Cambridge Technicals
Engineering

Unit 3: Principles of mechanical engineering

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

Mark Scheme for January 2020

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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>1</td><td>(i)</td><td></td><td>(Area =) 0.5 (10 x 8) +10 x 12
= 160 (cm^2)</td><td>C1
A1</td><td>Award C mark for correct method with a single error.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[2]</td><td></td></tr>
<tr><td></td><td>(ii)</td><td></td><td>{Volume =) 160 x 0.5 / 80 (cm^3)
(Mass =) 80 x 8 / 640 (g)
(Mass =) 0.64 (kg)</td><td>
C1
C1
A1</td><td>ecf i) throughout
in any units,
their volume x density, in any units</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[3]</td><td></td></tr>
<tr><td></td><td>(iii)</td><td></td><td>Use of second moment of area method, may be seen in vector format, table format or other.

<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>120</td><td>6</td><td>5</td><td>720</td><td>600</td></tr>
<tr><td>2</td><td>40</td><td>14.666...</td><td>6.66...</td><td>586.67</td><td>266.67</td></tr>
<tr><td></td><td>160</td><td></td><td></td><td>1306.67</td><td>866.67</td></tr>
</table>
$\bar{x} = \frac{1306.67}{160} = 8.17\ (cm)$
$\bar{y} = \frac{866.67}{160} = 5.42$ (cm)</td><td>
C1

C1

C1

C1

A1</td><td>Allow ecf from (i)
Area and co-ordinates of centroid found for first shape (numbers 120,6,5). Award if 2/3 correct.
Area and co-ordinates of centroid found for second shape (numbers 40, 14.67,6.67). Award if 2/3 correct.
The sum of their a_ix_i found and divided by their total area. (Using $\bar{x} = \frac{\sum a_i x_i}{total\ area}$)
The sum of their a_iy_i found and divided by their total area. (Using $\bar{y} = \frac{\sum a_i y_i}{total\ area}$)

BOTH correct answers for $\bar{x}$ and $\bar{y}$ rounding to 8.2 and 5.4 respectively to 2 s.f.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[5]</td><td></td></tr>
<tr><td>2</td><td>(a)</td><td></td><td>(Stress = E x strain =) 70 x 10^9 x 0.0015

= 105 MPa / 105,000,000 Pa/Nm^{-2}</td><td>C1

A1</td><td>Correct use of correct formula, allow pot error eg 70 x 0.15
Including correct unit</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[2]</td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td>Area = π x 0.005^2 / 7.854 X 10^{-5} (m^2)

Shear Stress = Shear Force÷Shear Area / 30000÷(2A)

= 191 MPa</td><td>C1

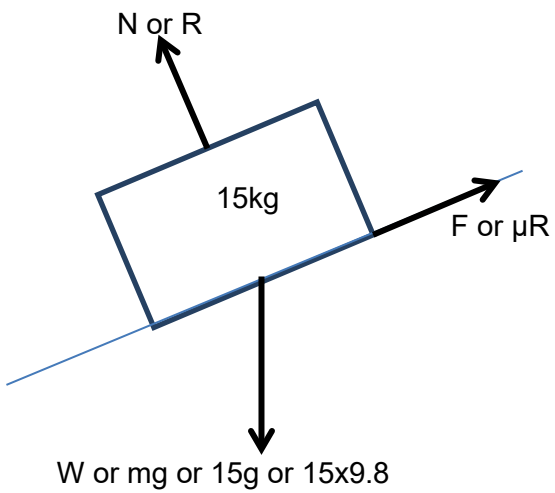
C1

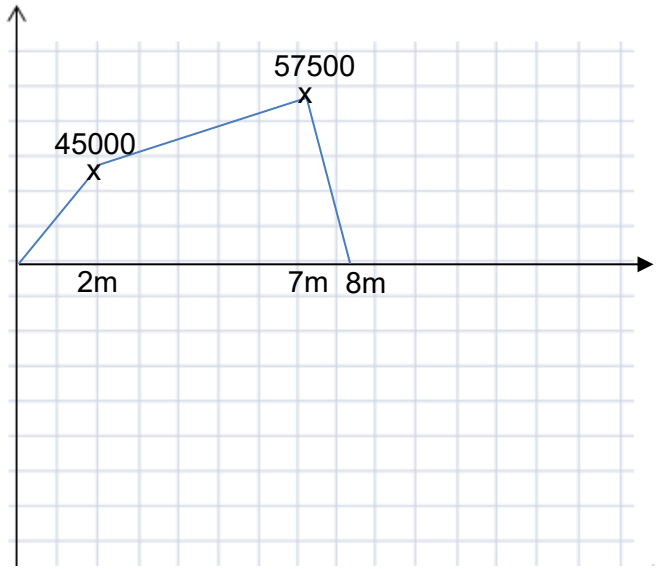
A1</td><td>Calculation of area in any units. May be seen within shear stress calculation
use of 2A must be seen

Must include unit. Accept alternative correct prefix.</td></tr>
</table>

Question			Answer/Indicative content	Mark	Guidance
				[3]	
	(c)	**(i)**	Elastic Limit / Limit of Proportionality	A1	
		(ii)	Elastic (deformation/ energy)	A1	NOT Force
		(iii)	Plastic / In-elastic (deformation/energy)	A1	NOT Force
				[3]	
3	**(a)**	**(i)**	Overall VR = product of drivers÷product of driven $= \frac{40 \times 80}{30 \times 20}$ (= 5.33..) OR 40÷30 AND 80÷20 seen (Output speed =) 90 x 5.33 = 480 rpm	C1 C1 A1	Use of formula for overall VR Allow (80÷20)x90 OR (40÷30)x90 for this C mark
				[3]	
		(ii)	(VR =) $\frac{n \times 80}{30 \times 20} = 6$ (n =) 45	C1 A1	Use of VR formula to set up equation
				[2]	
	(b)		To transmit rotary motion between axis that are not aligned To transmit motion between shafts that are at 90 degrees to each other To change the direction of motion of shafts	A1	Accept any sensible reference made to two axes/shafts which are at 90 degrees (Shafts need not necessarily be at 90 degrees to each other, although this is the most common)
				[1]	
	(c)		(diameter of input =) VR x diameter of output / 1.4 x 80 = 112 cm	C1 A1	Correct rearrangement of formula used
				[2]	
	(d)		Chopsticks, Tweezers, Stapler, Fishing rod, etc	A1	Accept any valid application. Accept bicep curl.
				[1]	
	(e)	**(i)**	(Output force = MA x input force = 2.05 x 160) = 328(N)	A1	
				[1]	
		(ii)	(b = a/MA = 1.2÷2.05) = 0.585(m)	A1	

Question			Answer/Indicative content	Mark	Guidance
				[1]	
4	**(a)**	**(i)**	(Resultant vertical force =) 250sin50 + 60sin30 - 120 / 101.511.. (Resultant horizontal force =) 250cos50 – 60cos30 / 108.735.. Magnitude = $\sqrt{101.511^2 + 108.735^2}$ $= 149\ (N)$ (148.7)	C1 C1 C1 A1	Allow a single error in sign or sin/cos Allow a single error in sign or sin/cos Pythagoras step with their forces Accept any answers rounding to 149
				[4]	
		(ii)	$tan^{-1}\left(\frac{108.735}{101.511}\right)$ = 47.0 (°)	C1 A1	$\tan^{-1}$ with their vertical and horizontal components in any order (or equivalent sin/cos using their resultant)
				[2]	
		(iii)	(Power = Force x velocity = 149 x 1.2 =) 179 (W) (178.44)	A1	Ecf part i)
				[1]	
	(b)		(Increase in GPE = mgh =) 4 x 9.8 x 0.8 / 31.36 (J) W.E principle: Work done by machine – Work against Friction = Inc. PE / Work done by machine – 50 = 31.36 (Work done machine =) 81.36 (J)	C1 C1 A1	Use of GPE formula Use of work energy principle, signs must be correct. Accept either in words or as a calculation.
				[3]	
5		**(i)**	(Use of suvat with u=0, s=4, v=0.8 and equation $v^2=u^2 + 2as$) $0.8^2 = (0 +) 2 \times 4a$ (a =) 0.08 (ms^{-2})	 C1 A1	
				[2]	

Question			Answer/Indicative content	Mark	Guidance
5		(ii)		C1 A1	2 out of 3 arrows correct Diagram as shown Accept labels written in words rather than symbols eg Normal Reaction Accept arrows if direction correct. Do not accept lines instead of arrows. Subtract 1 mark for each missing or incorrect arrow. Ignore acceleration arrow if clearly labelled. Accept 15g force resolved into components of 15gsin10 down slope and 15gcos10 into slope, but to be correct both are required and should be instead of 15g not as well as.
				[2]	
		(iii)	(Use of F=ma down slope) 15gsin10 – F = 15a (F =) 24.33 (N)	 C2 A1	 Award C1 if just one sign error or sin/cos error ecf i)
				[3]	
		(iv)	(μ = F/N =) 24.33/15gcos10 = 0.168	C1 A1	Award if EITHER cos10 or g is omitted (NOT BOTH) ecf iii)
				[2]	
		(v)	(When box stationary F= 15gsin10 =) 25.526 (μ = F/N = 25.526/15gcos10 =) 0.176 (Suitable range is) $0.168 \leq \mu < 0.176$	C1 C1 A1	Calculation of new F Inequality signs must be correct

Question			Answer/Indicative content	Mark	Guidance
				[3]	
6	**(a)**		Encastre	A1	Allow reasonable spelling errrors
				[1]	
	(b)	**(i)**	Moments about end A: R_B x 8 = 20000x2 + 60000x7 R_B = 57, 500 (N) Moments about end B OR Vertical Equilibrium: $R_A + R_B = 20000 + 60000$ R_A = 22,500 (N)	C1 A1 C1 A1	Must have 3 terms but allow one sign error or 1 incorrect distance.
				[4]	
		(ii)		C1 C1 C1 A1	0 moment at free ends, linear diagram Calculation of moment at 2m (22,500 x 2) ignore signs Calculation of moment at 7m (57,500 x 1) ignore signs Diagram as shown. Award all marks if opposite sign convention used and entire diagram is reflected about x-axis or y-axis. Allow values marked on axes or at critical values
				[4]	

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