Oxford Cambridge and RSA

Cambridge Technicals
Engineering

Unit 3: Principles of mechanical engineering

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

Mark Scheme for January 2019

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.

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Mark</th><th>Guidance</th></tr>
<tr><td colspan="6">For all questions, units shown in brackets are not required for full marks</td></tr>
<tr><td>1</td><td></td><td>(i)</td><td>Area = 120 x 40 + (π x 50^2) ÷ 2

= 8726.99…..(mm^2)
= 0.00872699….(m^2) and thickness = 0.005 m

Mass = 0.00872699 x 0.005 x 2700

= 0.12kg (0.1178)</td><td>C1

C1
C1

C1

A1</td><td>Attempt to calculate area in any units, must see evidence of use of πr^2
Any units
Dealing with units correctly, either converting mm to m for both area and thickness or converting density to kg/mm^3. May be seen at a later stage.
Their area x thickness x volume (ignore incorrect unit conversion)
Accept answers in range 0.117 – 0.120
Synoptic marks unit 2</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>Use of moment of area method, may be seen in vector format, table format or other.

<table>
<tr><td>Shape</td><td>Area</td><td>x_i</td><td>y_i</td><td>a_ix_i</td><td>a_iy_i</td></tr>
<tr><td>1</td><td>4800</td><td>60</td><td>20</td><td>288000</td><td>96000</td></tr>
<tr><td>2</td><td>1250π
(3926.99</td><td>50</td><td>61.221</td><td>196349.5</td><td>240414</td></tr>
<tr><td></td><td>8726.99</td><td></td><td></td><td>484349.5</td><td>336414</td></tr>
</table>

$\bar{x} = \frac{484349.5}{8726.99} = 55.5 \ldots$ (mm)

$\bar{y} = \frac{336414}{8726.99} = 38.5. \ldots$(mm)</td><td>C1

C1

C1

A1

A1</td><td>

Area and co-ordinates of centroid shown for 1 shape, condone one error
Area and co-ordinates of centroid shown for second shape, condone one error (if error is in 61.22..condone as long as evidence of 4r/3π, eg sight of 21.22)

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 $\bar{y}$)

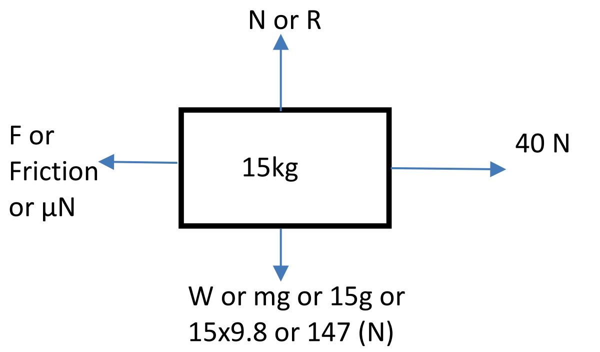
Both final answers rounded correctly</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[5]</td><td></td></tr>
<tr><td></td><td></td><td>(iii)</td><td>90 - θ =) $tan^{-1}\left(\frac{\bar{y}}{120-\bar{x}}\right) = tan^{-1}\left(\frac{38.5}{120-55.5}\right)$

(90 - θ =) 30.9° or (θ =) 59.1°</td><td>C1

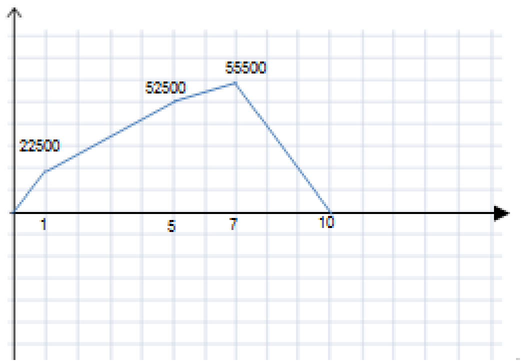
A1</td><td>Attempt to use $\tan^{-1}$ function with their x and y from ii) eg (38.5/55.5)
Accept answers rounding to 31° or 59° Ecf part ii)
Synoptic marks unit 1</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[2]</td><td></td></tr>
</table>

Question			Answer/Indicative content	Mark	Guidance
2	(a)	(i)	Overall VR = $\frac{product\ of\ drivers}{product\ of\ driven} = \frac{100\times80}{200\times120}$ = 1/3 or 0.333 OR VR A to B = 100/200 = 1/2 VR C to D = 80/120 = 2/3 Overall VR = ½ x 2/3 = 1/3	C1 A1	Attempt at formula for overall VR, must see use of product not sum OR C1 One appropriate VR correctly calculated A1 Correct overall VR **Accept VR = 3 for full marks using alternative correct formula i.e. VR= input speed/output speed**
				[2]	
		(ii)	Speed of input = speed of output / VR = 60/(1/3) = 180 (rpm)	A1	Ecf their VR from i) **DO NOT allow 20 if VR = 3**
				[1]	
		(iii)	MA = 1/VR = 3	A1	Ecf their VR from i) **Accept MA = 1/3 for full marks if their VR=3.**
				[1]	
	(b)		Diameter of input = Diameter of output x VR = 85 x 1.8 = 153 (cm)	A1	**Accept 47.22.. for full marks using alternative correct formula.**
				[1]	
	(c)	(i)	Class 2	A1	
				[1]	
		(ii)	MA = a/b = 0.8/0.5 = 1.6	A1	
				[1]	
		(iii)	Weight of load = 30 x 9.8 = 294 (N) Moment from Child's force = 200 x 0.8 = 160 (Nm) Moment from load = 294 x 0.5 = 147 (Nm) Child's moment of 160Nm is greater than that from the load so yes, the load can be lifted. OR Weight of load = 30 x 9.8 = 294 (N) F_o= MA x F_I = 1.6 x 200 = 320 (Nm) The maximum force the Child can lift is 320 Nm which is greater than the weight of the load, so yes the load can be lifted.	C1 C1 A1 (C1) (C1) (A1)	May be seen as part of later calculation Calculation of moment from Child's force or from load seen Comparison of two (correct) values made and correct conclusion drawn Calculation of maximum output force, ecf their MA from ii) Comparison with the weight of the load made and correct conclusion drawn (must compare with 294Nm not 30kg) Accept alternative method calculating Force to balance load (184N) and comparison with Weight of child
				[3]	

Question			Answer/Indicative content	Mark	Guidance
3	(a)	(i)	Net horizontal force = 200 – 120cos35 = 101.70… Net vertical force = 120sin35 – 20 = 48.829… Magnitude = $\sqrt{101.70..^2 + 48.829..^2}$ = 112.8 (N)	C1 C1 C1 A1	Attempt to find net vertical or horizontal force Attempt to find net vertical or horizontal force Allow sin/cos error on first C1 but not second Pythagoras used with their horizontal and vertical components If no marks given award C1 for correct resolution of 120N into components, as long as directions are clear (i.e. sin/cos correct way around) Synoptic marks unit 1 and 2
				[4]	
	(a)	(ii)	$F = ma$ so $a = F/m$ = 112.8../3 = 37.605.. (ms^{-2}) Use of $s = ut + at^2/2$ S= 4x8 + 0.5 x 37.6 x 8^2 = 1200 (m) (1235)	**C1** **C1** **A1**	Ecf their force from i) Correct suvat equation selected or numbers substituted correctly Ecf their acceleration. Allow g for 2nd C1
				[3]	
	(b)		Either P=Fv = 3200 x 25 = 80000 (W) Work = P x t = 80000 x 20 = 1 600 000 (J) Or Distance = velocity x time = 25 x 20 = 500 (m) Work = force x distance = 3200 x 500 = 1 600 000 (J)	 **C1** **A1**	 C1 A1
				[2]	

Question			Answer/Indicative content	Mark	Guidance
4		**(i)**	 	C1 A1	2 or more arrows correct All arrows correct (but see below) Arrows must have labels and arrowheads Condone no units indicated Condone appropriate alternative labels eg 'Normal Reaction' instead of N …. BUT NOT 147N for N Candidate may draw object travelling left in which case F and 40 should be switched round If candidate labels Friction force with answer from part ii) accept.
				[2]	
		(ii)	$F=\mu N = 0.04 \times 15 \times 9.8$ $=5.88$ (N)	C1 A1	Use of formula, condone omission of g for this mark
				[2]	
		(iii)	$\Sigma F=ma$: $40 - 5.88 = 15a$ $a= 2.3$ (2.275….. (m s^{-2}))	C1 C1 A1	Use of F=ma with at least one force. Must use mass not weight All elements correct. Ecf their friction from part ii) Must be rounded correctly correct unit must be included.
				[3]	
		(iv)	K.E $=\frac{1}{2}mv^2 = \frac{1}{2} \times 15 \times 2.7^2= 55$ (54.675 (J))	A1	
				[1]	
		(v)	Work-energy principle: Work done by friction = Loss in K.E 5.88d=54.675 Distance = 9.3 (9.2979….(m))	C1 A1	Attempt to use W-E principle. Must see sight of work done by friction. Condone additional work terms. Accept -5.88d = -54.675
				[2]	

Question			Answer/Indicative content	Mark	Guidance
5	(a)		Area = $\pi r^2 = \pi \times 0.004^2 = 5.0265\ldots \times 10^{-5}\ldots$ (m^2) OR $\pi \times 4^2 = 50.265..$ (mm^2)	C1	Calculating cross-section area, ignore units
			Shear stress = Shear force / 2A for double shear $= \frac{2000}{2 \times 5.0625.. \times 10^{-5}}$	C1	Use of formula with 2 x their area, ignore units
			= 19 894 368 Pa Allow rounding to 20 000 000 Pa or N m^{-2} OR =20 MPa or 20 N mm^{-2}	A1	Must include appropriate unit with their answer (eg 20 Pa scores 2)
				[3]	
	(b)		Young's Modulus or modulus of elasticity	A1	
				[1]	
	(c)		Original length = change in length / strain = 6/0.004 = =1500 (mm) or 1.5 (m)	C1 A1	Use of formula with 0.004 for strain. Ignore units If no units indicated assume answer is in mm
				[2]	
	(d)	(i)	Rack and pinion	A1	
				[1]	
		(ii)	Pillar drill, on railway tracks to help trains go uphill, steering system in a car	A1	Answers must be specific, eg do not accept 'car', 'train'. Accept any sensible alternative answer.
				[1]	
	(e)	(i)	No slippage occurs with the chain and sprocket (where it does on a belt and pulley) The chain and sprocket is more durable than the belt and pulley The chain and sprocket would need less maintenance than the belt and pulley (the chain would need replacing less often than the belt)	A1	If not clear which application candidate is referencing assume they are talking about the chain and sprocket. i.e 'it doesn't slip' gets mark, while 'it can slip' does not. Allow reference to "grip". If using this explanation a comparison must be made about relative occurrence, ie 'belt can snap' alone is not suitable without a comparison about it snapping more often than the chain
				[1]	
		(ii)	The flat belt and pulley is cheaper – accept quieter The chain and sprocket requires lubrication where the belt and pulley does not	A1	If not clear which application candidate is referencing assume they are talking about the belt. i.e 'it is cheaper' gets the mark while 'requires lubrication' does not.
				[1]	

Question			Answer/Indicative content	Mark	Guidance
6	(a)		Continuous	A1	Allow “continually….”
				[1]	
	(b)	(i)	Sum of moments about end A (or B) = 0 R_B x 10 – 20000x7 – 6000x5 – 15000x1 = 0 R_B = 18500 (N) Vertical equilibrium $R_A + R_B$ = 15000 + 6000 + 20000 ($R_A + R_B$ = 41000) R_A = 22500 (N)	 C1 A1 C1 A1	Attempt to take moments about either end, with at least two terms correct (ignore signs) May be seen as first step Ecf their R_B as long as M1 for moments step awarded If other methods used award B2 for each reaction Synoptic marks unit 1
				[4]	
		(ii)		C1 C1 C1 A1	0 moment at both free ends and a linear diagram 22500 or 55500 (ignore sign) - accept no label if carefully drawn to scale. 52500 (ignore sign) - accept no label if carefully drawn to scale. All values correct, signs consistent (either all positive or all negative). Points joined with approximately straight lines. Accept values marked either on y-axis or next to critical points Condone no units given
				[4]	

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