AS-Level
Topic : Normal Distribution
May : 2013-May :2025
Answers

Question 1

(i) $\text{P(tall)} = \text{P}\left(z > \dfrac{70 - 50}{16} \right) = \text{P}(z > 1.25)$	M1		+ve/-ve Standardising no cc no sq rt no sq
$\qquad\qquad = 1 - 0.8944$			
$\qquad\qquad = 0.106$	A1	**[2]**	Correct answer
(ii) $\text{P(short)} = (1 - 0.1056)/3$	M1		Subt their **(i)** from 1 or their **(i)** and multiplying by $\dfrac{1}{3}$ or $\dfrac{2}{3}$
$\qquad\qquad = 0.2981$	A1 ft		Rounding to 0.298, only ft for $\dfrac{(1-\textbf{(i)})}{3}$
$\qquad z = -0.53$	A1		$\pm$ z-value rounding to 0.53, condone ±0.24
$\qquad -0.53 = \dfrac{x - 50}{16}$	M1		Standardising with their z value (not a probability), no cc sq rt etc.
$\qquad\qquad x = 41.5$	A1	**[5]**	Correct answer

Question 2

(i) $\text{P}(x < 440)$			
$= \text{P}\left(z < \dfrac{440 - 445}{3.6} \right) = 1 - \Phi(1.389)$	M1		Standardising no cc no sq or sq rt
	M1		Correct area $(1 - \Phi)$ oe (indep)
$= 1 - 0.9176$			
$\qquad \text{Ans} = 0.0824$	A1	**[3]**	Rounding to correct answer accept 0.0825
(ii) $z = 1.881$	M1		±1.88 or 1.881 or 1.882 or 1.555 seen$\pm$
$\qquad \dfrac{c}{3.6} = 1.881$	M1		Equation with $\pm c/3.6$ or $2c/3.6$ only $=$ z or prob (can be implied)
$\qquad c = 6.77$	A1	**[3]**	Correct answer accept 6.78

Question 3

$z = 1.452$	B1		Rounding to ± 1.45
$1.452 = \dfrac{20 - \mu}{\mu/5}$	B1		$\dfrac{20 - \mu}{\mu/5}$ or $\dfrac{20 - 5\sigma}{\sigma}$ seen oe
$\mu = 15.5$	B1	**[3]**	rounding to correct answer

Question 4

4	(a)	$P(y < 0) = P\left(z < \dfrac{0 - \mu}{\mu/2}\right)$	M1		Standardising containing 0 (can be implied) and μ only
		$= P(z < -2)$	A1		z < –2 seen
		$= 1 - 0.9772 = 0.0228$	A1	[3]	Correct answer
	(b)	$P(x > 2.1) = 253/8000 = 0.031625$ $P(x < 2.1) = 0.968375 = \Phi(z)$	M1		1 – their 253/8000 used to obtain a z-value
		$z = 1.857$ or 1.858 or $1.859 = \dfrac{2.1 - 2.04}{\sigma}$	A1		Rounded to 1.86 seen
		$\sigma = 0.0323$	M1		Solving for σ using their z val must be a z val
			A1	[4]	Correct answer

Question 5

	$np = 350 \times 1/7\ (= 50)$ $npq = 350 \times 1/7 \times 6/7\ (= 42.857)$	B1 M1		Correct unsimplified np and npq standardising, with or without cc, must have sq rt
	$P(x\ \ 47) = P\left(z > \dfrac{46.5 - 50}{\sqrt{42.857}}\right) =$	M1 M1		continuity correction 46.5 or 47.5 correct area ie > 0.5 must be a Φ
	$P(z > -0.5346)$ $= 0.704$	A1	[5]	correct answer

Question 6

	(a)	$P(X < q + 82) = 0.72$ $z = 0.583$	M1		Rounding to ± 0.58 or ± 0.15 seen
		$\dfrac{\pm q}{7.4}$ or $\dfrac{\pm 2q}{7.4} = z$ or probabilty (o.e.)	M1		Standardising, no cc, no sq, no sq rt
		$q = 4.31$	A1	3	correct answer
	(b)	$\dfrac{0.5\mu - \mu}{\sigma} = \dfrac{\pm 0.5\mu}{\sigma}$	M1		Standardising attempt some μ/σ allow cc, sq rt, sq Can be implied
		$\dfrac{0.2\sigma^2}{\sigma} = -0.2\sigma = -0.580$	B1 M1		± 0.580 seen (accept ±0.58) substituting to eliminate μ or σ, arriving at numerical solution, any z value or probability – not dependent
		$\sigma = 2.90$ $\mu = 3.36$	A1	4	both answers correct, accept 2.9

Question 7

$$P(13.6 < X < 14.8) = P\left(\frac{13.6 - 14}{0.52} < z < \frac{14.8 - 14}{0.52}\right)$$

$$= P(-0.7692 < z < 1.538)$$
$$= \Phi(1.538) - [1 - \Phi(0.7692)]$$
$$= 0.9380 - [1 - 0.7791]$$
$$= 0.7171$$

$$P(8) = (0.7171)^8 (0.2829)^2 {}_{10}C_8$$

$$= 0.252$$

M1	Standardising 1 expression, no cc, no sq rt, no sq, ±, mean on num.
M1	$\Phi_1 + \Phi_2 - 1$ (indep) oe ($\Phi_2 - \Phi_1$ if cc used)
A1	Correct probability rounding to 0.72 here
M1	Binomial expression 10C8 $p^8 q^2$, $\Sigma p + q = 1$, any p
A1 5	Correct answer (rounding to 0.252)

Question 8

(i) $P(4, 5, 6) = (0.22)^4 (0.78)^4 8C4 +$
$(0.22)^5 (0.78)^3 8C5 + (0.22)^6 (0.78)^2 8C6$

$= 0.0763$

M1	Bin term with ${}_8C_r\, p^r (1-p)^{8-r}$
M1	seen $r \neq 0$ any $p < 1$ Summing 2 or 3 bin probs $p = 0.22$, $n = 8$
A1 [3]	Correct answer

(ii) prob = 0.13
mean = 300 × 0.13 = 39
var = 300 × 0.13 × 0.87 = 33.93

$$P(30 < x < 50) = P$$

$$\left(\frac{30.5 - 39}{\sqrt{33.93}} < z < \frac{49.5 - 39}{\sqrt{33.93}}\right)$$

$= P(-1.4592 < z < 1.8026)$
$= \Phi(1.8026) + \Phi(1.4592) - 1$
$= 0.9643 + 0.9278 - 1 = 0.892$

B1	Correct prob can be implied
B1ft	Correct unsimplified np and npq ft wrong 0.13
M1	Standardising a value need sq rt
M1	Cont correction 30.5 / 31.5 or 48.5/49.5 only
M1	Correct area $\Phi_1 + \Phi_2 - 1$ oe Rounding to correct answer
A1 [6]	SC P(31,..49)=300C31(0.13)^{31}(0.87)^{269} + … +300C49 etc.) B1B1

Question 9

(i) z = 0.878
$$\frac{190 - 160}{\sigma} = 0.878$$
σ = 34.2

B1	± 0.878, 0.88, rounding to 0.88 seen (190 − 160)/σ = something
M1	
A1 [3]	Correct answer

(ii) P(at least 1) = 1 − P(0)

$= 1 - (0.81)^{12} = 0.920$

M1	Using 1 − P(0), 1 − P(0, 1), P(1,2 … 12) or P(2, … 12) with $p = 0.19$ or 0.81, terms must be evaluated to get the M1
A1 [2]	Correct answer accept 0.92

Question 10

$$P(x < -2.4) = P\left(z < \frac{-2.4 - 1.5}{3.2}\right)$$

	M1		Standardising no cc can have sq
$= P(z < -1.219)$	M1		Correct area, i.e. < 0.5
$= 1 - 0.8886$			
$= 0.111$	A1	**[3]**	Correct answer rounding to 0.111

Question 11

(i)	$z = -1.406$	B1		Rounding to ± 1.41 seen
	$\dfrac{c - 14.2}{3.6} = -1.406$	M1		Standardising allow sq rt no cc
	$c = 9.14$	A1	3	Correct answer

(ii)	$P\left(\dfrac{15 - 14.2}{3.6}\right) < z < \left(\dfrac{16 - 14.2}{3.6}\right)$	M1		2 attempts at standardising no cc no sq rt
	$= \Phi(0.5) - \Phi(0.222)$	M1		Subt two Φs (indep mark)
	$= 0.6915 - 0.5879$			
	$= 0.1036$	A1		Needn't be entirely accurate, rounding to 0.10
	$P(\text{at least } 2) = 1 - P(0, 1)$	M1		Binomial term with $_7C_t p^r (1-p)^{7-r}$ seen $r \neq 0$ any $p < 1$
	$= 1 - (0.8964)^7 - (0.8964)^6 (0.1036)_7 C_1$	M1		$1 - P(0)$, $1 - P(1)$, $1 - P(0, 1)$ seen their p
	$= 1 - 0.8413$			
	$= 0.159$	A1	6	Correct answer accept 3sf rounding to 0.16

Question 12
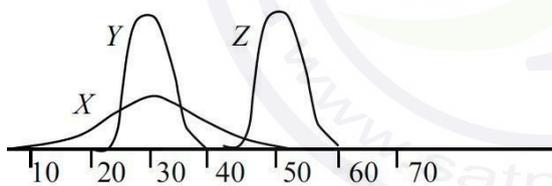
B1		X mean at 30, roughly from 10 to 50 or $15 - 45$
B1		Y same mean as X but higher and thinner
B1ft	3	Z same shape as Y but mean at 50 ft wrong Y

Question 13

(i)	$z = -1.282$	B1		Rounding to ± 1.28 seen
	$-1.282 = \dfrac{t - 6.5}{1.76}$	M1		Standardising, no cc, no sq or sq rt, $z \neq \pm 0.9, \pm 0.1$
	$t = 4.24$	A1	3	Correct answer, accept 4.25

(ii)	$P(z < 1) = 0.8413$	M1		$z = 1$ used to find a probability
	$P(\text{within 1sd of mean}) = 2\Phi - 1$ $= 0.6826$	B1		correct prob, accept answer rounding to 0.66, 0.67, 0.68, not from wrong working. If quoted, then implies first M1.
	$P(8, 9)$ $= {}^9C_8 (0.6826)^8 (0.3174) + (0.6826)^9$	M1 M1		Binomial term $p^r (1-p)^{9-r} \, {}^9C_r$, ${}^9C_r$ must be seen Binomial expression for $P(8) + P(9)$, any p
	$= 0.167$	A1	5	Correct ans

Question 14

(i)	$np = 252 \times 1/7 = 36$, $npq = 252 \times 1/7 \times 6/7 = 30.857$	B1		Unsimplified 36 and 30.857 seen, oe
	$P\left(z < \left(\dfrac{29.5 - 36}{\sqrt{30.857}}\right)\right) + P\left(z > \left(\dfrac{44.5 - 36}{\sqrt{30.857}}\right)\right)$	M1 M1		any standardising, sq rt needed any continuity correction either 29.5, 30.5, 43.5, 44.5
	$= P(z < -1.170) + P(z > 1.530)$			
	$= 1 - 0.8790 + 1 - 0.9370$	M1		correct area $2 - (\Phi_1 + \Phi_2)$
	$= 0.184$	A1	**5**	correct answer
(ii)	np and nq are both > 5	B1	**1**	must have both

Question 15

(i)	$z = -0.842$	B1		$\pm$ rounding to 0.84 seen
	$P(x > 1.35) = P\left(z > \dfrac{1.35 - 1.9}{\sigma}\right)$	M1		$\pm \dfrac{1.35 - 1.9}{\sigma} =$ a prob or a z-value NOT 0.8 or 0.2 allow a 1−...
	$-0.842 = -0.55/\sigma$			
	$\sigma = 0.653$	A1	**3**	Correct answer from correct working
(ii)	$P(x < 2) = P\left(z < \dfrac{2 - 1.9}{0.6532}\right)$	M1		$\pm$ standardising no continuity correction their σ
	$= P(z < 0.1531)$			
	$= 0.561$	A1	**2**	Correct answer
(iii)	$X \sim N(160, 32)$ $P(162.5 < x < 173.5) =$	B1		Unsimplified 160 and 32 seen
	$P\left(\dfrac{162.5 - 160}{\sqrt{32}} < z < \dfrac{173.5 - 160}{\sqrt{32}}\right)$	M1		Standardising need sq rt
	$P(0.442 < z < 2.386)$	M1		Any of 162.5, 163.5, 172.5, 173.5 seen
	$= \Phi(2.386) - \Phi(0.442)$	M1		$\Phi_2 - \Phi_1$ oe
	$= 0.9915 - 0.6707$	A1		One correct Φ to 3sf
	$= 0.321$	A1	**6**	Correct answer accept 0.320

Question 17

$1.751 = \dfrac{12 - \mu}{\sigma}$	B1		Rounding to ± 1.75 seen
$0.468 = \dfrac{9 - \mu}{\sigma}$	B1		± 0.468 seen
	M1		An eqn with a z-value, μ and σ no $\sqrt{\sigma}$, no σ^2
$\sigma = 2.34$	M1		Sensible attempt to eliminate μ or σ by substitution or subtraction, need a value
$\mu = 7.91$	A1	5	correct answers

Question 18

$P(21.6 < x < 28.7)$			
$= P\left(\left(\dfrac{21.6 - 24}{4.7}\right) < z < \left(\dfrac{28.7 - 24}{4.7}\right)\right)$	M1 A1		Standardising; no cc, no sq rt One rounding to $\Phi(0.841$ or $0.695)$
$= P(-0.5106 < z < 1) = \Phi(1) - \Phi(-0.5106)$	M1		$\Phi_1 + \Phi_2 - 1$
$= 0.8413 - (1 - 0.6953)$			
$= 0.537 \ (0.5366)$	A1	4	Correct answer

Question 19

(i) $P(<1.2) = P\left(z < \dfrac{1.2 - 1.9}{0.55}\right) = P(z < -1.2727)$	M1		Standardising for wt 1.2 or 2.5, no cc, sq, sq rt May be awarded in (ii) if not attempted in (i) Accept 0.102
$= 1 - \Phi(1.273) = 1 - 0.8986$			
$= 0.1014$	A1		First correct proportion seen
$P(>2.5) = P\left(z < \dfrac{2.5 - 1.9}{0.55}\right) = P(z > 1.0909)$			
$= 1 - \Phi(1.0909) = 1 - 0.8623$	A1		Second correct proportion seen
$= 0.138$			
$P(1.2 < wt < 2.5) = 1 - 0.101 - 0.138$	M1		Third proportion $1 -$ their previous 2 proportions or correct attempt for remaining proportion
$= 0.761$	A1√	5	Correct answer or $1 -$ *their* 2 previous correct proportions
(ii) $P(x > k) = 0.8 + 0.1377 = 0.9377$	M1		Valid method to obtain $P(x > k)$ or $P(x < k)$
$z = -1.536$	A1		± 1.536 seen accept 3sf rounding to 1.53 or 1.54
$-1.536 = \dfrac{k - 1.9}{0.55}$	M1		Attempt to solve equation with their 'correct' area z value, k, 1.9 and 0.55
$k = 1.06$	A1	4	Correct answer or rounding to 1.05

Question 19

$z = -2.326$	B1		$\pm\,2.325$ to $\pm\,2.33$ seen
$\dfrac{250 - 260}{\sigma} = -2.326$	M1		Standardising and = or < their z, no cc, sq, sq rt
$\sigma = 4.30$	A1	3	Correct ans

Question 20

(i)	$P(4, 5, 6) = (0.75)^4 (0.25)^4 \times {}^8C_4 +$ $(0.75)^5 (0.25)^3 \times {}^8C_5 + (0.75)^6 (0.25)^2 \times {}^8C_6$	M1		Bin term $p^r (1-p)^{8-r} \times {}^8C_r$ seen any p
		M1		Correct unsimplified answer
	$= 0.606$	A1	3	Correct ans
(ii)	$np = 160 \times 0.75 = 120 \quad npq = 30$	B1		Unsimplified mean and var correct
	$P(> 114) = P\left(z > \left(\dfrac{114.5 - 120}{\sqrt{30}}\right)\right)$	M1 M1 M1		Standardising, need sq rt Cont correction either 114.5 or 113.5 Correct area consistent with their working
	$= P(z > -1.004)$			
	$= \Phi(1.004) = 0.842$	A1	5	Correct ans
(iii)	np and nq both > 5	B1	1	Need both

Question 21

(a)	(i)	$P(x < 8) = P\left(z < \dfrac{8 - 7.15}{0.88}\right)$	M1		Standardising $\pm$, no cc no sq rt no sq
		$= \Phi(0.9659)$ $= 0.833$	A1	2	Correct answer
	(ii)	$z = 0.674$	B1		Accept $\pm\,0.674$ or 0.675 only
		$\dfrac{q - 7.15}{0.88} = 0.674$	M1		Standardised eqn $= \pm$ their z-value, allow sq or sq rt if already penalised in (i)
		$q = 7.74$	A1	3	Correct answer
(b)		$P(Y > 4\mu) = P\left(z > \left(\dfrac{4\mu - \mu}{(3\mu/2)}\right)\right) = P(z > 2)$	M1		Standardising no sq rt, no cc, no sq, one variable
		$= 1 - 0.9772$	A1		$z = \pm 2$ seen
		$= 0.0228$	A1	3	correct ans SR B1 if made-up values used and 0.0228 obtained

Question 22

(i)	$z_1 = \dfrac{70 - 66.4}{5.6} = 0.6429$	M1		Standardising one variable, no cc, no sq rt
	$z_2 = \dfrac{72.5 - 66.4}{5.6} = 1.089$	M1		Correct area $\Phi_2 - \Phi_1$
	$\Phi(1.089) - \Phi(0.643) = 0.8620 - 0.7399$	A1		Correct answer rounding to 0.12
	$= 0.1221$			
	$0.1221 \times 250 = 30.5$	M1		Mult by 250
	30 or 31 sheep	A1ft	5	Correct answer ft their 0.1221
(ii)	$66.4 - 59.2 = 7.2$	M1		Subt from 66.4
	$66.4 + 7.2 = 73.6$	A1	2	Correct answer
(iii)	$z = 0.674$	B1		± 0.674 or 0.675 seen
	$\dfrac{67.5 - \mu}{4.92} = 0.674$	M1		Standardising with a z-value no cc no sq rt
	$\mu = 64.2$	A1	3	Correct answer

Question 23

(i)	$P(\text{large}) = 1 - \Phi\left(\dfrac{29 - 21.7}{6.5}\right)$	M1 M1		Standardising no cc no sq rt Correct area $1 - \Phi$
	$= 1 - \Phi(1.123) = 1 - 0.8692$	A1		Rounding to 0.13
	$= 0.1308$			
	$P(0,1) = (0.8692)^{8\backslash} + {}^8C_1(0.1308)(0.8692)^7$	M1		Any bin term with ${}^8C_x p^x (1-p)^{8-x}$ $\ 0 < p < 1$
		M1		Summing bin $P(0) + P(1)$ only with $n = 8$, oe
	$= 0.718$	A1	[6]	Correct ans
(ii)	$= 1 - (0.8692)^n > 0.98$	M1		eq/ineq involving their $(0.8692)^n$ or $(0.1308)^n$, 0.02 or 0.98 oe with or
	$(0.8692)^n < 0.02$	M1		without a 1 solving attempt (could be trial and
	Least number $= 28$	A1	[3]	error) – may be implied by their answer correct answer

Question 24

	$\mu = 300 \times 0.072 = 21.6$, $\sigma^2 = 20.0448$	B1		300×0.072 seen and $300 \times 0.072 \times 0.928$ seen or implied
				($\sigma = 4.4771, \sigma^2 = 20(.0)$) oe
	$P(x < 18) = P\left(z < \dfrac{17.5 - 21.6}{\sqrt{20.0448}}\right)$	M1		$\pm$Standardising, their mean/var, with sq root
		M1		Cont corr 17.5 or 18.5
	$= P(z < -0.9157)$			
	$= 1 - 0.8201$	M1		Correct area $1 - \Phi$
	$= 0.180$	A1	[5]	Answer wrt 0.180, nfww

Question 25

	$z = 1.136$	B1		± 1.136 seen, not ± 1.14,
	$1.136 = \dfrac{195 - \mu}{22}$	M1		Standardising, no cc no sq rt, equated to their z not 0.128 or 0.872
	$\mu = 170$	A1	[3]	Correct answer, nfww

Question 26

(a) (i)	prob $= p\left(z < \dfrac{30 - 35.2}{4.7}\right)$	M1		Standardising no sq rt no cc no sq	
	$= \mathrm{P}(z < -1.106)$	M1		$1 - \Phi$	
	$= 1 - 0.8655 = 0.1345$	A1		Correct ans rounding to 0.13	
	$0.1345 \times 52 = 6.99$	A1	4	Correct final answer accept 6 or 7 if 6.99 not seen but previous prob 0,1345 correct	
(ii)	$\Phi(t) = 0.648 \qquad z = 0.380$	B1		0.648 seen	
	$0.380 = \dfrac{t - 35.2}{4.7}$	M1		standardising allow cc, sq rt,sq, need use of tables not 0.148, 0.648, 0.352, 0.852	
	$t = 37.0$	A1	3	correct answer rounding to 37.0	
(b)	$\dfrac{7 - \mu}{\sigma} = -0.8\sigma \quad$ so $\quad 7 - \mu = -0.8\sigma$	B1		± 0.8 seen	
		B1		± 0.44 seen	
	$\dfrac{10 - \mu}{\sigma} = 0.44 \quad$ so $10 - \mu = 0.44\sigma$	M1		An eqn with z-value, μ and σ no sq rt no cc no sq	
		M1		Sensible attempt to eliminate μ or σ by subst or subtraction, need at least one value	
	$\mu = 8.94 \qquad \sigma = 2.42$	A1	5	Correct answers	

Question 27

(i)	$\mathrm{P}(5, 6, 7) = {}^8C_5(0.68)^5(0.32)^3 + {}^8C_6(0.68)^6(0.32)^2 + {}^8C_7(0.68)^7(0.32)$	M1		Binomial term ${}^8C_x\, p^x(1-p)^{8-x}$ seen $0 < p < 1$
		M1		Summing 3 binomial terms
		A1		Correct unsimplified answer
	$= 0.722$	A1	[4]	Correct answer
(ii)	$np = 340,\ npq = 108.8$	B1		Correct (unsimplified) mean and var
	$\mathrm{P}(x > 337) = \mathrm{P}\left(z > \dfrac{337.5 - 340}{\sqrt{108.8}}\right)$	M1		standardising with sq rt must have used 500
		M1		cc either 337.5 or 336.5
	$= \mathrm{P}(z > -0.2396)$	M1		correct area (> 0.5) must have used 500
	$= 0.595$	A1	[5]	correct answer
(iii)	$np\ (340) > 5$ and $nq\ (160) > 5$	B1	[1]	must have both or at least the smaller, need numerical justification

Question 28

$P(x < 3.273) = 0.5 - 0.475 = 0.025$	**M1**	Attempt to find z-value using tables in reverse
$z = -1.96$	**A1**	± 1.96 seen
$\dfrac{3.2 - \mu}{0.714} = -1.96$	**M1**	Solving their standardised equation z-value not nec
$\mu = 4.60\text{s}$	**A1** [4]	Correct ans accept 4.6

Question 29

(i)	$P(0, 1, 2) =$ $(0.92)^{19} + {}^{19}C_1(0.08)(0.92)^{18} + {}^{19}C_2(0.08)^2(0.92)^{17}$	**M1** **M1**	Binomial term ${}^{19}C_x p^x (1-p)^{19-x}$ seen $0<p<1$ Correct unsimplified expression
	$= 0.809$	**A1** 3	Correct answer (no working SC B2)
(ii)	$P(\text{at least } 1) = 1 - P(0)$ $= 1 - P(0.92)^n > 0.90$ $0.1 > (0.92)^n$ $n > 27.6$	**M1** **M1**	Eqn with their 0.92^n, 0.9 or 0.1, 1 not nec Solving attempt by logs or trial and error, power eqn with one unknown power
	Ans 28	**A1** 3	Correct answer, not approx., $\approx, \geqslant, >, \leqslant, <$
(iii)	$np = 1800 \times 0.08 = 144$ $npq = 132.48$	**B1**	correct unsimplified np and npq seen accept 132.5, 132, 11.5, awrt 11.51
	$P(\text{at least } 152) = P\left(z > \left(\dfrac{151.5 - 144}{\sqrt{132.48}} \right) \right)$	**M1** **M1**	standardising, with $\sqrt{}$ cont correction 151.5 or 152.5 seen
	$= P(z > 0.6516)$ $= 1 - 0.7429$ $= 0.257$	**M1** **A1** 5	correct area $1 - \Phi$ (probability) correct answer
(iv)	Use because 1800×0.08 (and 1800×0.92 are both) > 5	**B1** 1	$1800 \times 0.08 > 5$ is sufficient $np>5$ is sufficient if clearly evaluated in (iii) If $npq>5$ stated then award B0

Question 30

(i)	$z = 1.127$	**B1**		± 1.127 seen accept rounding to ± 1.13
	$1.127 = \dfrac{136-125}{\sigma}$	**M1**		Standardising no cc no sq rt, with attempt at z
	$\sigma = 9.76$	**A1**	3	(not ± 0.8078, ± 0.5517, ± 0.13, ± 0.87) Correct ans
(ii)	$P(131 < x < 141) = P\left(\dfrac{131-125}{9.76} < z < \dfrac{141-125}{9.76}\right)$	**M1**		Standardising once with their sd, no $\sqrt{}$, ², allow cc
	$= \Phi(1.639) - \Phi(0.6147)$	**M1**		Correct area $\Phi 2 - \Phi 1$
	$= 0.9493 - 0.7307$			
	$= 0.2186$	**M1**		Mult by 170, P<1
	Number $= 0.2186 \times 170 = 37$ or 38 or awrt 37.2	**A1**	4	Correct answer, nfww

Question 31

(a) (i)	$P(x > 3900) = P\left(z > \dfrac{3900-4520}{560}\right)$	**M1**		Standardising no cc no sq rt no sq
	$= P(z > -1.107) = \Phi(1.107)$	**M1**		Correct area Φ ie > 0.5
	$= 0.8657$	**A1**		Prob rounding to 0.866
	Number of days $= 365 \times 0.0.8657$	**B1✓**	4	Correct answer ft their wrong prob if previous A0, $p < 1$, ft must be accurate to 3sf
	$= 315$ or 316 (315.98)			
(ii)	$z = 1.165$	**B1**		± 1.165 seen
	$1.165 = \dfrac{8000-m}{560}$	**M1**		Standardising eqn allow sq, sq rt, cc, must have z-value eg not 0.122, 0.878, 0.549, 0.810.
	$m = 7350$ (7347.6)	**A1**	3	Correct answer rounding to 7350
(iii)	$P(0, 1) = (0.878)^6 + {}^6C_1(0.122)^1(0.878)^5$	**M1**		Binomial term ${}^6C_x\, p^x(1-p)^{6-x}$ $0 < p < 1$ seen
		M1		Correct unsimplified expression
	$= 0.840$ accept 0.84	**A1**	3	Correct answer
	Normal approx. to Binomial. M0, M0, A0			
(b)	$P(< 2\mu) = P\left(z > \dfrac{2\mu - \mu}{\sigma}\right) = P(z < 1.5)$	**M1**		Standardising with μ and σ
		M1		Attempt at one variable and cancel
	$= 0.933$	**A1**	3	Correct answer

Question 32

(i)	let $P(2, 4, 6)$ all $= p$ then $P(1, 3, 5)$ all $= 2p$ $3p + 6p = 1$ $p = 1/9$ so prob (3) $= 2/9$ (0.222)	M1 M1 A1 [3]	Using P(even) = 2P(odd) or vice versa oe Summing P(odd+ even) or P(1, 2, 3, 4, 5, 6) = 1 Correct answer
(ii)	$P(5, 5, 6) = 2/9 \times 2/9 \times 1/9 \times {}^3C_2$ $= 4/243$ (0.0165)	M1 M1 A1 [3]	Mult three probs together Mult by 3 oe ie summing 3 options Correct answer
(iii)	$\mu = 100 \times 1/3 = 33.3$, $\sigma = 100 \times 1/3 \times 2/3 = 22.2$ $P(x \leqslant 37) = P\left(z \leqslant \dfrac{37.5 - \dfrac{100}{3}}{\sqrt{\dfrac{200}{9}}} \right) = P(z \leqslant 0.8839)$ $= 0.812$	B1 M1 M1 M1 A1 [5]	Unsimplified 100/3 and 200/9 seen Standardising need sq rt 36.5 or 37.5 seen correct area using their mean Correct answer

Question 33

(i)	$\bar{x} = 80 - 147/30 = 80 - 4.9$ $= 75.1$ sd $= \sqrt{\left(\dfrac{952}{30} - \left(\dfrac{147}{30}\right)^2\right)} = \sqrt{7.72\ldots}$ sd $= 2.78$	M1 A1 M1 A1 [4]	For $-147/30$ oe seen Correct answer $952/30 - (\pm$ their coded mean$)^2$ Correct answer
(ii)	$P(x > 160) = P\left(z > \dfrac{160 - 148.6}{18.5} \right)$ $= P(z > 0.616)$ $= 1 - 0.7310$ $= 0.269$	M1 M1 A1 [3]	Standardising no cc no sq rt $1 - \Phi$ Correct answer

Question 34

	$\mu = 54.1$ $z = -1.11$ $-1.11 = \dfrac{50.9 - 54.1}{\sigma}$ $\sigma = 2.88$	B1 B1 M1 A1 [4]	Stated or evaluated Accept rounding to ± 1.1 Standardising no cc no sq rt Correct answer

Question 35

(i)	$z = -1.645$	B1	± 1.64 to 1.65 seen
	$-1.645 = \dfrac{0.9 - m}{0.35}$	M1	Standardising with a z-value accept $(0.35)^2$
	$m = 1.48$	A1 3	Correct answer

(ii)	$P(<2) = P\left(z < \dfrac{2 - 1.476}{0.35}\right)$	M1	Standardising no sq , FT *their m*, no cc
	$= P(z < 1.50)$	M1	Correct area i.e. F
	$= 0.933$	A1	Accept correct to 2sf here
	Prob $= (0.9332)^4$	M1	Power of 4, from attempt at P(z)
	$= 0.758$	A1 5	Correct answer

(iii)	$P(t > 0.6\mu) = P\left(z > \dfrac{0.6\mu - \mu}{\mu/3}\right)$	M1	Standardising attempt with 1 or 2 variables
	$= P(z > -1.2)$	M1	
	$= 0.885$	A1 3	Eliminating μ or σ
			Correct final answer

Question 36

(i)	$^{12}C_8\ (0.65)^8(0.35)^4 + {}^{12}C_9\ (0.65)^9(0.35)^3 + {}^{12}C_{10}\ (0.65)^{10}(0.35)^2$	M1	Bin term with $^{12}C_r\, p^r(1-p)^{12-r}$ seen $r \neq 0$ any $p<1$
		M1	Summing 2 or 3 bin probs p = 0.65 or 0.35, n = 12
	$= 0.541$	A1 [3]	
(ii)	$P\left(\overline{R}R\overline{R}R\right) = 0.35 \times 0.35 \times 0.35 \times 0.65$	M1	Mult 4 probs either $(0.35)^3(0.65)$ or $(0.65)^3(0.35)$
	$= 0.0279$	A1 [2]	
(iii)	$P(7) = 0.2039$ (unsimplified)	B1	$^{12}C_7\,(0.65)^7(0.35)^5$
	Mean = 250×'0.2039' (= 50.9798) Var = 250×'0.2039' × '(1 − 0.2039)' (= 40.5851)	B1	Correct unsimplified np and npq using 'their 0.2039' but not 0.65 or 0.35
	$P(>54) = P\left(\dfrac{54.5 - 50.9798}{\sqrt{40.5851}}\right)$	M1	Standardising need sq rt – must be from working with 54
	$= P(z > 0.5526)$	M1	cc either 53.5 or 54.5
	$= 1 - \Phi(0.5526) = 1 - 0.7098$	M1	correct area < 0.5 i.e. $1 - \Phi$ - must be from working with 54
	$= 0.290$	A1 [6]	

Question 37

(i)	$z = 1.015$	**B1**	Accept z between ± 1.01 and 1.02
	$1.015 = \dfrac{70 - 69}{\sigma}$	**M1**	Standardising
	$\sigma = 0.985 \ (200/203)$	**A1** [3]	
(ii)	$58 + 9 = 67$	**M1**	$58 + 9$ seen or implied (or 69-58 or 69-9)
	$P(>67) = P\left(z > \dfrac{67-69}{0.9852}\right)$	**M1**	Standardising $\pm z$ no cc allow their sd (must be +ve)
			Alt. 1 $69-58 = 11$, $P(>9) = P\left(z > \dfrac{9-11}{0.9852}\right)$
			Alt.2 $69-9 = 60$, $P(>58) = P\left(z > \dfrac{58-60}{0.9852}\right)$
	$= P(z > -2.03)$ $= 0.9788$	**M1**	Correct prob area
	300×0.9788	**M1**	Multiply their prob (from use of tables) by 300
	$= 293.6$ so 293	**A1** [5]	– accept 293 or 294 from fully correct working

Question 38

(i)	$P(x > 10.2) = P\left(z > \dfrac{10.2 - 9.5}{1.3}\right)$	**M1**	Standardising allow cc, sq rt, sq
	$= P(z > 0.53846)$ $= 1 - 0.7046$	**M1**	$1 - \Phi$ final solution attempt
	$= 0.295$	**A1** [3]	
(ii)	$z = -1.282$	**B1**	$\pm$ rounding to 1.28 seen
	$-1.282 = \dfrac{t - 9.5}{1.3}$	**M1**	Standardising correctly can be $\pm z$ value here
	$t = 7.83$	**A1** [3]	Correct answer from $z = -1.282$ only
(iii)	$P(x < 8.8) = 0.2954$ by symmetry	**B1**	oe method, FT *their 0.2954 from (i)*
	Days $= 365 \times 0.2954$	**M1**	Mult a probability <1 by 365
	$= 107$ or 108	**A1** [3]	Correct answer (no decimals)

Question 39

(i)	0.72	**B1** [1]	
(ii)	$np = 180 \times 0.72$, $npq = 180 \times 0.72 \times 0.28$ $X \sim N(129.6, 36.288)$	**B1**✓	180×0.72, $180 \times 0.72 \times 0.28$ seen, their values or correct
	$P(x > 115) = P\left(z > \dfrac{115.5 - 129.6}{\sqrt{36.288}}\right)$	**M1**	Standardising ($\pm$) must have sq rt
		M1	cc either 115.5 or 114.5 seen
	$= P(z > -2.341)$	**M1**	Correct area, Φ from final answer attempt fully correct method
	$= 0.990$	**A1** [5]	

Question 40

(i)	$P(x < 3.0) = P\left(z < \dfrac{3.0 - 2.6}{0.25}\right)$	**M1** **M1**	Standardising no sq rt no cc Correct area i.e. prob > 0.5 legit
	$+ P(z < 1.6) = 0.945$	**A1** [3]	
(ii)	$X \sim B(500, 0.9452) \sim N(472.6, 25.898)$	**M1**	$500 \times '0.9452'$ and $500 \times '0.9452' \times ('1 - 0.9452')$ seen oe
	$P\left(z > \dfrac{479.5 - 472.6}{\sqrt{25.89848}}\right) = P(z > 1.3558)$	**M1** **M1** **M1**	Standardising must have sq rt. All M marks indep cc either 479.5 or 480.5 seen
	$= 1 - 0.9125 = 0.0875$	**A1** [5]	correct area i.e. < 0.5
(iii)	500×0.9452 and $500 \times (1 - 0.9452)$ are both > 5	**B1**✓ [1]	must see at least $500 \times 0.0548 > 5$oe ft their (i) accept $np > 5$, $nq > 5$ if both not $npq > 5$

Question 42

(i)	$P(2) = {}^7C_2(0.1)^2(0.9)^5$ $= 0.124$	M1 A1	[2]	Bin term ${}^7C_2p^2(1-p)^5$ $\quad 0 < p < 1$
(ii)	$(0.15)^1(0.1)^2(0.75)^2 \times 5!/2!2!$	M1		Mult probs for options, $(0.15)^a(0.1)^b(0.75)^c$ where a + b + c sum to 5
		M1		Mult by 5!/2!2! oe
	$= 0.0253$ or $81/3200$	A1	[3]	
(iii)	mean = 365×0.15 (= 54.75 or 219/4) Var = 365× 0.15×0.85 (= 46.5375 or 3723/80)	B1		Correct unsimplified mean **and** var, oe
	$P(x > 44) = P\left(z > \dfrac{44.5 - 54.75}{\sqrt{46.5375}}\right)$	M1 M1 M1		± Standardising need sq rt cc either 44.5 (or 43.5) Φ
	$= P(z > -1.5025)$ $= 0.933$	A1	[5]	Correct answer accept 0.934

Question 43

(i)	$P(\text{small}) = P\left(z < \dfrac{95-150}{50}\right)$	M1		± standardising using 95, no cc, no sq, no sq rt
	$= P(z < -1.1)$ $= 1 - 0.8643$ $= 0.136$	M1 A1	[3]	$1 - \Phi$ (in final answer)
(ii)	$z = 1.282$	B1		± rounding to 1.28
	$1.282 = \dfrac{x-150}{50}$	M1		Standardised eqn in their z allow cc
	$x = 214$ g	A1	[3]	
(iii)	P(small) = 0.1357, P(large) = 0.1357 symmetry P(medium) = 1 − 0.1357×2 = 0.7286 **AG**	B1	[1]	Correct answer legit obtained
(b)	Expected cost per banana = 0.1357×10 + 0.1357×25 + 0.7286×20 = 19.3215 cents	*M1		Attempt at multiplying each 'prob' by a price and summing
	Total cost of 100 bananas	DM1		Mult by 100
	= 1930 (cents) ($19.30)	A1	[3]	

(i)	$P(< 4.5) = P\left(z < \dfrac{4.5 - 4.2}{0.6}\right) = P(z < 0.5)$	M1		Standardising once no cc no sq no sq rt
	$= 0.6915$			
	$P(< 3.5) = P\left(z < \dfrac{3.5 - 4.2}{0.6}\right) = P(z < -1.167)$			
	$= 1 - 0.8784 = 0.1216$	M1		$\Phi_1 - (1 - \Phi_2)$ $[P_1 - P_2, 1 > P_1 > 0.5, 0.5 > P_2 > 0]$ oe
	$0.6915 - 0.1216 = 0.570$	A1	[3]	
(ii)	$z = 1.175$	B1		± 1.17 to 1.18 seen
	$1.175 = \dfrac{t - 4.2}{0.6}$	M1		Standardising no cc, allow sq, sq rt with z – value (not ± 0.8106, 0.5478, 0.4522, 0.1894, 0.175 etc.)
	$t = 4.91$	A1	[3]	Correct answer from $z = 1.175$ seen (4sf)
(iii)	$(0.88)^n < 0.003$	M1		Inequality or eqn in 0.88, power correctly placed using n or $(n \pm 1)$, 0.003 or $(1 - 0.003)$ oe
	$n > \lg(0.003)/\lg(0.88)$ $n > 45.4$	M1		Attempt to solve by logs or trial and error (may be implied by answer)
	$n = 46$	A1	[3]	Correct integer answer

Question 45

(i)	Bin $(7, 0.8)$	M1		$^7C_n\, p^n (1-p)^{7-n}$ seen
	$P(6, 7) = {}^7C_6 (0.8)^6 (0.2)^1 + (0.8)^7$	M1		Correct unsimplified expression for $P(6,7)$
	$= 0.577$	A1	[3]	
(ii)	mean $= 100 \times 0.2 = 20$ Var $= 100 \times 0.2 \times 0.8 = 16$	B1		Correct unsimplified mean and var
	$P(\text{at most } 30) = P\left(z < \dfrac{30.5 - 20}{\sqrt{16}}\right)$	M1 M1 M1		Standardising must have sq rt, their μ, variance cc either 29.5 or 30.5 Correct area Φ, from final process
	$= P(z < 2.625)$ $= 0.996$	A1	[5]	

Question 46

(i)	$P(< 1) = P\left(z < \dfrac{1 - 1.04}{0.017}\right) = P(z < -2.353)$	M1		Standardising no cc, no $\sqrt{\ }$ or sq
	$= 1 - 0.9907$	M1		$1 - \Phi$ (final process)
	$= 0.0093$	A1	[3]	
(ii)	expected number $1000 \div 1.04 = 961$ or 962	B1	[1]	Or anything in between
(iii)	$z = -1.765$	B1		± 1.76 to 1.77
	$-1.765 = \dfrac{1 - \mu}{0.017}$	M1		Standardising must have a z-value, allow $\sqrt{\ }$ or sq
	$= 1.03$	A1	[3]	
(iv)	expected number $= 1000 \div 1.03 = 971$ or 970	B1✓	[1]	Or anything in between, ft their (iii)

$z = 0.674$	**M1**		± 0.674 seen
$0.674 = \dfrac{k-20}{7}$	**M1**		Standardising no cc, no sq, no sq rt
$k = 24.7$	**A1**	[3]	

Question 48

(a)(i)	$0.674 = \dfrac{8.8-\mu}{\sigma} \implies 0.674\sigma = 8.8-\mu$	**B1**	± 0.674 seen
	$-0.935 = \dfrac{7.7-\mu}{\sigma} \implies -0.935\sigma = 7.7-\mu$	**B1**	± 0.935 seen (condone ± 0.934)
		M1	An eqn with a z-value, μ and σ allow sq rt, sq cc
		M1	sensible attempt to eliminate μ or σ by substitution or subtraction
	$\sigma = 0.684$ $\mu = 8.34$	**A1**	correct answers (from -0.935)
	Total:	**5**	
(a)(ii)	$P(<8.2) = P\left(z < \dfrac{8.2-7.9}{0.44}\right)$	**M1**	Standardising no cc no sq rt no sq
		M1	Correct area ie Φ, final solution
	$= P(z < 0.6818) = 0.7524$	**A1**	Correct prob rounding to 0.752
	$P(3) = {}^5C_3 (0.7524)^3 (0.2476)^2$	**M1**	Binomial ${}^5C_x$ powers summing to 5, any p, $\Sigma p = 1$
	$= 0.261$	**A1**	
	Total:	**5**	
(b)	$P(<1.5\mu) = P\left(z < \dfrac{1.5\mu - \mu}{\mu}\right) = P(z < 0.5)$	*M1	standardising with μ and σ (σ may be replaced by μ)
		DM1	just one variable
	$= 0.692$	**A1**	
	Total:	**3**	

Question 49

$np = 160 \times 0.1\ (16)$ $npq = 160 \times 0.1 \times 0.9\ (14.4)$	**B1**	Correct unsimplified np and npq
$P(>17) = P\left(z > \dfrac{17.5-16}{\sqrt{14.4}}\right) = P(z > 0.3953)$	**M1**	Standardising need $\surd$
	M1	16.5 or 17.5 seen in standardised eqn for continuity correction
$= 1 - 0.6536$	**M1**	Correct area from their mean $(1 - \Phi)$, final solution
$= 0.346$	**A1**	
Total:	**5**	

(a)	$P(x > 0) = P\left(z > \pm \dfrac{0 - \mu}{\sigma}\right)$ $= P\left(z > \dfrac{-\mu}{\mu / 1.5}\right)$ or $P\left(z > \dfrac{-1.5\sigma}{\sigma}\right)$	M1	±Standardising, in terms of μ and/or σ with $0 - \ldots$ in numerator, no continuity correction, no $\surd$
	$= P(z > -1.5)$	A1	Obtaining z value of ±1.5 by eliminating μ and σ, SOI
	$= 0.933$	A1	
	Total:	**3**	
(b)	$z = -1.151$	B1	$\pm z$ value rounding to 1.1 or 1.2
	$-1.151 = \dfrac{70 - 120}{s}$	M1	± Standardising (using 70) equated to a z-value, no cc, no squaring, no $\surd$
	$\sigma = 43.4$ or 43.5	A1	
	Totals:	**3**	

Question 51

$np = 270 \times 1/3 = 90$, $npq = 270 \times 1/3 \times 2/3 = 60$	B1	Correct unsimplified np and npq, SOI
$P(x > 100) = P\left(z > \dfrac{99.5 - 90}{\sqrt{60}}\right) = P(z > 1.2264)$	M1 M1	±Standardising using 100 need sq rt Continuity correction, 99.5 or 100.5 used
$= 1 - 0.8899$	M1	Correct area $1 - \Phi$ implied by final prob. < 0.5
$= 0.110$	A1	
Total:	**5**	

Question 52

(i)	$(z =) \dfrac{4.2 - 3.9}{\sigma}$	M1	Standardising, not square root of σ, not σ^2
	$z = 0.916$ or 0.915	B1	Accept $0.915 \leqslant \pm z \leqslant 0.916$ seen
	$\sigma = 0.328$	A1	Correct final answer (allow 20/61 or 75/229)
	Total:	**3**	
(ii)	$z = 4.4 - 3.9/$their 0.328 or $z = 3.4 - 3.9/$their 0.328 $= 1.5267 \qquad = -1.5267$	M1	Standardising attempt with 3.4 or 4.4 only, allow square root of σ, or σ^2
	$\Phi = 0.9364$	A1	$0.936 \leqslant \Phi \leqslant 0.937$ or $0.063 \leqslant \Phi \leqslant 0.064$ seen
	Prob $= 2\Phi - 1 = 2(0.9364) - 1$	M1	Correct area $2\Phi - 1$OE i.e. $\Phi = -(1 - \Phi)$, linked to final solution
	$= 0.873$	A1	Correct final answer from $0.9363 \leqslant \Phi \leqslant 0.9365$
	Total:	**4**	
(iii)	dividing (0.5) by a larger number gives a smaller z-value or more spread out as sd larger or use of diagrams	*B1	No calculations or calculated values present e.g. $(\sigma =)0.656$ seen Reference to spread or z value required
	Prob is less than that in (ii)	DB1	Dependent upon first B1
	Total:	**2**	

Question 53

(a)(i)	$z = 0.674$		B1	rounding to ± 0.674 or 0.675
	$0.674 = \dfrac{6.8 - \mu}{0.25\mu}$		M1	standardising, no cc, no sq rt, no sq, σ may still be present on RHS
			M1	subst and sensible solving for μ must collect terms, n z-value needed can be 0.75 or 0.7734 need a value for μ
	$\mu = 5.82$		A1	
		Total:	**4**	
ᵢ(a)(ii)	$P(X < 4.7) = P\left(z < \dfrac{4.7 - 5.819}{1.4548}\right)$		M1	$\pm$ standardising no cc, no sq rt, no sq unless penalised in (a)(i)
	$= \phi(-0.769) = 1 - 0.7791$		M1	correct side for their mean i.e. $1 - \phi$ (final solution)
	$= 0.221$		A1	
		Total:	**3**	
6(b)	$P(<15.75) = P\left(z < \dfrac{15.75 - 16}{0.2}\right) = 1 - P(z < 1.25) = 1 - 0.8944 = 0.1056$ and $P(>16.25) = 0.1056$ by sym		*M1	Standardising for 15.75 or 16.25 no cc no sq no sq rt unless penalised in (a)(i) or (a)(ii)
	$P(\text{usable}) = 1 - 0.2112 = 0.7888$		B1	$2\phi - 1$ OE for required prob, (final solution)
	Usable rods $= 1000 \times 0.7888 =$		DM1	Mult their prob by 1000 dep on recognisable attempt to standardise
	788 or 789		A1	
		Total:	**4**	

Question 54

⁽(i)	$P(t > 6) = P\left(z > \dfrac{6 - 5.3}{2.1}\right) = P(z > 0.333)$	M1	Standardising, no continuity correction, no sq, no sq rt
	$= 1 - 0.6304$	M1	Correct area $1 - \Phi$ (< 0.5), final solution
	$= 0.370$ or 0.369	A1	
		3	
(ii)	$z = 1.645$	B1	± 1.645
	$1.645 = \dfrac{x - 5.3}{2.1}$	M1	Standardising, no continuity correction, allow sq, sq rt. Must be equated to a z-value
	$x = 8.75$ or 8.755 or 8.7545	A1	
		3	
(iii)	$n = 10, p = 0.05$	M1	Bin term $^{10}C_x \, p^{\,x}(1-p)^{10-x}$
	$P(0, 1, 2) = (0.95)^{10} + {}^{10}C_1(0.05)(0.95)^9 + {}^{10}C_2(0.05)^2(0.95)^8$	M1	Correct unsimplified answer
	$= 0.988$ (0.9885 to 4 sf)	A1	
		3	
(iv)	$P(\text{misses bus}) = P(t < 0)$	*M1	Seeing t linked to zero
	$= P\left(z < \dfrac{0 - 5.3}{2.1}\right) = P(z < -2.524) = 1 - \Phi(2.524)$ $= 1 - 0.9942$	DM1	Standardising with $t = 0$, no continuity correction, no sq, no sq rt
	$= 0.0058$	A1	
		3	

Question 55

(i)	$P(>65) = P\left(z > \dfrac{65-61.4}{12.3}\right) = P(z > 0.2927)$	M1	Standardising no continuity correction, no square or square root, condone ± standardisation formula
		M1	Correct area (< 0.5)
	$= 1 - 0.6153 = 0.385$	A1	
		3	
(ii)	$P(<65) = 0.6153$ so $P(<k) = 0.25 + 0.6153 = 0.8653$	B1	
	$z = 1.105$	B1	$z = \pm 1.105$ seen or rounding to 1.1
	$1.105 = \dfrac{k-61.4}{12.3}$	M1	standardising allow ±, cc, sq rt, sq. Need to see use of tables backwards so must be a z-value, not $1 - z$ value.
	$k = 75.0$	A1	Answers which round to 75.0. Condone 75 if supported.
		4	
(iii)	$2.326 = \dfrac{97.2 - \mu}{\sigma}$	B1	± 2.326 seen (Use of critical value)
	$-0.44 = \dfrac{55.2 - \mu}{\sigma}$	B1	± 0.44 seen
		M1	An equation with a z-value, μ, σ and 97.2 or 55.2, allow $\sqrt{\sigma}$ or σ^2
		M1	Algebraic elimination μ or σ from *their* two simultaneous equations
	$\mu = 61.9$ $\sigma = 15.2$	A1	both correct answers
		5	

Question 56

5(i)	*EITHER:* $P(>2) = 1 - P(0, 1, 2)$	(M1	Binomial term of form $^{30}C_x p^x (1-p)^{30-x}$, $0 < p < 1$ any p
	$= 1 - (0.96)^{30} - {}^{30}C_1(0.04)(0.96)^{29} - {}^{30}C_2(0.04)^2(0.96)^{28}$ $(= 1 - 0.2938\ldots - 0.3673\ldots - 0.2219\ldots)$	A1	Correct unsimplified answer
	$= 1 - 0.883103 = 0.117 \ (0.116896)$	A1)	
	OR: $P(>2) = P(3,4,5,6,\ldots.30)$	(M1	Binomial term of form $^{30}C_x p^x (1-p)^{30-x}$, $0 < p < 1$ any p
	$= {}^{30}C_3(0.04)^3(0.96)^{27} + {}^{30}C_4(0.04)^4(0.96)^{26} + \ldots + (0.04)^{30}$	A1	Correct unsimplified answer
	$= 0.117$	A1)	
		3	
5(ii)	$np = 280 \times 0.1169 = 32.73$, $npq = 280 \times 0.1169 \times 0.8831 = 28.9$	M1 FT	Correct unsimplified np and npq, FT their p from **(i)**,
	$P(\geqslant 30) = P\left(z > \dfrac{29.5 - 32.73}{\sqrt{28.9}}\right) = P(z > -0.6008)$	M1	Substituting *their* μ and σ ($\sqrt{npq}$ only) into the Standardisation Formula
		M1	Using continuity correction of 29.5 or 30.5
		M1	Appropriate area Φ from standardisation formula $P(z > \ldots.)$ in final solution
	$= 0.726$	A1	
		5	

Question 57

(i)	$P(<570) = P\left(z < \dfrac{570-500}{91.5}\right) = P(z < 0.7650)$ $= 0.7779$	**M1**	Standardising for either 570 or 390, no cc, no sq, no $\sqrt{}$
	$P(<390) = P\left(z < \dfrac{390-500}{91.5}\right) = P(z < -1.202)$	**A1**	One correct z value
	$= 1 - 0.8853 = 0.1147$	**A1**	One correct Φ, final solution
	Large: 0.222 (0.2221) Small: 0.115 (0.1147)	**A1**	Correct small and large
	Medium: 0.663 (0.6632)	**A1FT**	Correct Medium rounding to 0.66 or ft 1 − (their small + their large)
		5	
(ii)	$1.645 = \left(\dfrac{x-500}{91.5}\right)$	**B1**	± 1.645 seen (critical value)
		M1	Standardising accept cc, sq, sq rt
	$x = 651$	**A1**	$650 \leqslant$ Ans $\leqslant 651$
		3	
(iii)	$P(x > 610) = 0.1147$ (symmetry)	**M1**	Attempt to find upper end prob $x > 610$ or $\Phi(x)$, ft their $P(< 390)$ from **(i)**
	$0.3 + 0.1147 = 0.4147 \Rightarrow \Phi(x) = 0.5853$	**M1**	Adding 0.3 to *their* $P(x > 610)$ or subt 0.5 from $\Phi(x)$ or 0.8853 − 0.3
	$z = 0.215$ or 0.216	**M1**	Finding $z = \Phi^{-1}(0.5853)$
	$0.215 = \dfrac{k-500}{91.5}$	**M1**	Standardising and solving, accept cc, sq, sq rt
	$k = 520$	**A1**	
		5	

Question 58

(i)	$P(4) + P(5) = {}^5C_4\left(\dfrac{1}{4}\right)^4\left(\dfrac{3}{4}\right)^1 + {}^5C_5\left(\dfrac{1}{4}\right)^5\left(\dfrac{3}{4}\right)^0$	**M1**	One binomial term, with $p < 1$, $n=5$, $p + q=1$
	$= 0.014648.. + 0.00097656..$	**M1**	Add 2 correct unsimplified binomial terms
	$= 0.0156$ or $\dfrac{1}{64}$	**A1**	
		3	
(ii)	$1 - P(0) > 0.995:\ 0.75^n < 0.005$	**M1**	Equation or inequality involving 0.75^n and 0.005 or 0.25^n and 0.995
	$n\log 0.75 < \log 0.005$ $n > 18.4:$	**M1**	Attempt to solve *their* exponential equation using logs, or trial and error May be implied by their answer
	$n = 19$	**A1**	
		3	
(iii)	$p = 0.25$, $n = 160$: mean = 160 x 0.25 (= 40) variance = 160 x 0.25 x 0.75 (=30)	**B1**	Correct unsimplified mean and variance
	$P(X < 50) = P\left(Z < \dfrac{49.5-40}{\sqrt{30}}\right)$	**M1**	Use standardisation formulae must include square root.
		M1	Use continuity correction ±0.5 (49.5 or 50.5)
	$= P(Z < 1.734) = 0.959$	**A1**	Correct final answer
		4	

Question 59

'(i)	$P(X > 410) = 225/6000 = 0.0375$ $P\left(Z > \dfrac{410 - 400}{\sigma}\right) = 0.0375 : 0.9625$	**M1**	Use $1 - 225/6000 = 0.9625$ to find z value
	z value $= \pm 1.78$	**A1**	z value: ± 1.78
	$\dfrac{10}{\sigma} = 1.78$	**M1**	$(410-400)/\sigma = $ *their z* (must be a z value)
	$\sigma = 5.62$	**A1**	
		4	
(ii)	We need $P(Z < -1.5)$ and $P(Z > 1.5)$	**M1**	Attempt at $P(Z < -1.5)$ or $P(Z > 1.5)$ $1 - \Phi(1.5)$ seen
	$\Phi(-1.5) + 1 - \Phi(1.5)$ $= 2 - 2\Phi(1.5)$	**M1**	Or equivalent expression with values
	$= 2 - 2 \times 0.9332 = 0.1336 \ (0.134)$	**A1**	Correct to 3sf
	Number expected $= 500 \times 0.1336$ $= 66.8$: 66 or 67 packets	**B1ft**	0.1336 used or FT their 4sf probability times 500, (not 0.9625 or 0.0375) rounded or truncated
		4	

Question 60

'(i)	$z_1 = \pm \dfrac{4.1 - 5.7}{0.8} = -2 \qquad z_2 = \pm \dfrac{5 - 5.7}{0.8} = -0.875$	**M1**	At least one standardising no cc no sq rt no sq using 5.7 and 0.8 and either 4.1 or 5
	$P(\text{Toffee Apple}) = P(d < 5.0) - P(d < 4.1)$ $= P(z < -0.875) - P(z < -2)$ $= \Phi(-0.875) - \Phi(-2)$ $= \Phi(2) - \Phi(0.875)$	**M1**	Correct area $\Phi - \Phi$ legitimately obtained – need 2 negative z-values or 2 positives – not one of each
	$= 0.9772 - 0.8092 = 0.168$ (or $0.1908 - 0.0228$)	**A1**	Correct final answer
	Total:	**3**	
'(ii)	$np = 250 \times 0.168 = 42, \qquad npq = 34.944$	**B1ft**	Correct unsimplified mean and var – ft their prob for **(i)** providing $(0 < p < 1)$ Implied by $\sigma = \sqrt{34.944} = 5.911$
	$P(< 50) = P\left(z < \dfrac{49.5 - 42}{\sqrt{34.944}}\right) = P(z < 1.2687)$	**M1**	$\pm$ Standardising using 50, their mean and sd; must have sq rt.
		M1	49.5 or 50.5 seen as a cc
	$= \Phi(1.2687)$	**M1**	Correct area $\Phi(> 0.5$ for $+ z$ and < 0.5 for $-z$)in their final answer
	$= 0.898$	**A1**	Correct final answer
	Total:	**5**	

Question 61

2(i)	$z = 0.674$	B1	z value ±0.674
	$0.674 = \dfrac{0--3}{\sigma}$	M1	$\pm$Standardising with 0 and equating to a z-value
	$\sigma = 4.45$	A1	Correct answer www ie not ignoring a minus sign
	Total:	3	
(ii)	P(0, 1)	M1	Any bin of form ${}^8C_x(0.75)^x(0.25)^{8-x}$ any x
	$= (0.75)^8 + {}^8C_1(0.25)(0.75)^7$	M1	Correct unsimplified answer, may be implied by numerical values
	$0.1001 + 0.2670 \quad = 0.367$	A1	Correct answer
	Method 2 $1 - P(8,7,6,5,4,3,2) = 1 - (0.25)^8 - {}^8C_1(0.75)(0.25)^7 - \ldots$	M1	Any bin of form ${}^8C_x(0.75)^x(0.25)^{8-x}$ any x
	$- {}^8C_2(0.75)^6(0.25)^2$	M1	Correct unsimplified answer
	$= 0.367$	A1	Correct answer
	Total:	3	

Question 62

(i)	**Method 1** $P(<11) = 1 - P(11, 12, 13)$	M1	Binomial expression of form ${}^{13}C_x\,(p)^x(1-p)^{13-x}$, $0 < x < 13$, $0 < p < 1$
	$= 1 - {}^{13}C_{11}(0.6)^{11}(0.4)^2 - {}^{13}C_{12}(0.6)^{12}(0.4) - (0.6)^{13}$	M1	Correct unsimplified answer
	$= 0.942$	A1	CAO
	Method 2 $P(<11) = P(0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10)$	M1	Binomial expression of form ${}^{13}C_x\,(p)^x(1-p)^{13-x}$ $0 < x < 13$, $0 < p < 1$
	$= (0.4)^{13} + {}^{13}C_1(0.4)^{12}(0.6) + \ldots + {}^{13}C_{10}(0.4)^3(0.6)^{10}$	M1	Correct unsimplified answer
	$= 0.942$	A1	CAO
		3	
(ii)	$\mu = 130 \times 0.35 = 45.5 \quad \text{var} = 130 \times 0.35 \times 0.65 = 29.575$	B1	Correct unsimplified mean and var (condone $\sigma^2 = 29.6$, $\sigma = 5.438$)
	$P(\geqslant 50) = P\left(z > \dfrac{49.5 - 45.5}{\sqrt{29.575}}\right) = P(z > 0.7355)$	M1	Standardising, using $\pm\left(\dfrac{x - their\,\text{mean}}{their\,\sigma}\right)$, x = value to standardise 49.5 or 50.5 seen in $\pm$ standardisation equation
	$= 1 - \Phi(0.7355)$	M1	Correct final area
	$= 1 - 0.7691$	M1	
	$= 0.231$	A1	Correct final answer
		5	
(iii)	$1 - (0.65)^n > 0.98$ or $0.02 > (0.65)^n$	M1	Eqn or inequality involving, 0.65^n and 0.02 **or** 0.35^n and 0.98
	$n > 9.08$	M1	Attempt to solve their eqn or inequality by logs **or** trial and error
	$n = 10$	A1	CAO
		3	

Question 63

(i)	$z = -1.282$	**B1**	± 1.282 seen
	$-1.282 = \dfrac{440 - \mu}{9}$	**M1**	$\pm$Standardisation equation with 440, 9 and μ, equated to a z-value, (not $1 - z$-value or probability e.g. 0.1841, 0.5398, 0.6202, 0.8159)
	$\mu = 452$	**A1**	Correct answer rounding to 452, not dependent on B1
		3	
(ii)	$P(z > 1.8) = 1 - 0.9641 = 0.0359$	**B1**	
	Number $= 0.0359 \times 150$ $= 5.385$	**M1**	$p \times 150$, $0 < p < 1$
	(Number of cartons =) 5	**A1FT**	Accept either 5 or 6, not indicated as an approximation, e.g. ~, about **FT** *their* $p \times 150$, answer as an integer
		3	

Question 64

(i)	$P(4, 5, 6) = {}^{15}C_4(0.22)^4(0.78)^{11} + {}^{15}C_5(0.22)^5(0.78)^{10} +$	**M1**	One binomial term ${}^{15}C_x p^x(1-p)^{15-x}$ $0 < p < 1$
	${}^{15}C_6(0.22)^6(0.78)^9$	**A1**	Correct unsimplified expression
	$= 0.398$	**A1**	Correct answer
		3	
(ii)	$\mu = 145 \times 0.22 = 31.9$ $\qquad \sigma^2 = 145 \times 0.22 \times 0.78 = 24.882$	**B1**	Correct unsimplified mean and variance
	$P(x > 26) = P\left(z > \dfrac{26.5 - 31.9}{\sqrt{24.882}}\right) = P(z > -1.08255)$	**M1**	Standardising must have sq rt
		M1	25.5 or 26.5 seen as a cc
	$= \Phi(1.08255)$	**M1**	Correct area Φ, must agree with their μ
	$= 0.861$	**A1**	Correct final answer accept 0.861, or 0.860 from 0.8604 not from 0.8599
		5	

Question 65

(a)	$z_1 = 2.4$	**B1**	± 2.4 seen accept 2.396
	$z_2 = -0.5$	**B1**	± 0.5 seen
	$2.4 = \dfrac{36800 - \mu}{\sigma}$	**M1**	Either standardisation eqn with z value, not 0.5082, 0.7565, 0.0082, 0.6915, 0.3085, 0.6209, 0.0032 or any other probability
	$-0.5 = \dfrac{31000 - \mu}{\sigma}$	**M1**	Sensible attempt to eliminate μ or σ by substitution or subtraction from their 2 equations (z-value not required), need at least 1 value stated
	$\sigma = 2000$ $\mu = 32000$	**A1**	Both correct answers
		5	
(b)	$P(X < 3\mu) = P\left(z < \dfrac{3\mu - \mu}{(4\mu/3)}\right)$ or $P = \left(z < \dfrac{(9\sigma/4) - (3\sigma/4)}{\sigma}\right)$	**M1**	Standardise, in terms of one variable, accept σ^2 or $\sqrt{\sigma}$
	$P\left(z < \dfrac{6}{4}\right)$	**M1**	$\dfrac{6}{4}$ or $\dfrac{6}{4\sigma}$ seen
	$= 0.933$	**A1**	Correct final answer
		3	

Question 66

(i)	$z_1 = \pm\dfrac{90-120}{24} = -\dfrac{5}{4}$, $z_2 = \pm\dfrac{140-120}{24} = \dfrac{5}{6}$	M1	At least one standardisation, no cc, no sq rt, no sq using 120 and 24 and either 90 or 140
	$= \Phi\left(\dfrac{20}{24}\right) - \Phi\left(-\dfrac{30}{24}\right)$	A1	–5/4 and 5/6 unsimplified
	$= \Phi(0.8333) - (1 - \Phi(1.25))$ $= 0.7975 - (1 - 0.8944)$ or $0.8944 - 0.2025 = 0.6919$	M1	Correct area $\Phi - \Phi$ legitimately obtained and evaluated from phi(their z_2) – phi (their z_1)
	$= 0.692$ AG	A1	Correct answer obtained from 0.7975 and 0.1056 oe to 4sf or 0.6919 seen www
		4	
(ii)	**Method 1**		
	Probability = P(2, 3, 4) $= 0.692^2(1 - 0.692)^2 \times {}^4C_2 + 0.692^3(1 - 0.692) \times {}^4C_3 + 0.692^4$	M1	Any binomial term of form $4C_x p^x (1-p)^{4-x}$, $x \neq 0$ or 4
		B1	One correct bin term with $n = 4$ and $p = 0.692$,
	$= 0.27256 + 0.40825 + 0.22931$	M1	Correct unsimplified expression using 0.692 or better
	$= 0.910$	A1	Correct answer
	Method 2:		
	$1 - P(0, 1) =$	M1	Any binomial term of form $4C_x p^x (1-p)^{4-x}$, $x \neq 0$ or 4
	$1 - 0.692^0(1 - 0.692)^4 \times {}^4C_0 - 0.692^1(1 - 0.692)^3 \times {}^4C_1$	B1	One correct bin term with $n = 4$ and $p = 0.692$
	$= 1 - 0.00899 - 0.0808757$	M1	Correct unsimplified expression using 0.692 or better
	$= 0.910$	A1	Correct answer
		4	

Question 67

(i)	P(X>1800) = 0.96, so P($Z > \dfrac{1800 - 2000}{\sigma}$) = 0.96	B1	± 1.75 seen
	$\Phi(\dfrac{200}{\sigma}) = 0.96$ $\dfrac{200}{\sigma} = 1.751$	M1	$z = \pm\dfrac{1800 - 2000}{\sigma}$, allow cc, allow sq rt, allow sq equated to a z-value
	$\sigma = 114$	A1	Correct final answer www
		3	
(ii)	Mean = $300 \times 0.2 = 60$ and variance = $300 \times 0.2 \times 0.8 = 48$	B1	Correct unsimplified mean and variance
	P($X < 70$) = P($Z > \dfrac{69.5 - 60}{\sqrt{48}}$)	M1	$Z = \pm\dfrac{x - their\,60}{\sqrt{their\,48}}$
	$= \Phi(1.371)$	M1	69.5 or 70.5 seen in an attempted standardisation expression as cc
	$= 0.915$	A1	Correct final answer
		4	
(iii)	$np = 60$, $nq = 240$: both > 5, (so normal approximation holds)	B1	Both parts evaluated are required
		1	

Question 68

'(a)(i)	$P(X < 4) = P\left(Z < \dfrac{4 - 3.24}{0.96}\right)$		M1	±Standardisation formula, no cc, no sq rt, no square
	$= P\left(Z < 0.7917\right) = 0.7858$		A1	$0.7855 < p \leqslant 0.7858$ or p = 0.786 Cao (implies M1A1 awarded), may be seen used in calculation
	their $0.7858 \times 365 = 286$ (or 287)		B1ft	*Their* probability × 365 provided 4sf probability **seen**. FT answer rounded or truncated to nearest integer. No approximation notation used.
			3	
(a)(ii)	$P(X < k) = P(Z < \dfrac{k - 3.24}{0.96}) = 0.8$		B1	(z=) ± 0.842 seen
	$\dfrac{k - 3.24}{0.96} = 0.842$		M1	$z = \pm \dfrac{k - 3.24}{0.96}$, allow cc, sq rt or square equated to a z-value (0.7881, 0.2119, 0.158, 0.8, 0.2 etc. are not acceptable)
	$k = 4.05$		A1	Correct final answer, www
			3	
'(a)(iii)	$P(-1.5 < Z < 1.5) =$		M1	$\Phi(z = 1.5)$ or $\Phi(z = -1.5)$ seen used or p = 0.9332 seen
	$\Phi(1.5) - \Phi(-1.5) = 2\Phi(1.5) - 1$ $= 2 \times 0.9332 - 1$ oe		M1	Correct final area expression using *their* probabilities
	$= 0.866$		A1	Correct final answer
			3	
'(b)	$P(Y > 0) = P\left(Z > \dfrac{0 - \mu}{\sigma}\right) \equiv P\left(Z > \dfrac{0 - \mu}{3\mu/4}\right)$ or $P\left(Z > \dfrac{0 - \left(\dfrac{4\sigma}{3}\right)}{\sigma}\right)$		M1	±Standardisation attempt in terms of one variable no sq rt or square, condone ±0.5 as cc
	$= P(Z > -4/3)$		A1	Correct unsimplified standardisation, no variables
	$= 0.909$		A1	Correct final answer
			3	

Question 69

'(a)	$P(X < 29.4) = P(Z < \dfrac{29.4 - 31.4}{\sqrt{3.6}})$ $= P(Z < -1.0541)$		M1	Standardise, no cc, must have sq rt.
	$= 1 - 0.8540$		M1	Obtain 1 − prob
	$= 0.146$		A1	Correct final answer
			3	
(b)	$P(X < 12) = \dfrac{42}{400} = 0.105$ and $P(X > 19) = \dfrac{58}{400} = 0.145$		M1	Eqn with μ, σ and a z-value. Allow cc, wrong sign, but not $\sqrt{\sigma}$ or σ^2
	$\dfrac{12 - \mu}{\sigma} = -1.253$		B1	Any form with z value rounding to ±1.25
	$\dfrac{19 - \mu}{\sigma} = 1.058$		B1	Any form with z value rounding to ±1.06
	$12 - \mu = -1.253\sigma$ $19 - \mu = 1.058\sigma$ $7 = 2.307\sigma$ or $36.455 + 2.307\mu = 0$ oe		M1	Solve 2 equations in μ, σ eliminating to 1 unknown
	$\mu = 15.8, \sigma = 3.03$		A1	Correct answers
			5	

Question 70

(i)	$1 - (P(7) + P(8) + P(9))$ $= 1 - ({}^9C_7\ 0.8^7 \times 0.2^2\ \ + {}^9C_8\ 0.8^8 \times 0.2^1 + {}^9C_9\ 0.8^9 \times 0.2^0)$	M1	Any binomial term of form ${}^9C_x p^x (1-p)^{9-x}$, $x \neq 0$
		M1	Correct unsimplified expression
	$= 1 - (0.3019899 + 0.3019899 + 0.1342177)$ $= 0.262$	A1	Correct answer
		3	
(ii)	Mean = $200 \times 0.8 = 160$: var = $200 \times 0.8 \times 0.2 = 32$	B1	Both unsimplified
	$P(X > 166) = P(Z > \dfrac{166.5 - 160}{\sqrt{32}})$	M1	Standardise, $z = \pm \dfrac{x - their\,160}{\sqrt{their\,32}}$ with square root
		M1	166.5 or 165.5 seen in attempted standardisation expression
	$= P(Z > 1.149) = 1 - 0.8747$	M1	$1 - a$ Φ-value, correct area expression, linked to final answer
	$= 0.125$	A1	Correct final answer
		5	
(iii)	$np = 160$, $nq = 40$: both > 5 (so normal approx. holds)	B1	Both parts required
		1	

Question 71

(i)	$P(X < 132) = P\left(Z < \dfrac{132 - 140}{12} \right) = P(Z < -0.6667)$	M1	Using $\pm$ standardisation formula, no continuity correction, not σ^2 or $\sqrt{\sigma}$
	$= 1 - 0.7477$	M1	Appropriate area Φ from standardisation formula $P(z < \dots.)$ in final solution
	$= 0.252$ awrt	A1	Condone linear interpolation = 0.25243
		3	
(ii)	P(time>k) = 0.675, $z = -0.454$	B1	± 0.454 seen
	$\dfrac{k - 140}{12} = -0.454$	M1	An equation using the standardisation formula with a z-value (not $1-z$), condone σ^2 or $\sqrt{\sigma}$
	$k = 135, 134.6, 134.55$	A1	B0M1A1 max from -0.45
		3	

Question 72

(i)	$P(79 < X < 91) = P\left(\dfrac{79 - 85}{6.8} < Z < \dfrac{91 - 85}{6.8} \right)$ $= P(-0.8824 < Z < 0.8824)$	M1	Using $\pm$ standardisation formula for either 79 or 91, no continuity correction
	$= \Phi(0.8824) - \Phi(-0.8824)$ $= 0.8111 - (1 - 0.8111)$	M1	Correct area ($\Phi - \Phi$) with one +ve and one –ve z-value or $2\Phi - 1$ or $2(\Phi - 0.5)$
	$= 0.622$	A1	Correct answer
		3	
(ii)	$z = -1.751$	B1	± 1.751 seen
	$-1.751 = \dfrac{t - 85}{6.8}$	M1	An equation using $\pm$ standardisation formula with a z-value, condone σ^2 or $\sqrt{\sigma}$
	$t = 73.1$	A1	Correct answer
		3	

Question 73

(i)			
$P(<700) = P\left(z < \dfrac{700-830}{120}\right) = P(z < -1.083)$		M1	Using $\pm$ standardisation formula, no continuity correction, not σ^2 or $\sqrt{\sigma}$
$= 1 - 0.8606$		M1	Appropriate area Φ from standardisation formula $P(z<\ldots)$ in final probability solution, (<0.5 if z is $-$ve, >0.5 if z is $+$ve)
$= 0.1394$		A1	Correct final probability rounding to 0.139
Expected number of female adults $= 430 \times$ *their* 0.1394 $= 59.9$ So 59 or 60		B1	FT *their* 3 or 4 SF probability, rounded or truncated to integer
		4	

(ii)			
$P(\text{giraffe} < 830+w) = 95\%$ so $z = 1.645$		B1	± 1.645 seen (critical value)
$\dfrac{(830+w)-830}{120} = \dfrac{w}{120} = 1.645$		M1	An equation using the standardisation formula with a z-value (not $1-z$), condone σ^2 or $\sqrt{\sigma}$ not 0.8519, 0.8289
$w = 197$		A1	Correct answer
		3	

(iii)			
$P(\text{male} > 950) = 0.834$, so $z = -0.97$		B1	± 0.97 seen
$\dfrac{950-1190}{\sigma} = -0.97$		M1	Using $\pm$ standardisation formula, condone continuity correction, σ^2 or $\sqrt{\sigma}$, condone equating with non z-value not 0.834, 0.166
$\sigma = 247$		A1	Condone $-\sigma = -247$. www.
		3	

Question 74

(i)			
$P(h < 148) = 0.67$		B1	$z = \pm 0.44$ seen
$\dfrac{h-148}{8} = 0.44$		M1	z-value $= \pm \dfrac{(h-148)}{8}$
$151.52 \approx 152$		A1	CAO
		3	

(ii)			
$P(144 < X < 152) = P\left(\dfrac{144-148}{8} < Z < \dfrac{152-148}{8}\right)$		M1	Using $\pm$ standardisation formula for either 144 or 152, $\mu = 148$, $\sigma = 8$ and no continuity correction, allow σ^2 or $\sqrt{\sigma}$
$= P\left(-\dfrac{1}{2} < Z < \dfrac{1}{2}\right) = 0.6915 - (1 - 0.6915) = 2 \times 0.6915 - 1$		M1	Correct final area legitimately obtained from phi(*their* z_2) $-$ phi(*their* z_1)
$= 0.383$		A1	Final probability answer
$0.383 \times 120 = 45.96$ Accept 45 or 46 only		B1FT	*Their* prob (to 3 or 4 sf) $\times$ 120, rounded to a whole number or truncated
		4	

Question 75

(i)(a)	$P(0, 1, 2) = {}^6C_0\, 0.3^0\, 0.7^6 + {}^6C_1\, 0.3^1\, 0.7^5 + {}^6C_2\, 0.3^2\, 0.7^4$	**M1**	Binomial term of form ${}^6C_x p^x (1-p)^{6-x}$ $0 < p < 1$ any p, $x \neq 6, 0$
	$0.1176\ldots + 0.3025\ldots + 0.3241\ldots$	**A1**	Correct unsimplified answer
	0.744	**A1**	Correct final answer
		3	
(i)(b)	P(support neither choir) $= 1 - (0.3 + 0.45) = 0.25$	**M1**	0.25^n seen alone, $1 < n \leqslant 6$
	P(6 support neither choir) $= 0.25^6$ $= 0.000244$ or $\dfrac{1}{4096}$	**A1**	Correct final answer
		2	
7(ii)	Mean $= 240 \times 0.25 = 60$ Variance $= 240 \times 0.25 \times 0.75 = 45$	**B1FT**	Correct unsimplified $240p$ and $240pq$ where p =*their* P(support neither choir) or 0.25
	$P(X < 50) = P\left(Z < \dfrac{49.5 - 60}{\sqrt{45}}\right) = P(Z < -1.565)$	**M1**	Substituting *their* μ and σ (condone σ^2) into the $\pm$Standardisation Formula with a numerical value for '49.5'.
		M1	Using continuity correction 49.5 or 50.5 within a standardisation expression
	$1 - 0.9412$	**M1**	Appropriate area Φ from standardisation formula P($z < \ldots$) in final solution, (< 0.5 if z is –ve, > 0.5 if z is +ve)
	0.0588	**A1**	Correct final answer
		5	

Question 76

(i)	$P(X < 45) = P\left(Z < \dfrac{45 - 40}{8}\right)$ $= P(Z < 0.625)$	**M1**	$\pm$ Standardise, no continuity correction, σ^2 or $\sqrt{\sigma}$, formula must be seen
	$0.734(0)$	**A1**	CAO
		2	
(ii)	$1 - 2(1 - (i)) = 2(i) - 1 = 2((i) - 0.5)$	**M1**	Use result of **part (i)** or recalculated to find area OE
	0.468	**A1ft**	$0 < $ FT from **(i)** < 1 or correct.
		2	
(iii)	$P(X < 10) = 48/500 = 0.096$ $z = -1.305$	**B1**	$z = \pm 1.305$
	$P(X > 24) = 76/500 = 0.152$ $z = 1.028$	**B1**	$z = \pm 1.028$
	$10 - \mu = -1.305\sigma$ $24 - \mu = 1.028\sigma$	**M1**	Form 1 equation using 10 or 24 with μ, σ, z–value. Allow continuity correction, not $\sigma^2, \sqrt{\sigma}$
	$14 = 2.333\sigma$	**M1**	OE Solve two equations in σ and μ to form equation in one variable
	$\sigma = 6.[00], \quad \mu = 17.8[3]$	**A1**	CAO, WWW
		5	

Question 77

(i)	$P(8, 9, 10) = {}^{10}C_8\, 0.66^8\, 0.34^2 + {}^{10}C_9\, 0.66^9\, 0.34^1 + 0.66^{10}$	**M1**	Correct binomial term, ${}^{10}C_a\, 0.66^a(1-0.66)^b$ $a+b = 10,\ 0 < a,b < 10$
		A1	Correct unsimplified expression
	0.284	**B1**	CAO
		3	

(ii)	$np = 0.66 \times 150 = 99$ $npq = 0.66 \times (1-0.66) \times 150 = 33.66$	**B1**	Accept evaluated or unsimplified μ, σ^2 numerical expressions, condone $\sigma = \sqrt{33.66} = 5.8017$ or 5.802 CAO
	$P(X > 84) = P\left(Z > \dfrac{84.5 - 99}{\sqrt{33.66}} \right)$	**M1**	$\pm$ Standardise, $\dfrac{x - their\,99}{\sqrt{their\,33.66}}$, condone σ^2, x a value
		M1	84.5 or 83.5 used in *their* standardisation formula
	$(= P(Z > -2.499))$	**M1**	Correct final area
	0.994	**A1**	Final answer (accept 0.9938) SC if no standardisation formula seen, B2 P($Z > -2.499$) = 0.994
		5	

Question 78

(i)	$P(46 < X < 53) = P\left(\dfrac{46 - 49.2}{2.8} < Z < \dfrac{53 - 49.2}{2.8} \right)$	**M1**	Using $\pm$ standardisation formula for either 46 or 53, no continuity correction, σ^2 or $\sqrt{\sigma}$
	$P(-1.143 < Z < 1.357)$	**A1**	Both standardisations correct unsimplified
	$\Phi(1.357) + \Phi(1.143) - 1$ $= 0.9126 + 0.8735 - 1$	**M1**	Correct final area
	0.786	**A1**	Final answer
		4	

(ii)	$\dfrac{t - 49.2}{2.8} = -1.406$	**B1**	± 1.406 seen
		M1	An equation using $\pm$ standardisation formula with a z-value, condone σ^2 or $\sqrt{\sigma}$
	45.3	**A1**	
		3	
(iii)	$P(X < 46) = 0.1265$	**M1**	Calculated or ft from (i)
	$P(2PB < 46) = 3(1 - 0.1265)\,0.1265^2$	**M1**	$3(1-p)p^2,\ 0 < p < 1$
	0.0419	**A1**	
		3	

Question 79

3(a)	$P(X > 87) = P\left(Z > \dfrac{87-82}{\sigma}\right) = 0.22$	**M1**	Using ± standardisation formula, not σ^2, not $\sqrt{\sigma}$, no continuity correction
	$P\left(Z < \dfrac{5}{\sigma}\right) = 0.78$ $\left(\dfrac{5}{\sigma} =\right) 0.772$	**B1**	AWRT ±0.772 seen B0 for ±0.228
	$\sigma = 6.48$	**A1**	
		3	
3(b)	$P\left(-\dfrac{4}{\sigma} < Z < \dfrac{4}{\sigma}\right) = P(-0.6176 < Z < 0.6176)$	**M1**	Using ±4 used within a standardisation formula (SOI), allow σ^2, $\sqrt{\sigma}$ and continuity correction
		M1	Standardisation formula applied to **both** *their* ±4
	$\Phi = 0.7317$ Prob $= 2\Phi - 1 = 2(0.7317) - 1$	**M1**	Correct area $2\Phi - 1$ oe linked to final solution
	$= 0.463$	**A1**	
		4	

Question 80

(a)	$1 - P(6, 7, 8)$ $= 1 - ({}^8C_6\, 0.7^6 0.3^2 + {}^8C_7\, 0.7^7 0.3^1 + 0.7^8)$	**M1**	One term ${}^8C_x\, p^x (1-p)^{8-x}$, $0 < p < 1$, $x \neq 0$
	$= 1 - 0.55177$	**A1**	Correct unsimplified expression, or better
	$= 0.448$	**A1**	
	Alternative method for question 5(a)		
	$P(0, 1, 2, 3, 4, 5)$ $= 0.3^8 + {}^8C_1\, 0.7^1 0.3^7 + {}^8C_2\, 0.7^2 0.3^6 + {}^8C_3\, 0.7^3 0.3^5 +$ ${}^8C_4 0.7^4 0.3^4 + {}^8C_5\, 0.7^5 0.3^3$	**M1**	One term ${}^8C_x\, p^x (1-p)^{8-x}$, $0 < p < 1$, $x \neq 0$
		A1	Correct unsimplified expression, or better
	$= 0.448$	**A1**	
		3	
(b)	Mean $= 120 \times 0.7 = 84$ Var $= 120 \times 0.7 \times 0.3 = 25.2$	**B1**	Correct mean and variance, allow unsimplified
	$P(\text{more than } 75) = P\left(z > \dfrac{75.5 - 84}{\sqrt{25.2}}\right)$	**M1**	Substituting *their* μ and σ into the ±standardising formula (any number), not σ^2, not $\sqrt{\sigma}$
		M1	Using continuity correction 75.5 or 74.5
	$P(z > -1.693)$	**M1**	Appropriate area Φ, from final process, must be a probability
	$= 0.955$	**A1**	Allow $0.9545 < p \leqslant 0.955$
		5	

Question 81

(a)	$P(X < 21) = P\left(z < \dfrac{21-15.8}{4.2}\right) = \Phi(1.238)$	**M1**
	0.892	**A1**
		2
(b)	$z = \pm 0.674$	**B1**
	$\dfrac{k-15.8}{4.2} = 0.674$	**M1**
	18.6	**A1**
		3

Question 82

(a)	$\dfrac{1}{\frac{1}{4}} = 4$	**B1**
		1
(b)	$\dfrac{9}{64} \quad (= 0.141)$	**B1**
		1
(c)	$P(X < 6) = 1 - \left(\dfrac{3}{4}\right)^5$ (**FT** *their* probability/mean from part **(a)**)	**M1**
	0.763	**A1**
		2
(d)	Mean $= 80 \times 0.25 = 20$ Var $= 80 \times 0.25 \times 0.75 = 15$	**M1**
	$P(\text{more than } 25) = P\left(z > \dfrac{25.5-20}{\sqrt{15}}\right)$	**M1**
	$P(z > 1.42)$	**M1**
	$1 - 0.9222$	**M1**
	0.0778	**A1**
		5

Question 83

(a)	$P(X < 25) = P\left(z < \dfrac{25 - 40}{12}\right) = P(z < -1.25)\,P(X < 25) = P(z <)$	M1
	$1 - 0.8944$	M1
	0.106	A1
		3
(b)	0.8944 divided by 3 (**M1** for 1 - *their* **(a)** divided by 3)	M1
	0.298 **AG**	A1
		2
(c)	0.2981 gives $z = 0.53$	B1
	$\dfrac{h - 40}{12} = 0.53$	M1
	$h = 46.4$	A1
		3

Question 84

(a)	$1 - P(10, 11, 12)$ $= 1 - [\,^{12}C_{10}\,0.72^{10}0.28^2 + \,^{12}C_{11}\,0.72^{11}0.28^1 + 0.72^{12}]$	M1
	$1 - (0.19372 + 0.09057 + 0.01941)$	A1
	0.696	A1
		3
(b)	$0.28^3 \times 0.72 = 0.0158$	B1
		1
(c)	Mean $= 100 \times 0.72 = 72$ Var $= 100 \times 0.72 \times 0.28 = 20.16$	M1
	$P(\text{less than } 64) = P\left(z < \dfrac{63.5 - 72}{\sqrt{20.16}}\right)$ (**M1** for substituting *their* μ *and* σ into $\pm$standardisation formula with a numerical value for '*63.5*')	M1
	Using either 63.5 or 64.5 within a $\pm$standardisation formula	M1
	Appropriate area Φ, from standardisation formula $P(z<...)$ in final solution $= P(z < -1.893)$	M1
	0.0292	A1
		5

Question 85

(a)	$P(56 < X < 66) = P\left(\dfrac{56-62}{5} < z < \dfrac{66-62}{5}\right)$ $= P(-1.2 < z < 0.8)$	**M1**	Using ± standardisation formula at least once, no $\sqrt{\sigma}$ or σ^2, allow continuity correction
	$\Phi(0.8) + \Phi(1.2) - 1$ $= 0.7881 + 0.8849 - 1$	**M1**	Appropriate area Φ, from standardisation formula in final solution
	0.673	**A1**	
		3	
(b)	$z = 1.127$	**B1**	$\pm(1.126 - 1.127)$ seen, 4 sf or more
	$\dfrac{60t - 62}{5} = 1.127$ $60t = 5.635 + 62 = 67.635$	**M1**	z-value $= \pm\dfrac{(60t - 62)}{5}$ condone z-value $= \pm\dfrac{(t-62)}{5}$ no continuity correction, condone $\sqrt{\sigma}$ or σ^2
	$t = 1.13$	**A1**	CAO
		3	

Question 86

(a)	$P(X > 11.3) = P\left(z > \dfrac{11.3 - 10.1}{1.3}\right) = P(z > 0.9231)$	**M1**	Using ± standardisation formula, no $\sqrt{\sigma}$ or σ^2, continuity correction
	$1 - 0.822$	**M1**	Appropriate area Φ, from standardisation formula $P(z > \ldots)$ in final solution
	0.178	**A1**	$0.1779\ldots$
		3	
(b)	$z = -0.674$	**B1**	± 0.674 seen (critical value)
	$\dfrac{t - 10.1}{1.3} = -0.674$	**M1**	An equation using ±standardisation formula with a z-value, condone $\sqrt{\sigma}$ or σ^2, continuity correction.
	$t = 9.22$	**A1**	AWRT. Only dependent on M1
		3	
(c)	$P(8.9 < X < 11.3) = 1 - 2 \times their\ \mathbf{3(a)}$ $\equiv 2(1 - their\ \mathbf{3(a)}) - 1$ $\equiv 2(0.5 - their\ \mathbf{3(a)})$ $= 0.644$	**B1 FT**	FT from *their* **3(a)** < 0.5 or correct, accept unevaluated probability OE
	Number of days $= 90 \times 0.644$ $= 57.96$	**M1**	$90 \times their\ p$ seen, $0 < p < 1$
	So 57 (days)	**A1 FT**	Accept 57 or 58, not 57·0 or 58·0, no approximation/rounding stated FT must be an integer value

Question 87

(a)	$P(X > 4.2) = P\left(z > \dfrac{4.2 - 3.5}{0.9}\right)$ $= P(z > 0.7778)$	**M1**	Using ± standardisation formula, no $\sqrt{\sigma}$ or σ^2, continuity correction
	$1 - 0.7818$	**M1**	Appropriate area Φ, from standardisation formula $P(z>\ldots)$ in final solution
	0.218	**A1**	
		3	
(b)	$z = -1.282$	**B1**	±1.282 seen (critical value)
	$\dfrac{t - 3.5}{0.9} = -1.282$	**M1**	An equation using ±standardisation formula with a z-value, condone $\sqrt{\sigma}$, σ^2 and continuity correction
	$t = 2.35$	**A1**	AWRT, only dependent on M mark
		3	
(c)	$P(2.8 < X < 4.2) = 1 - 2 \times$ *their* **5(a)** $\equiv 2(1 - \text{their } \mathbf{5(a)}) - 1$ $\equiv 2(0.5 - \text{their } \mathbf{5(a)})$ $= 0.5636$	**B1 FT**	FT from *their* **5(a)** < 0.5 or correct Accept unevaluated probability OE Accept 0.564
	Number of days $= 365 \times 0.5636 = 205.7$	**M1**	$365 \times$ *their p*
	So, 205 (days)	**A1 FT**	Accept 205 or 206, not 205·0 or 206·0 no approximation/ rounding stated FT must be an integer value

Question 88

(a)	$P\left(\left(\dfrac{85 - 96}{18}\right) < z < \left(\dfrac{100 - 96}{18}\right)\right)$	**M1**	Use of ±standardisation formula once with appropriate values substituted, no continuity correction, not σ^2 or $\sqrt{\sigma}$.
	$P(-0.6111 < z < 0.2222)$ $= \Phi(0.2222) + \Phi(0.6111) - 1$ $= 0.5879 + 0.7294 - 1$	**M1**	Appropriate area Φ, from final process, must be probability. Use of $(1 - z)$ implies M0.
	0.317	**A1**	Final answer which rounds to 0·317.
		3	
(b)	$z = \pm 1.175$	**B1**	$1.17 \leqslant z \leqslant 1.18$ or $-1.18 \leqslant z \leqslant -1.17$
	$-1.175 = \dfrac{t - 96}{18}$	**M1**	An equation using ±standardisation formula with a z-value, condone σ^2, $\sqrt{\sigma}$ or continuity correction. E.g. equating to 0·88, 0·12, 0·8106, 0·1894, 0·5478, 0·4522, ±0·175 or ±2·175 implies M0.
	74.85 or 74.9	**A1**	$74.85 \leqslant t \leqslant 74.9$
		3	

Question 89

(a)	$z_1 = \dfrac{4-\mu}{\delta} = -1.378$	**B1**	$1.378 \leqslant z_1 \leqslant 1.379$ or $-1.379 \leqslant z_1 \leqslant -1.378$
	$z_2 = \dfrac{10-\mu}{\sigma} = 0.842$	**B1**	$0.841 \leqslant z_2 \leqslant 0.842$ or $-0.842 \leqslant z_2 \leqslant -0.841$
	Solve to find at least one unknown: $\dfrac{4-\mu}{\sigma} = -1.378$	**M1**	Use of $\pm$standardisation formula once with μ, σ, a z-value and 4 or 10, allow continuity correction, not σ^2 or $\sqrt{\sigma}$
	$\dfrac{10-\mu}{\sigma} = 0.842$	**M1**	Use either the elimination method or the substitution method to solve two equations in μ and σ.
	$\sigma = 2.70 \quad \mu = 7.72$	**A1**	$2.70 \leqslant \sigma \leqslant 2.71 \quad 7.72 \leqslant \mu \leqslant 7.73$
		5	
(b)	$\Phi(2) - \Phi(-2) = 2\Phi(2) - 1$	**M1**	Identifying 2 and −2 as the appropriate z-values
	$2 \times their\ 0.9772 - 1$	**B1**	Calculating the appropriate area from stated phis of z-values which must be $\pm$ the same number
	0.9544 or 0.9545	**A1**	Accept AWRT 0.954
	$0.9544 \times 800 = 763.52$ 763 or 764	**B1 FT**	FT *their* 4SF (or better) probability, final answer must be positive integer
		4	

Question 90

$\left[P(X > 1.1) = \dfrac{72}{2000} (= 0.036) \right]$ $z = \pm 1.798$		B1	$1.79 < z \leqslant 1.80,\ -1.80 \leqslant z < -1.79$ seen
$\dfrac{1.1 - 1.04}{\sigma} = 1.798$		B1	1.1 and 1.04 substituted in $\pm$standardisation formula, allow continuity correction, not σ^2 or $\sqrt{\sigma}$
$\left[\dfrac{0.06}{\sigma} = 1.798 \right]$		M1	Equate *their* $\pm$standardisation formula to a z-value and to solve for the appropriate area leading to final answer (expect $\sigma < 0.5$). $\left(\text{Accept} \pm \dfrac{0.06}{\sigma} = z - \text{value} \right)$
$\sigma = 0.0334$		A1	$0.03335 \leqslant \sigma \leqslant 0.0334$. At least 3 3s.f.
		4	

Question 91

$\left[P\left(\left(\dfrac{25.2 - (25.5 + 0.50)}{0.4} \right) < z < \left(\dfrac{25.2 - (25.2 - 0.50)}{0.4} \right) \right) \right]$ $= P\left(-\dfrac{0.5}{0.4} < z < \dfrac{0.5}{0.4} \right)$		M1	Use of $\pm$ Standardisation formula once; no continuity correction, σ^2, $\sqrt{\sigma}$
$[= 2\Phi(1.25) - 1]$		A1	For AWRT 0.8944 SOI
$= 2 \times 0.8944 - 1$		M1	Appropriate area $2\Phi - 1$ OE, from final process, must be probability
0.7888		A1	Accept AWRT 0.789
Number of rods $= 0.7888 \times 500$ $= 394$ or 395		B1FT	Correct or FT *their* 4SF (or better) probability, final answer must be positive integer, not 394.0 or 395.0, no approximation/rounding stated, only 1 answer
		5	

Question 92

(a)	$P(X > 43.2) = P\left(Z > \dfrac{43.2 - 41.2}{3.6}\right) = P(Z > 0.5556)$	**M1**	Use of ±Standardisation formula once, allow continuity correction, not σ^2, $\sqrt{\sigma}$.
	$1 - \Phi(0.5556) = 1 - 0.7108$	**M1**	Appropriate area Φ, from final process, must be probability.
	0.289	**A1**	AWRT
		3	
(b)	Probability = 1 − *their* **(a)** = 1 − 0.2892 = 0.7108	**B1FT**	1 − *their* **(a)** or correct.
	$0.7108 \times 365 = 259.4$ 259, 260	**B1FT**	FT *their* 4SF (or better) probability, final answer must be positive integer.
		2	
(c)	$z = \pm 1.645$	**B1**	CAO, critical z value.
	$\dfrac{t - 41.2}{3.6} = -1.645$	**M1**	Use of ±standardisation formula with μ, σ equated to a z-value, no continuity correction, allow σ^2, $\sqrt{\sigma}$.
	$t = 35.3$	**A1**	
		3	

Question 93

(a)	$\left[P(X > 28.6) =\right] P\left(Z > \dfrac{28.6 - 32.2}{9.6}\right)$ $[= P(Z > -0.375)]$	**M1**	28.6, 32.2 and 9.6 substituted appropriately in ± Standardisation formula once, allow continuity correction of ± 0.05, no σ^2, $\sqrt{\sigma}$.
	$[\Phi(their\ 0.375) =]\ their\ 0.6462$	**M1**	Appropriate numerical area, from final process, must be probability, expect > 0.5.
	0.646	**A1**	AWRT
		3	
(b)	$z = \pm 0.842$	**B1**	$0.841 < z \leqslant 0.842$ or $-0.842 \leqslant z < -0.841$ seen.
	$\dfrac{t - 32.2}{9.6} = 0.842$	**M1**	Substituting 32.2 and 9.6 into ± standardisation formula, no continuity correction, allow σ^2, $\sqrt{\sigma}$, must be equated to a z-value.
	$t = 40.3$	**A1**	$40.28 \leqslant t \leqslant 40.3$ WWW
		3	
(c)	$P\left(-\dfrac{15}{9.6} < Z < \dfrac{15}{9.6}\right)$ $P(-1.5625 < Z < 1.5625)$	**M1**	Identifying at least one of $\dfrac{15}{9.6}$ and $-\dfrac{15}{9.6}$ as the appropriate z-values or substituting *their* (32.2 ± 15) into ± Standardisation formula once, no continuity correction, σ^2 nor $\sqrt{\sigma}$. Condone ± 1.563 for **M1**.
		A1	$p = 0.941$ AWRT SOI
	$\left[2\ \Phi\left(\dfrac{15}{9.6}\right) - 1\right]$ $= 2 \times 0.9409 - 1$	**M1**	Appropriate area $2\Phi - 1$ oe, (eg $1 - 2 \times 0.0591$, $2 \times (0.9409 - 0.5)$ or $0.9409 - 0.0591$), from final process, must be probability > 0.5.
	0.882	**A1**	
		4	

Question 94

(a)(i)	$P(X > 142) = P\left(Z > \dfrac{142-125}{24}\right)$	**M1**	Substitution of correct values into the ±Standardisation formula, allow continuity correction, not σ^2, $\sqrt{\sigma}$.
	$[= P(Z > 0.7083) =]1 - 0.7604$	**M1**	Appropriate numerical area Φ, from final process, must be probability, expect $p < 0.5$.
	0.2396	**A1**	$0.239 \leqslant p \leqslant 0.240$ to at least 3sf.
	Their 0.2396×365 $[= 87.454]$	**M1**	**FT** *their* 4sf (or better) probability.
	87 or 88	**A1 FT**	Final answer must be positive integer, no indication of approximation/rounding, only dependent on previous **M** mark. **SC B1 FT** for *their* 3sf probability $\times$ 365 = integer value, condone 0.24 used.
		5	
(a)(ii)	$P(0, 1) = 0.7604^{10} + {}^{10}C_1 \times 0.2396^1 \times 0.7604^9$ $[= 0.064628 + 0.20364]$	**M1**	One term: ${}^{10}C_x\, p^x (1-p)^{10-x}$ for $0 < x < 10$, any p.
		A1 FT	Correct unsimplified expression using *their* probability to at least 3sf from **(a)(i)** or correct.
	0.268	**A1**	AWRT, WWW.
		3	
(b)	$z = \pm 1.282$	**B1**	Correct value only, critical value.
	$\dfrac{t - 125}{24} = -1.282$	**M1**	Use of ± Standardisation formula with correct values substituted, allow continuity correction, σ^2, $\sqrt{\sigma}$, to form an equation with a z-value and not probability.
	$t = 94.2$	**A1**	AWRT, condone AWRT 94.3. Not dependent on **B** mark.
		3	

Question 95

(a)	$P(46 < X < 62) = P\left(\dfrac{46-55}{6} < Z < \dfrac{62-55}{6}\right)$	**M1**	46 or 62, 55 and 6 substituted into ±standardisation formula once. Condone 6^2 and continuity correction ± 0.5
	$= P\left(-1.5 < Z < \dfrac{7}{6}\right)$	**B1**	Both standardisation values correct, accept unsimplified
	$\left[= \Phi\left(\dfrac{7}{6}\right) - (1 - \Phi(1.5))\right]$ $= 0.8784 + (0.9332 - 1)$	**M1**	Calculating the appropriate area from stated Φs of z-values, must be probabilities.
	0.812	**A1**	$0.8115 < p \leqslant 0.812$
		4	
(b)	$z = \pm 0.674$	**B1**	CAO, critical z-value
	$\dfrac{36 - 42}{\sigma} = -0.674$	**M1**	36 and 42 substituted in ±standardisation formula, no continuity correction, not σ^2, $\sqrt{\sigma}$, equated to a z-value
	$\sigma = 8.9[0]$	**A1**	WWW. Only dependent on M.
		3	
(c)	P(male < 46) = $1 - their$ $0.9332 = 0.0668$	**M1**	FT value from part **(a)** or Correct: $1 - \Phi\left(\dfrac{46-55}{6}\right)$, condone continuity correction, σ^2, $\sqrt{\sigma}$, **and** probability found. Condone unsupported correct value stated.
	P(female < 46) = $P\left(Z < \dfrac{46-42}{their\, 8.90}\right) [= \Phi(0.449)]$ $= 0.6732$	**M1**	46, 42 and *their* 4(b) σ (or correct σ) substituted in ±standardisation formula, condone continuity correction, σ^2, $\sqrt{\sigma}$, **and** probability found Condone $\dfrac{4}{their\, 8.90}$.
	P(both) = 0.0668×0.6732	**M1**	Product of *their* 2 probabilities ($0 <$ both < 1) Not 0.25 or *their* final answer to **4(a)** used.
	0.0450 or 0.0449	**A1**	$0.0449 \leqslant p \leqslant 0.0450$
		4	

Question 96

(a)	$[P(142 < X < 205)] = P\left(\dfrac{142-170}{25} < z < \dfrac{205-170}{25}\right)$	**M1**	Use of $\pm$ standardisation formula once substituting 170, 25 and either 142 or 205 appropriately.. Condone 25^2 and continuity correction ±0.5.
	$P(-1.12 < z < 1.4)$	**A1**	Both correct. Accept unsimplified.
	$\Phi(1.4) - (1 - \Phi(1.12)) = 0.9192 + 0.8686 - 1$	**M1**	Calculating the appropriate area from stated phis of z-values.
	0.788	**A1**	AWRT, not from wrong working
		4	
(b)	$P(X > 205) = 1 - 0.9192 = 0.0808$	**B1 FT**	Correct or FT from part **5(a)**.
	$(0.0808 \times 0.30 + their\ 0.788 \times 0.24) \times 20000$	**M1**	Correct or $their\ 0.0808 \times 0.30 \times k + their\ 0.788 \times 0.24 \times k$, k positive integer.
	[\$]4266.24	**A1**	$4265 < \text{income} \leqslant 4270$, not from wrong working
		3	
(c)	$[P\left(Z > \dfrac{w-182}{20}\right) = 0.72]$	**B1**	$0.5828 \leqslant z \leqslant 0.583$ or $-0.583 \leqslant z \leqslant -0.5828$ seen.
	$\dfrac{w-182}{20} = -0.583$	**M1**	182 and 20 substituted in $\pm$ standardisation formula, no continuity correction, not σ^2, $\sqrt{\sigma}$, equated to a z-value.
	$w = 170$	**A1**	$170 \leqslant w < 170.35$
		3	

Question 97

(a)	$[P(10, 11, 12) =]$ $^{12}C_{10}\,0.72^{10}\,0.28^2 + {}^{12}C_{11}\,0.72^{11}\,0.28^1 + {}^{12}C_{12}\,0.72^{12}\,0.28^0$	**M1**	One term $^{12}C_x\,p^x(1-p)^{12-x}$, for $0 < x < 12$, $0 < p < 1$.
	$= 0.193725 + 0.0905726 + 0.0194084$	**A1**	Correct expression, accept unsimplified, no terms omitted, leading to final answer.
	0.304	**B1**	Final answer $0.3036 < p \leqslant 0.304$.
	Alternative method for question 5(a)		
	$[1 - P(0,1,2,3,4,5,6,7,8,9) =]$ $1 - (^{12}C_0\,0.72^0\,0.28^{12} + {}^{12}C_1\,0.72^1\,0.28^{11} + {}^{12}C_2\,0.72^2\,0.28^{10} +$ $^{12}C_3\,0.72^3\,0.28^9 + {}^{12}C_4\,0.72^4\,0.28^8 + {}^{12}C_5\,0.72^5\,0.28^7 +$ $^{12}C_6\,0.72^6\,0.28^6 + {}^{12}C_7\,0.72^7\,0.28^5 + {}^{12}C_8\,0.72^8\,0.28^4 +$ $^{12}C_9\,0.72^9\,0.28^3)$	**M1**	One term $^{12}C_x\,p^x(1-p)^{12-x}$, for $0 < x < 12$, $0 < p < 1$.
		A1	Correct expression, accept unsimplified, no terms omitted, leading to final answer.
	0.304	**B1**	Final answer $0.3036 < p \leqslant 0.304$.
		3	
(b)	Mean $= [0.52 \times 90 =] 46.8$, var $= [0.52 \times 0.48 \times 90] = 22.464$	**B1**	46.8 and 22.464 or 22.46 seen, allow unsimplified, $(4.739 < \sigma \leqslant 4.740$ imply correct variance).
	$[P(X < 40) =] P\left(z < \dfrac{39.5-46.8}{\sqrt{22.464}}\right)$	**M1**	Substituting *their* mean and *their* variance into $\pm$standardisation formula (any number for 39.5), not σ^2, $\sqrt{\sigma}$.
		M1	Using continuity correction 39.5 or 40.5 in *their* standardisation formula.
	$= [P(Z < -1.540)] = 1 - 0.9382$	**M1**	Appropriate area Φ, from final process, must be probability.
	0.0618	**A1**	$0.06175 \leqslant p \leqslant 0.0618$
		5	

Question 98

(a)	$[P(1.98 < X < 2.03) =]P\left(\dfrac{1.98-2.02}{0.03} < z < \dfrac{2.03-2.02}{0.03}\right)$ $[= P(-1.333 < z < 0.333)]$	**M1**	Use of ±standardisation formula once with 2.02, 0.03 and either 1.98 or 2.03 substituted appropriately. Condone 0.03^2 and continuity correction ±0.005, not √0.03.
	$[= \Phi(0.333) - (1 - \Phi(1.333))]$ $= 0.6304 + 0.9087 - 1$	**M1**	Calculating the appropriate probability area from *their* z-values. (or $0.6304 - 0.09121$ or $(0.9087 - 0.5) + (0.6304 - 0.5)$ etc)
	0.539	**A1**	$0.539 \leqslant z < 0.5395$ Only dependent upon 2nd M mark. If M0 scored **SC B1** for $0.539 \leqslant z < 0.5395$.
		3	
(b)	$[P(X > 2.6) = \dfrac{134}{5000} = 0.0268]$ $[P(X < 2.6) = 1 - 0.0268 =] \; 0.9732$	**B1**	0.9732 or $\dfrac{4866}{5000}$ or $\dfrac{2433}{2500}$ seen.
	$\dfrac{2.6 - 2.55}{\sigma} = 1.93$	**M1**	Use of ±standardisation formula with 2.6 and 2.55 substituted, no $\sigma^2, \sqrt{\sigma}$ or continuity correction.
		M1	*Their* standardisation formula with values substituted equated to z-value which rounds to ±1.93.
	$\sigma = 0.0259$	**A1**	AWRT 0.0259 or $\dfrac{5}{193}$. If M0 earned, **SC B1** for correct final answer.
		4	

Question 99

(a)	$P(X < 6) = P\left(Z < \dfrac{6-5.2}{1.5}\right) = P(Z < 0.5333)$	**M1**	6, 5.2, 1.5 substituted into ± standardisation formula, condone 1.5^2, continuity correction ±0.5
	0.703	**A1**	
		2	
(b)	$z_1 = \dfrac{3-\mu}{\sigma} = -1.329$	**B1**	$1.328 < z_1 \leqslant 1.329$ or $-1.329 \leqslant z_1 < -1.328$
	$z_2 = \dfrac{8-\mu}{\sigma} = 0.878$	**B1**	$0.877 < z_2 \leqslant 0.878$ or $-0.878 \leqslant z_2 < -0.877$
	Solve to find at least one unknown: $\dfrac{3-\mu}{\sigma} = -1.329$ $\dfrac{8-\mu}{\sigma} = 0.878$	**M1**	Use of the ± standardisation formula once with μ, σ, a z-value (not 0.8179, 0.7910, 0.5367, 0.5753, 0.19, 0.092 etc.) and 3 or 8, condone continuity correction but not σ^2 or $\sqrt{\sigma}$
		M1	Use either the elimination method or the substitution method to solve their two equations in μ and σ
	$\sigma = 2.27, \quad \mu = 6.01$	**A1**	$2.26 \leqslant \sigma \leqslant 2.27, \; 6.01 \leqslant \mu \leqslant 6.02$
		5	
(c)	$[P(Z < -1) + P(Z > 1)] \; \Phi(1) - \Phi(-1) =$ $= 2 - 2\,\Phi(1)$ $= 2 - 2 \times 0.8413$	**M1**	Identify 1 and −1 as the appropriate z-values.
		M1	Calculating the appropriate area from stated phis of z-values which must be ± the same number
	0.3174	**A1**	Accept AWRT 0.317
	Number of leaves: $2000 \times 0.3174 = 634.8$ so 634 or 635	**B1 FT**	FT *their* 4 s.f. (or better) probability, final answer must be positive integer no approximation or rounding stated
		4	

Question 100

Mean $= 80 \times 0.32 = 25.6,$ var $= 80 \times 0.32 \times 0.68 = 17.408$	**B1**	25.6 and 17.4[08] seen, allow unsimplified. 4.172… implies correct variance.
$P(X < 20) = P\left(Z < \dfrac{19.5 - 25.6}{\sqrt{17.408}}\right) = P(Z < -1.462)$	**M1**	Substituting *their* 25.6 and 17.408 into ±standardisation formula (any number for 19·5), not $\sigma^2, \sqrt{\sigma}$.
	M1	Using continuity correction 19·5 or 20·5 in *their* standardisation formula.
$= [1 - \Phi(1.462)] = 1 - 0.9282$	**M1**	Appropriate area Φ, from final process, must be probability. (Expect final ans < 0·5). Note: the correct final answer may imply M1 from use of calculator.
0.0718	**A1**	$0.0718 \leqslant p \leqslant 0.0719$
	5	

Question 101

$[P(X > 1.11) =] P(Z > \dfrac{1.11-1.04}{0.06}) = P(Z > 1.167)$		**M1**	1.11, 1.04 and 0.06 substituted into ±Standardisation formula, no continuity correction not 0.06^2 or $\sqrt{0.06}$
$= 1 - 0.8784$		**M1**	1 – *their* 0.8784 as final answer, must be probability. (Expect final ans < 0·5).
0.122		**A1**	$0.1216 \leqslant p \leqslant 0.122$ **SC M0 M1 B1** for 0.122 with no standardisation formula.
		3	

Question 102

$[P(X < w) = P(Z < \dfrac{w-1.04}{0.06}) = 0.81]$		**B1**	$0.8775 < z \leqslant 0.878$ or $-0.878 \leqslant z < -0.8775$ seen.
$\dfrac{w-1.04}{0.06} = 0.878$		**M1**	1.04 and 0.06 substituted in ±standardisation formula, no continuity correction, not σ^2, $\sqrt{\sigma}$, equated to a z-value.
$w = 1.09$		**A1**	$1.09 \leqslant w \leqslant 1.093$
		3	

Question 103

(a)	$[P(X<54.8)] = P(Z < \dfrac{54.8-55.6}{1.2})$	**M1**	Use of ± standardisation formula, with 54.8, 55.6 and 1.2 substituted. condone 1.2^2, $\sqrt{1.2}$ or continuity correction of 54.75 or 54.85
	$[= P(Z < -0.6667)] = 1 - 0.7477$	**M1**	Appropriate area Φ, from final process, must be probability.
	$= 0.2523$	**A1**	$0.252 \leqslant p \leqslant 0.2525$ If A0 scored **S CB1** for $0.252 \leqslant p \leqslant 0.2525$
	$[\text{Expected number} =] 400 \times 0.2523 = 100.92$ 100 or 101	**B1 FT**	FT *their* 4SF (or better) probability from a normal calculation. Must be a single integer answer.
		4	
(b)	$[P(-\tfrac{1}{2} < Z < \tfrac{1}{2}) = \Phi(\tfrac{1}{2}) - \Phi(-\tfrac{1}{2}) =]$ $2\Phi\left(\dfrac{1}{2}\right) - 1$ $= 2 \times their\,0.6915 - 1$ or $their\,0.6915 - (1 - their\,0.6915)$ or $2 \times (0.6915 - 0.5)$	**M1**	{Both ½ and –½ seen as z-values **or** appropriate use of +½ or –½} **and** {no other z-values in part}. Condone $\dfrac{56.2-55.6}{1.2}$ and $\dfrac{55[.0]-55.6}{1.2}$ seen as z-values.
		M1	Calculating the appropriate area from stated phis of z-values which must be ± the same number.
	0.383	**A1**	$0.3829 \leqslant z \leqslant 0.383$ If A0 scored **SC B1** for $0.3829 \leqslant z \leqslant 0.383$
		3	

Question 104

(a)	$[1 - P(10, 11, 12) =]$ $1 - (\,^{12}C_{10}\ 0.9^{10}\ 0.1^2 + \,^{12}C_{11}\ 0.9^{11}\ 0.1^1 + \,^{12}C_{12}\ 0.9^{12}\ 0.1^0\,)$ $= 1 - (0.230128 + 0.376573 + 0.282430)$	**M1**	One term $^{12}C_x\ p^x\,(1-p)^{12-x}$, for $0 < x < 12$, $0 < p < 1$
		A1	Correct expression, accept unsimplified, no terms omitted, leading to final answer.
	0.111	**B1**	Mark the final answer at the most accurate value, $0.1108 < p \leqslant 0.111$ WWW.
(b)	$[\text{Mean} = 80 \times 0.9 =]\ 72,$ $[\text{Variance} = 80 \times 0.9 \times 0.1] = 7.2$	**B1**	72 and 7.2 seen, allow unsimplified. May be seen in standardisation formula. ($2.683 \leqslant \sigma < 2.684$ imply correct variance).
	$P(X > 69) = P(Z > \dfrac{69.5 - 72}{\sqrt{7.2}})$	**M1**	Substituting *their* mean and $\sqrt{their\ \text{variance}}$ into $\pm$standardisation formula (any number for 69·5), not *their* 7.2, not $\sqrt{their}$ 2.683
		M1	Using continuity correction 69·5 or 68·5 in *their* standardisation formula.
	$[= P(Z > -0.9317) =]$ $\Phi(0.9317)$	**M1**	Appropriate area Φ, from final process, must be probability.
	0.824	**A1**	$0.8239 \leqslant p \leqslant 0.8243$ WWW.
		5	
(c)	$np = 72$, $nq = 8$ Both greater than 5, [so approximation is valid]	**B1**	*np, nq* evaluated accurately. **both** *np* & *nq* referenced correctly. > 5 or greater than 5 seen.
		1	

Question 105

(a)	$[P(3, 4, \ldots 7) = 1 - P(0, 1, 2, 8)]$ $= 1 - (\,^8C_0\ 0.48^0\ 0.52^8 + \,^8C_1\ 0.48^1\ 0.52^7$ $+ \,^8C_2\ 0.48^2\ 0.52^6 + \,^8C_8\ 0.48^8\ 0.52^0\,)$	**M1**	One term $^8C_x\ p^x\,(1-p)^{8-x}$, for $0 < x < 8$, $0 < p < 1$
	$= 1 - (0.00534597 + 0.039478 + 0.127544 + 0.0028179)$	**A1**	Correct expression, accept unsimplified, no terms omitted, leading to final answer.
	0.825	**B1**	Mark the final answer at the most accurate value. $0.8248 < p \leqslant 0.825$ WWW.
(b)	$[\text{Mean} = 0.52 \times 125 =]\ 65,$ $[\text{var} = 0.52 \times 0.48 \times 125 =]\ 31.2$	**B1**	65 and 31.2 seen, allow unsimplified. May be seen in standardisation formula. ($5.585 < \sigma \leqslant 5.586$ imply correct variance).
	$[P(X > 72) =]\ P(Z > \dfrac{72.5 - 65}{\sqrt{31.2}})\ [= P(Z > 1.343)]$	**M1**	Substituting *their* 65 and $\sqrt{their\ 31.2}$ into $\pm$standardisation formula (any number for 72·5), not *their* 31.2, $\sqrt{their}$ 5.586.
		M1	Using continuity correction 72·5 or 71·5 in *their* standardisation formula. Note $\dfrac{\pm 7.5}{\sqrt{31.2}}$ or $\dfrac{\pm 7.5}{5.586}$ seen gains **M2** BOD
	$= 1 - 0.9104$	**M1**	Appropriate area Φ, from final process, must be probability.
	0.0896	**A1**	$0.0896 \leqslant p \leqslant 0.0897$ WWW.
		5	

Question 106

(a)	$P(X<132) = P\left(Z < \dfrac{132-125.4}{18.6}\right) = P(Z<0.3548)$	M1	Use of ±standardisation formula with 132 and 125.4 substituted, condone continuity correction 132±0.5 and use of 18.6^2, $\sqrt{18.6}$
	0.639	A1	$0.6385 < p \leqslant 0.639$ If M0 scored, **SC B1** for $0.6385 < p \leqslant 0.639$
		2	
(b)	$\dfrac{108-117}{\sigma} = -1.175$	B1	$1.1749 < z \leqslant 1.175$ or $-1.175 \leqslant z < -1.1749$
		M1	108 and 117 substituted in ±standardisation formula, no continuity correction, not σ^2, $\sqrt{\sigma}$, equated to a z-value.
	$\sigma = 7.66$	A1	$7.659 \leqslant \sigma \leqslant 7.66$ If M0 scored, **SC B1** for $7.659 \leqslant \sigma \leqslant 7.66$
		3	
(c)	$P(-1.5 < Z < 1.5)$ $[\Phi(1.5) - \Phi(-1.5)]$ $[= 2\Phi(1.5)-1]$ $= 2 \times their\,0.9332 - 1$ **or** $their\,0.9332 - (1 - their\,0.9332)$ **or** $2 \times (their\,0.9332 - 0.5)$	M1	{Both 1.5 and −1.5 seen as z-values **or** appropriate use of 1.5 or −1.5} **and** {no other z-values in part}.
		M1	Calculating the appropriate area from stated phis of z-values which must be ± the same number. Condone *their* 0.0668 as $(1 - their\,0.9332)$.
	0.8664	A1	Accept answers wrt 0.866 If A0 scored **SC B1** for answers wrt 0.866
	$0.8664^3 = 0.650[36\ldots]$	B1 FT	FT *their* 4SF (or better) probability, accept final answers to 3SF.
		4	

Question 107

(a)	$[P(X<74) =]\,P\left(Z < \dfrac{74-62.3}{8.4}\right)[= P(Z<1.393)]$	M1	Use of ± standardisation formula with 74, 62.3 and 8.4 substituted appropriately, not 8.4^2, not $\sqrt{8.4}$, no continuity correction.
	$= 0.918$	A1	$0.918 \leqslant p \leqslant 0.9185$.
		2	
(b)	$[P(50 < X < 74) = P]\left(\dfrac{50-62.3}{8.4} < Z < \dfrac{74-62.3}{8.4}\right)$ $[P(-1.464 < Z < 1.393)]$	M1	Use of ± standardisation formula with both 74 (may be seen in 6(a) if *their* value seen) & 50, 62.3 and 8.4 substituted appropriately. Condone use of 8.4^2, $\sqrt{8.4}$ and continuity correction ±0.5 (73.5 or 74.5 and 49.5 or 50.5).
	$[\Phi(1.464) + \Phi(1.393) - 1]$ $0.9285 + 0.9182 - 1$	M1	Calculating the appropriate probability area from stated Φ of z-values (leading to *their* final answer > 0.5) but not symmetrical values.
	$= 0.847$	A1	$0.8465 \leqslant p < 0.8475$. **SC B1** for $0.8465 \leqslant p < 0.8475$ if M0A0 awarded.
	$(0.8467)^4 = 0.514$	B1 FT	Accept $0.513 \leqslant p \leqslant 0.514$. FT (*their* 4-figure $p)^4$, $0 < p < 1$.
		4	
(c)	$z_1 = \dfrac{36-\mu}{\sigma} = -0.739$ $z_2 = \dfrac{54-\mu}{\sigma} = 1.282$	B1	$-0.740 < z_1 < -0.738$ or $0.738 < z_1 < 0.740$.
		B1	$z_2 = \pm 1.282$ (critical value).
		M1	Use of the ±standardisation formula once with μ, σ and a z-value (not 0.23, 0.77, 0.90, 0.10, ±0.261, ±0.282…). Condone continuity correction ±0.5, not σ^2, $\sqrt{\sigma}$.
	Solve, obtaining values for μ and σ $\mu = 42.6$, $\sigma = 8.91$	M1	Solve using the elimination method, substitution method or other appropriate approach to obtain values for both μ and σ.
		A1	$42.58 \leqslant \mu \leqslant 42.6$, $8.90 \leqslant \sigma \leqslant 8.91$.
		5	

Question 108

Mean $=120 \times 0.4 = 48$ Var $=120 \times 0.4 \times 0.6 = 28.8$	**B1**	48 and $28\frac{4}{5}$, 28.8 seen, allow unsimplified. ($5.366 \leqslant \sigma \leqslant 5.367$ or $\frac{12\sqrt{5}}{5}$ implies correct variance).	
$P(36 \leqslant X \leqslant 54) = P(\frac{35.5-48}{\sqrt{28.8}} < Z < \frac{54.5-48}{\sqrt{28.8}})$	**M1**	Substituting *their* μ and σ into one ±standardisation formula (any number for 35.5 or 54.5), condone σ^2 and $\sqrt{\sigma}$.	
	M1	Using continuity correction 35.5, 36.5 or 53.5, 54.5 once in *their* standardisation formula. Note: $\frac{\pm 12.5}{\sqrt{28.8}}$ or $\frac{\pm 6.5}{\sqrt{28.8}}$ seen gains M2 BOD.	
$[= P(-2.3292 < Z < 1.211) =] 0.8871 + 0.9900 - 1$	**M1**	Appropriate area Φ, from final process. Must be a probability. Expect final answer > 0.5. Note: correct final answer implies this M1.	
$= 0.877$	**A1**	$0.877 \leq p < 0.8772$.	
	5		

Question 109

(a)	$\left[P(X<16) = P\left(Z < \frac{16-28}{\sigma} \right) = 0.1 \right]$ $\frac{16-28}{\sigma} = -1.282$	**B1**	± 1.282 seen, cao – critical value.	
		M1	Use of the ±standardisation formula with 16, 28, σ and a z-value (not 0.1, 0.9, 0.282, 0.5398, 0.8159) equated to a z-value. Condone continuity correct ± 0.5, not $\sigma^2, \sqrt{\sigma}$. Condone $\pm \frac{12}{\sigma} = -1.282$.	
	$\sigma = 9.36$	**A1**		
		3		
(b)	$[1 - P(0, 1, 2) =] 1 - (^{12}C_0(0.1)^0(0.9)^{12} + ^{12}C_1(0.1)^1(0.9)^{11} + ^{12}C_2 (0.1)^2(0.9)^{10})$ $[1 - (0.2824 + 0.3766 + 0.2301)]$	**M1**	One term $^{12}C_x \left(p \right)^x (1-p)^{12-x}$, $0 < p < 1$. $x \neq 0,1,2$.	
		A1	Correct expression, accept unsimplified, no terms omitted leading to final answer.	
	0.111	**B1**	$0.1108699\ldots$ rounded to at least 3SF.	
	Alternative Method for Question 6(b)			
	$P(3,4,5,6,7,8,9,10,11,12) = ^{12}C_3(0.1)^3(0.9)^9 + ^{12}C_4(0.1)^4(0.9)^8 + \ldots + ^{12}C_{11}(0.1)^{11}(0.9)^1 + ^{12}C_{12}(0.1)^{12}(0.9)^0$ $[0.08523 + 0.02131 + \ldots + 1.08 \times 10^{-10} + 1 \times 10^{-12}]$	**M1**	One term $^{12}C_x \left(p \right)^x (1-p)^{12-x}$, $0 < p < 1$. $x \neq 0,1,2$.	
		A1	Correct expression, accept unsimplified, no terms omitted leading to final answer.	
	0.111	**B1**	$0.1108699\ldots$ rounded to at least 3SF.	
		3		
(c)	$[P(-1.3 < Z < 1.3)$ $= 2\, \Phi(1.3) - 1]$ $= 2 \times 0.9032 - 1$	**B1**	Identifying at least one of -1.3 or 1.3 as the appropriate z-values.	
		M1	Calculating the appropriate probability area from 2 symmetrical z-values (leading to their final answer, expect > 0.5).	
	$= 0.806, \frac{504}{625}$	**A1**	$0.8064, 0.806 \leqslant p < 0.8065$.	
	$[\text{In 365 days } 0.8064 \times 365]$ $= 294$ or 295	**B1 FT**	Strict FT *their* at least 4-figure probability (not z-value). Final answer must be positive integer, no approximation or rounding stated.	
		4		

Question 110

(a)	$[P(15.4 < X < 16.8) =] P(\frac{15.4-16.5}{0.6} < Z < \frac{16.8-16.5}{0.6})$ $[= P(-1.833 < Z < 0.5)]$	**M1**	Use of ± standardisation formula once with 16.5, 0.6 and either 15.4 or 16.8 substituted.
	$[= \Phi(0.5) + \Phi(1.833) - 1 =]$ $0.6915 + 0.9666 - 1$	**M1**	Calculating the appropriate probability area (leading to their final answer, expect > 0.5). $0.6915 - (1 - 0.9666)$ or $(0.6915 - 0.5) + (0.9666 - 0.5)$ OE are alternatives.
	$= 0.658$	**A1**	$0.658 \leq p < 0.6585$. If A0 scored, **SC B1** for $0.658 \leqslant p < 0.6585$.
	[Expected number =] 0.6581×150 $= 98, 99$	**B1 FT**	FT *their* 4SF (or better) probability from a normal calculation. Must be a positive single integer answer. No approximation notation.
		4	

(b)	$\left[P\left(Z > \frac{17.1-18.4}{\sigma} \right) = 0.72 \right]$ $\frac{17.1-18.4}{\sigma} = -0.583$	**B1**	$0.5825 < z \leqslant 0.583$ or $-0.583 \leqslant z < -0.5825$ seen.
		M1	Use of the ± standardisation formula with 17.1, 18.4, σ and a z-value (not 0.28, 0.72, 0.4175, 0.2358, 0.7642, 0.6103, 0.3897, …). Condone continuity correct ± 0.05, not $\sigma^2, \sqrt{\sigma}$.
	$\sigma = 2.23$	**A1**	AWRT
		3	

(c)	[Mean = 120×0.72 =] 86.4 [Var = $120 \times 0.72 \times 0.28$ =] 24.192	**B1**	86.4, $84\frac{2}{5}$ and $24\frac{24}{125}$, 24.192 to at least 3SF seen, allow unsimplified. May be seen in standardisation formula. ($4.918 \leqslant \sigma \leqslant 4.919$ implies correct variance) Incorrect notation is penalised.
	$P(X < 80) = P(Z < \frac{79.5-86.4}{\sqrt{24.192}})$	**M1**	Substituting *their* mean (not 18.4) and *their* positive 4.9185 into ± standardisation formula (any number for 79.5), condone *their* 4.918^2 and $\sqrt{their}\ 4.918$.
		M1	Using continuity correction 79.5 or 80.5 in *their* standardisation formula.
	$[P(Z < -1.4029) = 1 - \Phi(1.403)]$ $1 - 0.9196$	**M1**	Appropriate area Φ, from final process, must be a probability. Expect final answer < 0.5. Note: correct final answer implies this M1.
	0.0804	**A1**	$0.0803 \leqslant p \leqslant 0.0804$
		5	

Question 111

(a)			
$P(Z > \dfrac{20-14.6}{5.2}) = P(Z > 1.03846)$		**M1**	Use of $\pm$ standardisation formula with 20, 14.6 and 5.2 not σ^2, not $\sqrt{\sigma}$, no continuity correction.
$1 - 0.8504$		**M1**	Calculating the appropriate probability area (leading to their final answer).
0.150		**A1**	0.1496, $0.149 < p \leqslant 0.15[0]$. Only dependent on the 2nd M mark so M0M1A1 possible. **SC B1** for $0.149 < p \leqslant 0.15[0]$ if M0M0A0 awarded.
$[250 \times \textit{their } 0.1496 =]$ 37, 38		**B1 FT**	Strict FT *their* at least 4-figure probability seen anywhere (give BOD if they go on to use 0.150). Final answer must be positive integer, no approximation or rounding stated.
		4	

(b)			
$z_1 = \dfrac{14.5 - \mu}{\sigma} = -0.842$		**B1**	$-0.843 < z_1 < -0.841$ or $0.841 < z_1 < 0.843$.
$z_2 = \dfrac{18.5 - \mu}{\sigma} = -0.44$		**B1**	$-0.441 < z_2 < -0.439$ or $0.439 < z_2 < 0.441$.
		M1	Use of the $\pm$standardisation formula once with μ, σ and a z-value (not 0.20, 0.80, 0.67, 0.23, 0.5793, 0.7881, 0.7486, 0.591 or 1-z i.e. 0.158 etc.). Condone continuity correction ± 0.05, not σ^2, $\sqrt{\sigma}$.
Solve, obtaining values for μ and σ. $\mu = 22.9$, $\sigma = 9.95$		**M1**	Solve using the elimination method, substitution method or other appropriate approach to obtain values for both μ and σ.
		A1	AWRT 22.9, 9.95 .
		5	

Question 112

(a)			
$[P(1.42 < X < 1.52) =] P(\dfrac{1.42-1.5}{0.05} < Z < \dfrac{1.52-1.5}{0.05})$		**M1**	Use of $\pm$ standardisation formula once with 1.5, 0.05 and either 1.42 or 1.52, allow σ^2 or $\sqrt{\sigma}$, no continuity correction.
$[= P(-1.6 < Z < 0.4) = \Phi(0.4) + \Phi(1.6) - 1]$ $= 0.6554 + 0.9452 - 1$ or $0.6554 - 0.0548$		**M1**	Calculating the appropriate probability area (leading to their final answer, expect > 0.5).
$= 0.601$		**A1**	$0.6005 < p \leqslant 0.601$ **SC B1** for 0.601 with no standardisation seen.
		3	

(b)			
$\left[P(X < 0.9) = P\left(Z < \dfrac{0.9-0.75}{\sigma}\right) = 0.68 \right]$		**B1**	$0.467 < z \leqslant 0.468$ or $-0.468 \leqslant z < -0.467$ seen
$\dfrac{0.9-0.75}{\sigma} = 0.468$		**M1**	$\pm$standardisation formula with 0.9, 0.75, σ equating to a z-value (not 0.32, 0.68, 0.532, 0.7517, 0.2483, 0.6255,) . Condone continuity correct ± 0.05, not σ^2, $\sqrt{\sigma}$. Condone $\pm\dfrac{0.15}{\sigma} = 0.468$.
$\sigma = 0.321$, $\dfrac{25}{78}$		**A1**	$0.3205 \leqslant \sigma < 0.3215$ **SC B1** if M0 www.
		3	

Question 113

(a)(i)	$[P(X < 170) =] P\left(Z < \dfrac{170-166}{10}\right)$	**M1**	Use of ± standardisation formula with 170, 166 and 10 substituted appropriately, condone $10^2, \sqrt{10}$, condone continuity correction ±0.5.
	$[= P(Z < 0.4) =]\ 0.655$	**A1**	$0.655 \leqslant p < 0.6555$ If M0 awarded, **SC B1** for correct answer www.
		2	
(a)(ii)	$\left[P\left(Z > \dfrac{h-166}{10}\right) = 0.4\right]$	**B1**	$0.253 \leqslant z \leqslant 0.2535$ or $-0.2535 \leqslant z \leqslant -0.253$ seen.
	$\dfrac{h-166}{10} = 0.253$	**M1**	Use of the ±standardisation formula with h, 166, 10 and a z-value (not $1 - z$-value), not $10^2, \sqrt{10}$, no continuity correction.
	$h = 168.53$	**A1**	If M0 scored, **SC B1** for $168.53 \leqslant h \leqslant 168.535$, 168.5. **SC B1** for 168.54 from $z = 0.254$.
		3	
(b)	$\left[P(X > 0) = P\left(Z > \dfrac{0-\mu}{\sigma}\right) = \right] P\left(Z > \dfrac{[0]-\mu}{\frac{2}{3}\mu}\right)$ Or $P\left(Z > \dfrac{[0] - \frac{3}{2}\sigma}{\sigma}\right)$	**M1**	Use of the ±standardisation formula with 0, μ and $\frac{2}{3}\mu$ substituted for σ. Or use of the ±standardisation formula with $0, \sigma$ and $\frac{3}{2}\sigma$ substituted for μ.
	$= P(Z > -1.5)$	**A1**	-1.5 seen, no additional terms (e.g. $x - 1.5$ A0). Condone $Z < 1.5$. If M0 scored, **SC B1** $Z > -1.5$ or $Z < 1.5$ seen www.
	$= 0.933$ final answer	**A1**	$0.933 \leqslant p < 0.9333$. If M0 scored, **SC B1** $0.933 \leqslant p < 0.9333$ seen www.
		3	

Question 114

	$[\text{Mean} = 200 \times 0.15 =]\ 30$ $[\text{Var} = 200 \times 0.15 \times 0.85 =]\ 25.5$	**B1**	30 and 25.5, $25\frac{1}{2}, \frac{51}{2}$ seen, allow unsimplified. May be seen in standardisation formula. $[\sigma =]\ 5.049 \leqslant \sigma \leqslant 5.05[0]$, $\frac{\sqrt{102}}{2}$ implies correct variance. Correct notation is required.
	$[P(X > 40) =] P\left(Z > \dfrac{40.5 - 30}{\sqrt{25.5}}\right)$	**M1**	Substituting *their* mean and *their* positive 5.04975 into ±standardisation formula (any number for 40.5), not *their* σ^2 or $\sqrt{their\ \sigma}$.
		M1	Using continuity correction 39.5 or 40.5 in *their* standardisation formula.
	$[1 - \Phi(2.079)]$ $1 - 0.9812$	**M1**	Appropriate area Φ, from final process, must be a probability.
	$= 0.0188$	**A1**	$0.01875 < p \leqslant 0.0188$
		5	

Question 115

(a)	$[P(X < 76) =] \; P\left(Z < \dfrac{76-80.5}{6.6}\right)$	**M1**	Use of ± standardisation formula with 76, 80.5 and 6.6, condone 6.6^2 or $\sqrt{6.6}$, no continuity correction.
	$[= \Phi(-0.6818) = 1 - \Phi(0.6818) =]$ $1 - 0.7524 = 0.2476$	**M1**	Calculating the appropriate probability area (leading to their final answer).
	24.8%	**A1**	24.75% < ans ⩽ 24.8% (percentage value required). If A0 scored, **SC B1** for 24.75% < ans ⩽ 24.8% www.
		3	

(b)	[% of large eggs = 100 − 40 − 24.76 = 35.24] $\left[P\left(Z > \dfrac{x-80.5}{6.6}\right) = 0.40 + 0.2476 = 0.6476\right]$ $\dfrac{x-80.5}{6.6} = 0.378$	**B1**	0.378 ⩽ z < 0.3791 or −0.3791 < z ⩽ −0.378 seen.
		M1	Use of ± standardisation formula with x, 80.5, 6.6 and a z-value (not 0.6476, 0.3524, 0.4, 0.2476) (treat ±0.38 as a z-value), not 6.6^2, not $\sqrt{6.6}$, no continuity correction.
	$x = 83[.0]$	**A1**	awrt 83.0
		3	

(c)	Mean $= 150 \times 0.4 = 60$ Var $= 150 \times 0.4 \times 0.6 = 36$	**B1**	60 and 36 seen, allow unsimplified.
	$P(X > 68) = P\left(Z > \dfrac{68.5-60}{\sqrt{36}}\right)$	**M1**	Substituting *their* 60 and *their* 6 into ±standardisation formula (any number for 68.5), condone *their* σ^2 and *their* $\sqrt{\sigma}$.
		M1	Using continuity correction 67.5 or 68.5 in *their* standardisation formula.
	$P(Z > 1.417) = 1 - \Phi(1.417)$ $[= 1 - 0.9217]$	**M1**	Appropriate area Φ, from final process, must be a probability.
	0.0783	**A1**	0.07825 < p ⩽ 0.0783 If A0 scored, **SC B1** for 0.07825 < p ⩽ 0.0783.
		5	

Question 116

(a)	$[P(X > 1.26) = P\left(Z > \dfrac{1.26-1.20}{0.16}\right)$ $\left[= P(Z > 0.375)\right]$	**M1**	Use of ± standardisation formula with 1.26, 1.20 and 0.16, not σ^2, not σ, no continuity correction.
	$= 1 - 0.6462$	**M1**	Calculating the appropriate probability area, (leading to their final probability, expect < 0.5).
	$= 0.354$	**A1**	0.3538, 0.3535 < p ⩽ 0.354. Only dependent on the 2nd M mark. **SC B1** for 0.3535 < p ⩽ 0.354 if M0M0A0 awarded.
	$[500 \times \textit{their } 0.3538] = 176, \; 177$	**B1 FT**	Strict FT *their* at least 4-figure calculated probability, seen anywhere (not a z-value). Final answer must be a single positive integer value, no approximation or rounding stated.
		4	

(b)	$\left[P\left(Z > \dfrac{2.40-2.50}{\sigma}\right) = 0.20\right]$	**B1**	−0.842 ⩽ z < −0.8415 or 0.8415 < z ⩽ 0.842 seen.
	$\dfrac{2.40-2.50}{\sigma} = -0.842$	**M1**	Use of the ±standardisation formula with 2.40, 2.50, σ and a z-value (not 0.20, 0.80, 0.158, 0.7881, 0.2119, 0.5793, 0.4207, …), not σ^2. Condone continuity correction of ±0.005. Condone $-\dfrac{0.1}{\sigma} = -0.842$ etc. for M1.
	$\sigma = 0.119$	**A1**	0.1185 < σ ⩽ 0.119.
		3	

(c)	[Mean = $80 \times 0.2 =$]16 [Variance = $80 \times 0.2 \times 0.8 =$]12.8	B1	16 and 12.8 seen, allow unsimplified. May be seen in standardisation formula. $\frac{8\sqrt{5}}{5}$, 3.5777... to at least three significant figures implies correct variance. Incorrect notation penalised.
	$[P(X < 22) = P(Z < \frac{21.5-16}{\sqrt{12.8}})$ $[P(Z < 1.537) = \Phi(1.537)]$	M1	Substituting *their* 16 (not 1.2, 2.5) and *their* 12.8 (not 0.16, *their* 0.119) in the ±standardising formula (any number for 21.5), condone σ^2 or $\sqrt{\sigma}$.
		M1	Using continuity correction 21.5 or 22.5 in *their* standardisation formula.
		M1	Appropriate area Φ, from final process, must be a probability.
	0.938	A1	$0.9375 < p \leqslant 0.938$.
		5	

Question 117

(a)	$P\left(Z > \frac{1.93-1.64}{0.25}\right) = P(Z > 1.16)$	M1	Using ± standardisation formula with 1.93, 1.64 and 0.25 substituted, not σ^2, not $\sqrt{\sigma}$, no continuity correction.
	$1 - 0.8770$	M1	Appropriate area Φ resulting from a standardisation, from final process, must be probability. Note: the appropriate probability answer implies this M1.
	0.123	A1	$0.123 \leqslant p < 0.12303$ If M0 M0, **SC B1** if no standardisation shown.
		3	
(b)	$\frac{1.56-\mu}{\sigma} = -0.44$	B1	$-0.441 < z_1 < -0.439$ or $0.439 < z_1 < 0.441$ seen.
	$\frac{1.86-\mu}{\sigma} = 0.674$	B1	$z_2 = 0.674$ or $z_2 = -0.674$ seen, CAO, critical value.
		M1	Use of the ±standardisation formula once with μ, σ equating to a z-value (not 0.33, 0.67. 0.25, 0.75, 0.6293, 0.5987, 0.7486, 0.7734, $(1 - 0.44)$, $(1 - 0.674)$). Condone continuity correct ±0.005, not $\sigma^2, \sqrt{\sigma}$.
	Solve, obtaining values for μ and σ $\mu = 1.68$, $\sigma = 0.269$	M1	Solve two equations in μ and σ using the elimination method, substitution method or other appropriate approach to obtain values for both μ and σ.
		A1	AWRT $\mu = 1.68$, $\sigma = 0.269$. If one or both of the M marks have not been awarded, **SC B1** for both correct.
		5	

Question 118

(a)	$P(X > 184) = P\left(Z > \frac{184-131}{54}\right)$ [$= P(Z > 0.9815)$]	M1	Use of ±standardisation formula with 184, 131 and 54, no continuity correction. Condone use of σ^2, $\sqrt{\sigma}$.
	$1 - 0.837$ [$= 0.163$]	M1	Calculating the appropriate probability area (leading to their final answer).
	Percentage [$= 0.163 \times 100$] $= 16.3$	A1	AWRT
		3	
(b)	$[P(X < w) = P(Z < \frac{w-131}{54}) = 0.2]$	B1	$-0.842 \leqslant z < -0.8415$ or $0.8415 < z \leqslant 0.842$ seen.
	$\frac{w-131}{54} = -0.842$	M1	Use of the ±standardisation formula with 131, 54, w and a z-value (not 0.2, 0.8, 0.158, 0.508[0], 0.492[0], 0.7881, 0.2119, 0.5593, 0.4407).
	$w = 85.5$	A1	$85.5 \leqslant p \leqslant 85.6$ Signs must be consistent to create a positive answer.
		3	

Question 119

(a)	$P(23 < X < 35) = P(\frac{23-28}{3.3} < Z < \frac{35-28}{3.3})$ $[= P(-1.515 < Z < 2.121)]$	**M1**	Using ±standardisation formula once with 23 or 35, 28 and 3.3, allow σ^2, allow $\sqrt{\sigma}$, no continuity correction.
		A1	One fully correct ± standardisation formula.
	$[= \Phi(2.121) + \Phi(1.5151) - 1]$ $= 0.9830 + 0.9351 - 1$	**M1**	Appropriate area Φ, from final process, must be a probability.
	$= 0.918$	**A1**	AWRT
		4	

(b)	$[P(X > 7.6) = P(Z > \frac{7.6-8.5}{\sigma}) = 0.75]$	**B1**	0.674 or $-$0.674 seen. CAO as critical value.
	$\frac{7.6-8.5}{\sigma} = -0.674$	**M1**	Use of the ±standardisation formula with 7.6, 8.5, σ and a z-value (not 0.75, 0.25, 0.7734, 0.2266, 0.5987 nor $1 - z$-value: 0.326, 0.5987). Condone use of $\frac{\pm 0.9}{\sigma}$.
	$\sigma = 1.34$	**A1**	$1.33 \leqslant \sigma \leqslant 1.34$
		3	

Question 120

(a)	$[P(X > 170) = P(Z >]\frac{170-176}{4.8})$	**M1**	Using ± standardisation formula with 170, 176 and 4.8 substituted appropriately. Condone σ^2 and $\sqrt{\sigma}$. No continuity correction.
	$[\Phi(1.25)] = 0.894$	**M1**	Appropriate area Φ, from final process, must be a probability. Expect final answer > 0.5.
		A1	0.894 or $0.89435 \leqslant p \leqslant 0.8944$. If A0 scored, **SC B1** for 0.894 or $0.89435 \leqslant p \leqslant 0.8944$, WWW.
		3	

(b)	$P(h < 170) = 1 - 0.8944 = 0.1056$	**M1**	$1 - their$ **3(a)** seen or implied by 0.7056 or 0.2944
	$\frac{k-176}{4.8}[= \Phi^{-1}(0.1056+0.6)] = 0.541$	**B1**	$0.540 < z \leqslant 0.541$ or $-0.541 \leqslant z < 0.540$ seen.
		M1	Use of ±standardisation formula with k, 176, 4.8 equated to a z-value (**not** 1.25, 0.7601, 0.2399, 0.7056, 0.7257, 0.8313, 0.253 ±0.894, 0.6, 0.4), not 4.8^2, not $\sqrt{4.8}$, no continuity correction.
	$k = 178.6$	**A1**	CAO (answer required to 1 dp).
		4	

Question 121
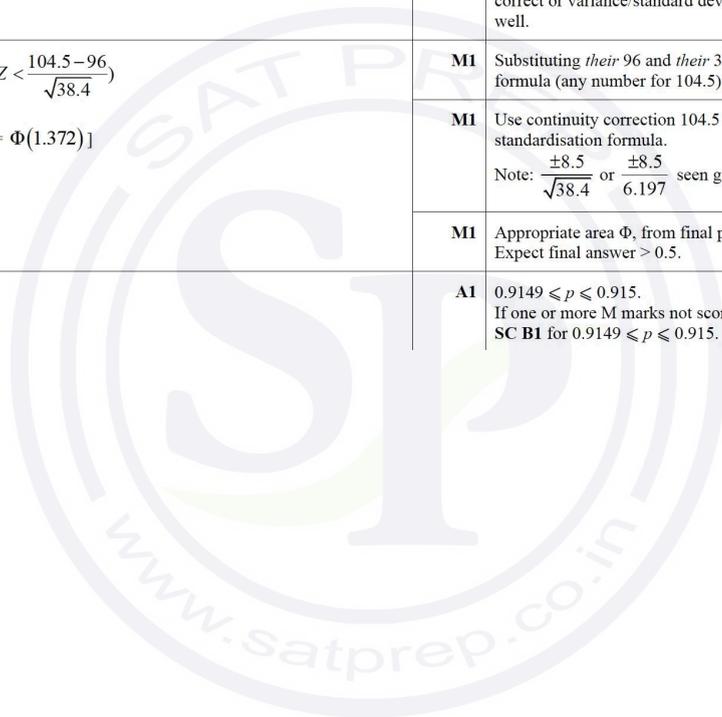
(a)			
$[P(X < 18.2) = P(Z < \dfrac{18.2 - 19.8}{2.4})]$		**M1**	Use of ± standardisation formula with 18.2, 19.8 and 2.4 substituted appropriately, no continuity correction. Condone $\sigma^2 (2.4^2)$ or $\sqrt{\sigma} (\sqrt{2.4})$.
$= [\Phi(-0.6667) = 1 - \Phi(0.6667)]$ $= 1 - 0.7477$		**M1**	Calculating the appropriate probability areas (leading to their final answer, expect < 0.5). Note: 0.432 is z-value of 0.667 so is not an appropriate probability area (M0).
$= 0.252(3)$		**A1**	AWRT 0.252 SOI, accept 0.2525. If one or both M marks not awarded, **SC B1** for AWRT 0.252 SOI, accept 0.2525.
[Expected number = $0.2523 \times 450 = 113.5$,] = 113 or 114		**B1FT**	Strict FT *their* at least 4 figure probability × 450. (Check with calculator). One integer answer only. No indication of 'approximation', e.g. $\approx, \cong, about$.
		4	

(b)			
$[P(X > 25.5) = 0.26$ so $P(Z > \dfrac{25.5 - 23.4}{\sigma}) = 0.26]$		**B1**	$0.643 \leqslant z \leqslant 0.6435$ or $-0.6435 \leqslant z \leqslant -0.643$ seen.
$\dfrac{25.5 - 23.4}{\sigma} = 0.643$		**M1**	± standardisation formula with 25.5, 23.4, σ equating to a z-value, (not $1 - their$ z-value…). Condone continuity correction ±0.05, not σ^2, not $\sqrt{\sigma}$.
$\sigma = 3.27$		**A1**	$3.26 \leqslant \sigma \leqslant 3.27$. Do not award for improper fractions.
		3	

Question 122

(a)			
$\dfrac{182.7 - \mu}{\sigma} = 1.282$ $\dfrac{162.5 - \mu}{\sigma} = -0.253$		**B1**	1.282 or – 1.282 seen, CAO (critical value).
		B1	$-0.2535 < z \leqslant -0.253$ or $0.253 \leqslant z < 0.2535$ seen.
		M1	One standardisation formula, not σ^2, or $\sqrt{\sigma}$, with 182.7 or 162.5 substituted correctly equated to a z value (not 0.9, 0.1, 0.8159, 0.5398, 0.4, 0.6, 0.6554, 0.7257, …).
Solve, obtaining values for μ and σ		**M1**	Either a single expression with one variable eliminated formed or two expressions with both variables on the same side seen with at least one variable value stated.
$\mu = 165.8$, $\sigma = 13.2$		**A1**	Answers must be to at least 1 DP (context).
		5	

(b)	**Method 1**		
$[P(X < 8) = 1 - P(8, 9, 10) =] 1 - ({}^{10}C_8 (0.6)^8 (0.4)^2 + {}^{10}C_9 (0.6)^9 (0.4)^1 + (0.6)^{10})$ $[= 1 - (0.12093 + 0.040311 + 0.0060466)]$		**M1**	One term ${}^{10}C_x (p)^x (1-p)^{10-x}$. With $0 < p < 1, x \neq 0$ or 10.
		A1	Correct unsimplified expression. Allow 10 for ${}^{10}C_9$. Condone omission of last bracket only. If both brackets omitted in unsimplified expression allow recovery for final stated calculation of $1 - 0.1673$ or final answer WRT 0.8327.
$= 0.833$		**B1**	$0.8327 < p \leqslant 0.833$.
Method 2			
$(0.4)^{10} + {}^{10}C_1 (0.6)^1 (0.4)^9 + {}^{10}C_2 (0.6)^2 (0.4)^8 + {}^{10}C_3 (0.6)^3 (0.4)^7 +$ ${}^{10}C_4 (0.6)^4 (0.4)^6 + {}^{10}C_5 (0.6)^5 (0.4)^5 + {}^{10}C_6 (0.6)^6 (0.4)^4 + {}^{10}C_7 (0.6)^7 (0.4)^3$ $[1.0486 \times 10^{-4} + 1.5729 \times 10^{-3} + … + 0.21499]$		**M1**	One term ${}^{10}C_x (p)^x (1-p)^{10-x}$. With $0 < p < 1, x \neq 0$ or 10.
		A1	Correct unsimplified expression.
$= 0.833$		**B1**	$0.8327 < p \leqslant 0.833$.
		3	

Question 123

(a)			
$P(83 < X < 95) = P(\dfrac{83-90}{8} < Z < \dfrac{95-90}{8})$		**M1**	Using ± standardisation formula with 90, 8 and *either* 83 *or* 95. Not σ^2, not σ, no continuity correction.
$= P(-0.875 < Z < 0.625)$		**A1**	Both ±0.875 OE and ±0.625 OE seen. If M0 scored, **SC B1** for both ±0.875 and ±0.625 seen
$[\Phi(0.625) + \Phi(0.875) - 1]$ $= 0.7340 + 0.8092 - 1$		**M1**	Calculating the appropriate probability area, leading to their final probability. Expect final answer > 0.5.
$= 0.543$		**A1**	0.5432, $0.543 \leqslant p < 0.5435$. Only dependent on the 2nd M mark.
		4	

(b)			
[Mean $=160 \times 0.6 =]96$ [Var $=160 \times 0.6 \times 0.4 =]38.4$		**B1**	96 and 38.4 seen, allow unsimplified. May be seen in the standardisation formula. $\left(\dfrac{8\sqrt{15}}{5}, 6.19677\ldots \text{to at least 4 SF} \text{ implies correct variance}\right)$ Withold mark if variance clearly identified as standard deviation, condone N(96, $\sqrt{38.4}$) if standardisation formula correct or variance/standard deviation correctly stated as well.
$P(X < 105) = P(Z < \dfrac{104.5 - 96}{\sqrt{38.4}})$		**M1**	Substituting *their* 96 and *their* 38.4 into the ±standardising formula (any number for 104.5), condone σ^2 or $\sqrt{\sigma}$.
$[P(Z < 1.372) = \Phi(1.372)]$		**M1**	Use continuity correction 104.5 or 105.5 in *their* standardisation formula. Note: $\dfrac{\pm 8.5}{\sqrt{38.4}}$ or $\dfrac{\pm 8.5}{6.197}$ seen gains M2 BOD.
		M1	Appropriate area Φ, from final process, must be a probability. Expect final answer > 0.5.
$= 0.915[0]$		**A1**	$0.9149 \leqslant p \leqslant 0.915$. If one or more M marks not scored, **SC B1** for $0.9149 \leqslant p \leqslant 0.915$.

Question 124

(a)	$[P(56 < X < 75) =] \; P\left(\dfrac{56-65.8}{9.6} < Z < \dfrac{75-65.8}{9.6}\right)$ $\left[= P(-1.0208 < Z < 0.9583)\right]$	**M1**	Use of ±standardisation formula once with 65.8, 9.6 and either 56 or 75. No continuity correction, not σ^2, not $\sqrt{\sigma}$.
	$[\Phi(0.9583) + \Phi(1.0208) - 1]$ $= 0.8309 + 0.8463 - 1$ or $0.8309 - (1 - 0.8463)$ or $0.8309 - 0.1537$ or $(0.8309 - 0.5) + (0.8463 - 0.5)$ or $0.3309 + 0.3463$	**M1**	Appropriate probability area Φ, from final process. Must be a probability. (expect > 0.5).
	$= 0.677$	**A1**	AWRT. If 1 or more M mark not awarded, **SC1** for final answer 0.677 AWRT WWW.
		3	
(b)	$\left[P\left(Z < \dfrac{59.1-72.4}{\sigma}\right) = 0.10\right]$	**B1**	1.282 or − 1.282 seen cao (critical value).
	$\dfrac{59.1-72.4}{\sigma} = -1.282$	**M1**	±standardisation formula with 59.1, 72.4, σ equating to a z-value (not 0.1, 0.9, 0.5398, 0.4602, 0.8159, 0.1841). Condone continuity correction of ±0.05, not σ^2 and not $\sqrt{\sigma}$. Condone $\pm\dfrac{13.3}{\sigma} = -1.282$.
	$\sigma = 10.4$	**A1**	AWRT. Signs must be consistent throughout. If M1 not awarded, **SC1** $\sigma = 10.4$ WWW.
		3	
(c)	$\left[(0.9)^4 (0.1) = \right] 0.0656[1]$	**B1**	
		1	
(d)	**Method 1**		
	$[P(X < 5) =] \; 1 - (0.9)^4$	**M1**	$1 - (0.9)^d \; d = 4, 5.$
	$= 0.344$	**A1**	0.3439.
	Method 2		
	$[P(X < 5) =] \; 0.1 + (0.1)(0.9) + (0.1)(0.9)^2 + (0.1)(0.9)^3$ or $1 - \left((0.1)(0.9)^4 + (0.1)(0.9)^5 + (0.1)(0.9)^6 + (0.9)^7\right)$	**M1**	$0.1 + (0.1)(0.9) + (0.1)(0.9)^2 + (0.1)(0.9)^3 \left[+(0.1)(0.9)^4\right]$ or $1 - \left(\left[(0.1)(0.9)^4\right] + (0.1)(0.9)^5 + (0.1)(0.9)^6 + (0.9)^7\right)$.
	$= 0.344$	**A1**	0.3439.
		2	

Question 125

(a)	$[P(X < 2.65) =] \; P(Z < \dfrac{2.65 - 2.50}{0.12}) \; [= P(Z < 1.25)]$	**M1**	Substituting 2.65, 2.50 and 0.12 into the ±standardisation formula allow σ^2 or $\sqrt{\sigma}$. Condone continuity correction ±0.005.
	$= 0.894$	**A1**	$0.894 \leqslant p \leqslant 0.8944$.
		2	
(b)	$P(Z > \dfrac{2.50 + 1.65 \times 0.12 - 2.50}{0.12}) \; = P(Z > 1.65)$	**M1**	Seeing $2.50 + 1.65 \times 0.12$ or 2.698 and 2.50 and 0.12 substituted into the ±standardisation formula with a direct attempt to find the probability area. Accept numerator of 1.65×0.12. Accept Z linked to 1.65 with a direct attempt to find the probability area. Do not allow σ^2 or $\sqrt{\sigma}$. No continuity correction.
	$= 1 - 0.9505 = 0.0495$	**A1**	AWRT.
	Expected number $= 0.0495 \times 160 = 7.92$, so 7 or 8	**B1 FT**	Strict **FT** *their* at least 4-DP calculated probability, seen anywhere (not a *z*-value). Final answer must be a single positive integer value, no approximation or rounding stated.
		3	
(c)	$\dfrac{1.26 - \mu}{\sigma} = -0.739$	**B1**	$0.738 < z_1 < 0.740 \; or \; -0.740 < z_1 < -0.738$ seen.
		B1	$0.150 < z_2 < 0.152 \; or \; -0.152 < z_2 < -0.150$ seen.
	$\dfrac{1.35 - \mu}{\sigma} = -0.151$	**M1**	Use of the ±standardisation formula once with μ, σ equating to a *z*-value (not 0.77, 0.23, 0.44, 0.56, 0.7794, 0.5910, 0.6700, 0.7123, 0.2206, 0.4090, 0.3300, 0.2877). No continuity correction, not σ^2, not $\sqrt{\sigma}$.
	Solve, obtaining values for μ and σ $\mu = 1.37$, $\sigma = 0.153$	**M1**	Solve 2 equations in μ and σ using the elimination method, substitution method or other appropriate approach to obtain values for both μ and σ.
		A1	AWRT $\mu = 1.37$, $\sigma = 0.153$. If one or both the **M** marks have been withheld, **SCB1** for both correct.
		5	

Question 126

(a)	$P\left(\dfrac{72.4-74.8}{3.2} < Z < \dfrac{76.3-74.8}{3.2}\right)$	**M1**	Use of ±standardisation formula once with 74.8, 3.2 and either 72.4 or 76.3. No continuity correction, not σ^2, not $\sqrt{\sigma}$.
	$[\Phi(0.75)+\Phi(0.4688)-1]$ $= 0.7734 + 0.6804 - 1$ or $(0.7734-0.5)+(0.6804-0.5)$ or $0.7734 - 0.3196$ or $0.6804 - 0.2266$ or $0.2734 + 0.1804$	**M1**	Calculating the appropriate probability area, must be a probability (assume a 4SF value in the calculation it is a probability, assume a 3SF value in the calculation it is not a probability). (leading to their final answer, expect < 0.5). Unless there is a misread, the probability area calculation must be structured as shown.
	$= 0.4538$	**A1**	AWRT 0.454 WWW.
	Expected number = $0.4538 \times 120 = 54.46$ so 54 (or 55) (One integer answer stated)	**B1 FT**	Strict **FT** *their* 4-figure probability × 120 (check with calculator). One integer answer. No indication of approximation, e.g. $\approx, \cong$, about, 2SF.
		4	
(b)	$\dfrac{0.202-\mu}{\sigma} = 0.842$	**B1**	$0.841 < z_1 < 0.843$ *or* $-0.843 < z_1 < -0.841$ seen.
		B1	$0.582 < z_2 < 0.584$ *or* $-0.584 < z_2 < -0.582$ seen.
	$\dfrac{0.185-\mu}{\sigma} = -0.583$	**M1**	Use of the ±standardisation formula once with μ, σ equating to a z-value (not 0.20, 0.80, 0.28, 0.72, 0.5793, 0.4207, 0.6103, 0.3897, 0.7881, 0.2119, 0.7642, 0.2358, −0.417, 0.417, -0.158 0.158, etc). No continuity correction, not σ^2, not $\sqrt{\sigma}$.
	Solve, obtaining values for μ and σ $\mu = 0.192$, $\sigma = 0.0119$	**M1**	Solve 2 equations in μ and σ with an attempt at the elimination method, substitution method or other appropriate approach to obtain values for both μ and σ.
		A1	AWRT $\mu = 0.192$, $\sigma = 0.0119$. There must be consistency with signs in the solution, e.g. $\sigma = \dfrac{0.017}{-1.425} = 0.0119$ is not acceptable, **A0**. If one or both the **M** marks have been withheld, **SCB1** for both correct WWW.
		5	
(c)	**Method 1**		
	$[P(X < 3) = P(0, 1, 2) =]$ $0.8^{10} + {}^{10}C_1\,0.8^9\,0.2 + {}^{10}C_2\,0.8^8\,0.2^2$ $[= 0.107374 + 0.268435 + 0.301989]$	**M1**	One term of the form ${}^{10}C_x\left(p\right)^x\left(1-p\right)^{10-x}$, $0 < p < 1, x \neq 0$ or 10.
		A1	Correct un-simplified expression.
	0.678	**B1**	$0.677 < p \leqslant 0.678$.
	Method 2		
	$[P(X < 3) = 1 - P(3, 4, 5, 6, 7, 8, 9, 10) =]$ $1 - \{{}^{10}C_3\,0.8^7\,0.2^3 + {}^{10}C_4\,0.8^6\,0.2^4 + \ldots + 0.2^{10}\}$	**M1**	One term of the form ${}^{10}C_x\left(p\right)^x\left(1-p\right)^{10-x}$, $0 < p < 1, x \neq 0$ or 10.
		A1	Correct un-simplified expression.
	0.678	**B1**	$0.677 < p \leqslant 0.678$
		3	

Question 127

	$P\left(Z < \dfrac{1.48-\mu}{0.14}\right) = 0.22$	**B1**	$0.771 < z < 0.773$ or $-0.773 < z < -0.771$ seen.
	$\dfrac{1.48-\mu}{0.14} = -0.772$	**M1**	Use of the ±standardisation formula with μ, 1.48 and 0.14 and equating to a z-value (not 0.78, 0.22, 0.5871, 0.7823, 0.228). Condone σ^2, $\sqrt{\sigma}$ and continuity correction ±0.005.
	$\mu = 1.59$	**A1**	$1.585 < \mu \leqslant 1.59$. If **M0** scored **SC B1** for correct answer WWW.
		3	