Q1 $\mathbf{f}(t) = 1 - e^{-r/3}$ (t>0)II(i)For median $m, \frac{1}{2} = 1 - e^{-m/3}$ M1attempt to solve, here or for 90th percentile. Depends on previous $\Rightarrow m = 2.079$ A1M1attempt to solve, here or for 90th percentile. $D = 1 - e^{-r/3}$ $\Rightarrow m = 2.079$ A1M1 $\therefore e^{-r/3} = 0.1 \Rightarrow -\frac{P}{3} = \ln 0.1 = -2.3026$ A1 $\Rightarrow p = 6.908$ A1(ii) $f(t) = \frac{d}{dt}$ F(0) $= \frac{1}{3}e^{-r/3}$ M1 $\mu = \int_{0}^{\pi} \frac{1}{3}e^{-r/3}dt$ M1 $\mu = \int_{0}^{\pi} \frac{1}{3}e^{-r/3}dt$ M1 $\mu = \int_{0}^{\pi} \frac{1}{3}e^{-r/3}dt$ M1 $= [0 - 0] + \left[\frac{e^{-r/3}}{-1/3}\right]_{0}^{\pi} = 3$ M1(iii) $P(r > \mu) = 1$ from cdf1 $e^{-\mu/3} = e^{-1}$ $(1ii)$ $P(r > \mu) = 1$ from cdf1 $e^{-\mu/3} = e^{-1}$ $(1ii)$ $\frac{1}{r} < (approx) N \left(\frac{3}{3}, \frac{9}{30} = 0.3\right)$ B1NB1N $(1i)$ $\frac{1}{242\sqrt{03}} = 4.095;$ must refer to SD (T), not SD(T))i.e. outlier $\Rightarrow$ doubt $\frac{2}{\sqrt{30}} = 2.191$ , refer to N(0.1), sig at (eg) 5% $\Rightarrow$ doubt $18$					
$\begin{bmatrix} \text{if of incutal } m, \frac{1}{2} = 1 - e \\ \therefore e^{-m/3} = \frac{1}{2} \Rightarrow -\frac{m}{3} = \ln \frac{1}{2} = -0.6931 \\ \Rightarrow m = 2.079 \\ \text{For 90^{th} percentile } p, 0.9 = 1 - e^{-p/3} \\ \therefore e^{-p/3} = 0.1 \Rightarrow -\frac{p}{3} = \ln 0.1 = -2.3026 \\ \Rightarrow p = 6.908 \\ \text{A1} \\ \end{bmatrix} \\ \begin{bmatrix} \text{f}(t) = \frac{d}{dt} F(t) \\ = \frac{1}{3} e^{-t/3} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} + 3 \int_{0}^{\infty} e^{-t/3} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 3 \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 3 \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 3 \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 0.3 \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 0.3 \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 0.3 \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 2.191, \text{refer to N(0,1), sig at (eg) 5\%} \\ \text{f}(t) = 2 \text{ oubbt} \\ \text{oubt} \\ \text{oubt} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 2.191, \text{refer to N(0,1), sig at (eg) 5\%} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 2.191, \text{refer to N(0,1), sig at (eg) 5\%} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 2.191, \text{refer to N(0,1), sig at (eg) 5\%} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 2.191, \text{refer to N(0,1), sig at (eg) 5\%} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 2.191, \text{refer to N(0,1), sig at (eg) 5\%} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 2.191, \text{refer to N(0,1), sig at (eg) 5\%} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = 2.191, \text{refer to N(0,1), sig at (eg) 5\%} \\ \text{f}(t) = \frac{1}{3} \left[ \frac{(e^{-t/3})}{1/3} \right]_{0}^{*} = \frac$	Q1	$F(t) = 1 - e^{-t/3}$ (t>0)			
$\begin{vmatrix} \Rightarrow m = 2.079 & A1 \\ For 90^{th} percentile p, 0.9 = 1 - e^{-p/3} & M1 \\ \therefore e^{-p/3} = 0.1 \Rightarrow -\frac{p}{3} = \ln 0.1 = -2.3026 & A1 \end{vmatrix}$ $\begin{vmatrix} \text{III} \\ \Rightarrow p = 6.908 & A1 & M1 \\ = \frac{1}{3} e^{-t/3} & M1 \\ = \frac{1}{3} \left[ \frac{m^{-t/3}}{1/3} \right]_{0}^{a} + 3\int_{0}^{a} e^{-t/3} dt \\ = \frac{1}{3} \left[ \frac{m^{-t/3}}{1/3} \right]_{0}^{a} = 3 & M1 \\ = [0 - 0] + \left[ \frac{e^{-t/3}}{-1/3} \right]_{0}^{a} = 3 & A1 \\ = 0.3679 & A1 & \text{ft c's mean (>0)} & 2 \\ \hline (iv) \\ \overline{T} - (approx) N \left( 3, \frac{9}{30} = 0.3 \right) & B1 \\ = \frac{B1}{3} N \\ ft c's mean (>0) & B1 \\ O.3 & OB \\ B1 & OB \\ O.3 & OB \\ B1 & OB \\ O.3 & OB \\ OB$	(i)	2		percentile. Depends on previous	
$\begin{array}{c c} \text{if of } \text{ yo percentre } p, \text{ we real} \\ \vdots e^{-p/3} = 0.1 \Rightarrow -\frac{p}{3} = \ln 0.1 = -2.3026 \\ \Rightarrow p = 6.908 & \text{A1} \end{array}$ $\begin{array}{c c} \text{if } (1) = \frac{d}{dt} F(0) \\ = \frac{1}{3} e^{-t/3} & \text{A1} \\ \mu = \int_{0}^{\pi} \frac{1}{3} e^{-t/3} dt \\ = \frac{1}{3} \left[ \frac{pe^{-t/3}}{-1/3} \right]_{0}^{\pi} + 3 \int_{0}^{\pi} e^{-t/3} dt^{2} \\ = \left[ 0 - 0 \right] + \left[ \frac{e^{-t/3}}{-1/3} \right]_{0}^{\pi} = 3 & \text{A1} \end{array}$ $\begin{array}{c c} \text{M1} \\ \text{M1} \\ \text{A1} \\ \text{M1} \\ \text{A1} \\ \text{M1} \\ \text{A1} \\ \text{M1} \\ \text{M1} \\ \text{M1} \\ \text{M1} \\ \text{M1} \\ \text{If the mean.} \\ \text{A1} \end{array}$ $\begin{array}{c c} \text{for } p > 0, \text{but condone absence of this} \\ \text{M1} \\ \text{H1} $		$\Rightarrow m = 2.079$	A1	M mark.	
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$			M1		
$\begin{array}{c} \begin{array}{c} & \prod_{i=1}^{N_{1}} $			A1		5
$\mu = \int_{0}^{\infty} \frac{1}{3} e^{-t/3} dt$ $= \frac{1}{3} \left[ \frac{fe^{-t/3}}{-1/3} \right]_{0}^{\infty} + 3 \int_{0}^{\infty} e^{-t/3} dt \right]$ $= \left[ 0 - 0 \right] + \left[ \frac{e^{-t/3}}{-1/3} \right]_{0}^{\infty} = 3$ (iii) $P(T > \mu) = \left[ \text{from cdf} \right] e^{-\mu/3} = e^{-1}$ $= 0.3679$ (iv) $\overline{T} \sim (\text{approx}) N \left( 3, \frac{9}{30} = 0.3 \right)$ (v) $\frac{\text{EITHER}}{SDs \text{ from } \mu} (3 + 2\sqrt{0.3} = 4.095; \frac{1}{3\sqrt{30}} = 0.3)$ (v) $\frac{\text{EITHER}}{SDs \text{ from } \mu} (3 + 2\sqrt{0.3} = 4.095; \frac{1}{3\sqrt{30}} = 2.191, \text{ refer to } N(0,1), \text{ sig at (eg) 5\%}$ $\frac{42 - 3}{3\sqrt{30}} = 2.191, \text{ refer to } N(0,1), \text{ sig at (eg) 5\%}$ $\Rightarrow \text{ doubt}$ $A1$ $A1$ $A1$ $A1$ $A1$ $A1$ $A1$ $A1$	(ii)		M1		
$ \begin{array}{c cccc} \mu = \int_{0}^{\infty} \frac{1}{3} te^{-t/3} dt & & M1 & Quoting standard result gets 0/3 \\ = \frac{1}{3} \left[ \frac{te^{-t/3}}{-1/3} \right]_{0}^{\infty} + 3 \int_{0}^{\infty} e^{-t/3} dt \right] & & M1 & attempt to integrate by parts \\ = \left[ 0 - 0 \right] + \left[ \frac{e^{-t/3}}{-1/3} \right]_{0}^{\infty} = 3 & & A1 & & & & & \\ \hline (iii & P(T > \mu) = \left[ \text{from cdf} \right] e^{-\mu/3} = e^{-1} & & & & & & & \\ = 0.3679 & & & & & & & & \\ \hline (iv) & \overline{T} \sim (\text{approx}) N \left( 3, \frac{9}{30} = 0.3 \right) & & & & & & \\ \hline T \sim (\text{approx}) N \left( 3, \frac{9}{30} = 0.3 \right) & & & & & & \\ \hline (v) & & & & & & \\ \hline EITHER \text{can argue that 4.2 is more than 2} & & & & \\ \hline (v) & & & & & \\ \hline SDS \text{ from } \mu \\ (3 + 2\sqrt{0.3} = 4.095; & & & & \\ \hline must \text{ refer to SD}(\overline{T}), \text{ not SD}(T)) \\ & & & & & \\ \hline e = \text{ doubt} & & & & \\ \hline OR & & & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \Rightarrow \text{ doubt} & & & \\ \hline OR & & & \\ \end{array}$		$=\frac{1}{3}e^{-t/3}$	A1		
$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix}_{0}^{\infty} = 3$ $\begin{bmatrix} 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix}_{0}^{\infty} = 1$ $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix}_{0}^{\infty} = 1$ $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix}_{0}^{\infty} = 1$ $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 $		~ 3	M1	Quoting standard result gets 0/3	
$\begin{bmatrix}  0-0  + \left[\frac{-1/3}{-1/3}\right]_{0} = 3 \\ A1 \end{bmatrix}$ $\begin{bmatrix} (iii) \\ P(T > \mu) = [from cdf] e^{-\mu/3} = e^{-1} \\ = 0.3679 \end{bmatrix}$ $\begin{bmatrix} A1 \\ ft c's mean (>0) \end{bmatrix}$ $\begin{bmatrix} 1 \\ rc's mean (>0) \end{bmatrix}$ $\begin{bmatrix} 1 \\ rc's mean (>0) \end{bmatrix}$ $\begin{bmatrix} 1 \\ rc's mean (>0) \\ 0.3 $			M1	attempt to integrate by parts	
)=0.3679A1ft c's mean (>0)2(iv) $\overline{T} \sim (approx) N \left(3, \frac{9}{30} = 0.3\right)$ B1 B1N ft c's mean (>0) 0.33(v) <b>EITHER</b> can argue that 4.2 is more than 2 SDs from $\mu$ ( $3+2\sqrt{0.3} = 4.095$ ; must refer to SD ( $\overline{T}$ ), not SD( $T$ )) i.e. outlierM1 A1 M1 A1 M1 A1 		$= \left[0 - 0\right] + \left[\frac{e^{-t/3}}{-1/3}\right]_{0}^{\infty} = 3$	A1		5
(iv) $\overline{T} \sim (\operatorname{approx}) \operatorname{N}\left(3, \frac{9}{30} = 0.3\right)$ B1 B1 B1 B1N ft c's mean (>0) 0.33(v) <b>EITHER</b> can argue that 4.2 is more than 2 SDs from $\mu$ $(3+2\sqrt{0.3} = 4.095;$ must refer to SD ( $\overline{T}$ ), not SD(T)) i.e. outlierM1 M1 A1 M1 M1 A1 M1 msignificance test: $\frac{4.2-3}{3/\sqrt{30}} = 2.191$ , refer to N(0,1), sig at (eg) 5% $3/\sqrt{30} = 2.191$ , refer to N(0,1), sig at (eg) 5%M1 M1 M1 Depends on first M, but could imply it.3	(iii	$P(T > \mu) = [from cdf] e^{-\mu/3} = e^{-1}$	M1	[or via pdf]	
T ~ (approx) N $\begin{bmatrix} 3, \frac{1}{30} = 0.3 \end{bmatrix}$ B1 B1ft c's mean (>0) 0.33(v)EITHER can argue that 4.2 is more than 2 SDs from $\mu$ $(3+2\sqrt{0.3} = 4.095;$ $\underline{must}$ refer to SD $(\overline{T})$ , not SD(T)) i.e. outlierM1 A13 $\Rightarrow$ doubtM1 A1 $\underline{OR}$ significance test: $\frac{4.2-3}{3/\sqrt{30}} = 2.191$ , refer to N(0,1), sig at (eg) 5% $\Rightarrow$ doubtM1 A1Depends on first M, but could imply it.3	)	=0.3679	A1	ft c's mean (>0)	2
SDs from $\mu$ $(3+2\sqrt{0.3} = 4.095;$ <u>must</u> refer to SD (T), not SD(T)) i.e. outlier $\Rightarrow$ doubt OR formal significance test: $\frac{4.2-3}{3/\sqrt{30}} = 2.191$ , refer to N(0,1), sig at (eg) 5% $\Rightarrow$ doubt $\Rightarrow$ doubt A1 Depends on first M, but could imply it. A1	(iv)	$\overline{T} \sim (\text{approx}) \operatorname{N}\left(3, \frac{9}{30} = 0.3\right)$	B1	ft c's mean (>0)	3
$\begin{array}{c c} \Rightarrow \text{ doubt} & M1 \\ \hline \mathbf{OR} & \text{formal} \\ \hline \frac{4.2 - 3}{3/\sqrt{30}} = 2.191, \text{ refer to N(0,1), sig at (eg) 5\%} \\ \Rightarrow \text{ doubt} & A1 \end{array} \qquad $	(v)	SDs from $\mu$ (3+2 $\sqrt{0.3}$ = 4.095; <u>must</u> refer to SD ( $\overline{T}$ ), not SD(T))			
ORformalM1significance test: $\frac{4.2-3}{3/\sqrt{30}} = 2.191$ , refer to N(0,1), sig at (eg) 5%M1 $\Rightarrow$ doubtM1Depends on first M, but could imply it.					3
$\Rightarrow$ doubt A1 imply it.		OR formal significance test:			
$\Rightarrow$ doubt A1		$\frac{4.2-3}{3/\sqrt{30}}$ = 2.191, refer to N(0,1), sig at (eg) 5%	M1	-	
		$\Rightarrow$ doubt	A1		18

$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	<u> </u>				
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	Q2	$X \sim N(180, \sigma = 12)$		suggest that (s)he appears to have neglected to use the difference columns of the Normal distribution tables penalise the	
$ \begin{array}{ c c c c c c c c } \hline = 1-0.7976 = 0.2024 & A1 & & & & & & & \\ \hline & & & & & & & & & & \\ \hline & & & &$	(i)	P (X <170) = P (Z < $\frac{170 - 180}{12}$ = -0.8333)	М		•
$ \begin{array}{ c c c c c c } \hline & & & & & & & & & & & & & & & & & & $			A1		
$ \begin{array}{ c c c c c c } \hline & & & & & & & & & & & & & & & & & & $		= 1 - 0.7976 = 0.2024	A1		3
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$		1 0000000000000000000000000000000000000			C
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	(ii)	$X + X + X + X + X = N(900 \sigma^2 - 720[\sigma - 26.8328])$	<b>B</b> 1	Mean	-
$\begin{array}{ c c c c c c c c } P(\text{this} < 840) = P(Z < \frac{840 - 900}{26.8328} = -2.236) \\ = 1 - 0.9873 = 0.0127 \end{array} \qquad $	(11)	$X_1 + X_2 + X_3 + X_4 + X_5 + 10(00, 0) = 720[0 - 20.0520]$			
$ \begin{array}{ c c c c c c c c } \hline =& 1-0.9873 = 0.0127 & A1 & c.a.o. & 3 \\ \hline & & & & \\ \hline & & & & & \\ \hline & & & & &$		0.40 0.00	DI	variance. Accept su.	
$ \begin{array}{ c c c c c c c c } \hline =& 1-0.9873 = 0.0127 & A1 & c.a.o. & 3 \\ \hline & & & & \\ \hline & & & & & \\ \hline & & & & &$		$P(\text{this} < 840) = P(Z < \frac{840 - 900}{210000} = -2.236)$			
(iii) $Y \sim N(50, \sigma = 6)$ $X + Y \sim N(230, \sigma^2 = 180[\sigma = 13.4164])$ B1         P(this > 240) = P(Z > $\frac{240 - 230}{13.4164} = 0.7454)$ B1 $= 1 - 0.7720 = 0.2280$ A1         (iv) $\frac{1}{4}X \sim N\left(45, \sigma^2 = \frac{1}{16} \times 144 = 9[\sigma = 3]\right)$ Require t such that $0.9 = P(\text{this } < t) = P\left(Z < \frac{t - 45}{3}\right) = P(Z < 1.282)$ $\therefore t - 45 = 3 \times 1.282 \Rightarrow t = 48.85 (48.846)$ (v) $I = 45 + T$ where $T \sim N(120, \sigma = 10)$ $\therefore I \sim N(165, \sigma = 10)$ $P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5)$ $= 1 - 0.9332 = 0.0668$ (vi) $J = 30 + \frac{3}{5}T$ where $T \sim N(120, \sigma = 10)$ (vii) $J = 30 + \frac{3}{5}T$ where $T \sim N(120, \sigma = 10)$		2010020			
$\begin{array}{c} (ii) \\ ) \\ X + Y \sim N(230, \sigma^2 = 180[\sigma = 13.4164]) \\ P(\text{this} > 240) = P(Z > \frac{240 - 230}{13.4164} = 0.7454) \\ = 1 - 0.7720 = 0.2280 \end{array} \qquad $		=1-0.9873=0.0127	Al	c.a.o.	3
$\begin{array}{c} (ii) \\ ) \\ X + Y \sim N(230, \sigma^2 = 180[\sigma = 13.4164]) \\ P(\text{this} > 240) = P(Z > \frac{240 - 230}{13.4164} = 0.7454) \\ = 1 - 0.7720 = 0.2280 \end{array} \qquad $					
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	(iii	$Y \sim N(50, \sigma = 6)$			
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	)				
$\begin{array}{ c c c c c } P(\text{this} > 240) = P(Z > \frac{240 - 230}{13.4164} = 0.7454) \\ = 1 - 0.7720 = 0.2280 \end{array} \qquad $		$X + Y \sim N(230, \sigma^2 = 180[\sigma = 13.4164])$	B1	Mean.	
$=1-0.7720 = 0.2280$ A1c.a.o.3(iv) $\frac{1}{4}X \sim N\left(45, \sigma^2 = \frac{1}{16} \times 144 = 9[\sigma = 3]\right)$ Require t such that $0.9 = P(\text{this } < t) = P\left(Z < \frac{t-45}{3}\right) = P(Z < 1.282)$ B1Variance. Accept sd. FT incorrect mean. Formulation of requirement. $1.282$ $(t)$ $I = 45 + T$ where $T \sim N(120, \sigma = 10)$ $\therefore I \sim N(165, \sigma = 10)$ B1for unchanged $\sigma$ (candidates might work with P (T<105))			B1	Variance. Accept sd.	
(iv) $\frac{1}{4}X \sim N\left(45, \sigma^2 = \frac{1}{16} \times 144 = 9[\sigma = 3]\right)$ Require t such that $0.9 = P(\text{this } < t) = P\left(Z < \frac{t-45}{3}\right) = P(Z < 1.282)$ B1 Formulation of requirement. $(0.9 = P(\text{this } < t)) = P\left(Z < \frac{t-45}{3}\right) = P(Z < 1.282)$ $\therefore t-45 = 3 \times 1.282 \Rightarrow t = 48.85 (48.846)$ B1 A1It only for incorrect mean.(v) $I = 45 + T$ where $T \sim N$ (120, $\sigma = 10$ ) $\therefore I \sim N(165, \sigma = 10)$ B1 for unchanged $\sigma$ (candidates might work with P (T<105))		P (this > 240) = P(Z > $\frac{240 - 230}{13.4164} = 0.7454$ )			
$\frac{1}{4} A^{-N} N \begin{pmatrix} 43.6 & -\frac{1}{16} & -\frac{1}{16} & -\frac{1}{16} \\ Require t \text{ such that} \\ 0.9 = P(\text{this} < t) = P \left( Z < \frac{t-45}{3} \right) = P(Z < 1.282) \\ \therefore t - 45 = 3 \times 1.282 \Rightarrow t = 48.85 (48.846) \\ (v)  I = 45 + T \text{ where } T \sim N (120, \sigma = 10) \\ \therefore I \sim N(165, \sigma = 10) \\ P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5) \\ = 1 - 0.9332 = 0.0668 \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T$		= 1 - 0.7720 = 0.2280	A1	c.a.o.	3
$\frac{1}{4} A^{-N} N \begin{pmatrix} 43.6 & -\frac{1}{16} & -\frac{1}{16} & -\frac{1}{16} \\ Require t \text{ such that} \\ 0.9 = P(\text{this} < t) = P \left( Z < \frac{t-45}{3} \right) = P(Z < 1.282) \\ \therefore t - 45 = 3 \times 1.282 \Rightarrow t = 48.85 (48.846) \\ (v)  I = 45 + T \text{ where } T \sim N (120, \sigma = 10) \\ \therefore I \sim N(165, \sigma = 10) \\ P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5) \\ = 1 - 0.9332 = 0.0668 \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T \text{ where } T \sim N (120, \sigma = 10) \\ (vi)  J = 30 + \frac{3}{5}T$	(iv)	1 ( $2$ 1 $r$ $1$ )	<b>B</b> 1	Variance Accept sd	
Require t such that $0.9 = P(\text{this } < t) = P\left(Z < \frac{t-45}{3}\right) = P(Z < 1.282)$ MFormulation of requirement. $1.282$ $\therefore t-45 = 3 \times 1.282 \Rightarrow t = 48.85 (48.846)$ A11.282(v) $I = 45 + T$ where $T \sim N (120, \sigma = 10)$ $\therefore I \sim N(165, \sigma = 10)$ B1for unchanged $\sigma$ (candidates might work with P ( $T < 105$ )) $P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5)$ $= 1 - 0.9332 = 0.0668$ A1c.a.o.2(vi) $J = 30 + \frac{3}{5}T$ where $T \sim N (120, \sigma = 10)$ Cands might work with $P(\frac{3}{5}T < 75)$ .2	(11)	$\frac{1}{4}X \sim N[45, \sigma^2 = \frac{1}{16} \times 144 = 9[\sigma = 3]]$	DI	—	
$\begin{array}{ c c c c c } \hline 0.9 = P(\text{this} < t) = P\left(Z < \frac{t - 45}{3}\right) = P(Z < 1.282) \\ \therefore t - 45 = 3 \times 1.282 \Rightarrow t = 48.85 (48.846) & \text{A1} \\ \hline \text{A1} & \text{It only for incorrect mean} & 4 \\ \hline \text{(v)} & I = 45 + T \text{ where } T \sim \text{N} (120, \ \sigma = 10) \\ \therefore I \sim \text{N}(165, \ \sigma = 10) & \text{B1} & \text{for unchanged } \sigma \text{ (candidates might work with P (T < 105))} \\ P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5) \\ = 1 - 0.9332 = 0.0668 & \text{A1} & \text{c.a.o.} & 2 \\ \hline \text{(vi)} & J = 30 + \frac{3}{5}T \text{ where } T \sim \text{N} (120, \ \sigma = 10) & \text{Cands might work with} \\ P\left(\frac{3}{5}T < 75\right). & \end{array}$			м		
Image: Image of the system			M		
$\begin{array}{ c c c c c c } \hline & \therefore t - 45 = 3 \times 1.282 \Rightarrow t = 48.85  (48.846) & A1 & \text{ft only for incorrect mean} & 4 \\ \hline & (v) & I = 45 + T \text{ where } T \sim N  (120,  \sigma = 10) \\ & \therefore I \sim N(165, \sigma = 10) & B1 & \text{for unchanged } \sigma  (\text{candidates might work with P}  (T < 105)) \\ & P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5) \\ & = 1 - 0.9332 = 0.0668 & A1 & \text{c.a.o.} & 2 \\ \hline & (vi) & J = 30 + \frac{3}{5}T \text{ where } T \sim N  (120,  \sigma = 10) & Cands \text{ might work with } P\left(\frac{3}{5}T < 75\right). & \end{array}$				1.282	
(v) $I = 45 + T$ where $T \sim N (120, \sigma = 10)$ $\therefore I \sim N(165, \sigma = 10)$ B1 $P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5)$ $= 1 - 0.9332 = 0.0668$ (vi) $J = 30 + \frac{3}{5}T$ where $T \sim N (120, \sigma = 10)$ Cands might work with $P(\frac{3}{5}T < 75)$ .			<b>B</b> 1		
$\begin{array}{ c c c c c } \hline & & \therefore I \sim N(165, \sigma = 10) \\ P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5) \\ = 1 - 0.9332 = 0.0668 \end{array} \qquad $		: $t - 45 = 3 \times 1.282 \Longrightarrow t = 48.85 (48.846)$	A1	ft only for incorrect mean	4
$\begin{array}{ c c c c c } \hline & & \therefore I \sim N(165, \sigma = 10) \\ P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5) \\ = 1 - 0.9332 = 0.0668 \end{array} \qquad $					
$\begin{array}{ c c c c c } \hline & & \therefore I \sim N(165, \sigma = 10) \\ P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5) \\ = 1 - 0.9332 = 0.0668 \end{array} \qquad $	(v)	$I = 45 + T$ where $T \sim N$ (120, $\sigma = 10$ )			
$P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5)$ $= 1 - 0.9332 = 0.0668$ A1 Cands might work with P (T<105)) A1 C.a.o. 2 (vi) $J = 30 + \frac{3}{5}T$ where $T \sim N (120, \sigma = 10)$ Cands might work with $P(\frac{3}{5}T < 75).$			B1	for unchanged $\sigma$ (candidates	
$P(I < 150) = P(Z < \frac{150 - 165}{10} = -1.5)$ = 1 - 0.9332 = 0.0668 A1 c.a.o. 2 (vi) $J = 30 + \frac{3}{5}T$ where $T \sim N(120, \sigma = 10)$ Cands might work with $P(\frac{3}{5}T < 75)$ .				<b>C</b>	
$\begin{array}{ c c c c c c } & = 1 - 0.9332 = 0.0668 & A1 & c.a.o. & 2 \\ \hline \hline (vi) & J = 30 + \frac{3}{5}T & \text{where } T \sim N \ (120, \ \sigma = 10) & Cands \ \text{might work with} \\ P\left(\frac{3}{5}T < 75\right). & \end{array}$		150-165			
$\begin{array}{ c c c c c c } & = 1 - 0.9332 = 0.0668 & A1 & c.a.o. & 2 \\ \hline \hline (vi) & J = 30 + \frac{3}{5}T & \text{where } T \sim N \ (120, \ \sigma = 10) & Cands \ \text{might work with} \\ P\left(\frac{3}{5}T < 75\right). & \end{array}$		$P(I < 150) = P(Z < \frac{100}{10} = -1.5)$			
(vi) $J = 30 + \frac{3}{5}T$ where $T \sim N$ (120, $\sigma = 10$ ) Cands might work with $P(\frac{3}{5}T < 75)$ .			Δ1	C 3 O	2
			111	<i>c.u.o.</i>	-
	(wi)	3		Cande might work with	
	(1)	$J = 30 + \frac{5}{5}T$ where $T \sim N$ (120, $\sigma = 10$ )			
$\frac{3}{5}T \sim N(72,36)$		J			
				$\frac{3}{5}T \sim N(72,36)$	

$\therefore J \sim \mathrm{N}\left(102, \sigma^2 = \frac{9}{25} \times 100 = 36[\sigma = 6]\right)$	B1 B1	Mean. Variance. Accept sd.	
$P(J < 105) = P(Z < \frac{105 - 102}{6} = 0.5) = 0.6915$	A1	c.a.o.	3
			18

Q3				
(a)	$H_0: \mu_D = 0$ (or $\mu_A = \mu_B$ )	B1	Hypotheses in words only must include "population".	
	$H_1: \mu_D > 0$ (or $\mu_B > \mu_A$ )	B1	Or "<" for <i>A</i> − <i>B</i> .	
	where $\mu_D$ is "mean for B – mean for A"	B1	For adequate verbal definition. Allow absence of "population" if correct notation $\mu$ is used, but do NOT allow " $\overline{X}_A = \overline{X}_B$ " or similar unless $\overline{X}$ is clearly and explicitly stated to be a <u>population</u> mean.	
	Normality of <u>differences</u> is required <u>MUST</u> be PAIRED COMPARISON <i>t</i> test. Differences are:	B1		
	2.1 1.0 0.8 0.6 0.4 -1.0 -0.3	0.8	0.9 1.1	
	$\overline{d} = 0.64$ $s_{n-1} = 0.8316$	B1	$s_n = 0.7889$ but do <u>NOT</u> allow this here or in construction of test statistic, but FT from there.	
	Test statistic is $\frac{0.64 - 0}{\frac{0.8316}{\sqrt{10}}}$	M	Allow c's $\overline{d}$ and/or $s_{n-1}$ . Allow alternative: 0 + (c's 1.833) $\times \frac{0.8316}{\sqrt{10}}$ (= 0.4821) for	
			subsequent comparison with $\overline{d}$ . (Or $\overline{d}$ – (c's 1.833) × $\frac{0.8316}{\sqrt{10}}$	
			(= 0.1579) for comparison with 0.)	
	=2.43(37).	A1	c.a.o. but ft from here in any case if wrong. Use of $0 - \overline{d}$ scores M1A0, but ft.	
	Refer to $t_9$ .	М	No ft from here if wrong.	
	Single-tailed 5% point is 1.833.	A1	No ft from here if wrong.	
	Significant.	E1	ft only c's test statistic.	11
	Seems mean amount delivered by B is greater that that by A	E1	ft only c's test statistic. Special case: ( $t_{10}$ and 1.812) can score 1 of these last 2 marks if either form of conclusion is given.	11
(b)	We now require Normality for the amounts delivered by machine A.	B1		

For machine A, $\bar{x} = 250.19$ $s_{n-1} = 3.8527$ CI is given by $250.19 \pm 2.262 \frac{3.8527}{\sqrt{10}}$	B1 M B1 M	$s_n = 3.6549(83)$ but do NOT allow this here or in construction of CI. ft c's $\overline{x} \pm$ . 2.262 ft c's $s_{n1}$ .	
= 250.19 $\pm$ 2.75(6) = (247.43(4), 252.94(6)) 250 is in the CI, so would accept H <sub>0</sub> : $\mu$ = 250, so no evidence that machine is not	A1 E1	c.a.o. Must be expressed as an interval. ZERO/4 if not same distribution as test. Same wrong distribution scores maximum M1B0M1A0. Recovery to $t_9$ is OK.	7
working correctly in this respect.			
			18

Q4 (i)									
(1)		$\underbrace{1 \qquad 30}_{31}$	62	70	3	34	3 7		
	e <sub>i</sub>	1.49 37.85 39.34	55.6 2	58.3 2	4	14.62 46	2.10 5.72		
	$X^2 =$	1.7681 + 0.7318 +	2.3392	+ 2.0222		M M	from wror	M1 for correct method ngly grouped or	
	=	6.86				A1	ungrouped	1 table.	
	Refer	to $\chi_1^2$ .				М	from wror ungrouped	rect df (= cells – 3) ngly grouped or d table, and FT. e, no FT if wrong.	
	Uppe	r 5% point is 3.84				A1		here if wrong.	
	0	ficant				E1		test statistic.	
	Sugge	ests Normal model	does no	ot fit		E1	ft only c's	test statistic.	7
(ii) (A)	t test	unwise				E1			
(**)		cause underlying p Normal	opulatio	on appear	rs	E1	FT from rework in (i	esult of candidate's )	2

Data	Median 301	Difference	Rank of  diff			
301.3		0.3	3	Μ	for differences.	
301.4		0.4	4		ZERO in this section if	
299.6		- 1.4	8		differences not used.	
302.2		1.2	7			
300.3		- 0.7	5		for ranks.	
303.2		2.2	10	Μ	FT if ranks wrong.	
302.6		1.6	9	A 1		
301.8		0.8	6	A1		
300.9		- 0.1	1			
300.8		- 0.2	2			
<i>T</i> = 1 +2 + 39)	-5+8=10	6 (or 3+4+6+	7+9+10 =	B1		
,	ubles of Wi	ilcoxon single	e sample	Μ		
(/paired) s						
(/paired) s		9 used) 5% ta	ul is	М		
(/paired) s Lower (or needed	upper if 39	9 used) 5% ta 0 (or 45 if 39		M A1		
(/paired) s Lower (or needed Value for Result is r	upper if $39$ n = 10 is 1 not signific	0 (or 45 if 39 ant	used)	A1 E1		
(/paired) s Lower (or needed Value for Result is r	upper if $39$ n = 10 is 1 not signific	0 (or 45 if 39	used)	A1		9