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A Level in Design and Technology: Design Engineering (H404/01)

Principles of Design Engineering

Sample Question Paper Version 3.1

Date – Morning/Afternoon

Time allowed: 1 hour 30 minutes

You may use:
- a scientific calculator
- a ruler
- geometrical instruments

First name									
Last name									
Centre number						**Candidate number**				

INSTRUCTIONS
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. Additional paper may be used if necessary, but you must clearly show your candidate number, centre number and question number(s).
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Do **not** write in the bar codes.

INFORMATION
- The total mark for this paper is **80**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*****).
- This document consists of **20** pages.

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Answer **all** the questions.

1 **Fig.1** shows a folding bicycle.

This image has been redacted due to third party copyright restrictions. For other examples of this type of question please see our past papers, available through our website and Interchange. Alternatively, see our ExamBuilder platform for the full list of relevant mock questions.

Fig.1

(a) Folding bicycles are a relatively recent innovation.

Explain **one** reason, apart from reducing space why designers are now developing bicycles to be foldable.

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(b) Bicycles are designed with ergonomic features.

Analysing the bicycle in **Fig.1** explain **two** of the ergonomic features of the folding bicycle.

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(c) **(i)** The frame of the folding bicycle in **Fig.1** is made from aluminium alloy.

Explain **two** working properties of aluminium alloy which makes it a suitable material for the frame.

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(ii) The aluminium alloy used in the manufacture of the bicycle frame has a density of $2.78\,g\,cm^{-3}$.

$4\,079\,cm^3$ of alloy is used in the manufacture of each casing.

All other fixtures and fittings have a mass of 3 467g.

Calculate the overall mass of the folding bicycle in kg.

Mass = ……kg **[2]**

(d) The total weight of the bicycle and rider is 148 N.
The area of each tyre in contact with the ground is 500 mm^2.

Calculate the pressure each tyre exerts on the ground in $N\,mm^{-2}$.

Pressure each tyre exerts on the ground = ……$N\,mm^{-2}$ **[2]**

(e) **Fig.2** shows the chain and sprocket drive used on the rear wheel of the folding bicycle. Several rear sprocket sizes are provided, allowing the rider to change gear whilst riding. The smallest rear sprocket is selected for the maximum speed.

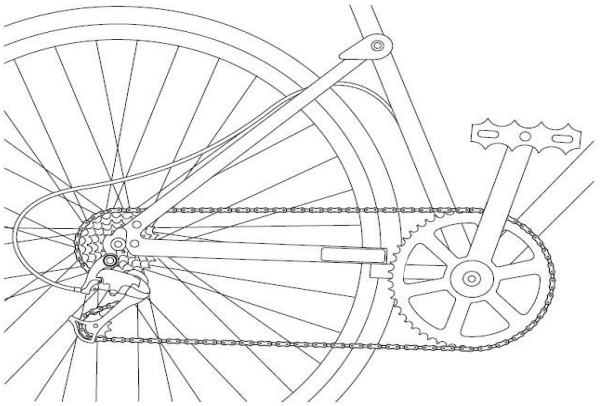


Fig.2

The bicycle data is summarised below:

Maximum required bicycle speed	7.8 ms^{-1}
Maximum comfortable pedaling rate	1.3 rev s^{-1}
Rear wheel diameter	406 mm
Number of teeth on smallest rear sprocket	11 teeth

The bicycle designer needs to determine the number of teeth on the front sprocket (which is turned by the pedals) so that the bicycle can be ridden at the maximum speed.

Use the data to calculate the number of teeth needed on the front sprocket.

Number of teeth…….**[4]**

(f) Discuss the ways in which concern for the environment might impact on the manufacture of a folding bicycle.

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2 Automated technology plays an increasingly important role in industrial production processes.

(a) An automated guided vehicle (AGV) is used to move stock, parts and sub-assemblies around a factory. An AGV is operated by a programmable controller.

Give **two** advantages of using AGVs during a production process.

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(b) The wheel rotation of an AGV is sensed using an optical shaft encoder.
The shaft encoder has 24 slots as shown in **Fig.3**.

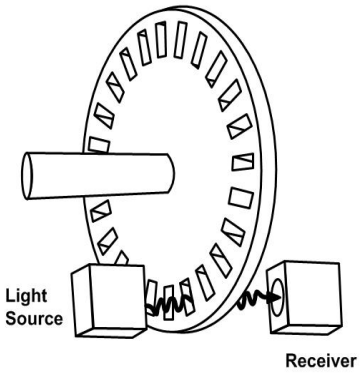


Fig.3

(i) Calculate the minimum rotation angle that can be detected by the shaft encoder.

……**[1]**

(ii) When the optical shaft encoder is rotating at one particular speed, the receiver produces the output current signal shown in **Fig.4**.

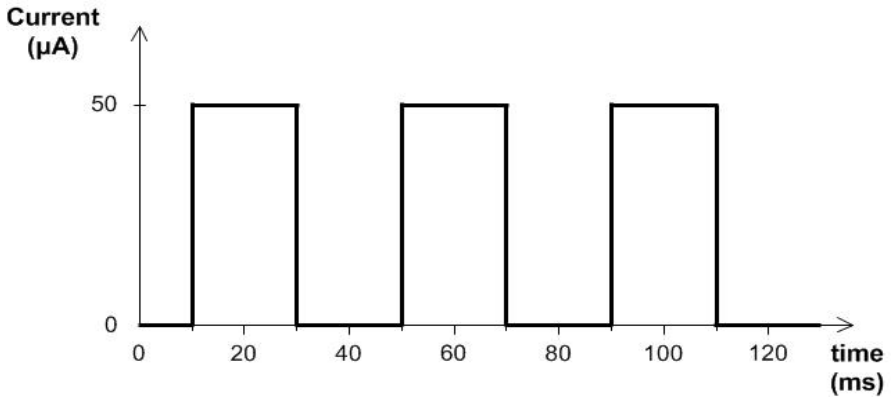


Fig.4
(Not to scale)

Calculate the rotational speed of the shaft encoder in rev s^{-1}.

Rotational speed ……..rev s^{-1}

[2]

(iii) The receiver on the shaft encoder is connected to the input of a microcontroller as shown in **Fig.5**.

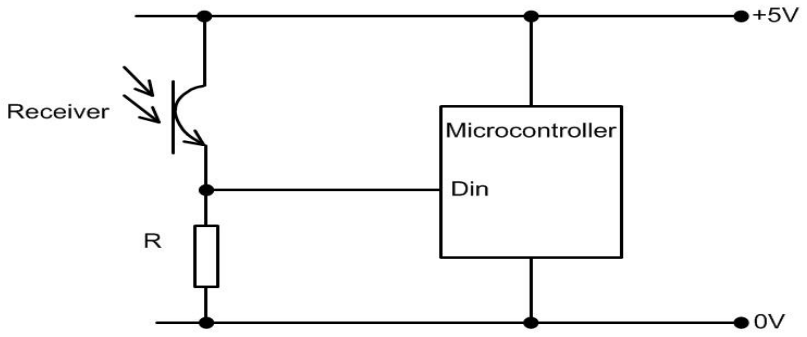


Fig.5

Resistor **R** is used to convert the current signal from the receiver into a voltage signal.

The microcontroller requires a logic 1 input voltage of at least 3V.

Calculate the minimum value of **R** in Ω.

Minimum value of **R** = …… Ω. **[2]**

(c) Pick and place robots are another example of automated technology.

Fig. 6 shows the plan view of the arm of a pick and place robot. The arm can rotate and extend.

The robotic arm collects objects from Point P, before placing them at Point Q.

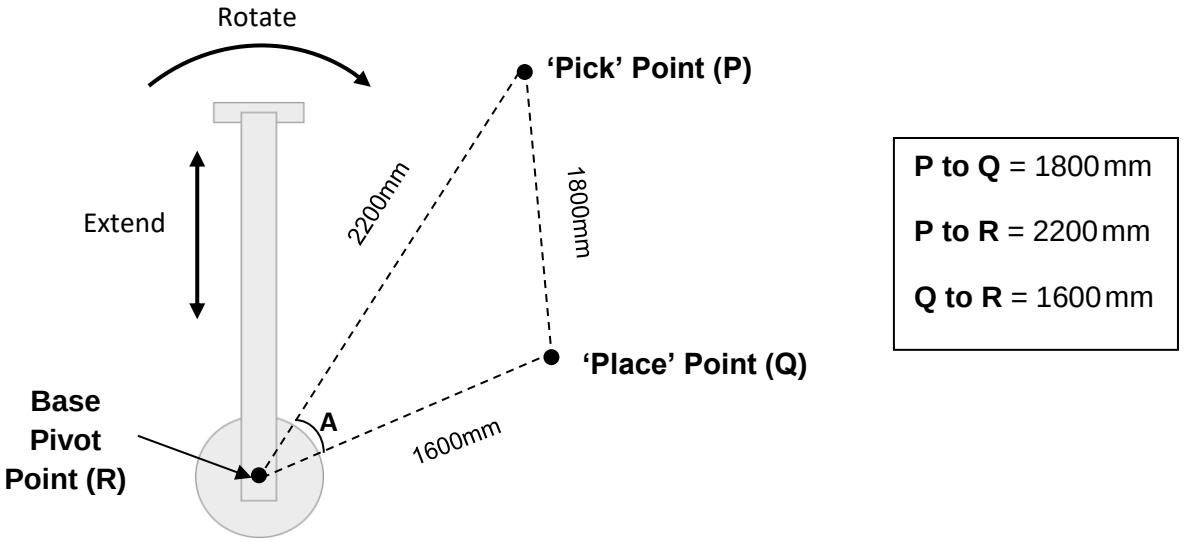


Fig. 6

The arm rotation is driven by a stepper motor operating through a gearbox with a 12 : 1 reduction ratio.

The stepper motor has 200 steps per revolution, and is controlled by a microcontroller.

(i) Calculate the angle A through which the robotic arm must rotate to move from Point P to Point Q.

Angle ……**[3]**

(ii) The robotic arm needs to move from Point P to Point Q in a time of 2s. Calculate the pulse frequency needed to drive the stepper motor.

Pulse frequency = ……Hz **[4]**

(iii) The robotic arm is an **open-loop** control system.

Describe, with reference to the robotic arm, how an open-loop system operates.

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(iv) Explain why an open-loop control system used in the robotic arm needs to be reset to a datum at switch-on and explain how this is achieved.

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3 The constant evolution of electronic products is influenced by a range of factors.

(a) Explain **two** ways, other than quality control, that the implementation of international standards impacts on the design of electronic products.

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(b)* Discuss, using examples, how considerations regarding the design, purchase and supply of products can extend their usable lives.

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4 **(a)** **Fig. 7** shows a mechatronic turnstile system used to control access to a public transport system.



Fig.7

(i) The customers' tickets use a 'contactless' technology to enable entry.

Describe how **one** suitable contactless technology enables data to be read from the ticket.

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(ii) Explain **two** reasons why bearings would be used in the mechanical gate system.

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(iii) Explain **one** implication of the improper use of lubrication on mechanical systems.

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(b) **Fig. 8** shows the plan view of the compound gearing system within the turnstile. The numbers indicate the number of teeth on each spur gear.

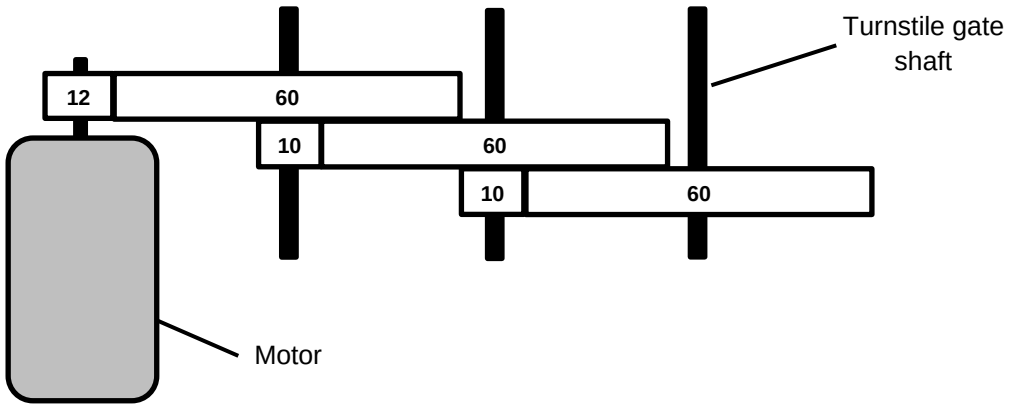


Fig. 8

(i) The turnstile gate shaft rotates through 45° during the gate opening cycle.

Calculate the number of revolutions turned by the motor.

Number of revolutions = ……**[3]**

(ii) During the turnstile gate opening cycle, the motor ramps-up (accelerates) at 230 rev s^{-2} until it reaches a full speed of 50 rev s^{-1} which it then maintains before ramping-down (decelerating) at the same rate of 230 rev s^{-2}.

Fig.9 shows the graph of motor speed against time.

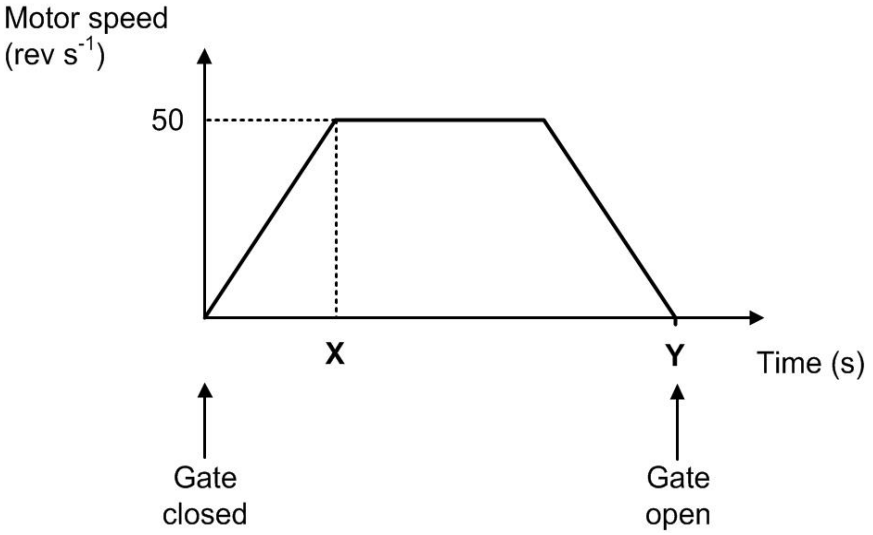


Fig.9
Not to scale

Calculate the values of **X** and **Y** on the time axis.

X …….. seconds, **Y** …….. seconds **[5]**

(iii) Explain **one** reason why the designer chose to ramp down the motor speed at the end of the opening cycle rather than maintaining full speed for as long as possible.

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(c) Total Quality Management (TQM) is used throughout manufacturing and assembly processes.

Discuss the ways in which TQM improves quality within manufacturing.

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END OF QUESTION PAPER

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Summary of updates

Date	Version	Details
April 2022	3.1	Updated copyright acknowledgements. Figure 1 – Image of a folding bicycle redacted due to third party copyright restrictions.

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