2019 Paper 1 – Model Solution

NOTE: When using a calculator, the examiner uses as many decimal places as their calculator shows (often 6 or 7), rounding to the requisite number of places at the very end. When working with very large or very small numbers, not doing this can lead to a correct method giving an answer that is quite a way away from the answer in the mark-scheme, so be mindful of this.

1a. Identify three ways in which the manufacturer of the home lift can ensure the safe operation of the lift by its users. [3]
1. Ensuring that the motor will not energise until the door is properly closed.
2. Locking the door while the lift is moving.
3. Ensuring that the motor speed is gradually ramped up rather than engaging it abruptly.

1bi. The lift moves at a speed of 0.08 m s^{-1}. Calculate the time taken in seconds for the lift to rise between floors which are 2800 mm apart. Show your working. [3]
(v)elocity = (d)istance covered / (t)ime taken
t = d/v
d = 2800mm = 2.8m
t = 2.8 / 0.08 = **35s**

1bii. Analysing the data in Fig. 1.2, calculate the motor rotational speed required in revolutions per minute (rpm) to cause the nut to climb up the thread at a speed of 0.08ms^{-1}. Show your working.

8mm pitch means that one revolution causes the lift to travel up by 0.008m.
10 revolutions per second of the output would result in an upward velocity of 0.08ms^{-1}
10rps = 600rpm output speed of the motor.

Driven Teeth / Driver Teeth = Velocity Ratio
30 / 20 = 3/2 = 1.5

Input Speed / Output Speed = 1.5
Input Speed / 600 = 1.5
Input Speed = 1.5 x 600 = **900rpm**

1biii. Give two reasons why a double chain drive is used in this application. [2]
1. Redundancy in the event of one chain breaking, to avoid the user being stuck between floors.
2. Halves the amount of torque transmitted through a single chain, to reduce wear.
3. The chains can be smaller and easier to handle/install compared to a single larger chain.

1biv. The maximum total mass of the lift and occupants is 350 kg. Calculate the power required in watts (W) to raise the 350 kg lift at a velocity of 0.08 m s^{-1}. Show your working. [3]

Combine provided formula:

m = 350
g = 9.81
As the velocity is 0.08 meters per second, we will use 0.08 for h and 1 for t.

Power = (350 x 9.81 x 0.08) / 1 = **274.68W**

1bv. Conventional lifts usually use a cable mechanism with an electric motor located at the top of the lift shaft. Explain one advantage and one disadvantage of using a screw thread and nut mechanism in a lift. [3]

Adv: Improved safety - if there is a power cut or the chains fail, the lift will not fall.
Dis: Would require a very long screw thread in a building with multiple floors. May not be practical.

1c. (c) Discuss, using examples, the significance of good user interface design in engineered products. [8]

Good UI is able to simplify a complex product for the user. Where an interface is for users to utilise without any training (e.g. a lift), a good UI will allow them to correctly operate the lift intuitively and the controls provided should be minimalist. Inclusivity can be built in by putting Braille on the lift buttons.

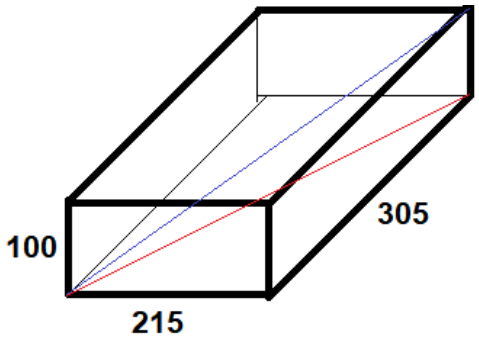
There an interface is for a high-safety application such as the controls for a nuclear power plant, systems must be designed with Poka-Yokes built in where possible (e.g. switch covers over the most sensitive controls) to prevent accidental operations of the controls.

Where an interface is for a consumer product such as a smartphone, the UI should be designed to behave intuitively. This can be achieved using skeuomorphic elements which will be immediately familiar to the user such as buttons and sliders.

Good UI can lead to a more positive brand image – the original iPhone was marketed as the phone that, '*you already know how to use'*.

2a. The box has internal dimensions of 305 × 215 × 100 mm. Calculate the maximum straight part length which can be shipped in this cardboard box. Give your answer in mm to 1 decimal place and show your working. [3]

The longest distance inside the box is from the bottom corner of the bottom of the box to the opposite corner at the top of the box – the blue line in the sketch to the right.



Start by finding the distance of the red line.

$a^2 + b^2 = c^2$
$c = \text{sqrt}(215^2 + 305^2)$
$c = 373.2$

Now use the red line and the height of the box to calculate the blue line.

$a^2 + b^2 = c^2$
$c = \text{sqrt}(373.2^2 + 100^2)$
$c \approx$ **386.4mm**

2bi. Name an instrument which could be used to measure the diameter of the part shown in Fig. 2.2 to a precision of 0.02 mm. [1]

Vernier Calliper or a Micrometer.

2bii. Calculate the mass in grams (g) of the part shown in Fig. 2.2. Give your answer to 1 decimal place and show your working. [5]

Calculate circular part first. Since the density is in g/cm^3, I'll use cm throughout.
Area = πr^2
r = 26/2 = 13mm = 1.3cm

Area = π x 1.3^2 = 5.31cm^2
Volume = Area x Height = 5.31 x 1.5 = 7.97cm^3

Calculate conical part:
Volume = 1/3 x Base area x height = 1/3 x 5.31 x 2 = 3.50cm^3

Total volume = 7.97+3.5 = 11.47cm^3

Total mass = 8.73 x 11.47 = **100.1g**

2biii. The part in Fig. 2.2 is to be turned on a centre lathe from a cylindrical brass bar with diameter 30 mm and length 35 mm. Calculate the volume in mm^3 of the waste brass generated. Give your answer to 1 decimal place and show your working. [2]

Volume of bar:
Area = πr^2 = π x 15^2 = 225π = 706.9mm^2
Volume = 706.9 x 35 = 24,741.5mm^3

Volume of part: 11.47cm^3 = 11,470mm^3
Difference: 24,741.5 - 11,470 = **13,271.5mm^3**

2biv. The diameter of the part must be 26.00 mm with a tolerance of ±2%. Calculate the minimum allowable diameter in mm of the part. Show your working. [2]

1% of 26mm is 26/100 = 0.26mm.
26 – 0.26x2 = **25.48mm**

2c. Use the formula, $v^2 = u^2 + 2as$, to calculate the initial velocity, u, at which the ball needs to leave the machine so that it just reaches the required height of 2.5 m. Give your answer in m s^{-1} and show your working. [2]

$v^2 = u^2 + 2as$
$v^2 - 2as = u^2$
sqrt(v^2 - 2as) = u

s = 2.5
a = -9.81ms^{-2}
v = 0ms^{-1} (as it stops at 2.5m height)
u = sqrt(0^2 – (2 x -9.81 x 2.5))
u = sqrt(– (2 x -9.81 x 2.5)
u = **7.0ms^{-1}**

3a. Discuss the implications to manufacturers of producing Kitemark approved products. [8]

(*Note: In this question, you would only get marks to arguments which relate to the implications for the manufacturer*)

There are a number of benefits that come from demonstrating that recognised high standards are in place: Increased sales, improved customer loyalty and better brand image. Increased product reliability will result in fewer recalls, and so there would be less chance of costly customer litigation.

In order to achieve the standard(s) in question for a product, some requirements that may mean changing the product's design and, in turn, changing a manufacturing method. Both of these would

almost certainly have cost implications, such as employee re-training or necessitate investment in new machinery.

BSI documents are quite expensive to purchase, and the manufacturer may find that the standard(s) might impose constraints on a design which are restrictive and limiting. This said, a clear set of standards can be helpful in guiding designers.

3bi. Explain what is meant by '*enterprise*' in the context of designing. [2]
A bold venture capturing innovation, bold decision making and resourcefulness in order to making the most of an opportunity to earn money.

3bii. Describe two ways in which enterprise can help drive the development of new product ideas. [4]

Entrepreneurship is the process of launching a new business, taking a financial risk in the hope of a good return. An entrepreneur will have the resilience to recover from setbacks, learning lessons along the way.

Entrepreneurs may seek to form commercial partnerships, enabling them to share ideas amongst other experts to gain access to global technology. Alternatively, they may seek to source funding *via* Venture capitalists – stakeholders who invest money into entrepreneurial companies who then have a strong interest in the company's success.

4. A 12 V battery is used to power the robotic lawnmower. The robotic lawnmower returns to a charging station placed at the edge of the lawn to recharge its battery. The charging station requires a source of power. Identify two issues associated with providing power to the charging station. [2]

It will rain periodically, so the changer will need to be appropriately IP rated in order for it to be safe for outdoor use.

As the charger will be outside constantly, the housing will need to be designed not to corrode.

4bi. Describe how the rigidity of the thermo-softening polymer part in Fig. 4.2a and Fig. 4.2b is achieved through effective designing. [2]

There are ribs designed into part. These create triangulation, which will prevent the plastic moving up and down as the mower moves around.

4bii. State the industrial method used to manufacture the thermo-softening polymer part and identify one piece of evidence from either figure that leads you to this conclusion. [2]

Injection moulding. There are three ejector pin marks clearly visible in the second photo.
(*note: I could also have commented that the part is all one colour, has thin walls or that it has extruded text*)

4biii. The >PP< marking that is visible on the surface of the product in Fig. 4.2b identifies the type of thermo-softening polymer that has been used. Explain one reason why a plastic manufacturer marks the type of plastic used on their product in this way. [2]

Many plastics are difficult to distinguish from one another. This mark will make it easier for it to be recycled at its end of life, as the recycling centre will know it is made from polypropylene and it will be less likely to end up in landfill.

4c. Compare the use of DC motors and stepper motors for driving the wheels of a robotic lawnmower. [4]

Stepper motors provide greater accuracy of movement, as each step provides a known amount of rotation (typically 1.8 degrees) – a DC motor is simply on or off. This control would be advantageous if the mower is required to 'know' the shape of the lawn.

DC motors require less complex drive circuitry, making them easier to diagnose and maintain for engineers who service and repair the units after they are sold.

DC motors tend to be able to deliver more torque than the equivalent stepper motor, which may be required if a lawn is on a slope.

4d. Use this function description to complete the system diagram below for the robotic lawnmower. [4]

NOTE: for this answer, you would need to simply add 4 more shapes to the diagram, with arrow lines on. I've picked out all the bullet points from the question, so that you can see where I got my answers from.

At the set time, the lawnmower automatically undocks from its charging station, starts its grass-cutting blade and begins to move across the lawn.
Inputs: real-time clock
Outputs: blade motor, left-hand motor, right-hand motor

A cable, buried around the edge of the lawn, carries an electronic signal which the lawnmower detects and uses to avoid running off the edge of the lawn.
Inputs: Edge run-off sensor

Proximity sensors on the lawnmower detect the presence of obstacles in the lawnmower's path so that they can be avoided.
Inputs: Proximity sensor

The lawnmower monitors its battery voltage and if the voltage falls below a set level the lawnmower returns to its charging station.
Input: Battery voltage

4ei. Calculate the voltage (V) at point VA in Fig. 4.3 when the battery voltage is 10.5 V. Give your answer to 2 decimal places and show your working. [3]

$V_2 = V_s \times (R_2 / R_1 + R_2)$ (Using potential divider formula)

$V_2 = 10.5 \times (1800 / 3900 + 1800)$

$V_2 = 10.5 \times 0.316 =$ **3.32V**

OR…

$V_{in} = IR$ (Creative use of Ohm's Law)

$I = V_{in}/R = 10.5 / (1800+3900) = 0.00184A$

$V_a = IR_2 = 0.00184 \times 1800 =$ **3.32V**

4eii. Calculate the ADC value produced when the input voltage V_A is at the value you calculated in part (e)(i). Give your answer as a rounded-down integer and show your working. [3]

V_a / V_t = ADC Reading / ADC_{maxV}
3.32 / 5 = ADC Reading / 1023
ADC Reading = (3.32/5) * 1023 = 679.272 = 679

…or…

5 / 1023 = 0.00488758 (value of 1 analogue 'unit').
3.32 / 0.00488758 = 679.27 = **679**

4eiii. Draw a flowchart of the robotic lawnmower subroutine to check the battery voltage and generate an alert if the battery voltage falls below 10.5V. [3]

NOTE: Remember that if you are writing a subroutine, it is something which is 'called' by the main program that runs on the PIC. The subroutine, therefore, should do its job and then end, so that the main part of the code can continue to run. In this case, if the answer to the analogue input diamond is a 'no', I don't loop back again to check.