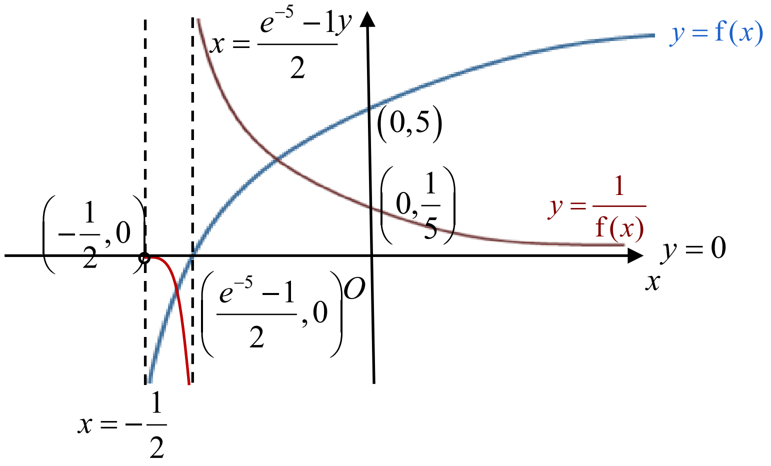
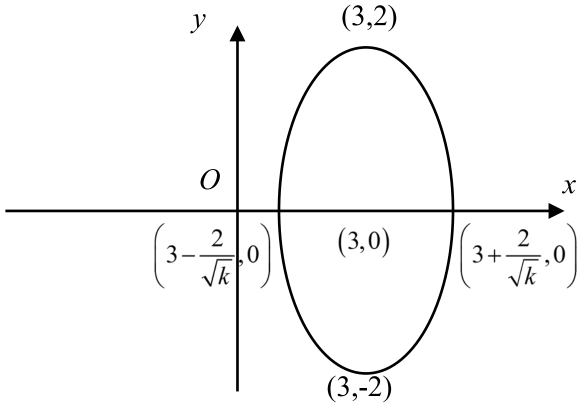
1(i)		
1 (ii)	In the equation $y=\ln(-2x)$, replace x with $(-x)$ gives us $y=\ln(2x)$. First, <u>reflect</u> the graph of $y=\ln(-2x)$ in the y-axis. In the equation $y=\ln(2x)$, replace x with $x+\frac{1}{2}$ gives us $y=\ln(2x+1)$. Next, <u>translate</u> the graph of $y=\ln(2x)$, $\frac{1}{2}$ units in the negative x-direction. In the equation $y=\ln(2x+1)$, replace y with $y-5$ gives us $y=\ln(2x+1)+5$. Lastly, <u>translate</u> the graph of $y=\ln(2x+1)$, 5 units in the positive y-direction.	

2(a)

$$y^2 + k\left(x-3\right)^2 = 4$$

$k > 0$

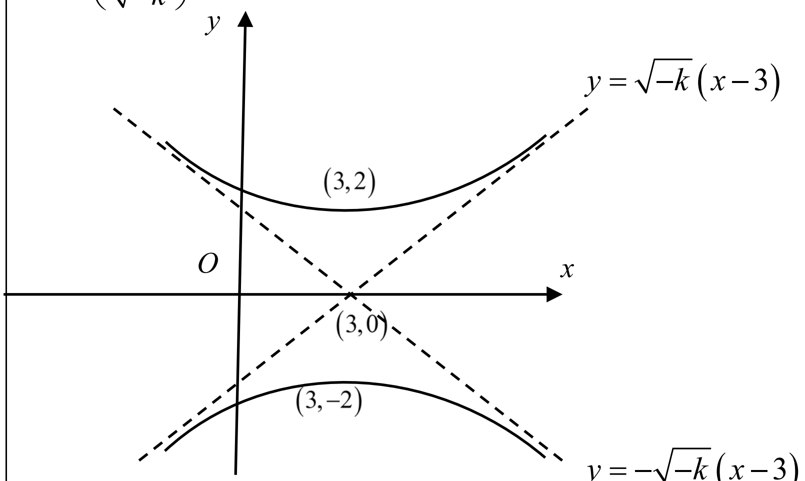
$$\frac{y^2}{2^2} + \frac{\left(x-3\right)^2}{\left(2/\sqrt{k}\right)^2} = 1$$



$k < 0$

$$y^2 - \left(-k\right)\left(x-3\right)^2 = 4$$

$$\frac{y^2}{2^2} - \frac{\left(x-3\right)^2}{\left(\frac{2}{\sqrt{-k}}\right)^2} = 1$$



(b) (i)	Volume $= \pi \int_3^4 \left[4 - k(x-3)^2\right] \mathrm{d}x$ $= \pi \left[4x - \frac{k}{3}(x-3)^3\right]_3^4$ $= \pi \left(16 - \frac{k}{3} - 12\right)$ $= \pi \left(4 - \frac{k}{3}\right)$	
(ii)	Volume $= \int_3^4 \left(\frac{1}{2}\right)^2 \left[4 - k(x-3)^2\right] \mathrm{d}x$ $= \left(\frac{1}{2}\right)^2 \int_3^4 \left[4 - k(x-3)^2\right] \mathrm{d}x$ $= \left(\frac{1}{2}\right)^2 \pi \left(4 - \frac{k}{3}\right)$ $= \frac{\pi}{4}\left(4 - \frac{k}{3}\right)$	

3 (a)	$\frac{4+x^2}{\sqrt{4-x}}=\left(4+x^2\right)\left(4-x\right)^{-\frac{1}{2}}$ $=4^{-\frac{1}{2}}\left(4+x^2\right)\left(1-\frac{x}{4}\right)^{-\frac{1}{2}}$ $=\frac{1}{2}\left(4+x^2\right)\left(1+\left(-\frac{1}{2}\right)\left(-\frac{x}{4}\right)+\frac{\left(-\frac{1}{2}\right)\left(-\frac{3}{2}\right)}{2!}\left(-\frac{x}{4}\right)^2+...\right)$ $=\frac{1}{2}\left(4+x^2\right)\left(1+\frac{x}{8}+\frac{3}{128}x^2+...\right)$ $=\frac{1}{2}\left(4+\frac{1}{2}x+\frac{3}{32}x^2+x^2+...\right)$ $=2+\frac{1}{4}x+\frac{35}{64}x^2+...$ expansion is valid for $\left\|-\frac{x}{4}\right\|<1$ $\Rightarrow -4<x<4$ $\therefore \{x\in\mathbb{R}:-4<x<4\}$	
3(b) (i)	$\frac{\mathrm{d}y}{\mathrm{d}x}=\frac{\cos x}{1+\sin x}$ Differentiating $\left(1+\sin x\right)\frac{\mathrm{d}y}{\mathrm{d}x}=\cos x$ w.r.t x, $\left(1+\sin x\right)\frac{\mathrm{d}^2y}{\mathrm{d}x^2}+\cos x\frac{\mathrm{d}y}{\mathrm{d}x}=-\sin x$ (shown)	

3(ii)	Differentiating w.r.t. x, $\cos x\frac{\mathrm{d}^2y}{\mathrm{d}x^2}+(1+\sin x)\frac{\mathrm{d}^3y}{\mathrm{d}x^3}-\sin x\frac{\mathrm{d}y}{\mathrm{d}x}+\cos x\frac{\mathrm{d}^2y}{\mathrm{d}x^2}=-\cos x$ When $x=0$, $y=\ln(1+0)=0$ $\frac{\mathrm{d}y}{\mathrm{d}x}=\frac{\cos 0}{1+\sin 0}=1$ $(1+0)\frac{\mathrm{d}^2y}{\mathrm{d}x^2}+1=0$ $\frac{\mathrm{d}^2y}{\mathrm{d}x^2}=-1$ $(1)(-1)+(1+0)\frac{\mathrm{d}^3y}{\mathrm{d}x^3}-(0)(1)+(1)(-1)=-1$ $\frac{\mathrm{d}^3y}{\mathrm{d}x^3}=1$ $y=0+(1)x+\frac{(-1)}{2!}x^2+\frac{(1)}{3!}x^3+\ldots$ $=x-\frac{1}{2}x^2+\frac{1}{6}x^3+\ldots$	
3(iii)	$\ln\left(\frac{1-\sin x}{2}\right)=\ln(1+\sin(-x))-\ln 2$ $=-\ln 2+(-x)-\frac{1}{2}(-x)^2+\frac{1}{6}(-x)^3+\ldots$ $=-\ln 2-x-\frac{1}{2}x^2-\frac{1}{6}x^3+\ldots$	
4(i)	A normal to p_1 is $\begin{pmatrix}1\\3\\-2\end{pmatrix}\times\begin{pmatrix}1\\0\\1\end{pmatrix}=\begin{pmatrix}3\\-3\\-3\end{pmatrix}=-3\begin{pmatrix}-1\\1\\1\end{pmatrix}$. A normal to p_2 is $\begin{pmatrix}4\\1\\3\end{pmatrix}$. Since $\begin{pmatrix}-1\\1\\1\end{pmatrix}\cdot\begin{pmatrix}4\\1\\3\end{pmatrix}=-4+1+3=0$, p_1 is perpendicular to p_2.	

<table>
<tr><td>4(ii)</td><td>

Show $(1,0,-1)$ lies on *l*.

Equation of p_1 is $\underset{\sim}{r}\cdot\begin{pmatrix}-1\\1\\1\end{pmatrix}=-2$

Since $\begin{pmatrix}1\\0\\-1\end{pmatrix}\cdot\begin{pmatrix}-1\\1\\1\end{pmatrix}=-1+0-1=-2$, $(1,0,-1)$ lies on p_1.

Since $4(1)+0+3(-1)=1$, $(1,0,-1)$ lies on p_2.

Since $(1,0,-1)$ lies on both planes, it lies on *l*.

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<tr><td></td><td>

Find equation of line

Line *l* is parallel to $\begin{pmatrix}-1\\1\\1\end{pmatrix}\times\begin{pmatrix}4\\1\\3\end{pmatrix}=\begin{pmatrix}2\\7\\-5\end{pmatrix}$.

Equation of $l:\mathbf{r}=\begin{pmatrix}1\\0\\-1\end{pmatrix}+t\begin{pmatrix}2\\7\\-5\end{pmatrix}, t\in\mathbb{R}$

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<tr><td></td><td>

<u>**Alternative #1**</u>

$p_1:\mathbf{r}.\begin{pmatrix}-1\\1\\1\end{pmatrix}=\begin{pmatrix}0\\3\\-5\end{pmatrix}.\begin{pmatrix}-1\\1\\1\end{pmatrix} \quad \Rightarrow \quad p_1:-x+y+z=-2 \quad ---(1)$

$p_2:4x+y+3z=1 \quad ---(2)$

Solving (1) and (2) simultaneously, by GC, equation of *l*:

$\mathbf{r}=\begin{pmatrix}3/5\\-7/5\\0\end{pmatrix}+s\begin{pmatrix}-2/5\\-7/5\\1\end{pmatrix}, s\in\mathbb{R}$

$\mathbf{r}=\begin{pmatrix}3/5\\-7/5\\0\end{pmatrix}+t\begin{pmatrix}-2\\-7\\5\end{pmatrix}, t\in\mathbb{R}$

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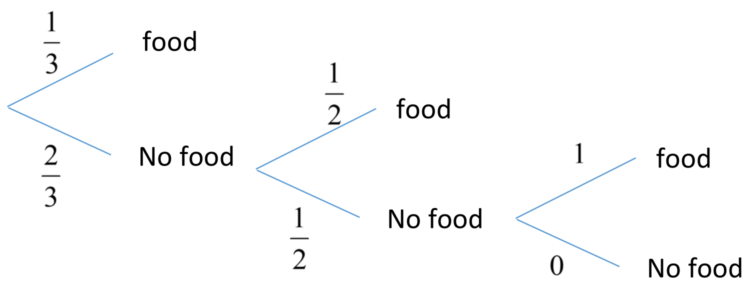
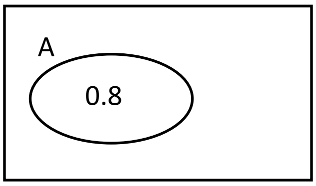
</table>

(iii)	Let C be the point $(1,0,-1)$ on l and F be the foot of perpendicular of B to l. $\overrightarrow{BC}=\begin{pmatrix}1\\0\\-1\end{pmatrix}-\begin{pmatrix}2\\2\\-3\end{pmatrix}=\begin{pmatrix}-1\\-2\\2\end{pmatrix}$ $\overrightarrow{BF}=\left(\overrightarrow{BC}\cdot\frac{\mathbf{n}_1}{\lvert\mathbf{n}_1\rvert}\right)\frac{\mathbf{n}_1}{\lvert\mathbf{n}_1\rvert}$, where $\mathbf{n}_1$ is a normal to p_1 $=\frac{\left(\overrightarrow{BC}\cdot\mathbf{n}_1\right)\mathbf{n}_1}{\lvert\mathbf{n}_1\rvert^2}$ $=\frac{1}{3}\left(\begin{pmatrix}-1\\-2\\2\end{pmatrix}\cdot\begin{pmatrix}-1\\1\\1\end{pmatrix}\right)\begin{pmatrix}-1\\1\\1\end{pmatrix}=\frac{1}{3}\begin{pmatrix}-1\\1\\1\end{pmatrix}$ $\overrightarrow{BA}=\overrightarrow{OA}-\overrightarrow{OB}=\begin{pmatrix}0\\3\\-5\end{pmatrix}-\begin{pmatrix}2\\2\\-3\end{pmatrix}=\begin{pmatrix}-2\\1\\-2\end{pmatrix}$ Area of $\triangle ABB'=2\times\left(\text{Area of }\triangle ABF\right)$ $=2\times\frac{1}{2}\left\lvert\overrightarrow{BA}\times\overrightarrow{BF}\right\rvert$ $=\left\lvert\begin{pmatrix}-2\\1\\-2\end{pmatrix}\times\frac{1}{3}\begin{pmatrix}-1\\1\\1\end{pmatrix}\right\rvert=\frac{1}{3}\left\lvert\begin{pmatrix}3\\4\\-1\end{pmatrix}\right\rvert$ $=\frac{\sqrt{26}}{3}$ units^2	

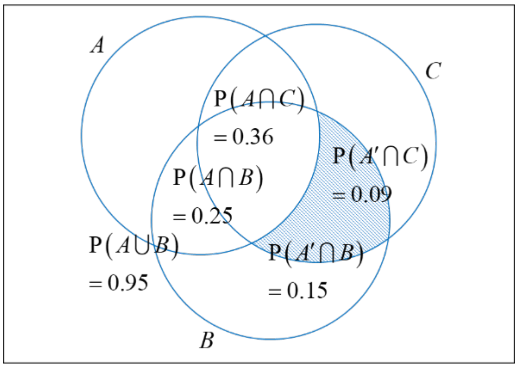
	Alternative (finding $\overrightarrow{BF}$ using $\overrightarrow{CF}$) $\overrightarrow{CB} = \begin{pmatrix} 2 \\ 2 \\ -3 \end{pmatrix} - \begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix} = \begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix}$ $\overrightarrow{CF} = \dfrac{\left(\overrightarrow{CB} . \begin{pmatrix} 2 \\ 7 \\ -5 \end{pmatrix}\right)\begin{pmatrix} 2 \\ 7 \\ -5 \end{pmatrix}}{4+49+25}$ $= \dfrac{1}{78}\left(\begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix} . \begin{pmatrix} 2 \\ 7 \\ -5 \end{pmatrix}\right)\begin{pmatrix} 2 \\ 7 \\ -5 \end{pmatrix} = \dfrac{1}{3}\begin{pmatrix} 2 \\ 7 \\ -5 \end{pmatrix}$ $\overrightarrow{BF} = \overrightarrow{CF} - \overrightarrow{CB} = \dfrac{1}{3}\begin{pmatrix} 2 \\ 7 \\ -5 \end{pmatrix} - \begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix} = \dfrac{1}{3}\begin{pmatrix} -1 \\ 1 \\ 1 \end{pmatrix}$	
(iv)	Q lies p_1 and p_2, hence Q lies in the line l.	
(v)	$\left[\begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix} + t\begin{pmatrix} 2 \\ 7 \\ -5 \end{pmatrix}\right] . \begin{pmatrix} a \\ 3 \\ 1 \end{pmatrix} = -9$ $a - 1 + (2a+16)t = -9 \qquad --------(*)$ Case 1: If $a = -8$, (*) is true for all values of t. Case 2: If $a \neq -8$, $t = -\dfrac{a+8}{2a+16} = -\dfrac{1}{2}$. $\mathbf{r} = \begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix} + \left(-\dfrac{1}{2}\right)\begin{pmatrix} 2 \\ 7 \\ -5 \end{pmatrix} = \begin{pmatrix} 0 \\ -3.5 \\ 1.5 \end{pmatrix}$ In both cases, we have $(0, -3.5, 1.5)$ lying on both l and p_3. Hence, coordinates of Q is $(0, -3.5, 1.5)$.	
5i	Number of ways $= \dfrac{8!}{3!}$ $= 6720$	
5ii	Different cases: SxxxxSxxxxxS, SxxxxxSxxxxS, xSxxxxSxxxxS, and SxxxxSxxxxSx. Number of ways $= 4 \times \dfrac{9!}{2!2!}$ $= 362880$	

	$\mathrm{P}(\text{all 8 letters distinct}) = \dfrac{{}^{2}C_1 \times {}^{3}C_1 \times {}^{2}C_1 \times {}^{5}C_5}{{}^{12}C_8}$ $= \dfrac{4}{165}$ **<u>Alternative</u>** $\mathrm{P}(\text{all 8 letters distinct})$ $= \left(\dfrac{2}{12}\right)\left(\dfrac{3}{11}\right)\left(\dfrac{2}{10}\right)\left(\dfrac{1}{9}\right)\left(\dfrac{1}{8}\right)\left(\dfrac{1}{7}\right)\left(\dfrac{1}{6}\right)\left(\dfrac{1}{5}\right)\times 8!$ $= \dfrac{4}{165}$	
6i	$\mathrm{P}(X=1) = \dfrac{1}{3}$ $\mathrm{P}(X=2) = \dfrac{2}{3}\times\dfrac{1}{2} = \dfrac{1}{3}$ $\mathrm{P}(X=3) = \dfrac{2}{3}\times\dfrac{1}{2}\times 1 = \dfrac{1}{3}$ 	

6ii	(ii) $\mathrm{P}(X=x)=\frac{1}{N}$, for $x = 1, 2, \ldots, N$ $\mathrm{E}(X)=\frac{N+1}{2}$ (by symmetry) <u>OR</u> $\mathrm{E}(X)=1\cdot\frac{1}{N}+2\cdot\frac{1}{N}+\cdots+N\cdot\frac{1}{N}$ $=\frac{1}{N}(1+2+\cdots N)$ $=\frac{1}{N}\left(\frac{N}{2}(1+N)\right)$ $=\frac{N+1}{2}$ $\mathrm{Var}(X)=\mathrm{E}(X^2)-[\mathrm{E}(X)]^2$ $=\sum_{x=1}^{N}x^2\mathrm{P}(X=x)-\left(\frac{N+1}{2}\right)^2$ $=\frac{1}{N}\sum_{x=1}^{N}x^2-\left(\frac{N+1}{2}\right)^2$ $=\frac{1}{N}\left[\frac{N(N+1)(2N+1)}{6}\right]-\left(\frac{N+1}{2}\right)^2$ $=\frac{N+1}{12}[2(2N+1)-3(N+1)]$ $=\frac{(N+1)(N-1)}{12}$	
7i	$\mathrm{P}(A\cup B)=\mathrm{P}(A)+\mathrm{P}(B)-\mathrm{P}(A\cap B)$ $0.95=0.8+0.4-\mathrm{P}(A\cap B)$ $\mathrm{P}(A\cap B)=0.25$ *A* and *B* are not independent because $\mathrm{P}(A\cap B)=0.25\neq 0.32=(0.8)(0.4)=\mathrm{P}(A)\mathrm{P}(B)$.	
7ii	$0.2 < c \leq 1$  Think: If $\mathrm{P}(C)\leq 0.2$ then it is possible for $C\subseteq A'$. This means it is still possible for A and C to not intersect. But when $\mathrm{P}(C)>0.2$, this scenario won't happen!	

7iii

$$\begin{aligned}\mathrm{P}(A\cap C) &= \mathrm{P}(C\mid A)\mathrm{P}(A)\\ &= (0.45)(0.8)\\ &= 0.36\end{aligned}$$



Note that $P(A\cap B)=0.25,\ P(A\cap B')=0.15$

Note that $P\left((A\cup B)'\right)=1-0.95=0.05$ and

$$\begin{aligned}P(A'\cap C) &= P(C)-P(A\cap C)\\ &= 0.45-0.36=0.09\end{aligned}.$$

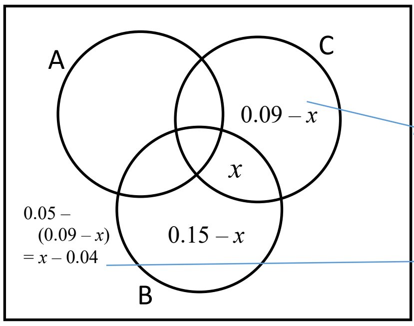
Hence,

$\min\left(\mathrm{P}(A'\cap B\cap C)\right)=0.09-0.05=0.04$ and

$\max\left(\mathrm{P}(A'\cap B\cap C)\right)=0.09$ which occurs when $(A'\cap C)\subseteq(A'\cap B)$.

Alternative:

Let $\mathrm{P}(A'\cap B\cap C)=x$. Note that $P(A\cap B)=0.25,\ P(A\cap B')=0.15$ and $\mathrm{P}(A\cap C)=0.36$. We also know that $P\left((A\cup B)'\right)=1-0.95=0.05$. Using these to fill up the venn diagram below:



Since all probabilities are at least 0 and at most 1, we must have

max value of x = 0.09

and

min value of x = 0.04

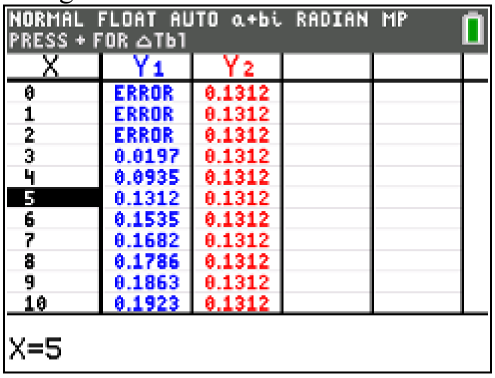
8(a)

$\mathrm{B}(n, p)$

Given: $\mathrm{E}(X) = 2.75 \quad \Rightarrow np = 2.75 \quad ---(1)$

$\mathrm{P}(X < 2) = \mathrm{P}(X \le 1) = 0.13122$

<u>Method 1:</u>
Using GC:



Hence $n = 5$

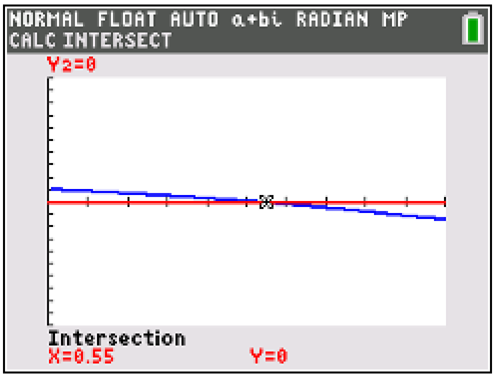
$$p = \frac{2.75}{5} = 0.55$$

<u>Method 2:</u>

$\mathrm{P}(X = 0) + \mathrm{P}(X = 1) = 0.13122$

$(1-p)^n + np(1-p)^{n-1} = 0.13122$

From (1): $(1-p)^{\frac{2.75}{p}} + 2.75(1-p)^{\frac{2.75}{p}-1} = 0.13122$



From the GC: $p = 0.55$

$$\therefore n = \frac{2.75}{0.55} = 5$$

bi

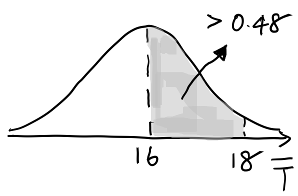
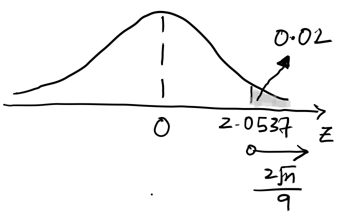
(1) The probability that a resident uses Sharebike is $\dfrac{a}{100}$ for all the n residents.
(2) The residents use Sharebike independently.

bii	$X \sim \mathrm{B}(45, 0.08)$ $\mathrm{P}(9 \le X \le 13) = \mathrm{P}(X \le 13) - \mathrm{P}(X \le 8)$ $= 0.00843$	
biii	$X \sim \mathrm{B}(12, r)$, where $r = \dfrac{a}{100}$ $\mathrm{P}(X=1) < \mathrm{P}(X=2)$ and $\mathrm{P}(X=2) > \mathrm{P}(X=3)$ $\binom{12}{1} r(1-r)^{11} < \binom{12}{2} r^2(1-r)^{10}$ and $\binom{12}{2} r^2(1-r)^{10} > \binom{12}{3} r^3(1-r)^9$ $r(1-r)^{10}\left[12(1-r)-66r\right] < 0$ and $r^2(1-r)^9\left[66(1-r)-220r\right] > 0$ Since $(1-r) > 0$ and $r > 0$, $12 - 78r < 0$ and $66 - 286r > 0$ $r > \dfrac{2}{13}$ and $r < \dfrac{3}{13}$ $\therefore \dfrac{2}{13} < r < \dfrac{3}{13}$ $\therefore \dfrac{200}{13} < a < \dfrac{300}{13}$	
9 (i)	Let $w = x - 425$ $\bar{x} = \bar{w} + 425 = 425 - \dfrac{136}{40} = 421.6$ (exact value) $s_x^2 = s_w^2 = \dfrac{1}{39}\left(4927.5 - \dfrac{(-136)^2}{40}\right) = \dfrac{4465.1}{39} = 114.49 \approx 114$	
(ii)	Let μ g be the population mean. $\mathrm{H}_0 : \mu = 425$ $\mathrm{H}_1 : \mu \ne 425$ Level of Significance: 5% Test Statistic: Since $n = 40$ is large, by Central Limit Theorem, $\overline{X}$ is approximately normal. When H_0 is true, $Z = \dfrac{\overline{X} - 425}{S/\sqrt{n}} \sim \mathrm{N}(0,1)$ approximately. Computation: p-value = 0.044466 (or z-value = –2.0097) Conclusion: Since p-value = 0.0445 < 0.05, (or $\lvert -2.01 \rvert > 1.96$), H_0 is rejected at 5% level of significance. Hence there is **sufficient evidence to conclude that the mean mass of a can of beans is not 425g.**	
(iii)	No assumption is needed. Since the sample size is large, by Central Limit Theorem, the distribution of the **sample mean mass** of a can of beans, $\overline{X}$, is **approximately** normal.	
(iv)	There is a probability of 0.05 that the test concludes that the mean mass of a can of beans is not 425g which it is actually 425g.	

(v)	Let Y g be the mass of a packet of frozen corn and μ_Y g be the population mean. $H_0 : \mu_Y = 380$ $H_1 : \mu_Y < 380$ Level of Significance: $\alpha\%$ Test Statistic: When H_0 is true, $Z = \dfrac{\overline{Y} - 380}{12/\sqrt{n}} \sim N(0,1)$ Computation: $\overline{y} = 375$, p-value = 0.053292 (or z-value = –1.6137) For H_0 not to be rejected, p-value > $\dfrac{\alpha}{100}$ $\Rightarrow 0.053292 > \dfrac{\alpha}{100}$ $\therefore \{\alpha \in \mathbb{R} : 0 < \alpha < 5.33\}$	
10 (i)	Let X and Y be the masses, in g, of a randomly chosen butter cookie and a randomly chosen chocolate cookie respectively. $X \sim N\left(15, 0.4^2\right)$ and $Y \sim N\left(20, 1.2^2\right)$ $P(X > 15.5) = 0.10565 \approx 0.106 \quad (\text{to 3 s.f.})$	
(ii)	Let W be the number of butter cookies (out of 10) with mass more than 15.5g. $W \sim N(10, 0.10565)$ $P(W \geq 4) = 1 - P(W \leq 3)$ $= 0.0155$	
(iii)	Let $S = \dfrac{6}{100}(X_1 + \ldots + X_{12}) + \dfrac{7.5}{100}(Y_1 + \ldots + Y_{12})$ $E(S) = \dfrac{6}{100}(12)(15) + \dfrac{7.5}{100}(12)(20)$ $= 28.8$ $\text{Var}(S) = \left(\dfrac{6}{100}\right)^2 (12)(0.4)^2 + \left(\dfrac{7.5}{100}\right)^2 (12)(1.2)^2$ $= 0.104112$ (exact value) $S \sim N(28.8, 0.104112)$ $P(S < 29) = 0.732$	

<table>
<tr><td>(iv)</td><td>We assume that the masses of cookies are independent of each other.

Note: It is insufficient to say that “mass of a butter cookie is independent of the mass of a chocolate cookie”. This is because for the 12 butter cookies bought, we also need the condition that the mass of a butter cookie is independent of the mass of any other butter cookie. The same goes for the 12 chocolate cookies bought.</td><td></td></tr>
<tr><td>(v)</td><td>Suppose T follows normal distribution i.e.
$T \sim \mathrm{N}\left(16, 9^2\right)$
$\mathrm{P}\left(T < 0\right) = 0.037720$
which is not insignificant and time taken cannot be negative.
Hence a normal distribution, with this mean and standard deviation, would not give a good approximation to the distribution of T.

Alternatively,
Due to the empirical rule of normal distribution, we would expect approximately 95% of the data to lie within 2 standard deviation from the mean. $16 \pm 2(9)$ have a range of values from -2 to 34.
This would mean a non-negligible/significant 2.5% will have values below -2, which is impossible as time taken cannot be negative.
Hence a normal distribution, with this mean and standard deviation, would not give a good approximation to the distribution of T.</td><td></td></tr>
<tr><td>(vi)</td><td>Since $n \geq 30$, by Central Limit Theorem,
$\overline{T} \sim \mathrm{N}\left(16, \frac{9^2}{n}\right)$ approximately.
$\mathrm{P}\left(16 < \overline{T} < 18\right) > 0.48$
$\mathrm{P}\left(\overline{T} > 18\right) < 0.5 - 0.48 = 0.02$

Given $\mathrm{P}\left(Z > \frac{18-16}{9/\sqrt{n}}\right) < 0.02$
$\mathrm{P}\left(Z > \frac{2\sqrt{n}}{9}\right) < 0.02$
From the GC, $\mathrm{P}\left(Z > 2.0537\right) = 0.02$
$\frac{2\sqrt{n}}{9} > 2.0537$
$n > 85.4$
Least n = 86
</td><td></td></tr>
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2021 JC2 H2 Mathematics Prelim P2 Solutions