Cambridge Technicals
Engineering

Unit 3: Principles of mechanical engineering

Level 3 Cambridge Technical Certificate/Diploma in Engineering
05822 - 05825

Mark Scheme for January 2021

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

Annotations

Annotation	**Meaning**
tick	Correct response worthy of a mark. Number of ticks = number of marks awarded.
cross	Incorrect response
Omission mark (carat)	Incomplete response
ECF	Error carried forward
BOD	Benefit of doubt
NBOD	No benefit of doubt
POT	Power of ten error
RE	Rounding error
SF	Significant figure error

If the data given in a question is to 2 sf, then allow to 2 or more significant figures. If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Penalise a rounding error in the second significant figure once only in the paper.

Subject-specific marking instructions

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy/answer marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.
C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.
A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Question			Answer/Indicative content	Mark	Guidance
1	(i)		Weight = mg= 2 x 9.8 = 19.6 (N)	A1	
				[1]	
	(ii)		Horizontal component = 25(N) Magnitude = $\sqrt{25^2 + 19.6^2}$ = 31.8 (N)	C1 C1 A1	 Pythagoras step with their components ecf (i)
				[3]	
	(iii)		Acceleration = Resultant force/mass = 31.8/2 = 15.9 ms^{-2}	 A1 A1	ecf their (ii)
				[2]	
	(iv)		Momentum = mass x velocity speed = 15/2 = 7.5 (ms^{-1})	 A1	
				[1]	
	(v)		K.E. = ½ mv^2 = 0.5 x 2 x 7.5^2 = 56.25 (J)	A1	ecf their (v)
				[1]	
	(vi)		The forces are concurrent	A1	Accept 'all the forces meet at a single point' if term concurrent not used
				[1]	
2	(a)	(i)	Compound spur gear system	A1	Must include 'compound' term
				[1]	
		(ii)	Wormgear and wormwheel	A1	Accept just wormgear
				[1]	
		(iii)	Chain-driven sprocket	A1	Allow chain drive or similar but not just "chain".
				[1]	
	(b)	(i)	MA = 105/150 = 0.7	A1	
				[1]	
		(ii)	a = MA x b = 0.7 x 1.2 = 0.84(m)	A1	ecf their (i)
				[1]	
	(c)	(i)	teeth on output = teeth input/VR =48/2.5 (= 19.2) It is not possible to have 19.2 teeth on a gear so the VR cannot be achieved exactly	M1 A1	Use of VR formula to calculate number of teeth in output Conclusion regarding integer number of teeth
				[2]	
		(ii)	diameter of input = VR x diameter of output = 2.5 x 22 = 550 (mm)	A1	Accept 55 cm or 0.55 m.
				[1]	

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Mark</th><th>Guidance</th></tr>
<tr><td></td><td></td><td>(iii)</td><td>The belt and pulley system can slip (while the spur gears will not) OR
The belt and pulley system will wear out more quickly/is less durable/will need replacing more often</td><td>A1</td><td>If no direct reference made to property of belt and pulley or spur gears assume response refers to belt and pulley
Not “more slip” or “more likely to slip” because spur gears do not slip.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[1]</td><td></td></tr>
<tr><td></td><td>(d)</td><td></td><td>The steering mechanism/system</td><td>A1</td><td>Any sensible reference to car steering. Not steering wheel.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[1]</td><td></td></tr>
<tr><td>3</td><td>(a)</td><td>(i)</td><td>Use of moment of area formula, may be seen in table form, vector form, or separate calculations.

<table>
<tr><th>Shape</th><th>Area</th><th>x_i</th><th>y_i</th><th>a_ix_i</th><th>a_iy_i</th></tr>
<tr><td>1</td><td>8000</td><td>20</td><td>100</td><td>160000</td><td>800000</td></tr>
<tr><td>2</td><td>2400</td><td>70</td><td>20</td><td>168000</td><td>48000</td></tr>
<tr><td>3</td><td>4000</td><td>120</td><td>50</td><td>480000</td><td>200000</td></tr>
<tr><td></td><td>14400</td><td></td><td></td><td>808000</td><td>1048000</td></tr>
</table>
OR
<table>
<tr><th>Shape</th><th>Area</th><th>x_i</th><th>y_i</th><th>a_ix_i</th><th>a_iy_i</th></tr>
<tr><td>1</td><td>5600</td><td>70</td><td>20</td><td>392000</td><td>112000</td></tr>
<tr><td>2</td><td>6400</td><td>20</td><td>120</td><td>128000</td><td>768000</td></tr>
<tr><td>3</td><td>2400</td><td>120</td><td>70</td><td>288000</td><td>168000</td></tr>
<tr><td></td><td>14400</td><td></td><td></td><td>808000</td><td>1048000</td></tr>
</table>
$\bar{x} = \frac{808000}{14400} = 56.1\ (mm)$
$\bar{y} = \frac{1048000}{14400} = 72.8$ (mm)</td><td>C1

C1

C1

A1
A1</td><td>Area and co-ordinates of centroid found for first shape. Award if 2/3 correct.

Area and co-ordinates of centroid found for second or third shape. Award if 2/3 correct.
Note candidates may have split into different shapes than the 2 examples given here.

The sum of their a_ix_i (or a_iy_i) found and divided by their total area.
(Using $\bar{x} = \frac{\sum a_i x_i}{total\ area}$ oe for $\bar{y}$)

Correct answers for $\bar{x}$ and $\bar{y}$, rounded correctly to 2 sf or better.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[5]</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>$\tan^{-1}\left(\frac{140-56.1}{100-72.8}\right)$
$= 72.0^o$</td><td>C1
A1</td><td>Ecf part (ii). Award for any attempt using arctan and their x/y values.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[2]</td><td></td></tr>
</table>

Question			Answer/Indicative content	Mark	Guidance
	(b)	(i)	Area = π x 0.006^2 = 1.131 x 10^{-4} (m^2) Stress = 60000/their area = 530 MPa or 530,000,000 Pa	C1 C1 A1	Calculation of cross-sectional area, in any unit Accept answers of 530,000,000 or 530 Unit must agree with their calculation, eg for 530 Pa award A1A0. Accept Nm^{-2} instead of Pa, or Nmm^{-2} instead of MPa.
				[3]	
		(ii)	Strain = 0.006/1.2 = 0.005	C1 A1	Award if 6 used instead of 0.006
				[2]	
		(iii)	Young's modulus = Stress/Strain = 530,000,000/0.005 = 106 GPa Yes, this test agrees as the value calculate for E is in the range 105 - 120GPa.	M1 A1	Calculation of E with their values from (i) and (ii) Do not award unless E found
				[2]	
		(iv)	The stress caused by the tensile force is within the elastic region of the material (530 Mpa < 800 MPa). So yes, the test is consistent with an elastic limit of 800 MPa.	A1	Conclusion of test results being consistent required.
				[2]	
4	(i)		Use of suvat with u=0, s=120, v=18 and equation $v^2=u^2 + 2as$ $18^2 = 0 + 2x120a$ a = 1.35 (ms^{-2})	C1 A1	
				[2]	
	(ii)		Driving force = work/distance = 360,000/120 D = 3000 (N) $\sum F = ma$ 3000 – R = 1800 x 1.35 R = 570 (N)	C1 A1 C1 A1 A1	Use of correct formula, award if 360 used instead of 360000 Use of F=ma All terms and signs correct Allow FT of their D for last 3 marks.
				[5]	
5	(i)		Volume = 4.5 x 1 x 0.08 = 0.36 (m^3) Mass = Volume x density = 0.36 x 740 = 266.4 kg	C1 C1 C1 A1	volume = l x w x d, award if 8 used instead of 0.08 ecf their volume
				[4]	

Question			Answer/Indicative content	Mark	Guidance
	(ii)	(*A*)	Total downward force = (266.4 + 100) x 9.8 3590.72 (N) Reaction force at each support = 3590.72/2 = 1795.36 (N)	C1 A1 A1	Recognition of need to multiply loads in kg by 9.8 Total load. Allow load in kg. Half total load since symmetric. Ecf their total load in N. 183.2 scores 2 marks
				[3]	
		(*B*)	1795.36 x 2.25 – (266.4 x 9.8/2)x1.125 = 2571 (Nm)	C1 A1	Allow very close attempt
				[2]	
6	**(a)**	**(i)**	20000 x 3 + 40000x= 28000 x 2.5 $x = 0.25\ (m)$	C1 A1 A1	Attempt to set up an equation for moments about tower All terms present and correct
				[3]	
		(ii)	Load x 8 + 28000 x 2.5= 20000x3 + 40000x2.6 Load = 11750 (N)	C1 A1 A1	Equation set up with at least one term correct or total moment from counterweights calculated but not as part of equation All terms present and correct
				[3]	
	(b)		Work done = Change in energy 20000 = 200 x 9.8 x h h = 10.2 (m)	C1 C1 A1	Attempt to use work-energy principle Correct equation
				[3]	

OCR (Oxford Cambridge and RSA Examinations)
The Triangle Building
Shaftesbury Road
Cambridge
CB2 8EA

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk

For staff training purposes and as part of our quality assurance programme your call may be recorded or monitored

Oxford Cambridge and RSA Examinations
is a Company Limited by Guarantee
Registered in England
Registered Office; The Triangle Building, Shaftesbury Road, Cambridge, CB2 8EA
Registered Company Number: 3484466
OCR is an exempt Charity

OCR (Oxford Cambridge and RSA Examinations)
Head office
Telephone: 01223 552552
Facsimile: 01223 552553