine must print exactly nine characters. If the string is longer than nine characters, your subroutine must print the first nine characters. If the string is shorter than nine characters, your subroutine must print additional spaces around the string to bring the total length to nine characters. If the number of spaces needed is odd, the subroutine must use one more leading space than trailing space.

To make your life easier in the later MPs, neither of these subroutines may change any register values. In other words, except for R7, which is modified by JSR, both subroutines must preserve all bits in all other registers. Note that you are probably going to want to use TRAP instructions in both subroutines, so you should also preserve the return address (in R7) and restore it before executing the RET (JMP R7) instruction.

You may find it useful to develop look-up tables for one or both of these subroutines. A look-up table specifies a function from a small, contiguous set of integers to an arbitrary result type. For example, in a later MP, you might use a look-up table to translate an integer from 0 to 4 into one of the day names at the top of the schedule in the figure ("MONDAY", "TUESDAY", and so forth). If each element in a look-up table requires a single memory address, one can add the index to the base address for the table to find the address at which the desired element is stored.

You may want to use a look-up table to translate string length into a count of leading spaces, for example.

You may also find it tempting to use a look-up table of strings for slots. While such an approach is acceptable, we encourage you to think about other ways to generate the hour output.

As you develop your subroutines, you may want to include code to test them at the start of the assembly file. Since the LC-3 will begin execution at the start of the file by default, you can then easily test your subroutines with the LC-3 tools.

Specifics

- Your code must be written in LC-3 assembly language and must be contained in a single file called **`mp1.asm`**. We **will not grade** files with any other name.
- Your subroutine for printing one of the schedule slot hours must be called PRINT_SLOT.
    - You may assume that R1 (the slot number) holds a value from 0 to 14 when your subroutine is called.
    - Your subroutine must not change any register values other than R7.
    - Your subroutine must output exactly nine characters to the display, including three leading spaces, an appropriate hour number (R1+6 as a two-digit number, possibly including a leading zero), two zeroes, and two trailing spaces.
- Your subroutine for printing a string centered in nine characters must be called PRINT_CENTERED.
    - You may assume that the string starting at the address in R1 is valid and is terminated by an ASCII NUL character (x00, extended to x0000 in LC-3 memory).
    - You may NOT make any assumptions about string length. In particular, string length can be any non-negative integer, including 0.
    - Your subroutine must not change any register values other than R7.
    - Your subroutine must output exactly nine characters to the display. For strings longer than nine characters, the first nine characters should be displayed. For strings shorter than nine characters, leading and trailing spaces must be added to output nine total characters. For short, even-length strings, use one more leading space than trailing space.
- Your code must not execute data—any bits generated using .FILL, .STRINGZ, .BLKW, or other data-generating pseudo-ops or directives.
- Except for loads (NOT stores) from the string passed to PRINT_CENTERED, neither subroutine may access LC-3 memory outside of that allocated by your **`mp1.asm`** program. If you need space, use .FILL or .BLKW to create it, and use labels to address it.
- You may not assume anything about how many times either subroutine is called, nor about the sequence of calls to your subroutines, nor about the input values other than as specified here.
- Your code must be well-commented, and must include a table describing how registers are used within each subroutine. Follow the style of examples provided to you in class and in the textbook.
- You may leave any code that you have used for testing at the start of your file, provided that it does not in any way interfere with your subroutines' functionality.

Testing

Testing is your responsibility. We have provided a file called **`test1.asm`** that performs a basic test on your code. Instructions on how to use it are included at the start of the file, and you may want to generalize the approach to suit your own purposes in testing your code.

We suggest that you write a loop to output all possible values of the slot number for PRINT_SLOT. There are only 15 of them.

We also suggest that you test PRINT_CENTERED with strings of various lengths.

Grading Rubric

Functionality (65%)

- PRINT_SLOT
  - 15% - produces correct output for any slot number from 0 to 14 (in R1)
  - 10% - does not modify any register value other than R7 when called, and does not access memory outside of **`mp1.asm`**
- PRINT_CENTERED
  - 30% - produces correct output for any string length (string in R1)
  - 10% - does not modify any register value other than R7 when called, only reads the string provided, and otherwise does not access memory outside of **`mp1.asm`**

Style (20%)

- 10% - PRINT_SLOT not organized as nested conditionals (a look-up table is ok; 16 chunks of code selected by conditionals are not)
- 10% - PRINT_CENTERED not organized as nested conditionals (use a look-up table or a right shift)

Comments, Clarity, and Write-up (15%)

- 5% - each subroutine has a paragraph explaining what it does and how it must be called (these are given to you; you just need to document your work)
- 10% - code is clear and well-commented

Note that some categories in the rubric may depend on other categories and/or criteria. For example, if your code does not assemble, you will receive no functionality points. Note also that the remaining LC-3 MPs (two of them) will build on these subroutines, so you may have difficulty testing those MPs if your code does not work properly for this MP. You will also be penalized heavily if your code executes data. Finally, your subroutines must be written so that they can be called any number of times in any order with any legal input values, and we will deduct points if such is not the case.