Question Number	Scheme	Marks
1(a)	Select a random number as the starting point	B1
	Take every 50th employee	B1
		(2)
(b)	e.g. The alphabetical list may not be **random** or May be **biased** as list not truly random or Some **combinations** of names are **not possible**	B1
		(1)
(c)	0	B1
		(1)
	Notes	Total 4
(a)	B1 for realising they need to select a random number as the starting point	
	B1 for realising they need to take every 50^{th} employee	
(b)	B1 for a suitable disadvantage. Sight of the words in bold oe for those reasons are sufficient provided there is no contradiction or not a correct reason Condone "may not be representative". "some employees with the same surname won't be chosen" Do not allow any reference to requiring a sampling frame as it already has one e.g. "a sampling frame is needed because there is an alphabetical list"	
(c)	B1 0	

Question Number	Scheme	Marks
2 (a)	<table><tr><td>**Kettle**</td><td>*A*</td><td>*B*</td><td>*C*</td><td>*D*</td><td>*E*</td><td>*F*</td><td>*G*</td></tr><tr><td>**Price (£)**</td><td>99.99</td><td>14.99</td><td>34.97</td><td>49.99</td><td>19.97</td><td>29.99</td><td>8.99</td></tr><tr><td>**Aarush Rank**</td><td>2</td><td>5</td><td>4</td><td>1</td><td>7</td><td>3</td><td>6</td></tr><tr><td>**Actual rank**</td><td>1</td><td>6</td><td>3</td><td>2</td><td>5</td><td>4</td><td>7</td></tr></table>	M1
	$\sum d^2 = 1+1+1+1+4+1+1$ [=10]	M1
	$r_s = 1-\frac{6\times"10"}{7\times 48}$	dM1
	$= 0.8214...$ awrt 0.821	A1cso
		(4)
(b)	$H_0 : \rho = 0 \quad H_1 : \rho > 0$	B1
	Critical Value $r_s = 0.7143$	M1
	Either reject H_0/ result is significant/ r_s does lie in the critical region	M1
	Conclude there is evidence to support that Aarush can **rank** the **kettles** in order of **price**.	A1
		(4)
(c)	Aarush has already ranked them or the order / price is not normally distributed	B1
		(1)
(d)	Kettle *A* and *D* would have a tied rank (1.5)	B1
		(1)
	Notes	Total 10
(a)	M1 for an attempt to rank Aarush's order and actual order (at least 4 correct in either row)	
	M1 for finding differences between each pair of their ranks and evaluating $\sum d^2$ imp by A1	
	dM1 dependent on previous 2 M marks being awarded. Using $r_s = 1-\frac{6\times\sum d^2}{7\times 48}$	
	A1 awrt 0.821 or allow $\frac{23}{28}$	
(b)	B1 both hypotheses stated in terms of ρ or ρ_s (condone if appears as p – it cannot be in terms of *r*) If their $r_s < 0$ condone $H_1 : \rho < 0$	
	M1 allow |their CV| = 0.7143 or better	
	M1 for a correct non-contradictory statement consistent with their r_s ($r_s < 1$) and their CV if signs are compatible. Allow eg Accept H_1 or for correct conclusion in context on its own.	
	A1 dependent on all of the previous method marks but independent of hypotheses. For correct conclusion in context which must be rejecting H_0 and has **rank**, **kettles** and **price** and no contradictory statements.	
(c)	B1 for a correct reason e.g. (some of) the data has already been ranked, Aarush has not given the prices (only the ranks) oe. Condone "it is ordinal data"	
(d)	B1 for the idea that both *A* and *D* will have same rank (1.5) If the rank is stated it must be 1.5. Must mention both *A* and *D* (or imply) and allow explanations such as "equal rank", "average rank". Condone "order" for rank. If an incorrect rank or letter pairing is given then B0.	

Question Number	Scheme	Marks
3(a)	$H_0 : \mu = 328 \quad H_1 : \mu \neq 328$ oe	B1
	Significance level is 5%	dB1
	(328 is within the interval therefore) no evidence to support that μ is not 328	B1
		(3)
(b)	$1.96 \times \frac{\sigma}{\sqrt{150}} = \frac{329.76 - 327.84}{2} \left(= 0.96\right)$ oe or e.g. $328.8 + 1.96 \times \frac{\sigma}{\sqrt{150}} = 329.76$ or $328.8 - 1.96 \times \frac{\sigma}{\sqrt{150}} = 327.84 \ \left[\sigma = 5.9987\right]$	M1 B1
	$328 - 2.3263 \times \frac{"5.9987"}{\sqrt{200}}$ oe or $328 + 2.3263 \times \frac{"5.9987"}{\sqrt{200}}$ oe	M1 B1
	$328 \pm 2.3263 \times \frac{"5.9987"}{\sqrt{200}}$ oe	dM1
	(327.0132… , 328.986…) (awrt 327, awrt 329)	A1
		(6)
(c)	$X \sim \mathrm{B}(5, 0.98)$ or $Y \sim \mathrm{B}(5, 0.02)$	M1
	$\mathrm{P}(X \geq 4)$ or $\mathrm{P}(Y \leq 1) = {}^5C_4 (0.98)^4 (0.02) + (0.98)^5$ oe	A1
	$= 0.9961\ldots$ awrt 0.996	A1
		(3)
	Notes	Total 12
(a)	**Note that many are carrying out a full hypothesis test by finding the distribution of the sample mean. These three marks can still be scored. You do not need to check the calculations to score in (a)**	
	B1 for both hypotheses correct in terms of μ (do not accept use of $\bar{x}$)	
	dB1 correct significance level given. Allow $(\alpha =)$ 0.05 Do not allow if more than one given. This mark is dependent on a two tail test being indicated with their hypotheses condoning slips in notation e.g. use of $\bar{x}$ Do not allow $p = 0.05$ on its own.	
	B1 idea that $\mu = 328$ is supported. Allow e.g. "do not reject H_0" provided $H_0 : \mu = 328$ but condone poor notation for their null hypothesis. Does not need to be in context.	
(b)	M1 forms an equation to find σ Allow $1.6 < \lvert z \rvert < 2$ **may be seen in (a)** or implied by awrt 6	
	B1 use of awrt 1.96 in the calculation **may be seen in (a)** or implied by their value for σ	
	M1 correct method to find one end of the confidence interval using their σ Allow $2.3 < \lvert z \rvert < 3.1$ condone use of 150 rather than 200 (may be implied by awrt 327 or awrt 329 if no incorrect working is seen)	
	B1 awrt 2.3263 seen	
	dM1 dependent on both the previous method marks being awarded. Fully correct method using their σ and using n = 200 to find both ends of the confidence interval. A correct confidence interval with no working – send to review	
	A1 (awrt 327, awrt 329) Condone missing brackets	
(c)	M1 use of Binomial e.g. B(5, 0.98) or B(5, 0.02) or 0.98^5 or ${}^5C_x \times 0.98^x \times 0.02^{5-x}$ (may be implied by awrt 0.0922 or awrt 0.904 within a calculation or awrt 0.996)	
	A1 for ${}^5C_4 \times 0.98^4 \times 0.02 + 0.98^5$ oe eg awrt 0.0922 + awrt 0.904 or implied by awrt 0.996	
	A1 awrt 0.996	

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>4(a)</td><td>H_0: favourite flavours occur in the ratio 10 : 5 : 2 : 3</td><td rowspan="2">B1</td></tr>
<tr><td></td><td>H_1: favourite flavours do not occur in the ratio 10 : 5 : 2 : 3</td></tr>
<tr><td></td><td>
<table>
<tr><td></td><td>Chocolate</td><td>Vanilla</td><td>Strawberry</td><td>Other</td></tr>
<tr><td>observed</td><td>188</td><td>95</td><td>40</td><td>77</td></tr>
<tr><td>expected</td><td>200</td><td>100</td><td>40</td><td>60</td></tr>
<tr><td>$\frac{(O_i-E_i)^2}{E_i}$</td><td>$\frac{(188-"200")^2}{"200"}$
$(=0.72)$</td><td>$\frac{(95-"100")^2}{"100"}$
$(=0.25)$</td><td>$\frac{(40-"40")^2}{"40"}$
$(=0)$</td><td>$\frac{(77-"60")^2}{"60"}$
$(=4.816\ldots)$</td></tr>
<tr><td>$\frac{O_i^2}{E_i}$</td><td>$\frac{188^2}{"200"}$
$(=176.72)$</td><td>$\frac{95^2}{"100"}$
$(=90.25)$</td><td>$\frac{40^2}{"40"}$
$(=40)$</td><td>$\frac{77^2}{"60"}$
$(=98.816\ldots)$</td></tr>
</table>
</td><td>M1
M1</td></tr>
<tr><td></td><td>$\sum \frac{(O_i-E_i)^2}{E_i} = 5.786\ldots$ or $\sum \frac{O_I^2}{E_I} - 400 = 405.7867 - 400$ (awrt 5.79)</td><td>A1</td></tr>
<tr><td></td><td>$\nu = 3$</td><td>B1</td></tr>
<tr><td></td><td>CV is 7.815</td><td>B1ft</td></tr>
<tr><td></td><td>[5.79 < 7.815] so insufficient evidence to reject H_0 or not significant</td><td>M1</td></tr>
<tr><td></td><td>There is no evidence to suggest that people's favourite flavours of ice-cream do not occur in the given ratio. oe</td><td>A1ft</td></tr>
<tr><td></td><td></td><td>(8)</td></tr>
<tr><td>(b)(i)(ii)</td><td>$\frac{188\times130}{400}$ or $\frac{112\times95}{400}$</td><td>M1</td></tr>
<tr><td></td><td>61.1 and 26.6</td><td>A1</td></tr>
<tr><td></td><td></td><td>(2)</td></tr>
<tr><td>(c)</td><td>6</td><td>B1</td></tr>
<tr><td></td><td></td><td>(1)</td></tr>
<tr><td></td><td>Notes</td><td>Total 11</td></tr>
<tr><td>(a)</td><td colspan="2">B1 Both hypotheses correct. Must state the ratio or refer to the "given ratio" oe. Does not need to state the actual flavours.
Accept statements e.g. H_0 : the proportion of people who like different ice creams is 10:5:2:3 Accept H_0 : the ratio 10:5:2:3 is correct. Do not accept e.g. H_0 : the manager's belief is correct (without reference to the ratio)</td></tr>
<tr><td></td><td colspan="2">M1 At least 2 expected values correct. Check if each cell has been calculated separately and the totals add up to 200, 100, 40 and 60 (seen)</td></tr>
<tr><td></td><td colspan="2">M1 Correct method seen or may be implied by values for at least 2 flavours. Implied by awrt 5.79</td></tr>
<tr><td></td><td colspan="2">A1 awrt 5.79</td></tr>
<tr><td></td><td colspan="2">B1 correct degrees of freedom stated or implied by any awrt 0.072 0.115 0.216 0.352 0.584 6.251 7.815 9.348 11.345 12.838</td></tr>
<tr><td></td><td colspan="2">B1ft awrt 7.815 follow through on 6 degrees only = 12.592</td></tr>
<tr><td></td><td colspan="2">M1 Independent of hypotheses, ft their χ^2 value and their CV. A correct comment. Allow</td></tr>
</table>

	"Accept H_0" or e.g. "do not reject H_0" Do not award if contradicting non contextual comments given. If their χ^2 value < their CV e.g. "do not reject H_0" If their χ^2 value > their CV e.g. "reject H_0" (May be implied by a correct ft contextual comment)
	A1ft **dependent on all the previous method marks**. A correct contextual comment for their χ^2 value and their CV that mentions **flavour** and **ratio** oe (does not need to state the actual ratio) Accept sufficient evidence to support the manager's belief oe condone "the manager is correct"
(b)	M1 A correct method to find one of the values. Implied by one correct value
	A1 Both answers correct.
(c)	B1 cao

Question Number	Scheme	Marks
5(a)	$H_0 : \mu_p - \mu_f = 1$ oe	B1
	$H_1 : \mu_p - \mu_f > 1$ oe	B1
	s.e. $= \sqrt{\frac{9}{605} + \frac{4}{45}} = \left[\sqrt{0.10376...}\right] = [0.322\ldots]$	M1
	$z = \pm \frac{7.0 - 5.6 - 1}{"\sqrt{\frac{9}{605} + \frac{4}{45}}"}$	dM1
	$= 1.24175...$ awrt 1.24	A1
	CV 5% one tailed = ±1.6449 (see notes)	B1
	Not significant, do not reject H_0	dM1
	Insufficient evidence that **full-time** staff are more than **one minute** faster than **part-time** staff or manager's **claim** is not supported	A1ft
		(8)
(b)	Assume **both** samples are **normal** or **both** large enough for **CLT** oe	B1
	Assume $s^2 = \sigma^2$ for **both** samples	B1
	Assume individual result**s** are independent	
		(2)
(c)	$\bar{a} = \frac{45 \times 7 + 8}{46} \left[= 7.0217...\right]$	M1
	$\sum a^2 = 44 \times 4 + 45 \times 7^2 + 8^2 \left[= 2445\right]$	M1
	$s^2 = \frac{"2445" - 46 \times "7.0217..."^2}{45}$	M1
	$= 3.93285\ldots$ awrt 3.93	A1
		(4)
	Notes	Total 14
(a)	B1 H_0 correct oe e.g. $H_0 : \mu_f - \mu_p = -1$ Must be in terms of μ Use of $\bar{t}$ is B0. May use other letters to p and f but must be defined	
	B1 H_1 correct oe e.g. $H_1 : \mu_f - \mu_p < -1$ **SC** B0B1 for $H_0 : \mu_f - \mu_p = 1$ and $H_1 : \mu_f - \mu_p > 1$ Must be in terms of μ Use of $\bar{t}$ is B0 May use other letters to p and f but must be defined	
	M1 Correct method to find s.e. may be seen within formula to standardise (implied by awrt ±1.24)	
	dM1 dep on previous M being awarded. Correct method to find z value (implied by awrt ±1.24)	
	A1 awrt ±1.24	
	B1 awrt ±1.6449 or p-value awrt $0.107 > 0.05$ oe	
	dM1 all previous method marks awarded for a correct conclusion ft their z value and CV	
	A1ft dependent on all previous method marks but independent of hypotheses. A correct statement in context with the words in bold oe which does not reject H_0. ft their z value and CV Note B0B0M1dM1A1B0dM1A1ft is possible	
	Candidates who incorrectly test $H_0 : \mu_f - \mu_p = 1$ and $H_1 : \mu_f - \mu_p > 1$ will score maximum B0B1M1dM0A0B1dM0A0	
(b)	B1 One correct assumption. Accept e.g. (times taken by) employees chosen follow a normal distribution, times taken follow a normal distribution, employees are selected	

	independently. Samples are independent is B0
	B1 2 correct assumptions. Need to see reference to both for each assumption but condone if written as one sentence or statement e.g. both samples are normally distributed and $s^2 = \sigma^2$
(c)	M1 correct method to find $\bar{a}$ may be implied by awrt 7.02 or may be seen within a calculation e.g. $\left(s^2 =\right) \dfrac{2445 - \dfrac{(45\times 7+8)^2}{46}}{45}$
	M1 correct method to find $\sum a^2$ may see e.g. $2381+8^2$ which may be embedded within their calculation to find the sample variance. Sight of 2445 implies this mark
	M1 correct method to find s^2 ft their $\bar{a}$ (which cannot be 315) and $\sum a^2$ (which cannot be 2381)
	A1 awrt 3.93

Question Number	Scheme	Marks
6(a)	$E(C + C + C) = 3.6$ oe	B1
	$\text{Var}(C + C + C) = 0.03^2 + 0.03^2 + 0.03^2$ [= 0.0027]	M1
	$P(C + C + C > 3.5) = P\left(Z > \left(\pm\frac{3.5 - "3.6"}{\sqrt{"0.0027"}}\right)[= -1.9245...]\right)$	M1
	= 0.9726 (calc 0.97285…) **awrt 0.973**	A1
		(4)
(b)	$E(R - R) = 0$	M1
	$\text{Var}(R - R) = 0.03^2 + 0.03^2$ [= 0.0018]	M1
	$P((R - R) > 0.05) = P\left(Z > \left(\frac{0.05 - "0"}{\sqrt{"0.0018"}}\right)[= 1.1785...]\right)$ [= 0.119 (calc 0.119296…)]	M1
	$2 \times P((R - R) > 0.05) = 2 \times "0.119"$	M1
	= 0.238 table or 0.23859…calc **awrt 0.238/0.239**	A1cso
		(5)
(c)	$\mu_G = 2.5 + 10 \times 2.3 [= 25.5]$	M1
	$\sigma_G{}^2 = 0.1 + 10 \times 0.03^2 [= 0.109]$	M1
	Let $X = G - 2T$	M1
	$\mu_X = "25.5" - 2 \times 2.5 [= 20.5]$	M1
	$\sigma_X{}^2 = "0.109" + 4 \times 0.1 [= 0.509]$	M1
	$P(G - 2T < 20) = P\left(Z < \frac{20 - "20.5"}{\sqrt{"0.509"}}[= -0.7008...]\right)$	M1
	= 0.242 (table) or 0.2417… (calc) **awrt 0.242**	A1
		(7)
	Notes	Total 16
(a)	B1 Correct value for $E(C + C + C)$ may be seen e.g. $\frac{18}{5}$ or implied by later calculation	
	M1 Correct method to find the variance. Condone 0.03^4 instead of 0.03^2 may be implied by calculation or awrt 0.973	
	M1 Correct standardisation using their mean and sd. Allow $\pm\frac{3.5 - "3.6"}{\sqrt{"0.0027"}}$ may be implied by $P(Z > \text{awrt} -1.92)$ or $P(Z < \text{awrt} 1.92)$ or awrt 0.973	
	A1 awrt 0.973 do not isw	
(b)	M1 for 0 may be seen or implied by later calculation	
	M1 correct method to find $\text{Var}(R - R)$ may be implied by 0.0018 or $\frac{9}{5000}$ or a later calculation. Must be a numerical value or expression.	
	M1 Correct standardisation using their mean and Var Allow ±	
	M1 2 × "their 0.119"	
	A1 awrt 0.238	
(c)	M1 Correct method for finding the mean of G may be implied by 25.5 or later work or sight of 20.5 (or may subtract 20 so 0.5)	
	M1 Correct method for finding the var of G may be implied by sight of 0.109 provided this is not to find the variance of $10R - T$. May be implied by 0.509	

	M1 Realising they need to find $\pm\ (G-2T)$. Allow $\pm\ (G-2T-20)$ may be seen as part of a probability expression or implied by their calculation
	M1 Correct method for finding the mean of X which may be from using their mean of G (which must be correct if no method or value is seen) Allow 0.5
	M1 Correct method for finding the var of X which may be from using their variance of G (which must be correct if no method or value is seen) may be implied by $10\times0.03^2+0.5$ or 0.509
	M1 Correct standardisation using their mean and standardisation for $G-2T$ (condone $G-T$) leading to a probability < 0.5 Allow 0 – "0.5" for numerator for correct use of 20 with their "20.5" and their "0.509"
	A1 awrt 0.242 from a correct distribution
	Note candidates who attempt $10R+T<2T+20\Rightarrow10R-T<20$ can score maximum M1M0M0M1M0M1A0 (the first method mark is implied by the fourth method mark)

Question Number	Scheme	Marks
7(a)	$\mathrm{E}(D) = x + 2$	M1
	$\mathrm{Var}(D) = \dfrac{\left((x+5)-(x-1)\right)^2}{12} \left[= 3\right]$	M1
	$\overline{D} \sim N\left(x+2, \dfrac{3}{n}\right)$	A1
		(3)
(b)	$"x+2" = 22.101 + "2"\ (= 24.101)$ or $"x+2" = 24.6 \Rightarrow 24.6 - "2"\ (= 22.6)$	M1
	$24.6 - "2.5758"\sqrt{\dfrac{"3"}{n}} = "24.101"$ oe	B1M1 dM1
	$n = 80$	A1cao
		(5)
	Notes	Total 8
(a)	M1 E(D) correct	
	M1 Correct method to find Var(D) Must be subtracting the correct way round but condone missing brackets	
	A1 for a fully correct distribution. Either states $\mathrm{N}\left(x+2, \dfrac{3}{n}\right)$ or accept e.g. "normal" with mean = $x+2$ and variance = $\dfrac{3}{n}$ oe Must be seen in (a)	
(b)	M1 For a correct method to find d using x as 22.101 in their $"x+2"$ from (a) or a correct method to find x by rearranging their $"x+2"$ to $x = 24.6 - "2"$ Implied by 24.101 or 22.6 or ± 0.499 oe $x + 2 = 24.6$ on its own is M0	
	B1 for awrt ± 2.5758 may be implied by an unrounded value for n of awrt 79.94	
	M1 for $24.6 \pm z\sqrt{\dfrac{\sigma^2}{n}}$ or $"22.6" \pm z\sqrt{\dfrac{\sigma^2}{n}}$ where $2.55 < \lvert z \rvert < 2.6$ (ft their mean and variance from (a) or may restart). May be part of an equation. **Their numerical variance does not have to be substituted in for this mark.** This mark can still be scored if it is equated inconsistently to 22.101 eg $24.6 - z\sqrt{\dfrac{\sigma^2}{n}} = 22.101$ oe eg $z\sqrt{\dfrac{\sigma^2}{n}} = 2.499$ or $\sqrt{\dfrac{\sigma^2}{n}} = \dfrac{4165}{4293}\ (= 0.970...)$	
	dM1 dep on both the previous M marks awarded. For setting up a valid equation (allow 22.101 instead of "24.101" provided it is correctly paired with "22.6"). **Their numerical variance must be substituted in for this mark.** $24.6 - "2.5758"\sqrt{\dfrac{"3"}{n}} = "24.101"$ or $"22.6" - "2.5758"\sqrt{\dfrac{"3"}{n}} = 22.101$ oe eg $"-2.5758" = \dfrac{"24.101" - 24.6}{\sqrt{\dfrac{"3"}{n}}}$ or $"2.5758"\sqrt{\dfrac{"3"}{n}} = "0.499"$	
	A1 cao dependent on seeing a correct equation but allow use of $z = 2.576$ so M1B0M1dM1A1 is possible. Note awrt 79.94 seen can imply B1	