1. **Give a short answer to the following questions related to labs (total: 20 points)**

   (1) ***GPIO*** (3 points). Write a short C code to initialize ***pin 2 and pin 13 of GPIO port B*** as ***digital output***, ***push-pull***, ***low output speed***, and ***no pull-up, no pull-down***.

   SOLUTION:

```
// Set mode of pin 2 and pin 13 as digital output
GPIOB->MODER &= ~((3<<4) | (3<<26));
GPIOB->MODER |= ((1<<4) | (1<<26));

OR
GPIOB->MODER &= ~(0xC000030);
GPIOB->MODER |= 0x4000010;

// Set output type of pin 2 and pin 13 as push-pull
GPIOB->OTYPER &= ~((1<<2) | (1<<13));

OR
GPIOB->OTYPER &= ~(0x2004);

// Set output speed of pin 2 and pin 13 as low speed
GPIOB->OSPEEDR &= ~((3<<4) | (3<<26));

OR
GPIOB->OSPEEDR &= ~(0xC000030);

// Set pin 2 and pin 13 as no pull-up, no pull-down
GPIOB->PUDPR &= ~((3<<4) | (3<<26));

OR
GPIOB->PUPDR &= ~(0xC000030);
```

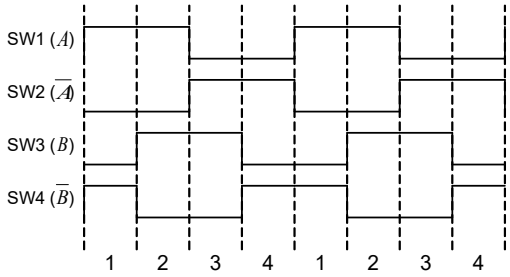
   (2) **GPIO** (3 points)**.** A GPIO output pin can be configured as push-pull or open-drain. Explain their difference.

   SOLUTION:

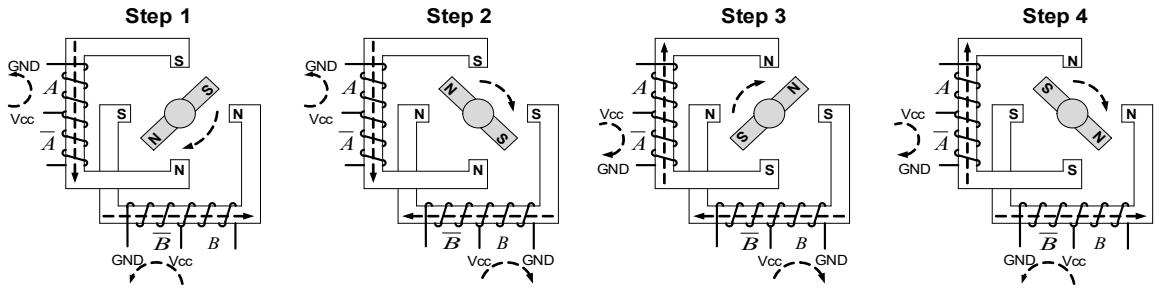
Push Pull:
output logic 1 ⟺ the voltage of the output pin is Vcc
output logic 0 ⟺ the voltage of the output pin is 0V

Open Drain:
output logic 1 ⟺ output pin is Hiz
output logic 0 ⟺ the voltage of the output pin is 0V

(3) ***Stepper Motor*** (5 points). Complete the C code below to repeatedly turn a stepper motor clockwise using full stepping. ***Note that the GPIO pin number starts with 0, and each phase is connected accordingly to the table below.***



Phase	Pin
A	PB 4
$\overline{A}$	PB 5
B	PB 6
$\overline{B}$	PB 7



Complete the following C code:

```
// Don't forget to complete the FullStep array!
unsigned char FullStep[4] = {0x90, 0x50, 0x60, 0xA0};


for(;;) {
    for(int i = 0; i < 4; i++){
      // Don't forget to include the delay!
      // Use waitms() as your delay function!
      waitms(10);
      GPIOB->ODR &= ~(0xF0);
      GPIOB->ODR |= FullStep[i];









    }
}
```

(4) ***LCD*** (3 points). Suppose the duty ratio of an LCD is 1/3 and it has 99 display segments (pixels). How many pins are required to drive this LCD?

SOLUTION:

$$duty\ ratio = \frac{1}{3} \rightarrow \#common\ terminals = 3$$

$$\#pins = \frac{\#pixels}{\#common\ terminals} + \#common\ terminals$$

Thus,

99/3 + 3 = 36 pins

(5) ***Keypad*** (6 points). The keypad scanning algorithm is widely used to detect which key is pressed. The algorithm has two iterations of loops: looping over the row pins and then looping over the column pins. Suppose all row pins are set as output and all column pins are set as input.
Explain the two steps used to detect which key is pressed!

SOLUTION:

This solution is from the textbook which is slightly different from the solution we did in our labs. If the student explains the approach we did in the labs it is also an acceptable solution.

1. **Identify the column number of the pressed key.** Set the output of all row pins as zero and read all column pins. If all columns are read as 1, then no key has been pressed. If one of them is zero, then at least one of the keys in that corresponding column is pushed down.
2. **Identify the row number of the pressed key.** Drive the output of the first row low (zero) while keeping the other rows at high (one). For example, suppose the input of column C2 is read as zero. If the input of C2 is still zero when the output of row R1 is high, then the pressed key is not located in row R1. Otherwise, row R1 is the row in which the pressed key is located. We repeat the process for all the other rows until the row is identified successfully.