Section 1 Multiple choice questions:

Q1a Which of the following statement/statements is/are CORRECT?

(a) The speed of sound in the solid is directly proportional to its frequency
(b) The velocity of sound traveling in a gaseous medium, in general, is slower than in a liquid medium or in a solid medium
(c) The products of the frequency and the wavelength of a sound wave is constant
(d) The velocity of sound in vacuum is the same as in the gaseous medium

Ans: (b) and (c)

Q1b Which of the following statement/statements is/are NOT CORRECT?

(a) The speed of sound is different in different materials.
(b) The velocity of sound in water is proportional to the water temperature.
(c) The speed of sound in a medium is inversely proportional to its frequency.
(d) The frequency of a sound is proportional to its wavelength.

Ans: (c) and (d)

Q2a A car horn generating a tone f_s = 2000 Hz moves towards a stationary observer at a speed of v_s =50 m/s. What is the frequency f_0 (Hz) being heard by the observer? You may assume that the velocity of sound in air is v_a = 333 m/s.

(a) 1699.7 Hz
(b) 1738.9 Hz
(c) 2300.3 Hz
(d) 2353.3 Hz

Ans: (d)

Ans: $f_0 = f_s * va/(va - vs) = (2000)(333)/(333 - 50) = 2353.3$ Hz

Q2b A car horn generating a tone f_s = 1800Hz moves away from a stationary observer at a speed of v_s =50 m/s. What is the frequency f_0 (Hz) being heard by the observer? You may assume that the velocity of sound in air is v_a = 335 m/s.

(a) 1531.3 Hz
(b) 1566.2 Hz
(c) 2068.7 Hz
(d) 2115.8 Hz

Ans: (b)
Ans: $f_0 = f_s * va/(va + vs) = (1800)(335)/(335 + 50) = 1566.2$ Hz

Q3a In the MicroBit python language, the command “display.scoll” belongs to which type of the following programming structures?

(a) Sequence
(b) Selection
(c) Iteration
(d) None of the above

Ans: (a)

Q3b In the MicroBit python language, the command “while” belongs to which type of programming structures?

(a) Sequence
(b) Selection
(c) Iteration
(d) None of the above

Ans: (c)

Q4a Refer to the type of the digital multimeter used during the GE1354 laboratory, what is/are the possible function(s) it can offer?

(a) To measure the AC and DC voltage of a signal
(b) To measure the AC and DC current of a signal
(c) To measure the resistance of a component
(d) To measure the waveform of a signal
(e) To measure the distance between a surface and the meter
(f) To generate a 50Hz sinusoidal waveform

Ans: (a), (b) and (c)

Q4b Refer to the type of the digital oscilloscope used during the GE1354 laboratory, what is/are the possible function(s) it can offer?

(a) To measure the AC and DC voltage of a signal
(b) To measure the AC and DC current of a signal
(c) To measure the resistance of a component
(d) To measure the waveform of a signal
(e) To measure the distance of between a surface and the meter
(f) To generate a 50Hz sinusoidal waveform

Ans: (a), (b) and (d)

Q5a Which of the following statement/statements about a standalone MicroBit board is/are NOT CORRECT?

(a) Detect the earth's magnetic field.
(b) Detect its surrounding light
(c) Communicate with each other through a wireless link
(d) Measure an analog signal using any one of its GPIO pin

Ans: (d)

Q5b Which of the following statement/statements about a MicroBit board is/are CORRECT?

(a) Detect the fall motion of an object.
(b) Being programmed by either python language or MakeCode only
(c) Generate a PWM signal using any one of its GPIO pin
(d) Measure its surrounding temperature

Ans: (a) and (d)

Q6a. Determine the fundamental frequency of the waveform $v(t) = 10 \sin (1000\pi t) + 2 \cos (4000 \pi t)$ V.

a. 500Hz
b. 1kHz
c. 2kHz
d. Not periodic

Q6b. What is the fundamental frequency of the waveform $v(t) = 10 \sin (2000\pi t) + 2 \cos (4000 \pi t)$ V ?

a. 1kHz
b. 1.5kHz
c. 500Hz
d. Not periodic

Q7a. What are the amplitude and frequency of the waveform $v(t) = 6 \sin(3000\pi t) + 8 \cos(3000 \pi t)$ V ?

a. 10V, 1.5kHz
b. 14V, 1.5kHz
c. 10V, 3kHz
d. 14V, 3kHz

Q7b. What are the amplitude and frequency of the waveform $v(t) = 6 \sin(5000\pi t) + 8 \sin(5000 \pi t)$ V ?

a. 14V, 2.5kHz
b. 9V, 2.5kHz
c. 9V, 5kHz
d. 14V, 5kHz

Q8a. If the full-scale voltage of a 10-bit analog-to-digital converter is 5V, what is the maximum quantization error?

a. 2.44 mV
b. 4.89 mV
c. 5.86 mV
d. 11.7 mV

The LSB is $5 / (2^{10}) / 2 = 2.44$ mV.

Q8b. If the full-scale voltage of an 8-bit analog-to-digital converter is 3V, what is the maximum quantization error?

a. 5.86 mV
b. 11.7 mV
c. 2.44 mV
d. 4.89 mV

The LSB is $3 / (2^{8}) / 2 = 5.86$ mV.

Q9a. If the output signal of a sensor is 5 sin (500π t) + 3 cos (7000π t), what is the minimum sampling frequency so the signal can be recovered?

a. 7 kHz
b. 1 kHz
c. 3.5 kHz
d. 2 kHz

The highest frequency component is 3.5kHz. Thus, the sampling frequency is at least 7kHz.

Q9b. If the output signal of a sensor is 5 cos (6000π t) + sin (2000π t), what is the minimum sampling frequency so the signal can be recovered?

a. 6 kHz
b. 2 kHz
c. 1 kHz
d. 4 kHz

The highest frequency component is 3kHz. Thus, the sampling frequency is at least 6kHz.

Q10a. Two voltage sources have their output waveforms periodic. If they are connected in series, is the total voltage always periodic?

Undetermined
No.
Yes.

Q10b. Three voltage sources have their output waveforms periodic. If they are connected in series, is the total voltage always periodic?

Undetermined
No.
Yes.

Section 2 Long questions

LQ1(a)
As shown in Figure A, a student wrote the following program to detect the heartbeat of himself using the heartbeat measuring circuit board as shown in Figure B. He wants to display his heartbeat at the MicroBit display using "display scrolling mode."
Answer the following questions.

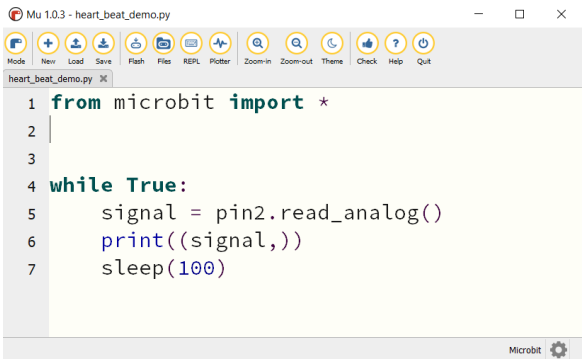

Figure A

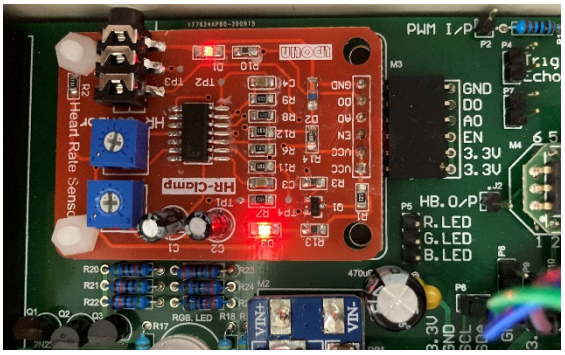

Figure B

(a) Which MicroBit pin should be connected to the heartbeat monitor output pin A0 to get the signal? Justify your answer. [1 mark]

(b) Describe the steps that the student should the student do \to display his heartbeat waveform. [2 marks]

(c) What will happen if the value "100" in line 7 increases to "250"? [1 mark]

(d) The student adds a code "display. scroll(signal)" between lines 5 and 6 to display his heartbeat. Do you think it will work? Justify your answer. [1 mark]

Ans

(a) Since line 5 should the pin of analog read is pin 2 (0.5 marks), the "A0" pin of the heartbeat device circuit should be connected to pin 2 of the Microbit circuit. (0.5 marks)

(b) After downloading, the MircoBit program (0.5 marks), click the "Plotter" icon of the Mu Editor (0.5 marks). After that, press the result button of the MicroBit (0.5 marks). Then the heart bit waveform should display at the console (0.5 marks).

(c) The sleep command at line 7 is delay command, and the value inside refers to the delay in ms (0.5 marks). Increasing the number will increase the loop time, so the waveform should be displayed slower (0.5 marks).

(d) Since the "signal variable" contains the sampled heartbeat analog voltage, not the heartbeat counts (0.5 marks), so it will not work (0.5 marks).

Remarks: all the sensible answers are acceptable

LQ1(b)
As shown in Figure A, a student wrote the following program to detect the heartbeat of himself using the heartbeat measuring circuit board as shown in Figure B. He wants to display his heartbeat at the MicroBit display using "display scrolling mode."
Answer the following questions.

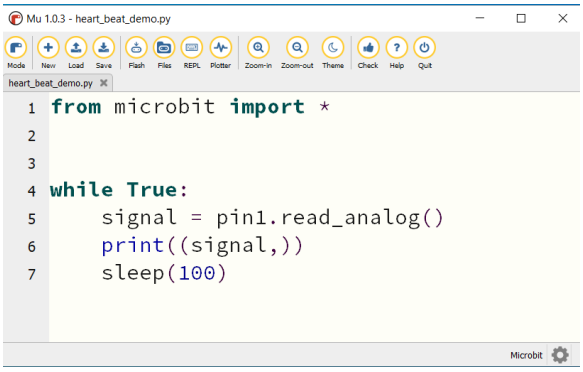

Figure A

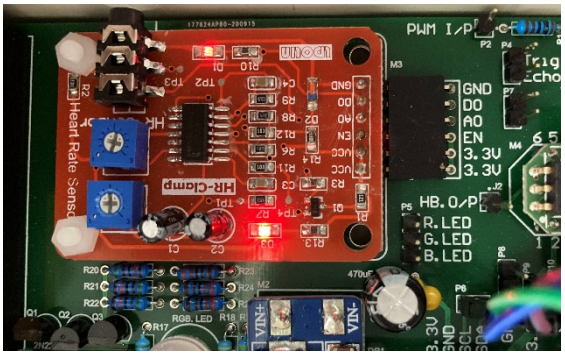

Figure B

(a) Which MircoBit pin should be connected to the heartbeat monitor output pin A0 to get the signal? Justify your answer

(b) Describe the steps that the student should the student do \to display his heartbeat waveform.

(c) Explain the function of the command in line 7, and its function in the program.

(d) The student adds a code "display.show(signal)" between lines 5 and 6 to display his heartbeat. Explain why it will not work.

Ans

(a) Since line 5 should the pin of analog read is pin 1 (0.5 marks), the "A0" pin of the heartbeat device circuit should be connected to pin 1 of the Microbit circuit. (0.5 marks)

(b) After downloading the MircoBit program (0.5 marks), click the "Plotter" icon of the Mu Editor (0.5 marks). After that, press the result button of the MicroBit (0.5 marks). Then the heart bit waveform should display at the console (0.5 marks).

(c) The sleep command at line 7 is a delay command, and the value inside refers to the delay time in ms. Increasing the number will increase the loop time, so the waveform should be displayed slower.

(d) Since the "signal variable" contains the sampled heartbeat analog voltage, not the heartbeat counts, so it will not work.

Remarks: all the sensible answers are acceptable

L2a

Consider a 3-bit analog-to-digital converter (ADC) with full-scale voltage of 10V. The ADC can only sample positive signal. It is used to sample the output of a sensor. The sensor output can be expressed as $4 + 6 \sin(20000\pi t)$ V.

(a) Discuss how the analog signal is conditioned, so that full waveform can be sampled. (2 mark)

(b) What should the gain of the signal conditioning circuit be? (1 mark)

(c) The conversion time of the ADC is 68μs. Give comment on the suitability of using such ADC to sample the sensor output. (1 mark)

(d) Suggest the maximum conversion time of the ADC so that the signal can be recovered. (1 mark)

Ans

(a) Offset the voltage (1 mark), attenuate the signal (1 mark) so that the variation is within the operating range.

(b) The full scale is 10V. The signal is [-2, 10], implying that the range is 12. Thus, the signal should be attenuated by 10/12 = 0.8333. (1 mark)

(c) As the maximum frequency is 10k, the period is 100μs. If the conversion time is 68μs, the minimum required sampling frequency cannot be achieved. (1 mark)

(d) 50μs. (1 mark)

L2b

The full-scale voltage of an analog-to-digital converter (ADC) is 10V. The ADC is used to sample an analog signal $5 + V_m \sin(20000\pi t)$ V.

(a) What is the minimum required number of bits of the ADC so that the resolution of each bit is less than 40mV? (1 mark)

(b) What is the maximum value of V_m if it is necessary to extract the full waveform shape of the input signal? (1 mark)

(c) If all bits in the ADC output is "1", what is the minimum possible value of the input? (1 mark)

(d) Discuss the maximum conversion time of the ADC allowed. (1 mark)

(e) What is the sampled waveform if the sampling frequency is 5kHz? (1 mark)

Ans

(a) 10 / 0.04 = 250 levels. Thus, an 8-bit ADC. (1 mark)

(b) $V_m = 5$. (1 mark)

(c) 509 x 10 / 512 = 9.94V (1 mark)

(d) 1 / 20k = 50μs (1 mark)

(e) DC waveform (1 mark)