Question 1

(i)	$X \sim N(11,3^2)$ $P(X < 10) = P\left(Z < \frac{10-11}{3}\right)$ $= P(Z < -0.333)$ $= \Phi(-0.333) = 1 - \Phi(0.333)$ $= 1 - 0.6304 = 0.3696$	M1 for standardizing M1 for use of tables with their *z*-value M1 *dep* for correct tail A1CAO (must include use of differences)	**4**
(ii)	P(3 of 8 less than ten) $= \binom{8}{3} \times 0.3696^3 \times 0.6304^5 = 0.2815$	M1 for coefficient M1 for $0.3696^3 \times 0.6304^5$ A1 FT (min 2sf)	**3**
(iii)	$\mu = np = 100 \times 0.3696 = 36.96$ $\sigma^2 = npq = 100 \times 0.3696 \times 0.6304 = 23.30$ $Y \sim N(36.96,23.30)$ $P(Y \geq 50) = P\left(Z > \frac{49.5-36.96}{\sqrt{23.30}}\right)$ $= P(Z > 2.598) = 1 - \Phi(2.598) = 1 - 0.9953$ $= 0.0047$	M1 for Normal approximation with correct (FT) parameters B1 for continuity corr. M1 for standardizing and using correct tail A1 **CAO (**FT 50.5 or omitted CC)	**4**
(iv)	H_0: $\mu = 11$; H_1: $\mu > 11$ Where μ denotes the mean time taken by the new hairdresser	B1 for H_0, as seen. B1 for H_1, as seen. B1 for definition of μ	**3**
(v)	Test statistic $= \frac{12.34-11}{3/\sqrt{25}} = \frac{1.34}{0.6}$ $= 2.23$ 5% level 1 tailed critical value of z = 1.645 2.23 > 1.645, so significant. There is sufficient evidence to reject H_0 It is reasonable to conclude that the new hairdresser does take longer on average than other staff.	M1 must include √25 A1 (FT their μ) B1 for 1.645 M1 for sensible comparison leading to a conclusion A1 for conclusion in words in context (FT their μ)	**5**
			19

Question 2

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

x	2.61	2.73	2.87	2.96	3.05	3.14	3.17	3.24	3.76	4.1
y	3.2	2.6	3.5	3.1	2.8	2.7	3.4	3.3	4.4	4.1
Rank x	10	9	8	7	6	5	4	3	2	1
Rank y	6	10	3	7	8	9	4	5	1	2
d	4	-1	5	0	-2	-4	0	-2	1	-1
d^2	16	1	25	0	4	16	0	4	1	1

$$r_s = 1 - \frac{6\Sigma d^2}{n(n^2-1)} = 1 - \frac{6\times 68}{10\times 99}$$

= 0.588 (to 3 s.f.) [*allow* 0.59 to 2 s.f.]</td><td>M1 for ranking (allow all ranks reversed)

M1 for d^2

A1 for $\Sigma d^2 = 68$

M1 for method for r_s

A1 f.t. for $|r_s| < 1$
NB No ranking scores zero</td><td>5</td></tr>
<tr><td>(ii)</td><td>H_0: no association between x and y

H_1: positive association between x and y

Looking for positive association (one–tail test): critical value at 5% level is 0.5636

Since 0.588> 0.5636, there is sufficient evidence to reject H_0,
i.e. conclude that there is positive association between true weight x and estimated weight y.</td><td>B1 for H_0, in context.

B1 for H_1, in context.

NB H_0 H_1 <u>not</u> ito ρ

B1 for $\pm$ 0.5636

M1 for sensible comparison with c.v., provided $|r_s| < 1$
A1 for conclusion in words & in context, f.t. their r_s and sensible cv</td><td>5</td></tr>
<tr><td>(iii)</td><td>$\Sigma x = 31.63$, $\Sigma y = 33.1$, $\Sigma x^2 = 101.92$, $\Sigma y^2 = 112.61$, $\Sigma xy = 106.51$.

$S_{xy} = \Sigma xy - \frac{1}{n}\Sigma x\Sigma y = 106.51 - \frac{1}{10}\times 31.63\times 33.1$

$= 1.8147$

$S_{xx} = \Sigma x^2 - \frac{1}{n}(\Sigma x)^2 = 101.92 - \frac{1}{10}\times 31.63^2 = 1.8743$

$S_{yy} = \Sigma y^2 - \frac{1}{n}(\Sigma y)^2 = 112.61 - \frac{1}{10}\times 33.1^2 = 3.049$

$r = \frac{S_{xy}}{\sqrt{S_{xx}S_{yy}}} = \frac{1.8147}{\sqrt{1.8743\times 3.049}} = 0.759$</td><td>M1 for method for S_{xy}

M1 for method for at least one of S_{xx} or S_{yy}

A1 for at least one of S_{xy}, S_{xx}, S_{yy} correct.

M1 for structure of r

A1 (awrt 0.76)</td><td>5</td></tr>
<tr><td>(iv)</td><td>Use of the PMCC is better since it takes into account not just the ranking but the actual value of the weights. Thus it has more information than Spearman's and will therefore provide a more discriminatory test.

Critical value for rho = 0.5494
PMCC is very highly significant whereas Spearman's is only just significant.</td><td>E1 for has values, not just ranks
E1 for contains more information
Allow alternatives.
B1 for a cv
E1 dep</td><td>4</td></tr>
<tr><td></td><td></td><td></td><td>19</td></tr>
</table>

Question 3

(i)	(*A*) P(*X* = 1) = 0.1712 – 0.0408 = 0.1304 *OR* = $e^{-3.2}\dfrac{3.2^1}{1!}$ = 0.1304 (*B*) P(*X* ≥ 6) = 1 – P(*X* ≤ 5) = 1 – 0.8946 = 0.1054	M1 for tables A1 (2 s.f. WWW) M1 A1	**4**
(ii)	(*A*) λ = 3.2 ÷ 5 = 0.64 P(*X* =1) = $e^{-0.64}\dfrac{0.64^1}{1!}$ = 0.3375 (*B*) P(exactly one in each of 5 mins) = 0.3375^5 = 0.004379	B1 for mean (SOI) M1 for probability A1 B1 (FT to at least 2 s.f.)	**4**
(iii)	Mean no. of calls in 1 hour = 12 × 3.2 = 38.4 Using Normal approx. to the Poisson, *X* ~ N(38.4, 38.4) $P(X \le 45.5) = P\left(Z \le \dfrac{45.5-38.4}{\sqrt{38.4}}\right)$ = P(*Z* ≤ 1.146) = Φ(1.146) = 0.874 (3 s.f.)	B1 for Normal approx. with correct parameters (SOI) B1 for continuity corr. M1 for probability using correct tail A1 CAO, (but FT 44.5 or omitted CC)	**4**
(iv)	(*A*) Suitable arguments for/against each assumption: (*B*) Suitable arguments for/against each assumption:	E1, E1 E1, E1	**4**
			16

Question 4

(i)

H_0: no association between age group and sex;
H_1: some association between age group and sex;

Expected		Sex: Male	Sex: Female	**Row totals**
Age group	Under 40	81.84	42.16	**124**
	40 – 49	73.92	38.08	**112**
	50 and over	42.24	21.76	**64**
Column totals		**198**	**102**	**300**

Contribution to test statistic		Sex: Male	Sex: Female
Age group	Under 40	1.713	3.325
	40 – 49	0.059	0.114
	50 and over	2.255	4.378

$X^2 = 11.84$

Refer to Ξ_2^2
Critical value at 5% level = 5.991
Result is significant
There is some association between age group and sex .

NB if H_0 H_1 reversed, or 'correlation' mentioned, do not award first B1or final E1

B1 (in context)	
M1 A1 for expected values (to 2dp)	
M1 for valid attempt at $(O–E)^2/E$	
M1dep for summation	**6**
A1CAO for X^2	
B1 for 2 deg of f	**4**
B1 CAO for cv	
B1 dep on their cv & X^2	
E1 (conclusion in context)	

(ii)

The analysis suggests that there are more females in the under 40 age group and less in the 50 and over age group than would be expected if there were no association.
The reverse is true for males.
Thus these data do support the suggestion.

E1	
E1	**3**
E1dep (on at least one of the previous E1s)	

(iii)

Binomial(300, 0.03) soi
$n = 300$, $p = 0.03$ so
EITHER: use Poisson approximation to Binomial with
$\lambda = np = 9$
Using tables: $P(X \geq 12) = 1 - P(X \leq 11)$

$= 1 - 0.8030 = 0.197$

OR: use Normal approximation N(9, 8.73)

$$P(X > 11.5) = P\left(Z > \frac{11.5 - 9}{\sqrt{8.73}}\right)$$

$= P(Z > 0.846)) = 1 - 0.8012 = 0.199$

B1 CAO	
EITHER:	
B1 for Poisson	
B1dep for Poisson(9)	
M1 for using tables to find $1 - P(X \leq 11)$	
A1	
OR:	
B1 for Normal	
B1dep for parameters	
M1 for using tables with correct tail (cc not required for M1)	**5**
A1	

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