OCR
Oxford Cambridge and RSA

# Monday 11 October 2021 – Morning

## A Level in Design and Technology: Design Engineering

**H404/01** Principles of Design Engineering

**Time allowed: 1 hour 30 minutes**

**You can use:**
- a ruler (cm/mm)
- a scientific calculator
- geometrical instruments

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

**INSTRUCTIONS**
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. You can use extra paper if you need to, but you must clearly show your candidate number, the centre number and the question numbers.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

**INFORMATION**
- The total mark for this paper is **80**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*****).
- This document has **24** pages.

**ADVICE**
- Read each question carefully before you start your answer.

Answer **all** the questions.

**1** **Fig. 1.1** shows a cordless electric screwdriver.


**Fig. 1.1**

**(a)** **(i)** Designers often aim to make their products inclusive so that they are easy-to-use by a wide range of users.

Identify **two** ways in which the electric screwdriver in **Fig. 1.1** has been designed to be an inclusive and easy-to-use product.

1 .....

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2 .....

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**[2]**

**(ii)** One million electric screwdrivers are manufactured every year using a high-volume production process.

The production runs continually for 365 days per year.

Calculate the average time in seconds to manufacture **one** electric screwdriver. Give your answer to **2** decimal places. Show your working.

Average time ..... seconds

**[2]**

**(b)** The specification for the electric screwdriver is given in **Table 1.2**.

| | |
|---|---|
| **Battery** | 3.6 V lithium-ion rechargeable |
| **Output speed** | 215 rpm |
| **Maximum torque** | 4.5 Nm |

**Table 1.2**

The electric screwdriver uses an epicyclic gear system.

**(i)** Explain **two** reasons why the designer chose to use an epicyclic gearbox in this product.

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**[4]**

**(ii)** The epicyclic gearbox in the electric screwdriver consists of two identical stages. Each stage has a gear ratio of 7:1.

Use the information in **Table 1.2** to calculate the rotational speed of the motor in the electric screwdriver. Give your answer in rpm and show your working.

Rotational speed of motor ..... rpm

**[3]**

**(c)** A new electric screwdriver is being developed. The current drawn by the motor is measured as the torque load on the motor is varied.

**Fig. 1.3** is a graph of the results.

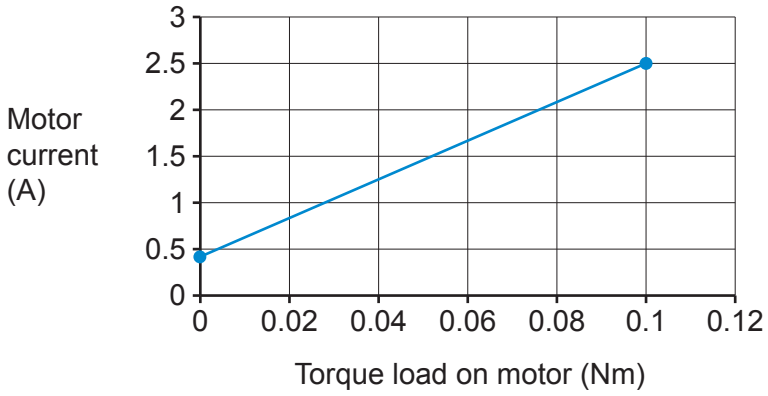


**Fig. 1.3**

**(i)** Use **Fig. 1.3** to identify the current of the motor when the load on the motor is 0.04 Nm.

Motor current ..... A **[1]**

**(ii)** An electronic system is being developed to monitor the torque load on the motor.

**Fig. 1.4** shows part of the circuit diagram for the new electronic system.

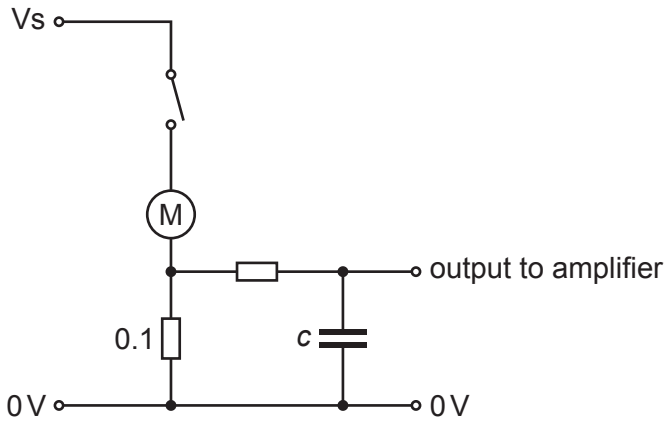


**Fig. 1.4**

Calculate the voltage across the 0.1 Ω resistor when the motor current is 2.5A. Show your working.

Voltage ..... V

**[2]**

**(iii)** Component *c* in **Fig. 1.4** is a capacitor.

Explain **one** reason why a capacitor is used in electronic systems.

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..... **[2]**

**(iv)** The output voltage signal from the circuit in **Fig. 1.4** is fed into an amplifier subsystem with a voltage gain of 4.

Describe the effect the amplifier will have on the voltage signal.

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..... **[2]**

**(d)** During the development of an electric screwdriver, 3D block models would be made to test ergonomic factors and to communicate ideas with stakeholders.

Use annotated sketches and/or notes to show how a non-functional model of an electric screwdriver, such as the type shown in **Fig. 1.1**, could be made.

Identify any relevant equipment, materials and processes. **[6]**

**2** **(a)** A metal part is being manufactured using an old working drawing which has measurements in inches.

A hole is required with a diameter of ¼ inch.

The drill bits available are:

**3 mm  4 mm  5 mm  6 mm  7 mm  8 mm**

**(i)** Assuming 1 inch = 25.4 mm, identify the drill bit that will drill a hole closest to the required size. Show your working.

Drill bit ..... mm

**[2]**

The tolerance for the ¼ inch hole is ± 5%.

**(ii)** Determine whether the drill bit you specified in **part (a)(i)** would produce a hole that is within this tolerance. State Yes or No. Show your working.

Within tolerance .....

**[3]**

**(b)** A polymer moulding manufacturer produced a batch of 5000 gears. Each gear was inspected and 80 gears were found to be faulty.

**(i)** Calculate the probability of a gear being faulty in the batch.

Probability .....

**[1]**

**(ii)** Use your answer to **part (b)(i)** to calculate the minimum number of gears which should be inspected if the probability of a faulty gear remains the same. Show your working.

Minimum number of gears .....

**[2]**

**(c)** **Fig. 2.1** shows the basic design for a zip-line for a children's play park.

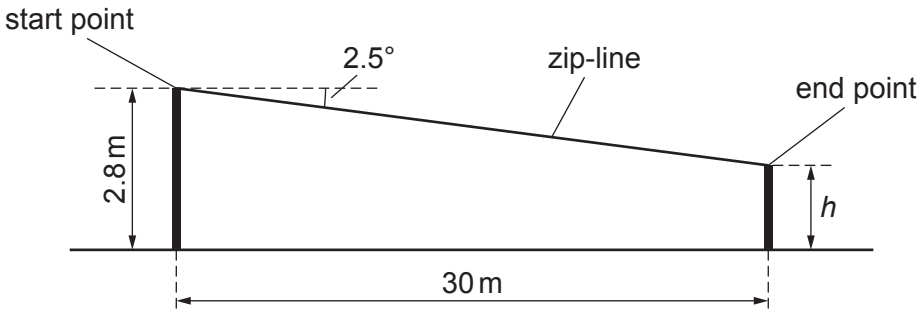


**Fig. 2.1**
(not to scale)

**(i)** Calculate the height *h* in m. Give your answer to **1** decimal place and show your working.

Assume that the zip-line does not sag.

*h* ..... m

**[3]**

**(ii)** **Fig. 2.2** shows construction details of the start point for the zip-line.

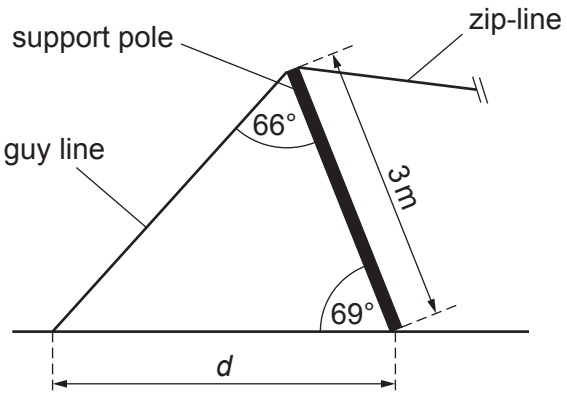


**Fig. 2.2**
(not to scale)

Calculate the distance *d* in m**.** Give your answer to **2** decimal places and show your working.

*d* ..... m

**[4]**

**(iii)** A risk assessment is carried out on the zip-line for the children's play park.

The assessment suggests there is a 1 in 25 000 chance of failure each day it is used.

Calculate the probability of failure over a 25-year period if the zip-line is used for 300 days per year.

Give your answer as a percentage and show your working.

Probability of failure over a 25-year period ..... %

**[4]**

**3** **(a)** In the 1980s, electric lighting was mainly provided by incandescent light bulbs which contained a tungsten filament. Incandescent light bulbs have now generally been replaced by light emitting diode (LED) light bulbs as they are more efficient.

**Fig. 3.1** shows an incandescent light bulb.

**Fig. 3.2** shows an LED light bulb.

**Fig. 3.1**

**Fig. 3.2**

Data for each light bulb is given in **Table 3.3**.

| | **Incandescent light bulb** | **LED light bulb** |
|---|---|---|
| **Power** | 60 W | 9 W |
| **Light output** | 820 lumens | 800 lumens |
| **Lifetime** | 1200 hours | 25 000 hours |

**Table 3.3**

**(i)** Identify **two** design features of the LED light bulb which have been influenced by the style and function of the incandescent light bulb.

1 .....

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2 .....

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**[2]**

**(ii)*** In 2009 the European Union (EU) began to ban the sale of incandescent light bulbs, forcing consumers to change to LED light bulbs.

Discuss the impact of changing from incandescent light bulbs to LED light bulbs.

In your answer you **must** refer to the impact on:

- industry
- the lifestyle of users
- the environment.

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**(b)** The marketing lifecycle of a successful product can be divided into initial demand, growth in popularity and decline over time.

Describe **two** methods used by manufacturers to create more demand and maintain a longer product popularity.

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2 .....

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**[4]**

**4** **Fig. 4.1** shows an electrically powered cool box. The product is portable and is used to keep food and drinks cool on a hot day.

**Fig. 4.1**

**(a)** The electrically powered cool box shown in **Fig. 4.1** is manufactured from multiple materials. Several different thermo softening polymers and several different metals are used.

Identify **two** properties of thermo softening polymers which make them suitable for the manufacture of parts in an electrically powered cool box.

1 .....

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2 .....

..... **[2]**

**(b)** **(i)** Identify **one** part in an electrically powered cool box that would be made from metal.

..... **[1]**

**(ii)** State a metal that would be used to manufacture the part of the electrically powered cool box you have identified in **part (b)(i)**. State a property of this metal that would make it suitable for use.

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..... **[2]**

**(c)** End of life (EOL) legislation requires producers to be responsible for their products when they become waste.

Describe **two** ways in which a manufacturer can try to ensure that products, such as the electrically powered cool box, can be successfully recovered and effectively processed when they reach the end of their life.

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2 .....

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**[4]**

**(d)** A photograph of the polymer handle of the electrically powered cool box is shown in **Fig. 4.2**.

**Fig. 4.2**

**(i)** The performance of the handle is enhanced by the design features visible in **Fig. 4.2**.

Describe how the performance of the handle is enhanced by its design.

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..... **[4]**

**(ii)** The handle is likely to break if the electrically powered cool box is carried when it is overloaded.

Sketch a diagram to show the likely mode of failure of the handle. Mark the forces acting on the handle. **[2]**

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**(e)** **Table 4.3** shows the technical specification for an electrically powered cool box.

| | |
|---|---|
| **Supply voltage** | 12 V DC or 230 V AC |
| **Power consumption** | 42 W |
| **Maximum cooling** | 18 °C below external air temperature |
| **Internal storage volume** | 28 litres |

**Table 4.3**

**(i)** Calculate the current in amps when the electrically powered cool box is plugged into a 12 V supply. Show your working.

Current ..... A

**[2]**

**(ii)** At the prototype stage of development, the electrically powered cool box would be tested to ensure that it meets the technical specification.

Use annotated sketches and/or notes to:

- outline a test that could be carried out on the prototype electrically powered cool box to evaluate the maximum cooling criteria specified in **Table 4.3**
- identify any relevant equipment required
- show how the results would be used to assess the suitability of the prototype. **[6]**

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