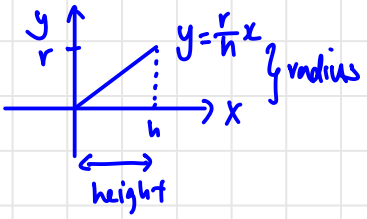
(1) $\begin{pmatrix}3\\-2\\10\end{pmatrix} \times \begin{pmatrix}2\\3\\-2\end{pmatrix} = \begin{pmatrix}-26\\26\\13\end{pmatrix} = 13\begin{pmatrix}-2\\2\\1\end{pmatrix}$

$\therefore$ unit vector : $\frac{1}{3}\begin{pmatrix}-2\\2\\1\end{pmatrix}$

(2) a) (i) Vol: $\int_0^h \pi k^2 x^2 \, dx = \left[\frac{\pi}{3}k^2x^3\right]_0^h = \frac{\pi}{3}k^2h^3$

(ii) let $k = \frac{r}{h}$ $\therefore$ Vol of cone $= \frac{\pi}{3}\left(\frac{r}{h}\right)^2 h^3 = \frac{\pi}{3}r^2h$ ✻ shown



b) $(0.6-k)^2 + (0.6k)^2 = k^2$

$0.36 - 1.2k + k^2 + 0.36k^2 = k^2$

$k = 3$ or $\frac{1}{3}$

so $y = 1.8$ or 0.2

(3) a) since all coefficients are real, $1-2i$ is also a root. Let 3rd root be α, $\alpha \in \mathbb{R}$

$z^3 + pz^2 - z + q = \left((z-1)+2i\right)\left((z-1)-2i\right)(z-\alpha)$

$= \left((z-1)^2+4\right)(z-\alpha)$

$= (z^2-2z+5)(z-\alpha)$

compare coefficient of z : $-1 = 2\alpha + 5$

$\alpha = -3$ $\therefore$ roots are $1 \pm 2i$ & -3.

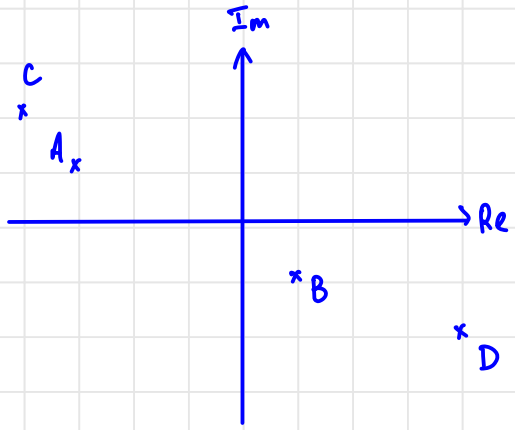
$\therefore q = 15$

z^2 : $p = 3 - 2 = 1$

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b)(i)



O, C, D are collinear & O is the midpoint of CD.

(ii) Reflection about the real axis.

4 a)

	1st	6th	22nd
AP	a	$a+5d$	$a+21d$
GP	a (1st)	ar^4 (5th)	ar^6 (7th)

$ar^4 = a+5d$ $\qquad$ $ar^6 = a+21d$

$r^4 = 1+5\left(\frac{d}{a}\right)$ $\qquad$ $r^6 = 1+21\left(\frac{d}{a}\right)$

$\frac{d}{a} = \frac{r^4-1}{5}$ $\qquad$ $\frac{d}{a} = \frac{r^6-1}{21}$

so $21r^4 - 21 = 5r^6 - 5$

$5r^6 - 21r^4 + 16 = 0$

$r = 2, 1, -1, -2$

rej $\because r > 0$

if $r=1$ $\quad$ 5th term G.P. $\neq$ 6th term AP $\because d \neq 0$

Hence $r=2$ //

$\frac{d}{a} = 3 \Rightarrow d = 3a$

$\{ a : a \in \mathbb{R},\ a \neq 0 \}$

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4 b) $S_{37} = \frac{37}{2}(2a + 36d) = \frac{37}{2}(2a + 108a) = 2035a$

$S_n = \frac{a(2^n - 1)}{2 - 1} = a(2^n - 1)$

$|2035a - a(2^n - 1)| = 12a$

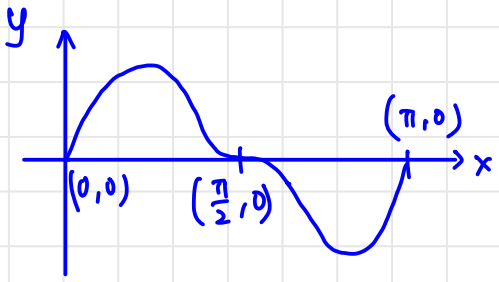
$\because a \neq 0$ $\quad 2036 - 2^n = 12$ or $2036 - 2^n = -12$

$2023 = 2^n$ $\quad 2048 = 2^n$

$n = 10.9$ $\quad n = 11$ #

rej $\because n \in \mathbb{Z}$

(5) a)



b) $y = \cos^2 x \sin 2x = 2\cos^3 x \sin x$

$\frac{dy}{dx} = -6\cos^2 x \sin^2 x + 2\cos^4 x$

$-6\cos^2 x \sin^2 x + 2\cos^4 x = 0$

$\cos^2 x(-3\sin^2 x + \cos^2 x) = 0$

$\cos^2 x = 0$ $\quad x = \frac{\pi}{2}$

$\cos^2 x = 3\sin^2 x$

$\frac{1}{3} = \tan^2 x$

$\tan x = \pm \frac{1}{\sqrt{3}}$

$x = \frac{\pi}{6}, \frac{5\pi}{6}$

$y = 2\cos^3\left(\frac{\pi}{6}\right)\sin\frac{\pi}{6} = 2\left(\frac{\sqrt{3}}{2}\right)^3\left(\frac{1}{2}\right) = \frac{3}{8}\sqrt{3}$

$\therefore$ max point $\left(\frac{\pi}{6}, \frac{3\sqrt{3}}{8}\right)$

#1 Math Tuition

Solutions serve as a guide only

c) $\int_0^{\pi/4} 2\cos^3 x \sin x \, dx = \left[\frac{-\cos^4 x}{2}\right]_0^{\pi/4} = \frac{1}{2}\left[-\left(\frac{\sqrt{2}}{2}\right)^4 + 1\right] = \frac{3}{8}$

(6) a) Sample, 40 is subset of 55.

b) Every employee has equal chance to be selected, hence it will be unbias.

c) $2\ 1\ 1\ 1$
$^{22}C_1\ ^{18}C_1\ ^{9}C_1\ ^{6}C_1 = 224532$

$3\ 0\ 1\ 1$
$^{22}C_3\ ^{9}C_1\ ^{6}C_1 = 83160$

$3\ 1\ 1\ 0$
$^{22}C_3\ ^{18}C_1\ ^{9}C_1 = 249480$

Total: 557172 ✱

(7) a) $\frac{ry}{^{20}C_2} = \frac{ry}{190} = \frac{28}{95}$ $\quad \frac{rb}{190} = \frac{4}{19}$

$ry = 56$ $\quad rb = 40$

$\frac{y}{b} = \frac{56}{40} = \frac{7}{5}$

$\therefore 5y = 7b$

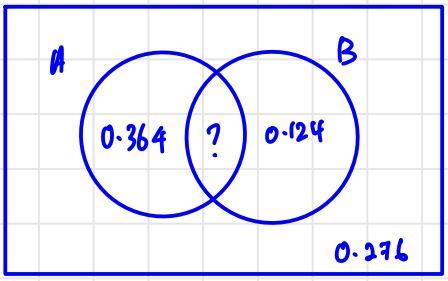
$y : b$

$7 : 5$

$\because r + y + b = 20$ by observation: 8 red balls.

b) (i) $P(A \cap B) = 1 - 0.364 - 0.124 - 0.276$
$= 0.236 \neq 0$

$\therefore$ A & B are not M.E. events



(ii) $P(A) = 3/5$ $\quad P(B) = 9/25$

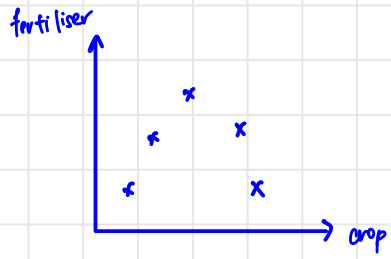
$P(A)P(B) = \frac{3}{5} \times \frac{9}{25} = 0.216 \neq P(A \cap B)$

$\therefore$ A & B are not independent

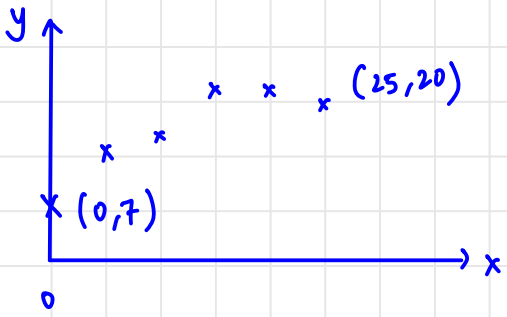
(8) a) Check if the data points on a scatter plot diagram follow a straight line.

b) (i) There is no linear r/s. May exist curvilinear r/s.

(ii)

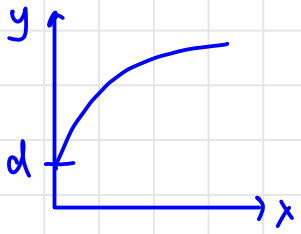


c)

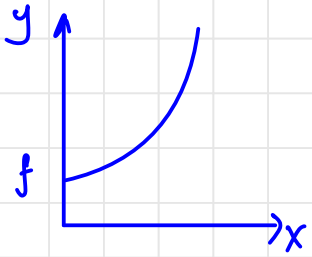


There is no increment in the crop yield from $x=15$ to 20. Hence non-linear r/s.

(ii) $y = c\sqrt{x} + d$



$y = ex^2 + f$



The graph of $y = ex^2 + f$ concave upwards, $y > 0$, $y' > 0$

The graph of $y = c\sqrt{x} + d$ concave downwards, $y > 0$, $y' < 0$

The data points on the scatter diagram seems to fall on a concave downwards curve.
Hence, $y = c\sqrt{x} + d$ is a better model.

(iii) $y = 2.91125\sqrt{x} + 7.40548$ when $x = 13$ $y = 17.902 \approx 17.9$ kg

(9) a) Req prob : $\frac{\text{Total \# of green sweets}}{100(12)} = \frac{174}{1200} = 0.145$

b) Let X be r.v. denoting # of red sweets out of 12.

$X \sim B(12, 0.3)$

$P(X < 5) = P(X \leq 4) = 0.72365 \approx 0.724$ #

c) Let Y be r.v. denoting # of packets of Tringos with less than 5 red sweets

$Y \sim B(7, 0.72365)$

$P(Y \geq 4) = 1 - P(Y \leq 3) = 0.90254 \approx 0.903$ #

d) Let W be r.v. denoting # of red sweets out of 864

$W \sim B(864, 0.3)$

$P(W > 250) = 1 - P(W \leq 250) = 0.7398 \approx 0.740$

e) Let T be r.v. denoting # of yellow sweets out of 12

$T \sim B(12, p)$

$^{12}C_2\, p^2 (1-p)^{10} + {}^{12}C_3\, p^3 (1-p)^9 = 0.206$

From G.C. $p = 0.07249 \approx 0.0725$ or $0.39985 \approx 0.400$

(10) a) (i) Let X be r.v. denoting time from Aytown to Beetown

$X \sim N(22, 3^2)$

$P(22.5 < X < 24) = 0.1813 \approx 0.181$

(ii) Let Y be r.v. denoting time spend at Beetown

$Y \sim N(75, 12^2)$

$X_1 + X_2 + Y \sim N(119, 162)$

$P(0 < X_1 + X_2 + Y < 120) = 0.5313 \approx 0.531$

(iii) Let W be r.v. denoting the travelling time using alternative route
$W \sim N(25, 4^2)$

$X - W \sim N(-3, 25)$

$P(X - W > 0) = 0.2742 \approx 0.274$

b) Let journey from Aytown to Seatown be $T \sim N(\mu, \sigma^2)$

$P(0 < T < 55) = 0.873$ $\quad$ $P(T > 49) = 0.471$

$\because P(T < 0) \approx 0$

$\Rightarrow P(T < 55) = 0.873$

$\frac{49 - \mu}{\sigma} = 0.0727$ — ②

$\frac{55 - \mu}{\sigma} = 1.141$ — ①

Solve ① & ② $\quad \mu = 48.59 \quad \sigma = 5.618$

Req Prob: $P(45 < T < 50) = 0.3376 \approx 0.338$

(11) a)(i) $H_0: \mu = 400$ $\quad$ H_0: null hypothesis

$H_1: \mu \neq 400$ $\quad$ H_1: alternative hypothesis

μ: population mean mass of bird seeds (400g)

(ii) $s^2 = \frac{1}{39}\left(1902 - \frac{120^2}{40}\right) = \frac{514}{13}$

Under H_0, since $n = 40$, n is large, by C.L.T, $\bar{X} \sim N\left(400, \frac{514/13}{40}\right)$ approx

Test statistic: $Z = \dfrac{\bar{x} - 400}{\sqrt{\frac{514}{13(40)}}}$

Critical region: Reject H_0 if

$$z < -1.9599 \quad \text{or} \quad z > 1.9599$$

$$\frac{\bar{x} - 400}{\sqrt{\frac{514}{13(40)}}} < -1.9599 \qquad \frac{\bar{x} - 400}{\sqrt{\frac{514}{13(40)}}} > 1.959$$

$$\bar{x} < 398.05 \qquad \bar{x} > 401.948$$

Hence critical region: Rej H_0 if $\bar{x} \leq 398.0$ or $\bar{x} \geq 402.0$

(iii) $\bar{x} = \frac{120}{40} + 400 = 403 \geq 402.0$

Hence, reject H_0 at 5% level of significance and conclude that the mean mass of bird seed is not 400 grams

b)(i) The owner is testing if the population mean mass of pet food per bag is more than 500 grams.

(ii) $z = 1.645$

(iii) The bags are not randomly selected as he only takes the last 5 bags per day.

Since the distribution of the pet food is unknown, taking a sample of 15 bags is not large enough to use C.L.T. to approximate the sample mean mass of pet food to a normal distribution.

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#1 Math Tuition

Section A: Pure Mathematics [40 marks]

1 Find a unit vector that is perpendicular to both $3\mathbf{i}-2\mathbf{j}+10\mathbf{k}$ and $2\mathbf{i}+3\mathbf{j}-2\mathbf{k}$. [4]

2 **(a)** **(i)** Use calculus to find the volume generated when the line $y = kx$, for $0 \leqslant x \leqslant h$, is rotated through 2π radians about the x-axis. [3]

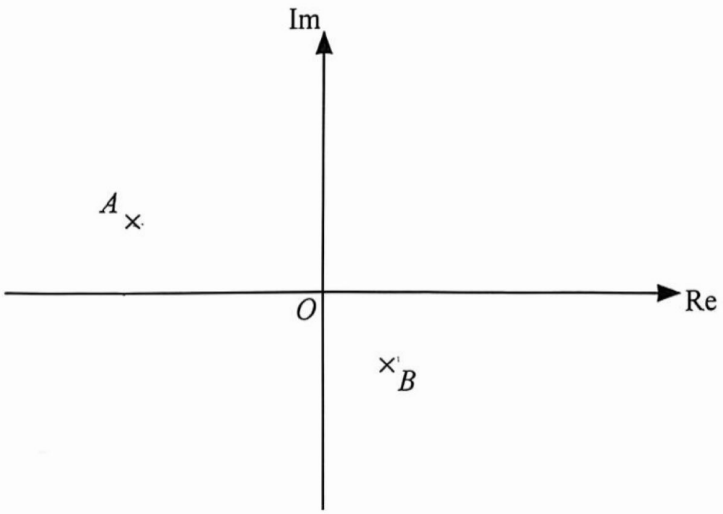
(ii) Hence show that the volume of a cone of height h and base radius r is $\frac{1}{3}\pi r^2 h$. [1]

(b) The straight line $y = kx$ cuts the curve $(x-k)^2+y^2 = k^2$ at the point where $x = 0.6$. Find exactly the possible values of y at this point. [3]

3 **(a)** One of the roots of the equation $z^3+pz^2-z+q = 0$, where p and q are real numbers, is $1+2\mathrm{i}$.

Find the other roots of the equation, the value of p and the value of q. [5]

(b) The points A and B on the Argand diagram represent the complex numbers w_1 and w_2 respectively.



The complex number w_3 is defined as $w_3 = w_1 - w_2$, and the complex number w_4 is defined as $w_4 = w_2 - w_1$.

(i) On the copy of the Argand diagram in the Printed Answer Booklet, mark the point C that represents w_3 and the point D that represents w_4.

State the geometrical relationship between points C and D. [3]

The points E and F represent the complex numbers w_1^* and w_2^* respectively.

(ii) Describe the transformation that maps the line AB onto the line EF. [2]

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4 An arithmetic series has first term a and common difference d, where $a \neq 0$ and $d \neq 0$. A geometric series has first term a and common ratio r, where $r > 0$.

The 6th term of the arithmetic series is equal to the 5th term of the geometric series.

The 22nd term of the arithmetic series is equal to the 7th term of the geometric series.

(a) Find the value of r and an expression for d in terms of a.

Describe the set of possible values of a. [5]

(b) The sum of the arithmetic series to 37 terms differs by $12a$ from the sum of the geometric series to n terms. Find the value of n. [4]

5 **(a)** Sketch the graph of the curve $y = \cos^2 x \sin 2x$ for $0 \leqslant x \leqslant \pi$ giving the exact coordinates of the points of intersection with the x-axis. [2]

(b) Find the exact coordinates of the maximum point. You do not have to show this is a maximum point. [4]

(c) **Do not use a calculator in answering this part.**

Find the exact area bounded by the curve, the x-axis and the lines $x = 0$ and $x = \frac{1}{4}\pi$. [4]

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[Turn over

Section B: Probability and Statistics [60 marks]

6 The employees of a certain company are put into teams based on the jobs that they do. The company consists of 22 employees from the Red team, 18 from the Blue team, 9 from the Green team and 6 from the Yellow team.

The manager of the company wishes to find out the opinions of the employees about the office facilities provided for employees. Questionnaires are given to all employees but only the 40 employees from the Red team and the Blue team return them.

(a) Explain whether these 40 employees comprise a sample or a population. [1]

The manager decides to form a committee of employees to discuss the results of the questionnaire.

(b) State an advantage of choosing a random sample of employees for the committee. [1]

The manager decides that the committee will consist of 5 employees, such that

- the committee includes an employee from the Green team,
- at least three teams are represented on the committee and
- there are more members from the Red team than from any other single team on the committee.

(c) Find the number of ways in which the committee can be formed. [4]

7 **(a)** A bag contains 20 balls. Some of the balls are red, some are yellow and the rest are blue. Two balls are taken, at random and at the same time from the bag. The probability that one of the balls is red and the other one is yellow is $\frac{28}{95}$. The probability that one of the balls is red and the other one is blue is $\frac{4}{19}$.

Determine the number of red balls originally in the bag. [5]

(b) Events A and B are such that $\mathrm{P}(A \cap B') = 0.364$, $\mathrm{P}(A' \cap B) = 0.124$ and $\mathrm{P}((A \cup B)') = 0.276$.

(i) Show that A and B are **not** mutually exclusive events. [2]

(ii) Determine whether A and B are independent events. [2]

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8 Three researchers are investigating the effect of the amount of fertiliser used on crop yields.

(a) Tang uses Fertiliser A. He calculates that the product moment correlation coefficient between the amount of fertiliser used per square metre and the crop yield per square metre is 0.98.

State what else Tang should do before deciding whether a linear model is a good fit to the data. [1]

(b) Xi uses Fertiliser B. He finds that the product moment correlation coefficient between the amount of fertiliser used per square metre and the crop yield per square metre is approximately 0.

(i) Explain how Xi should interpret the results of his investigation. [1]

(ii) Sketch a scatter diagram with at least 5 points to illustrate a product moment correlation coefficient of approximately 0. [1]

(c) Leia uses Fertiliser C. She sets up 6 test plots of land. The table shows the amount of fertiliser, x grams, used per square metre of each plot and the crop yield, y kilograms, per square metre of each plot.

x	0	5	10	15	20	25
y	7	14	16	21	21	20

(i) Sketch the scatter diagram for Leia's data, and explain how you know that the crop yield is not linearly related to the amount of fertiliser used. [2]

(ii) By drawing sketches of the equations below, where c, d, e and f are positive constants, explain which is a better model for the relationship between the amount of fertiliser used and the crop yield.

$y = c\sqrt{x} + d$ $\qquad$ $y = ex^2 + f$ [3]

(iii) Use the better model to find an estimate for the crop yield per square metre when the amount of fertiliser used is 13 grams per square metre. Give your answer correct to 3 significant figures. [3]

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[Turn over

9 Tringos are sweets that are made in four different colours: red, yellow, purple and green. They are sold in packets containing 12 randomly chosen sweets.

(a) A student wishes to estimate the proportion of Tringos that are green. She checks the contents of 100 randomly chosen packets of Tringos and finds the information summarised in the table.

number of green sweets in a packet	0	1	2	3	4	5	6 or more
frequency	15	32	27	18	6	2	0

Use the information in the table to estimate the probability that a randomly chosen Tringo is green. [2]

The probability that a randomly chosen Tringo is red is 0.3.

(b) Find the probability that a packet of 12 Tringos contains fewer than 5 red sweets. [1]

(c) Find the probability that at least 4 out of 7 randomly chosen packets of Tringos contain fewer than 5 red sweets. [2]

Tringos are delivered to shops in cartons containing 72 randomly chosen packets of 12 sweets.

(d) Find the probability that there are more than 250 red sweets in a randomly chosen carton of Tringos. [2]

The probability that a randomly chosen Tringo is yellow is p.

(e) Given that the probability that a randomly chosen packet of 12 Tringos contains either 2 or 3 yellow sweets is 0.206, find the **two** possible values of p. Give your values correct to 3 decimal places. [3]

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10 In this question you should assume that the distributions are all independent of each other.

Mrs Ng lives in Aytown. She often drives to the neighbouring towns of Beetown and Seatown.

(a) The time taken, in minutes, for Mrs Ng to drive from Aytown to Beetown using her usual route has the distribution $N(22, 3^2)$.

(i) Find the probability that Mrs Ng takes between 22.5 and 24 minutes for a randomly chosen journey from Aytown to Beetown. [1]

Mrs Ng often visits the shops in Beetown. The time, in minutes, she spends at the shops has the distribution $N(75, 12^2)$. The time taken for the journey from Beetown to Aytown also has the distribution $N(22, 3^2)$.

(ii) Find the probability that a randomly chosen trip from Aytown to the shops at Beetown and back to Aytown by Mrs Ng takes less than 2 hours. [3]

The time taken, in minutes, for Mrs Ng to drive from Aytown to Beetown using an alternative route has the distribution $N(25, 4^2)$.

(iii) Find the probability that a randomly chosen journey from Aytown to Beetown using the alternative route takes less time than a randomly chosen journey using Mrs Ng's usual route. [3]

(b) The time taken, in minutes, for the journey from Aytown to Seatown is also normally distributed. The probability that a randomly chosen journey takes less than 55 minutes is 0.873 and the probability that a randomly chosen journey takes more than 49 minutes is 0.471.

Find the probability that a randomly chosen journey from Aytown to Seatown takes between 45 and 50 minutes. [4]

Question 11 is on the back page.

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[Turn over

11 **(a)** A company uses a machine to pack bird seed into packets. Packets should contain a mean mass of 400 grams of seed. Following maintenance to the packing machine, the owner of the company wishes to check if packets contain a mean mass of 400 grams of seed. He decides to carry out a hypothesis test at the 5% level of significance.

The owner finds the masses, x grams, of bird seed in a random sample of packets. Summary data is as follows.

$n = 40$ $\quad \Sigma(x-400) = 120$ $\quad \Sigma(x-400)^2 = 1902$

(i) Write down the hypotheses for the test, defining the parameter(s) you use. [2]

(ii) Find the critical region for the test, giving your answer in grams correct to 1 decimal place. [4]

(iii) State the conclusion of the test in the context of the question. [2]

(b) The company also has a machine that fills bags with pet food. The mean mass of pet food is stated to be 500 grams per bag. Following comments from customers, the owner of the company decides to carry out a z-test using

$H_0 : \mu = 500$

$H_1 : \mu > 500$.

(i) State what the owner is testing for. [2]

(ii) State the critical z-value used for this test when it is carried out at the 5% level of significance. [1]

The machine is used each week from Monday to Friday. The owner decides to take the last 5 bags filled on Monday, Wednesday and Friday one week, to make up a sample of 15 bags for his test.

(iii) Give **two** reasons why the owner's sample is **not** suitable for this test. [2]

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