A Level Statistics

AQA Past Exam SOLUTIONS

TOPIC: The Normal Distribution

For the new specification, students can now use the Casio Claswiz calculator to find Normal probabilities. For old AQA questions this was not the case and more work was involved for the students. Therefore, some of the questions will be worth a lot more marks than will be on offer in an up to date Edexcel exam

Candidates may use any calculator allowed by Pearson regulations. Calculators must not have retrievable mathematical formulae stored in them.

Instructions

• Use **black** ink or ball-point pen.

• If pencil is used for diagrams/sketches/graphs it must be dark (HB or B). Coloured pencils and highlighter pens must not be used.

• **Fill in the boxes** at the top of this page with your name, centre number and candidate number.

• Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.

• Answer the questions ***on paper***

• You should show sufficient working to make your methods clear. Answers without working may not gain full credit.

• Unless otherwise stated, statistical tests should be carried out at the 5% significance level.

• When a calculator is used, the answer should be given to three significant figures unless otherwise stated.

Information

• ***You may use the*** booklet 'Statistical Formulae and Tables'

• There are **13** questions in this question paper. The total mark for this paper is ***217***

• The marks for **each** question are shown in brackets – use this as a guide as to how much time to spend on each question.

Advice

• Read each question carefully before you start to answer it.

• Try to answer every question.

• Check your answers if you have time at the end.

• If you change your mind about an answer, cross it out and put your new answer and any working underneath.

• Check your answers if you have time at the end.

AQA_JAN_2012_3

Q	Solution	Marks	Total	Comments
3(a)(i)	Volume, $X \sim N(32, 10^2)$			
	$P(X < 40) = P\left(Z < \frac{40-32}{10}\right)$	M1		Standardising 40 with 32 and 10; allow $(32 - 40)$
	$= P(Z < 0.8)$	A1		CAO; ignore inequality and sign May be implied by a correct answer
	$= 0.788$	A1	3	AWRT (0.78814)
(ii)	$P(X > 25) = P(Z > -0.7)$			
	$= P(Z < +0.7)$	M1		Area change May be implied by a correct answer or an answer > 0.5
	$= 0.758$	A1	2	AWRT (0.75804)
(iii)	$P(25 < X < 40) =$ (i) – (1 – (ii))	M1		OE; allow new start ignoring (i) & (ii) Allow even if incorrect standardising providing 0 < answer < 1 May be implied by a **correct** answer
	$= 0.78814 - (1 - 0.75804) = 0.546$ **Note:** If (ii) is 0.242, then $(0.788 - 0.242) = 0.546 \Rightarrow$ M0 A0	A1	2	AWRT (0.54618)
(b)	$P(B > £65) =$			
	$P\left(Z > \frac{48.5-32}{10}\right)$ or $P\left(Z > \frac{65-42.88}{13.4}\right)$	M1		Attempt to change from B to X using (48 to 49), 32 and 10 or Attempt to work with distribution of B using 65, (42.8 to 42.9) and 13.4
	$= P(Z > 1.65) = 1 - P(Z < 1.65)$	m1		Area change May be implied by a correct answer or an answer < 0.5
	$= 1 - 0.95053 = 0.049$ to $0.05(0)$	A1	3	AWFW (0.04947)
(c)	Other **fuels** Other **vehicles** with an example (not other cars) Other types of **customer** Minimum purchase (policy) Purchases in integer/fixed £s Customers filling fuel cans	B2,1	2	Size of car/engine/fuel tank $\Rightarrow$ B0 Price of fuel $\Rightarrow$ B0 Customer paying capacity $\Rightarrow$ B0 Must be **two clearly different** valid reasons for award of B2 Drivers and vehicles related $\Rightarrow$ B1 eg lorry drivers & lorries
		Total	**12**	

AQA_JAN_2013_2

Q	Solution	Marks	Total	Comments
2				**In (a), ignore the inclusion of a lower limit of 0; it has no effect on the answer**
	Volume, $V \sim N(106, 2.5^2)$			
(a)	$P(V < 110) = P\left(Z < \frac{110-106}{2.5}\right)$	M1		Standardising 110 with 106 and 2.5; allow $(106 - 110)$
	$= P(Z < \underline{\mathbf{1.6}})$	A1		CAO; ignore inequality and sign May be implied by a **correct** answer
	$= \underline{\mathbf{0.945}}$	A1	**3**	AWRT (0.94520)
(b)	$P(V > 100) = P(Z > -2.4) = P(Z < +2.4)$	M1		**Correct** area change May be implied by a **correct** answer **or** by an answer **> 0.5**
	$= \underline{\mathbf{0.991 \text{ to } 0.992}}$	A1	**2**	AWFW (0.99180)
(c)	$P(104 < V < 108) = P(-a < Z < a) =$			
	$P(Z < a) - (1 - P(Z < a))$ **or** $2 \times P(Z < a) - 1$	M1		OE; $a = 0.8$ is **not** a requirement May be implied by **0.788 seen** **or** by a **correct** answer
	$= 0.788 - (1 - 0.788) = 0.788 - 0.212$ **or** $= 2 \times 0.788 - 1$	A1		AWRT (0.78814/0.21186) Condone 0.211 May be implied by a **correct** answer
	$= \underline{\mathbf{0.576}}$	A1	**3**	AWRT (0.57628)
(d)	$P(V \neq 106) = \underline{\mathbf{1 \text{ or one or unity or } 100\%}}$	B1	**1**	CAO; accept nothing else but ignore additional words providing they are not contradictory (eg certain so = 1)
		Total	**9**	

AQA_JUNE_2012_5

Q	Solution	Marks	Total	Comments
5				**In (a)(i) & (c), ignore the inclusion of a lower limit of 0; it has no effect on either answer**
(a)	Weight, $W \sim N(2.75,\ 0.15^2)$			
(i)	$P(W < 2.8) = P\left(Z < \frac{2.8-2.75}{0.15}\right)$	M1		Standardising 2.8 with 2.75 and 0.15; allow $(2.75 - 2.8)$
	$= P(Z <$ **0.33 or 1/3**$)$	A1		AWRT/CAO; ignore inequality and sign May be implied by a **correct** answer
	= **0.629 to 0.633**	A1		AWFW (0.63056)
(ii)	$P(W > 2.5) = P(Z > -1.67) = P(Z < +1.67)$	M1		**Correct** area change May be implied by a **correct** answer **or** an answer **> 0.5**
	= **0.951 to 0.953**	A1	5	AWFW (0.95221)
(b)	Weight, $X \sim N(5.25,\ 0.20^2)$			
(i)	$P(5.1 < X < 5.3) = P(Z < 0.25) - P(Z < -0.75)$ = **0.59871**	B1		Must have diff of 2 probs for each B1 Accept 0.599
	MINUS [(1 – 0.77337) or 0.22663] = **0.372(08)**	B1	2	Accept 0.773 or 0.227 AG; do **not** mark simply on answer
(ii)	$P(0 \text{ in } 4) = [1 - 0.372]^4$	M1		Accept [1 – c's (b)(i)]^4
	$= 0.628^4 =$ **0.155 to 0.156**	A1	2	AWFW (0.15554)
(c)	Weight, $Y \sim N(10.75,\ 0.50^2)$			
	Variance of $\bar{Y}_6$ = **$0.5^2/6$ = 0.0416 to 0.0417** **or** Sd of $\bar{Y}_6$ = **$0.5/\sqrt{6}$ = 0.204**	B1		CAO or AWFW Stated or used CAO or AWRT
	$P(\bar{Y}_6 < 10.5) = P\left(Z < \frac{10.5-10.75}{\sqrt{0.041\dot{6}}}\right) =$	M1		Standardising 10.5 with 10.75 and $\sqrt{0.041\dot{6}}$ OE; allow $(10.75 - 10.5)$
	$P(Z < -1.22) = 1 - P(Z < 1.22) =$	m1		**Correct** area change May be implied by a correct answer **or** an answer **< 0.5**; but do **not** award for use of $z = \pm 0.22$
	$1 - (0.88877 \text{ to } 0.89065) =$ **0.109 to 0.112**	A1	4	AWFW (0.11034) (1 – answer) ⇒ B1 M1 max
	Total		**13**	

AQA_JUNE_2013_2

Q	Solution	Marks	Total	Comments
				Accept percentage equivalents in (a)
2(a)(i)	Weight, $X \sim N(421, 2.5^2)$ $P(X = 421) =$ **0 or zero or nought or 0%**	B1		CAO; accept nothing else but ignore additional words providing that they are not contradictory (eg impossible so = 0)
(ii)	$P(X < 425) = P\left(Z < \frac{425-421}{2.5}\right)$	M1		Standardising 425 with 421 and 2.5 but allow $(421 - 425)$
	$= P(Z < 1.6) =$ **0.945 to 0.946**	A1		AWRT (0.94520)
(iii)	$P(418 < X < 424) = P(-a < Z < a) =$			
	$P(Z < a) - (1 - P(Z < a))$ **or** $2 \times P(Z < a) - 1$	M1		OE; $a = 1.2$ or correct standardising are **not** required May be implied by **0.885** (AWRT) **seen anywhere** **or** by a **correct** answer
	$= 0.885 - (1 - 0.885) = 0.885 - 0.115$ **or** $= 2 \times 0.885 - 1$	A1		AWRT (0.88493/0.11507) Implied by a **correct** answer
	$=$ **0.769 to 0.77**	A1	6	AWFW (0.76986)
(b)	$0.98 \Rightarrow z =$ **2.05 to 2.06**	B1		AWFW (2.0537)
	$\left(\frac{x-421}{2.5}\right) = 2(.0)$ to 2.4	M1		Standardising x with 421 and 2.5 but allow $(421 - x)$; **and** equating to a ***z*-value** (*ignore sign*) May be implied by a **correct** answer
	$x =$ **426 to 426.3**	A1	3	AWFW (426.13) ***Must be consistent signs throughout***
(c)	$0.01 \Rightarrow z =$ **–2.33 to –2.32**	B1		AWFW; (*ignore sign*) (–2.3263)
	$z = \left(\frac{410-\mu}{3.0 \text{ or } 2.5}\right)$	M1		Standardising 410 with μ and (3.0 or 2.5) but allow $(\mu - 410)$
	$\left(\frac{410-\mu}{3.0}\right) = -2.6$ to -2.3	A1		Equating to a ***z*-value** (*ignore sign*) May be implied by a **correct** answer
	$\mu =$ **417**	Adep1	4	AWRT (416.98) Dependent on previous A1 ***Must be consistent signs throughout***
	Total		**13**	

AQA_JAN_2007_6

Q	Solution	Marks	Total	Comments
(a)(i)	$P(X < 45) = P\left(Z < \frac{45-37}{8}\right)$	M1		Standardising (44.5, 45 or 45.5) with 37 and ($\sqrt{8}$, 8 or 8^2) and/or $(37 - x)$
	$= P(Z < 1)$	A1		CAO; ignore sign
	$= 0.841$	A1	3	AWRT (0.84134)
(ii)	$P(30 < X < 45) = (i) - P(X < 30)$	M1		Used; OE
	$= (i) - P(Z < -0.875)$			
	$= (i) - [1 - (0.80785 \text{ to } 0.81057)]$	m1		Area change
	$= 0.648$ to 0.652	A1	3	AWFW (0.65056)
(b)	$0.12 \Rightarrow z = 1.17$ to 1.18	B1		AWFW; ignore sign (1.1750)
	$z = \frac{45-40}{\sigma}$	M1		Standardising 45 with 40 and σ
	$= 1.175$	m1		Equating z-term to z-value but not using 0.12, 0.88 or $\lvert 1 - z \rvert$
	$\sigma = 4.23$ to 4.28	A1	4	AWFW
(c)	**Route A:** $P(X > 45) = 1 - (a)(i)$ **Route B:** $P(Y > 45) = 0.12$ so Monica should use **Route B** (smaller prob)	B1 ↑Dep↑ B1√	2	OE; must use 45 √ on (a)(i); allow Route Y
(d)	Mean of $\bar{W} = 18$	B1		CAO; can be implied by **use** in standardising
	Variance of $\bar{W} = \frac{12^2}{36} = 4$	B1		CAO; OE
	$P(\bar{W} > 20) = P\left(Z > \frac{20-18}{2}\right)$	M1		Standardising 20 with 18 and 2 and/or $(18 - 20)$
	$= P(Z > 1) = 0.159$	A1√	4	AWRT (0.15866); √ on (a)(i) if used
(e)	In part (d)	B1	1	CAO; OE
	Total		**17**	

AQA_JAN_2010_1

Q	Solution	Marks	Total	Comments
1(a)(i)	$X \sim N(10.2,\ 0.15^2)$			
	$P(X<10.5) = P\left(Z<\frac{10.5-10.2}{0.15}\right)$	M1		Standardising (10.45, 10.5 or 10.55) with 10.2 and ($\sqrt{0.15}$, 0.15 or 0.15^2) and/or $(10.2-x)$
	$= P(Z<2)$	A1		CAO; ignore inequality and sign May be implied by a correct answer
	$= 0.977$	A1	3	AWRT (0.97725)
(ii)	$P(10.0<X<10.5)$ $=$ [C's (a)(i)] $-$ $P(X<10.0)$	M1		Or equivalent; must be clear correct method if answer incorrect and answer >0
	$=$ (a)(i) $-$ $P(Z<-1.33)$			Method correct using -1.3 gives 0.88 to 0.881 $\Rightarrow$ M1 m1 A0
	$=$ (a)(i) $-$ $(1-p)$			
	$= 0.97725 - (1 - 0.90824)$	m1		Area change May be implied by a correct answer or answer >0.5
	$= 0.885$ to 0.887	A1	3	AWFW (0.88604) M1 m1 A1 for $0.90824 - [1 - (a)(i)]$ $= 0.886$ M1 m0 A0 for (a)(i) $- 0.90824$ $= 0.0685$ M0 mo A0 for answer < 0
(b)	$P(X>10)$ = p[from (a)(ii)] $= 0.908$ to 0.909	B1F		Correct value **or** F on value used or implied in (a)(ii) providing >0.5 Use of -1.3 gives 0.9032
	$P(6 \text{ rolls} > 10) = 0.90824^6$	M1		Accept any probability to power 6
	0.56 to 0.565	A1	3	AWFW
	Note: B0F M1 A0 is possible			
		Total	**9**	

AQA_JAN_2008_1

Q	Solution	Marks	Total	Comments
1(a)(i)	$P(X < 3.5) = P\left(Z < \frac{3.5-3.3}{0.16}\right) =$	M1		Standardising (3.45, 3.5 or 3.55) with 3.3 & ($\sqrt{0.16}$, 0.16 or 0.16^2) and/or $(3.3 - x)$
	$P(Z < 1.25) =$	A1		CAO; ignore sign
	0.894 to 0.895	A1	3	AWFW (0.89435)
(ii)	$P(X > 3.0) = P\left(Z > \frac{3.0-3.3}{0.16}\right) =$	M1		Standardising (2.95, 3 or 3.05) with 3.3 & ($\sqrt{0.16}$, 0.16 or 0.16^2) and/or $(3.3 - x)$
	$P(Z > -1.875) = P(Z < 1.875) =$	m1		Correct area change
	0.969 to 0.97(0)	A1	3	AWFW (0.96960)
(iii)	$P(3.0 < X < 3.5) =$ (i) – [1 – (ii)] =	M1		OE
	0.863 to 0.865	A1	2	AWFW: CSO (0.86395)
(b)	$0.025 \Rightarrow z = 1.96$	B1		CAO; ignore sign
	$z = \frac{3.1-\mu}{0.16}$	M1		Standardising 3.1 with μ and 0.16; allow $(\mu - 3.1)$
	$= -1.96$	m1		Equating z-term to z-value; not using 0.025, 0.975, $\lvert 1 - z \rvert$ or $\Phi(0.025) = 0.507$ to 0.512
	Hence $\mu = 3.4(0)$ to 3.42	A1	4	AWFW; CSO (3.4136)
	Total		**12**	

AQA_JAN_2009_3

Q	Solution	Marks	Total	Comments
3	$X \sim N(5.08, 0.05^2)$			
(a)(i)	$P(X<5) = P\left(Z<\frac{5-5.08}{0.05}\right) = P(Z<-1.6)$	M1		Standardising (4.5, 4.95, 5, 5.05 or 5.5) with 5.08 and ($\sqrt{0.05}$, 0.05 or 0.05^2) and/or $(5.08-x)$
	$= 1 - P(Z<1.6) = 1 - 0.9452$	m1		Area change; may be implied
	$= 0.0545$ to 0.055	A1	3	AWFW (0.0548) (1 – answer) ⇒ M1 max
(ii)	$P(5<X<5.10) = P(X<5.10) - (i)$	M1		Or equivalent; must be clear correct method if answer incorrect and answer > 0
	$= P(Z<0.4) - (i)$ $= 0.65542 - 0.0548$			
	$= 0.6$ to 0.601	A1	2	AWFW (0.60062)
(b)(i)	Variance of $\bar{X}_4 = 0.05^2/4 = 0.000625$ SD of $\bar{X}_4 = 0.05/2 = 0.025$	B1		CAO; stated or used
	$P(\bar{X}_4 > 5.05) = P\left(Z>\frac{5.05-5.08}{0.025}\right)$	M1		Standardising 5.05 with 5.08 and 0.025; allow (5.08 – 5.05)
	$= P(Z>-1.2) = P(Z<1.2)$	m1		Area change; may be implied
	$= 0.884$ to 0.886	A1	4	AWFW (0.88493) (1 – answer) ⇒ B1 M1 max
(ii)	Zero	B1	1	CAO; or equivalent (ignore any working)
(c)	1% (0.01) ⇒ $z = -2.33$ to -2.32	B1		AWFW; ignore sign (–2.3263)
	$z = \frac{5-\mu}{0.05}$	M1		Standardising 5 with μ and 0.05 or 0.025; allow $(\mu - 5)$
	$= -2.3263$	A1		Only allow: ±2.05 to ±2.06 ±2.32 to ±2.33 ±2.57 to ±2.58
	$\mu = 5.11$ to 5.12	A1		AWFW (5.1163)
	Note: $\frac{5-\mu}{0.05} = 2.3263 \Rightarrow 5.116$ ⇒ B1 M1 A1 A0			Or equivalent inconsistent signs
			4	
		Total	**14**	

AQA_JAN_2011_6

Q	Solution	Marks	Total	Comments
6(a)	Volume, $V \sim N(412, 8^2)$			
(i)	$P(V<400)=P\left(Z<\frac{400-412}{8}\right)$	M1		Standardising 400 with 412 and 8 and/or $(412-x)$
	$=P(Z<-1.5)=1-P(Z<1.5)$	M1		Area change May be implied by a correct answer or an answer < 0.5
	$=1-0.93319=0.066$ to 0.067	A1	3	AWFW (0.06681)
(ii)	$P(V>420)=P(Z>1)$	B1		CAO but ignore inequality and sign May be implied by a correct answer
	$=1-P(Z<1)=1-0.84134$ $=0.158$ to 0.159	B1	2	AWFW (0.15866)
(iii)	$P(V=410)=0$ or zero or impossible	B1	1	Ignore any working B0 for 'impossible to calculate' or 'no answer'
(b)(i)	A statement/indication that (–) 1.6449 and/or 2.3263 are z-values Do **not** allow $\Phi(0.99)=2.3263$, etc but **allow** $\Phi^{-1}(0.99)=2.3263$ Do **not** award for z-value(s) simply embedded in standardisation statement(s)	B1		Simple statement that $z=\pm1.6449$ and/or $z=\pm2.3263$ **or** sketch of normal curve with at least one z-value marked
	A clear use of $z=\frac{v-\mu}{\sigma}$ or $v=\mu+2\sigma$ with 400 and/or 420 (condone sign errors)	M1		**SC** Immediate algebraic use of $v-\mu=z\sigma \Rightarrow$ B1 M1 A0
	The two given equations correctly derived	A1	3	AG; watch for sign inconsistencies
(ii)	Thus $20=(2.3263+1.6449)\sigma$	M1		A sensible (one that would lead to values required if completed correctly) attempt at solving the two given equations by eliminating μ or σ Do **NOT** allow MC or MR
	$\sigma=5.04$	A1		AWRT (5.03626)
	$\mu=408$	A1	3	AWRT (408.284)
	Total		**12**	
	TOTAL		**75**	

AQA_JUNE_2007_7

Q	Solution	Marks	Total	Comments
7(a)	Time, $X \sim N(48, 20^2)$			
(i)	$P(X < 60) = P\left(Z < \frac{60-48}{20}\right) =$	M1		Standardising (59.5, 60 or 60.5) with 48 and ($\sqrt{20}$,20 or 20^2) and/or $(48 - x)$
	$P(Z < 0.6) = 0.725$ to 0.73	A1	2	AWFW (0.72575)
(ii)	$P(30 < X < 60) =$ $P(X < 60) - P(X < 30) =$ (i) $- P(X < 30) =$ (i) $- P(Z < -0.9) =$	M1		Difference or equivalent Standardising other than 60 and 30 $\Rightarrow$ max of M1 m1 A0
	(i) $- \{1 - P(Z < +0.9)\} =$ $0.72575 - \{1 - 0.81594\} =$	m1		Area change
	0.54 to 0.542	A1	3	AWFW (0.54169)
(iii)	$0.9 \Rightarrow z = 1.28$ to 1.282	B1		AWFW (1.2816)
	$z = \frac{k-48}{20}$	M1		Standardising k with 48 and 20
	$= 1.2816$	m1		Equating z-term to z-value; not using 0.9, 0.1, $\lvert 1 - z \rvert$ or $\Phi(0.9) = 0.81594$
	$k = 73.6$ to 74	A1	4	AWFW
(b)	Time, $Y \sim N(37, 25^2)$			
(i)	Use of $\mu - (2 \text{ or } 3) \times \sigma =$ $37 - (50 \text{ or } 75)$	M1		Or equivalent justification
	$< 0 \Rightarrow$ likely negative times	B1	2	for (likely) negative times
(ii)	Central Limit Theorem or n large / > 30	B1	1	
(iii)	Variance of $\bar{Y} = \frac{25^2}{35}$	B1		OE; stated or used
	$P(\bar{Y} > 40) = P\left(Z > \frac{40-37}{25/\sqrt{35}}\right) =$	M1		Standardising 40 with 37 and $25/\sqrt{35}$ and/or $(37 - 40)$
	$P(Z > 0.71) = 1 - P(Z < 0.71) =$	m1		Area change
	0.238 to 0.24	A1	4	AWFW (1 – 0.76115)
	Total		**16**	
	TOTAL		**75**	

AQA_JUNE_2008_5

Q	Solution	Marks	Total	Comments
5	Height $X \sim N(140, 2.5^2)$			
(a)(i)	$P(X < 145) = P\left(Z < \frac{145-140}{2.5}\right) =$	M1		Standardising (144.5, 145 or 145.5) with 140 and ($\sqrt{2.5}$, 2.5 or 2.5^2) and/or (140 – x)
	$P(Z < 2) =$	A1		2 CAO; ignore sign
	0.977 to 0.98(0)	A1	3	AWFW (0.97725)
(ii)	$P(138 < X < 142) =$ $P(X < 142) - P(X < 138) =$	M1		Difference (142 – 138)
	$P(Z < 0.8) - P(Z < -0.8) =$	B1		0.8 CAO
	$P(Z < 0.8) - \{1 - P(Z < 0.8)\} =$ $(0.78814) - (1 - 0.78814) =$	m1		Correct area change
	0.576 to 0.58(0)	A1	4	AWFW (0.57628)
(b)	0.85 (85%) $\Rightarrow z = -1.03$ to -1.04	B1		AWFW; ignore sign (–1.0364)
	$z = \frac{x-140}{2.5}$	M1		Standardising x with 140 and 2.5; allow (140 – x)
	$= \pm 1.03$ to ± 1.04	A1		Equating z-term to the z-value
	Hence $x = 137.3$ to 137.5	A1	4	AWFW; CSO (137.41)
(c)	Variance of $\bar{X}_4 = \frac{2.5^2}{4} = 1.56(25)$ SD of $\bar{X}_4 = \frac{2.5}{2} = 1.25$	B1		CAO; stated or used
	$P(\bar{X}_4 > 139) = P\left(Z > \frac{139-140}{\sqrt{2.5^2/4}}\right) =$	M1		Standardising 139 with 140 and 1.25; allow (140 – 139)
	$P(Z > -0.8) = P(Z < 0.8) =$	m1		Correct area change
	0.788 to 0.79(0)	A1	4	AWFW (0.78814)
	Total		**15**	

AQA_JUNE_2009_3

Q	Solution	Marks	Total	Comments
3(a)	$X \sim N(253,\ 5^2)$			
(i)	$P(X<250) = P\left(Z<\frac{250-253}{5}\right) =$	M1		Standardising (249.5, 250 or 250.5) with 253 and ($\sqrt{5}$, 5 or 5^2) and/or $(253-x)$
	$P(Z<-0.6) = 1 - P(Z<0.6)$			
	$= 1 - 0.72575$	m1		Area change; may be implied
	$= 0.274$ to 0.275	A1	3	AWFW (0.27425) (1 – answer) ⇒ M1 max
(ii)	$P(245<X<250) = [\text{C's(a)(i)}] - P(X<245)$	M1		Or equivalent; must be clear correct method if answer incorrect and answer > 0
	$=$ (i) $- P(Z<-1.6) = 0.27425 - 0.0548$			
	$= 0.219$ to $0.22(0)$	A1	2	AWFW (0.21945) M1 A0 for [1 – (i)] – 0.0548 = 0.67095 M0 A0 for 0.9452 – [(i)] = 0.67095 M1 A1 for 0.9452 – [1 – (i)] = 0.21945
(iii)	$P(X=245) = 0$ or zero or impossible	B1	1	Ignore any working B0 for 'for impossible to calculate'
(b)	98% (0.98) ⇒ $z = -2.05$ to -2.06	B1		AWFW; ignore sign (–2.0537)
	$z=\frac{245-253}{\sigma}$	M1		Standardising 245 with 253 and σ; allow $(253-245)$
	$= -2.0537$	A1		Only allow: ±2.05 to ±2.06 ±2.32 to ±2.33
	$\sigma = 3.88$ to $3.9(0)$	A1		AWFW (3.8954)
	Note: $\frac{245-253}{\sigma} = 2.0537 \Rightarrow \sigma = 3.8954$ ⇒ B1 M1 A1 A0		4	Or equivalent inconsistent signs
		Total	**10**	

Q	Solution	Marks	Total	Comments
3 (a) (i)	Time, $X \sim N(65, 20^2)$			
	$P(X < 90) = P\left(Z < \frac{90-65}{20}\right)$ – $\left[P\left(Z < \frac{0-65}{20}\right) = P(Z < -3.25) = 0.00058\right]$	M1		Standardising (89.5, 90 or 90.5 or 59.5, 60 or 60.5) with 65 and ($\sqrt{20}$, 20 or 20^2) and/or $(65 - x)$ **May be gained in (a)(i) or (a)(ii)**
	$= P(Z < \mathbf{1.25})$	A1		CAO; ignore inequality and sign May be implied by a correct answer
	$= \mathbf{0.893}$ **to** $\mathbf{0.895}$	A1		AWFW (0.89435)
(ii)	$P(X > 60) = P(Z > -0.25)$			
	$= P(Z < 0.25)$	M1		Area change May be implied by a correct answer or answer > 0.5
	$= \mathbf{0.598}$ **to** $\mathbf{0.599}$	A1	5	AWFW (0.59871)
(b) (i)	$P(1 \text{ in } 6 = 60) =$ **0 or zero or impossible**	B1	1	Ignore any working B0 for 'impossible to calculate'
(ii)	$P(X < 60) = 1 - [(a)(ii)]$ **or** (0.401 to 0.402)	M1		May be implied
	$P(6 \text{ in } 6 < 60) = p^6$ with $0 < p < 1$	M1		Any probability to power 6; do **not** allow multiplying factors
	$= (0.40129)^6 =$ **0.004 to 0.00425**	A1dep	3	Dependent on M1 M1 (0.0041759)
(iii)	Variance of $\bar{X}_6 = \mathbf{20^2/6 = 66.6}$ **to 66.7**	B1		CAO/AWFW Stated or used **anywhere in (b)**
	or Sd of $\bar{X}_6 = \mathbf{20/\sqrt{6} = 8.16}$ **to 8.17**			CAO/AWFW
	$P(\bar{X}_6 < 60) = P\left(Z < \frac{60-65}{20/\sqrt{6}}\right) =$	M1		Standardising 60 with 65 and **$20/\sqrt{6}$ or equivalent** allow (65 – 60)
	$P(Z < -0.61) = 1 - P(Z < 0.61)$	m1		Area change May be implied by a correct answer or answer < 0.5
	$= 1 - 0.72907 =$ = **0.27(0) to 0.271**	A1	4	AWFW (0.27093) (1 – answer) ⇒ B1 M1 max
	Note: Watch for answers to (ii) and (iii) interchanged			
	Total		**13**	

AQA_JUNE_2011_2

Q	Solution	Marks	Total	Comments
2				
(a)(i)	Diameter, $D \sim N(57.15,\ 0.04^2)$			
	$P(D < 57.2) = P\left(Z < \frac{57.2 - 57.15}{0.04}\right)$	M1		Standardising 57.2 with 57.15 and 0.04; allow $(57.15 - 57.2)$
	$= P(Z < \mathbf{1.25})$	A1		CAO; ignore inequality and sign May be implied by a **correct** answer
	$=$ **0.894 to 0.895**	A1	3	AWFW (0.89435)
(ii)	$P(57.1 < D < 57.2)$			
	$= p - (1 - p)$	M1		Allow even if incorrect standardising providing $p-(1-p)$ **seen** May be implied by a correct answer
	$= 2 \times 0.89435 - 1 =$ **0.788 to 0.79(0)**	A1	2	AWFW (0.78870)
(b)(i)				
	$P(16 \text{ balls} < 57.2) = p^{16}$ with $0 < p < 1$	M1		Any probability to power 16 or $1 - p^{16}$; do **not** allow multiplying factors *If only seen in (b)(ii), allow just M1*
	$= [(a)(i)]^{16} = (0.89435)^{16} =$ **0.166 to 0.17(0)**	A1	2	AWFW (0.16754)
(ii)	Variance of $\bar{D}_{16} =$ **$0.04^2/16 = 0.0001$** **or** Sd of $\bar{D}_{16} =$ **$0.04/\sqrt{16} = 0.01$**	B1		CAO Stated or used (*see* **Notes** *below*) CAO *If only seen in (b)(i), allow just B1*
	$P(\bar{D}_{16} > 57.16) = P\left(Z > \frac{57.16 - 57.15}{0.01}\right)$	M1		Standardising 57.16 with 57.15 and **0.01 or equivalent**; allow $(57.15 - 57.16)$
	$= P(Z > 1) = 1 - P(Z < 1)$	m1		Area change May be implied by a correct answer or answer < 0.5
	$=$ 1 − 0.84134 = = **0.158 to 0.159**	A1	4	AWFW (0.15866) (1 − answer) ⇒ B1 M1 max
	Notes: Ignore partial/incomplete attempts at (ii) in (i) if followed by correct method			Mark two complete answers in (i) as two attempts so (0 + 2)/2 ⇒ 1max
	Answer to (i) or (ii) repeated			Mark as per scheme; thus (2 max, 0) or (0, 4 max)
	Total		**11**	

AQA_JUNE_2015_2

Q	Solution	Marks	Total	Comments
2				**Accept percentage equivalent answers in (a) but see GN3**
(a)(i)	$P(X < 90) = P\left(Z < \frac{90-91}{0.8}\right)$	M1		Standardising 90 with 91 and 0.8; allow (91 – 90)
	$= P(Z < -1.25) = 1 - P(Z < -1.25)$	m1		**Correct** area change Can be implied by a **correct** answer **or** by an **answer < 0.5**
	$= (1 - 0.89435) = \underline{\mathbf{0.105 \text{ to } 0.106}}$	A1	**(3)**	AWFW (0.10565)
(ii)	$P(X \neq 90) = \underline{\mathbf{1 \text{ or one or unity or } 100\%}}$	B1	**(1)**	CAO; accept nothing else but ignore zeros after decimal point (eg 1.00) Ignore additional words providing that they are not contradictory (eg certain so = 1)
Note	**1** $P(X \neq 90) = P(Z \neq 0) \Rightarrow$ B0 unless followed by 1 OE			
(iii)	$P(91 < X < 92.5) = P(0 < Z < 1.875)$			
	$= (0.969 \text{ to } 0.972) - 0.5$ **or** $= 0.5 - (0.028 \text{ to } 0.031)$	B1		AWFW/CAO OE; can be implied by a **correct** final answer CAO/AWFW
	$= \underline{\mathbf{0.47}}$	B1	**(2)**	AWRT (0.46960)
			6	
(b)	1% (0.01) $\Rightarrow z = \underline{\mathbf{-2.33 \text{ to } -2.32}}$	B1		AWFW; seen anywhere, ignore sign (–2.3263)
	$P(Y < 150) = P\left(Z < \frac{150-153}{\sigma}\right)$	M1		Standardising 150 with 153 and σ/s; allow (153 – 150)
				(–1.2816)
	$\frac{\pm(150-153)}{\sigma} = \begin{pmatrix} \pm 1.28 \text{ AWRT} \\ \text{or} \\ \pm 2.32 \text{ to } \pm 2.33 \text{ AWFW} \end{pmatrix}$	m1		Can be implied by a **correct** answer
				(–2.3263)
	$\sigma = \underline{\mathbf{1.3}}$	A1	**4**	AWRT (1.28960)
Note	**1** Award A0 if the signs are not consistent throughout, so, for example, (150 – 153)/+2.3263 gives $\sigma = 1.3 \Rightarrow$ B1, M1, m1, A0			
		Total	**10**	

AQA_JUNE_2014_2

Q	Solution	Marks	Total	Comments
2	**No MR or MC in this question**			**Accept %age equivalents in (a)(i) to (iii)**
(a)	Time, $X \sim N(7.5,\ 1.6^2)$			
(i)	$P(X < 10) = P\left(Z < \frac{10-7.5}{1.6}\right)$	M1		Standardising 10 with 7.5 and 1.6 but allow $(7.5 - 10)$; $z^2 \Rightarrow$ M0
	$= P(Z < 1.5625) =$ **0.94**	A1	**(2)**	AWRT (0.94091)
(ii)	$P(X > 6) = P(Z > -0.9375) = P(Z < 0.9375)$	M1		**Correct** area change; 0.9375 or correct standardising are **not** required Can be implied by final **answer > 0.5**
	= **0.82 to 0.83**	A1	**(2)**	AWFW (0.82575)
(iii)	$P(5 < X < 10) =$ $P(Z < 1.5625) - P(Z < -1.5625) =$			
	(i) − [1 − (i)] **or** 1 − 2 × [1 − (i)] = [2 × (i)] − 1	M1		OE; any **correct** difference in areas using (a)(i) or $P(5 < X < 10)$ Can be implied by a **correct** final answer
	= 2 × 0.94091 − 1 = = **0.88**	A1	**(2)**	AWRT (0.88182)
			6	
(b)	80% (0.8) $\Rightarrow$ z = **0.84**	B1		AWRT; ignore sign (0.8416)
	$P(Y < 15) = P\left(Z < \frac{15-\mu}{2.4 \text{ or } 1.6}\right)$	M1		Standardising 15 with μ and (2.4 or 1.6) but allow $(\mu - 15)$
	$\left(\frac{15-\mu}{2.4}\right)$ = 0.84(16) or 1.28(16)	m1		Equating expression with σ = **2.4** to either **z-value** (*ignore sign*) Can be implied by a **correct** answer
	μ = **12.95 to 13**	A1	**4**	AWFW (12.9802) ***Must be consistent signs throughout***
		Total	**10**	

AQA_JUNE_2017_3

Q	Solution	Marks	Total	Comments
3	**Accept the equivalent percentage answers with %-sign (see GN5)**			
(a)(i)	$P(W < 9) = P\left(Z < \frac{9 - 8.25}{1.25}\right)$	M1		Standardising **9** with **8.25** and **1.25**; allow $(8.25 - 9)$
	$= P(Z < 0.6) =$ **0.725 to 0.726**	A1	**(2)**	AWFW (0.72575)
(ii)	$P(W > 8) = P(Z > -0.2) = P(Z < 0.2)$	B1		CAO; ignore sign
	$=$ **0.579**	B1	**(2)**	AWRT (0.57926)
(iii)	$P(W \neq 8.25) =$ **1 or one or unity or 100%**	B1	**(1)**	CAO; accept nothing else but ignore zeros after decimal point (eg 1.00) Ignore additional words providing that they are not contradictory (eg certain so = 1)
(iv)	$P(8 < W < 10) = P(-0.2 < Z < 1.4)$ $= 0.91924 - (1 - (ii))$			
	$=$ **0.498 to 0.499**	B2	**(2)**	AWFW (0.49850)
			7	
(b)	$\mu =$ **15**	B1		CAO; (by symmetry)
	$2.5\% \Rightarrow z =$ **1.96**	B1		AWRT; ignore sign
	$(20 - 15)/\sigma = 1.96$ **or** $(10 - 15)/\sigma = -1.96$ **or** $1.96\sigma = 5$	M1		OE; **correct** equation
	$\sigma =$ **2.55**	A1		AWRT (2.55102)
	OR			
	$2.5\% \Rightarrow z =$ **1.96**	(B1)		AWRT; ignore sign
	$(20 - \mu)/\sigma = 1.96$ **or** $\mu + 1.96\sigma = 20$ $(10 - \mu)/\sigma = -1.96$ **or** $\mu - 1.96\sigma = 10$	(M1)		OE; **two correct** equations
	$\sigma =$ **2.55**	(A1)		AWRT (2.55102)
	$\mu =$ **15.0**	(B1)	**4**	AWRT (14.998 to 15.002)
		Total	**11**	

AQA_JUNE_2018_3

Q	Solution	Mark	Total	Comment
3 (a)(i)	$P(X < 377.5) = P\left(Z < \frac{377.5 - 365.0}{10.0}\right) =$	M1		Standardising **377.5** with **365** and **10** but allow $(365 - 372.5)$
	$P(Z < 1.25) =$ **0.894**	A1	(2)	AWRT (0.89435)
(ii)	$P(X > 367.5) = P(Z > 0.25) =$ $1 - P(Z < 0.25) = 1 - 0.59871$	M1		Area change; can be implied by answer < 0.5
	$=$ **0.401**	A1	(2)	AWRT (0.40129)
(iii)	$P(365 < X < 367.5) = [1 - (ii)] - 0.5$			
	$=$ **0.099**	B2	(2)	AWRT (0.09871)
			6	
(b) (i)	$0.05(0.95) \Rightarrow z =$ **−1.64 to −1.65**	B1		AWFW; ignore sign (−1.6449)
	$\frac{450 - 475}{\sigma} = \begin{pmatrix} \pm 1.28 \text{ AWRT} \\ \pm 1.64 \text{ to } \pm 1.65 \\ \pm 1.96 \text{ AWRT} \end{pmatrix}$	M1		Standardising **450** with **475** and σ but allow $(475 - 450)$ **and** equating to one of 3 listed z-values
	$\sigma =$ **15.2**	A1	3	CAO (15.198492) Must be **consistent signs** giving $\sigma > 0$
(ii) (A)	$P(12 \text{ ELP} > 450.0) = 0.95^{12} =$ **0.54 to 0.541**	B1	(1)	AWFW (0.540360)
(B)	$\text{Sd}(\bar{Y}_{12}) = \frac{15.1 \text{ to } 15.3}{\sqrt{12}} =$ **4.36 to 4.42**			AWFW (4.387862)
	or	B1		OE
	$\text{Var}(\bar{Y}_{12}) = \frac{15.1^2 \text{ to } 15.3^2}{12} =$ **19.00 to 19.51**			AWFW (19.253333)
	$P(\bar{Y}_{12} > 470.0) = P\left(Z > \frac{470.0 - 475.0}{(b)(i)/\sqrt{12}}\right)$	M1		Standardising **470** with **475** and $((b)(i))/\sqrt{12}$ (OE); $(b)(i) > 0$ and allow $(475 - 470)$
	$= P(Z >$ **−1.13 to −1.15**$)$	A1		AWFW; ignore sign Can be implied by answer
	$=$ **0.87 to 0.875**	A1	(4)	AWFW (0.87275)
			5	
		Total	14	