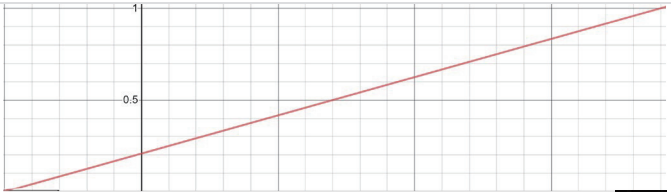
Question	Scheme	Marks
1. (a)	4	B1 (1)
(b)	$P(X=2)=3\times0.2\times0.8^2\left[=\frac{48}{125}=0.384\right]$ **or** $P(X=3)=0.8^3\left[=\frac{64}{125}=0.512\right]$	M1
	$[X=]$ 3 is the mode	A1 (2)
(c)	$P(W_1=2)=\frac{e^{-4}4^2}{2}$ [=0.1465] **and** $P(X_1=2)=3\times0.2\times0.8^2$ $[=\frac{48}{125}=0.384]$	M1
	$P(W_1 \text{ and } X_1=2)=\frac{e^{-4}4^2}{2}\times(3\times0.2\times0.8^2)$ [= 0.1465 × 0.384]	M1
	= 0.05626564… awrt **0.0563**	A1 (3)
(d)	$X_1=0$ and $W_1>0$, $X_1=1$ and $W_1>1$, $X_1=2$ and $W_1>2$, $X_1=3$ and $W_1>3$	M1
	0.008×(1 – 0.0183) + 0.096×(1 – 0.0916) + 0.384×(1 – 0.2381) + 0.512×(1 – 0.4335)	M1M1
	= 0.677677… awrt **0.678**	A1 (4)
		[10 marks]

	Notes
(a)	B1 cao
(b)	M1 valid attempt at either probability.
	A1 3 (M1 must be scored)
	NB answer only with no method is M0A0
(c)	1st M1 both $P(W_1=2)$ Allow (0.2381 – 0.0916) and $P(X_1=2)$
	2nd M1 Poisson probability × binomial probability. If no working shown these probabilities must be correct
	A1 awrt 0.0563
(d)	1st M1 for listing at least 3 combinations. Implied by 2nd M1.
	2nd M1 for sum of at least 3 correct products Condone consistent use of the tables for 3.5 or 4.5 rather than 4
	3rd M1 for a fully correct expression eg 0.008×(0.9817) + 0.096×(0.9084) + 0.384×(0.7619) + 0.512×(0.5665) condone 0.9816 and 0.7618 Allow figures to 3sf for method or awrt 0.00785 + awrt 0.0872 + awrt 0.293 + awrt 0.290 (allow 0.29)
	A1 awrt 0.678
	Alternative: $W_1=1$ and $X_1=0$, $W_1=2$ and $X_1<2$, $W_1=3$ and $X_1<3$, $W_1\geq4$ 0.0733×0.008 + 0.1465×0.104 + 0.1954×0.488 + (1 – 0.4335) awrt 0.000586 + awrt 0.0152 + awrt 0.0954 + awrt 0.567

Question	Scheme	Marks
2. (a)	$\mathrm{E}(T)=\int_0^4 \frac{1}{192}t(t^3-48t+128)\,\mathrm{d}t$	M1
	$=\frac{1}{192}\left[\frac{t^5}{5}-16t^3+64t^2\right]_0^4$ **or** $\left[\frac{t^5}{960}-\frac{1}{12}t^3+\frac{1}{3}t^2\right]_0^4$ oe	dM1
	$=\frac{1}{192}\left(\frac{4^5}{5}-16(4^3)+64(4^2)-0\right)=\frac{16}{15}\text{min}\rightarrow 1$ minute 4 seconds	A1
		(3)
(b)	$\mathrm{P}(\text{call takes between 1 and 3 minutes})=\int_1^3 \frac{1}{192}(t^3-48t+128)\,\mathrm{d}t$	
	mor $\left[\frac{t^4}{768}-\frac{1}{8}t^2+\frac{2}{3}t\right]_1^3$ oe	M1
	$=\frac{1}{192}\left(\left(\frac{3^4}{4}-24(3^2)+128(3)\right)-\left(\frac{1^4}{4}-24(1^2)+128(1)\right)\right)=\frac{7}{16}$ *	dM1 A1*cso
		(3)
(c)	$C\sim \mathrm{B}(256,\frac{7}{16})\approx \mathrm{N}(112,63)$	M1 A1
	$\mathrm{P}(C>125)\approx \mathrm{P}\left(Z>\frac{125.5-112}{\sqrt{63}}\right)$	M1M1
	$\mathrm{P}(Z>1.70)=1-0.9554=0.0446$	A1
		(5)
	Notes	**[11 marks]**
(a)	1st M1 for using $\int tf(t)\,\mathrm{d}t$ ignore limits. $t^4\rightarrow t^5$ or $t^2\rightarrow t^3$ or $t\rightarrow t^2$ for at least one term, ignore coefficients. Implied by an answer of $\frac{16}{15}$ or 1 minute 4 seconds (allow 64) or awrt 1.067	
	2nd dM1 dep on previous M1 fully correct integration with limit of 4 and 0 or 4 substituted (204.8) This mark is not implied by a correct answer	
	A1 the second M1 mark must be awarded 1 min 4 s (accept 64)	
	NB an answer of $\frac{16}{15}$ or 1 minute 4 seconds or 64 or awrt 1.067 with no working gains M1M0A0.	
(b)	1st M1 attempt to integrate $\int \mathrm{f}(t)\,\mathrm{d}t$ $t^n\rightarrow t^{n+1}$ for at least one term. Ignore limits. If they have integrated f(t) in part (a) and used this in part (b) we will allow this mark.	
	2nd M1 (dep on 1st M1) for use of correct limits. Must see substitution into their expression. If integration correct allow $\frac{1}{192}\left(\left(\frac{81}{4}-216+384\right)-\left(\frac{1}{4}-24+128\right)\right)$ or $\frac{1}{192}\left(\frac{753}{4}-\frac{417}{4}\right)$ or $\frac{251}{256}-\frac{139}{256}$	
	1st A1* cso $\frac{7}{16}[=0.4375]$ fully correct solution (correct integration and substitution) . Answer is given so both method marks must be awarded.	
(c)	1st M1 use or sight of Normal approximation with mean 112	
	1st A1 correct mean and variance (condone 63^2 if used $\sqrt{63}$ in the standardisation)	
	2nd M1 standardising using their mean and variance. Allow use of 124.5, 125, 125.5, 126, 126.5 or on the numerator 12.5, 13, 13.5, 14, 14.5	
	3rd M1 use of continuity correction 125 ± 0.5 Implied by numerator of 12.5 or 13.5	
	2nd A1 awrt 0.0445/0.0446 [calc 0.0444865…]	
	[Exact binomial gives 0.0448518… and gains no marks]	

Question	Scheme	Marks
3. (a)	$\frac{19}{24}$	B1
		(1)
(b)	$P(\lvert R\rvert > 3.5) = \frac{-3.5-(-5)}{19-(-5)} + \frac{19-3.5}{19-(-5)}, = \frac{17}{24}$	M1, A1
		(2)
(c)		M1 A1
		(2)
(d)(i)	$P(R_1 > 10) = \frac{19-10}{19-(-5)}\left[= \frac{9}{24} = 0.375\right]$	M1
	$[P(R > 10)]^3 = \left(\frac{9}{24}\right)^3 = \frac{27}{512}$	M1 A1
		(3)
(ii)	$1 - [P(R < 10)]^3 = \frac{387}{512}$	M1 A1
		(2)
	Notes	**[10 marks]**
(a)	B1 allow awrt 0.792	
(b)	M1 sum of two regions from uniform distribution or $1-\frac{3.5-(-3.5)}{19-(-5)}\left[=1-\frac{7}{24}\right]$ oe You may ft their denominator from (a)	
	A1 allow awrt 0.708	
	SC M1A0 for $P(-3.5 < R < 3.5) = \frac{7}{24}$ (awrt 0.292) **or** for finding $P(R > 3.5) = \frac{31}{48}$(awrt 0.646) and $P(R < -3.5) = \frac{1}{16}$(0.0625)	
(c)	M1 straight line with increasing gradient. Allow a horizontal line to the right of 19 and/or a horizontal line to the left of – 5	
	A1 starting at (–5, 0) and finishing at (19, 1) Need to be clear labels for −5, 19 and 1. 0 may be labelled or implied by the x- axis	
(d) (i)	1st M1 for $P(R > 10)$ eg $1-\frac{10-(-5)}{19-(-5)}$ no need to simplify. Implied by 0.375 or $\frac{27}{512}$ You may use their denominator from (a)	
	2nd M1 ["their $P(R > 10)$"]^3 They may use their denominator from (a) otherwise ft their $P(R > 10)$ only if it is clearly labelled.	
	A1 allow awrt 0.0527	
(ii)	M1 Use of $1 - p^3$ $0 < p < 1$ (none are greater than 10cm from origin) or $3p^2(1-p) + 3p(1-p)^2 + (1-p)$ $0 < p < 1$ working needs to be shown	
	A1 allow awrt 0.756	
	SC M1A0 for finding the P (exactly 1 is > 10cm) = $\frac{225}{512}$ = (0.439…)	

Question	Scheme	Marks
4. (a)	$[P(Y = 0) < 0.05]$	
	$(1 - 0.07)^n < 0.05$	M1
	$n \log (0.93) < \log (0.05)$	M1
	$n > 41.28\ldots$ $n = 42$	A1
		(3)
(b)	H_0: $p = 0.08$ H_1: $p \neq 0.08$	B1
	$X \sim B(75, 0.08) \rightarrow Po(6)$	M1
	$P(X \ldots 11) = 1 - P(X \text{„} 10)$	M1
	$= 1 - 0.9574 = 0.0426$ [> 0.025]	A1
	Do not Reject H_0 or not significant or 11 does not lie in the CR	dM1
	There is not significant evidence to suggest that the **proportion** of pears weighing more than 180g has **changed**	A1
		(6)
		[9 marks]
	Notes	
(a)	1st M1 For 0.93^n or 0.93^{42} or 0.93^{41}	
	2nd M1 for $n \log (0.93) < \log (0.05)$ or $\log_{0.93} 0.05$„ n Allow = or „ condone > or … or $0.93^{42} = 0.0474\ldots$ or 0.0475 (min 4 dp) Implied by 41.28… or awrt 41.3	
	A1 42 cao **NB** An answer of 42 gains 3/3	
	SC condone for M1 M0 A0 $\left([e^{-3} =]0.04978\ldots \text{ (min 4dp) and } -0.07n = -3\right)$	
(b)	B1 both hypotheses correct (may use p or π but do not allow p(x)) Allow 8% connected to H_0 and H_1 correctly	
	1st M1 writing or using Poisson approximation with mean 6.	
	2nd M1 for writing or using $1 - P(X \text{„} 10)$ or for a CR method (must give a CR) giving $P(X \text{„} 11) = 0.9799$ or $P(X \ldots 12) = 0.0201$ Implied by awrt 0.0426 or correct CR	
	1st A1 for 0.0426 or CR: $X \ldots 12$ ignore lower CR. NB M1A1 for $P(X \text{„} 10) = 0.9574$ on its own	
	3rd dM1 Independent of their hypotheses dependent on 2nd M1 but A correct statement i.e. not significant/do not reject H_0/Not in CR/reject H_1 Do not allow non-contextual conflicting statements.	
	2nd A1 For a correct contextual statement. Need proportion oe and changed oe Allow the farmers **belief** (oe) is not supported (bold words) Do not accept contradicting statements. No hypotheses is A0	
	NB Award d M1A1 for a correct contextual statement on its own	
	SC1: Use of one-tailed test may score B0M1M1A1M1A0 for rejecting H_0	
	SC2: Use of Binomial throughout max (3/6) B1M0M1A0dM1A0	
	SC3: normal approximation prob = 0.0277 (maximum 3 out of 6) B1 M0 M1 for writing or using $1 - P(X \text{„} 10.5)$ allow < implied by awrt 0.027/0.028 A0 dM1A0	

Question	Scheme	Marks
5. (a)	$X \sim \text{Po}(7.5)$	B1
(i)	$P(X = 10)$ [$= 0.8622 - 0.7764 = \frac{e^{-7.5}(7.5)^{10}}{10!}$] $= 0.0858\ldots$ awrt **0.0858**	B1
(ii)	$P(6 \leqslant X \leqslant 11) = P(X \leqslant 11) - P(X \leqslant 5)$ [$=0.9208 - 0.2414$]	M1
	$= 0.6794$ awrt **0.679**	A1
		(4)
(b)	Y = number of samples that contain 0 particles	
	$Y \sim \text{B}(12, p)$ or $\text{B}(12, e^{-0.15m})$ or $\text{B}(12, e^{-\lambda})$	M1
	[$P(Y \geqslant 2) =$] $1 - P(Y \leqslant 1) = 0.1184$	M1
	$P(Y \leqslant 1) = 0.8816 \rightarrow$ from tables [$p =$] 0.05	A1
	S = number of particles per m millilitres	
	$S \sim \text{Po}(0.15m)$	M1
	$P(S = 0) = 0.05$ or $e^{-0.15m} = "0.05"$	M1
	$-0.15m = \ln(0.05) \rightarrow m = 19.9715\ldots$ awrt **20.0**	A1
		(6)
		[10 marks]

	Notes
(a)	1st B1 writing or using Po(7.5) May be implied by a correct probability
(i)	2nd B1 awrt 0.0858 [calc = 0.0858303…]
(ii)	M1 writing or using $P(X \leqslant 11) - P(X \leqslant 5)$
	A1 awrt 0.0679 [calc = 0.06793222…]
(b)	1st M1 writing or using B(12, p) Allow Binomial with $n = 12$ or B(12,…) May be implied by 0.05
	2nd M1 for $1 - P(Y \leqslant 1) = 0.1184$ (or better) or $P(Y \leqslant 1) = 0.8816$ oe eg $(1-p)^{12} + 12p(1-p)^{11} = 0.8816$ Implied by 0.05
	1st A1 0.05(seen)
	3rd M1 writing or using Po($0.15m$) May be implied by $e^{-0.15m}$
	4th M1 ft their p ($0 < p < 1$) for an equation of the form $e^{-0.15m} = "0.05"$ (allow $e^{-\lambda} = "0.05"$) Allow $0.15m = 3$
	2nd A1 Allow 20 or awrt 20.0 Allow trial and error to solve their equation

Question	Scheme	Marks
6. (a)	$\int_0^2 0.1x\,\mathrm{d}x + \int_2^4 kx(8-x)\,\mathrm{d}x = \frac{31}{45}$	M1
	$\left[\frac{0.1x^2}{2}\right]_0^2 + k\left[4x^2 - \frac{x^3}{3}\right]_2^4 = \frac{31}{45}$	M1
	$0.2 + k\left(64 - \frac{64}{3} - (16 - \frac{8}{3})\right) = \frac{31}{45} \rightarrow k = \frac{1}{60}$	dM1 A1
		(4)
(b)(i)	$a = \left[\left(1 - \frac{31}{45}\right) \div 2 =\right] \frac{7}{45}$	B1
(ii)	$\mathrm{P}(0 \text{ „ } X \text{ „ } 5.5) = \frac{31}{45} + "a" \times 1.5 = \frac{83}{90}$	M1 A1
		(3)
(c)	$\int_0^x 0.1t\,\mathrm{dt} = \frac{0.1x^2}{2}$	B1
	$\int_0^2 0.1t\,\mathrm{dt} + \int_2^x "\frac{1}{60}" t(8-t)\,\mathrm{d}t,$ $\qquad \frac{31}{45} + \int_4^x "\frac{7}{45}"\,\mathrm{d}t$	M1, M1
	$[\mathrm{F}(x) =]\begin{cases} 0 & x < 0 \\ 0.05x^2 & 0 \text{ „ } x < 2 \\ \frac{1}{60}(4x^2 - \frac{x^3}{3} - \frac{4}{3}) & 2 \text{ „ } x < 4 \\ \frac{7}{45}x + \frac{1}{15} & 4 \text{ „ } x < 6 \\ 1 & x \ldots 6 \end{cases}$	B1 A1 A1 (6)
	Notes	**[13 marks]**
(a)	1st M1 sum of two integrals = $31/45$ (ignore limits) It may be equated to 31/45 later in their working. Condone missing dx	
	2nd M1 attempt at integration $x \rightarrow x^2$ or $x^2 \rightarrow x^3$ for at least one	
	3rd dM1 dep on 1st M1 being awarded for use of correct limits	
	A1 $k = \frac{1}{60}$ cao Allow $0.01\dot{6}$ or equivalent exact value $k = \frac{1}{60}$ with no working gains 4/4 $\qquad k = \frac{1}{60}$ from $0.2 = 2k(8-2)$ gains M0M0M0A0	
(b)(i)	B1 $a = \frac{7}{45}$ cao allow $0.1\dot{5}$ or equivalent exact value	
(ii)	M1 ft "their value of a" for $\frac{31}{45} + 1.5 \times "a"$ or $1 - 0.5 \times "a"$	
	A1 $\frac{83}{90}$ cao Allow $0.9\dot{2}$ or equivalent exact value	
(c)	1st B1 a correct integration of 2nd line of pdf if have + C must get $C = 0$	
	1st M1 a correct method to find 3rd line of cdf Condone incorrect integration (allow k) Allow $0.2 + \int_2^x "\frac{1}{60}" t(8-t)\,\mathrm{d}t$ **or** $\int "\frac{1}{60}" t(8-t)\,\mathrm{d}t + C$ and F(2) = 0.2	
	2nd M1 a correct method to find 4th line of cdf Condone incorrect integration (allow a) Allow $\int "\frac{7}{45}"\,\mathrm{d}t + C$ and F(6) = 1 but do **not** allow **their** $\mathrm{F}(4) + \int_4^x \frac{7}{45}"\,\mathrm{d}t$	
	For the next 3 marks limits condone < for „ and „ for < and …for >	
	2nd B1 1st and 5th lines correct with correct limits. Allow 1 range to be otherwise for the limits, Must have consistent use of letter throughout for this mark	
	1st A1 3rd line correct with correct limits Allow equivalent un-simplified expressions	
	2nd A1 4th line correct with correct limits Allow equivalent un-simplified expressions	

Question	Scheme	Marks
7. (a)	$Y \sim B(20, p)$ p = P(sample contains counter with a 9 on it)	
	$p = \left(1 - \frac{9}{10} \times \frac{8}{9} \times \frac{7}{8}\right)$ oe **or** $\left(\frac{1}{10} \times \frac{9}{9} \times \frac{8}{8} \times 3\right)$ oe **or** $\left(\frac{6}{10} \times \frac{5}{9} \times \frac{1}{8} \times 3 + \frac{6}{10} \times \frac{3}{9} \times \frac{1}{8} \times 6 + \frac{3}{10} \times \frac{2}{9} \times \frac{1}{8} \times 3\right)$ oe $\left[= \frac{3}{10}\right]$	M1A1
(i)	$E(Y) = 20 \times "\frac{3}{10}" [= 6]$	B1
(ii)	$Var(Y) = 20 \times "\frac{3}{10}" \times (1 - "\frac{3}{10}") = 4.2$	M1A1
		(5)
(b)	(7,7,7) (7,7,8), [(7,8,7), (8,7,7)] (7,7,9), [(7,9,7), (9,7,7)]	B2
		(2)
(c)	m | 7 | 8 $P(M = m)$ | $\frac{6}{10} \times \frac{5}{9} \times \frac{4}{8} + 3 \times \frac{6}{10} \times \frac{5}{9} \times \frac{3}{8} + 3 \times \frac{6}{10} \times \frac{5}{9} \times \frac{1}{8}$ $= \frac{2}{3}$ | $1 - P(M = 1)$ $= \frac{1}{3}$	B1 M1 M1 A1 A1
		(5)
	Notes	**[Total 12]**
(a)	1st M1 For all methods condone missing ×3 and /or ×6 Allow $\frac{{}^{1}C_{1} \, {}^{9}C_{2}}{{}^{10}C_{3}}$ oe	
	Condone with replacement - condone missing ×3 and /or ×6 $1 - \left(\frac{9}{10}\right)^3$ **or** $\left(\frac{6}{10}\right)^2 \times \frac{1}{10} \times 3 + \frac{6}{10} \times \frac{3}{10} \times \frac{1}{10} \times 6 + \left(\frac{3}{10}\right)^2 \times \frac{1}{10} \times 3 + \ldots$ [=0.271]	
	1st A1 A fully correct expression without replacement or 0.3 NB $E(Y) = 6$ implies the 1st M1 1st A1	
(i)	B1 for 20 × probability – no need to calculate	
and (ii)	2nd M1 Use of $np(1-p)$ or $np\left(1 - \frac{np}{20}\right)$	
	2nd A1 variance = 4.2	
(b)	B1B1 all 3 correct (with none incorrect – ignore arrangements of the correct numbers) (B1B0 any one correct and no incorrect **or** 2 or 3 correct and only one incorrect)These can be awarded in part (c) provided that they are clearly identified as having a median of 7 More than one incorrect is B0B0	
(c)	B1 for identifying that the only possible medians are 7 and 8. Allow 9 if it has a probability of 0	
	1st M1 correct expression for P(M = 7) Implied by 2/3 **or** P(M = 8) Implied by 1/3 $P(M = 8) = \frac{3}{10} \times \frac{2}{9} \times \frac{1}{8} + 3 \times \frac{6}{10} \times \frac{3}{9} \times \frac{2}{8} + 3 \times \frac{3}{10} \times \frac{2}{9} \times \frac{1}{8} + 6 \times \frac{6}{10} \times \frac{3}{9} \times \frac{1}{8}$	
	Condone with replacement $P(M = 7) = \left(\frac{6}{10}\right)^3 + 3 \times \left(\frac{6}{10}\right)^2 \times \frac{3}{10} + 3 \times \left(\frac{6}{10}\right)^2 \times \frac{1}{10} \left[= \frac{81}{125} = 0.648\right]$ or $P(M = 8) = \left(\frac{3}{10}\right)^3 + 3 \times \frac{6}{10} \times \left(\frac{3}{10}\right)^2 + 3 \times \left(\frac{3}{10}\right)^2 \times \frac{1}{10} + 6 \times \frac{6}{10} \times \frac{3}{10} \times \frac{1}{10} \left[= \frac{81}{250} = 0.324\right]$	
	2nd M1 Total of the 2 probabilities for 7 and 8 =1 or a correct expression without replacement for both P(M = 7) and P(M = 8) condone with replacement	
	1st A1 $P(M = 7) = \frac{2}{3}$ oe 2nd A1 $P(M = 8) = \frac{1}{3}$ oe	