Level 3 Technical Level
DESIGN ENGINEERING
MECHATRONIC ENGINEERING
J/506/5953

Unit 3 Mathematics for Engineers

Mark scheme

January 2019

Version: 1.0 Final

191Aj5065953/MS

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from aqa.org.uk

Level of response marking instructions

Level of response mark schemes are broken down into levels, each of which has a descriptor. The descriptor for the level shows the average performance for the level. There are marks in each level.

Before you apply the mark scheme to a student's answer read through the answer and annotate it (as instructed) to show the qualities that are being looked for. You can then apply the mark scheme.

Step 1 Determine a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the descriptor for that level. The descriptor for the level indicates the different qualities that might be seen in the student's answer for that level. If it meets the lowest level then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer. With practice and familiarity you will find that for better answers you will be able to quickly skip through the lower levels of the mark scheme.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level, ie if the response is predominantly level 3 with a small amount of level 4 material it would be placed in level 3 but be awarded a mark near the top of the level because of the level 4 content.

Step 2 Determine a mark

Once you have assigned a level you need to decide on the mark. The descriptors on how to allocate marks can help with this. The exemplar materials used during standardisation will help. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the example to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the example.

You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the Indicative content to reach the highest level of the mark scheme.

An answer which contains nothing of relevance to the question must be awarded no marks.

0 1 . 1 Calculate the surface area needed to manufacture the 250 containers.
Give your answer to the nearest whole number in m^2

[7 marks]

Ends:
$2(150 \times 125) = 37\,500\ mm^2$

Sides:
$2(375 \times 150) = 112\,500\ mm^2$

Top and bottom:
$2(375 \times 125) = 93\,750\ mm^2$

Area for 1 container:
$(37\,500 + 112\,500 + 93\,750)mm^2 = 243\,750\ mm^2$ **or** $0.24375\ m^2$

Total area for 250 containers:
$250 \times 0.24375\ m^2 = 60.9375\ m^2 \equiv 61\ m^2$ to the nearest whole m^2

1 mark for each section area (3 marks maximum)
1 mark for adding together to find area for one container
1 mark for converting to m^2
1 mark for total area
1 mark for total area to nearest whole m^2

0 1 . 2 Calculate how much it will cost to weld the whole batch if the company charges £150 per hour for the use of the machine.

[3 marks]

$250 \times 3.7 = 925$ mins

$T_{tot} = \frac{925}{60} = 15.4166\ldots$ hours

$C_{tot} = 15.4166\ldots \times £150 = £2312.50$

1 mark for total time in minutes
1 mark for total time in hours
1 mark for total cost

0 2 . 1 Calculate the change in length of the bar. Answer in millimetres to 1 significant figure.

[10 marks]

$$A = \frac{\pi D^2}{4} = \frac{\pi \times (15 \times 10^{-3})^2}{4} = 176.7145\ldots \times 10^{-6}\ \text{m}^2$$

$$\sigma = \frac{F}{A} = \frac{25 \times 10^3 \text{N}}{176.7145\ldots \times 10^{-6}\ \text{m}^2} = 141.4710\ldots \text{Nm}^{-2}$$

$$E = \frac{\sigma}{\epsilon} \therefore \varepsilon = \frac{\sigma}{E} = \frac{141.4710\ldots \text{Nm}^{-2}}{200 \times 10^9\ \text{Nm}^{-2}} = 707.3553\ldots \times 10^{-6}$$

$$\epsilon = \frac{\Delta L}{L_o} \therefore \Delta L = L_o \times \epsilon = 1000 \times 707.3553\ldots \times 10^{-6} = 0.7073\ldots \text{ mm} \equiv 0.7 \text{ mm 1 sig. fig.}$$

1 mark for correct values used in area calculation
1 mark for correct answer
1 mark for correct values used in stress calculation
1 mark for correct answer
1 mark for correct values used in Young's modulus calculation
1 mark for correct answer
1 mark for correct strain transposition
1 mark for correct values
1 mark for correct answer
1 mark for 1 sig. fig

0 2 . 2 Use the formula method to solve the following quadratic equation:

$$x^2 + 6x + 8 = 0$$

[3 marks]

$a = 1, b = 6$ and $c = 8$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-6 \pm \sqrt{6^2 - (4)(1)(8)}}{2} \equiv \frac{-6+2}{2} or \frac{-6-2}{2}$$

Therefore, $x = -2$ or $x = -4$

1 mark for the correct values for a, b and c.
1 mark for each correct solution (maximum 2 marks)

0 3 Calculate the length of side *a*. Answer to the nearest millimetre.

[5 marks]

Using the cosine rule:

$a^2 = b^2 + c^2 - 2bc\cos A$

$a^2 = 155^2 + 100^2 - 2bc\cos A$

$a^2 = 34\,025 - 28\,095.5414\ldots$

$a^2 = 5929.4586\ldots$

Therefore,

$a = \sqrt{5929.4586\ldots} = 77.0029\ldots$mm **or** 77 mm to the nearest millimetre.

1 mark for correct formula
1 mark for correct values entered
1 mark for taking the square root
1 mark for correct answer
1 mark for the correct answer to nearest millimetre

0 4 Convert the Cartesian coordinates into polar coordinates.

[5 marks]

$r = \sqrt{175^2 + 125^2} = \sqrt{46\,250} = 215.0581\ldots$ mm **or** 215 mm 3 sig. fig. Or $25\sqrt{74}$.

$\theta = \tan^{-1}\frac{125}{175} = 35.5376\ldots°$ **or** 35.5° 3 sig. fig.

(215, 0.620) 3 sig. fig.

1 mark for correct method for the radius
1 mark for the correct answer
1 mark for correct method of calculating the angle
1 mark for correct answer
1 mark for both values to 3 sig. fig.

0 5 . 1 Calculate the mean torque value (Nm) of the data set.

[2 marks]

$$\text{Mean} = \frac{10.5 + 10.6 + 10.5 + 10.4 + 10.6 + 10.4 + 10.5 + 10.6 + 10.5 + 10.5}{10} = 10.5 \text{ Nm}$$

1 mark for the correct method
1 mark for the correct answer

0 5 . 2 Calculate the median torque value (Nm) of the data set.

[4 marks]

Organise the data set into ascending order.

= 10.4, 10.4, 10.5, 10.5, 10.5, 10.5, 10.5, 10.6, 10.6, 10.6

Take the mean of the two middle numbers (as there are an even set of numbers):

$$\text{Median} = \frac{10.5 + 10.5}{2} = 10.5 \text{ Nm}$$

2 marks for organising the numbers in ascending order
1 mark for using the two middle numbers then finding the mean
1 mark for correct answer

0 5 . 3 Explain how statistics can help the engineering industry in their quality assurance methods/procedures.

Give **two** examples in your answer.

[4 marks]

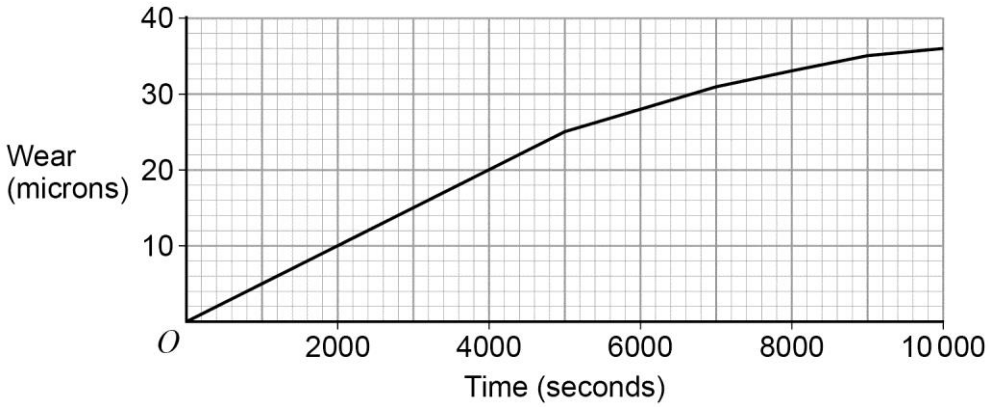
- Checking that tools aren't wearing during various manufacturing processes by calculating mean/average dimensions from batch/patrol inspections.
- Checking the thickness of coatings/paints on car body panels to determine that minimum quality standards are being adhered to.
- Use of coordinate measuring machines to check the dimension of a large batch of components to ensure they meet quality procedures. Checking average values.

Any of these or other suitable responses.

2 x 2 marks a total of 4 marks.

0 6 . 1 Plot a graph of the data set wear rate against time.

[3 marks]



1 mark for each correct axes labelling and ranges (**max 2 marks**)
1 mark for a similar curve to that above (don't be too harsh with the curve)

0 6 . 2 Explain what is happening to the wear rate between 0 and 5000 seconds.

[2 marks]

The wear rate is constant and shows a linear trajectory.

The gradient of the line is uniform and thus the wear rate is constant.

2 marks for these or similar answers

0 6 . 3 Explain what is happening to the wear rate between 5000 and 10 000 seconds.

[2 marks]

The wear rate is not constant and is beginning to fluctuate – the gradient isn't uniform.

The wear rate is reducing as time goes along/increases.

2 marks for these or similar answers

0 7 Calculate the length of the shaft to the nearest millimetre.

[10 marks]

$$A_{cyl} = \frac{\pi D^2}{4} = \frac{\pi \times \left(35 \times 10^{-3}\right)^2}{4} = 962.1127\ldots \times 10^{-6}\text{m}^2$$

13 200 g $\equiv$ 13.2 kg

$$\rho = \frac{\text{Mass } (m)}{\text{Volume } \left(V_{cyl}\right)} \therefore V_{cyl} = \frac{m}{\rho} = \frac{13.2}{7800} = 1.6923\ldots \times 10^{-3}\ \text{m}^3$$

$$V_{cyl} = A_{cyl}L_{cyl} \therefore L_{cyl} = \frac{V_{cyl}}{A_{cyl}} = \frac{1.6923\ldots \times 10^{-3}\ \text{m}^3}{962.1127\ldots \times 10^{-6}\text{m}^2} = 1.7589\ldots\text{m}$$

Better as $L_{cyl} =$ 1759 mm or 1.759 m to the nearest millimetre.

1 mark for correct values
1 mark for correct answer – area
1 mark for converting grams to kilogrammes
1 mark for correct density formula
1 mark for correct transposition
1 mark for correct value of volume
1 mark for correct transposition to find the length
1 mark for the values used
1 mark for the answer
1 mark for the correct answer to the nearest millimetre

0 8 . 1 Calculate the values of the **two** pressures p_1 and p_2

[7 marks]

$26 = 7p_1 - 2p_2$ Equation 1

$29 = 6p_1 + 5p_2$ Equation 2

From 1 $26 - 2p_2 = 7p_1 \therefore p_1 = \frac{26+2p_2}{7}$ Equation 3

Substitute Equation 3 into Equation 2:

$29 = 6\left(\frac{26+2p_2}{7}\right) + 5p_2 \therefore \frac{47}{7} = \frac{12}{7}p_2 + 5p_2$

Or

$\frac{47}{7} = \frac{47}{7}p_2$ and $p_2 = 1$

Now, substitute the value for p_2 into Equation 1 and solve for p_1.

$26 = 7p_1 - 2p_2 = 7p_1 - 2 \therefore p_1 = \frac{26+2}{7} = 4$

Therefore, $p_1 = 4$ and $p_2 = 1$

Any other combination of the above or other suitable method will suffice.

1 mark for labelling/setting up the equations
2 marks for writing one of the unknowns in terms of the other
2 marks for solving one of the unknowns
1 mark for substitution the first unknown into the other original equation
1 mark for finding the value of the second unknown

0 8 . 2 The pressure in a hydraulic system is 1.25 MN m^{-2}
Calculate the force if the area is 0.126 m^2 to 4 significant figures. You **must** show all of your working and include the correct units.

[3 marks]

$1.25x10^6\ Nm^{-2} \times 0.126\ m^2 = 157\ 500 \frac{N}{m^2} \times m^2 = 157\ 500\ N$

1 mark for correct method
1 mark for correct method of subtracting the indices
1 mark for the correct answer

0 9 . 1 By the use of integration, calculate the distance that the robot has travelled between $t = 0$ to $t = 4$ seconds. Answer to 2 significant figures.

[7 marks]

$$\int_0^4 v.dt = \int_0^4 (2t^2 + 5).dt = \left[\frac{2t^3}{3} + 5t\right]_0^4$$

Therefore,

$$\left[\frac{2(4)^3}{3} + 5(4)\right] - \left[\frac{2(0)^3}{3} + 5(0)\right] = 62.6666\ldots \text{ square units}$$

Better as 63 square units to 2 sig. fig.

1 mark for the correct notation
1 mark for each correct integral – **2 marks max**
1 mark for setting up the definite integral
1 mark for the subtraction
1 mark for the final answer
1 mark to 2 sig. fig.

0 9 . 2 Explain what this area represents by showing how you got to this solution.

[3 marks]

The area represents the total distance travelled by the robot.

The proof can be taken from:

$$\text{Area} = \delta v \times \delta t = \frac{\text{m}}{\text{s}} \times \text{s} = \text{m}$$

1 mark for this or a similar statement
2 marks for the proof using rules of indices

Assessment outcomes coverage

Assessment Outcomes	Marks and % of marks available in section A	Marks and % of marks available in section B	Total Marks
AO1:	18 marks 36%	09 marks 30%	27 marks
AO2:	07 Marks 14%	07 marks 14%	14 marks
AO3:	10 Marks 20%	07 marks 23%	17 marks
AO4:	04 Marks 08%	0 marks 0%	04 marks
AO5:	07 Marks 14%	0 Marks 0%	07 marks
AO6:	04 Marks 08%	07 Marks 23%	11 marks
Total Marks	**50**	**30**	**80**

Question	AO1	AO2	AO3	AO4	AO5	AO6
1	3	7				
2	3		10			
3	3			2		
4	3			2		
5	3				7	
6	3					4
7	3	7				
8	3		7			
9	3					7
Totals	**27**	**14**	**17**	**04**	**07**	**11**