



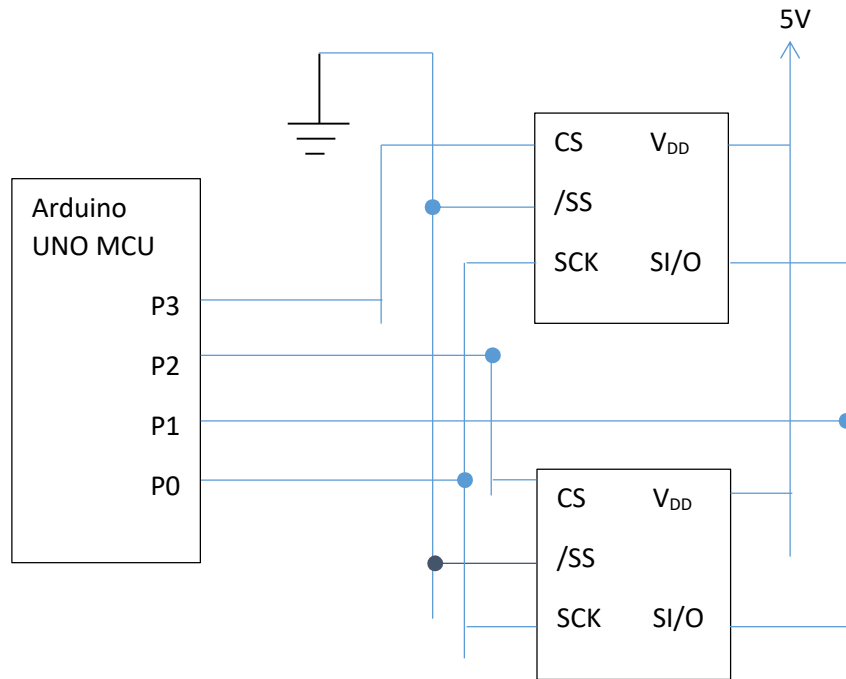
## MA2012 PYP Sol - Past Year Paper Questions

Introduction To Mechatronics Systems Design (Nanyang Technological University)

AY15/16

Q4.

a)



(10 marks)

a) No.

(1 marks)

b) 0.0625 degree per bit

(2 marks)

c) 2 bytes

(2 marks)

d)  $30 \text{ deg}/0.0625 = 480 \text{ bits} = 0 \ 0001 \ 1110 \ 0000$

(4 marks)

e) Continuous Conversion mode is appropriate as there is no power consumption limitation when the car's engine is on.

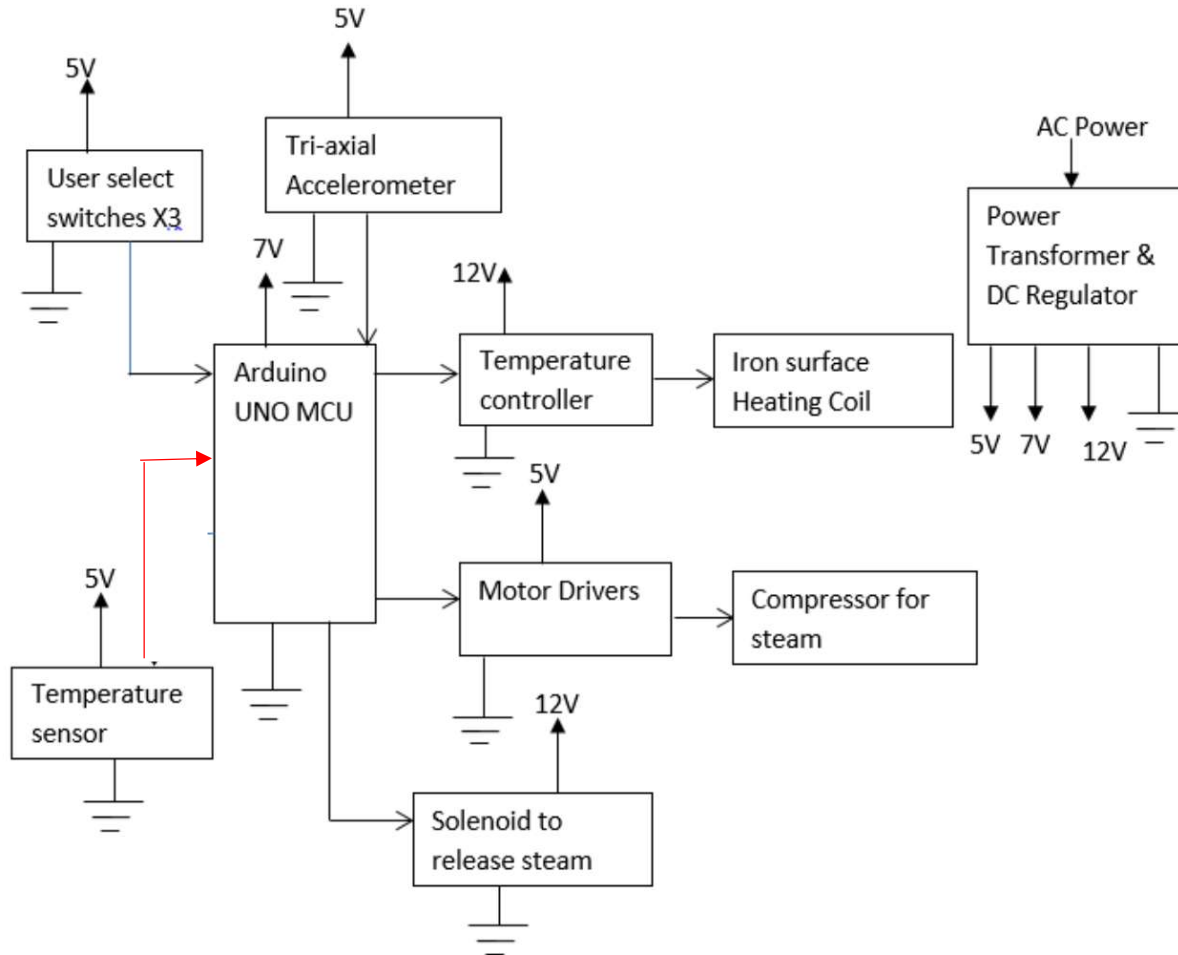
(3 marks)

f) 0000

(3 marks)

AY17/18

Q2)



Q3)

- a) Vertical axis rotation =  $-0.45 \text{ rad/s} = -25.78 \text{ deg/s} \rightarrow \text{use } 4xOUTX$   
Horizontal axis rotation =  $1.0 \text{ rad/s} = 57.30 \text{ deg/s} \rightarrow \text{use } OUTZ$   
 $4xOUTX = 1.23V + So*(-25.78) = 1.23 - 0.0333*25.78 = 0.372V$   
 $OUTZ = 1.23V + SoA*(57.30) = 1.23 + 0.0083*57.3 = 1.706V$   
Digitized  $OUTZ = 1.706/3.0*(2^{10}-1) \approx 582 = 246 \text{ (Hex)}$   
Digitized  $4xOUTX = 0.372/3.0*(2^{10}-1) \approx 127 = 7F \text{ (Hex)}$

(8 marks)

b) Temperature Sensitivity,  $SoDr = 0.037 \text{ \%}/^{\circ}\text{C}$

Temp change =  $25 - (-25) = 50 \text{ }^{\circ}\text{C}$

Percentage change =  $0.037 * 50 = 1.85\%$

$4xOUTX = 1.23 - 0.0333 * (1 - 0.0185) * 25.78 = 0.387\text{V}$

$OUTZ = 1.23 + 0.0083 * 57.3 * (1 - 0.0185) = 1.697\text{V}$

Digitized  $4xOUTX = 0.387 / 3.0 * (2^{10} - 1) \approx 132 = 84 \text{ (Hex)}$

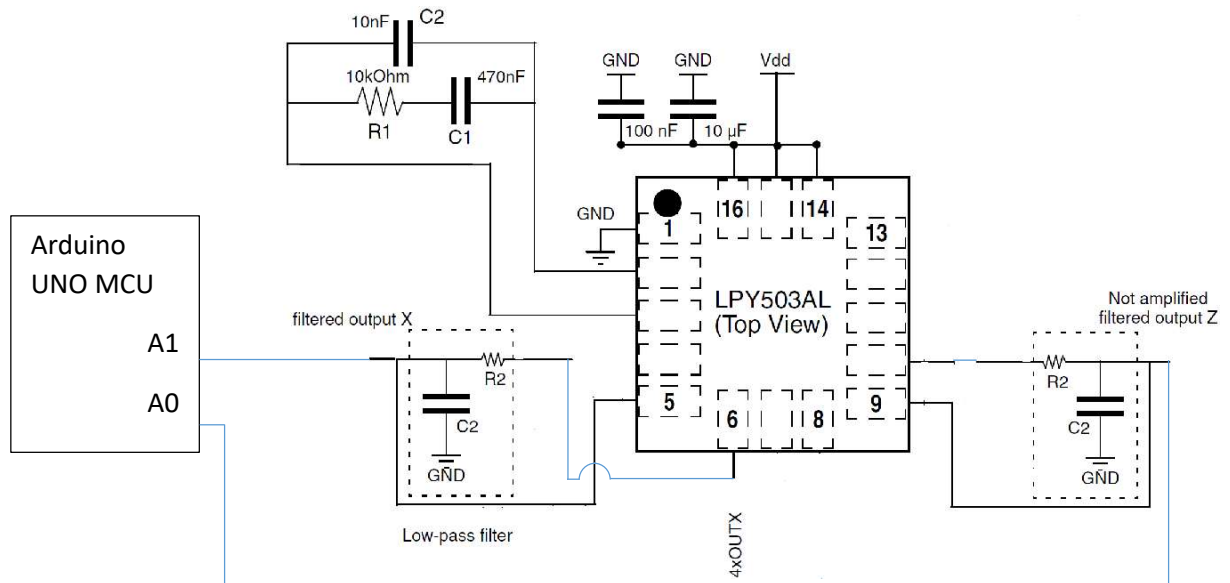
Digitized  $OUTZ = 1.697 / 3.0 * (2^{10} - 1) \approx 579 = 243 \text{ (Hex)}$

(6 marks)

c) No. Because the signal (angular velocity) does not fluctuate much, i.e. signal has no high frequency content.

(2 marks)

d)

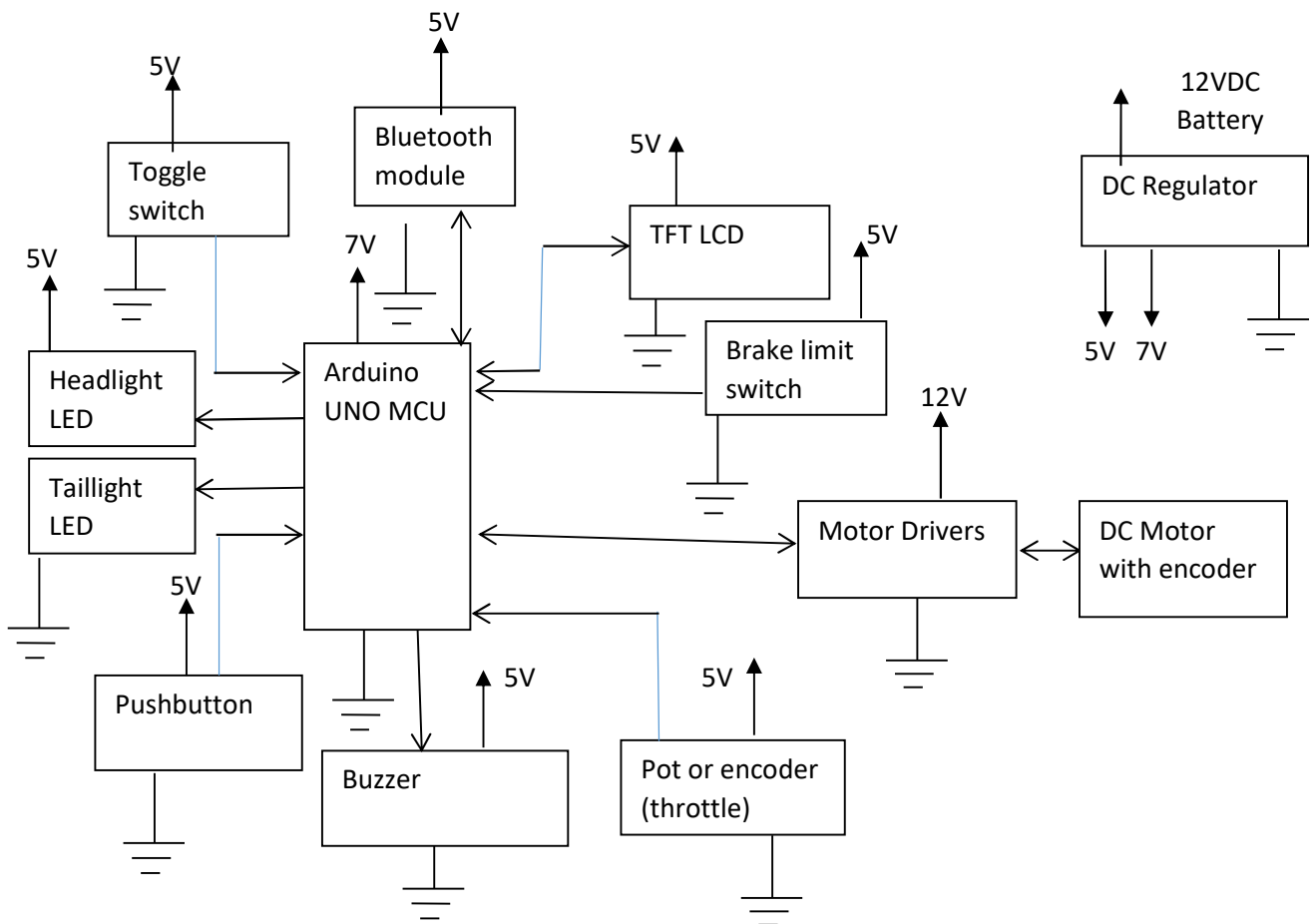


Note: A simple circuit diagram showing the correct pin connections would earn you full marks.

(9 marks)

AY18/19

Q2.



(25 marks)

AY2019/20

Q1.

a) Scale factor =  $5.0 / (200 - (-10)) = 23.8 \text{ mV}/^\circ\text{C}$

(2 mark)

b)

(i) The voltage output of the sensor,  $V_T = (100 - (-10)) \times 0.0238 = 2.619\text{V}$ .

For  $D1$ , the ADC has 10-bit resolution,

$$D1 = 2.619 / 5 \times (2^{10} - 1) = 535.8 \approx 536 = 0000\ 0010\ 0001\ 1000$$

For  $D2$ , the ADC has 5-bit resolution,

$$D2 = 2.619 / 5 \times (2^5 - 1) = 16.2 \approx 16 = 0001\ 0000$$

(7 marks)

(ii) Reduction of 1 degree will reduce the output voltage by  $23.8 \text{ mV}$ .

For a 5-bit ADC, the resolution is  $5 / 31 = 161.3 \text{ mV} / \text{unit}$

There will be no change in  $D2$  because the difference in voltage output is lower than the resolution of the ADC.

(4 marks)

c) The digital equivalents of  $T_T$  are set at  $D1_T = 535$  and  $D2_T = 16$ .

$$\text{The analog equivalent of } D1_T = (535 / 1023 \times 210^\circ\text{C}) - 10^\circ\text{C} = 99.8^\circ\text{C}$$

Since the thermocouple has a resolution of  $1.0^\circ\text{C}$ , LED2 will be turned on at  $100^\circ\text{C}$ .

$$\text{The analog equivalent of } D2_T = (16 / 31 \times 210^\circ\text{C}) - 10^\circ\text{C} = 98.4^\circ\text{C}$$

So LED2 will be turned on first at  $99^\circ\text{C}$  in rising temperature.

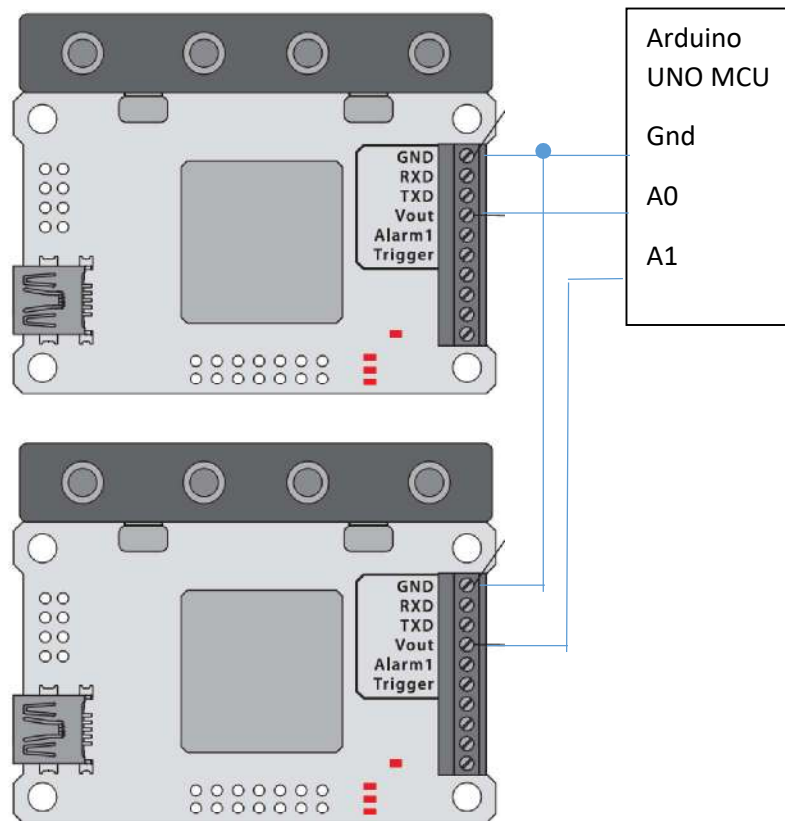
(9 marks)

d) In decreasing temperature, LED1 will be turned off first at  $99^\circ\text{C}$ . LED2 will be turned off at  $98^\circ\text{C}$ .

(3 marks)

Q4)

a)



(3 marks)

b)

(i)  $d = v / 3.3 \times (DH-DL) + DL$

$d1 = 2.5 / 3.3 \times (20-0) + 0 = 15.15m$

$d2 = 1.6 / 3.3 \times 20 = 9.09m$

$width = d1 + d2 = 24.24m$

There is no need to compensate for the distance apart of the 2 sensors because of the datum adjustment of  $-0.3m$ .

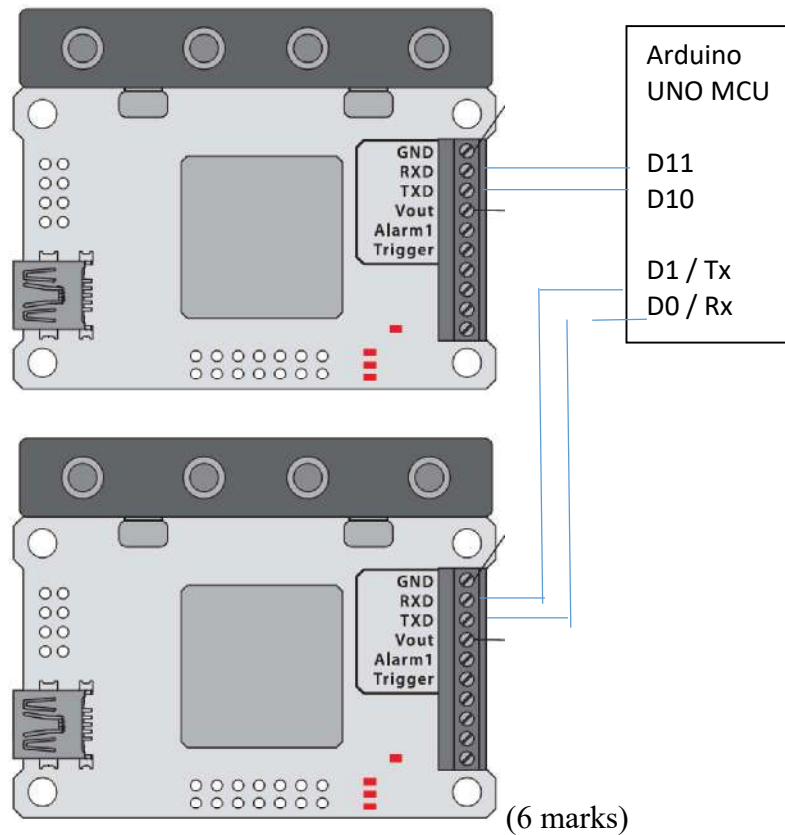
(7 marks)

(ii)  $Max\ Error \sim \pm 5cm \times 2 = \pm 10cm$

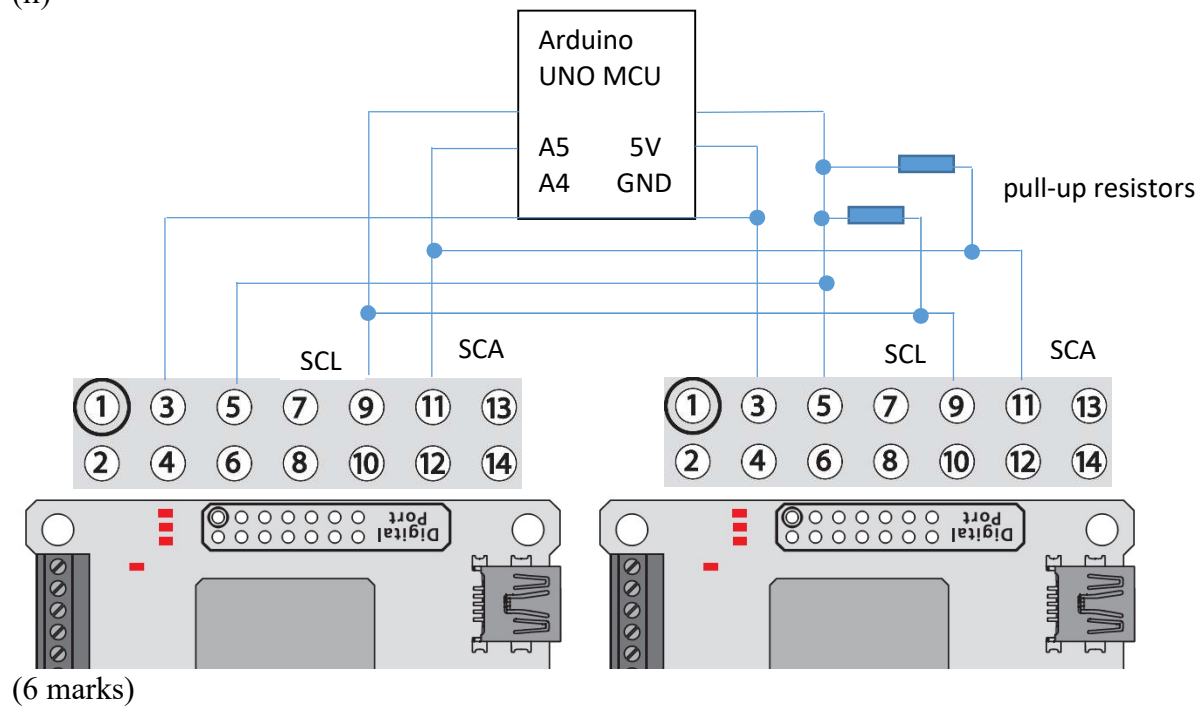
(3 marks)

c)(i)

To set up D11 and D10 (or other digital pins) as software virtual Tx and Rx respectively.



(ii)





Q4.

(a)-(i) Single-Ended Circuit

- Record the amplifier output at zero flowrate
- Compute the offset voltage, D between the recorded zero flowrate voltage and the reference value as indicated in the relevant flow curves (Fig. 6 or 7).
- Output a small PWM voltage via one of the digital pins to the negative input of the amplifier
- Slowly increment the voltage until D goes to zero.

(5 marks)

(ii) Differential Circuit

- The circuit, by design, will perform a Common Mode Rejection to remove the zero offset voltage.

(3 marks)

(b) Model 1002. Because the maximum flow rate of model 1001 is only 0.5 litre / min and hence not suitable for the application in Q3.

(3 marks)

(c) For model 1002, the output voltage at zero flowrate is around 95 mV. With an amplifier gain of 50x, the voltage into the ADC is  $50 \times 0.095 = 4.75\text{V}$ .

$$\text{Digitized value} = 4.75 / 5 * 1023 = 972 = 0x03CC$$

(6 marks)

(d) No, the saturation Analog input voltage is 5.0v. A gain of 100x would have produced a amplifier output voltage of 9.5V.

(4 marks)

(e) No it wouldn't change, because the amplifier output voltage will still be the same if calibration is properly done, regardless of the signal conditioning circuits.

(3 marks)