1 **(i)**	$X \sim B(20, 0.15)$ (***A***) *Either* $P(X = 1) = \binom{20}{1} \times 0.15^1 \times 0.85^{19} = 0.1368$ *or* $P(X = 1) = P(X \leq 1) - P(X \leq 0)$ $= 0.1756 - 0.0388 = 0.1368$	M1 $0.15^1 \times 0.85^{19}$ M1 $\binom{20}{1} \times p^1 q^{19}$ A1 CAO OR: M2 for 0.1756 – 0.0388 A1 CAO	**3**	With $p + q = 1$ Allow answer 0.137 with or without working or 0.14 if correct working shown See tables at the website http://www.mei.org.uk/files/pdf/formula_book_mf2.pdf For misread of tables 0.3917 – 0.1216 = 0.2701 allow M1M1A0 also for 0.1304 – 0.0261 = 0.1043
	(***B***) $P(X \geq 2) = 1 - P(X \leq 1)$ $= 1 - 0.1756 = 0.8244$	M1 for 1 – their 0.1756 A1 CAO	**2**	Provided 0.1756 comes from $P(X=0) + P(X=1)$ Allow answer 0.824 with or without working or 0.82 if correct working shown Point probability method: P(1) = 0.1368 , P(0) = 0.0388 So 1 - $P(X \leq 1)$ = 1 - 0.1756 gets M1 then mark as per scheme M0A0 for $1 - P(X \leq 1) = 1 - 0.4049 = 0.5951$ For misread of tables 1 – 0.3917 = 0.6083 allow M1A1 also for 1 – 0. 1304 = 0.8696 provided consistent with part (*A*) OR M1A0 if formula used in part (*A*)

(ii)	Let $X \sim B(n, p)$ Let p = probability of a 'no-show' (for population) H_0: $p = 0.15$ H_1: $p < 0.15$ H_1 has this form because the hospital management hopes to reduce the proportion of no-shows.	B1 for definition of p B1 for H_0 B1 for H_1 E1 Allow correct answer even if H_1 wrong	**4**	Allow p = P(no-show) for B1 Definition of p must include word probability (or chance or proportion or percentage or likelihood but NOT possibility). Preferably as a separate comment. However can be at end of H_0 as long as it is a clear definition 'p = the probability of no-show, NOT just a sentence 'probability is 0.15' H_0 : p(no-show) = 0.15, H_1 : p(no-show) < 0.15 gets B0B1B1 Allow p=15%, allow θ or π and ρ but not x. However allow any single symbol <u>if defined</u> Allow $H_0 = p$=0.15, Do not allow H_0 : P(X=x) = 0.15, H_1 : P(X=x) < 0.15 Do not allow H_0: =0.15, =15%, P(0.15), p(0.15), p(x)=0.15, x=0.15 (unless x correctly defined as a probability) Do not allow H_1:$p \leq 0.15$, Do not allow H_0 and H_1 reversed for B marks but can still get E1 Allow NH and AH in place of H_0 and H_1 For hypotheses given in words allow Maximum B0B1B1E1 Hypotheses in words must include probability (or chance or proportion or percentage) and the figure 0.15 oe.
(iii)	P($X \leq 1$) = 0.1756 > 5% So not enough evidence to reject H_0. Not significant. Conclude that there is not enough evidence to indicate that the proportion of no-shows has decreased.	M1 for probability seen, but not in calculation for point probability M1 dep for comparison A1	**4**	Zero for use of point prob - P(X = 1) = 0.1368 Do <u>NOT</u> FT wrong H_1 Allow accept H_0, or reject H_1 Full marks only available if 'not enough evidence to…' oe mentioned somewhere Do not allow 'enough evidence to reject H_1' for final mark but can still get 3/4 Upper end comparison: 1 – 0.1756 = 0.8244 < 95% gets

	Note: use of critical region method scores M1 for region {0} M1 for 1 does not lie in critical region, then A1 E1 as per scheme	E1 dep for conclusion in context.		M2 then A1E1 as per scheme <u>Line diagram method</u> M1 for squiggly line between 0 and 1 with arrow pointing to left, M1 0.0388 seen on diagram from squiggly line or from 0, A1E1 for correct conclusion <u>Bar chart method</u> M1 for line clearly on boundary between 0 and 1 and arrow pointing to left, M1 0.0388 seen on diagram from boundary line or from 0, A1E1 for correct conclusion
(iv)	$6 < 8$ So there is sufficient evidence to reject H_0 Conclude that there is enough evidence to indicate that the proportion of no-shows appears to have decreased.	M1 for comparison seen A1 E1 for conclusion in context	**3**	Allow '6 lies in the CR' Do NOT insist on 'not enough evidence' here Do not FT wrong H_1:p>0.15 but may get M1 In part (iv) ignore any interchanged H_0 and H_1 seen in part (ii)
(v)	For $n \leq 18$, P($X \leq 0$) > 0.05 so the critical region is empty.	E1 for P($X \leq 0$) > 0.05 E1 indep for critical region is empty	**2**	E1 also for sight of 0.0536 Condone P($X = 0$) > 0.05 or all probabilities or values, (but not outcomes) in table (for $n \leq 18$) > 0.05 Or 'There is no critical region' For second E1 accept 'H_0 would always be accepted' Do <u>NOT</u> FT wrong H_1 Use professional judgement - allow other convincing answers
		TOTAL	**18**	

2 **(i)**	E(X) = np = 12 × 0.2 = 2.4 Do not allow subsequent rounding.	M1 for product A1 CAO	**2**	If wrong n used consistently throughout, allow M marks only. NB If they round to 2, even if they have obtained 2.4 first they get M1A0. For answer of '2.4 or 2 if rounded up' allow M1A0 Answer of 2 without working gets M0A0. If they attempt E(X) by summing products xp give no marks unless answer is fully correct.
(ii)	X ~ B(12, 0.2) (***A***) P(Wins exactly 2) $= \binom{12}{2} \times 0.2^2 \times 0.8^{10} = 0.2835$ OR from tables $0.5583 - 0.2749 = 0.2834$	M1 $0.2^2 \times 0.8^{10}$ M1 $\binom{12}{2} \times p^2 q^{10}$ A1 CAO OR: M2 for 0.5583 – 0.2749 A1 CAO	**3**	With $p + q = 1$ Also for 66 × 0.004295 Allow answers within the range 0.283 to 0.284 with or without working or 0.28 to 0.283 if working shown See tables at the website http://www.mei.org.uk/files/pdf/formula_book_mf2.pdf
	(***B***) P(Wins at least 2) $= 1 - 0.2749 = 0.7251$	M1 P($X \leq 1$) M1 1-P($X \leq 1$) A1 CAO	**3**	M1 0.2749 seen M1 1 – 0.2749 seen Allow 0.725 to 0.73 but not 0.72. Point probability method: P(1) = $12 \times 0.2 \times 0.8^{11} = 0.2062$, P(0) = $0.8^{12} = 0.0687$ So P($X \leq 1$) = 0.2749 gets M1 then mark as per scheme SC1 for 1 – P($X \leq 2$) = 1 – 0.5583 = 0.4417 For misread of tables value of 0.2749 , allow 0 in (*A*) but MAX M1M1 in (*B*) For P(X>1) = P(X=2) + P(X=3) + P(X=4) +.... allow M1 for 0.2835+0.2362+0.1329+0.0532+0.0155 and second M1 for 0.0033+0.0005+0.0001 and A1 for 0.725 or better M0M0A0 for 1 - P(X=1) = 1 – 0.2062 = 0.7938

(iii)	Let p = probability that Ali wins a game H_0: $p = 0.2$ H_1: $p > 0.2$ H_1 has this form as Ali claims that he is better at winning games than Mark is. *EITHER Probability method:* $P(X \geq 7) = 1 - P(X \leq 6)$ $= 1 - 0.9133 = 0.0867 > 5\%$ So not significant, so there is not enough evidence to reject the null hypothesis and we conclude that there is not enough evidence to suggest that Ali is better at winning games than Mark. Must include 'not enough evidence' or something similar for E1. 'Not enough evidence' can be seen in the either for the A mark or the E mark. Do not allow final conclusions for E1 such as : 'there is evidence to suggest that Ali is no better at winning games than Mark' or 'Mark and Ali have equal probabilities of winning games'	B1 for definition of p in context B1 for H_0 B1 for H_1 E1 B1 for $P(X \geq 7)$ B1 for 0.0867 Or 1 – 0.9133 seen M1 for comparison with 5% dep on B1 for 0.0867 A1 for not significant or 'accept H_0' or 'cannot reject H_0' or 'reject H_1' E1 dep on M1A1 Do not award first B1 for poor symbolic notation such as $P(X = 7) = 0.0867$ Th comment applies to all methods	**4** **5**	Minimum needed for B1 is p = probability that Ali wins. Allow p = P(Ali wins) for B1 Definition of p must include word probability (or chance or proportion or percentage or likelihood but NOT possibility). Preferably as a separate comment. However can be at end of H_0 as long as it is a clear definition ' p = the probability that Ali wins a game, NOT just a sentence 'probability is 0.2' H_0 : p(Ali wins) = 0.2, H_1 : p(Ali wins) > 0.2 gets B0B1B1Allow p=20%, allow θ or π and ρ but not x. However allow any single symbol <u>if defined</u> Allow $H_0 = p$=0.2, Allow $H_0 : p = {}^{2}/_{10}$ Do not allow $H_0 : P(X=x) = 0.2$, $H_1 : P(X=x) > 0.2$ Do not allow H_0: =0.2, =20%, P(0.2), p(0.2), p(x)=0.2, x=0.2 (unless x correctly defined as a probability) Do not allow H_1:$p \geq 0.2$, Do not allow H_0 and H_1 reversed for B marks but can still get E1 Allow NH and AH in place of H_0 and H_1 For hypotheses given in words allow Maximum B0B1B1E1 Hypotheses in words must include probability (or chance or proportion or percentage) and the figure 0.2 oe. Zero for use of point prob - $P(X = 7) = 0.0546$

	OR Critical region method: Let $X \sim B(20, 0.2)$ $P(X \geq 7) = 1 - P(X \leq 6) = 1 - 0.9133 = 0.0867 > 5\%$ $P(X \geq 8) = 1 - P(X \leq 7) = 1 - 0.9679 = 0.0321 < 5\%$ So critical region is {8,9,10,11,12,13,14,15,16,17,18,19,20} 7 does not lie in the critical region, so not significant, So there is not enough evidence to reject the null hypothesis and we conclude that there is not enough evidence to suggest that Ali is better at winning games than Mark.	B1 for 0.0867 B1 for 0.0321 M1 for at least one comparison with 5% A1 CAO for critical region and not significant or 'accept H_0' or 'cannot reject H_0' or 'reject H_1' *dep* on M1 and at least one B1 E1 dep on M1A1		Allow any form of statement of CR eg $X \geq 8$, 8 to 20, 8 or above, $X > 8$, {8, …}, annotated number line, etc but not $P(X \geq 8)$ {8,9,10,11,12} gets max B2M1A0 – tables stop at 8. NB USE OF POINT PROBABILITIES gets B0B0M0A0 Use of complementary probabilities Providing there is sight of 95%, allow B1 for 0.9133, B1 for 0.9679, M1 for comparison with 95% A1CAO for correct CR See additional notes below the scheme for other possibilities **PLEASE CHECK THAT THERE IS NO EXTRA WORKING ON THE SECOND PAGE IN THE ANSWER BOOKLET**
		TOTAL	**17**	

3 **(i)**	X ~ B(18, 0.1) (***A***) P(2 faulty tiles) $= \binom{18}{2} \times 0.1^2 \times 0.9^{16} = 0.2835$ OR from tables $0.7338 - 0.4503 = 0.2835$ (***B***) P(More than 2 faulty tiles) $= 1 - 0.7338 = 0.2662$	M1 $0.1^2 \times 0.9^{16}$ M1 $\binom{18}{2} \times p^2 q^{16}$ A1 CAO OR: M2 for 0.7338 – 0.4503 A1 CAO M1 P($X \leq 2$) M1 *dep* for 1-P($X \leq 2$) A1 CAO	**3** **3**
	(***C***) E(X) = np = 18 × 0.1 = 1.8	M1 for product 18 × 0.1 A1 CAO	**2**
(ii)	(A) Let p = probability that a randomly selected tile is faulty H_0: $p = 0.1$ H_1: $p > 0.1$	B1 for definition of p in context B1 for H_0 B1 for H_1	**3**
	(B) $_1$ has this form as the manufacturer believes that the number of faulty tiles may <u>increase</u>.	E1	**1**
(iii)	Let X ~ B(18, 0.1) P($X \geq 4$) = 1 – P($X \leq 3$) = 1 – 0.9018 = 0.0982 > 5% P($X \geq 5$) = 1 – P($X \leq 4$) = 1 – 0.9718 = 0.0282 < 5% So critical region is {5,6,7,8,9,10,11,12,13,14,15,16,17,18}	B1 for 0.0982 B1 for 0.0282 M1 for at least one comparison with 5% A1 CAO for critical region *dep* on M1 and at least one B1	**4**
(iv)	4 does not lie in the critical region, (so there is insufficient evidence to reject the null hypothesis and we conclude that there is not enough evidence to suggest that the number of faulty tiles has increased.	M1 for comparison A1 for conclusion **in context**	**2**
		TOTAL	**18**