Question			Answer	Marks	Guidance	
1	(i)		**EITHER:**			
			$S_{xy} = \sum xy - \frac{1}{n}\sum x \sum y = 40.66 - \frac{1}{60} \times 43.62 \times 55.15$	M1*	For method for S_{xy}	
			$= 0.56595$			
			$S_{xx} = \sum x^2 - \frac{1}{n}\left(\sum x\right)^2 = 32.68 - \frac{1}{60} \times 43.62^2$	M1*	For method for at least one of S_{xx} or S_{yy}	
			$= 0.96826$			
			$S_{yy} = \sum y^2 - \frac{1}{n}\left(\sum y\right)^2 = 51.44 - \frac{1}{60} \times 55.15^2$	A1	For at least one of S_{xy}, S_{xx} or S_{yy} (to 2 sf) Note Allow 0.57322 for S_{xy} and 0.76634 for S_{yy} from rounding mean of y to 0.919.	
			$= 0.74796$			
			$r = \frac{S_{xy}}{\sqrt{S_{xx}S_{yy}}} = \frac{0.56595}{\sqrt{0.96826 \times 0.74796}} = 0.665$	M1 dep* A1	For structure of r For answer rounding to 0.66 or 0.67	
			OR:	**[5]**		
			$\text{cov}(x,y) = \frac{\sum xy}{n} - \bar{x}\bar{y} = 40.66/60 - (43.62/60 \times 55.15/60)$	M1*	For method for cov (x,y)	
			$= 0.0094325$			
			$\text{rmsd}(x) = \sqrt{\frac{S_{xx}}{n}} = \sqrt{(0.96826/60)} = \sqrt{0.016137\ldots} = 0.1270$	M1*	For method for at least one msd or rmsd	
			$\text{rmsd}(y) = \sqrt{\frac{S_{yy}}{n}} = \sqrt{(0.74796/60)} = \sqrt{0.012466} = 0.1117$	A1	For at least one of cov (x,y), msd or rmsd correct (to 2 sf)	
			$r = \frac{\text{cov}(x,y)}{\text{rmsd}(x)\text{rmsd}(y)} = \frac{0.0094325}{0.1270 \times 0.1117} = 0.665$	M1 dep* A1	For structure of r For answer rounding to0.66 or 0.67	
					Methods mixed – max M0M1A1M0A0	
				[5]		

Question			Answer	Marks	Guidance	
1	(ii)		H_0: $\rho = 0$ H_1: $\rho > 0$ (one-tailed test)	B1	For H_0, H_1 in symbols. Hypotheses in words must refer to population. Do not allow alternative symbols unless clearly defined as the population correlation coefficient.	
			where ρ is the population correlation coefficient	B1	For defining ρ. Condone omission of "population" if correct notation ρ is used, but if ρ is defined as the **sample** correlation coefficient then award **B0**. Allow "ρ is the pmcc".	
			For $n = 60$, 5% critical value = 0.2144	B1	For critical value	
			Since 0.665 > 0.2144, the result is significant.	M1	For sensible comparison leading to a conclusion provided that $\|r\| < 1$. The comparison can be in the form of a diagram as long as it is clear and unambiguous. Sensible comparison: e.g. 0.665 > 0.2144 is 'sensible' whereas 0.665 > - 0.2144 is 'not sensible'. Reversed inequality sign e.g. 0.665 < 0.2144 etc. gets max M1 A0.	
			Thus we have sufficient evidence to reject H_0	A1	For reject H_0 o.e. FT their r and critical value from 5% 1-tail column.	
			There is sufficient evidence at the 5% level to **suggest** that there is **positive** correlation between FEV1 before and after the two-week course.	E1	For correct, **non-assertive** conclusion in context (allow 'x and y' for context). E0 if H_0 and H_1 not stated, reversed or mention a value other than zero for ρ in H_0.	
				[6]		

Question			Answer	Marks	Guidance	
1	(iii)		The underlying population must have a bivariate Normal distribution. Yes, since the scatter diagram appears to have a roughly elliptical shape.	B1 E1 **[2]**	Condone "bivariate Normal distribution", "underlying bivariate Normal distribution", but **do not allow** "the **data** have a bivariate Normal distribution" Condone 'oval' or suitable diagram	
1	(iv)		The significance level is the probability of rejecting the null hypothesis when in fact it is true.	E1* E1dep* **[2]**	For "probability of rejecting H_0" or "probability of a significant result". For "when H_0 is true"	
1	(v)		$\sum x = 43.62 + 0.45 = 44.07$ $\sum y = 55.15 - 0.45 = 54.70$ $\sum xy = 40.66$ $\sum x^2 = 32.68 + 1 - 0.55^2 = 33.3775$ $\sum y^2 = 51.44 - 1 + 0.55^2 = 50.7425$	B1 B1 B1 **[3]**	For $\sum x$ or $\sum y$ or $\sum xy$ For $\sum x^2$ or $\sum y^2$ (to 2 dp) For all correct (ignore n)	
2	(i)		P(At least one has red hair) = $1 - 0.97^{10}$ = 0.263	M1 A1 **[2]**	M1 for $1 - 0.97^{10}$ Allow 0.26	
2	(ii)		(Because X is binomially distributed), n is large and p is small. Mean = 1.8	E1 E1 B1 **[3]**	Allow "sample is large" for n is large Allow "$np < 10$" or "mean ≈ variance" for "p is small" Do not allow "the probability is small"	

Question			Answer	Marks	Guidance	
2	(iii)	(*A*)	$P(X = 2) = e^{-1.8}\frac{1.8^2}{2!} = 0.2678$ OR = 0.7306 – 0.4628 = 0.2678	M1 A1 **[2]**	For calculation for $P(X = 2)$ FT their mean. Allow answer to 3sf.	
2	(iii)	(*B*)	$P(X > 2) = 1 – P(X \leq 2) = 1 – 0.7306$ = 0.2694	M1 A1 **[2]**	$1 – P(X \leq 2)$ used. e.g.$1 – P(X \leq 2) = 1 – 0.4628$ gets M0 CAO	
2	(iv)		The mean ($np = 1.8$) is too small It is not appropriate to use a Normal approximation	E1* E1dep* **[2]**	For "mean is too small" or "mean < 10" For "not appropriate". Do not allow "p is too small".	
2	(v)		Binomial(5000, 0.03)	B1* B1dep* **[2]**	For binomial, or B(,) For parameters	
2	(vi)		Mean $5000 \times 0.03 = 150$ Variance $= 5000 \times 0.03 \times 0.97 = 145.5$ Using Normal approx. to the binomial, $X \sim N(150, 145.5)$ $P(X \geq 160) = P\left(Z \geq \frac{159.5 – 150}{\sqrt{145.5}}\right)$ $= P(Z > 0.7876) = 1 – \Phi(0.7876) = 1 – 0.7846$ = 0.215 (to 3 sig.fig.)	B1 B1 B1 M1 A1 **[5]**	For mean (soi) For variance (soi) For continuity corr. For probability using correct tail and structure (condone omission of/incorrect c.c.) CAO, (Do not FT wrong or omitted CC) Allow 0.2155. Do not allow 0.216	

Question			Answer	Marks	Guidance	
3	(i)		$P(Y = 76) = P\left(\frac{75.5-76}{12} \le Z \le \frac{76.5-76}{12}\right)$ $= P(-0.04166\ldots < Z < 0.04166\ldots)$ $= \Phi(0.04166\ldots) - (1 - \Phi(0.04166\ldots))$ $= 2 \times \Phi(0.04166\ldots) - 1$ $= 2 \times 0.5167 - 1$ $= 0.0334$	B1 M1 M1 A1 **[4]**	For one correct continuity correction used For standardizing For correctly structured probability calculation. CAO inc use of diff tables. Allow 0.0330 – 0.0340 www.	
3	(ii)		$P(Y \ge 80) = P\left(Z \ge \frac{79.5-76}{12}\right)$ $= P(Z > 0.2917) = 1 - \Phi(0.2917)$ $= 1 - 0.6148 = 0.3852 = 0.385$ to 3 sig fig	B1 M1 A1 **[3]**	For correct cc used For correct structure CAO do not allow 0.386	
3	(iii)		$3 \times 0.3852 \times 0.6148^2 = 0.4368$	M1 A1 **[2]**	3 × their p × (1 – their p)^2 FT their p. Allow 2sf if working seen.	

Question			Answer	Marks	Guidance	
3	(iv)		**EITHER:** P(Score $\geq k$) = 0.1			
			$\Phi^{-1}(0.9) = 1.282$	B1	For 1.282	
			$\frac{k-76}{12} = 1.282$	M1	Allow $k - 0.5$ used for k. Positive z used.	
			$k = 76 + (1.282 \times 12) = 91.38$ or $k = 76 + 0.5 + (1.282 \times 12) = 91.88$	A1	For 91.38 or 91.88	
			91.38 > 90.5 or 91.88 > 91	M1	Relevant comparison (e.g. diagram)	www
			so lowest reported mark = 92	A1		
			OR Trial and improvement method	M1	M1 for attempt to find P(Mark ≥ integer)	
			P(Mark ≥ 91) = P(Score ≥ 90.5) = 0.1135	A1	A1 for 0.1135	
			P(Mark ≥ 92) = P(Score ≥ 91.5) = 0.0982	A1	A1 for 0.0982	
			P(Mark ≥ 91) > 10% and P(Mark ≥ 92) < 10%	M1	M1 for comparisons	www
			so lowest reported mark = 92	A1		
				[5]		
3	(v)		$P(Y \leq 50) = 0.2$			
			$P(Z \leq \frac{50.5-\mu}{12}) = 0.2$	B1	For 50.5 used	
			$\frac{50.5-\mu}{12} = \Phi^{-1}(0.2) = -0.8416$	B1	For –0.8416. Condone – 0.842 Condone 0.8416 if numerator reversed.	
				M1	For structure.	
			$\mu = 50.5 + (12 \times 0.8416) = 60.6$	A1	CAO	
				[4]		

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th><th></th></tr>
<tr><td>4</td><td>(i)</td><td></td><td>H_0: no association between sex and artist preferred
H_1: some association between sex and artist preferred

<table><tr><td>EXPECTED</td><td>Monet</td><td>Renoir</td><td>Degas</td><td>Cézanne</td></tr><tr><td>Male</td><td>12.13</td><td>28</td><td>13.07</td><td>16.8</td></tr><tr><td>Female</td><td>13.87</td><td>32</td><td>14.93</td><td>19.2</td></tr></table>
<table><tr><td>CONTRIB’N</td><td>Monet</td><td>Renoir</td><td>Degas</td><td>Cézanne</td></tr><tr><td>Male</td><td>1.4081</td><td>0.3214</td><td>1.8626</td><td>0.2881</td></tr><tr><td>Female</td><td>1.2321</td><td>0.2813</td><td>1.6298</td><td>0.2521</td></tr></table>
$X^2 = 7.28$
Refer to χ_3^2

Critical value at 10% level = 6.251

Result is significant

There is evidence to suggest that there is some association between sex and artist preferred

NB if H_0 H_1 reversed, or ‘correlation’ mentioned, do not award first B1 or final E1

[12]</td><td>B1

M1
A2

M1
A2

B1
B1

B1

B1

E1</td><td>For both hypotheses in context

For expected values
(to 2 dp where appropriate)
(allow A1 for at least one row or column correct)

For valid attempt at $(O–E)^2/E$
For all correct (to 2 dp) and presented in a table or clear list. (Allow A1 for at least one row or column correct)

Allow 7.27
for 3 deg of f

CAO for cv No FT from here if wrong or omitted, unless p-value used instead

FT their X^2

For correct (FT their X^2), non-assertive conclusion, in context.</td><td>

NB:These three marks cannot be implied by a correct final value of X^2

www

B1 for p-value = 0.0636</td></tr>
</table>

Question			Answer	Marks	Guidance	
4	(ii)		Monet: **More females and fewer males than expected** prefer Monet, as indicated by l**arge contribution(s)** (of 1.4081 and 1.2321). Renoir: Preferences are much **as expected**, as indicated by s**mall contributions.** Degas: **Fewer females and more males than expected** prefer Degas, as indicated by **large contribution(s)** (of 1.8626 and 1.6298). Cézanne: Preferences are much **as expected**, as indicated by s**mall contributions**.	E1* E1dep* E1 E1* depE1* E1 **[6]**	FT their table of contributions	NB MAX 3/6 for answers not referring to contributions (explicitly or implicitly). SC1 Renoir and Cézanne have correct comments for both but without referring to contributions