Pearson
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Mark Scheme (Results)

June 2023

Pearson BTEC Nationals
In Engineering (31706H)
Unit 1: Engineering Principles

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Unit 1: Engineering Principles – 2306

General marking guidance

- All learners must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do, rather than be penalised for omissions.
- Examiners should mark according to the mark scheme, not according to their perception of where the grade boundaries may lie.
- All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed-out work should be marked UNLESS the candidate has replaced it with an alternative response.

Specific marking guidance

This mark scheme uses the following types of marks:

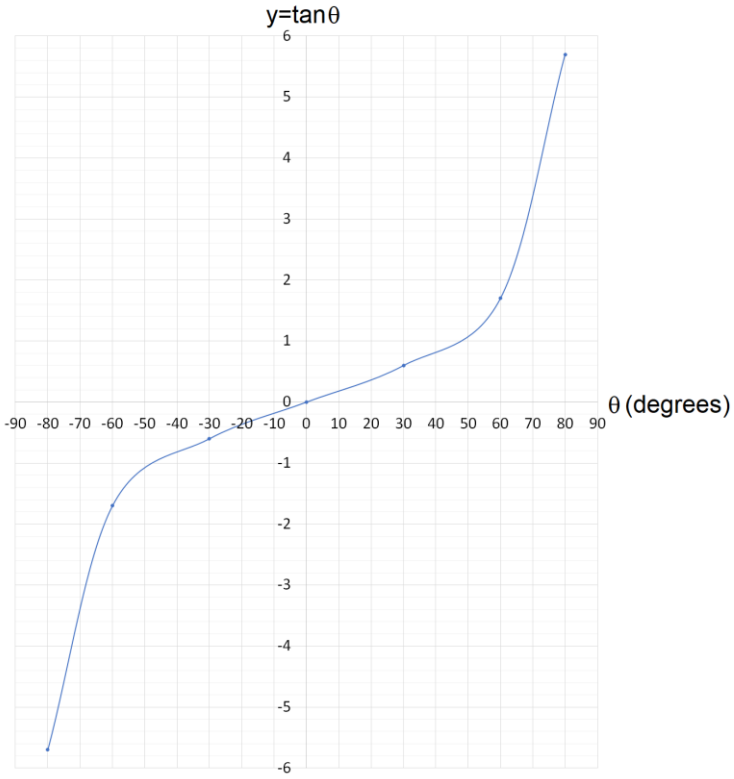
- M marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
- A marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
- B marks are unconditional accuracy marks (independent of M marks)
- Marks should not be subdivided.

Abbreviations:

- ft – follow through
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC - special case
- oe – or equivalent (and appropriate)
- dp - decimal places
- sf - significant figures

<table>
<tr><th>Question number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>1(a)</td><td>
<table>
<tr><td>Angle (θ)</td><td>-80°</td><td>-60°</td><td>-30°</td><td>0°</td><td>30°</td><td>60°</td><td>80°</td></tr>
<tr><td>y</td><td>-5.7</td><td>-1.7</td><td>-0.6</td><td>0</td><td>0.6</td><td>1.7</td><td>5.7</td></tr>
</table>

Correct calculation of y (1) cao
Award 1 mark for 5 correct values

Note: do not penalise if answers are given to more than 1 decimal place.
</td><td>(1)</td></tr>
<tr><td>(b)</td><td>


Both axes with appropriate labels (1) (horizontal Angle/degrees/θ /°, vertical y, tanθ, distance(km))
Both axes with appropriate values (1)
Accurate plotting of the form of the graph (1) (ft)

</td><td>(3)</td></tr>
</table>

Question number	Working	Answer	Notes	Mark
2	Volume of cone: $V = 1/3 \times \pi r^2 h$ $r = 160/2 = 80mm$ $V = 1/3 \times \pi \times 80^2 \times 60$ $V =$ **$402124\ mm^3$** or $V =$ **$402 \times 10^3\ mm^3$** or $V =$ **128000π**	$V = 402124\ mm^3$ Or $V = 4.02 \times 10^{-4} m^3$ Accept answers rounding to $402000\ mm^3$	M1 for conversion of diameter to radius M1 for correct substitution of values (ft) A1 for correct volume of the cone (ft)	**(3)**

Question number	Working	Answer	Notes	Mark
3 (a)	$\theta = 103 \times 2\pi/360$ **$\theta = 1.80$ rad**	$\theta = 1.80$ rad Accept answers rounding to 1.8 rad	M1 for correct substitution of values A1 for correct answer for θ (ft)	**(2)**
(b)	$A = \frac{1}{2} r^2 \theta$ $A = 0.5 \times 70^2 \times 1.8$ **$A = 4410\ mm^2$** NB: If θ has not been rounded in part (a) then $A = 4404.34\ mm^2$	$A = 4410\ mm^2$ Accept answers in a range of $4400\ mm^2$ to $4410\ mm^2$	M1 for correct substitution of values (ft) A1 for correct answer for A (ft)	**(2)**

Question number	Working	Answer	Notes	Mark
4	Cosine rule $a^2 = b^2 + c^2 - 2bc \cos A$ $a^2 = 8.3^2 + 5.8^2 - 2x8.3x5.8xCos105$ $a^2 = 102.53 - 96.28Cos105$ $\boldsymbol{a^2 = 127.45}$ $a = \sqrt{127.45}$ $\boldsymbol{a = 11.29m}$	a = 11.29m accept answers rounding to 11.3m	M1 for identification of the cosine rule M1 for correct substitution of values A1 for the correct answer for a^2 (ft) A1 for correct answer for a (ft)	**(4)**

Question number	Working	Answer	Notes	Mark
5	$-2t^2 + 11t - 15 = 0$ $-(2t^2 - 11t + 15) = 0$ $-(2t - 5)(t - 3) = 0$ $2t-5 = 0$ or $t - 3 = 0$ Therefore $t= 5/2 = 2.5$ and $t = 3$ **Alternative method 1** $-2t^2 + 11t - 15 = 0$ $15 + 2t^2 - 11t = 0$ $2t^2 - 11t + 15 = 0$ $(2t - 5)(t - 3) = 0$ $2t - 5 = 0$ or $t - 3 = 0$ Therefore $t= 5/2 = 2.5$ and $t = 3$ **Alternative method 2** $-2t^2 + 11t - 15 = 0$ $t^2 - 5.5t + 7.5 = 0$ $(t - 2.5)(t - 3) = 0$ $t-2.5 = 0$ or $t - 3 = 0$ Therefore $t= 2.5$ and $t = 3$	$\underline{t = 2.5}$ and $\underline{t = 3}$	M1 for creating an equation when h=15 M1 for identifying one suitable factor or M2 for identifying two suitable factors e.g. (2t -5) and (t -3) (ft) B1 for correct answer for time 1 (ft) B1 for correct answer for time 2 (ft) M1 for creating an equation when h=15 M1 for identifying two suitable factors (3 and 2.5) (ft) M1 for factorising to give factors in terms of t (ft) B1 for correct answer for time 1 (ft) B1 for correct answer for time 2 (ft)	**(5)**

	Alternative method 3: (-2t+a)(t +b) Multiply out brackets: $-2t^2$ – 2tb +at +ab So: ab= -15 and -2b + 1 = 11 By trial and error or substitution: a = 5 and b = -3 So: (-2t+5)(t-3) 2t-5 = 0 or t - 3 = 0 Therefore t= 5/2 = 2.5 and t = 3 Award a maximum of 3 marks if solved using the formula method. Note: consider approach to take if no working is shown			

Section B

Question number	Answer	Mark
6	C - Equilibrant	**(1)**

Question number	Answer	Mark
7	A – Metres per second squared	**(1)**

Question number	Working	Answer	Notes	Mark
8 (a)	F = mg F = 580 x 9.81 F = 5689.8 N Or **F= 5.69 kN**	F = 5689.8 N Or F= 5.69 kN	M1 for correct substitution of values A1 for correct answer for force (ft)	**(2)**
(b)	W = Fs W = 5689.8 x 1.8 **W = 10241.64 J**	W = 10241.64 J Accept answers rounding to 10242 J or 10.242 kJ	M1 for correct substitution of values (ft) A1 for correct answer for work done (ft) A1 (dep) for correct unit	
	Alternative method W = PE PE = mgh PE = 580 x 9.81 x 1.8 **W = 10241.64 J**		M1 for correct substitution of values (ft) A1 for correct answer for work done (ft) A1 (dep) for correct unit	
	Accept 'Nm' as the SI unit.			**(3)**

Question number	Working	Answer	Notes	Mark
9 (a)	UDL = 4.2 x 1.2 UDL = 5.04 kN	UDL = 5.04 kN Or 5040 N	A1 for correct answer for UDL (cao)	**(1)**
(b)	Moments around A Note: midpoint of the UDL = 0.6 Clockwise moment = 0.6 x 5.04 + (1.2+0.25) x 6.9 = 3.024 + 10.005 = 13.029 Anticlockwise moments = 1.7 x R_B 13.029= 1.7R_B R_B = 13.029/1.7 R_B = 7.66 kN Alternative method: R_B x 1.7 = (0.6 x 5.04) + (6.9 x 1.45) Note: 1.2 + 0.25 = 1.45 R_B = 13.029/1.7	R_B = 7.66 kN Or 7660 kN Accept answers rounding to 7.7kN or 7700N	M1 for recognising M = Fd A1 for calculating midpoint of UDL (may be implied) M1 for CW moments with two terms (ft) M1 for ACW moments M1 for rearranging in terms of R_B (ft) A1 for correct answer for R_B (ft)	**(6)**

Question number	Answer	Mark
10	Award **one** mark for each valid statement up to a maximum of **two** marks. • The space probe will **remain** at constant velocity / move in a straight line (1) unless acted on by an external force / gravity / there is a resultant force (1) • If there are no other / net forces acting (1) the space probe will move along a straight line / at a constant velocity indefinitely (1)	**(2)**

Question number	Working	Answer	Notes	Mark
11	Density = mass/volume ρ = 4250/5 **ρ = 850 kg/m^3** Mass flow rate (ṁ) = ρAV 40mm^2 = 40x10^{-6}m^2 Mass flow rate = 850 x 40x10^{-6} x 2 **Mass flow rate = 0.068 kg/s**	Mass flow rate = 0.068 kg/s Or 68 x 10^{-3} kg/s Accept answers rounding to 0.07 kg/s	M1 for correct substitution of values A1 for correct answer for ρ (cao) M1 for correct conversion of mm^2 to m^2 M1 for recognition of mass flow rate (ṁ) M1 for correct substitution of values (ft) A1 for correct answer for Mass flow rate (ṁ) (ft)	**(6)**

Question number	Working	Answer	Notes	Mark
12	**Method 1** Wheel is a solid disc (cylinder) therefore k = 0.5 $I = kmr^2$ $I = 0.5 \times 2 \times 0.3^2$ **$I = 0.09$ kg m^2** $\omega = v/r$ $\omega = 5/0.3$ $\omega = 5/0.3$ **$\omega = 16.67$ rad/s** $KE = 1/2 \times I \times \omega^2$ $KE = 1/2 \times 0.09 \times 16.67^2$ **KE = 12.5 J** **Method 2** Wheel is a solid disc (cylinder) therefore k = 0.5 $I = kmr^2$ $I = 0.5 \times 2 \times 0.3^2$ $I = 0.09$ kg m^2 Frequency of rotation (f) = 5 / (2xπx0.3) = 2.653 RPS (where 2xπx0.3 is the circumference) Angular frequency / speed equation $\omega = 2x\pi xf$ $\omega = 2 \times \pi \times 2.653$ $\omega = 16.673$ rads / s $KE = 1/2 \times I \times \omega^2$ $KE = 1/2 \times 0.09 \times 16.67^2$ KE = 12.5 J	<u>KE = 12.5 J</u> Accept answers in the range 12.4 to 12.6 J	M1 for recognising the relationship between I, ω and KE M1 for correct substitution of values A1 for correct value for I (ft) M1 for recognising the equation for angular velocity M1 for correct substitution of values (ft) A1 for correct value for ω (ft) M1 for the correct substitution of values (ft) A1 for the correct answer for KE (ft) M1 for recognising the relationship between I, ω and KE M1 for correct substitution of values (ft) A1 for correct value for I (ft) A1 for the correct answer for frequency of rotation M1 for correct substitution of values (ft) A1 for the correct value of ω (ft) M1 for the correct substitution of values (ft) A1 for the correct answer for KE (ft)	**(8)**

Section C

Question Number	Answer	Mark
13	C - Kirchhoff's law	(1)

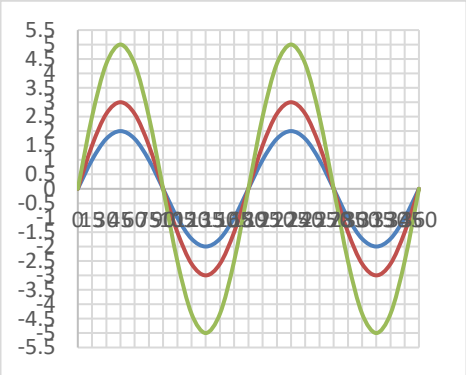
Question Number	Answer	Mark
14	A – Ampere-turns per weber	(1)

Question number	Working	Answer	Notes	Mark
15	$1/C_t = 1/C_2 + 1/C_3$ $1/C_t = 1/33 + 1/56$ $1/C_t = 0.04816$ $C_t = 1/0.04816$ $C_t = 20.764$ F Alternative method $C_t = (C_2 \times C_3)/ (C_2 + C_3)$ $C_t = (33 \times 56)/ (33 + 56)$ $C_t = 1848/89$ $C_t = 20.764$	$C_t = 20.764$ F Accept answers rounding to 20.8 F	M1 for correct substitution of values M1 for rearranging in terms of C_t (ft) A1 for the correct answer for C_t (ft) M1 for recognition of how to add 2 fractions M1 for correct substitution of values (ft) A1 for the correct answer for C_t (ft)	(3)

Question number	Working	Answer	Notes	Mark
16 (a)	$P_{in} = IV$ $P_{in} = 120 \times 5$ $P_{in} = 600$ W	<u>P = 600 W</u> Or <u>P = 600 J/s</u>	M1 for correct substitution of values A1 for correct answer for P (ft) A1 (dep) for correct unit	**(3)**
(b)	$\eta = P_{out}/P_{in}$ $P_{out} = \eta \times P_{in}$ $P_{out} = 0.65 \times 600$ $P_{out} = 390$ W	<u>P_{out} = 390 W</u> <u>or P_{out} = 390 J/s</u>	M1 for rearranging in terms of P_{out} (may be implied) M1 correct substitution of values (ft) A1 for correct answer for P_{out}(ft)	**(3)**

Question number	Working	Answer	Notes	Mark
17	$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$ $r^2 = \frac{q_1 q_2}{4\pi\varepsilon_0 F}$ $r^2 = \frac{(1.2 \times 10^{-16})(1.7 \times 10^{-16})}{4\pi(8.85 \times 10^{-12})(8.2 \times 10^{-8})}$ $r^2 = 2.24 \times 10^{-15}$ $r = \sqrt{2.24 \times 10^{-15}}$ r = **4.7×10^{-8} m**	<u>r = 4.7×10^{-8} m</u>	M1 for rearranging in terms of r^2 (at any stage of the calculation) M1 for fully correct substitution of values (ft) A1 for correct answer for r^2 (cao) A1 for correct answer for r(ft)	**(4)**

Question number	Working	Answer	Notes	Mark
18	$W = 0.5\ LI^2$ $L = 2W/\ I^2$ $L = 2 \times 37.5/10^2$ **L = 0.75H** $2mS = 0.002\ S$ or $2x10^{-3}$ $E = -L(di/dt)$ $E = -0.75 \times (10/0.002)$ **E = -3750V** **Alternative method** $W = 0.5\ LI^2$ $L = 2W/\ I^2$ $L = 2 \times 37.5/10^2$ **L = 0.75H** $L = N\Phi/I$ $\Phi = IL/N$ $\Phi = 0.75 \times 10/500$ **Φ = 0.015** $E = Blv = - N\ d\Phi/dt$ $E = -500 \times 0.015/2x10^{-3}$ **E = -3750 V**	E = -3750V	M1 for recognition of relationship between E, W and L M1 for rearranging in terms of L M1 for correct substitution of values (ft) A1 for correct answer for L (ft) M1 for converting mS to S M1 for correct substitution of values (ft) A1 for correct answer for E(ft) M1 for recognition of relationship between E, W and L M1 for rearranging in terms of L M1 for correct substitution of values (ft) A1 for correct answer for L (ft) M1 for rearranging in terms of Φ A1 for correct answer for Φ (ft) A1 for correct answer for E (ft)	**(7)**

Question number	Working	Answer	Notes	Mark
19	Combined waveform:  Peak value from either plotting or calculation = 5V RMS voltage = peak /√2 RMS = 5/√2 or RMS = 3.536 V Average value = 2 x peak / π Average = 2 x 5/π Average = 3.183 V Form factor = RMS/average Form factor = 3.536/3.183 Form factor = 1.11 Method 2 RMS voltage = peak /√2 V_{RMS1} = 2/√2 V_{RMS1} = 1.414 V_{RMS2} = 3/√2 V_{RMS2} = 2.121 Total V_{RMS} = 3.535 V Average value = 2 x peak / π V_{AVE1} = 2 x 2/π V_{AVE1} = 1.273 V	Form factor = 1.11 Accept answers rounding to 1.1	M1 for plotting or calculating peak value M1 for correct substitution of values (ft) A1 for correct answer for RMS voltage (ft) M1 for recognising the relationship between peak, average values and form factor M1 for correct substitution of values (ft) A1 for correct answer for Average value(ft) M1 for correct substitution of values (ft) A1 for correct answer for form factor (ft)	**(8)**

	V_{AVE2} = 2 x 3/π V_{AVE2} = 1.910 V Total V_{AVE} = 3.183 Form factor = Total V_{RMS}/ Total V_{AVE} Form factor = 3.535/3.183 Form factor = 1.11		A1 for calculating RMS V1 A1 for calculating RMS V2 A1 for correct answer for RMS total voltage (ft) M1 for recognising the relationship between peak, average values and form factor A1 for answer for Average V1 A1 for answer for Average V2 M1 for correct substitution of values (ft) A1 for correct answer for form factor (ft)	