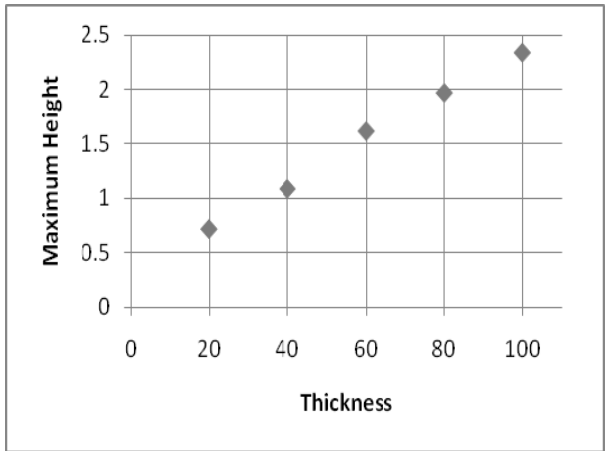
Question			Answer	Marks	Guidance	
1	(i)			G1 G2,1,0 **[3]**	G1 For axes suitably labelled with some indication of **linear** scale provided. G2 for points plotted correctly. G1 if 4 points plotted correctly. G0 if two or more incorrectly plotted/omitted points. Special Case SC1 for points visibly correct on axes where no indication of scale has been provided.	Allow *x* & *y* Allow axes reversed.
1	(ii)		Thickness is the independent variable since the values of 'Thickness' are not subject to random variation, but are determined by the manufacturer.	E1 **[1]**	Allow explanations referring to thickness being "controlled" by the manufacturer. Allow equivalent interpretations.	
1	(iii)		$\bar{t} = 60,\ \bar{h} = 1.548$ $b = \frac{S_{th}}{S_{tt}} = \frac{546.8 - (300 \times 7.74/5)}{22000 - 300^2/5} = \frac{82.4}{4000} =$ 0.0206	B1 M1* A1	For $\bar{t}$ and $\bar{h}$ used. SOI (e.g. can be implied by $b = 0.0206$) For attempt at **calculating** gradient (b) for h on t. For 0.0206 cao	
			OR $b = \frac{546.8/5 - (60 \times 1.548)}{22000/5 - 60^2} = \frac{16.48}{800} =$ 0.0206 hence least squares regression line is: $h - \bar{h} = b(t - \bar{t})$			

Question			Answer	Marks	Guidance	
			$\Rightarrow \quad h - 1.548 = 0.0206\,(t - 60)$	M1 dep*	For equation of line, using their b, $b > 0$, and passing through their $(\bar{t}, \bar{h})$	
			$\Rightarrow \quad h = 0.0206\,t + 0.312$	A1 **[5]**	Final equation must have h as the subject. **CAO** Allow $h = 0.021\,t + 0.31$, Allow $h = 0.021\,t + 0.288$ NOTE If equation given in terms of y and x then A0 unless x & y defined appropriately	
1	**(iv)**	**(*A*)**	$(0.0206 \times 70) + 0.312 = 1.754$ Likely to be reliable as interpolation	B1 E1 **[2]**	Allow 1.75 FT their equation provided $b > 0$	
1	**(iv)**	**(*B*)**	$(0.0206 \times 120) + 0.312 = 2.784$ Could be unreliable as extrapolation	B1 E1 **[2]**	Allow 2.78 FT their equation provided $b > 0$ Condone "reliable as 120 is not too far away from the data used to produce the equation"	
1	**(v)**		Thickness = 40 $\Rightarrow$ predicted max height $= (0.0206 \times 40) + 0.312 = 1.136$ Residual = 1.09 – 1.136 = –0.046	 M1 M1 A1 **[3]**	 For prediction. FT their equation provided $b > 0$ For difference between 1.09 and prediction. Allow –0.05	
1	**(vi)**		Regression line gives a prediction of $(0.0206 \times 200) + 0.312 = 4.432$ This is **well above** the observed value. It could be that the relationship breaks down for larger thickness, or that the relationship is not linear	B1* E1 dep* E1 **[3]**	B1 for obtaining a prediction from regression equation or from graph E1 for noting the large difference between prediction and actual value E1 for suitable interpretation regarding the relationship between maximum height and thickness	

Question			Answer	Marks	Guidance	
2	(i)	(*A*)	$P(X = 0) = \frac{e^{-2.1}2.1^0}{0!}$	M1	For calculation	
			$= 0.1225$	A1	**CAO** Allow 0.122	
			Or from tables $P(X = 0) = 0.1225$			
				[2]		
2	(i)	(*B*)	$P(X \geq 2) = 1 - P(X \leq 1) = 1 - 0.3796$	M1	M1 for **use of** correct structure. i.e. M0 for use of $1 - P(X \leq 2)$ or $1 - 0.6796$ Using $\lambda = 2.0$ leading to $1 - 0.4060$ gets M1	
			$= 0.6204$	A1 **[2]**	CAO Allow 0.6203, 0.620	
2	(i)	(*C*)	New $\lambda = 5 \times 2.1 = 10.5$ P(Between 5 and 10 in 5 mins)	B1	For mean (SOI)	
			$= 0.5207 - 0.0211$	M1	For $P(X \leq 10) - P(X \leq 4)$ used.	e.g. $1 - 0.9379$ leads to B0M1A0
			$= 0.4996$	A1 **[3]**	CAO Allow 0.500, 0.50. Condone 0.5 www.	
2	(ii)		Mean number in 60 minutes = $60 \times 2.1 = 126$			
			Using Normal approx. to the Poisson,	B1	For Normal approx.	
			$X \sim N(126, 126)$	B1	For correct parameters (SOI)	
			$P(X \geq 130) = P\left(Z \geq \frac{129.5 - 126}{\sqrt{126}}\right)$	B1	For correct continuity correction	
			$= P(Z > 0.3118) = 1 - \Phi(0.3118)$	M1	For correct probability structure	
			$= 1 - 0.6224$			
			$= 0.3776$	A1	CAO**, (**Do not FT wrong or omitted CC). Allow 0.378www & 0.3775	
				[5]		

Question			Answer	Marks	Guidance	
2	(iii)		(Because if butterflies are blown in pairs,) the events will no longer be occurring singly.	E1 **[1]**		Accept 'not independent'
2	(iv)		P(3 or fewer) = P(3 or fewer individuals and no pairs) + P(0 or 1 individual and 1 pair)	M1	For P(0 pairs) (= 0.8187)	
			= (0.9068 × 0.8187) + (0.4932 × (0.9825 – 0.8187))	M1	For P(1 pair) (= 0.1638 or 0.1637)	First two M1s can be awarded for 0.9825
			= (0.9068 × 0.8187) + (0.4932 × 0. 1638)	M2	For structure M2 for correct 6 combinations identified and their probabilities added, M1 for 5 combinations identified and their probabilities added.	
			= 0.7424 + 0.0808			
			= 0.8232	A1	CAO Allow awrt 0.823	
			Or using D for the number of pairs and S for the number of singles $P(D = 0) \times P(S = 0) = e^{-0.2} \times e^{-1.7}$ = 0.1495… $P(D = 0) \times P(S = 1) = e^{-0.2} \times 1.7e^{-1.7}$ = 0.2542… $P(D = 0) \times P(S = 2) = e^{-0.2} \times 1.7^2e^{-1.7} \div 2$ = 0.2161… $P(D = 0) \times P(S = 3) = e^{-0.2} \times 1.7^3e^{-1.7} \div 3!$ = 0.1224… $P(D = 1) \times P(S = 0) = 0.2e^{-0.2} \times e^{-1.7}$ = 0.0299… $P(D = 1) \times P(S = 1) = 0.2e^{-0.2} \times 1.7e^{-1.7}$ = 0.0508… Or $P(D = 0) \times P(S = 3) + P(D = 1) \times P(S = 1)$ $P(D = 0) \times P(S = 2) + P(D = 1) \times P(S = 0)$ $P(D = 0) \times P(S = 1)$ $P(D = 0) \times P(S = 0)$		P(3 butterflies) (= 0.1733…) P(2 butterflies) (= 0.2460…) P(1 butterfly) (= 0.2542…) P(0 butterflies) (= 0.1495…)	

Question			Answer	Marks	Guidance	
			Or $P(D \leq 1) \times P(S \leq 1) = 0.98247 \times 0.49324$ $D(D = 0) \times P(S = 2) = 0.21613$ $D(D = 0) \times P(S = 3) = 0.12247$	**[5]**		
3	**(i)**	**(*A*)**	$P(X < 450) = P\left(Z < \frac{450 - 435}{30}\right)$	M1	For standardising. M0 if 'continuity correction' applied	
			$= P(Z < 0.5) = \Phi(0.5)$	M1	For correct structure	
			$= 0.6915$	A1 **[3]**	CAO Allow 0.692	
3	**(i)**	**(*B*)**	$P(400 < X < 450)$ $= P\left(\frac{400 - 435}{30} < Z < \frac{450 - 435}{30}\right)$ $= P(-1.1667 < X < 0.5)$			
			$= \Phi(0.5) - \Phi(-1.1667)$	M1	For correct structure	
			$= 0.6915 - 0.1216$	B1	For use of difference column to obtain 0.8784, 0.8783, 0.1216 or 0.1217. Condone 0.8782 or 0.1218	
			$= 0.5699$	A1 **[3]**	FT "their 0.6915" – 0.1216 (or 0.1217)	
3	**(ii)**		P(all 5 between 400 and 450) $= 0.5699^5$	M1		
			$= 0.0601$	A1 **[2]**	FT Allow 0.060	

Question			Answer	Marks	Guidance	
3	(iii)		$P(Y < 350) = 0.2$, $P(Y > 390) = 0.1$			
			$P(Z < \frac{350-\mu}{\sigma}) = 0.2$			
			$\Phi^{-1}(0.2) = -0.8416$			
			$\frac{350-\mu}{\sigma} = -0.8416$	M1	For equation as seen or equivalent with their –ive z value	If 'continuity corrections' applied allow M marks but do not award final A marks
			$P(Z > \frac{390-\mu}{\sigma}) = 0.1$			
			$\Phi^{-1}(0.9) = 1.282$	B1	For 1.282 or -0.8416	
			$\frac{390-\mu}{\sigma} = 1.282$	M1	For equation as seen or equivalent with their +ive z value	
			$350 = \mu - 0.8416\sigma$			
			$390 = \mu + 1.282\sigma$			
			$2.1236\sigma = 40$			
			$\sigma = 18.84$	A1	Allow 18.8	Answers to max 2 d.p.
			$\mu = 350 + (0.8416 \times 18.84) = 365.85$	A1	Allow 365.86, 366, 365.9	
				[5]		
3	(iv)		$\Phi^{-1}(0.975) = 1.96$	B1	For using a suitable pair of z values e.g. ± 1.96	
			$a = 365.85 - (1.96 \times 18.84)$	M1	For either equation provided that a suitable pair of z-values is used. e.g. +2.326 and –1.751	
			$= 328.9$	A1	FT their μ and σ to 2 d.p. (A0 if 'continuity correction' used)	Accept any correct values of a and b.
			$b = 365.85 + (1.96 \times 18.84)$			
			$= 402.8$	A1	FT their μ and σ to 2 d.p. (A0 if 'continuity correction' used)	
				[4]		

Question			Answer	Marks	Guidance	
4	(a)		H_0: no association between grade and hours worked H_1: some association between grade and hours worked;	B1	Hypotheses in context	
			<table><tr><td></td><td>Less than 5hrs</td><td>At least 5hrs</td></tr><tr><td>A or B</td><td>17.05</td><td>13.95</td></tr><tr><td>C or lower</td><td>15.95</td><td>13.05</td></tr></table>	M1 A1	Any row/column correct For expected values (to 2 dp)	
			<table><tr><td></td><td>Less than 5hrs</td><td>At least 5hrs</td></tr><tr><td>A or B</td><td>0.5104</td><td>0.6238</td></tr><tr><td>C or lower</td><td>0.5456</td><td>0.6669</td></tr></table>	M1 A1	For valid attempt at $(O-E)^2/E$. Any row column correct. For all correct	NB These M1A1 marks cannot be implied by a correct final value of X^2
			$X^2 = 2.347$	B1		
			Refer to χ_1^2	M1	For 1 deg of freedom. No FT from here if wrong.	
			Critical value at 5% level = 3.841	A1	CAO for cv or *p*-value = 0.1255. SC1 for cv or *p*-value if 1 dof not seen.	
			Result is not significant. There is insufficient evidence to suggest that there is any association between hours worked and grade.	E1	For conclusion in context. NB if H_0 H_1 reversed, or 'correlation' mentioned, do not award first B1 or final E1	
				[9]		

Question			Answer	Marks	Guidance	
4	(b)		$\bar{x} = 417.79$	B1	For $\bar{x}$	
			H_0: $\mu = 420$;	B1	For use of 420 in hypotheses. Hypotheses in words must refer to population. Do not allow alternative symbols unless clearly defined as the population mean.	
			H_1 : $\mu \neq 420$	B1	For both correct	
			Where μ denotes the mean volume of the cans of tomato purée (in the population)	B1	For definition of μ. Condone omission of "population" if correct notation μ is used, but if μ is defined as the **sample** mean then award **B0**.	
			Test statistic $= \frac{417.79 - 420}{3.5/\sqrt{10}} = \frac{-2.21}{1.107} = -1.997$	M1* A1	must include $\sqrt{10}$ FT their $\bar{x}$	
			Lower 1% level 2 tailed critical value of z = – 2.576	B1*	For –2.576 Must be –2.576 unless it is clear that absolute values are being used.	
			–1.997 > – 2.576	M1 dep*	For sensible comparison leading to a conclusion.	
			So not significant. There is insufficient evidence to reject H0			
			There is insufficient evidence to suggest that the average volumes of the cans of tomato purée is not 420ml	A1	For conclusion in words in context provided that correct cv used. FT only candidate's test statistic.	
				[9]		

ADDITIONAL NOTES REGARDING QUESTION 4 (b)

Critical Value Method
$420 – 2.576 \times 3.5 \div \sqrt{10}$ gets M1*B1*
= 417.148… gets A1
417.79 > 417.148.. gets M1dep* for sensible comparison
A1 still available for correct conclusion in words & context

Confidence Interval Method
CI centred on 417.79 + or $– 2.5756 \times 3.5 \div \sqrt{10}$ gets M1* B1*
= (414.93…, 420.64..) gets A1
NOTE that the final M1dep* A1 available only if 2.576 used.
"Contains 420" gets M1dep*
A1 still available for correct conclusion in words & context

Probability Method
Finding P(sample mean < 417.79) = 0.0229 gets M1* A1 B1*
0.0229 > **0.005*** gets M1dep* for a sensible comparison if a conclusion is made.
A1 available for a correct conclusion in words & context.
Condone P(sample mean > 417.79) = 0.9771 for M1* but only allow A1 B1* if sensible comparison made, at which point the final M1dep* and A1 are still available

ADDITIONAL NOTE REGARDING OVER-SPECIFICATION OF ANSWERS
Over-specification by providing final answers correct to 5 or more significant figures will be penalised. When this applies, candidates may lose no more than 2 marks per question and no more than 4 marks in total. The only exception to this rule is in Question 3 parts (iii) & (iv) – see guidance notes.