TYPE 1
Forward

12 **(b)**

	$\Phi\left(\frac{\mu+\sigma-\mu}{\sigma}\right) = 0.8413$	B1	0.8413 (p) seen or implied (can use their own numbers)
	$P(\lvert z\rvert < 1) = 0.3413 \times 2 = 0.6826$	M1	finding the correct area i.e. $2p - 1$
	$0.6826 \times 800 = 546$ (accept 547)	A1 **3**	correct answer, must be a positive integer
	OR *SR* $800 \times 2/3 = 533$ or 534	SR B1	for 2/3
		B1	for 533 or 534 or B2 if 533 or 534 and no working

19 (i) $P(X > 0) = 1 - \Phi\left(\frac{0 - -15.1}{\sqrt{62}}\right)$ M1 Standardising, sq rt, no cc

$= 1 - \Phi(1.918)$ M1 Prob < 0.5 after use of normal tables

$= 1 - 0.9724$

$= 0.0276$ or answer rounding to A1 **[3]** Correct answer

22 $20p = 1.6 \quad p = 0.08$	M1 A1		Equation relating $20p$ to the mean Correct p can be implied
$P(X > 2) = 1 - \{(0.92)^{20} + {}^{20}C_1(0.08)(0.92)^{19} + {}^{20}C_2(0.08)^2(0.92)^{18}\}$	M1		Bin expression involving $p^x(1-p)^{20-x}\,{}^{20}C_x$ any p
$= 1 - (0.1887 + 0.3281 + 0.2711)$	M1		Subtracting 2 or 3 binomial probs from 1, one of which is P(0)
$= 0.212$	A1	**[5]**	Correct answer

28 (i) $P(x > 10.9) = P(z > \frac{10.9-11}{0.095})$	M1		Standardising, no cc, no sq rt
$= P(z > -1.0526)$ $= 0.8538$ (0.854)	A1	**[2]**	Rounding to correct answer
(ii) P(at least 2 < 10.9) = 1 – P(0, 1)	M1		Bin expression with $\sum$ powers = 6, ${}^6C_x$, $p + q = 1$.
$= 1 - (0.8538)^6 - {}^6C_1(0.1462)(0.8538)^5$	A1ft		Reasonably correct unsimplified expression ft their **(i)**
$= 0.215$	A1	**[3]**	Rounding to correct answer

33 **(i)**	$P(X > 20) = P(z > -6.4/3.7)$ $= P(z > -1.730)$ $= 0.9582$	M1 A1	Standardising no cc no sq rt Prob rounding to 0.958
	Number of students = 335 or 336	A1ft [3]	Correct answer ft their prob, must be integer
(ii)	P(very slow) = 0.05	B1	0.05 or 0.95 seen
	P(0, 1, 2) = $(0.95)^8 + {}^8C_1(0.05)^1(0.95)^7 + {}^8C_2(0.05)^2(0.95)^6$	M1	Binomial term with ${}^8C_r p^r (1-p)^{8-r}$ seen any p
	$= 0.6634 + 0.2793 + 0.0515$ $= 0.994$	M1 A1 [4]	Correct expression for P(0, 1, 2), p close to 0.05 Answer rounding to 0.994

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(b)	$P(X < a + 33) = 0.75$	M1	Using 0.75 oe
	$z = 0.674$	A1	± 0.674 seen
	$\frac{a+33-33}{\sqrt{21}} = 0.674$	M1	Standardising, no cc, must have sq rt
	$a = 3.09$	A1 **[4]**	Correct answer

52	$z_1 = \frac{30-28.3}{\sqrt{4.5}} = 0.8014$	M1	Standardising at least one value, sq rt.ess; no cc
	$z_2 = \frac{25-28.3}{\sqrt{4.5}} = -1.5556$	M1	$\Phi_1 + \Phi_2 - 1$ oe
	$\Phi_1 - (1 - \Phi_2) = 0.7884 + 0.9401 - 1$ $= 0.729$	A1 **[3]**	Correct answer

62 **(i)**	$\Phi\left(\frac{84.5-82}{\sqrt{126}}\right) \Phi\left[\frac{83.5-82}{\sqrt{126}}\right]$	M1	Standardising using 83.5 or 84.5, must have square root
	$= \Phi(0.2227) - \Phi(0.1336)$ $= 0.5883 - 0.5533$	M1	Subtracting two probabilities, both > 0.5 or both < 0.5
	$= 0.0350$	A1 **3**	Correct answer
(ii)	$P(x > 87) = 1 - \Phi\left(\frac{87-82}{\sqrt{126}}\right) = 1 - \Phi(0.445)$	M1	Standardising, no cc, must have square root
	$= 1 - 0.6718 = 0.3282$	A1	Correct probability
	$P(0, 1) = (0.6718)^5 + {}_5C_1(0.3282)(0.6718)^4$	M1	Any binomial term of form ${}_5C_x p^x (1-p)^{5-x}, x \neq 0$
	$= 0.471$	A1 **4**	Correct answer
(iii)	$P(x < 87) = 0.6718$	M1	Finding $P(x < 87)$, value > 0.5
	$P(x < k) = 0.9718$	M1	Adding 0.3 to their 0.6718 or equivalent
	$z = 1.908$ or 1.909	A1	Correct z
	$1.909 = \pm\frac{k-82}{\sqrt{126}}$	M1	Equation with k, 82 or 81.5 or 82.5, $\sqrt{126}$, and a z-value
	$k = 103$	A1 **5**	Correct answer rounding to 103

Type 2
Reverse

12 (a)	$\frac{5.2-2s}{s}=-1.282$	M1	Equation with $\pm$ correct LHS seen here or later, can be μ or s, no cc
		B1	± 1.282 seen accept ± 1.28 or anything in between
		M1	solving their equation with recognisable z-value and only 1 unknown occurring twice
	$s = 7.24$ or 7.23	A1 **4**	correct final answer

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(ii) $z = -1.22$ $-1.22 = \frac{0-\mu}{\sqrt{40}}$	B1	$z = \pm 1.22$
	M1	an equation in μ, recognisable z, $\sqrt{40}$, no cc
$\mu = 7.72$ c.a.o	A1 **[3]**	correct answer c.w.o from same sign on both sides

20 (i) $z = 0.674$ $\frac{1002-\mu}{8} = 0.674$	B1	$\pm$ 0.674 or rounding to, seen, e.g. 0.6743
	M1	Standardising and attempting to solve for μ, must use recognisable z-value, no cc, no sq rt, no sq
$\mu = 997$	A1 **[3]**	Correct answer rounding to 997
(ii) $P(2) = 3 \times \frac{225}{900} \times \frac{224}{899} \times \frac{675}{898}$ $= 0.140$	M1	900 × 899 × 898 or ${}^{900}C_3$ seen in denom
	A1 **[2]**	Correct answer not 0.141 or 0.14
OR $\frac{{}^{225}C_2 \times {}^{675}C_1}{{}^{900}C_3}$		

24 (i) mean = 51	B1 **[1]**	
(ii) $z = \pm 0.674$	B1	Correct z
$\pm(63 - 51) / \sigma = 0.674$	M1	Standardising, no cc, no $\sqrt{\sigma}$, no σ^2
$\sigma = 17.8$	A1 **[3]**	Correct answer

26	(+/–) 1.045, (+/–) 0.313	B1, B1	1 correct z-value, the other correct z-value.
	$20.9 - \mu = -0.313\ \sigma$ $30 - \mu = 1.045\ \sigma$	M1	Valid attempt to solve 2 equations relating to μ, σ, 30, 20.9. No $\sqrt{\sigma}$, σ^2
	$\sigma = 6.70$ $\mu = 23.0$	A1 A1 **[5]**	correct answer correct answer

29	**(i)** $P(X < 2\mu) = P\left(z < \frac{2\mu - \mu}{\sigma}\right)$	M1	Standardising, and attempt to get 1 variable, no cc, no $\sqrt{}$, no sq
	$= P(z < \mu/\sigma) = P(z < 5/3)$	A1	±5/3 seen oe
	$= 0.952$	A1 **[3]**	Rounding to correct answer
	(ii) $P\left(X < \frac{\mu}{3}\right) = P\left(z < \frac{-2\mu}{3\sigma}\right)$	M1	standardising attempt resulting in $z \leqslant -$ some μ/σ allow $\pm\left(\frac{\mu/3 - \mu}{\sigma}\right)$
	$\frac{-2\mu}{3\sigma} = 1.047$	B1	±1.047 seen
	$\mu = -1.57\sigma$	A1 **[3]**	correct single number, answer must have a minus sign and μ = …..σ

39	**(a)** $z > \frac{2\mu - \mu}{\sigma} = \frac{\mu}{\sigma} = \frac{7\sigma^2}{3\sigma}$	M1	Standardising attempt resulting in $z >$ some μ/σ
	$\frac{7\sigma}{3} = 1.272$	M1 B1	Substituting to eliminate μ or σ 1.272 seen
	$\sigma = 0.545$ $\mu = 0.693$	A1 **[4]**	Both answers correct

61	$z = -1.036 = \frac{5.6 - 93}{\sigma}$	B1 M1		± (1.036 to 1.037) seen Equation with 5.6 or 13.0, 9.3, σ and a z value, no cc
	$\sigma = 3.57$	A1	**3**	Correct final answer

TYPE 3
Binomial----> Normal

2 (i) $c\int_0^5 t(25-t^2)\,dt = 1$	M1	For equating to 1 and a sensible attempt to integrate
$c\left[\frac{25t^2}{2}-\frac{t^4}{4}\right]_0^5 = 1$	A1	For correct integration and correct limits
$c\left[\frac{625}{2}-\frac{625}{4}\right] = 1 \Rightarrow c = \frac{4}{625}$	A1 **3**	For given answer correctly obtained
(ii) $\int_2^4 ct(25-t^2)\,dt = \left[\frac{25ct^2}{2}-\frac{ct^4}{4}\right]_2^4 = c[136]-c[46]$	M1*	For attempting to integrate f(t) between 2 and 4 (or attempt 2 and 4)
	M1*dep	For subtracting their value when t = 2 from their value when t = 4
$= \frac{72}{125}$ (0.576)	A1 **3**	For correct answer
(iii) $\int_0^5 ct^2(25-t^2)\,dt = \left[\frac{4}{625}\times\frac{25t^3}{3}-\frac{4}{625}\times\frac{t^5}{5}\right]_0^5$	M1*	For attempting to integrate $tf(t)$, no limits needed
	A1	For correct integrand can have c (or their c)
	M1*dep	For subtracting their value when t=0 from their value when t=5
$= \frac{8}{3}$	A1 **4**	For correct answer

4 (i)	constant p, independent trials, fixed number of trials, only two outcomes	**B1**	For an option
		B1 **2**	For a second option
(ii)	P(X<4) = $0.72^{14} + {}_{14}C_1 \times 0.28 \times 0.72^{13} + {}_{14}C_2 \times 0.28^2 \times 0.72^{12} + {}_{14}C_3 \times 0.28^3 \times 0.72^{11}$	**M1**	For adding with some C in P(0 + 1 + 2 + 3) or P(1 + 2 + 3) or P(0 + 1 + 2 + 3 + 4) or P(1 + 2 + 3 + 4)
		M1	For 0.28 and 0.72 to powers which sum to 14 Need 2 or more terms
	(= 0.0101 + 0.0548 + 0.1385 + 0.2154)	**A1**	For completely correct unsimplified form
	= 0.419	**A1** **4**	For correct final answer **NB** 0.418 is A0 if PA # 1 or A1 if PA # 2

(iii) $\mu = 50\ x\ 0.28\ (= 14)$	**B1**		For 14 and 10.08 seen, can be implied
σ^2 = 50 x 0.28 x 0.72 (=10.08)	**M1**		For standardising with or without cc, must have sq root
P(more than 18) = 1 - $\Phi\left(\frac{18.5-14}{\sqrt{10.08}}\right)$	**M1**		For continuity correction 17.5 or 18.5 AND a final answer < 0.5
= 1 – $\Phi(1.417)$			
= 1 – 0.9218 or 0.9217			
= 0.0782 or 0.0783	**A1**	**4**	For correct answer NB 0.078 is A0 if RE # 1 or A1 if RE # 2

5 μ = 160, σ^2 = 96	**B1**		For 160 and 96 seen or implied by 9.798
P($\leq$165) = $\Phi\left(\frac{164.5-160}{\sqrt{96}}\right)$ = Φ (0.4593)	**M1** **M1**		For standardising, must have square root For continuity correction, either 165.5 or 164.5
	M1		For using tables and finding correct area (i.e.> 0.5)
= 0.677	**A1**	**[5]**	For correct answer

9 (i) 1 – P(0, 1, 2) = 1 – $((0.91)^{14} + (0.09)(0.91)^{13} \times {}_{14}C_1 + (0.09)^2(0.91)^{12} \times {}_{14}C_2)$ = 1 –(0.2670 + 0.3698 + 0.2377) = 0.126	M1 B1 B1 A1	4	For 1 – P(0, 1, 2) Correct numerical expression for P(0) or P(1) Correct numerical expression for P(2) Correct answer
(ii) $\mu = 200 \times 0.76 = 152$, $\sigma^2 = 200 \times 0.76 \times 0.24 = 36.48$ P(X >155) $= 1 - \Phi\left(\frac{155.5-152}{\sqrt{36.48}}\right) = 1 - \Phi(1.5795)$ = 1 – 0.7188 = 0.281	B1 M1 M1 M1 A1	5	For both mean and variance correct For standardising , with or without cc, must have $\sqrt{}$ on denom For use of continuity correction 154.5 or 155.5 For finding an area < 0.5 from their z For answer rounding to 0.281

11 (i) $(0.6)^{10} \times (0.4)^{10} \times {}_{20}C_{10}$ $= 0.117$	M1 A1	**2**	3 term binomial expression involving ${}_{20}C_{\text{something}}$ and powers summing to 20 Correct final answer
(ii) P(18, 19, 20) $= (0.6)^{18}(0.4)^2\ {}_{20}C_2 + (0.6)^{19}(0.4)^1\ {}_{21}C_1 + (0.6)^{20}$ $= 0.003087 + 0.000487 + 0.00003635$ $= 0.00361$	M1 A1 A1		Summing three or 4 binomial expressions One correct unsimplified expression allow 0.4 0.6 muddle Correct answer
OR using normal approx N(12,4.8) $z = \dfrac{17.5-12}{\sqrt{4.8}}$ $= 2.51$	M1 A1		Standardising, cc 16.5 or 17.5, their mean, $\sqrt{}$ (their var) 2.51 seen
Prob = 1 – 0.9940 = 0.0060	A1	**3**	0.0060 seen must be 0.0060
(iii) $\mu = 150 \times 0.60 = 90$ $\sigma^2 = 150 \times 0.60 \times 0.40 = 36$ P($88 < X < 97$) $= \Phi\left(\dfrac{97.5-90}{6}\right) - \Phi\left(\dfrac{87.5-90}{6}\right)$ $= \Phi(1.25) - \Phi(-0.4166)$ $= 0.8944 - (1 - 0.6616)$ $= 0.556$	B1 M1 M1 A1 M1 A1	**6**	For seeing 90 and 36 For standardising , with or without cc, must have sq rt on denom one continuity correction 97.5 or 96.5 or 87.5 or 88.5 0.8944 or 0.6616 or 0.3384 or 0.3944 or 0.1616 seen subtracting a probability from their standardised 97 prob correct answer

13	**(i)**	$P(\geqslant 3) = 1 - P(0, 1, 2)$	M1	For attempt at 1 – P(0, 1, 2) or 1 – P(0, 1, 2, 3) or P(3...15) or P(4...15)
		$= 1 - (6/7)^{15} - {}_{15}C_1\,(1/7)\,(6/7)^{14} - {}_{15}C_2\,(1/7)^2\,(6/7)^{13}$	M1	For 1 or more terms with 1/7 and 6/7 to powers which sum to 15 and ${}_{15}C_{something}$
		$(= 1 - 0.0990 - 0.2476 - 0.2889)$	A1	Completely correct unsimplified form
		$= 0.365$ (accept 0.364)	A1 **4**	Correct final answer
	(ii)	$\mu = 56 \times 1/7\ (= 8)$ $\sigma^2 = 56 \times 1/7 \times 6/7\ (= 6.857)$	B1	8 and 6.857 or 6.86 or 2.618 seen or implied
		P(more than 7) $= 1 - \Phi\left(\dfrac{7.5-8}{\sqrt{6.857}}\right)$	M1	Standardising attempt with or without cc, must have square root
		$= \Phi\left(\dfrac{8-7.5}{\sqrt{6.857}}\right) = \Phi(0.1909)$	M1	Continuity correction either 7.5 or 6.5
			M1	Final answer > 0.5 (award this if the long way is used and the final answer is > 0.5)
		$= 0.576$	A1 **5**	Correct final answer

15 (i) $P(X=5) = (0.65)^5 \times (0.35)^2 \times {}_7C_5$	M1		Expression with 3 terms, powers summing to 7 and a ${}_7C$ term
$= 0.298$ allow 0.2985	A1	**2**	Correct answer
(ii) $\mu = 50 \times 0.65\ (= 32.5)$, $\sigma^2 = 50 \times 0.65 \times 0.35\ (= 11.375)$	B1		32.5 and 11.375 seen or implied
P(fewer than 29) $= \Phi\left(\dfrac{28.5-32.5}{\sqrt{11.375}}\right)$	M1		standardising, with or without cc, must have sq rt
	M1		for continuity correction 28.5 or 29.5
$= 1 - \Phi(1.186)$	M1		correct area ie < 0.5 must be from a normal approx
$= 1 - 0.8822$ $= 0.118$	A1	**5**	correct answer
(iii) $0.65\,n \geq 8$	M1		equality or inequality with *np* and 8
smallest $n = 13$	A1	**2**	correct answer

17 (i)	(0.05)(0.75)(0.15) = 0.00563 (9 / 1600)	M1 B1 A1 **3**	Multiplying 3 probs only, no Cs 0.05 or 0.15 or 1/5 × ¼ seen Correct answer
(ii)	P(at least 8) = P(8, 9, 10) $={}_{10}C_8(0.75)^8(0.25)^2+{}_{10}C_9(0.75)^9(0.25)+(0.75)^{10}$ = 0.526	B1 M1 A1 **3**	Binomial expression involving $(0.75)^r(0.25)^{10-r}$ and a C , $r \neq 0$ or 10 Correct unsimplified expression can be implied Correct answer
(iii)	$\mu = 90 \times 0.75 = 67.5$ $\sigma^2 = 90 \times 0.75 \times 0.25 = 16.875$ P($X > 60$) $= 1 - \Phi\left(\frac{60.5 - 67.5}{\sqrt{16.875}}\right) = \Phi(1.704)$ = 0.956	B1 M1 M1 A1 **5**	90×0.75 (67.5) and $90 \times 0.75 \times 0.25$ (16.875 or 16.9) seen For standardising , with or without cc, must have $\sqrt{}$ on denom For use of continuity correction 60.5 or 59.5 For finding an area > 0.5 from their z For answer rounding to 0.956

18 mean = $200 \times 0.08 = 16$ var = 14.72 P($X \geq 15$) = $1 - \Phi\left(\frac{14.5 - 16}{\sqrt{14.72}}\right)$ = Φ (0.391) = 0.652	B1 M1 M1 M1 A1 **[5]**	For both 16 and 14.7 seen For standardising, with or without cc, must have $\sqrt{}$ in denom For use of continuity correction 14.5 or 15.5 For finding a prob > 0.5 from their z, legit For answer rounding to 0.652 c.w.o
19 (i) P($X > 0$) = $1 - \Phi\left(\frac{0 - -15.1}{\sqrt{62}}\right)$ = 1 – Φ (1.918) = 1 – 0.9724 = 0.0276 or answer rounding to **(ii)** $z = -1.22$ $-1.22 = \frac{0 - \mu}{\sqrt{40}}$ $\mu = 7.72$ c.a.o	M1 M1 A1 **[3]** B1 M1 A1 **[3]**	Standardising, sq rt, no cc Prob < 0.5 after use of normal tables Correct answer $z = \pm 1.22$ an equation in μ, recognisable z, $\sqrt{40}$, no cc correct answer c.w.o from same sign on both sides

21	**(i)**	$P(X < 3) = P(0) + P(1) + P(2)$ $= (0.84)^{11} + (0.16)(0.84)^{10} \times {}^{11}C_1 + (0.16)^2(0.84)^9 \times {}^{11}C_2$ $= 0.1469 + 0.30782 + 0.2931$ $= 0.748$	M1 M1 A1	**[3]**	Binomial term with ${}^{11}C_r p^r (1-p)^{11-r}$ seen Correct expression for P(0, 1, 2) or P(0, 1, 2, 3) Can have wrong p Correct final answer. Normal approx M0 M0 A0
	(ii)	$\mu = 125 \times 0.64 = 80$ $\sigma^2 = 125 \times 0.64 \times 0.36 = 28.8$ $P(X > 73) = 1 - \Phi\left(\frac{73.5 - 80}{\sqrt{28.8}}\right)$ $= \Phi(1.211)$ $= 0.887$	B1 M1 M1 M1 A1	**[5]**	80 and 28.8 or 5.37 seen standardising, with or without cc, must have sq rt in denom continuity correction 73.5 or 72.5 only correct region (> 0.5 if mean > 73.5, vv if mean < 73.5 correct answer

23 **(i)**	$\frac{{}^4C_2 \times {}^7C_1}{{}^{11}C_3} = 0.255$	M1	Using 2 combs mult for numerator and 1 comb for denom
		M1	Correct denom or num unsimplified
		A1	Correct answer
	OR $\frac{4}{11} \times \frac{3}{10} \times \frac{7}{9} \times 3$	M1	Multiplying 3 correct probs
		M1	Mult by 3 or Σ their 3 options
	= 0.255 (14/55) (42/165)	A1 **[3]**	Correct answer
(ii)	P(3rd is orange) = P(*P, P, O*) + P(*P, O, O*) + P(*O, P, O*) + P(*O, O, O*)	M1	Summing four 3-factor options with or without replacement
	$= \frac{4}{11} \times \frac{3}{10} \times \frac{7}{9} + \frac{4}{11} \times \frac{7}{10} \times \frac{6}{9} + \frac{7}{11} \times \frac{4}{10} \times \frac{6}{9} + \frac{7}{11} \times \frac{6}{10} \times \frac{5}{9}$	A1	At least 3 correct unsimplified options
	$= \left[\frac{14}{165} + \frac{28}{165} + \frac{28}{165} + \frac{7}{33} \right]$		
	= 7/11 (0.636	A1	Correct answer. Award B3 if the correct answer is stated with no working.
	OR using a tree diagram	**[3]**	
(iii)	$P(P \mid O) = \frac{P(P \cap O)}{P(O)}$	M1	Substituting in cond prob formula with at least one 3-factor product in num, and denom their **(ii)** or 7/11
	$= \frac{P(P,P,O) + P(P,O,O)}{P(O)}$	M1	Summing exactly 2 three-factor products in num
	$= \frac{28/110}{7/11} = \frac{28}{70} = \frac{4}{10} = 0.4$	A1 **[3]**	Correct answer
(iv)	$\mu = 121 \times \frac{4}{11} = 44$	B1	44 and 28 or 5.29 seen
	$\sigma^2 = 121 \times \frac{4}{11} \times \frac{7}{11} = 28$	M1	Standardising, with or without cc, must have sq rt on denom
	$P(X < 39) = \Phi\left(\frac{38.5 - 44}{\sqrt{28}} \right)$	M1	cc either 39.5 or 38.5
	$= \Phi(-1.039)$	M1	Correct area "1 – Φ" seen
	= 1 – 0.8506		
	= 0.149	A1 **[5]**	Correct answer

25	P(total 7) = P(3,4 or 4,3) = 2/16	M1	Attempt to find P(7) + P(8)
	P(total 8) = P(4,4) = 1/16		
	P(7 or more) = 3/16	A1	3/16 seen
	Expected $200 \times \frac{3}{16} = 37.5$	M1	Multiplying their prob by 200
		A1ft **[4]**	Correct final answer ft their prob

32 mean = 200 × 2/15 (= 26.67) (80/3) variance = 200 × 2/15 × 13/15 (= 23.11)(208/9)	B1	mean and variance correct
P(21 < X < 35) = $P\left(\frac{21.5-26.67}{\sqrt{23.11}}\right) < z < \frac{34.5-26.67}{\sqrt{23.11}}$	M1 M1	standardising, ±, with or without cc, must have sq rts continuity corrections 20.5 or 21.5, 34.5 or 35.5
= P(–1.075 < z < 1.629) = 0.8589 + 0.9483 – 1 = 0.807	M1 A1 [5]	$\Phi_1 + \Phi_2 - 1$ answer rounding to 0.807

35 (i) constant/given prob, independent trials, fixed/given no. of trials, only two outcomes	B1 B1 [2]	One option correct Three options correct
(ii) P(8, 9, 0, 1) =	M1	One term seen involving $(0.3)^x(0.7)^{9-x}({}^9C_x)$
${}^9C_8(0.3)^8(0.7) + (0.3)^9 + (0.7)^9 + {}^9C_1(0.3)(0.7)^8$	A1	Correct unsimplified expression
= 0.196	A1 [3]	Correct answer
(iii) mean = 90 × 0.3 = 27 var = 18.9	B1	Expressions for 27 and 18.9 (4.347) seen
$P(X > 35) = 1 - \Phi\left(\frac{35.5-27}{\sqrt{18.9}}\right)$	M1	Standardising one expression, must have sq rt in denom, cc not necessary
= 1 – Φ(1.955) = 0.0253	M1	Continuity correction applied at least once
$P(X < 27) = \Phi\left(\frac{26.5-27}{\sqrt{18.9}}\right) = 1 - \Phi(0.115)$ = 0.4542	M1	$(1 - \Phi_1) + (1 - \Phi_2)$ accept (0.0329 + 0.5) if no cc
Total prob = 0.480 accept 0.48	A1 [5]	Rounding to correct answer

38 $18p = 2.7$ $p = 0.15$ P(2, 3, 4) = ${}^{18}C_2 \times (0.15)^2(0.85)^{16} + {}^{18}C_3(0.15)^3(0.85)^{15}$ $+ {}^{18}C_4(0.15)^4(0.85)^{14}$ = 0.655	B1 M1 A1 A1 **[4]**	Correct value for p Summing 3 binomial probs o.e Correct unsimplified answer Correct answer

42 (i) $np = 24$, $npq = 4.8$	B1	24 and 4.8 or $\sqrt{4.8}$ seen can be unsimplified
$z = \pm\left(\frac{24.5-24}{\sqrt{4.8}}\right) = 0.228$	M1 M1	Standardising, need sq rt, cc not necessary Continuity correction 24.5 or 25.5 used
Prob = 0.590	A1 **[4]**	Correct answer must be from 24.5
(ii) np and nq both > 5.	B1 **[1]**	Need both

46	$\mu = 250 \times 0.86 = 215$	B1		250 × 0.86 and 250 × 0.86 × 0.14 seen o.e
	$\sigma^2 = 250 \times 0.86 \times 0.14 = 30.1$	M1		Standardising, with or without cc, must have sq rt in denom
	$\mathrm{P}(X > 210) = 1 - \Phi\left(\dfrac{210.5 - 215}{\sqrt{30.1}}\right)$	M1		Continuity correction 210.5 or 209.5 only
	$= \Phi(0.820)$	M1		Correct region (> 0.5) ft their mean
	$= 0.794$	A1	[5]	Correct answer

54	**(i)** $\mathrm{P}(2 < X < 12) = 1 - \mathrm{P}(0, 1, 2, 12)$	M1		Using binomial with ${}_{12}\mathrm{C}_{\text{something}}$ and powers summing to 12, $\Sigma p = 1$
	$= 1 - (0.35)^{12} - (0.65)(0.35)^{11}{}_{12}\mathrm{C}_1 - (0.65)^2(0.35)^{10}{}_{12}\mathrm{C}_2 - (0.65)^{12}$	A1		Correct unsimplified answer
	$= 1 - 0.0065359$			
	$= 0.993$	A1	[3]	Accept 0.994 from correct working only
	(ii) $1 - (0.87)^n > 0.95$	M1		Equality or inequality in (0.87 or 0.78 or 0.35), power n or $n - 1$, 0.95 or 0.05
	$0.05 > (0.87)^n$	M1		Attempt to solve an equation with a power in (can be implied)
	$n = 22$	A1	[3]	Correct answer

TYPE 4
Advanced Mix

1 (i) $\bar{x} = 375.3$ $\sigma^2_{n-1} = 8.29$	B1 M1 A1 **3**	For correct mean (3.s.f) For legit method involving *n*-1, can be implied For correct answer
(ii) p = 0.19 or equiv.	B1	For correct p
$0.19 \pm 2.055 \times \sqrt{\frac{0.19 \times 0.81}{200}}$	M1	For correct form $p \pm z \times \sqrt{\frac{pq}{n}}$ either/both sides
	B1	For z = 2.054 or 2.055
$0.133 < p < 0.247$	A1 **4**	For correct answer

3 (i)	z = 0.674 or 0.675 allow 0.67 to 0.675	**B1**	For correct z, can be + or -
	$\frac{52-\mu}{5}$ = 0.674	**M1**	For an equation relating 52, 5, μ and any $z \neq$ 0.5987 or 0.7734 ish
	μ = 48.6	**A1**	For correct answer
(ii)	$z_1 = \frac{40-48.63}{5}$ = -1.726	**M1**	For standardising 40 or 46, 5 or $\sqrt{5}$ in denom or 5^2 with their mean, no cc
	$z_2 = \frac{46-48.63}{5}$ = 0.526		
	prob = 0.9578 – 0.7005 = 0.2573	**M1**	For subtracting two probs consistent with their mean ie usually $\Phi_1 - \Phi_2$ or $(1 - \Phi_1) - (1 - \Phi_2)$ but could be of type $\Phi_1 - (1 - \Phi_2)$ if their mean is in between 40 and 46
	$(0.2573)^4$	**M1**	For raising their answer above to a power 4
	= 0.00438 or 4.38 x 10^{-3} accept 0.00449 x 10^{-3} NB 0.0045 gets A0 and RE #1	**A1 ft** **4**	For correct answer

6 (i) $z_1 = 0.02/0.15 = 0.1333$	**M1**	For standardising one value, no cc
$z_2 = - 0.08/0.15 = -0.5333$	**M1**	For standardising the other value, no cc. SR ft on no sq rt
area= $\Phi(0.1333) - \Phi(-0.533)$ $= \Phi(0.1333) - [1 - \Phi(0.5333)]$ $= 0.5529 + 0.7029 - 1$ $= 0.256$	**M1** **A1**	For finding correct area (i.e. two Φ s - 1) For correct answer
Prob all 4 = $(0.256)^4$ (0.00428 to 0.00430)	**A1ft [5]**	For correct answer, ft from their **(i)**, if $p<1$, allow 0.0043
(ii) $z = \pm 1.282$ or 1.28 or 1.281	**B1**	For correct z, + or - or both
$\pm 1.282 = \frac{b}{0.15}$	**M1**	For seeing an equation involving + or - of their z, b, 0.15 (their z can only be 0.842 or 0.84 or 0.841)
limits between 1.71 and 2.09	**A1ft [3]**	both limits needed, ft 1.77 to 2.03 on 0.842 only

7 (i) $1.282 = (5130-\mu)/ 40.6$	B1		For $\pm$ 1.282 seen, or 1.28, 1.281, not 1.29 or 1.30
	M1		For standardising, with or without sq rt, squared, no cc
$\mu = 5080$ (5078) rounding to 5080	A1	**3**	For correct answer
(ii) $P(<5000) = \Phi[(5000-5078)/ 40.6]$	M1		For standardising, criteria as above, can include cc
$= \Phi(-1.921)$	M1		For correct area found using tables ie < 0.5ft on wrong (i)
$= 1 - 0.9727$ $= 0.0273$ or 2.73%	A1	**3**	For correct answer, accept 0.0274
(iii) $\mu = 60$, var = 54	B1		For 60 and 54 seen (could be sd or variance)
P(fewer than 65) = $\Phi(64.5 - 60) / \sqrt{54}$	M1		For using 64.5 or 65.5 in a standardising process
$= \Phi(0.6123)$	M1		For standardising, must have $\sqrt{}$(their 54) in denom
$= 0.730$ accept 0.73	A1	**4**	For correct answer

8 (i) $1.645 = \frac{50-38}{\sigma}$ $\sigma = 7.29$	B1 M1 A1	**3**	Using $z = +/- 1.645$ or 1.65 Equation with 38, 50, σ and a recognisable z-value Correct answer
(ii) $z = \frac{30-38}{their\,\sigma}$ $(= -1.097)$ $P(z < 30) = 1 - \Phi(1.097)$ $= 1 - 0.8637$ $= 0.136$	M1 M1 A1	**3**	Standardising, no cc Finding correct area ie < 0.5 Correct answer
(iii) $1-(0.95)^9$ $= 0.370$	B1 B1	**2**	$(0.95)^9$ seen correct answer

10 (i) heights, weights, times etc of something	B1	**1**	Any sensible set of data, must be qualified
(ii) $z = 0.64 = \frac{\mu - 10}{\sqrt{21}}$	B1 M1		$z = \pm 0.64$ seen equation relating 10, $\sqrt{21}$, 21, μ and their z or 1 – their z, (must be a recognisable z value ie not 0.77)
$\mu = 12.9$	A1	**3**	correct answer
(iii) $z = \frac{22-12.9}{\sqrt{21}}$ $= 1.986$	M1		standardising, with or without sq rt, no cc, must be their mean
$P(X > 22) = 1 - \Phi(1.986)$ $= 1 - 0.9765$ $= 0.0235$	M1ft		correct area ie < 0.5, ft on their mean >22
$300 \times 0.0235 = 7.05$ answer = 7	M1 A1	**4**	mult by 300 correct answer, accept 7 or 8 must be integer

14 (i) $z = \pm 1.68$	B1		Number rounding to 1.68 seen
$z = \frac{5.5-4.5}{\sigma}$	M1		Standardising and attempting to solve with their z, ; must be z value, no cc, no σ^2 ,no $\sqrt{\sigma}$
$\sigma = 0.595$ accept 25/42	A1	**3**	Correct answer
(ii) $z_1 = \frac{3.8-4.5}{0.5952} = -1.176$	M1		For standardising 3.8 or 4.8, mean 4.5 not 5.5, their σ or $\sqrt{\sigma}$ or σ^2 in denom
$z_2 = \frac{4.8-4.5}{0.5952} = 0.504$	A1ft		One correct z-value, ft on their σ
prob = $\Phi(0.504) - (1-\Phi(1.176))$ $= 0.6929 - (1-0.8802)$	M1		Correct area ie $\Phi_1 + \Phi_2 - 1$ or $\Phi_1 - \Phi_2$ if μ taken to be 5.5
$= 0.573$	A1	**4**	Correct answer only

16	**(i)**	$-0.674 = \dfrac{7-\mu}{2.6}$	B1 M1 M1	± 0.674 seen only Standardising must have a recognisable z-value, no cc and 2.6 For solving their equation with recognisable z-value, μ and 2.6 not 1 – 0.674 or 0.326, allow cc
		$\mu = 8.75$	A1 **4**	Correct answer
	(ii)	$\mathrm{P}(X > 6.2) = \mathrm{P}\left(z > \dfrac{6.2-6.5}{2.6}\right)$	M1	Standardising, no cc on the 6.2
		$= \mathrm{P}(z > -0.1154)$ $= 0.546$	M1 A1 **3**	prob > 0.5 Correct answer

27	**(i)**	$\mathrm{P}(X = 2)) = (0.25)^2 \times (0.75)^6 \times {}^8\mathrm{C}_2$	M1	3 term binomial expression involving ^{8}C something, powers summing to 8
		$= 0.311$	A1 **[2]**	correct answer
	(ii)	$12 \times 0.25 = 3$, < 5 so not possible	B1 **[1]**	
	(iii)	mean = 40×0.25 (= 10) variance = $40 \times 0.25 \times 0.75$ (= 7.5)	B1	40×0.25 and $40 \times 0.25 \times 0.75$ seen, o.e.
		$\mathrm{P}(X \text{ at least } 13) = \mathrm{P}\left(z > \dfrac{12.5-10}{\sqrt{7.5}}\right)$	M1	standardising, ±, with or without cc, must have sq rt
		$= \mathrm{P}(z > 0.913)$	M1	continuity correction 12.5 or 13.5
		$= 1 - \Phi(0.913)$	M1	correct area, i.e. < 0.5 legit
		$= 1 - 0.8194$ $= 0.181$	A1 **[5]**	correct answer

31	**(i)**	$0.431 = \dfrac{135-\mu}{\sigma}$	B1	One ±z-value correct, accept 0.430
			B1	A second ±z-value correct
		$-0.842 = \dfrac{127-\mu}{\sigma}$	M1	Solving two equations relating μ, σ, 135, 127 and their z-values (must be z-values)
		$\sigma = 6.29$	A1	Correct answer accept 6.28
		$\mu = 132$	A1 [5]	Correct answer
	(ii)	$\mathrm{P}(X < 145) = \mathrm{P}\left(z < \dfrac{145-132.3}{6.284}\right)$	M1	Standardising no sq rt no cc
		$= \mathrm{P}(z < 2.023)$	M1	Correct use of normal tables
		$= 0.978$	A1 [3]	Answer rounding to 0.978 or 0.979
	(iii)	$p = 1/3$		
		P(at least 2) = 1 – P(0, 1)	M1	Binomial expression with powers summing to 8 and $^8\mathrm{C}_{\text{something}}$. (any p)
		$= 1 - [\,(2/3)^8 + {}^8\mathrm{C}_1 \times (1/3)^1 (2/3)^7\,]$	A1	Correct unsimplified expression
		$= 0.805$	A1 [3]	Answer rounding to 0.805

34 (i) Zotoc: $z = \frac{367 - 320}{21.6} = 2.176$ Ganmor: $z = \frac{367 - 350}{7.5} = 2.267$	M1	Standardising either car's fuel, no cc, no sq, no √
P(Zotoc) = 0.985	A1	Correct answer
P(Ganmor) = 0.988	A1 [3]	Correct answer
(ii) $z = 0.23$	B1	± 0.23 seen
$0.23 = \frac{x - 320}{21.6}$	M1	Standardising either car, no cc, no sq rt, no sq
$x = 324.968$	M1ind	320 + d – 320 i.e. just d on num
$d = 4.97$	A1 [4]	Correct answer, –4.97 gets A0

37 (i) $z = 0.807$	B1	0.807 seen
$0.807 = \frac{10 - 8.2}{\sigma}$	M1	standardising, must have σ, no sq rt, no cc and a z-value
s = 2.23	A1 [3]	correct answer
(ii) P(> 1 min from mean) = P(mod $z > \frac{1}{2.23}$)	M1	standardising, their sd, no cc and adding two areas
$= \mathrm{P}(\lvert z \rvert > 0.4484)$ $= (1 - 0.6729) \times 2$ $= 0.654$	M1 A1 [3]	using $1 - \Phi(z)$ correct answer

(iii) P(> 2 longer) = 1 – P(0, 1, 2 longer)	M1	binomial term ${}^6C_x p^x(1-p)^{6-x}$
$= 1 - \{(0.79)^6 + {}^6C_1(0.21)(0.79)^5 + {}^6C_2(0.21)^2(0.79)^4\}$	A1	correct unsimplified answer
= 0.112	A1 [3]	correct answer
(iv) $\mu = 35 \times 0.5 = 17.5$ $\sigma^2 = 35 \times 0.5 \times 0.5 = 8.75$	B1	17.5 and 8.75 or $\sqrt{8.75}$ seen
$P(X < 16) = \Phi\left(\frac{15.5 - 17.5}{\sqrt{8.75}}\right)$	M1 M1	standardising, with or without cc, must have sd in denom continuity correction 15.5 or 16.5 only, seen
$= 1 - \Phi(0.676)$ $= 1 - 0.7505$ = 0.2495 (0.249 or 0.250)	M1 A1 [5]	using $1 - \Phi(z)$ correct answer
OR ${}^{35}C_0 0.5^0 0.5^{35} + {}^{35}C_1 0.5^1 0.5^{34} + {}^{35}C_2 0.5^2 0.5^{33} + ...$ $= 8582372584/2^{35} = 0.250$	M1 A1 M1 A1 A1	binomial term ${}^{35}C_x 0.5^x 0.5^{35-x}$ at least 2 correct terms ($x \neq 0$) seen summing 16 or 17 terms correct expression correct answer

43 (i) $z = -1.282$	B1	± 1.282 or ± 1.281 seen
$P(x < 20) = P\left(z < \frac{20 - \mu}{0.8}\right)$ $-1.282 = \frac{20 - \mu}{0.8}$	M1	Standardising, no cc, must have 0.8, must be a z-value
μ = 21.0 cm (21.0256)	A1 **[3]**	Correct answer
(ii) $P(21.5 < x < 22.5)$ $= P\left(\frac{21.5 - 21.03}{0.8}\right) < z < \left(\frac{22.5 - 21.03}{0.8}\right)$	M1	2 attempts at standardising with their mean, must have 0.8 oe
$= \Phi(1.8375) - \Phi(0.5875)$ $= 0.9670 - 0.7217$ = 0.2453	M1 A1	Subtracting 2 Φs ft their mean Needn't be entirely accurate, rounding to 0.24 or 0.25
$P(< 2) = P(0) + P(1)$ $= (0.7547)^4 + (0.2453)^1(0.7547)^3\ {}^4C_1$	M1 M1	Binomial term with ${}^4C_r p^r (1-p)^{4-r}$ seen $r \neq 0$, any $p < 1$ Bin expression for P(0) + P(1), any $p < 1$
= 0.746	A1 **[6]**	Accept 3sf rounding to 0.75

44 **(i)**	$z = \pm 1.751$	B1	Correct z
	$\pm \dfrac{20-\mu}{\mu/4} = 1.751$	M1	Standardising no cc, no sqrt, must be a z-value
	$\mu = 13.9$	A1 **[3]**	Correct answer
(ii)	$P(X < 10) = P(z < \pm \dfrac{10-13.91}{13.91/4})$	M1	Standardising attempt with 10, their μ and their $\mu/4$, no cc, no sqrt
	$= P(z < -1.124)$ $= 1 - 0.8694$ $= 0.131$	M1	"$\Phi_1 + \Phi_2 - 1$", ft their mean
	$P(10 < X < 20) = 0.96 - 0.131$ $= 0.829$ or 0.830	A1 **[3]**	Correct answer
(iii)	$\mu = 250 \times 0.96 = 240$ $\sigma^2 = 250 \times 0.96 \times 0.04 = 9.6$	B1	240 and 9.6 or sq rt 9.6 seen unsimplified
	$P(\geq 235) = 1 - \Phi\left(\pm \dfrac{234.5-240}{\sqrt{9.6}}\right)$	M1	Standardising, with or without cc, must have sq rt in denom
		M1	Continuity correction 234.5 or 235.5 only
	$= \Phi(1.775)$	M1	Correct region > 0.5, ft their mean
	$= 0.962$	A1 **[5]**	Correct answer

45 **(i)**	$(0.75)^n < 0.06$	M1*	Equation or inequality with 0.75^n and 0.06 or 0.94 seen
	$n > 9.78$	M1dep*	Attempt at solving by trial and error (can be implied) or using logarithms correctly
	$n = 10$	A1 **[3]**	Correct answer
(ii)	$E(X) = 14 \times 0.75$ or 10.5 Try $P(10) = {}^{14}C_{10}(0.75)^{10}(0.25)^4 = 0.220$	M1	Evaluating binomial probability for an integer value directly above or below their mean
	$P(11) = {}^{14}C_{11}(0.75)^{11}(0.25)^3 = 0.240$	M1	Evaluating the other binomial probability
	(mode is) 11	A1 **[3]**	Correct answer
	OR	M1	Evaluating binomial $P(n)$ and $P(n+1)$
		M1	Evaluating binomial P(10), P(11) and P(12)
		A1	Correct answer
(iii)	$P(> 11)$ $= {}^{14}C_{12}(0.75)^{12}(0.25)^2 + {}^{14}C_{13}(0.75)^{13}(0.25)^1 + (0.75)^{14}$	M1	A binomial term of the form ${}^{14}C_n p^n (1-p)^{14-n}$ seen, $n \neq 0$ or 14
		M1	Summing binomial P(12, 13, 14) or P(11, 12, 13, 14,)
	$= 0.281$	A1	Correct answer 0.280 – 0.282
	$P(3) = {}^5C_3\,(0.2811)^3(0.7189)^2$	M1	A binomial term of the form ${}^5C_3 p^3(1-p)^2$ seen, any p
	$= 0.115$	A1 **[5]**	Correct answer