The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 3 MODULE, AUTUMN SEMESTER 2020-2021

COMPUTER ENGINEERING AND MECHATRONICS

Time allowed FORTY-EIGHT hours

Open-book take-home examination

Answer ALL questions

For Section A you must submit a single zip file of the computer programs that you wish to have marked for this open-book examination. This should be named in the format '[Student ID]_MMME3085_Section_A.zip'.
At the top of each piece of code you write should be, in addition to any other, a comment statement indicating the question being undertaken and your candidate ID.

For Section B you, you must submit a single pdf document, produced in accordance with the guidelines provided on take-home examinations, that contains all of the work that you wish to have marked for this open-book examination. Your submission file should be named in the format '[Student ID]_MMME3085.pdf'*.*

Write your student ID number at the top of each page of your answers.

This work must be carried out and submitted as described on the Moodle page for this module. All work must be submitted via Moodle by the submission deadline. ***Work submitted after the deadline will not be accepted without a valid EC.***

No academic enquiries will be answered by staff and no amendments to papers will be issued during the examination. If you believe there is a misprint, note it in your submission but answer the question as written.
Contact your Module Teams Channel or SS-AssessEng-UPE@exmail.nottingham.ac.uk for support as indicated in your training.

Plagiarism, false authorship and collusion are serious academic offences *as defined in the University's Academic Misconduct Policy and will be dealt with in accordance with the University's Academic Misconduct Procedures. The work submitted by students must be their own and you must declare that you understand the meaning of academic misconduct and have not engaged in it during the production of your work.*

ADDITIONAL MATERIAL: Test file 'Results.txt' provided on Moodle.

SECTION A

Answer this section by writing programs in the C language using the GCC compiler within CodeBlocks

Note: All questions in this section requiring user input of numerical values should be designed and coded to reject invalid values (with suitable error messages displayed in such cases).

1. Develop a program that will display a parallelogram of width 10 using the hash (#) symbol. The user is to be prompted for the height, which should be in the range 1 to 10 inclusive.

   Sample output for a value of 4 being entered is shown in Figure Q1.

```
##########
 ##########
  ##########
   ##########
```

Figure Q1 – Sample output for input value of 4

[12]

2. The file 'Results.txt' provided contains text data with student first name, surname and exam mark on each line.

   You are to develop a program that:

   - Reads the values from the file, up to the end of the file, storing each line of data in a structure
   - Displays a message for each student showing the class of degree awarded as defined in Table Q2, e.g. Joseph White: Upper second-class degree. Valid marks are in the range 0 to 100

Class	Mark
First	>= 70
Upper second	60 to 69
Lower second	50 to 59
Third	40 to 49
Fail	< 40

Table Q2 – Class of degree awarded for given mark ranges

If you cannot read until the end of file, you may assume the file contains 15 lines - this will however reduce the maximum marks available to 17. [20]

3. Develop a function **external to main()** that is able to calculate the volume and surface area of a right cone given a radius (r) and height (h) using the equations below.

$$Volume = \pi r^2 \frac{h}{3}$$

$$Surface\ Area = \pi r(r + \sqrt{r^2 + h^2})$$

The function should meet the following design criteria:

- The function is to return a value of 0 (zero) if the volume and surface area are calculated successfully.
- The function is to return a value of -1 if either of the inputs are invalid.
- The radius and height can be non-integer values.
- Volume and surface area are to be returned via the argument list (using suitable variables).

The volume and surface are to be displayed in the calling function (in this case main()) to 3 decimal places of accuracy.

You are also required to write code in main() to prompt the user for input of radius and height.

As a test case, for r = 1.5 and h = 2.4: Volume = 5.655,
Surface area = 20.406 [18]

SECTION B

Answer this section on a paper and scan it in, submit your answer as a PDF file

4. It is required to design a feed drive system for a 3D printer using a DC motor to drive a ball screw through a gearbox with a reduction ratio of 8 to achieve a linear movement along the X-axis of the 3D printer as shown in Fig. Q 4. The lead of the ball screw is 2 mm. To achieve accurate control of the axis, a feedback control system is employed using a linear potentiometer to measure the linear displacement of the axis. The axis displacement range is 0-100mm and the corresponding output of the potentiometer is 0-5V. An Arduino Uno is used as a controller to regulate the movement of the axis based on the feedback from the sensor. The output of the sensor is connected to one of the analogue inputs on the Arduino (AI0).

(a) What is the minimum linear displacement that can be measured using this setup (i.e., resolution)? [3]

(b) If the above resolution is not enough to achieve the target manufacturing accuracy of the 3D printer. Two different solutions may be used : **1)** To use an incremental rotary encoder attached to the motor shaft (Note: the encoder will be attached to the motor not the ball screw) or **2)** To replace the controller (i.e., the Arduino Uno) with a controller which includes an analogue to digital converter (ADC) with higher specifications. If the requested resolution of the system is 10μm

i) For the first option, what is the minimum number of pulses per revolution required for the rotary encoder to achieve the desired precision? [6]

ii) For the second option, what is the minimum number of ADC bits to achieve the desired precision? With this minimum number, what is the resulting resolution? [6]

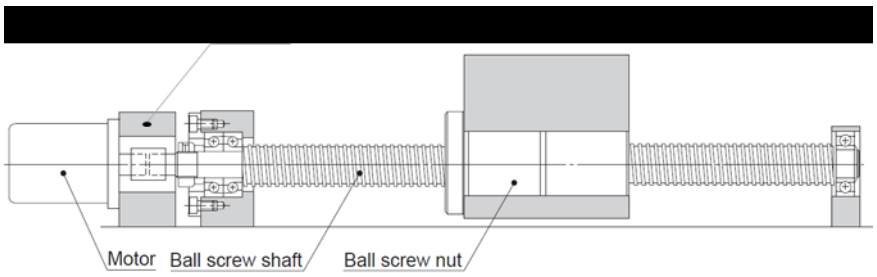

Figure Q4

5. Two different types of 7-segment display are shown in Fig. Q5: a common cathode (CC) 7-segment display where all the cathode terminals (-) are connected and the anode terminals (+) (A, B, C, … and G) are controlled individually by a microcontroller and, a common anode (CA) 7-segment display, where all the anodes of the LEDs are connected and the cathode terminals (A, B, C, … and G) are individually controlled by microcontroller. Note: any LED with 0V (or not connected) at the anode will be off regardless of the applied voltage on the cathode and any LED with 5V (or not connected) on the cathode will be off regardless of the applied voltage on the anode.
It is required to drive five of these 7-segment displays (three are CC type and two are CA type) with an Arduino Mega. Only 16 digital output pins are available on the Arduino (Port A: PA0-PA7 and Port B: PB0-PB7).

(a) Sketch how the five 7-segment displays can be connected to the Arduino given the above conditions. [10]

(b) In 200 words, explain how the student can write code to show the following combination of digits on the displays (23486). Your explanation will need to include identification of the data (at least for one digit of 23486) to be sent to Port A and Port B and the sequence of these data. Note: Do not write any code. No marks will be given for this. [10]

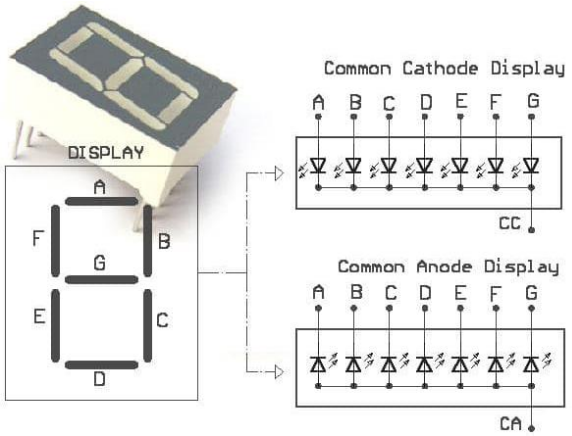

Figure Q5

6. Stepper motors are well-known for their excellent open-loop performance to control systems such as robotics, antennas, telescopes, and some toys. Stepper motors cannot run at high speeds but have a high holding torque which is normally defined by its torque-speed characteristic performance curve as the one shown in Fig. Q6. A ball-screw feed drive system of a 3D printer is driven by a stepper motor through a gearbox with a reduction ratio of 8 and the ball-screw lead is 2 mm. The desired maximum speed of the feed drive system is 3 mm/s and the equivalent moment of inertia with reference to the stepper motor shaft is $5x10^{-3}$ kg.m^2. The viscous drag torque of the feed drive system can be modelled as a proportional drag torque of 0.0002 Nm/RPM of the motor shaft speed. Assume that the motor with a torque-speed characteristic given in Fig. Q6 is selected for this feed drive system.

(a) Calculate the minimum time required for the feed drive system to accelerate uniformly from rest (0 mm/s) to the desired maximum speed (i.e., 3mm/s).

(b) Calculate the minimum time required for the feed drive system to decelerate uniformly from the desired maximum speed (i.e., 3mm/s) to rest (0 mm/s). [15]

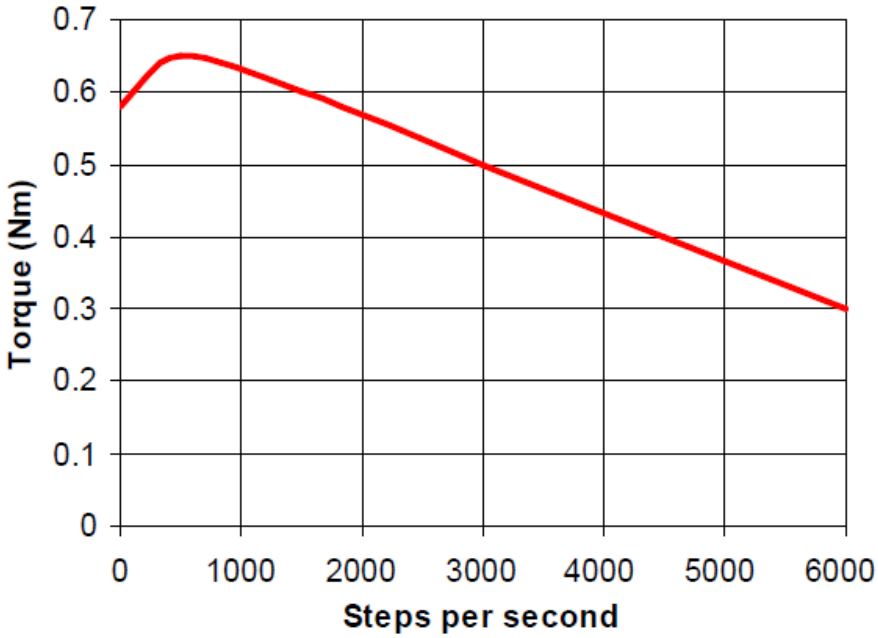

Figure Q6