AS-Level
Topic : Normal Distribution
May : 2013-May :2023
Answers

Question 1

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

Question 2

(i)	$P(x < 440)$ $= P\left(z < \frac{440-445}{3.6}\right) = 1 - \Phi(1.389)$	M1		Standardising no cc no sq or sq rt
	$= 1 - 0.9176$	M1		Correct area $(1 - \Phi)$ oe (indep)
	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±
	$\frac{c}{3.6} = 1.881$	M1		Equation with ± c/3.6 or 2c/3.6 only = z or prob (can be implied)
	$c = 6.77$	A1	**[3]**	Correct answer accept 6.78

Question 3

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

Question 4

4	**(a)**	$P(y < 0) = P\left(z < \frac{0 - \mu}{\mu / 2}\right)$	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 $1.859 = \frac{2.1 - 2.04}{\sigma}$	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
$P(x \quad 47) = P\left(z > \frac{46.5 - 50}{\sqrt{42.857}}\right) =$	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
$\frac{\pm q}{7.4}$ *or* $\frac{\pm 2q}{7.4} = z$ *or probabilty* (o.e.)	M1		Standardising, no cc, no sq, no sq rt
$q = 4.31$	A1	3	correct answer
(b) $\frac{0.5\mu - \mu}{\sigma} = \frac{\pm 0.5\mu}{\sigma}$	M1		Standardising attempt some μ/σ allow cc, sq rt, sq Can be implied
$\frac{0.2\sigma^2}{\sigma} = -0.2\sigma = -0.580$	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

2 $P(13.6 < X < 14.8) = P\left(\frac{13.6-14}{0.52} < z < \frac{14.8-14}{0.52}\right)$	M1		Standardising 1 expression, no cc, no sq rt, no sq, ±, mean on num.
$= P(-0.7692 < z < 1.538)$ $= \Phi(1.538) - [1 - \Phi(0.7692)]$	M1		$\Phi1 + \Phi2 - 1$ (indep) oe ($\Phi2 - \Phi1$ if cc used)
$= 0.9380 - [1 - 0.7791]$ $= 0.7171$	A1		Correct probability rounding to 0.72 here
$P(8) = (0.7171)^8(0.2829)^2 {}_{10}C_8$	M1		Binomial expression 10C8 p^8q^2, $\Sigma p + q = 1$, any p
$= 0.252$	A1	5	Correct answer (rounding to 0.252)

Question 8

(i) $P(4, 5, 6) = (0.22)^4(0.78)^4 8C4 + (0.22)^5(0.78)^3 8C5 + (0.22)^6(0.78)^2 8C6$	M1 M1		Bin term with ${}_8C_r\, p^r (1-p)^{8-r}$ seen $r \neq 0$ any $p < 1$ Summing 2 or 3 bin probs $p = 0.22$, $n = 8$
$= 0.0763$	A1	**[3]**	Correct answer
(ii) prob = 0.13	B1		Correct prob can be implied
mean = $300 \times 0.13 = 39$ var = $300 \times 0.13 \times 0.87 = 33.93$	B1ft		Correct unsimplified np and npq ft wrong 0.13
$P(30 < x < 50) = P\left(\frac{30.5-39}{\sqrt{33.93}} < z < \frac{49.5-39}{\sqrt{33.93}}\right)$	M1 M1		Standardising a value need sq rt Cont correction 30.5 / 31.5 or 48.5/49.5 only
$= P(-1.4592 < z < 1.8026)$ $= \Phi(1.8026) + \Phi(1.4592) - 1$	M1		Correct area $\Phi_1 + \Phi_2 - 1$ oe
$= 0.9643 + 0.9278 - 1 = 0.892$	A1	**[6]**	Rounding to correct answer SC $P(31,..49)=300C31(0.13)^{31}(0.87)^{269} + \ldots +300C49$ etc.) B1B1

Question 9

(i) $z = 0.878$	B1		± 0.878, 0.88, rounding to 0.88 seen
$\frac{190-160}{\sigma} = 0.878$	M1		$(190 - 160)/\sigma$ = something
$\sigma = 34.2$	A1	**[3]**	Correct answer
(ii) P(at least 1) = 1 – P(0)	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
$= 1 - (0.81)^{12} = 0.920$	A1	**[2]**	Correct answer accept 0.92

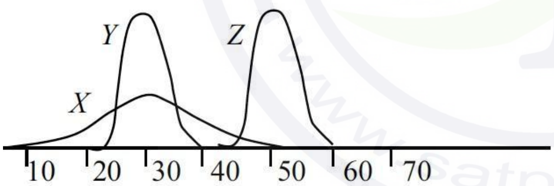
Question 10

$P(x < -2.4) = P\left(z < \frac{-2.4 - 1.5}{3.2}\right)$	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
$\frac{c - 14.2}{3.6} = -1.406$	M1		Standardising allow sq rt no cc
$c = 9.14$	A1	3	Correct answer
(ii) $P\left(\frac{15 - 14.2}{3.6}\right) < z < \left(\frac{16 - 14.2}{3.6}\right)$	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(at least 2) = 1 – P(0, 1) $= 1 - (0.8964)^7 - (0.8964)^6(0.1036)_7C_1$	M1		Binomial term with ${}_7C_r p^r(1-p)^{7-r}$ seen $r \neq 0$ any $p < 1$
$= 1 - 0.8413$	M1		1 – P(0), 1 – P(1), 1 – P(0, 1) seen their p
$= 0.159$	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 $\pm$ 1.28 seen
$-1.282 = \frac{t - 6.5}{1.76}$	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(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)	$X \sim N(160, 32)$	B1		Unsimplified 160 and 32 seen
	$P(162.5 < x < 173.5) =$ $P\left(\dfrac{162.5-160}{\sqrt{32}} < z < \dfrac{173.5-160}{\sqrt{32}}\right)$	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 Φ (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) $P(<1.2) = P\left(z < \dfrac{1.2-1.9}{0.55}\right) = P(z < -1.2727)$ $= 1 - \Phi(1.273) = 1 - 0.8986$	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
$= 0.1014$	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		± 2.325 to ± 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		Standardising, need sq rt
		M1		Cont correction either 114.5 or 113.5
	$= P(z > -1.004)$	M1		Correct area consistent with their working
	$= \Phi(1.004) = 0.842$	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 ± , no cc no sq rt no sq
		$= \Phi(0.9659)$ $= 0.833$	A1	2	Correct answer
	(ii)	$z = 0.674$	B1		Accept ± 0.674 or 0.675 only
		$\dfrac{q-7.15}{0.88} = 0.674$	M1		Standardised eqn = ± 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 $\Phi_2 - \Phi_1$
	$\Phi(1.089) - \Phi(0.643) = 0.8620 - 0.7399$ $= 0.1221$	A1		Correct answer rounding to 0.12
	$0.1221 \times 250 = 30.5$	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		$\pm$ 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(large) = $1 - \Phi\left(\dfrac{29 - 21.7}{6.5}\right)$	M1 M1		Standardising no cc no sq rt Correct area $1 - \Phi$
	$= 1 - \Phi(1.123) = 1 - 0.8692$ $= 0.1308$	A1		Rounding to 0.13
	$P(0,1) = (0.8692)^{8} + {}^8C_1(0.1308)(0.8692)^7$	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 without a 1
	$(0.8692)^n < 0.02$	M1		solving attempt (could be trial and error) – may be implied by their answer
	Least number = 28	A1	**[3]**	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,
$1.136 = \frac{195 - \mu}{22}$	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)	$\text{prob} = p\left(z < \frac{30 - 35.2}{4.7}\right)$	M1		Standardising no sq rt no cc no sq
	$= P(z < -1.106)$ $= 1 - 0.8655 = 0.1345$	M1 A1		$1 - \Phi$ 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)	$\Phi(t) = 0.648 \quad z = 0.380$	B1		0.648 seen
	$0.380 = \frac{t - 35.2}{4.7}$	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)	$\frac{7 - \mu}{\sigma} = -0.8$ so $7 - \mu = -0.8\sigma$	B1 B1		± 0.8 seen ± 0.44 seen
	$\frac{10 - \mu}{\sigma} = 0.44$ 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
	$\mu = 8.94 \quad \sigma = 2.42$	A1	5	Correct answers

Question 27

(i)	$P(5, 6, 7) = {}^8C_5(0.68)^5(0.32)^3 + {}^8C_6(0.68)^6(0.32)^2 + {}^8C_7(0.68)^7(0.32)$	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
	$P(x > 337) = P\left(z > \frac{337.5 - 340}{\sqrt{108.8}}\right)$	M1		standardising with sq rt must have used 500
		M1		cc either 337.5 or 336.5
	$= P(z > -0.2396)$ $= 0.595$	M1		correct area (> 0.5) must have used 500
		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
$\frac{3.2 - \mu}{0.714} = -1.96$	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
	$P(\text{ at least } 152) = P\left(z > \left(\frac{151.5 - 144}{\sqrt{132.48}}\right)\right)$	**M1** **M1**		standardising, with √ 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**		$\pm$ 1.127 seen accept rounding to $\pm$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 $\surd$, ^{2}, allow cc
	$= \Phi(1.639) - \Phi(0.6147)$	**M1**		Correct area $\Phi2 - \Phi1$
	$= 0.9493 - 0.7307$ $= 0.2186$	**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
		$= 0.8657$ Number of days $= 365 \times 0.0.8657$	**A1**		Prob rounding to 0.866
		$= 315$ or 316 (315.98)	**B1**$\surd$	4	Correct answer ft their wrong prob if previous A0, $p < 1$, ft must be accurate to 3sf
	(ii)	$z = 1.165$	**B1**		$\pm$ 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 Normal approx. to Binomial. M0, M0, A0	**A1**	3	Correct answer
(b)		$P(<2\mu) = P\left(z > \dfrac{2\mu-\mu}{\sigma}\right) = P(z < 1.5)$	**M1** **M1**		Standardising with μ and σ 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)	$\mu = 100\times1/3 = 33.3$, $\sigma = 100\times1/3\times2/3 = 22.2$ $P(x \leqslant 37) = P\left(z \leqslant \dfrac{37.5 - \frac{100}{3}}{\sqrt{\frac{200}{9}}}\right) = P(z \leqslant 0.8839)$ = 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 $\pm$ 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**		Eliminating μ or σ
	$= 0.885$	**A1**	3	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)	$P\left(\bar{R}\bar{R}\bar{R}R\right) = 0.35 \times 0.35 \times 0.35 \times 0.65$	**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
	$= P(z > 0.5526)$ $= 1 - \Phi(0.5526) = 1 - 0.7098$	**M1**		cc either 53.5 or 54.5
		M1		correct area < 0.5 i.e. 1 – Φ - must be from working with 54
	$= 0.290$	**A1**	[6]	

Question 37

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

Question 38

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

Question 39

(i)	0.72	**B1** [1]	
(ii)	$np = 180\times0.72$, $npq = 180\times0.72\times0.28$ X~N(129.6, 36.288)	**B1**√	180 × 0.72, 180 × 0.72 × 0.28 seen, their values or correct
	$P(x > 115) = P\left(z > \frac{115.5 - 129.6}{\sqrt{36.288}}\right)$	**M1**	Standardising (±) 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)	$P(x < 3.0) = P\left(z < \frac{3.0 - 2.6}{0.25}\right)$ $+ P(z < 1.6) = 0.945$	**M1** **M1** **A1** [3]	Standardising no sq rt no cc Correct area i.e. prob > 0.5 legit
(ii)	X~B(500, 0.9452) ~ N(472.6, 25.898) $P\left(z > \frac{479.5 - 472.6}{\sqrt{25.89848}}\right) = P(z > 1.3558)$ $= 1 - 0.9125 = 0.0875$	**M1** **M1** **M1** **M1** **A1** [5]	500 ×'0.9452' and 500×'0.9452'×('1 – 0.9452') seen oe Standardising must have sq rt. All M marks indep cc either 479.5 or 480.5 seen correct area i.e. < 0.5
(iii)	500× 0.9452 and 500× (1–0.9452) are both > 5	**B1**√ [1]	must see at least 500× 0.0548 > 5oe 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)	$(0.15)^1(0.1)^2(0.75)^2 \times 5!/2!2!$ $= 0.0253$ or $81/3200$	**M1** **M1** **A1**	 [3]	Mult probs for options, $(0.15)^a(0.1)^b(0.75)^c$ where a + b + c sum to 5 Mult by 5!/2!2! oe
(iii)	mean = 365×0.15 (= 54.75 or 219/4) Var = $365\times 0.15\times0.85$ (= 46.5375 or 3723/80) $P(x > 44) = P\left(z > \frac{44.5-54.75}{\sqrt{46.5375}}\right)$ $= P(z > -1.5025)$ $= 0.933$	**B1** **M1** **M1** **M1** **A1**	 [5]	Correct unsimplified mean **and** var, oe ± Standardising need sq rt cc either 44.5 (or 43.5) Φ Correct answer accept 0.934

Question 43

(i)	$P(\text{small}) = P\left(z < \frac{95-150}{50}\right)$ $= P(z < -1.1)$ $= 1 - 0.8643$ $= 0.136$	**M1** **M1** **A1**	 [3]	± standardising using 95, no cc, no sq, no sq rt $1 - \Phi$ (in final answer)
(ii)	$z = 1.282$ $1.282 = \frac{x-150}{50}$ $x = 214$ g	**B1** **M1** **A1**	 [3]	± rounding to 1.28 Standardised eqn in their z allow cc
(iii)	P(small) = 0.1357, P(large) = 0.1357 symmetry P(medium) = $1 - 0.1357\times2 = 0.7286$ **AG**	 **B1**	 [1]	 Correct answer legit obtained
(b)	Expected cost per banana = $0.1357\times10 + 0.1357\times25 + 0.7286\times20 = 19.3215$ cents Total cost of 100 bananas = 1930 (cents) ($19.30)	***M1** **DM1** **A1**	 [3]	Attempt at multiplying each 'prob' by a price and summing Mult by 100

Question 44

(i)	$P(<4.5) = P\left(z < \frac{4.5-4.2}{0.6}\right) = P(z < 0.5)$	M1		Standardising once no cc no sq no sq rt
	$= 0.6915$			
	$P(<3.5) = P\left(z < \frac{3.5-4.2}{0.6}\right) = P(z < -1.167)$			
	$= 1 - 0.8784 = 0.1216$	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
	$1.175 = \frac{t-4.2}{0.6}$	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±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 $= 100\times0.2 = 20$ Var $= 100\times0.2\times0.8 = 16$	B1		Correct unsimplified mean and var
	P(at most 30) $= P\left(z < \frac{30.5-20}{\sqrt{16}}\right)$	M1		Standardising must have sq rt, their μ, variance
		M1		cc either 29.5 or 30.5
		M1		Correct area Φ, from final process
	$= P(z < 2.625)$ $= 0.996$	A1	[5]	

Question 46

(i)	$P(<1) = P\left(z < \frac{1-1.04}{0.017}\right) = P(z < -2.353)$	M1		Standardising no cc, no √ or sq
	$= 1 - 0.9907$	M1		1 – Φ (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
	$-1.765 = \frac{1-\mu}{0.017}$	M1		Standardising must have a z-value, allow √ 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)

Question 47

$z = 0.674$	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)	$0.674 = \dfrac{8.8-\mu}{\sigma} \Rightarrow 0.674\sigma = 8.8 - \mu$	B1	±0.674 seen
	$-0.935 = \dfrac{7.7-\mu}{\sigma} \Rightarrow -0.935\sigma = 7.7 - \mu$	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

$np = 160\times0.1$ (16) $npq = 160\times0.1\times0.9$ (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 √
	M1	16.5 or 17.5 seen in standardised eqn for continuity correction
$= 1 - 0.6536$	M1	Correct area from their mean (1 – Φ), final solution
$= 0.346$	A1	
Total:	5	

Question 50

4(a)	$P(x > 0) = P\left(z > \pm\frac{0-\mu}{\sigma}\right)$ $= P\left(z > \frac{-\mu}{\mu/1.5}\right)$ or $P\left(z > \frac{-1.5\sigma}{\sigma}\right)$	M1	±Standardising, in terms of μ and/or σ with 0 - …. in numerator, no continuity correction, no √
	$= P(z > -1.5)$	A1	Obtaining z value of ±1.5 by eliminating μ and σ, SOI
	$= 0.933$	A1	
	Total:	3	
4(b)	$z = -1.151$	B1	$\pm z$ value rounding to 1.1 or 1.2
	$-1.151 = \frac{70-120}{s}$	M1	± Standardising (using 70) equated to a z-value, no cc, no squaring, no √
	$\sigma = 43.4$ 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
$P(x > 100) = P\left(z > \frac{99.5-90}{\sqrt{60}}\right) = P(z > 1.2264)$	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

5(i)	$(z =)\frac{4.2-3.9}{\sigma}$	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 $= 1.5267$ $\quad = -1.5267$	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
	$0.674 = \frac{6.8 - \mu}{0.25\mu}$	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, nc z-value needed can be 0.75 or 0.7734 need a value for μ
	$\mu = 5.82$	A1	
	Total:	4	
(a)(ii)	$P(X < 4.7) = P\left(z < \frac{4.7 - 5.819}{1.4548}\right)$	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)	$P(<15.75) = P\left(z < \frac{15.75 - 16}{0.2}\right) = 1 - P(z < 1.25) = 1 - 0.8944 = 0.1056$ 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(usable) = 1 – 0.2112 = 0.7888	B1	$2\phi - 1$ OE for required prob, (final solution)
	Usable rods=1000 × 0.7888 =	DM1	Mult their prob by 1000 dep on recognisable attempt to standardise
	788 or 789	A1	
	Total:	4	

Question 54

(i)	$P(t > 6) = P\left(z > \frac{6 - 5.3}{2.1}\right) = P(z > 0.333)$	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
	$1.645 = \frac{x - 5.3}{2.1}$	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(misses bus) = $P(t < 0)$	*M1	Seeing t linked to zero
	$= P\left(z < \frac{0 - 5.3}{2.1}\right) = P(z < -2.524) = 1 - \Phi(2.524)$ $= 1 - 0.9942$	DM1	Standardising with $t = 0$, no continuity correction, no sq, no sq rt
	$= 0.0058$	A1	
		3	

Question 55

(i)	$P(>65) = P\left(z > \frac{65-61.4}{12.3}\right) = P(z > 0.2927)$	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
	$1.105 = \frac{k-61.4}{12.3}$	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)	$2.326 = \frac{97.2-\mu}{\sigma}$	B1	± 2.326 seen (Use of critical value)
	$-0.44 = \frac{55.2-\mu}{\sigma}$	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
	$= 1\text{-}0.883103 = 0.117\ (0.116896)$	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)**,
	$P(\geqslant 30) = P\left(z > \frac{29.5-32.73}{\sqrt{28.9}}\right) = P(z > -0.6008)$	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 >….) in final solution
	$= 0.726$	A1	
		5	

Question 57

(i)	$P(<570) = P\left(z < \frac{570-500}{91.5}\right) = P(z < 0.7650)$ $= 0.7779$	M1	Standardising for either 570 or 390, no cc, no sq, no √
	$P(<390) = P\left(z < \frac{390-500}{91.5}\right) = P(z < -1.202)$	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)	$1.645 = \left(\frac{x-500}{91.5}\right)$	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 $z = \Phi^{-1}(0.5853)$
	$0.215 = \frac{k-500}{91.5}$	M1	Standardising and solving, accept cc, sq, sq rt
	$k = 520$	A1	
		5	

Question 58

3(i)	$P(4) + P(5) = {}^5C_4\left(\frac{1}{4}\right)^4\left(\frac{3}{4}\right)^1 + {}^5C_5\left(\frac{1}{4}\right)^5\left(\frac{3}{4}\right)^0$	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 $\frac{1}{64}$	A1	
		3	
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
	$P(X < 50) = P\left(Z < \frac{49.5-40}{\sqrt{30}}\right)$	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 = ±1.78	**A1**	z value: ± 1.78
	$\dfrac{10}{\sigma} = 1.78$	**M1**	$(410\text{-}400)/\sigma = \textit{their } z$ (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 × 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(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)	$np = 250 \times 0.168 = 42, \quad npq = 34.944$	**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**	± 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 Φ(> 0.5 for + z and < 0.5 for –z)in their final answer
	$= 0.898$	**A1**	Correct final answer
	Total:	**5**	

Question 61

(i)	$z = 0.674$	**B1**	z value ± 0.674
	$0.674 = \frac{0 - -3}{\sigma}$	**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 ${}^{8}C_{x}(0.75)^{x}(0.25)^{8-x}$ any x
	$= (0.75)^8 + {}^{8}C_1(0.25)(0.75)^7$	**M1**	Correct unsimplified answer, may be implied by numerical values
	$0.1001 + 0.2670 \quad = 0.367$	**A1**	Correct answer
	Method 2 $1 - P(8,7,6,5,4,3,2) = 1 - (0.25)^8 - {}^{8}C_1(0.75)(0.25)^7 - \ldots$	**M1**	Any bin of form ${}^{8}C_{x}(0.75)^{x}(0.25)^{8-x}$ any x
	$- {}^{8}C_2(0.75)^6(0.25)^2$	**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 $\sigma^2 = 29.6$, $\sigma = 5.438$)
	$P(\geqslant 50) = P\left(z > \frac{49.5 - 45.5}{\sqrt{29.575}}\right) = P(z > 0.7355)$	**M1**	Standardising, using $\pm\left(\frac{x - \textit{their}\ \text{mean}}{\textit{their}\ \sigma}\right)$, 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
	$-1.282 = \frac{440 - \mu}{9}$	M1	±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
	$P(x > 26) = P\left(z > \frac{26.5 - 31.9}{\sqrt{24.882}}\right) = P(z > -1.08255)$	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
	$2.4 = \frac{36800 - \mu}{\sigma}$	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
	$-0.5 = \frac{31000 - \mu}{\sigma}$	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)	$P(X < 3\mu) = P\left(z < \frac{3\mu - \mu}{(4\mu/3)}\right)$ or $P = \left(z < \frac{(9\sigma/4) - (3\sigma/4)}{\sigma}\right)$	M1	Standardise, in terms of one variable, accept σ^2 or $\sqrt{\sigma}$
	$P(z < \frac{6}{4})$	M1	$\frac{6}{4}$ or $\frac{6}{4\sigma}$ seen
	$= 0.933$	A1	Correct final answer
		3	

Question 66

(i)	$z_1 = \pm\frac{90-120}{24} = -\frac{5}{4}$, $z_2 = \pm\frac{140-120}{24} = \frac{5}{6}$	M1	At least one standardisation, no cc, no sq rt, no sq using 120 and 24 and either 90 or 140
	$= \Phi\left(\frac{20}{24}\right) - \Phi\left(-\frac{30}{24}\right)$	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 Φ – Φ 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($Z > \frac{1800-2000}{\sigma}$) = 0.96	B1	± 1.75 seen
	$\Phi(\frac{200}{\sigma}) = 0.96$ $\frac{200}{\sigma} = 1.751$	M1	$z = \pm\frac{1800-2000}{\sigma}$, allow cc, allow sq rt, allow sq equated to a z-value
	$\sigma = 114$	A1	Correct final answer www
		3	
(ii)	Mean = 300 × 0.2 = 60 and variance = 300 × 0.2 × 0.8 = 48	B1	Correct unsimplified mean and variance
	P(X < 70) = P($Z > \frac{69.5-60}{\sqrt{48}}$)	M1	$Z = \pm\frac{x - their\ 60}{\sqrt{their\ 48}}$
	$= \Phi(1.371)$	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)	$P(X<4)=P\left(Z<\frac{4-3.24}{0.96}\right)$	M1	±Standardisation formula, no cc, no sq rt, no square
	$= P\ (Z<0.7917)\ =\ 0.7858$	A1	0.7855 < p ⩽ 0.7858 or p = 0.786 Cao (implies M1A1 awarded), may be seen used in calculation
	their 0.7858 × 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)	$P(X<k)=P(Z<\frac{k-3.24}{0.96})=0.8$	B1	(z=) ± 0.842 seen
	$\frac{k-3.24}{0.96}=0.842$	M1	$z=\pm\frac{k-3.24}{0.96}$, 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 × 0.9332 – 1 oe	M1	Correct final area expression using *their* probabilities
	= 0.866	A1	Correct final answer
		3	
'(b)	$P(Y>0)=P\left(Z>\frac{0-\mu}{\sigma}\right)=P\left(Z>\frac{0-\mu}{3\mu/4}\right)$ or $P\left(Z>\frac{0-\left(\frac{4\sigma}{3}\right)}{\sigma}\right)$	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)	$P(X<29.4)=P(Z<\frac{29.4-31.4}{\sqrt{3.6}})$ $= P(Z<-1.0541)$	M1	Standardise, no cc, must have sq rt.
	$= 1-0.8540$	M1	Obtain 1 – prob
	= 0.146	A1	Correct final answer
		3	
(b)	$P(X<12)=\frac{42}{400}=0.105$ and $P(X>19)=\frac{58}{400}=0.145$	M1	Eqn with μ,σ and a *z*-value. Allow cc, wrong sign, but not $\sqrt{\sigma}$ or σ^2
	$\frac{12-\mu}{\sigma}=-1.253$	B1	Any form with *z* value rounding to ±1.25
	$\frac{19-\mu}{\sigma}=1.058$	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 × 0.8 = 160: var = 200 × 0.8 × 0.2 = 32	**B1**	Both unsimplified
	$P(X > 166) = P(Z > \frac{166.5 - 160}{\sqrt{32}})$	**M1**	Standardise, $z = \pm\frac{x - their160}{\sqrt{their32}}$ 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)	$P(X < 132) = P\left(Z < \frac{132 - 140}{12}\right) = P(Z < -0.6667)$	**M1**	Using ± standardisation formula, no continuity correction, not σ^2 or $\sqrt{\sigma}$
	= 1 – 0.7477	**M1**	Appropriate area Φ from standardisation formula P(z<….) 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
	$\frac{k - 140}{12} = -0.454$	**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)	$P(79 < X < 91) = P\left(\frac{79 - 85}{6.8} < Z < \frac{91 - 85}{6.8}\right)$ $= P(-0.8824 < Z < 0.8824)$	**M1**	Using ± standardisation formula for either 79 or 91, no continuity correction
	$= \Phi(0.8824) - \Phi(-0.8824)$ = 0.8111 – (1 – 0.8111)	**M1**	Correct area (Φ – Φ) with one +ve and one –ve z-value or 2 Φ – 1 or 2(Φ – 0.5)
	= 0.622	**A1**	Correct answer
		3	
(ii)	$z = -1.751$	**B1**	± 1.751 seen
	$-1.751 = \frac{t - 85}{6.8}$	**M1**	An equation using ± standardisation formula with a z-value, condone σ^2 or $\sqrt{\sigma}$
	$t = 73.1$	**A1**	Correct answer
		3	

Question 73

(i)	P (< 700) = $P\left(z < \frac{700-830}{120}\right)$ = P(z < –1.083)	M1	Using ± standardisation formula, no continuity correction, not σ^2 or $\sqrt{\sigma}$
	= 1 – 0.8606	M1	Appropriate area Φ from standardisation formula P(z<….) 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 × *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(giraffe < 830+w) = 95% so z = 1.645	B1	±1.645 seen (critical value)
	$\frac{(830+w)-830}{120} = \frac{w}{120} = 1.645$	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(male > 950) = 0.834, so z = –0.97	B1	± 0.97 seen
	$\frac{950-1190}{\sigma} = -0.97$	M1	Using ± standardisation formula, condone continuity correction, σ^2 or $\sqrt{\sigma}$, condone equating with non z-value not 0.834, 0.166
	σ = 247	A1	Condone –σ = –247. www.
		3	

Question 74

(i)	P(h < 148) = 0.67	B1	$z = \pm 0.44$ seen
	$\frac{h-148}{8} = 0.44$	M1	z-value = $\pm\frac{(h-148)}{8}$
	151.52 ≈ 152	A1	CAO
		3	
(ii)	$P(144 < X < 152) = P\left(\frac{144-148}{8} < Z < \frac{152-148}{8}\right)$	M1	Using ± standardisation formula for either 144 or 152, μ = 148, σ = 8 and no continuity correction, allow σ^2 or $\sqrt{\sigma}$
	$= P\left(-\frac{1}{2} < Z < \frac{1}{2}\right)$ = 0.6915 – (1 – 0.6915) = 2 × 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 × 120 = 45.96 Accept 45 or 46 only	B1FT	*Their* prob (to 3 or 4 sf) × 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 ... + 0.3025 ... + 0.3241 ...	**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 $\frac{1}{4096}$	**A1**	Correct final answer
		2	
7(ii)	Mean = 240 × 0.25 = 60 Variance = 240 × 0.25 × 0.75 = 45	**B1FT**	Correct unsimplified *240p* and *240pq* where p =*their* P(support neither choir) or 0.25
	$P(X < 50) = P\left(Z < \frac{49.5-60}{\sqrt{45}}\right) = P(Z < -1.565)$	**M1**	Substituting *their* μ and σ (condone σ^2) into the ±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< …) 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)	$P(X < 45) = P\left(Z < \frac{45-40}{8}\right)$ $= P(Z < 0.625)$	**M1**	± 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
	$\sigma = 6.[00]$, $\mu = 17.8[3]$	**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
	$P(X > 84) = P\left(Z > \frac{84.5 - 99}{\sqrt{33.66}}\right)$	**M1**	± Standardise, $\frac{x - their\,99}{\sqrt{their\,33.66}}$, 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)	$P(46 < X < 53) = P\left(\frac{46 - 49.2}{2.8} < Z < \frac{53 - 49.2}{2.8}\right)$	**M1**	Using ± 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)	$\frac{t - 49.2}{2.8} = -1.406$	**B1**	±1.406 seen
		M1	An equation using ± 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(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)	$P(X<21)=P\left(z<\frac{21-15.8}{4.2}\right)=\Phi(1.238)$	**M1**
	0.892	**A1**
		2
(b)	$z=\pm 0.674$	**B1**
	$\frac{k-15.8}{4.2}=0.674$	**M1**
	18.6	**A1**
		3

Question 82

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

Question 83

(a)	$\mathrm{P}(X < 25) = \mathrm{P}\left(z < \frac{25-40}{12}\right) = \mathrm{P}(z < -1.25)\mathrm{P}(X < 25) = \mathrm{P}(z <)$	**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**
	$\frac{h-40}{12} = 0.53$	**M1**
	$h = 46.4$	**A1**
		3

Question 84

(a)	$1 - \mathrm{P}(10, 11, 12)$ $= 1 - [{}^{12}C_{10}\, 0.72^{10} 0.28^2 + {}^{12}C_{11}\, 0.72^{11} 0.28^1 + 0.72^{12}]$	**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(less than 64) $= \mathrm{P}\left(z < \frac{63.5 - 72}{\sqrt{20.16}}\right)$ (**M1** for substituting *their μ and σ* into ±standardisation formula with a numerical value for '*63.5*')	**M1**
	Using either 63.5 or 64.5 within a ±standardisation formula	**M1**
	Appropriate area Φ, from standardisation formula P(z<…) in final solution $= \mathrm{P}(z < -1.893)$	**M1**
	0.0292	**A1**
		5

Question 85

(a)	$P(56 < X < 66) = P\left(\frac{56-62}{5} < z < \frac{66-62}{5}\right)$ $= P(-1.2 < z < 0.8)$	**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**	±(1.126 – 1.127) seen, 4 sf or more
	$\frac{60t-62}{5} = 1.127$ $60t = 5.635+62=67.635$	**M1**	z-value = $\pm\frac{(60t-62)}{5}$ condone z-value = $\pm\frac{(t-62)}{5}$ no continuity correction, condone $\sqrt{\sigma}$ or σ^2
	$t = 1.13$	**A1**	CAO
		3	

Question 86

(a)	$P(X > 11.3) = P(z > \frac{11.3-10.1}{1.3}) = P(z > 0 \cdot 9231)$	**M1**	Using ± standardisation formula, no $\sqrt{\sigma}$ or σ^2, continuity correction
	1 – 0.822	**M1**	Appropriate area Φ, from standardisation formula P(*z*>…) in final solution
	0·178	**A1**	0.1779…
		3	
(b)	$z = -0 \cdot 674$	**B1**	±0.674 seen (critical value)
	$\frac{t-10.1}{1.3} = -0 \cdot 674$	**M1**	An equation using ±standardisation formula with a *z*-value, condone $\sqrt{\sigma}$ or σ^2, continuity correction.
	$t = 9 \cdot 22$	**A1**	AWRT. Only dependent on M1
		3	
(c)	$P(8.9 < X < 11.3) = 1 - 2 \times$ *their* **3(a)** ≡ 2(1 – *their* **3(a)**) – 1 ≡ 2(0·5 – *their* **3(a)**) =0.644	**B1 FT**	FT from *their* **3(a)** < 0·5 or correct, accept unevaluated probability OE
	Number of days = 90 × 0·644 = 57·96	**M1**	90 × *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)	$P(X > 4.2) = P(\ z > \frac{4.2-3.5}{0.9})$ $= P(z > 0.7778)$	M1	Using ± standardisation formula, no $\sqrt{\sigma}$ or σ^2, continuity correction
	1 – 0·7818	M1	Appropriate area Φ, from standardisation formula P(z>…) in final solution
	0·218	A1	
		3	
(b)	$z = -1.282$	B1	±1.282 seen (critical value)
	$\frac{t-3.5}{0.9} = -1.282$	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 × *their* **5(a)** ≡ 2(1 – *their* **5(a)**) – 1 ≡ 2(0·5 – *their* **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 × 0·5636 = 205·7	M1	365 × *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)	$P\left(\left(\frac{85-96}{18}\right) < z < \left(\frac{100-96}{18}\right)\right)$	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)	$z = \pm 1{\cdot}175$	B1	$1{\cdot}17 \leqslant z \leqslant 1{\cdot}18$ or $-1{\cdot}18 \leqslant z \leqslant -1{\cdot}17$
	$-1.175 = \frac{t-96}{18}$	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	$74{\cdot}85 \leqslant t \leqslant 74{\cdot}9$
		3	

Question 89

(a)	$z_1 = \frac{4-\mu}{\delta} = -1.378$	**B1**	$1.378 \leqslant z_1 \le 1.379$ or $-1.379 \leqslant z_1 \leqslant -1.378$
	$z_2 = \frac{10-\mu}{\sigma} = 0.842$	**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: $\frac{4-\mu}{\sigma} = -1.378$ $\frac{10-\mu}{\sigma} = 0.842$	**M1**	Use of ±standardisation formula once with μ, σ, a z-value and 4 or 10, allow continuity correction, not σ^2 or $\sqrt{\sigma}$
		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 ± 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

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

Question 91

$\left[P\left(\left(\frac{25.2-(25.5+0.50)}{0.4}\right) < z < \left(\frac{25.2-(25.2-0.50)}{0.4}\right)\right)\right]$ $= P\left(-\frac{0.5}{0.4} < z < \frac{0.5}{0.4}\right)$	M1	Use of ± Standardisation formula once; no continuity correction, σ^2, $\sqrt{\sigma}$
$[= 2\Phi(1.25) - 1]$ $= 2 \times 0.8944 - 1$	A1	For AWRT 0.8944 SOI
	M1	Appropriate area 2Φ – 1 OE, from final process, must be probability
0.7888	A1	Accept AWRT 0.789
Number of rods = 0.7888×500 = 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)	$P(X > 43.2) = P\left(Z > \frac{43.2 - 41.2}{3.6}\right) = P(Z > 0.5556)$	**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 × 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.
	$\frac{t - 41.2}{3.6} = -1.645$	**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)	$[P(X > 28.6) =] P\left(Z > \frac{28.6 - 32.2}{9.6}\right)$ $[= P(Z > -0.375)]$	**M1**	28.6, 32.2 and 9.6 substituted appropriately in ± Standardisation formula once, allow continuity correction of ± 0.05, no σ^2, $\sqrt{\sigma}$.
	$[\Phi(\textit{their}\ 0.375) =]$ *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.
	$\frac{t - 32.2}{9.6} = 0.842$	**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)	$P\left(-\frac{15}{9.6} < Z < \frac{15}{9.6}\right)$ $P(-1.5625 < Z < 1.5625)$	**M1**	Identifying at least one of $\frac{15}{9.6}$ and $-\frac{15}{9.6}$ 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**.
	$[2\ \Phi(\frac{15}{9.6}) - 1]$ $= 2 \times 0.9409 - 1$	**A1**	$p = 0.941$ AWRT SOI
		M1	Appropriate area 2Φ – 1 oe, (eg 1 – 2 × 0.0591, 2 × (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)	$P(X > 142) = P\left(Z > \frac{142-125}{24}\right)$	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 × 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.
	$\frac{t-125}{24} = -1.282$	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)	$P(46 < X < 62) = P\left(\frac{46-55}{6} < Z < \frac{62-55}{6}\right)$	M1	46 or 62, 55 and 6 substituted into ±standardisation formula once. Condone 6^2 and continuity correction ±0.5
	$= P\left(-1.5 < Z < \frac{7}{6}\right)$	B1	Both standardisation values correct, accept unsimplified
	$\left[=\Phi\left(\frac{7}{6}\right) - (1 - \Phi(1.5))\right]$ $= 0.8784 + (0.9332 - 1)$	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
	$\frac{36-42}{\sigma} = -0.674$	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: $1 - \Phi\left(\frac{46-55}{6}\right)$,condone continuity correction, σ^2, $\sqrt{\sigma}$, **and** probability found. Condone unsupported correct value stated.
	P(female < 46) = $P\left(Z < \frac{46-42}{their\ 8.90}\right)[=\Phi(0.449)]$ $= 0.6732$	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 $\frac{4}{their\ 8.90}$.
	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)	$[P(142 < X < 205)] = P\left(\frac{142-170}{25} < z < \frac{205-170}{25}\right)$	**M1**	Use of ± 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).**
	$(0.0808 \times 0.30 + \textit{their}\ 0.788 \times 0.24) \times 20000$	**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**	$4265 <$ income $\leqslant 4270$, not from wrong working
		3	
(c)	$[P(Z > \frac{w-182}{20}) = 0.72]$	**B1**	$0.5828 \leqslant z \leqslant 0.583$ or $-0.583 \leqslant z \leqslant -0.5828$ seen.
	$\frac{w-182}{20} = -0.583$	**M1**	182 and 20 substituted in ± 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).
	$[P(X < 40) =]\ P\left(z < \frac{39.5 - 46.8}{\sqrt{22.464}}\right)$	**M1**	Substituting *their* mean and *their* variance into ±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)	$[P(1.98 < X < 2.03) =]P(\frac{1.98-2.02}{0.03} < z < \frac{2.03-2.02}{0.03})$ $[= P(-1.333 < z < 0.333)]$	**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)	$[P(X > 2.6) = \frac{134}{5000} = 0.0268]$ $[P(X<2.6) = 1 - 0.0268 =]$ 0.9732	**B1**	0.9732 or $\frac{4866}{5000}$ or $\frac{2433}{2500}$ seen.
	$\frac{2.6-2.55}{\sigma} = 1.93$	**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 $\frac{5}{193}$. If M0 earned, **SC B1** for correct final answer.
		4	

Question 99

(a)	$P(X < 6) = P(Z < \frac{6-5.2}{1.5}) = P(Z < 0.5333)$	**M1**	6, 5.2, 1.5 substituted into ± standardisation formula, condone 1.5^2, continuity correction ±0.5
	0.703	**A1**	
		2	
(b)	$z_1 = \frac{3-\mu}{\sigma} = -1.329$ $z_2 = \frac{8-\mu}{\sigma} = 0.878$	**B1**	$1.328 < z_1 \leqslant 1.329$ or $-1.329 \leqslant z_1 < -1.328$
		B1	$0.877 < z_2 \leqslant 0.878$ or $-0.878 \leqslant z_2 < -0.877$
	Solve to find at least one unknown: $\frac{3-\mu}{\sigma} = -1.329$ $\frac{8-\mu}{\sigma} = 0.878$	**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 × 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 = $80 \times 0.32 = 25.6$, $\text{var} = 80 \times 0.32 \times 0.68 = 17.408$	**B1**	25.6 and 17.4[08] seen, allow unsimplified. 4.172… implies correct variance.
$P(X < 20) = P(Z < \frac{19.5-25.6}{\sqrt{17.408}}) = P(Z < -1.462)$	**M1**	Substituting *their* 25.6 and 17.408 into ±standardisation formula (any number for 19·5), not σ^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

$[P(X > 1.11) =]P(Z > \frac{1.11-1.04}{0.06}) = P(Z > 1.167)$	**M1**	1.11, 1.04 and 0.06 substituted into ±Standardisation formula, no continuity correction not 0.06^2 or √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

$[P(X < w) = P(Z < \frac{w-1.04}{0.06}) = 0.81]$ $\frac{w-1.04}{0.06} = 0.878$	**B1**	$0.8775 < z \leqslant 0.878$ or $-0.878 \leqslant z < -0.8775$ seen.
	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)	$[P(X<54.8)] = P(Z < \frac{54.8-55.6}{1.2})$	**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 $0.252 \leqslant p \leqslant 0.2525$
	[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)	$[P(-\frac{1}{2} < Z < \frac{1}{2}) = \Phi(½) - \Phi(-½) =]$ $2\Phi\left(\frac{1}{2}\right) - 1$ $= 2 \times their\ 0.6915 - 1$ 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 $\frac{56.2-55.6}{1.2}$ and $\frac{55[.0]-55.6}{1.2}$ 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)	[Mean = 80 × 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).
	$P(X > 69) = P(Z > \frac{69.5-72}{\sqrt{7.2}})$	**M1**	Substituting *their* mean and $\sqrt{their\ \text{variance}}$ into ±standardisation formula (any number for 69·5), not *their* 7.2, not √*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, …7) = 1 – P(0, 1, 2, 8)] $= 1-({}^{8}C_0\ 0.48^0\ 0.52^8 + {}^{8}C_1\ 0.48^1\ 0.52^7 + {}^{8}C_2\ 0.48^2\ 0.52^6 + {}^{8}C_8\ 0.48^8\ 0.52^0)$	**M1**	One term ${}^{8}C_x\ p^x(1-p)^{8-x}$, 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).
	$[P(X > 72) =]P(Z > \frac{72.5-65}{\sqrt{31.2}})$ $[= P(Z > 1.343)]$	**M1**	Substituting *their* 65 and $\sqrt{their\ 31.2}$ into ±standardisation formula (any number for 72·5), not *their* 31.2, √ *their* 5.586 .
		M1	Using continuity correction 72·5 or 71·5 in *their* standardisation formula . Note $\frac{\pm 7.5}{\sqrt{31.2}}$ or $\frac{\pm 7.5}{5.586}$ 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($Z < \frac{132-125.4}{18.6}$) = 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)	$\frac{108-117}{\sigma} = -1.175$	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)	$P(-1.5 < Z < 1.5)$ $[\Phi(1.5) - \Phi(-1.5)]$ $[= 2\Phi(1.5) - 1]$ $= 2 \times \textit{their}\ 0.9332 - 1$ **or** $\textit{their}\ 0.9332 - (1 - \textit{their}\ 0.9332)$ **or** $2 \times (\textit{their}\ 0.9332 - 0.5)$	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)	$[P(X < 74) =]\ P\left(Z < \frac{74-62.3}{8.4}\right)[= P(Z < 1.393)]$	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)	$[P(50 < X < 74) = P]\left(\frac{50-62.3}{8.4} < Z < \frac{74-62.3}{8.4}\right)$ $[P(-1.464 < Z < 1.393)]$	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)	$z_1 = \frac{36-\mu}{\sigma} = -0.739$ $z_2 = \frac{54-\mu}{\sigma} = 1.282$	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 $\sigma^2, \sqrt{\sigma}$.
	Solve, obtaining values for μ and σ $\mu = 42.6, \quad \sigma = 8.91$	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 ${}^{12}C_x\,(p)^x(1-p)^{12-x}$, $0 < p < 1$. $x \neq 0,1,2$.
		A1	Correct expression, accept unsimplified, no terms omitted leading to final answer.
	0.111	**B1**	0.1108699… rounded to at least 3SF.
	Alternative Method for Question 6(b)		
	$P(3,4,5,6,7,8,9,10,11,12) = {}^{12}C_3(0.1)^3(0.9)^9 + {}^{12}C_4(0.1)^4(0.9)^8 + \ldots + {}^{12}C_{11}(0.1)^{11}(0.9)^1 + {}^{12}C_{12}(0.1)^{12}(0.9)^0$ $[0.08523 + 0.02131 + \ldots + 1.08\times10^{-10} + 1\times10^{-12}]$	**M1**	One term ${}^{12}C_x\,(p)^x(1-p)^{12-x}$, $0 < p < 1$. $x \neq 0,1,2$.
		A1	Correct expression, accept unsimplified, no terms omitted leading to final answer.
	0.111	**B1**	0.1108699… 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, $0.806 \leqslant p < 0.8065$.
	[In 365 days 0.8064×365] = 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	$0.658 \le p < 0.6585$. 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 × 0.72 × 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)	$P(Z > \frac{20-14.6}{5.2}) = P(Z > 1.03846)$	**M1**	Use of ± 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 × *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)	$z_1 = \frac{14.5-\mu}{\sigma} = -0.842$ $z_2 = \frac{18.5-\mu}{\sigma} = -0.44$	**B1**	$-0.843 < z_1 < -0.841$ or $0.841 < z_1 < 0.843$.
		B1	$-0.441 < z_2 < -0.439$ or $0.439 < z_2 < 0.441$.
		M1	Use of the ±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 $\sigma^2, \sqrt{\sigma}$.
	Solve, obtaining values for μ and σ. $\mu = 22.9, \quad \sigma = 9.95$	**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	